SB13 OULU

Sustainable procurement in urban regeneration and renovation
Northern Europe and North-West Russia

May 22–24, 2013

Proceedings

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SB13 Oulu

Sustainable Procurement in Urban Regeneration and Renovation

Conference proceedings

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Sustainable Procurement in Urban Regeneration and Renovation
PREFACE

SB 13 Oulu brings together the industry and leading knowledge of the research institutes, to share knowledge, and to improve our understanding of future development needs. In addition, workshop plays an important role within the conference, and versatile technical site tours deepen the understanding in practice.

The building and construction sectors play the key role in promoting sustainable development. The consumption of the resources and energy are high within the sectors. The level of greenhouse gas (GHG) emissions should be decreased. The building sector offers the largest single potential for energy efficiency in Europe. Innovation in renovation and urban regeneration throughout the life cycle is needed! SB13 Oulu focuses on:

- Intelligent steering – sustainable procurement and collaborative activities enable value creation!
- Life cycle value – comprehensive and integrated viewpoint enable optimal solutions!
- Sustainable building products, assessment & processes – innovative and global technologies enable sustainable forerunner services!
- User oriented services – inhabitants' happiness and customer satisfactions enable success and well-being.

SB13 Oulu is organised by the RIL – Finnish Association of Civil Engineers and VTT Technical Research Centre of Finland. SB13 Oulu is one of the regional Sustainable Building Conferences priming the World Conference SB14, co-sponsored by CIB, iiSBE, UNEP and Fidic. Around 70 papers were accepted for the conference. Majority of the papers were from Europe. We also received papers from Asia, Australia, Middle East, and America.

On behalf of the Organising Committee, I wish to thank all of the authors for their papers, and making this high quality conference possible. I express my gratitude to the Scientific Committee for reviewing the submitted abstracts and papers, and ensuring the quality of the accepted papers. I am most grateful to the organising committee – it has been fun working with you.

In addition, I wish to thank all the participants of the SB13 Oulu conference. Hopefully this initiative will promote further the sustainable procurement in urban regeneration and renovation, and collaborative actions. Looking forward to challenging discussions and networking!

Oulu, May 2013

Appu Haapio
Chair of the Scientific Committee

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The Role of Resource and Energy Quality Management in Sustainable Urban Development

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Summary

Until now our energy systems have been resource driven. We identify sources, generate energy products and build up a system to store and distribute them to an end user market. The result of this is that our focus is on resources with the highest revenues that logistically can be stored and distributed freely and will easily find its market in new energy based services and higher degree of individual mobility. Fossil fuels, oil, coal and gas, are products that best meet the above criteria. The best available technologies, possible sources of energy, the planning and the management of an urban energy system together with the development of societal needs are instruments that have to be tuned together to meet the sustainability criteria. It can be demonstrated how a general system approach based on these components can lead to more cost efficient solutions to meet the challenges of climate change.

During the last four decades, since the energy crises in the beginning of the seventies we have witnessed continuous developments of new technologies and building codes. The state of the art technology in house building in Northern Europe is now reaching one third of the energy losses we normally have for buildings built in the sixties.

It is not only the energy use of the building which is of importance for good energy economy but also the interface of the building energy system so that we have flexibility in the choice of the energy supply system.

The Swedish district heating network development is an excellent example where the systems are primarily built up for distribution of heat that is generated by burning fossil fuels but where the they have been gradually replaced by cogeneration heat, heat produce by heat pumps, heat generated from biofuels and from burning waste etc.

The energy situation in Iceland is very special. The development of small-scale hydropower, along with local use of geothermal resources, began in the early twentieth century. During the 1960s, major development of hydropower projects for larger energy-intensive industries began and during the 1970s – in the wake of the energy crisis – considerable national effort was initiated to identify geothermal sources and distribute their energy to more remote communities. In the late 1980s extensive development of geothermal power from high temperature sources became a competitive alternative to large-scale hydropower.

Geothermal energy can be used in all locations, high enthalpy geothermal for cogeneration of electricity and heat, low temperature geothermal as a source for direct use for heating and hot water and shallow geothermal resources at annual average temperature as a source for heat pump systems.

Keywords: Energy, resources, energy quality management, buildings, geothermal, district heating,

1. Introduction

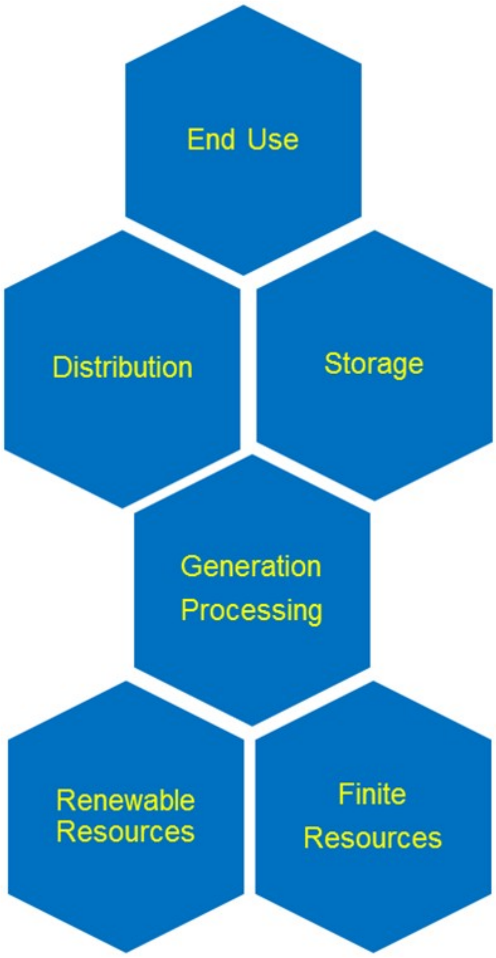

Fig. 1 The four levels of the energy system

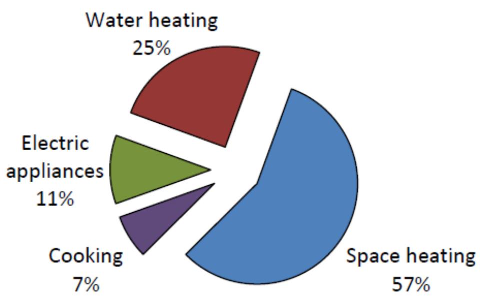

Fig. 2 End use of energy in households [1]

We can identify four major levels of a sustainable energy system.

The first is the resource level. This is where renewable sources with minimum emission of greenhouse gasses are identified and made available.

The second level is the generation where energy from the sources is extracted and processed into energy products that can meet the needs of the market.

The third level is the logistic level where energy is stored and distributed to meet the needs of the market in space and in time.

The fourth level is the end use level.

Until now our energy systems have been developed bottom up. We identify sources, generate energy products and build up a system to store and distribute them to an end user market. The result of this is that our focus is on resources with the highest revenues that logistically can be stored and distributed freely and will easily find its market in new energy based services and higher degree of individual mobility. Fossil fuels, oil, coal and gas, are products that best meet the above criteria.

The problem is the emissions resulting from the use of these energy sources. Energy wise they are high quality products that can be used to generate temperatures well over 1000 ^{O}C, generate electricity and run engines. They are however, to a large extent, used for low quality purposes such as space heating at 20 ^{O}C or heating water to 60 ^{O}C.´

If we would start from the beginning and looking for a solution to provide heat below 60 ^{O}C and cooling below 7 ^{O}C we would then come to the conclusion that the most plausible solution would be to drill from a ship at 1 km sea depth, several km under the seafloor and extract a liquid that we could bring home and burn for this purpose.

Our ancient methods were e.g. chopping fire wood and harvesting peat, animal feces, seaweed etc. in the neighborhood and burning. With growing population however we have problems with the capacity and sustainability of such solutions and have to identify a broader resource basis. Burning of waste from households, forestry and agriculture biofuels, geothermal energy, collecting and storing solar thermal energy are viable alternatives that have been known to cover to a large extent our low quality energy use. Also, when the resources are limited, the use of heat pumps to generate heat is a way to multiply the energy output per unit of high quality energy. The quality of a certain energy quantity is defined as the maximum fraction of the energy that can theoretically be converted into work. In this way an energy quantity can be divided into exergy, equal to the maximum work output, and the rest which is called anergy, [2], [3]. The concept of exergy based energy quality management in communities and buildings has been developed in [4], [5]

If we would from the start plan our energy system top down we would start with limiting the use of energy as much as possible and then sort the different modes of use into minimum quality levels that are needed to provide the necessary services.

The role of district heating in the energy systems gives clear examples on an effective resource and energy quality management which will be exemplified with the Scandinavian multiple resource strategy and the cascading use of the geothermal energy resource in Iceland.

2. The technologies

The best available technologies, possible sources of energy, the planning and the management of an urban energy system together with the development of societal needs are instruments that have to be tuned together to meet the sustainability criteria. It can be demonstrated how a general system approach based on these components can lead to more cost efficient solutions to meet the challenges of climate change.

We also have to see to that the building component and building material industry provides the necessary goods. They will not react before there is a real demand. This demand can be created by new regulations, by economical incitements and tax cuts from the government, with larger procurement for high standard products by development funds and larger real estate developers in cooperation, etc.

When the market is enlarged the rationality of greater production quantities and competition will lead to more favorable prices, lead to more cost efficient solutions to meet the challenges of climate change.

2.1 Technical advances in the past

During the last four decades, since the energy crises in the beginning of the seventies we have witnessed continuous developments of new technologies and building codes.

The state of the art technology in house building in Northern Europe is now reaching one third of the energy losses we normally have for buildings built in the sixties.

The most important components are

Thermal insulation and air tightness
Super insulated glazing
Heat recovery from exhaust air
Heat pumps
Co-generation of electricity and heat with district heating
Co-generation of electricity with district heating and cooling
Energy efficient appliances
Energy efficient lighting
Power management and control

2.2 Implementation of new technologies

The U-value or the thermal transmittance of constructions gives us the heat loss for one square meter and one degree temperature difference. If we multiply the U-value with the area of the construction and the temperature difference between outside and inside we will get the heat loss in watts.

Walls made of homogeneous brick had a U-value of about 0,5 W/m^{2}K and today we are building multilayer walls with 30 cm of mineral wool insulation with a U-value around 0,15 W/m^{2}K.

Roof constructions have insulation thicknesses which normally were around 200 mm with a U-value of 0,3 W/m^{2}K are now insulated with between 0,5 and 1,0 m giving a U-value well under 0,1 W/m^{2}K.

Even floor constructions toward the ground that before were only partly insulated are now insulated with 20-30 cm of insulation under the floor plate.

The double glazed window had a U-value of 3,0 W/m^{2}K. Today the state of the art window has special coating on the surface that transmits visible light but reflects long wave heat radiation. This together with special gas fillings in the cavity between the glasses results in a U-value close to 1,0 W/m^{2}K.

In buildings with bad air tightness the losses due to uncontrolled ventilation could be significant. With new standards and improved technology the common air leakage coefficient of 3 to 6 air exchanges per hour at 50 Pa pressure difference has been brought down below 1 air exchanges per hour.

With controlled ventilation it is possible to recover heat from the exhaust air to heat the inlet air. Common energy efficiency for an air to air heat exchanger is 60 % and for more advanced types up to 85%.

For the electricity use we see that the new light bulbs can provide the same light emission as the conventional light bulb with only 15-20 % of the electrical power needed for the conventional light bulb. The efficiency of almost all household appliances such as refrigerators, washing machines, television and computers has been improved considerably while at the same time we tend to increase our use of such appliances.

It is obvious that we, with modern technology and in a cost effective way, can produce housing with by far less energy use for heating and appliances than what we have in the existing building stock.

However, as the lifetime of buildings is about 70 years or more the renewal of the stock is taking place with between 1 and 2 % per year in a developed country. This makes the transition of the building stock towards a new energy standard very slow. But there are also other challenges to overcome.

There is a capacity problem. Most new housing and refurbishment planning is carried out by consulting engineers with background and training in conventional building technology. To bring new knowledge into the sector craves education, training, demonstration projects and new policies setting higher standards.

For energy efficient buildings we have higher initial investment cost that with time will be paid off by energy savings but also, because of better thermal comfort and living standard, by higher rent. We need convincing tools and valid examples to explain this to the banks and financing institutes in a convincing way.

2.3 The supply side

We also have to observe the supply side. A common convention in the treatment of the energy efficiency of buildings is to regard all energy in the same manner independent of the form or the source. With the so-called heat pump we can exemplify that this is very misleading.

We consider two buildings that both have the same need for heat and domestic hot water. One building has electrical resistant heaters in each room and separate electric boiler for each apartment. The other has a central boiler operating at 55 ^{O}C for the domestic hot water and water borne floor heating systems.

A heat pump is a device that with the help of an electrically driven compressor evaporates gas at a lower temperature where heat then is extracted at a low temperature, and then compresses the gas so it condenses at a higher temperature where the heat extracted at the lower temperature is emitted. In this way heat is moved from a low temperature heat source like for instance the outdoor air, a borehole in the ground or the bottom of a lake to a higher temperature heat storage which in our case is the central boiler.

For the electrically heated building we only have the opportunity to buy electricity from the grid that will be converted directly into heat. For the other building we can install a heat pump and save 2/3 of bought high quality energy.

The energy delivered to the heating system in form of heat will be 3 or 4 times the electrical energy to the compressor. This is possible because the quality of electrical energy is 1,0 while the quality of heat at 55 ^{O}C is around 0,1. In our processes energy is converted to another form but never lost. What is lost is the quality of the energy and theoretically we should get 10 times the amount of electrical energy in the form of heat at this temperature but practical limits to equipment size and cost efficiency set a limit to this.

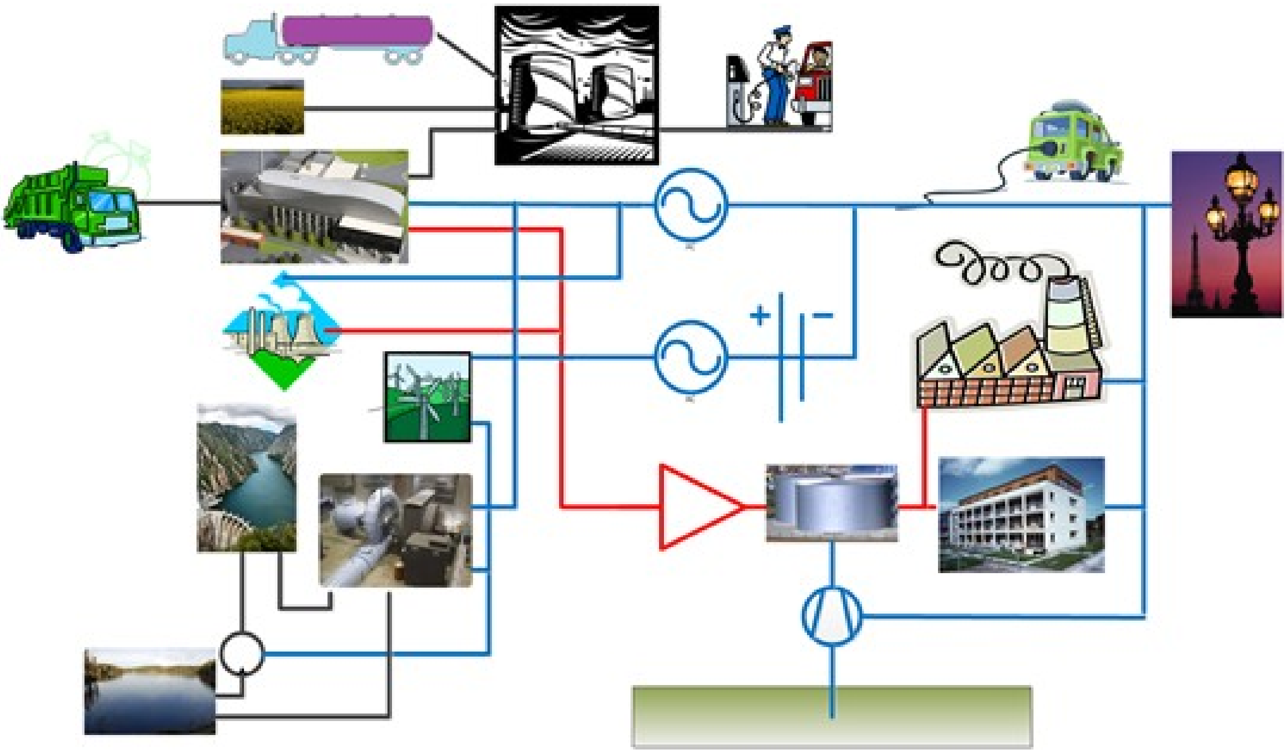

Fig. 3 Energy quality management. The energy need of the community can be fulfilled by utilising available sources and with logistics and control to use the right energy quality for the right purpose.

3. Energy quality management

From thermodynamics we learn that we do not consume or produce energy. Energy is neither lost nor created in our processes. Energy is converted from one form to another e.g. electricity to mechanical work or heat. What is lost is the quality of the energy or the exergy.

It is not only the energy use of the building which is of importance for good energy economy but also the interface of the building energy system so that we have flexibility in the choice of the energy supply system. Examples of this are for instance a large scale thermal power plant that produces electricity and heat in a co-generation process. The waste heat from the power generation is distributed over a district heating network to the nearby communities. An example of a tri-generation process is where a power generation process in combination with a heat pump produces electricity, district heating and district cooling.

Such tri-generation processes have also been planned for building projects where gas, instead of being directly used for heating and hot water is fuelling electrical generation and the waste heat from the process together with a heat pump provides the heating and the low temperature side of the heat pump process provides cooling for the building. In this way the high quality energy source, natural gas, is used to generate energy on different quality levels matching the actual use and providing means to make the best possible use of the energy quality of the gas.

4. The Scandinavian example

Environmental gain through building up infrastructure for district-wide heating and cooling can be as great as 70 per cent due to the flexibility associated with using various sources for heating, such as that from industrial processes waste, low-grade fuels such as garbage and waste from forestry

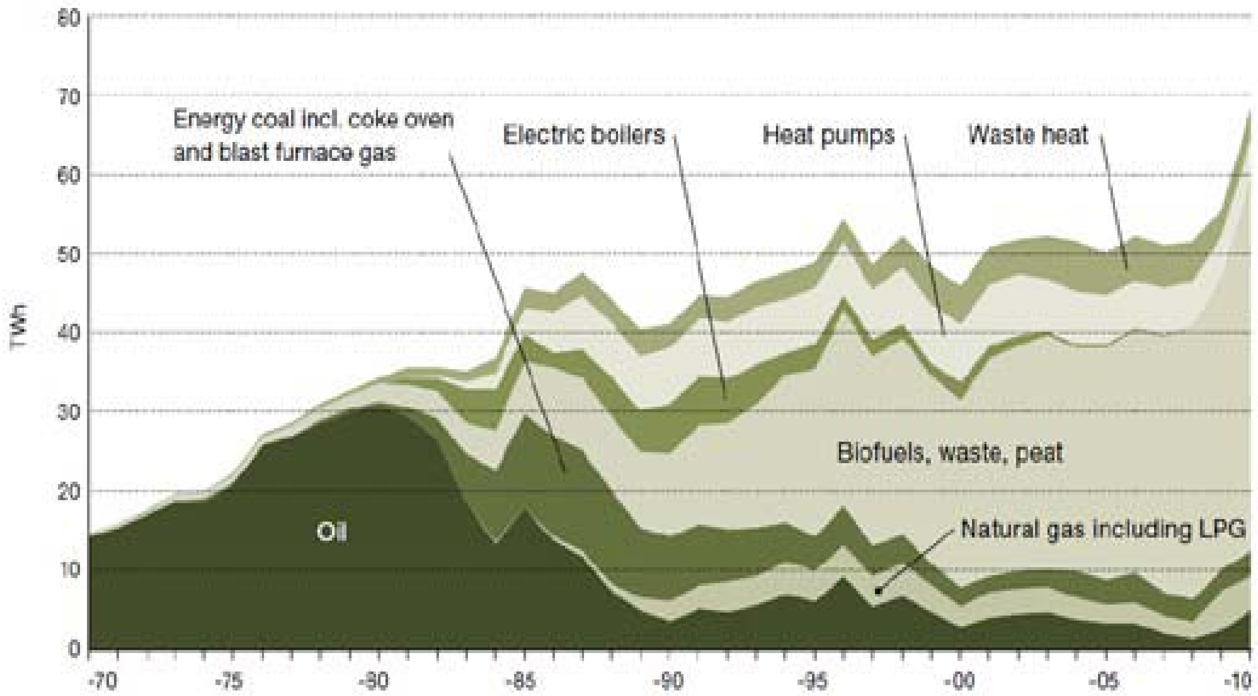

Fig. 4 The fuel mix for District heating in Sweden has changed from 100 % oil to low valued biofuels including waste and peat, [6].

and heat pumps. Geothermal heat accounts for the remaining 30 per cent. In many countries the general attitude is that introduction of such an infrastructure is beyond reason in established, well-populated areas. However, examples from Iceland and Scandinavia may prove the opposite.
The most important step towards increased use of renewable energy in buildings and to better energy quality management is to provide means to use low temperature sources for low quality use such as space heating and hot water in buildings. District heating provides the necessary flexibility in choice of energy resources.

The Swedish district heating network is an excellent example where the systems are primarily built up for distribution of heat that is generated by burning fossil fuels but where the they have been gradually replaced by cogeneration heat, heat produce by heat pumps, heat generated from biofuels and from burning waste etc.

We can also see how the Danish energy network with a high percentage of renewables is using the district heating system to receive temporary energy surplus from power generation by wind and biofuels.

5. The Icelandic example - Renewable energy driving economic growth

Fig. 5 Geothermal water reservoir tanks on a hill close to Reykjavik centre. Geothermal water is piped from wells in and around Reykjavik to the tanks and then from the tanks into the city to provide heating and hot water. (photo: Oddur Sigurðsson) [7]

Economic growth and development of the nation into a modern community with a relatively high standard of living goes hand in hand with its exploitation of sustainable natural energy resources. The development of small-scale hydropower, along with local use of geothermal resources, began in the early twentieth century.

5.1 Renewable energy utilization

During the 1960s, major development of hydropower projects for larger energy-intensive industries began and during the 1970s – in the wake of the energy crisis – considerable national effort was initiated to identify geothermal sources and distribute their energy to more remote communities. In the late 1980s extensive development of geothermal power from high temperature sources became a competitive alternative to large-scale hydropower. Growth in the use of electricity from hydropower – and both electricity and heat from geothermal sources. The energy situation in Iceland is very special.

When the oil crisis hit us in the early seventies a little more than 40 % of all buildings where heated by geothermal energy. The government and the municipalities decided to search for new geothermal energy sources and to build out the district heating systems to cover as big part of the market as possible. Today in a country of 103 thousand square kilometers with 330 000 inhabitants over 90 % of all households have geothermal district heating. The longest distance from the geothermal source to the furthest customer is 63 kilometers. At times the investment was considered uneconomical and the urge for energy security would be a strong factor in the decision making. Today geothermal heat only costs a fraction of what it would cost to heat with fossil fuels.

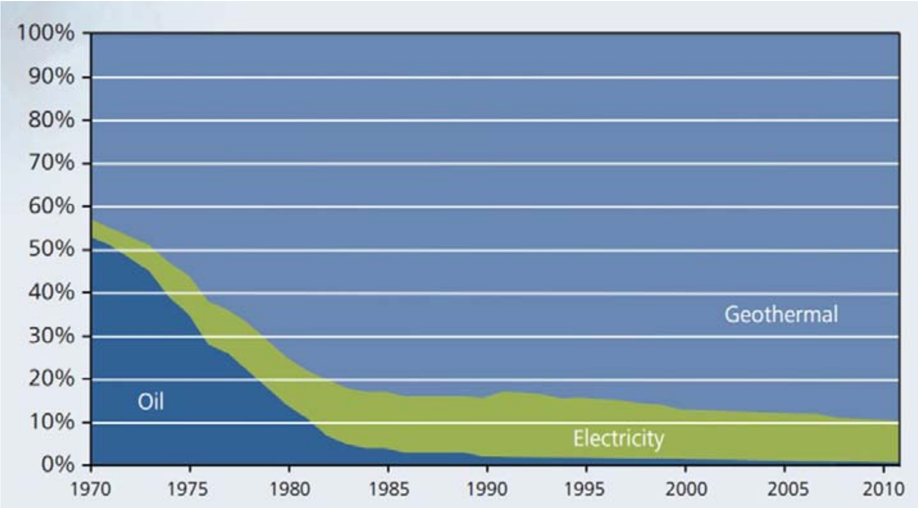

Fig. 6 The development of the geothermal resource for space heating in Iceland after 1970. The use of fossil fuel for these services is now practically down to zero. [7]

The geothermal water comes from low temperature sources at about 80 °C outside the volcanic belt stretching from southwest to northeast in Iceland and within the volcanic belt from thermal plants where heating water and electricity are produced in a cogeneration from high enthalpy or high temperature sources between 250 and 300 °C. Under Reykjavik we have a large reservoir of geothermal energy at 2 km depth.

Today the generation of electricity, 17.5 TWh/year, in Iceland is totally renewable. Hydropower stands for about 75 % and geothermal power for about 25 %. About 80 % of the electricity is sold to energy intensive industries such as aluminum smelters. Foreign companies invest in Iceland to gain access to cost efficient and environmental friendly energy. The total technical potential is estimated three times this but the access is limited due to aspects such as conservation of nature and wilderness and alternative land use. The additional usable potential could therefore be between 10 and 20 TWh.

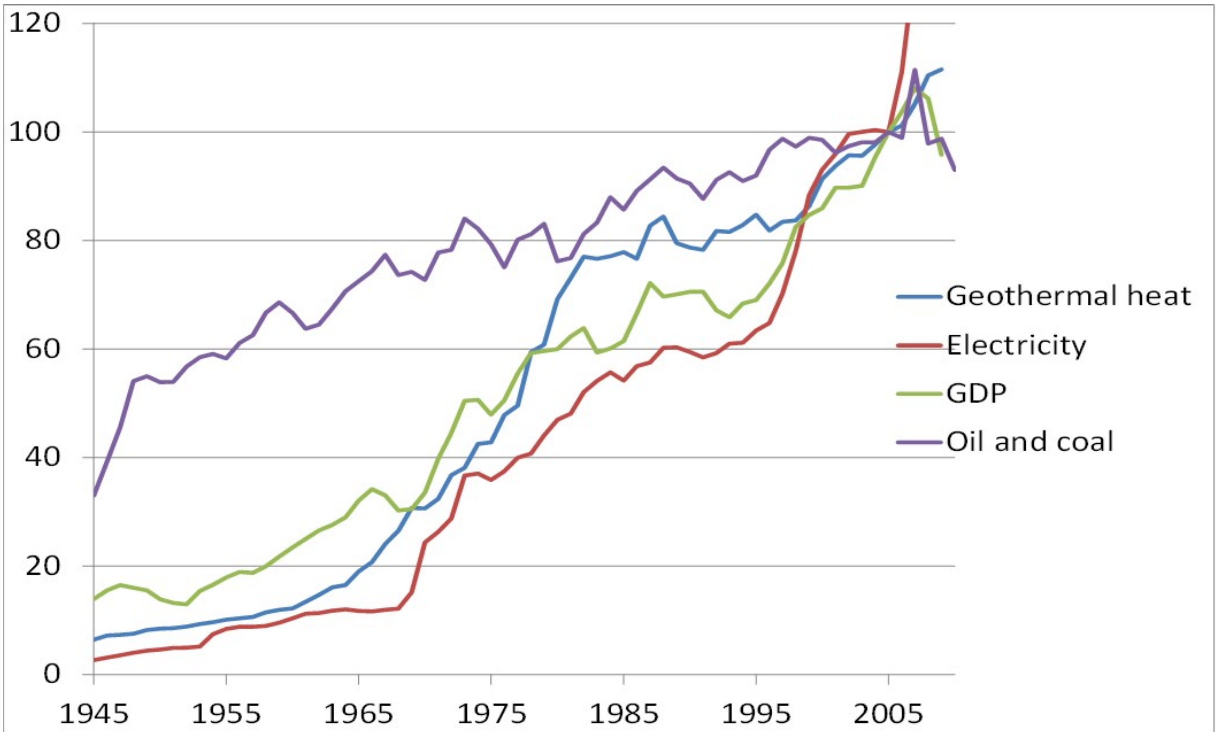

Fig. 7 Economic growth in Iceland related to generation of geothermal heat and electricity generation. All figures are per capita, converted to price index of 2005 and expressed as a percentage of the 2005 value. There is a strong resemblance between the curves for renewable energy generation and economic growth

The exploitation of the geothermal resources not only provides heating but alternative industrial possibilities such as greenhouses and aquacultures and also a new life style where people at northern latitudes can enjoy outdoor swimming even in wintertime and use the return water from the heating system to melt snow from pavements and driveways. We also see a clear distinction in attraction value and population growth between communities depending on whether they have access to geothermal water or not.

For Reykjavik, the capital of Iceland, geothermal heating, compared to oil heating, saves about two million tons of CO_2 emissions per year.

The remaining challenge for the Icelandic renewable energy policy is to initiate a transition to renewable energy use in the mobile sector, i.e. for automobiles and the fishing fleet. In spite of abundance of stationary electrical energy we still have to import a considerable amount of fossil fuels for the mobile sector. We are experimenting with the hydrogen cycles, battery cars, synthetic fuels from carbons and hydrogen and biofuels. The technologies are available but the cost is still too high for these options to be economically competitive to fossil fuels.

6. Geothermal potential in Europe

Iceland is not the only country where geothermal sources for direct heating use can be found. A geothermal map of Europe shows us the temperature at 2 km depth.
In Europe high enthalpy areas suitable for electricity generation can be found in Italy, Greece and Turkey but the use of low temperature geothermal reservoirs is already successfully utilized in Southampton, Paris, for greenhouse heating in the Netherlands and on several sites in Hungary while major projects are now in the planning stage for cities like Munich and Berlin.
It is also interesting to note that in some countries where no geothermal reservoirs at elevated temperatures can be found have successfully used shallow borehole systems as a source for ground heat pumps. Sweden has up to one million ground source heat pumps installed.

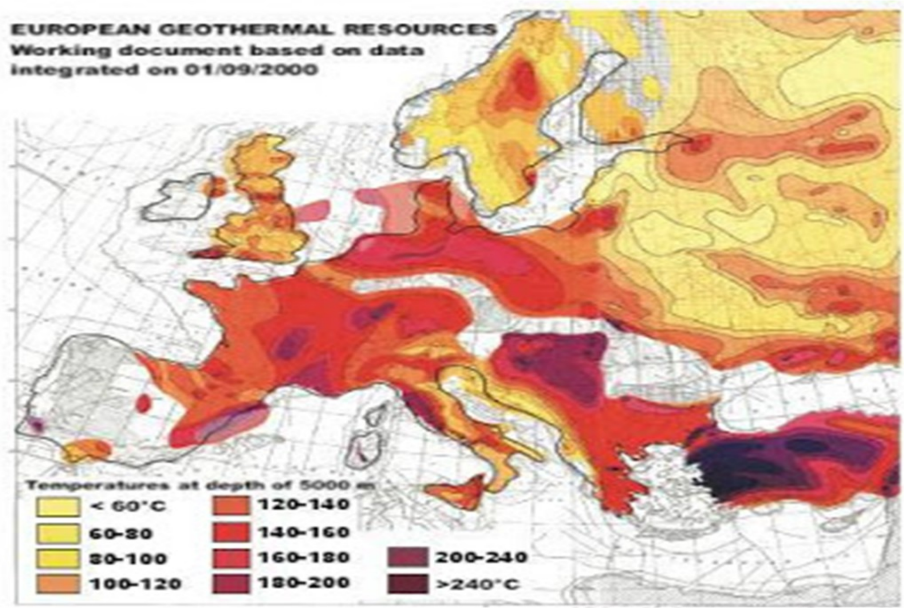

Fig. 8 Temperatures at 5 km depth. Temperatures above 60 ◦C can be used for space heating and hot water while temperatures above 150 ◦C are needed for electricity generation [10]

It seems that with increased research and knowledge more and more sites are found suitable for geothermal exploration. Looking at the map for the geothermal potential of Russia we see many possible areas for the extraction of heat even if the high enthalpy areas are few and mostly concentrated to the most eastern part.

7. The mobile energy sector

The greatest challenge remains implementing renewable energy sources within the transport and remote energy sector. Small population densities, vast distances from other countries and the importance of high-seas fisheries for the economy depend on transport that until now has run mostly on fossil fuels. With renewable electricity it makes sense for the transport sector to adapt to using the hydrogen cycle, batteries for storing electricity, or liquid fuels such as methanol and dimethyl ether (DME). Methanol is produced from the hydrolysis of hydrogen, with a relatively small amount of CO_2 separated from borehole geothermal fluids at the plant site. Methanol is then blended into fuel for use in standard petrol cars. Other commercially viable options include using methane gas from landfill as a fuel alternative in modified petrol cars and gathering animal and vegetable fat from restaurants and the food-processing industry which is converted into oil for diesel engines. The latter has been tested on cars, city buses and a fishing trawler, with encouraging results. Small-scale experiments that involve growing biofuel plants such as rapeseed have shown promising economic outcomes in Iceland, although it is clear production will vary considerably from year to year as a result of naturally occurring climate variations. Although DME may be used in diesel engines when fuel tanks are modified to withstand higher pressure, a feasibility study carried out on behalf of a major 300 MW plant in western Iceland that produces DME – from hydrogen and CO_2 from a ferrosilicon plant – showed that the production cost is prohibitively high when compared to fossil oil, despite the considerable environmental benefits. Iceland has also participated in several larger projects relating to the introduction of the hydrogen cycle into the transport energy sector. Cars and buses have run on hydrogen, as have electrical generators for ships, and a hydrogen filling station is now operating in Reykjavik. However, advances in fuel cell technology, although effective, have not delivered the cost efficiency that were anticipated at the start of the century.

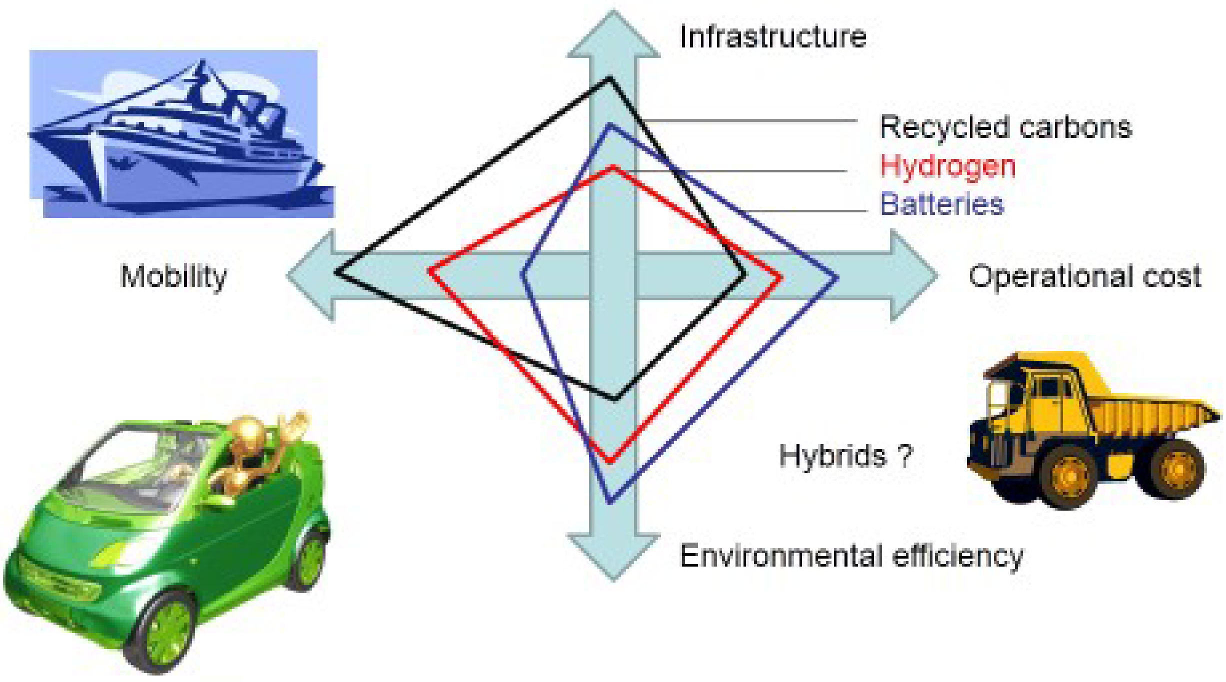

Fig. 9 Fuelling the mobile energy sector from renewable sources.

8. Conclusions:

Technologies that in an economical way can radically reduce the energy need for the built environment are available but the main obstacles for fast implementation are slow renewal of the housing stock, lack of human resources and appropriate financing.

The energy system of a building should be designed so that it can be served with as low quality energy as possible to provide maximum flexibility in the supply of energy from different sources.

Geothermal energy can be used in all locations: high enthalpy geothermal for cogeneration of electricity and heat, low temperature geothermal as a source for direct use for heating and hot water and shallow geothermal resources at annual average temperature as a source for heat pump systems.

We may not agree on what the possible CO_2 driven scenarios of climate change in the future may look like. We all however should be able to agree that the anthropogenic increase in CO_2 levels in the world atmosphere exposes humanity to higher risks of changes in the environment than we want to face in our, our children’s or their children’s lifetime.

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LifeCycle Tower – the Natural Change in Urban Architecture

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Summary

More than 50% of the world's population today lives in cities with more than 1 million inhabitants - and the trend is increasing. 40% of today's energy, CO_2 and resource consumption and 40% of waste production are accounted by the global construction industry. In the past, urban architecture has been based predominantly on conventionally produced prototypes with long, complex and resource-intensive construction work. A situation which the Cree GmbH, a subsidiary of the Austrian Rhomberg Group, intends to change with a hybrid construction system for multi-story buildings with up to 100 m height and 30 stories. The project is based predominantly on a renewable raw material - wood.

The goal of the project LifeCycle Tower was to develop a flexible, prefabricated, construction system as a new, independent product, which meets all technical and economical requirements of modern real estate markets. Additional emphasis was placed on the systematically improved resource- and energy efficiency. An integrated planning process was applied to the entire project. This means that representatives of all areas of knowledge (architecture, static, facility management, building technology, etc.) had worked jointly through the essential tasks in their entirety. Another central element was carrying out theoretical simulations, which were checked and confirmed with real trials (e. g. fire tests).

The result of the Project is a flexible “new to the world product”:

- for timber based multi-story buildings up to 100 m and 30 storeys
- for multiple uses such as office, apartment and/or hotel
- with a positive energy balance
- with an unmatched ecological footprint
- which is prefabricated and independent from manufacturers or geographical locations

Now, the theoretical development became reality. A prototype, LCT ONE, with eight stories was built in Dornbirn, Austria.

Impact on business & ecological environment

- up to 90% improved CO_2 - balance
- 50% improved resource efficiency
- Construction times cut by half
- Regional value added by local production possible
- Flexible usage and conversion of building

Keywords: Cree, life cycle tower, sustainability, hybrid timber, high-rise building, lct one, wood, resources, construction, large volume

1. Global challenge for the building industry

Processes of cultural, ecological and economic change observed around the world are leading to an altered frame of reference for and different demands on the building industry.

1.1 Urban growth

The urbanization of the world presents an enormous challenge to the future of mankind. Even today, 50% of the world's population lives in cities of more than a million inhabitants. Experts believe that this could rise to 75% within 30 years. Over the same period the world's population is expected to rise by 78 million people per year – roughly the population of Germany (United Nations 2008).

The countries that profit from an economic upswing strive to transform their cities into better places to live.

Buildings will have to reach greater heights to keep pace with the rising requirement for space. Accordingly the future activity of the global building industry will become concentrated in urban areas and on the construction of multi-story buildings.

1.2 Scarce resources

If present-day methods of using the world’s resources were maintained, then 2.5 planets would be required to satisfy the future demand for resources. For Europe in particular, where 90% of all raw materials have to be imported, guaranteeing the fulfilment of that need for resources will be an essential precondition for prosperity and social harmony.

Construction worldwide is responsible for around 40% of today's consumption of resources and energy as well as 40% of global CO_2 emissions (United Nations Environment Programme 2009). It is clear that efficient use of resources and energy, and a reduction in CO_2 emissions will be considerable factors in successfully addressing these issues. One of the consequences will be an increase in the statutory provisions and targets relating to energy and resource efficiency applicable in many countries.

1.3 Conventional construction

Up to now, urban development has been based mainly on conventionally built prototypes of complex construction. This entails high construction costs, long erection times and elevated design and construction risks.

Systematization and industrialization of the building production process, such as emerged decades ago in the automotive industry, has so far not been seen in the construction industry.

2. Integrated research – high-rise buildings in wood

The changing global construction scene was the trigger that spawned a research project over several years. An international interdisciplinary team of experts led by Cree GmbH has developed a new type of **wood-hybrid construction system for buildings up to 100 m high** (30 stories). The special feature of the research process was the integrated interplay of knowledge leaders from all the professions in the building industry, such as architecture, structural engineering, building physics, building services, process management, marketing etc.

Three main objectives were pursued:

2.1 Large-volume building

As a result of the global trend towards urbanisation, efforts were made to develop a solution for use in an urban context. The objective was the development of a multi-story building solution capable of reaching up to 30 stories or 100 m in height (Cree GmbH 2010).

2.2 Resource efficiency

The shortage of resources and the associated rising prices of raw materials turn the intelligent use of material goods into an enormous competitive advantage for the building industry. Therefore timber, a renewable and local resource, was chosen as the basis for the development of the new building system. Its reduced "ecological backpack" is only half that of conventional buildings (Manstein C & Reisinger H 2010). Most products we create from the resources of the earth contain far more material by virtue of their extraction, transport and processing than their self-weight alone would suggest. According to the renowned chemist and environmental researcher Prof. Friedrich Schmidt-Bleek all goods have an ecological backpack. To produce a kilogram of steel takes on average 8 kg of mineral ore and fossil fuels, a kilo of copper 348 kg, while a kilo of aluminium "actually" weighs 37 kg. Wood has an ecological rucksack of 1.2 kg. Moreover, wood as a material has the potential to improve the CO_2 balance by 90% (Braune A & Benter M 2010) and reduce the weight of the building by 50 % (Cree GmbH 2010).

2.3 System building

A further objective of the research was to develop a standardised universally usable modular system containing a significant proportion of building technical services (heating, cooling, ventilation,…). The individual elements should, as in the automotive industry, be capable of being prefabricated in a factory and modular to the extent required by the client. The concept of serial off-site production was intended to ensure economies of scale, consistently high quality and rapid erection of the building on site.

The **first research project "8+"** investigated the technical feasibility of buildings in wood construction. The results showed that it was technically feasible (from a structural engineering point of view) to erect buildings 80 m or more in height. The research did not consider the commercial marketability or the likelihood of obtaining statutory construction approval of the final concept. It was therefore not possible to construct a building based on principles of the "8+" research project.

The **second "LifeCycle Tower" research project** extended the findings of the "8+" project and developed a new building system modified to suit the requirements of the modern real estate market. Industrial prefabrication and special consideration of fire safety in the design led to the new product becoming ready for the market.

From research project to built property: with the "**LCT ONE"** the developed concept was transformed into reality in the form of an eight-story demonstration building.

3. The LifeCycle Tower – innovative building system for urban, sustainable architecture

3.1 Architecture

The system can be divided into three main components: core, hybrid slab and façade columns.

3.1.1 Access core

For the LifeCycle Tower research project, a rectangular core was adopted as the basic structure to ensure that the nodes in the stiffening components would be as few and as simple as possible and compatibility maintained with every available facade system. The core is erected in two sections, each 32 m high, in order to maximize stiffness and ductility while being economically competitive with conventional building systems. The reduction to two horizontal interfaces secures not only structural and economic benefits; it also permits a high degree of prefabrication and shortens the construction time. The central core for this project was selected primarily for its structural properties; however this arrangement also has disadvantages when it comes to efficient use of floor area, as incorporating the second escape route inevitably results in a less favourable rentable space ratio. In general, individual stories and their technical services can be accessed via one or several centralized or decentralized be used. The options are available depending on regional building regulations for tall access cores. The cores serve as the stiffening element of the building. While wood is the optimal choice as a material for the access cores, concrete and other non-combustible building materials can also buildings.

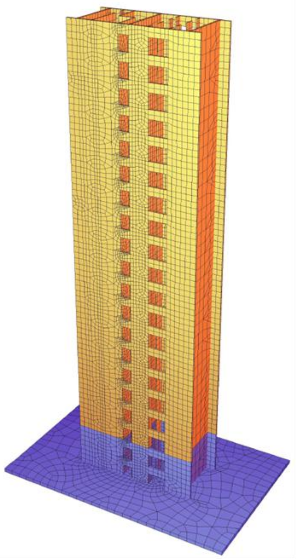
Fig.1: Core

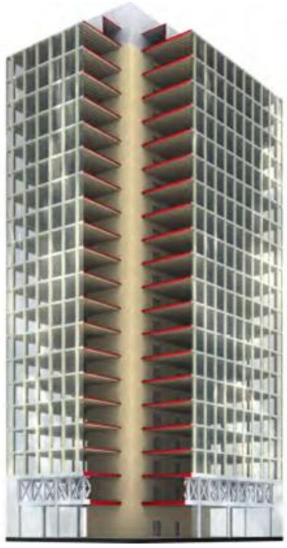
Fig. 2: Shell & Core

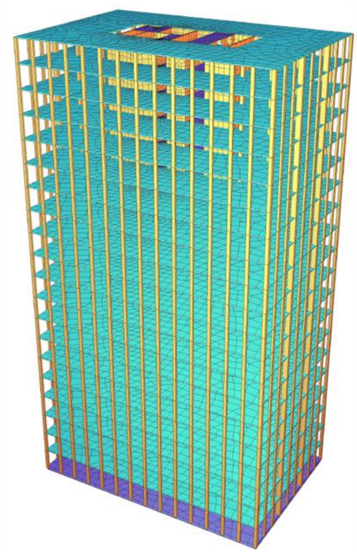
Fig.3: Shell & Core

3.1.2 Hybrid slab

A wood-concrete composite rib construction was chosen for the slab. This fulfils several functions: First, it enables the floor plan to be arranged freely thanks to its long span (<9.45 m) and secondly it guarantees the separation of the stories in the building from each other, as required by fire protection regulations. The space between the ribs allows the building services to be installed within the thickness of the slab. The system also increases the resistance to the spread of fire at the deck soffit. Suspended ceilings are not envisaged. The wood should be left visible for the room users to enjoy, as at the facade supports.


Fig.4: Hybrid slabs

3.1.3 Facade columns

Double columns, designed to provide the required fire resistance, transfer the facade forces directly to the slab, avoiding transverse compressive stresses, and then directly into the column pair below. The pull out or lateral forces, between the double columns and the hybrid slabs, are prevented from separating by strong, but simple, mortise and tenon joints. Wooden frames link several pairs of columns into one unit that can be installed together with the façade. The combined installation of primary and secondary facade elements allows site work to progress more quickly compared with conventional systems as this is a completely dry method in which no curing times are involved.

Fig.5: Loadbearing system

3.2 Modular construction

Prefabricated construction elements with consistent, standard solutions reduce the need for one-off designs. Construction details have already been incorporated and the components only have to be put together on site. Subsequent work involving non-prefabricated components, such as separate fire protection cladding, is kept to a minimum. The elemental approach avoids the need to construct complex details on site, which is difficult to ensure is done properly in such environments.

Fig.6: Construction phases

3.3 Energy design

A clever, highly energy-efficient building services concept was developed for the LifeCycle Tower, which can be built to low-energy, passive house or plus-energy standard. The qualities of the respective location are utilized optimally for the building. Priority is given to the use of renewable energy sources in the energy planning of the building, sources such as geothermal energy, for example, that can be used for both heating and cooling the building. The distribution and delivery system is adjusted to the respective system temperatures. Combined heating-cooling ceiling elements have been developed for space heating and cooling.

The lighting, a comfort ventilation system as well as smoke detectors and sprinklers are all integrated between the ceiling elements. Other possible elements focusing on the use of regenerative energy include solar thermal systems for hot water, regenerative fuel plants where high water temperatures are required and photovoltaic systems integrated in the facade. Despite sun protection measures, the demands on room temperatures in summer (comfort criteria and workplace guidelines) make the use of passive cooling ceilings to cool the building inevitable. However, the higher energy expense that this involves can be reduced by an intelligent control concept (exterior shading controls, automatic night cooling, occupancy sensors) and correct user behaviour.

3.4 Fire safety

Fire protection is an important aspect in obtaining approval to construct multi-story buildings. In the last 20 years, modern timber construction has experienced enormous growth both in terms of technology and in economic efficiency, which is also reflected in the continuous amendments to the statutory regulations. Significant differences within national and regional statutory regulations continue to mean that generally applicable statements about the likelihood of construction approval being granted for multi-story buildings cannot be made, all the more so because approval is very dependent on the proposed building use (hotel, office, residential).

A detailed analysis of the possibilities offered by timber construction and consideration of the risk of the spread of fire posed by the combustibility of wood led to the development of a certified fire protection concept. A number of large-scale fire tests have been carried out in Europe for the floor slab elements of the building system. These tests show the technology is able to withstand up to a two hour fire test. Based on the results of these tests, the components have been optimized leading to a reduction in the amount of concrete used, and the granting of the required REI 120 certificate.

4. Commercial considerations

Construction costs for a system-built LifeCycle Tower are fully comparable with those of a conventionally constructed building. A comparative analysis for the two building types found that the additional initial investment cost for the LifeCycle Tower was only 2%. The objective of the further research is to achieve cost leadership in the area of resource & energy-efficient large-volume buildings.

4.1 Industrial series production

Industrial prefabrication of standardized components will exploit the economic advantages of scale and learning curve effects. Factory quality assurance will also lead to minimisation of errors and consistently high quality of construction on site.

4.2 Supply chain management

Cree is not a manufacturer. The independence of contractors and subcontractors means that the best bids out of the local market suppliers can be accepted for production and erection. Capacity bottlenecks or overproduction can be evened out by flexible integration of the producing firms.

4.3 Life cycle-oriented design

The cost of erecting a building is responsible for only 20% of the total cost of the building over its entire life cycle. The concept of the LifeCycle Tower incorporated extensive considerations of cost-effective use, reuse and demolition of the building. One of the consequences of this is the absence of loadbearing partition walls in the structural frame, which allows room sizes to be freely varied in the future. A high energy standard ensures low operating costs and the wood can be used for energy generation following the cascading use principle at the end of the building's life cycle.

5. Implementation concept

5.1 Formation of Cree GmbH

A dedicated company with a present staff of 15 was set up in 2010 to further develop and market the findings of the research. The partners are Rhomberg Holding GmbH, Signa Holding and RIMO Privatstiftung. The development of the LifeCycle Tower and Cree has been met with acclaim and interest from all over the world, presented at international conferences and cited as a pioneering project in innovative timber construction by leading experts.

5.2 Proof of concept

5.2.1 Eight-story prototype LCT ONE

The design conclusions drawn from the research project were implemented in an eight-story (27 m) demonstration building built in Dornbirn, Austria. Based on this prototype, the advantages of the building concept (including resource and energy efficiency, up to 90% improved CO_2 balance, 50% shorter construction time, series production) are reported on a public stage. The project serves as an exemplary model for modern sustainable building and point the way ahead for the future development of this sector of the construction industry.

Fig.7: LCT ONE outside

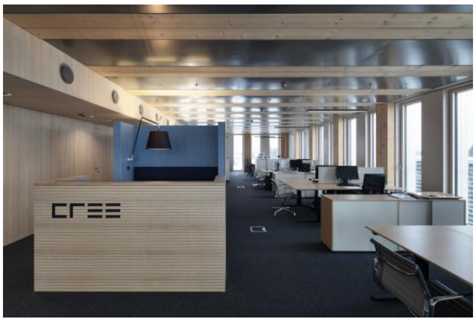

Fig.8: Cree office

Fig.9: LCT ONE at night

5.2.2 First customer project IZM (Illwerke Center Montafon)

The first commissioned project is a large building (120 m) with about 10.000 m² floor area being built in Vandans, Austria. The technical and economic advantages of the proposed LifeCycle Tower wood-hybrid building system were decisive in the commissioning. Verifiable compliance with the fire safety requirements and the ecological advantages of the system were further important factors in the acceptance of the tender by the client.

Fig.10: IZM building phase

Fig.11: IZM

5.3 International marketing

The building system in its finally developed form will be marketed internationally using LCT ONE and IZM as reference projects. Potential target markets will be analysed in parallel with the international positioning of the Cree brand.

5.4 Country-specific construction approval

The engineering feasibility of the tower based on its current stage of development can be confirmed. Construction approval of actual projects still has to be obtained from the competent authorities in each future location. A strategy of sequentially increasing the maximum permissible building height will be adopted to ensure future construction approval. Cumulative experience (construction approvals, fire safety concepts, certifications, testing,…) grows with every completed project and serves as the basis of discussions for obtaining approval of the next higher building class.

6. Conclusions

The concept offers enormous opportunities – for the local timber construction industry as well as housing component manufacturers, contractors and suppliers. The uniqueness of using wood as a visible and sensual construction material for high-rise buildings will lead to new modern perception of nature's building material.

In terms of its export potential, the LifeCycle Tower provides an opportunity for local skills to develop international connections and to strengthen the economy and research locations. It allows small and medium enterprises (SMEs) to benefit, above all those which in isolation are considered not to possess the necessary prerequisites for strategic internationalisation. The implementation and international marketing of the developed modular system opens the way for SMEs to international know-how transfer and real export opportunities.

Wood as local renewable construction material will become increasingly important: it secures regional or national independence interms of raw material supplies and protects against high prices.The propagation of the LifeCycle Tower concept in regions in which timber is of high importance therefore strengthens their economies and independence.

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Arctic Green City Rovaniemi

- a sustainability assessment for directing urban planning

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Summary

In Rovaniemi, at the Arctic Circle in Finland, a disposition plan for the central areas of the municipality was prepared during the years 2010-2012.Three principal options were worked out by the project steering group at an early stage of the process.

The comparison and impact assessment was done by describing the differences and consequences of the options verbally, which is the traditional method in Finnish area and community planning. In order to complement the comparison, and to take a new point of view, a BREEAM Communities (version 2008) preliminary assessment was conducted.

One impulse for doing an internatinally recognized sustainability assessment was the overall urban structure of Rovaniemi, called the Arctic Green City. The area of the city is over 8 000 km^2, the largest in Europe. With its 60 000 population, Rovaniemi is the 15th largest city in Finland. By these figures, the carbon footprint of the city should be colossal.

However, in practice 85 % of the population live within a cycling and walking distance of the centre.11 % live within the 400 hectares' planning area of the central area disposition plan. The user interface for the vast majority of the citizens of Rovaniemi is not car-dependant. Even for car users, the necessary daily trips are very short on average. Consequently, there are reasons for Rovaniemi to call itself an eco-efficient city.

This paper discusses the sustainabily assessment of the Rovaniemi central area disposition plan options in the context of Finnish urban planning practices, processes, and quality management. The influence of the preliminary sustainabily assessment on the final plan is brought forward though a post-planning assessment.

Keywords: BREEAM Communities, Disposition plan, Eco-efficiency, Master planning, Quality management, Rovaniemi, Sustainability, Urban planning

6. Introduction

In Rovaniemi, at the Arctic Circle in Finland, a disposition plan for the central areas of the city was prepared during the years 2010-2012. Three principal options were worked out by the project steering group at an early stage of the process. The comparison and impact assessment was done by describing verbally the differences and consequences of the options, which is the traditional method in Finnish area and community planning. In order to complement the comparison, and to take a new point of view, a preliminary BREEAM Communities (version 2008) sustainability assessment was conducted.

This paper discusses the sustainabily assessment of Rovaniemi central area disposition plan proposals in the context of Finnish urban planning practices, processes, and quality management. The influence of the preliminary sustainabily assessment on the final plan is brought forward though a post-planning assessment.

7. Quality Management in Urban Planning

7.1 Planning as a Process

In Finland, town and country planning is defined as steering land use. In practice, however, especially local detailed planning is very close to designing land use and buildings. To develop urban planning, it is essential to clarify the difference between steering and designing. According to Staffans and Väyrynen (2009), design should be closer to implementation, when again the function of steering is to define strategic goals and objectives for the quality of the end result [1].

In [Finnish] urban planning nowadays it is generally a rule that goals and quality requirements, in other words steering, is expressed in an abstract or frivolous way. On the other hand, in detailed plans, individual solutions are designed in detail. Detailed regulation and instruction for implementation might be necessary. However nowadays, when incorporated in the detailed plan, details come at a too early stage in the process. When implementation is timely, plan regulations often have become outdated, and a revision of the detailed plan is needed.

The confusion between the concepts of steering and design can be described by different interpretations about urban planning being either a *process* or a *project*. In the OPUS project (Urban planning as a learning process, 2009) [1], the process likeness of urban planning was accentuated. The authors have come to a conclusion that continuity, which is connected to process thinking, fits especially well in steering. Steering is seen as the definition of where urban planning is aiming at, based on political decision making. In practice, steering is a number of strategic decisions, policies and development documents, complemented by quality standards and other regulations.

In this paper, the concept [urban /area and community] planning is used equal to steering. The main function of the discussed case, the disposition plan for the central areas of Rovaniemi, is to steer future detailed planning.

7.2 Planning theories

The central development phases of theories on area and community planning - (1) the comprehensive-rationalistic theory, (2) the incrementalistic theory, (3) the theory of communicative planning, and (4) the agonistic theory - can be placed on fields of their own according to, on one hand, what perception of democracy they represent, and, on the other hand, how idealistic or realistic they are in relation to planning practices. Roininen and Oksanen (2012) present the following outline of the four above mentioned theories [2].

As pendulum movements have taken place in the development of planning theories, there has been a shift from a democracy model based on public advantage to an aggregative and further on to a deliberative model. According to Roininen and Oksanen (2012), the latest theories are connected the emerging agonistic model of democracy, applied in the agonistic planning theory (Hillier 2002) [2].

The *comprehensive-rationalistic theory* is based on expertise and scientific methods, and, defined though these, on the public advantage as an indicator of democracy in planning.

The *incrementalistic theory* (Lindblom 1959), brought forward negotiation planning between strong interest groups. Democracy is aggregative, the assumption being that everyone basically drives his or her own interest. Democracy equals to competition and dividing power.

According to the deliberative model, in democracy, processes through which different viewpoints can be brought forward and through which a common will can emerge, are essential. This correspond to the Habermasian *theory of communicative planning*, in which the starting point of rational communication is the assumption of universal competence criteria and the conception of an ideal discourse situation, not using power. For instance the aims of interaction in the Finnish Planning and Building Act (2000) express this type of Habermasian consensus thinking [2].

The theory of communicative planning has been criticized to be idealistic and utopian. A more realistic *agonistic theory* is offered as a replacement, accepting the fundamental incompatibility of the goals and values of different interest groups as the prevailing situation. Agonism is a will to deliver democratic decisions in a constructive spirit. These decisions are partly consensual, but also unsolved disagreements are accepted, based on mutual respect. Planning as communicative action is not only an action to consolidate planning conflicts in suitable conditions. It is an action to handle and solve conflicts together in a legitimately experienced way as well, even when the conflicts remain incompatible (Mäntysalo 2000) [2].

When acquainting oneself to the plan proceedings and documentation [5], the process of the disposition plan for the central areas of Rovaniemi can be described mainly to base on the agonistic theory, with features of the traditional comprehensive-rationalistic theory.

7.3 Managing Quality in Planning and Design

An European definition of quality, expressed in the ISO 9000 set of standards as *the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs,* also includes the point of view of the quality and aesthetics of the built environment and architecture. As presented in figure 1, Kirsten Arge has placed them into two boxes of a larger "quality cube", combining internally and externally defined issues of quality and the product [4].

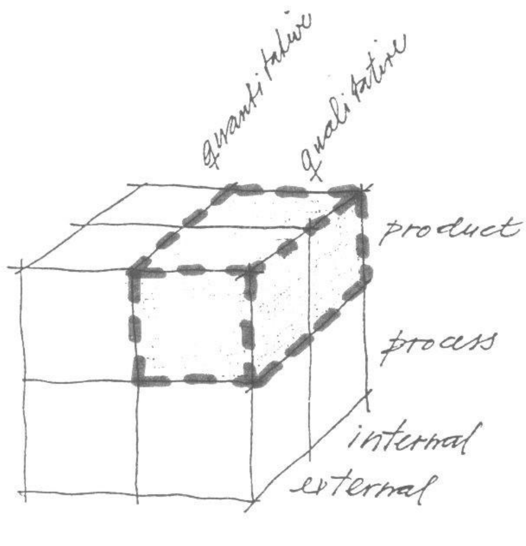

Fig 1: Quality issues of architecture within a general quality matrix

According to Arge, quantitative requirements can be objectively measured, when qualitative requirements imply subjective assessment. Usually, the task of experts is to interpret the qualitative demands into quantitative attributes. In some sectors, such as indoor air quality, this is possible. In other sectors this is much more difficult. For instance architectural quality can be one such sector, also because creative design is not problem solving but a special way of thinking of its own. A significant part of the information needed for design is implicit and cannot be expressed in words. Planning work can be defined as a dialectic game between technical, rational thinking and creative, experience based thinking [4].

As brought forward by Sirkiä (2008), another group of questions in managing quality in urban planning relates to the central concept in quality thinking, satisfying the customers' needs [3]. Where to find the quality expectations of end users and future inhabitants, and how to bring them into the planning process? Do the needs consist of airy picks of real estate brokers, of the deep experience of the planner, or of a combination of these two? Can a market research type of mechanisms be developed, through which the goals of the community, professional expertise and market expectations can be combined in each project?

In the case of the disposition plan for the central areas of Rovaniemi, the responsibility of quality was directed to the planning team. As documented in the plan proceedings (2012), quality assessments were conducted by experts, as internal parts of the planning process [5]. The above questions of quality management are presented in this paper without answers, just for describing the context.

7.4 Commitment to Quality

A planner's view of the city is not enough. Also visionary steering towards the adopted view is required. In a process based operational model, a vision is split into strategic goals, forming the base for more detailed objectives and indicators for sub-processes. As shown by Staffans and Väyrynen (2009), it is typical to Finnish urban planning to set goals without defining indicators and instruments to achieve them [1].

It is possible to administer the totality of different projects in a city by a so called development project portfolio. The choices connected to projects are done based on the city's development strategy. It is essential to understand, how changing just one factor influences the whole. By using a project portfolio, it is possible to identify what types of projects are missing from the city wholeness. Projects that are not essential, or are even counterproductive in achieving strategic goals, can be removed.

To enable actors in different phases to commit to the area vision, they should be involved in the process as early as possible. Developing and building a new area is such a long process that the original vision needs to be regularly updated, preferably in co-operation with the networks of actors in the area [1].

Staffans and Väyrynen (2009) consider, that quality assurance is needed at appropriate phases. The ultimate result of urban planning is not a detailed plan, and not even a built area. It is the good quality of the living environment and the satisfaction of the users of the area. The quality of an urban area is about the users' satisfaction, about the quality of the built environment as about the operational quality produced by the services in the area. A planning process normally ends when inhabitants move in and living in the area begins [1].

According to the plan documentation (2012), in the case of Rovaniemi the quality assurance of the disposition plan for the central area was incorporated in the planning process. The methods used were planning reviews by the planning team and by the steering group, and workshops with responsible authorities, stakeholders and local politicians [5].

7.5 Sustainability as Components of Quality

Sustainability issues in an urban planning process can be seen as quality objectives. In the case of Rovaniemi, the follow-up was incorporated in the planning process.

As a special tool in following up the sustainability components, the set of criteria of the BREEAM Communities (2008) certification system was used, by conducting a preliminary assessment. BREEAM Communities is the first area certification system globally, followed by a number of others. In a brief comparison of a few similar methods, BREEAM Communities turned out to be the most suitable in assessing sustainability in the national and local conditions of Finland and Rovaniemi. A special feature of the method was the possibility to tailor the weighting of scores.

8. Disposition Plan for the Central Areas of Rovaniemi

8.1 The Disposition Plan

The planning was programmed in 2009 and started in April 2010. The city council approved the plan in November 2012. The planning area consists of the central urban area of the regional administrative centre of the Lapland region.

According to the disposition plan report (2012), the area of the city is 8 016 km^2, of which 415 km^2 are water bodies. Rovaniemi is the largest city in Europe by area. With its 60 000 population, it is the 15th largest community in Finland. 85 % of the population live within a cycling and walking distance of the centre.11 % live within the 400 hectares' area of the central area disposition plan [6]. Figure 2 presents the city centre's accessibility in the context of the central areas of Rovaniemi.

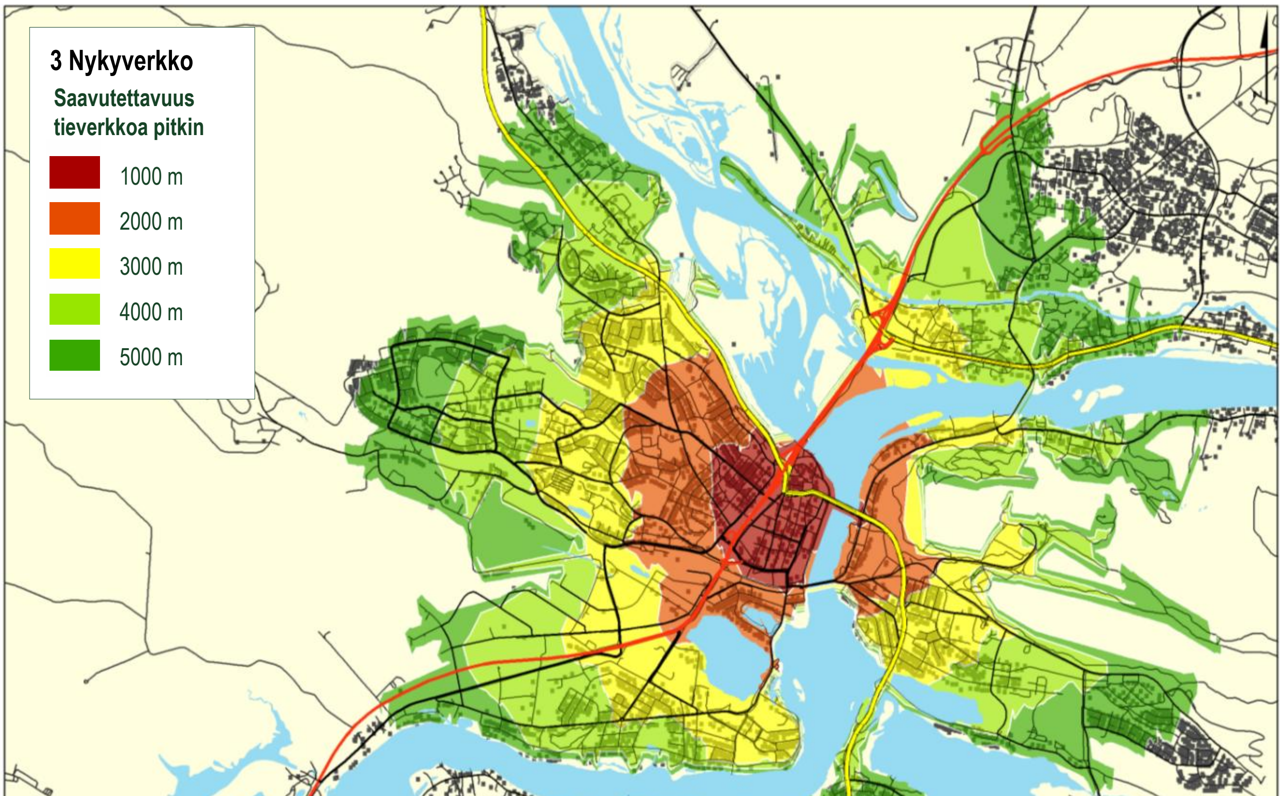

Fig 2: The City of Rovaniemi, a dense centre in a large community

8.2 Sustainability Objectives

As summarized in the plan report (2012), the main objective of the disposition plan for the central areas of Rovaniemi is to direct land use in the medium run, until the target year 2030. The disposition plan sets the framework for future detailed plans [6].

The technical committee of the City of Rovaniemi set the goals for the central area disposition plan in September 2009, aiming to ensure good urban environment while conducting and implementing individual projects though detailed planning, traffic planning and urban design.

The following general goals for sustainability were expressed:

* High density development is located in pedestrian and public transport zones.

* In existing areas for densification and new areas, sufficient space for local services is to be reserved and located within the public transport zone.

* In high density areas, sites are to be connected to the district heating network.

* Planning shall support the survival of existing services.

* In areas for densification, the needs for public services are to be taken into account, based on population prognoses.

* The quality and functions of green area networks are to be taken care of in planning.

8.3 The three Options for Development

At the initial stage of the city centre disposition plan, three principal options were worked out in the project steering group in autumn 2010. The development until the target year 2030 was outlined either by

1) allowing a moderate densification of the existing city centre, by

2) an active densification process encouraged by the city, or by

3) creating a new service centre at Erottaja, between the existing city centre and the potential future development area Lampela, located southeast of the existing centre.

The dimensioning of all three options was based on the population forecast, according to which the demand for new housing in the planning area would be 250 000 m^2 by the year 2030. Additionally, a demand of 80 000 m^2 for new service space was noted.

Depending on the degree of densification at the existing city centre, the development of potential new areas was planned by different area efficiency rates. As brought forward in the plan report (2012), the three city structure options were conceptualized using a virtual model and described for decision making in a report with visuals, text and calculations [6].

The basic differences between the three options were the questions of where to steer new development, as presented in figure 3.

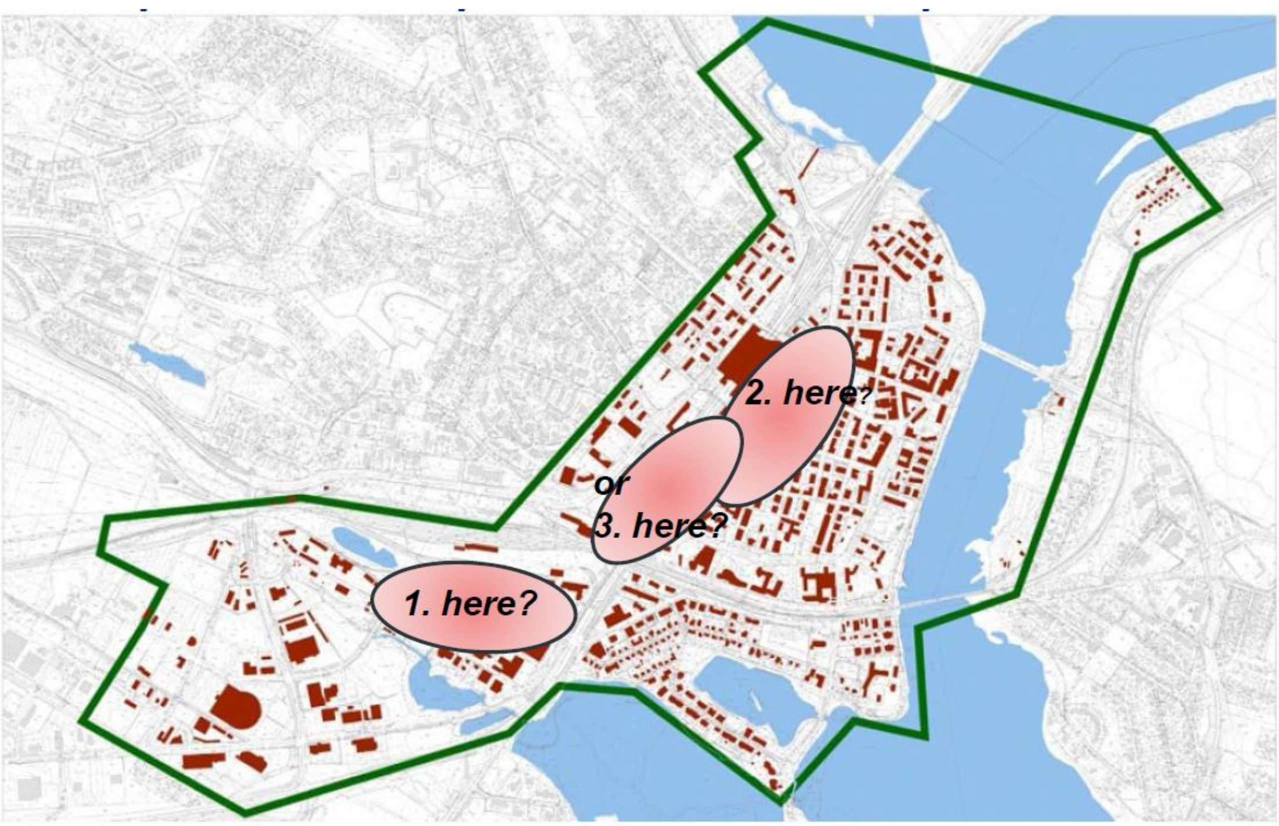

Fig 3: Options for locating the focus of new development

9. Assessing Sustainability

9.1 Comparing Development Options

The comparison and impact assessment of the three options was done by describing the differences and consequences of the options verbally, which is the traditional method in Finnish area and community planning processes.

In the comparison, the essential features in at the option phase of the planning process were emphasized, such as urban structure, traffic and movement, stormwater, and especially landscape and cityscape as important components of the attraction of Rovaniemi. The assessment was based on the analysis, conclusions and recommendations of the basic surveys for the disposition plan.

In order to complement the verbal comparison, and for bringing in a new point of view on sustainability issues, a preliminary BREEAM Communities (version 2008) assessment was conducted, using all 51 criteria of the method. One impulse for carrying out an internationally recognized sustainability assessment was the overall urban structure of Rovaniemi, calling itself the Arctic Green City.

The area of the city is over 8 000 km^2, the largest in Europe. With its 60 000 population, Rovaniemi is the 15th largest in Finland. By these figures, the carbon footprint of the city should be colossal. However, in practice 85 % of the population live within a cycling and walking distance of the centre.11 % live within the 400 hectares' planning area of the city centre disposition plan. The user interface for the vast majority of people of Rovaniemi is not car-dependant. As presented in the plan report (2012), even for car users living in the central areas of Rovaniemi, the necessary daily trips are very short on average [6].

As Roininen and Oksanen (2012) argue, in principle an expert and authority led follow-up and assessment model is in contradiction to the present practice of governance, which is based on interaction and citizen participation. It is naturally also a matter of choice: is it requested that the practice primarily serves governance from the viewpoint of answers, or are there development targets placed on follow-up and assessment as well, which emerge from the conditions of citizens [2]?

In the case of the Rovaniemi central area disposition plan, the assessment and comparison were seen more of a technical nature, as presented in the plan report (2012). Special emphasis in the planning process was put on interaction in the form of numerous open workshops [5].

9.2 BREEAM Communities Assessment of the three Options

The rationale for choosing BREEAM Communities (version 2008) for completing the legal framework comparison and assessment of the disposition plan options is discussed under point 2.5.

Figure 4 presents the relation of BREEAM Communities criteria in relation to the requirements of impact assessments of an urban plan stated in the Finnish planning and building decree. The method, although in a slightly different logic, addresses all the standard requirements.

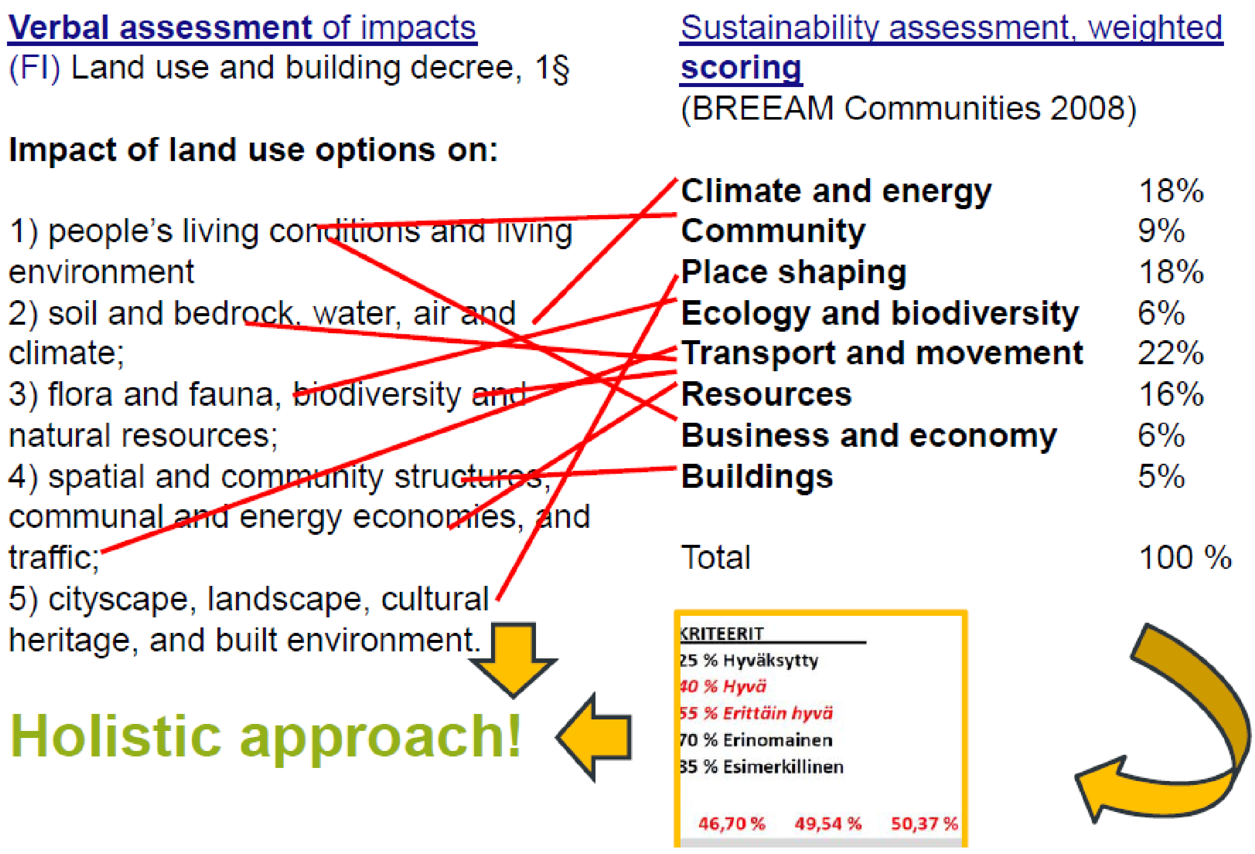

Fig 4. BREEAM Communities compared to impact assessment requirements of the Finnish Planning and Building Decree

A special feature of the BREEAM Communities method (version 2008) is that it allows tailoring for local conditions, eventually preparing for a bespoke assessment. The functions of the method and interrelationships between its criteria are described in detail in the asessor's manual (2009) [7].

In the case of Rovaniemi, 1/3 of the BREEAM Communities (2008) criteria could be applied as such, 1/3 neede to be modified, and 1/3 had to be replaced by Finnish equivalents. As described in the plan report (2012), the eight main criteria were weighted by the steering group (the base weighting is presented in brackets): Climate and energy 8(18)%, Community 10(9)%, Place making 22(18)%, Ecology and biodiversity 14(6)%, Traffic and movement 18(22)%, Resources 6(16)%, Services and economy 18(6)%, Buildings 4(5)%.

9.3 Results of the Preliminary Assessment

In the preliminary assessment, an overall score was accumulated for each of the three plan options, as a percentage of the maximum score. Figure 5 presents an example the summary spreadsheet of the assessment tool.

SLL Maunula **Test Assessment**
BREEAM Communities (Initial Assessment Framework) **310310 /TSi**

Category	Addresses	Regional Weighting	Credits Available	Credits A	% Score Achieved
1 Climate and Energy	Built form mitigation and adaptation issues	18 %	27	*16*	*59,26*
Flood Management, Energy and Water Efficiency, Renewable Energy, Infrastructure, Passive Design Principles					
2 Community	Consultation and local community involvement	9 %	12	*11*	*91,67*
Social Impact Assessment, Community Engagement, Sustainable Lifestyles, Facilities Management, Mixed of Use, Affordable Housing					
3 Place Shaping	Local area design and layout	18 %	33	*24,25*	*73,48*
Site Selection, Defensive Space, Active Frontages, Green Space, Secured by Design, Housing Density					
4 Ecology & Biodiversi	Protection of the ecological value of the site	6 %	9	*4*	*44,44*
Maintaining /Enhancing Habitat, Green Corridors, Ground Pollution, Contamineted Land, Landscaping Schemes					
5 Transport & Movem	Sustainable transport options	22 %	33	*20*	*60,61*
Walkable Neighbourhoods, Cycle Networks, Provision of Public Transport, Green Travel Plans, Construction Transport					
6 Resources	Sustainable use of resources	16 %	18	*12*	*66,67*
Land Use and Remediation, Material Selection, Waste Management, Construction Management, Modern Methods of Construction					
7 Business & Economy	Local and regional economic issues	6 %	15	*6*	*40,00*
Inward Investment, Local Employment, Knowledge Sharing, Sustainable Charters					
8 Buildings	Overall sustainability performance of buildings	5 %	6	*4*	*66,67*
BREEAM Buildings, Code for Sustainable Homes, EcoHomes					
Innovation		N/A	5		
		100 %	**153**	***97,25***	***64,63*** ***% TOTAL***

HUOM: esimerkki menetelmästä, tulos vain suuntaa antava

Fig 5: Example of accumulated assessment results

As the outcome of the assessment, all the three options scored quite well. Table 1 below presents the total score of each option as a percentage of the possible maximum score.

Table1: Sustainability scores of the three development options for the central areas of Rovaniemi

Option	*Score (%)*	*Grade*
(1) Moderate densification	46.7	Good
(2) Active densification	49.5	Good
(3) New service centre	50.4	Very Good

Assessed against international criteria, the development options for the central areas of Rovaniemi scored relatively well, achieving from 46.7 to 50.4 % of the total, equalling the grade “good” or “very good”.

In fact, the differences between the disposition plan options remained quite small in this assessment. The order of the options did not change in a sensitivity analysis, when changing weighting of the criteria. This was partly due to the fact that both the existing situation and planned new developments were included in the assessment. The existing building stock comprised two thirds and new development by 2030 one third of the gross floor area in each development option. A large constant in the form of existing built structures evened out differences. When conducting the assessment at a preliminary planning stage, also the non-existence of detailed input data brought the options close to each other under several criteria.

9.4 Choosing the Option for Further Planning

For further planning, a concept based on option two of the three as descibed under point 3.3., the active densification alternative, was adopted. Additionally, certain features of the other two options were taken in to account for the final disposition plan. According to calculations, the chosen option was also the most economical.

The chosen model, steering to active densification of the city centre, developing green connections and allowing more development across and upon the motorway through the centre, was seen best fullfilling the expressed targets of planning. As described in the plan report, the direction of growth of the city centre is towards southeast, in to the areas of Erottaja and Lampela [6].

9.5 Post-Planning Studies: Sustainability Assessments of the Final Plan

The disposition plan for the central areas of Rovaniemi was approved by the city council on 12.11.2012. Figure 6 is one caption of the virtual model, which was actively used in the planning, from the early phases of development options into the final proposal.

Fig 6: Visualization of the disposition plan for the central areas of Rovaniemi

To find out the influence of the sustainability studies during the planning process and of the impact of the preliminary assessment, another assessment of the final plan was carried out, firstly using the same version 2008 criteria. The scoring rose from around 50 % to 59 %, confirming the grade as “very good”. The plan had progressed in stormwater management, energy efficiency, reuse of existing structures, natural flora, cycling network, parking arrangements, traffic system, and in using local materials. Regression occurred only in the option of shared cars.

Meanwhile, the BREEAM Communities method was updated and streamlined for master planning. The new version was published in October 2012. BREEAM Communities (2012) is an independent, third party assessment and certification standard based on the established BREEAM methodology. It is a framework for considering the issues and opportunities that affect sustainability at the earliest stage of the planning and design process for a development. According to the updated manual (2012), the scheme addresses key environmental, social and economic sustainability objectives that have an impact on large-scale development projects [8].

The BREEAM Communities (2012) scheme covers the assessment and certification of the designs and plans for a development at the neighborhood scale or larger. As described in the technical manual, the assessment process incorporates three steps involved in the assessment of sustainability at the master planning level [8]:

1. *Establishing the principle of development*: during this step the degree to which the plan responds to improve sustainability that necessitate an area wide response, such as community-scale energy generation, transport and amenity requirements is assessed. All issues are covered to ensure a holistic strategy for the site.

2. *Determining the layout of the development*: this step includes detailed plans for how people will move around and through the area and where buildings and amenities will be located in the master plan.

3: *Designing the details*: this step involves more detailed design of the development including: the design and specification of landscaping, sustainable drainage solutions, transport facilities and the detailed design of the built environment.

In the second ”post-plan assessment”, steps one and two of the three described above were included. The third step proved to require more detailed information than what could be extracted of a disposition plan. The final plan was thus assessed against 28 criteria of the total of 40 in the BREEAM Communities (2012) method. The chosen plan option, when developed into a final disposition plan, had clearly improved its sustainability scoring. The total score was 82%, which gives an “excellent” rating.

10. Discussion and Conclusions

The selection of the sites for development is a critical factor in determining how sustainable a community will be. Many decisions taken during the planning stage of development will have a fundamental impact on its sustainability.

Master planning by nature is an iterative process, characterized by developing options and plans, consulting stakeholders, making assessments, and revising plans.

In the case of the disposition plan for the central areas of Rovaniemi, BREEAM Communities, especially its 2012 version, proved to be a useful tool in assessing sustainability issues in the master planning process. The strengths of the method were in bringing to the steering group and decision making tables the sustainability issues in a complicated process with a large number of actors and stakeholders. Observations from the sustainability assessment could be used in developing the disposition plan into an appropriate steering tool for detailed planning.

Master planning is an iterative process, characterised by gradually developing plans, interactivity and plan revisions. A critical factor is the choice of areas to be developed. The location to a great extent determines how sustainable or eco-efficient a new community will be. In general, a number of substantial decisions during the planning process also have a major impact. That was also the case in Rovaniemi. A good example is how in the planning process the ideas to start high-rise building were managed. That, however, is another story. The cityscape in the centre of Rovaniemi is not to change radically from the situation today, which is presented in figure 7.

Fig 7: Rovaniemi City Centre in summer 2010, view from the East

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Case Study - Härmälänranta Sustainable Urban Area Development

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Summary

Cities are expanding and new areas are developed. Area development aims for creating new areas for residential and commercial needs. Sustainable urban area planning is not about concentrating on a single aspect or a single people, but concentrating on a holistic view considering how the stakeholder network co-operates for creating a functioning area. The process in Härmälänranta evolved in three phases and involved multitude of stakeholders all the way through. The core of the success was co-operation and creating multidisciplinary teams that contain people for instance from different functions of municipalities, authorities, architects and developers.

High ambitions have sparked the development of tools and practises which can be used elsewhere. Design process started in 2010 with the first step: Living Area Design (LAD). The method, developed by Skanska, aims for creating an identity and brand for the area. As a result from LAD process four core values were identified: “A genuine person”, “comfortable”, “peace and quiet” and “on the jetty”. Based on four core values and urban analysis eight key design principles were chosen: waterfront location, identity and character, public and private, old and new, integration, green connection and a legible built form.

At the final stage of the process a master plan was created. The Härmälänranta masterplan is made up of two distinct components: The first part, The Design Codes, sets out the vision for the development of the site. The second part illustrates the application of the Design Codes through plans detailing the proposal for the site as a whole, and for several “zoom-in” areas. At this phase six different design codes were chosen to express the visions and focus areas of the project: Flexibility in the plan, variation in built form, compactness, persistence over time, visible processes and defined spaces.

LAD is nowadays a standard method used by Skanska in all its area development projects.The holistic approach guides the developers to choose cost efficient alternatives for example with optimised carbon footprint. Härmälänranta is a good example of joint effort and new way of thinking resulting sustainability. The journey towards sustainable cities does not stop at Tampere. The tools used at Härmälänranta have been further developed and used around Finland, with good results. The new way of involving all the stakeholders has been appreciated by city officials and residents alike.

Keywords: Living area development, holistic approach, urban life, urban development, sustainability, environmental impact, design codes.

1. Introduction

The urban fabric of cities supports urban life – it is the everyday life that takes place within the built environment that makes cities diverse and interesting places to be, work, visit and live. Daily life animates built form and, in turn, built form (the streets, the spaces, the architecture) makes possible certain ways of living. In the case of Härmälänranta, the area can be characterized by diverse housing options; a lively street environment; variation and creativity in architecture; plentiful private open spaces for personal life; well-defined and serviced public spaces; appropriate community infrastructure; and a tangible sense of being close to both "blue" and "green" spaces, ecology and nature. It is an urban area, which is well-connected both within the neighborhood, to its immediate surroundings, to its past, and to the broader context of the city.

First phase of Härmälänranta was started in 2007 and the second phase will be completed during years 2014-2024. Härmälänranta is a joint effort of City of Tampere, Municipality of Pirkkala and Skanska. Härmälänranta is supporting sustainable lifestyles and creating shared value. It's a place where it is easy to make the right choices and where the residents and other users gain knowledge and experience to live and act sustainably. Residents and people working in the area are encouraged to take initiatives creating a community of high living quality for good health, social relations and low environmental impact. Härmälänranta is an economically dynamic urban district with a mix of residential and work places as well as public and commercial services offering the people in the area a local supply of ecological products and services.

Härmälänranta has implemented triple bottom line to its design and has set ecological, economic and social goals. It aims to be a climate positive urban district. Härmälänranta has low consumption of energy, materials, water and other natural resources. The focus is on energy efficiency, life cycle perspective, sustainable transport solutions, eco-efficient buildings and sustainable production and consumerism.

High ambitions have sparked the development of tools and practices which can be used elsewhere. As a result of the quest to find the factors that impact energy efficiency and carbon dioxide emissions of the area, an energy and eco efficiency evaluation model was created. The model gives developers new possibilities to analyze the impacts of different energy efficiency measures on the area level already at the zoning phase. Härmälänranta has also served as a pilot area in several development programs; EcoDrive (Eco-efficient development of communities), Aida (Adaptive Innovative Development Process for Sustainable Area) and Keko (Eco-tools for urban development), which have been funded by Sustainable Community program ran by The Finnish Funding Agency for Technology and Innovation –Tekes.

2. Design Process

The overarching goal of the design process at Härmälänranta was to create sustainable urban area. The aim was to develop an area where it is good to live, work and visit. It was emphasized that development is more than designing great buildings; it's about over all identity of the area. Sustainable urban area planning is not about concentrating on a single aspect or a single people, but on a holistic view considering how the stakeholder network co-operates for creating a functioning area.

The process evolved in three phases and involved multitude of stakeholders all the way through. The core of the success was co-operation and creating multidisciplinary teams that contain people for instance from different functions of municipalities, authorities, architects and developers. Goals that guided the process were set for sustainability, living, architecture and construction. The Inspiration for Härmälänranta was searched from modern city districts like Hafencity in Hamburg and Hammarby Sjöstad in Stockholm. At Härmälänranta the end result, new urban living, combines active life with closeness to nature. The simplified process is presented in figure 1.

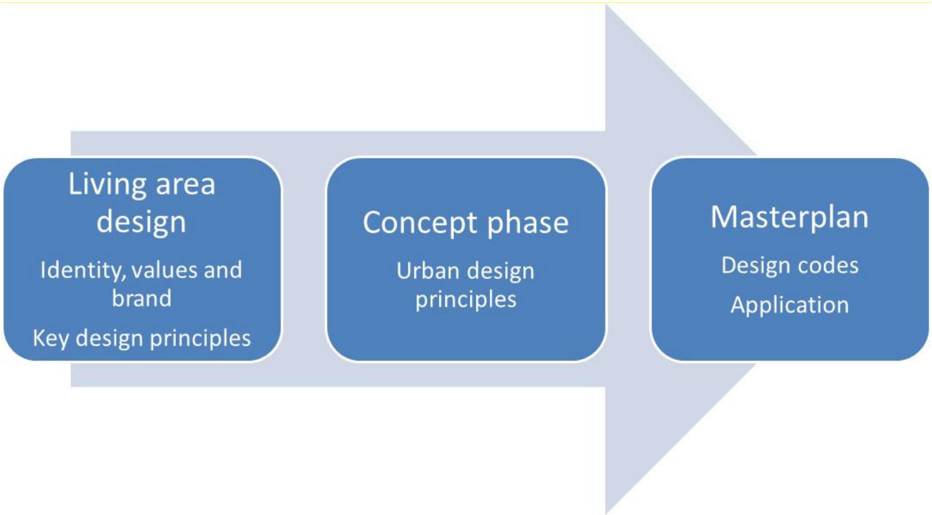

Figure 1. Simplified design process of Härmälänranta area

Design process started in 2010 with the first step: Living Area Design (LAD). The method, developed by Skanska, aims for creating an identity and brand for the area. The base is laid by identifying the needs of the residents in a multifaceted process. The core of the LAD process is workshops that are carried out in two steps. As a result of LAD 1 phase the core values of the area are identified. In the second phase (LAD 2), the core values are concretized and targets to the project are set. The series of workshops involved wide range of stakeholders from landowners to local companies, associations and local residents. LAD workshops gave people a new way to be involved in the development of their neighborhood, something that has been rarely done so extensively in Finland.

As a result of the LAD process four core values of the area were identified:

- **A Genuine Person**: Härmälänranta gathers for the needs of people, who have active and healthy lifestyles.
- **Comfortable:** Härmälänranta emphasizes a sense of familiarity and builds a sense of belonging. It is a long term home.
- **Peace and Quiet**: In Härmälänranta residents have always an option to relax in seclusion and a choice between public and privacy.
- **On the Jetty**: The shoreline of Härmälänranta is open to all, and provides a place and reason to go outside, in all seasons.

LAD workshops were complemented by urban analysis carried out by Tengbom architects. Analysis carefully considered the urban structure and form of the area, visual and physical connections to and from the site, and the role of Härmälänranta's postindustrial heritage and prominent waterfront location.

Based on four core values and urban analysis eight key design principles were put forward:

- **Waterfront location:** Lake provides possibilities for recreation year round
- **Identity and character**: Area will have a very distinctive identity, which residents will relate to.
- **Public and private:** There will be plenty of spaces for people to meet, but homes are private. There is a clear distinction between private and public spaces.
- **Old and new:** Heritage of an old industrial site and modern urban living go hand in hand in the area.
- **Integration**: Landscaping supports the areas ecosystem.
- **Green connections:** Nature is close in many ways.
- **A legible built form:** Every block has its own characteristic forms that complement the area.

- **Sustainable development**: Area is built to last with careful choice of materials and solutions.

The multi-disciplinary design team continued the process by putting forward an ambitious concept, with a series of Urban Design Principles to guide the disposition of built form across the site. Concept also included broad programs for design of key landscapes, based on principles of flexible use and visible ecological processes.

At the final stage of the process a master plan was created. The Härmälänranta masterplan is made up of two distinct components: The first part, The Design Codes, sets out the vision for the development of the site. The second part illustrates the application of the Design Codes through plans detailing the proposal for the site as a whole, and for several "zoom-in" areas. Design codes help concretizing key design principles as presented in table 1 and explained further on.

Key design principles / Design code	Sustainable development	Legible built form	Old & New	Indentity & Character	Waterfront Location	Public & Private	Integration	Green Connections
1.Flexibility in the plan	x	x	x	x				
2. Variation in Built Form		x		x				
3. Compactness	x	x		x	x		x	x
4. Persistence over time	x		x	x				x
5. Visible Processes	x	x	x	x	x		x	x
6. Defined Spaces		x		x		x	x	

Table 1. Key design principles and design codes of Härmälänranta

3. The objectives for sustainability in Härmälänranta

One of the main principles is that Härmälänranta will be a climate positive urban district. Härmälänranta will be adapted to future climate changes and have a low consumption of materials, water and other natural resources. Skanska's sustainability principles are followed in the process. For example in the buildings used materials will be M1 classified (in the Finnish emission classification of building materials products) [1]. The classification presents emission requirements for the materials used in ordinary work spaces and residences with respect to good indoor air quality. M1 stands for low emissions. [2]. Also a suitable Chain-of-custody process such as the Forest Stewardship Council (FSC) or Programme for the Endorsement of Forest Certification (PEFC) is required to be in place when timber or timber products are purchased.

In addition the focus is on energy efficiency, lifecycle perspective, sustainable transportation solutions, eco-efficient buildings and sustainable consumerism. During the zoning phase an energy and ecoefficiency evaluation model has been created. The model gives developers new possibilities to analyze the impacts of different energy efficiency measures on the area level already at the zoning phase. The analysis can even be taken beyond the traditional energy efficiency studies to energy consumption profiles. Buildings of the second phase of Härmälänranta will all be passive or zero energy buildings. In addition to this different energy sources are studied such as solar energy and heating, geothermal energy, or utilizing heat from lake or biomass. The holistic approach guides the developers to choose cost efficient alternatives with optimized carbon footprint. Härmälänranta is a good example of joint effort and new way of thinking resulting sustainability.

On social point of view Härmälänranta will be an urban district supporting sustainable lifestyles where it is easy to gain knowledge and experience of sustainability. Residents and people working in the area are encouraged to establish a community of high living quality and low environmental impacts. Social interaction is promoted and community and affinity is endorsed by different housing types and integration of new construction and existing buildings. Services, residential and work places are linked by public spaces. The land area will be reused in efficient way and the cultural heritage is preserved

Härmälänranta is to be spatially compact, coupling higher density development to high quality local public spaces via an integrated network of green spaces, streets, squares and blocks. The reason to aspire to a higher density urban environment in Härmälänranta is simple: through higher residential densities in the area, more people will have better access to a higher quality urban environment. A denser area will support a larger market for commercial services (supporting local shops, for instance), better social infrastructure (supporting, for instance, plans for a tram line through the area), and justifies investments in a higher quality public realm. It also leads to a more inhabited area, both during the day and night, enhancing the social qualities of the area.

Sustainability actions are based on the vision of creating the most sustainable urban district and tough goals and focus areas as presented in figure 2.

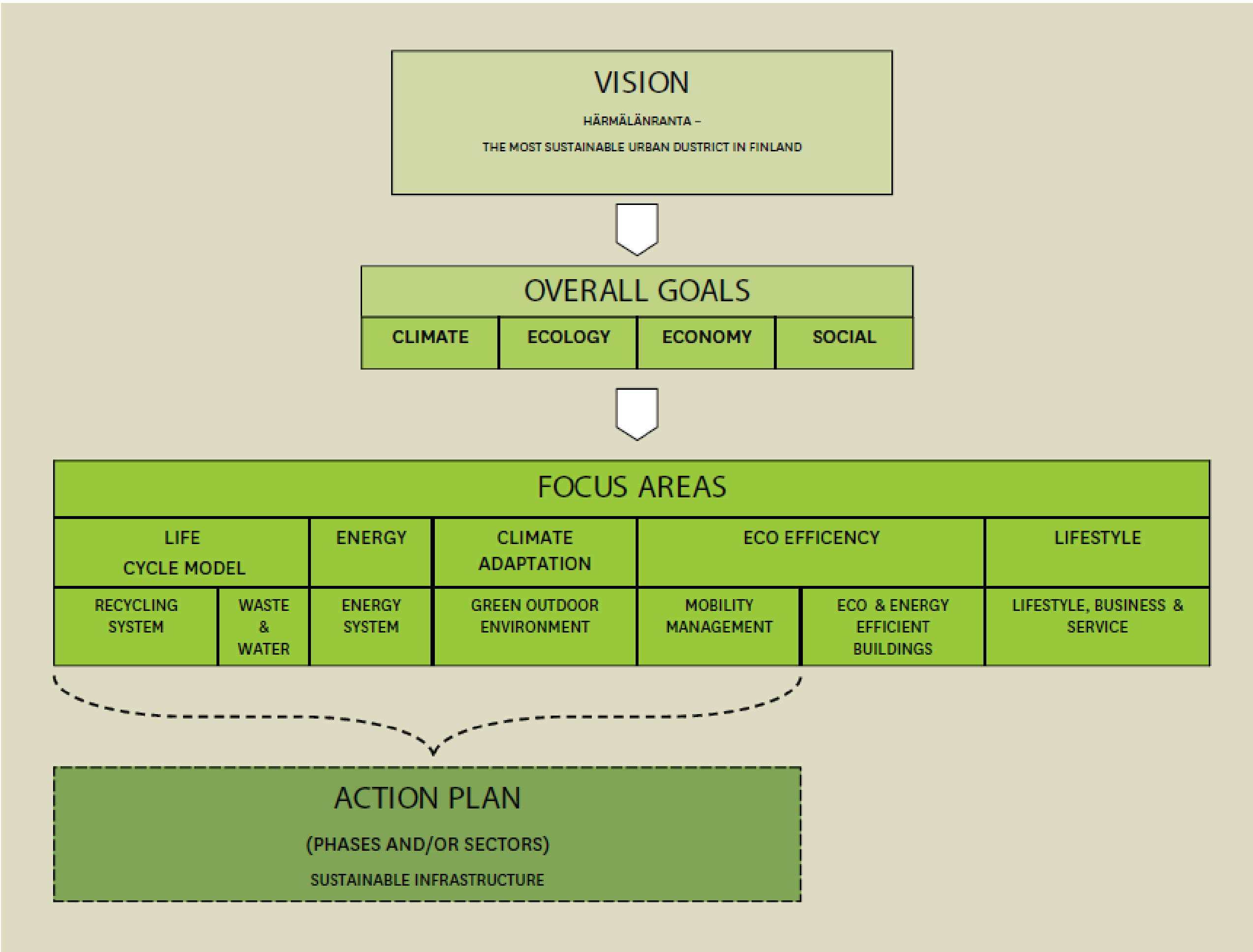

Figure 2. From vision to action plan.

4. Sustainability in Action – Design Codes

Design codes are a form of strategic planning which clearly describe aspirations in a project, setting out systematically the parameters of a vision in precise terms that can be understood and achieved by the designers working with a given development project [4]. In Härmälänranta there are six different design codes expressing the visions and focus areas of the project.

4.1 Design Code 1: Flexibility in the Plan

Flexibility refers to the ability to accommodate change. When it comes to flexibility in land use Härmälänranta is to be equipped to respond to changes in both the short term (for instance, the programmatic demands of the climate, through seasonal change) and the long term (for instance, by allowing for the eventual development of commercial uses at the ground floor in key locations as the local market establishes itself). [4] Existing buildings in the area can have short term or temporary use purposes during the development and construction period of the area. Streets and parks may also be used for different purposes depending on what time of the day it is. For example skate park can be turned in to outdoor cinema during the night.

Flexibility in the plan is contributing to sustainable development, legible built form, old & new and identity & character key design principles.

4.2 Design Code 2: Variation in Built Form

Urban development should be about variation in buildings, streets, landscapes and spaces within these. Variation in building types creates diversity in the scale and character of streets, courtyards and the public realm. The scale and type of dwellings also affect the social qualities of the neighborhood or city through the size of apartments [4]. The aim is to create interesting unique spaces, courtyards and streetscapes.

Variation in building heights and roof forms are to establish the strong visual presence of the area in the local and regional landscape. Härmälänranta's skyline will be recognizable from far, including from the center of Tampere. A monumental expression is to be avoided. Therefore, the high rise buildings are symmetrical placed. In general, the building heights within Härmälänranta vary from 2 to 6 floors. Higher volumes varying from 7 to 16 stories have purposefully been located to create an interesting dynamic and add to the variation of the area. The highest buildings, 14 to 16 stories, are strategically placed; facing the apple orchard and the waterfront establishing a visual connection to central Tampere, along the central boulevard to create an interesting view along the street and in contrast to the old factory, and a marker for the center of the area - the junction between the activity link and the central boulevard. [4]. Design code 2 is contributing to legible built form and identity & character of the area and aiming for sympathetic interfaces.

4.3 Design Code 3: Compactness

Härmälänranta is to accommodate a range of household types and will therefore be home to families of all kinds and sizes, including those with small children. As such, play equipment is to be planned in centrally accessible locations. Härmälänranta will be home to many residents who live in proximity to both each other and to the open spaces, streets and squares that form the public realm [4]. The public realm is to provide them with opportunities for interaction, and therefore provide a stimulus for social life.

Compact city aims to higher population density in order to maximize value of social goods like transportation and public open space. In other words this means resource efficiency. The reason to aspire to a higher density urban environment in Härmälänranta is simple: through higher residential densities in the area, more people will have better access to a higher quality urban environment. A dense population will secure local services, better public transportation means and higher quality of public realm. Härmälänranta will have higher density than surrounding areas such as Pirkkala and 1st stage of Härmälänranta.

For achieving compactness the provision of a movement network is crucial. It integrates all parts of the area with its key public spaces and public transport connections, as well as the area with its surroundings [4]. In a move away from the traffic segregation of the modernist planning of the post-War era, the street network in Härmälänranta will, in many places, integrate different transport modes (cycling, walking and cars) in a single “shared space”, rather than segregating modes from one another.

Emphasis is to be placed on pedestrian modes of travel. A variety of speeds and experiences, from spaces for a slow promenade to longer routes for jogging and dog walking, are to define the pedestrian path network in Härmälänranta. Each path is to have its own character and experiential qualities, reinforced by appropriate street furniture and lighting. Pedestrians are to be able to cross the blocks via open courtyards. Connections to regional bicycle and walking paths are to be well-lit and signposted.

Existing and proposed public transport stops form critical points of connection for the area. Bus routes will run through the center of the site, via the Activity Link. High density provides good ground for new ways of public transportation [4]. There are proposed stops for tram line on the southern edge of the site, if the city decides to invest in it.

The opportunity to use, experience and enjoy public spaces in Härmälänranta is to be open to all residents and visitors. Open access is particularly emphasized with respect to the waterfront and Creek Park. Open green spaces also provide an important part of the public realm, offering opportunities for social events, sports, contemplation and walking in both the winter and the summer months.

Compactness will support legible built form, identity & character, sustainable development and integration of key design principles of the area.

4.4 Design Code 4: Persistence over Time

The past of Härmälänranta will enrich the new urban area, imposing particular site-specific requirements on the planning of the area, and offering opportunities for the development of local character through design which rehabilitates and reinterprets the site's heritage [4]. The existing buildings are to be refurbished and for example establishment of a hotel is to be explored. These buildings can also be used for temporary purpose during the first phase of construction of the area.

An important part of the heritage of the site lies in prior land uses. These uses have left traces which are to be re-expressed in the new development: the large floor plates of the factory buildings translate into the basis for the 100 x 100 meter mega-blocks. The old road, Lentovarikonkatu, which traversed the site, forms the basis for the Activity Link [4]. The stone bridge is to be retained and restored. Further, the railway line that traversed the waterfront is to be recovered and highlighted in the landscape design.

Härmälänranta is to be built to last; using robust and durable materials which do not require replacement in the near future. Where possible, materials are sourced locally, and all materials are to be selected on the basis that they perform well with regard to specific local climatic demands.

4.5 Design Code 5: Visible Processes

The English Garden and Apple Orchard respectively symbolize the picturesque and productive possibilities of landscape. Both are time-honored, formal spaces that exist in poor condition today. The two areas are to have a central role in future Härmälänranta and as such are to be restored by new planting, and formalized with new "edges" and clarified path systems. Their use for recreation and cultivation respectively is to be retained and strengthened.

Another point of sustainability view is the landscape design of Härmälänranta. The design aims to adopt a palette of both native and locally adapted plants, which are not only able to withstand the local climate but thrive in such conditions [4]. Local vegetation brings longevity and sustainability to the landscape, which in turn provides habitat for native birds and wildlife, promotes biodiversity, and helps to enrich local ecosystems. The treatment of storm water on site adds to these values.

Stormwater treatment is to be made visible, with water brought to the surface in both the Central Boulevard and in the Creek Park, giving the area a consistent coastal character and integrating the blocks by acting as a repeated motif. An exposed channel is proposed to run down the middle of the Central Boulevard [4]. This channel is to deal with stormwater from the hard paved surfaces of the street. The channel is to be dry in periods of no rain and, after rain periods, water can be diverted into rain gardens which line the boulevard, feeding the trees which are planted in the central median. Rain gardens are also to be used on the waterfront in the shared space zone. Stormwater is to be treated within the Creek Park, with a retention basin planned for overflow events. In this way, water infrastructure is exposed and forms a key element of the landscape.

4.6 Design Code 6: Defined Spaces

Härmälänranta is an urban environment that balances activity with quiet. The edges between active and peaceful, public and private are to be distinct and the area is to provide opportunities for both. Rather than segregating land uses, Härmälänranta will rather clearly define boundaries in a mixed-use area characterized by strong overall variation [4]. Whilst commercial premises may exist alongside residential, residential exists along the public realm, and parking alongside courtyards, the edges between these different uses and spaces will be well-considered and clearly defined. Private and publics are interrelated, with privacy being dependent on a having a choice about who you wish to spend time with and around. In Härmälänranta, this choice of whether to spend time in public space, amongst a smaller group of friends, or by oneself, will always be present.

The space of the street defines an important part of the public realm [4]. The streets of Härmälänranta are to be clearly defined as public, through a clear sense of enclosure by a “street wall”; by unambiguous delineation of the interface between private and public; and, where appropriate, by “active” facades, which use transparent treatments to provide views to communal or commercial spaces.

Parking garages are confined to at-grade or half-basement levels, with the exception of garages located under streets, which can be built at basement level and accessed via abutting half-basement garages. Guest parking is to be provided on streets. Car parking is to be provided at a ratio of 1 space per 100 square meters of residential floor space, with guest parking to be provided on streets at a rate of 1 park per 10 residential units.

5. Conclusions

Härmälänranta is a good example of joint effort and new way of thinking resulting sustainability. Härmälänranta represents a new urban district where people can live active lives close to nature. The identity of the area is not a coincidence but a result of a long and rewarding process. The Living Area Design, LAD, method involves systematically wide range of stakeholders and ensures that multitude of views and wishes are heard during the design process. The method, developed by Skanska, has proofed its power at Härmälänranta, a joint effort of City of Tampere, Municipality of Pirkkala and Tampere.

At Härmälänranta bringing together authorities, landowners, local companies and associations in multitude of workshops brought design team ideas that could have otherwise gone unnoticed. Combining the outcome of the workshops with the urban area analysis formed a solid base for taking design process further. Values, brand and identity of the area are turned to action through Key Design Principles and Design Codes. The thorough process has not just ensured residents are heard but helped the projects team in their journey on creating one of the most sustainable urban districts in Finland.

The journey towards sustainable cities does not stop at Tampere. The tools used at Härmälänranta have been further developed and used around Finland, with good results. The new way of involving all the stakeholders has been appreciated by city officials and residents alike. LAD is nowadays a standard method used by Skanska in all its area development projects. Also the energy and ecoefficiency evaluation has been further developed in several projects. Multitude of tools combined with project teams’ ambition to develop interesting places to be, work, visit and live result in sustainable living that creates shared value.

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Sustainable renovation in urban environment: current situation in Finnish case study buildings

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Summary
This paper addresses the collaboration work within EU co-financed project INSULAtE (Improving Energy Efficiency of Housing Stock: Impacts on Indoor Environmental Quality and Public Health in Europe). The main aim of the project is to develop a common protocol for assessment of the impacts of building energy efficiency on indoor environmental quality and health. By employing the assessment protocol it is expected to demonstrate and quantify differences in the situations between before and after renovation. In this paper, only the current (pre-renovation) situation of recruited Finnish case study buildings was described and discussed. In the heating season 2011 - 2012 six multi-apartment buildings (22 apartments) for pre-renovation measurements were recruited in Finland. As a common feature, indoor environmental quality (based on measured indoor temperature, relative humidity, thermal index, particulate matter, and carbon dioxide concentrations) were on the verge of good level in most of the studied Finnish case buildings, which undergo renovation. Therefore it’s quite challenging to keep that level also after renovations. Any possible information of the new scheduled renovations in Finnish multi-family buildings is valuable and very welcome.

Keywords: Indoor environmental quality, pre-renovation, multi-family buildings.

1. Introduction
1.1 Background of the project

This paper addresses the collaboration work within EU Life + co-financed project INSULAtE - Improving Energy Efficiency of Housing Stock: Impacts on Indoor Environmental Quality and Public Health in Europe. INSULAtE is coordinated by the National Institute for Health and Welfare (Finland) and has two partners: Kaunas University of Technology (KTU, Lithuania) and Tampere University of Technology (TUT, Finland). Project objectives are: 1) to develop a common protocol for assessment of the impacts of building energy efficiency (EE) on indoor environmental quality (IEQ) and health; 2) to demonstrate the effects (both positive and negative) of EE on IEQ and health in 2-3 European countries; 3) to develop guidance and support the implementation of the related policies; transnational networking and dissemination of information. The project focuses on assessment of national programs targeting to improve EE of the existing housing stock, such as government supported improvement in thermal insulation, which is seen as a cost-effective EU-wide appropriate and proven EE measure.

1.2 Experience from previous research with some similarity

Efforts have been made to learn from the experience gained by previous research projects with some similarity. Norwegian research project Rebo [1] dealt with comprehensive upgrading of 1960-70's multi-family dwellings which included both internal and external renovations. The aim of the project was to show how post war residential environments can be improved in general, with a specific focus on concepts of energy efficiency, design for all (universal design) and residents' participation in the planning process. Two typical Norwegian owner occupied multi-story concrete blocks of flats (outside the city of Oslo and Bergen, respectively) were presented to illustrate the main findings. It was demonstrated that economically profitable upgrades according to the Passive House concept are possible, when the building mass is in poor condition and a major renovation must be undertaken. Additionally, indoor climate and comfort of the residents were improved. Retrofitting only according to the most urgent demands and slightly improved standards, may easily become unaffordable in the long term, and ruin the chances for more ambitious renovations in the future. Also, universal design and resident involvement in the renovation planning process were highlighted as requirements for success [1].

The sustainability of renovation for increased end-use energy efficiency for multi-family buildings in Sweden was analysed [2]. Multiple case studies were used to analyse the contribution of renovation packages drawn up with the goal of increasing end-use energy efficiency to a broader range of sustainability aspects. In each case study a multi-family building representing a typologically significant class in the Swedish building stock was considered. The analysis was performed according to reduced bought energy demand, life cycle costs, greenhouse gas emissions and 14 indicators from the Swedish environmental rating tool Environmentally Rated Building (ERB). In this way aspects related to energy (e.g. bought energy demand, non-renewable energy demand), indoor environmental quality, IEQ (noise, indoor air quality, thermal climate, daylight and moisture) and embedded hazardous materials are analysed simultaneously for proposed renovation packages in a systematic and consistent manner.

Taken together, the case studies show that whilst there is potential to increase end-use energy efficiency in the Swedish building stock with renovation packages that have lower LCC than lower-efficiency packages, energy-efficiency packages with relatively higher marginal investments seem to have higher LCC than lower-efficiency packages. Evaluation of measures with ERB indicators is important both to show IEQ advantages of packages (as a possible added value) through positive changes in indicator values and also to show where packages need to be amended to avoid negative consequences of renovation [2].

Nordic research project SURE (2009-2011) described Sustainable Refurbishment – life-cycle procurement and management by public clients [3]. Ten case studies described both differences and similarities between Norway (4), Denmark (2), Finland (3) and Iceland (1) when it comes to challenges for sustainable refurbishment. The similarities and differences between the cases and country specific parameters, together with the client discussions and internal workshops, have crystallized some important topics for a Nordic guideline on sustainable refurbishment of buildings.

One of the most important actions is to help the clients (building owners) to think sustainably. First, the finance model must be set and the process of defining sustainability has to be done. Then, a strategy and ambition level for the project is needed. The strategy and ambition level cannot be set before the client has a performance profile of the building, and therefore a condition survey is of high importance in a very early stage of the project. A list of sustainable indicators should be presented. The indicators should be mostly quantitative so that they can be measured and benchmarked. Further, the guideline should help the client to plan how to implement these indicators into the project, but also give guidance on how to check the indicators both during planning, building and operation [3].

An attempt was made to develop sustainable indicators within the FP7 project Perfection: Performance indicators for health, comfort and safety of the indoor environment (2009-2011) [4]. The aim of Perfection was to help enable the application of new building design and technologies that improve the impact of the indoor built environment on health, comfort, feeling of safety and positive stimulation. A set of Key Indoor Performance Indicators were developed and improved; indicated as KIPI-framework. It contains 4 main categories, each composed of 2 subcategories, and 31 performance indicators:

- Health and Comfort, dealing with items such as mould growth risk, ventilation/CO_2, combustion sources/infiltration, particulate matter, drinking water quality, operative temperature/PPD, illuminance, daylight factor, background noise level and reverberation time.
- Safety and Security, covering safety in use, feeling of safety, meeting current regulation, building type specific safety issues, personal and material security, security of information and reliability in exceptional cases.
- Usability and Positive stimulation, with as indicators access to and in the building, wayfinding, adjustability, view to outside, privacy, feelings and sensations and availability and quality of recreational spaces.
- Adaptability and Serviceability, in which versatility and protection, technical service life, adaptability to climate change, branding and cultural heritage, availability of services in the building, cleanliness and maintainability are considered.

From these four categories, health, safety and comfort are clearly covered by ongoing research and technological development. From the European point of view, health and safety are areas which are well subjected to regulations and standards, both existing and under development. Comfort seems to be less covered by regulations, but is well addressed in standards. The other sub-categories seem to draw in general less attention from policy makers, industry or the public [4]. It should be pointed out that the project Perfection involved no measurements and it was not related to the renovation of buildings. The validity, relevance, and applicability of KIPI-framework indicators may be further evaluated in INSULAtE project.

The efficiency of complete refurbishment of three 1950's residential buildings (each consisting 30 apartments) in Germany (Karlsruhe-Rintheim) was monitored in field test [5]. Six different retrofit scenarios in terms of insulation, heat production and delivery, domestic hot water production and air-handling systems were applied. Each retrofit solution was applied for ten apartments, an adequate number to evaluate the user-behaviour. For the evaluation of the efficiency of each retrofit solution, a high resolution monitoring system for rooms, apartments, and engineering systems were installed. In each room, for example, a monitoring module measures relative humidity, window opening, CO_2, VOC, and indoor temperature, as well as illumination of the ceiling in lux. In the course of the working process both static and dynamic calculations were done. The evaluation of the results demonstrated how, depending on the retrofit solution, primary energy savings up to 90% were possible. In parallel, the comfort inside the apartments was increased. Data from the monitoring system showed that for those buildings the heat consumption for space heating is in average 25% higher than the heat demand calculated following the EnEV (German energy saving ordinance) procedure. This result pointed to the emergence of a rebound effect, where some of the users tend to increase their consumption levels, once more energy efficient systems are available [5].

1.3 Demonstration activities in INSULAtE project

INSULAtE project aims to demonstrate and quantify differences in the situations between before and after renovations (pre and post energy improvement intervention) in building energy consumption, thermal conditions, ventilation/air exchange, performance of building structures, indoor air quality as well as occupant health and well-being. The changes can be either positive or negative, and the effects may be different in different countries. The methodology and criteria for the building, exposure and health-related assessment has been previously described and discussed [6].

In the first phase of the project case studies will be performed in two countries (Finland and Lithuania), including 20 multi-family buildings per country (basic assessment). Multi-family buildings are selected because current national programs aimed to improve energy efficiency of the housing stock focus on multi-family buildings. Case studies will be selected primarily amongst those who receive government support for renovation, e.g. insulation. During the first heating season 2011-2012, pre-renovation measurements were performed in six multi-apartment buildings in Finland. The main results of those measurements are presented and discussed in this paper.

2. Materials and methods

2.1 Case study buildings

In the heating season 2011 - 2012 six multi-apartment buildings for pre-renovation measurements were recruited. The buildings were located in five different cities in Southern part of Finland (Helsinki, Tampere, Porvoo, Imatra, Hämeenlinna). The studied multi-apartment buildings were constructed in 1928, 1976, 1977, 1977, 1977, and 1980. The inhabitants owned the apartments in five case buildings out of six, while one case was a rental building. Various kinds of renovations are planned at the recruited case study buildings. In one case building, as an example of minor renovation, only new windows will be installed and the fresh air intake system improved. As of another example, overall renovation of all building components, new balconies and splitting of large apartments will be performed.

2.2 Measurements and inquiries

The in situ measurements included indoor and outdoor temperature and relative humidity, surface temperature (recorded with thermographic camera), air flow (air ventilation rate) and pressure difference. Particulate matter concentration and carbon dioxide (CO_2) was recorded for 24 hours in each apartment. The measurements of volatile organic compounds (VOCs), aldehydes and NO_2 employed passive sampling (2 weeks). Settled dust was collected in order to measure concentration of mineral fibres (2 weeks) and microbial agents (2 months). The possible occurrence of radon was checked with passive sampling (2 months). Also, temperature (T) and relative humidity (RH) was recorded (2 months). Sampling log sheets were filled for each measurement. The study also included occupant questionnaires and a diary (filled by the residents for 2 weeks). The measurements were conducted from December 2011 to May 2012 in a total of 22 apartments. The methodology, results and discussion of some of the measurements are presented and analysed as follows.

2.2.1 Temperature and relative humidity

Temperature and relative humidity were recorded by means of data loggers. Although factory calibrated, the readings of loggers were re-checked and compared with each other in different temperature and relative humidity regimes. Indoor and outdoor T and RH values were recorded during the first visit of measurements as well as for long-term measurements. One logger per building was placed outdoor. It was placed, for example, at the balcony during the measurements or under entry shelter when entering and leaving the building. The logger should not be kept under rain or direct sun. Indoor T and RH values were recorded in each room of the apartment at the height of about 1 m, in occupied zone.

For long-term measurements data loggers were pre-programmed for logging T+RH values once an hour. Values were logged for at least two months in each case study apartment. Two loggers were placed per apartment. First, the inner surface temperatures of external walls were monitored with thermographic camera in order to record minimum surface temperatures i.e. the coldest spot. The floor to wall, wall to ceiling joints and external wall edges as well as window and door edges were carefully checked. One logger was placed on the floor facing outdoor wall at coldest spot. An instant vicinity of balcony door was frequently found to be the coldest spot. Another logger was placed in the middle of the apartment, at the height of about 1 m from the floor (warm spot). The loggers could be placed at same room, but not necessarily.

2.2.2 Carbon dioxide

Short term carbon dioxide (CO_2) was recorded with indoor air quality monitors (HD21AB). One monitor per apartment was placed during the first visit of measurements. The monitor was placed in the living room at the height about 0.5m from the floor (on the table etc.). CO_2 values were programmed to record once per minute for 24 hours.

2.2.3 Particulate matter

Particulate matter was recorded with direct reading optical particle counters (OPC). One OPC was set indoors of the apartment, if possible in the living room, close-by to the other sampling devices. The indoor OPC should be positioned in the area with no primary activities (e.g. TV, computer or other working equipment, which generates and attracts particulate matter). The sampling enclosure should be positioned so that the inlet would be situated at the height of 1-1.2 m from the floor surface. The sampler should be placed in a location that is both unobstructed and representative of the actual used area of the room. Another OPC was set outdoors; the most preferable place would be the apartment's balcony. Both OPC were configured to sample for 1 minute and hold for another 30 seconds. Indoor and outdoor particulate matter was recorded at the same time for at least 24 hours.

3. Results and discussion

3.1 Air and surface temperature, relative humidity, thermal index

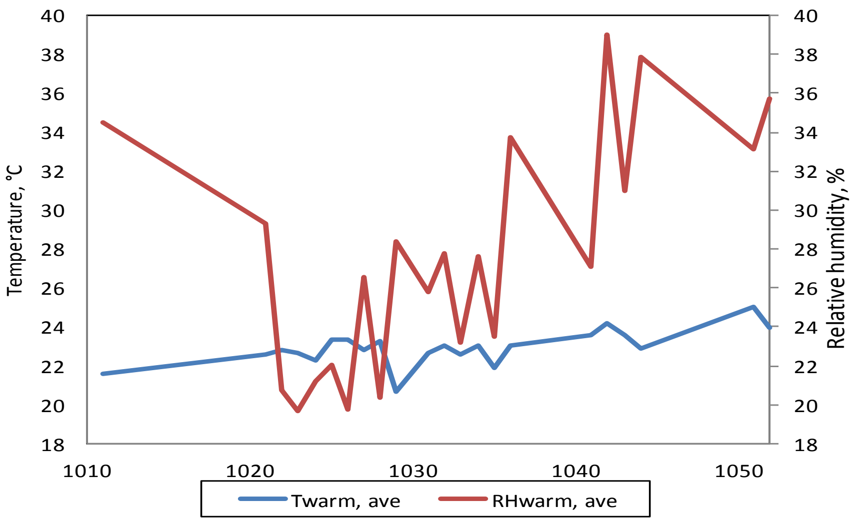

Fig. 1. The average indoor air temperature and relative humidity of 22 apartments

The average indoor air temperature and relative humidity measured in the middle of 22 apartments (warm spot) are shown in Fig. 1. The overall average temperature was 22.9 °C with the standard deviation of 0.91 °C. The overall relative humidity was 27.6 % with the standard deviation of 6.05 %.

Fig. 2 shows the temperature differences between the coldest spot and warm areas in nine

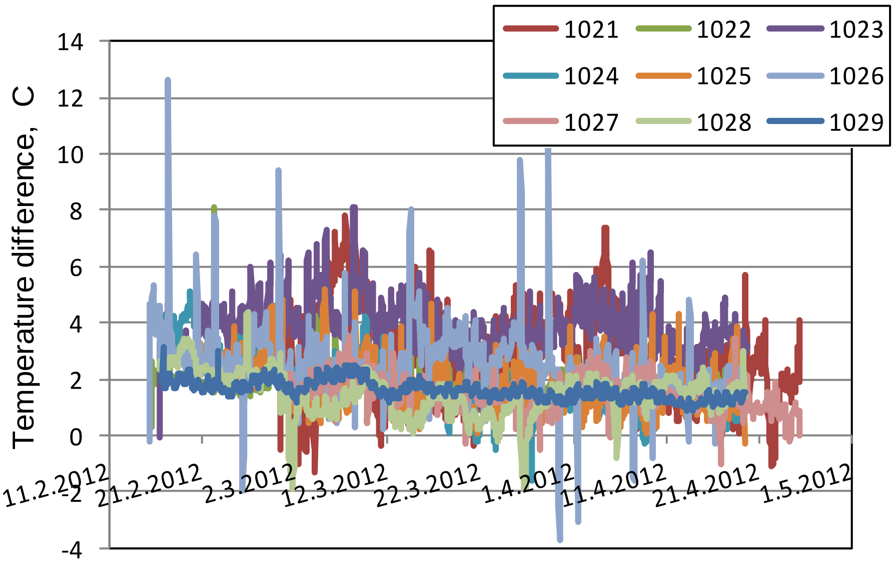

Fig. 2. Temperature difference between the coldest spot and warm areas in nine apartments of a case building (102)

different apartments of a case building (102). The average temperature difference was 2.13 °C. The temperature differences are varying in different apartments during the measuring period of two months. Also, the range of temperature differences within each apartment is variable. In apartment number 1029 the temperature difference is up to 3.1°C, whereas it is up to 8.1°C in apartment 1023, respectively. 2.

A few extreme individual values of temperature difference occurred in apartment 1026, as shown in Fig. Much lower temperature values in coldest spot were registered at these moments. Therefore, probably the coldest spot was influenced by nearby radiator, where heating was turned down for a short period of time.

Table 1 Finnish national limit values for temperature and thermal index, TI [7]

Apartment	Adequate level, °C	Adequate level, TI	Good level, °C	Good level, TI
Room temperature	18		21	
Operative temperature	18		20	
Wall temperature [1)]	16	81	18	87
Floor temperature [1)]	18	87	20	97
Single surface temperature	11	61	12	65
Air flow velocity	Flow chart 3		Flow chart 2	

1) Limit values defined on outdoor temperature -5 °C and indoor +21 °C, if the measured values differ, calculate thermal index, TI.

The Finnish Housing Health Guide [7] has set limit values for temperature and thermal index according to Table 1. The calculation of themal index values are shown based on the following formula (1).

$$TI = \frac{(T_s - T_o)}{(T_i - T_o)} \cdot 100 \quad (1),$$

where T_s is surface temperature, °C; T_o is outdoor temperature, °C and T_i is indoor temperature, °C [7].

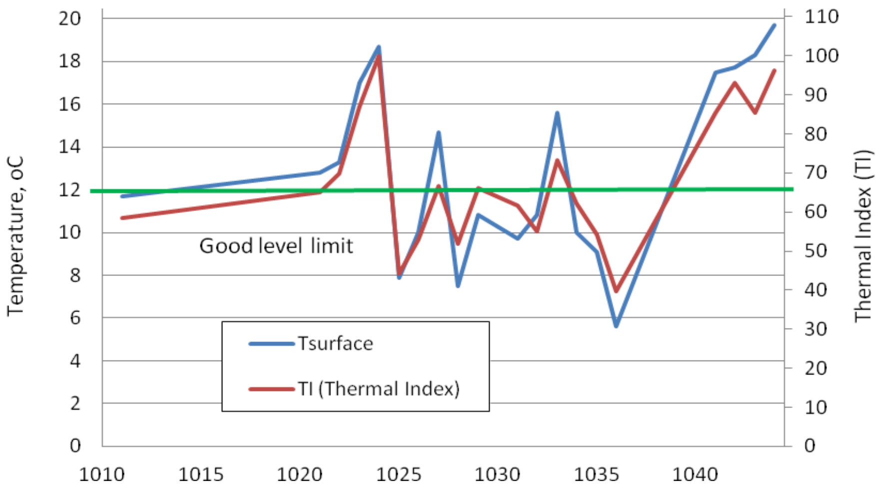

Fig. 3. Measured minimum surface temperature and calculated thermal indexes of 20 apartments

The measured minimum surface temperatures, calculated thermal index of 20 apartments could be found in Fig. 3. According to surface temperature and thermal index most of the apartments were on the verge of good level limit. It should be taken into account that the minimum surface temperature of the extenal walls at the apartments was recorded.

No peculiarly low surface temperatures occurred in the studied apartments of case buildings, which will undergo renovation in the near future.

3.2 Particulate matter

Figs 4-7 show the particulate matter concentration (PM2.5 and PM 10) in indoor air of two case study buildings - 102 (6 apartments) and 103 (6 apartments). For 24 hour measurements both EU and Finnish national limit value is set as 40 µg/m^3 for PM2.5 and 50 µg/m^3 for PM10 [8], marked as red horizontal line in Figs 4-7. WHO Air Quality Guidelines in Europe [9] and global update [10] recommend 25 µg/m^3 for PM2.5 and 50 µg/m^3 for PM10, marked as green horizontal line in Figs. 4-7.

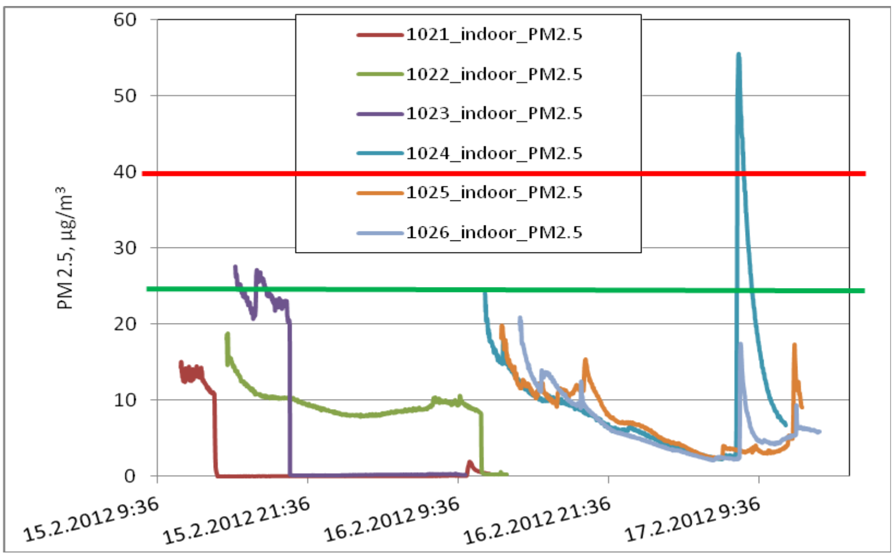

Fig. 4. PM2.5 concentration at the indoor air at the six apartments of a case building (102)

In general, both PM2.5 and PM10 concentrations in the indoor air at the apartments of case buildings 102 and 103 were rather low. The PM2.5 concentrations were almost always considerably lower than EU and Finnish national limit values. The PM10 concentrations were found to be higher. Still, during the most of the time of measurements, also PM10 concentrations were meeting EU and Finnish national limit value requirements. In some apartments high concentrations of both

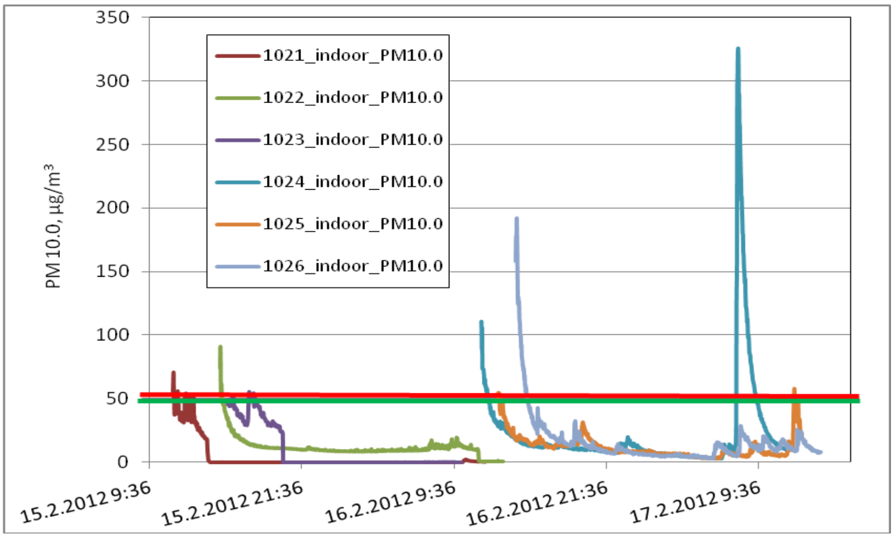

Fig. 5. PM10 concentration at the indoor air at the six apartments of a case building (102)

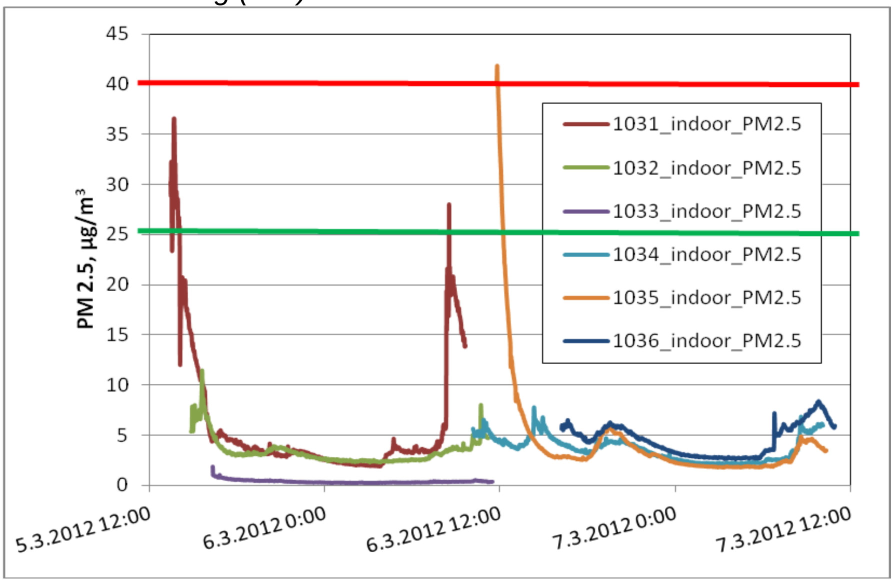

Fig. 6. *PM2.5 concentration at the indoor air at the six apartments of a case building (103)*

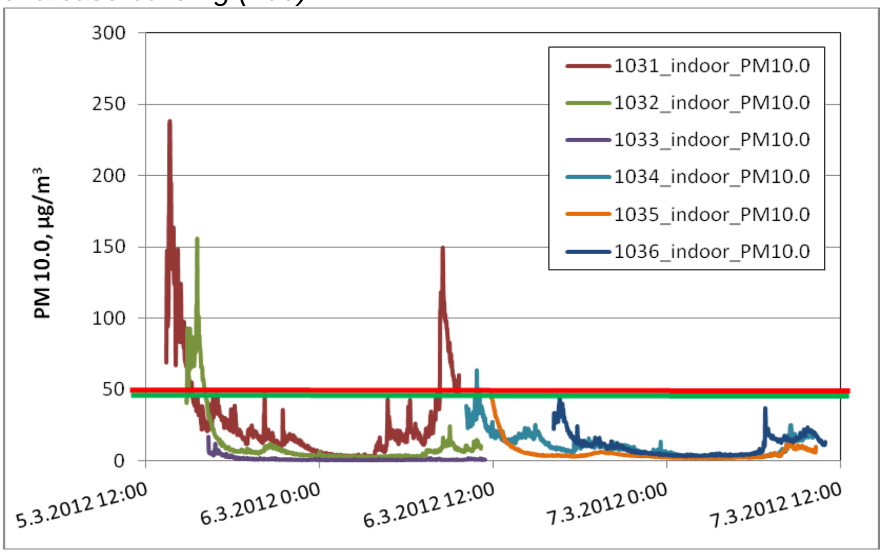

Fig. 7. *PM10 concentration at the indoor air at the six apartments of a case building (103)*

PM2.5 and especially PM10 were recorded at the beginning of the measurement. Naturally, that could have been caused by the measuring team (usually 2 persons), while performing the in-apartment measurements and setting up the equipment. However, the PM2.5 and PM10 concentrations in indoor air were decreasing rather quickly. As an exception, especially PM10 (but also PM2.5) concentrations were suddenly raising and dropping in apartment 1024 during the 24 hour measuring period. It was found that the "peak" was not related to outdoor particulate matter concentration (which was measured concurrently). Although, being a bit higher than indoor particulate matter, both outdoor PM2.5 and PM10.0 remained stable during the measurements at the balcony of apartment 1024. One possible reason could be that the residents have performed vacuum cleaning during the measurement period.

3.3 Carbon dioxide concentration

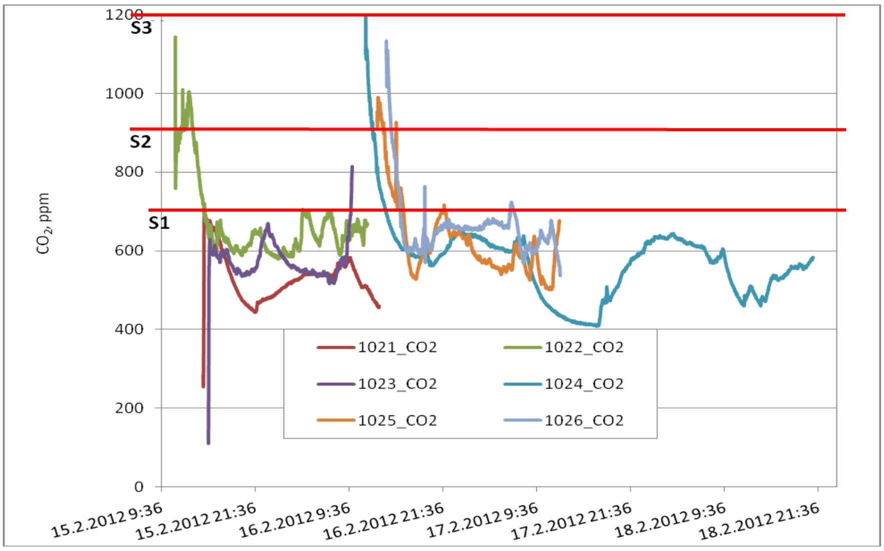

Fig. 8. Carbon dioxide concentration in indoor air of a case study building (102)

Figs 8 and 9 show the carbon dioxide (CO_2) concentration in indoor air of two case study buildings - 102 (6 apartments) and 103 (6 apartments). The ministry of social affairs and health of Finland has classified different safety levels for carbon dioxide. The limit value of safety level S1, S2, S3 and satisfactory level correspond to 700, 900, 1200 and 1500 ppm, respectively [7]. Corresponding safety levels are marked as red horizontal lines in Figs. 8 and 9.

The apartments 1021, 1022, 1023, 1024, 1025, 1026 showed an average CO_2 level of 530, 668, 573, 572, 625, 662 ppm, with an overall average of 605 ppm for case study building 102. The apartments 1031, 1032, 1033, 1034, 1035, 1036 demonstrated an average CO_2 level of 1000, 613, 583, 809, 712, 597 ppm, with an overall average of 719 ppm for case study building 103. Figs 8-9 and average CO_2 values show that the CO2 level of the most apartments (9 out of 12) corresponded generally to the safety level S1 (higher CO_2 concentration sometimes occured at the beginning of measurements). The CO_2 concentration of apartmetns 1034 and 1035 was generally corresponding to the safety level S2. In comparision with the others only apartment 1031 had considerably higher CO_2 concentration, which still corresponded to the safety lefel S3.

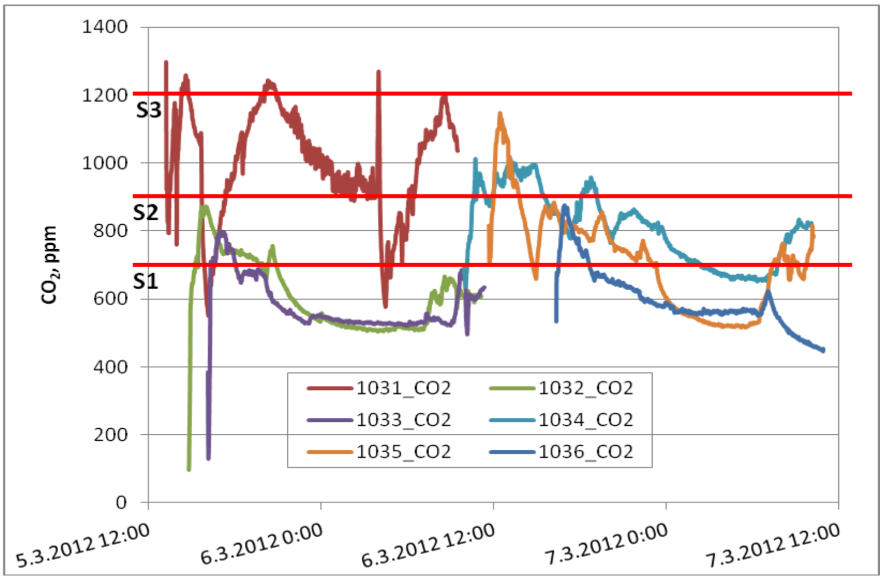

Fig. 9. Carbon dioxide concentration in indoor air of a case study building (103)

Most probably the CO_2 level is depending on the ventilation rate as well as the amount and activeness of residents. An attempt was made to find a correlation between CO_2 level and ventilation rate. The correlation was found to be rather weak and sometimes confusing. That could have been caused by the differences in measuring methodology. The ventilation rate was recorded only in one moment (when setting up the equpment), while CO_2 values were recorded once per minute for 24 hours. That issue requires to be studied further.

4. Conclusions

Current paper addresses the collaboration work within the EU Life + co-financed project INSULAtE. In this paper, only the current (pre-renovation) situation of recruited Finnish case study buildings was described and discussed. Yet, INSULAtE aims to demonstrate and quantify the differences in the situations between before and after renovations. As a common feature, indoor environmental quality (based on temperature, relative humidity, thermal index, particulate matter, and carbon dioxide measurements) were on the verge of good level in most of the apartments of studied Finnish case buildings, which undergo renovation. Therefore it's quite challenging to keep that level also after renovations. The other challenge is that during the heating season 2011 - 2012 only six multi-apartment buildings (22 apartments) were recruited in Finland. That might have been caused by a low eagerness of tenants to voluntarily participate in the study. Twenty case study buildings (and at least 5 apartments in each), which undergo renovations, are necessary for conducting the INSULAtE basic assessment in Finland. Any possible information of the new scheduled renovations in Finnish multi-family buildings is valuable and very welcome.

5. Acknowledgements

This work is carried out as a part of INSULAtE project, which is co-financed by EU Life+ programme. More information can be found from www.insulateproject.eu.

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Building-specific energy production, new concepts in local energy distribution network

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Summary

Building-specific energy production solutions are becoming more common in the near future. This allows the possessor of real estate to decide whether to use the energy production for transportation in addition to living, or sell it to the electricity distribution network. VTT has built an energy self-sufficient test apartment in Oulu for the research and development of building-specific energy production. The research environment, connected to the electricity distribution network, produces the energy required for living and motoring with its own solar and wind power.

Keywords: smart grid, solar power, wind power, local power distribution, in-house power plant

1. Introduction

There is plenty of information available about small power plants and lots of vendors are selling their products with great enthusiasm about the quality and high power output. However, reliable independent information is harder to get. This information is vital when calculations about investments and payback times are made. Also verification of simulation models may benefit from a real production data collected from a real production site. For these reasons VTT decided to set up a full scale testing environment for solar and wind energy production. The main research themes were allocated as follows:

- Establishing a in-house power plan on existing VTT premises, planning and building, practical issues related to licences and project management
- Integration of different components together, control and data collection including database, mainframe, user interfaces and internet connectivity
- Mobility; E-car, charging & discharging control, wireless monitoring of vehicle parameters
- Apartment: renovation of VTT janitors apartment to be used as “living lab”, with intelligent lighting and graphical user interfaces
- Smart Grid: Smart power management with remote control of devices and ability to sell & buy energy from network

In the following chapters these themes will be described in more detail.

2. Planning and building phase of the testing environment

The first task was to define what kind of components would be implemented to the test site: after an intensive planning period the following main components were introduced:

- wind power plant: big enough to supply at least one house/apartment
- solar power plant: also big enough for one house/apartment
- battery back-up for storage of energy
- E-car to study energy consumption for basic transportation
- advanced control, monitoring and measurement for the database (to be used in further analysis of the system)

After the basic definition, core planning was started with extended project group consisting of architect, construction designer, estate owner and technical support team from VTT. Since the goal was to place the power plant on the existing building the main problems to be solved were constructional. The load caused by the solar panels and windmill limited the assembly to few possible places. The solar panels need to be facing south and they must be installed to a certain angle to get the optimal amount of sun radiation. Thus only one side of the roof was found to be feasible. The roof was made of wooden board structure covered with roofing felt. The assembly rails of the solar cell were fixed on the roof without puncturing the surface. The electrical cables were brought through the ceiling with special ducts in order to prevent leaks. The biggest problem was to find a solid place for the windmill. Finally the best option was to mount the windmill steel platform on the top of the elevator shaft. Some reinforcing work was necessary before the final erection of the windmill could take place (see Fig. 1 and 2).

Figure 1Molding the steel frame

Figure 2 Reinforcing the shaft

The total assembly of the roof was completed in November 2011. The main milestones in the assembly process are listed below:

Milestones for the testing environment building project:

- Core Planning 1.4-31.5.2011
- Applying licences 1.6.2011
- Quotes for windmill &Solar systems 1.7.2011
- Quotes for subcontracting 1.7.2011
- Starting the preparatory work (construction & electrical) 1.8.2011
- Assembly for Windmill & Solar November 2011
- Renovation of test apartment November 2011-March 2012

- Test & production December 2011

Figure 3 Final rooftop assembly ready

The hub height of the windmill is 29,7 meters, steel mast rises 9 meters from the roof and the total weight of the structure is about 350 kg.

3. Integration of the system

The integration phase took place after the hardware components were installed. Integration is very important because communication and control would not be possible without it. However there are no common standards with communication specification and therefore manufacturers have applied their own protocols and interfaces. This was the starting point in VTT¨s system. Major components to be integrated were solar panel power inverter, windmill control, weather station, E-car, E-car loading system, lighting system for the apartment and 3-phase main inverter. The system included numerous measurement devices and control switches as well.
The control system is based on Linux-mainframe computer which has got the database and user interfaces for the main control of the system. This mainframe must have access to all parts of the system. System components are distributed to different parts of VTT building from roof to basement. The backbone of the communication network is Ethernet, but RS485, RS232, CAN-bus, USB, WiFi and some other product specific solutions are also being used.
The control system stores every minute all essential parameters of the system to the database. These values are used for verification of system performance, energy efficiency, investment calculations and simulation verifications. For instance solar power production data can be compared against the production of windmill power production, Weather information is also available from a Vaisala weather station on the same building.
The goal of the integration was to hide this complicated system from the end user and make the control of the system easy. The control user interface is graphical and it is using HTML5. This makes it versatile because user can access it by multiple devices (PDA's) using browser and internet access.

The user interface provides information of the system status and the energy consumption. It takes care of the energy distribution and power management by controlling the power plant and energy storage. With it the user can also buy or sell energy to the network. The system gives protection against blackouts by automatically switching to battery supply. With this the apartment can provide energy for normal living during several days.

Figure 4 Part of the control room components: front solar inverter from Vacon.

Figure 5 E-car and loading station.

4. Mobility issues

Mobility is an important part of living. VTT test system includes an E-car with necessary loading stations. E-car operates most of the time with solar and wind power. A special reservation system controls the energy consumption of the car and ensures that there is enough energy for the trip. The intelligent charging system takes care of fast charging of the car. The wireless monitoring system reads status information from the car and sends this to the main database. The energy efficiency of the E-car changes depending on the driving environment, the car can store braking energy back to the battery thus inside town the traveling distance may increase. On a cold weather the heating takes lots of the battery capacity reducing the available driving distance.

5. VTT's apartment: living lab

VTT had a apartment which was originally built for the janitor. Since many years there has not been janitor's in VTT and the apartment has been rented for VTT's visiting researchers. During the project this apartment was completely renovated to be used as "living lab", with intelligent lighting and energy management systems. The apartment has got two bedrooms, kitchen, living room, bathroom and sauna. The area of the apartment is 77 m^2. The biggest changes were made to the lighting system. The former system was based on light bulbs and it was completely replaced by led based illumination. The new system was designed based on instructions and recommendations about home lighting. Total power consumption was reduced from the former 3500 Watts to 300 Watts peak power with improved light intensity. In addition to this new led system is using 24V DC power and therefore it can operated directly lead acid battery power source. This arrangement has got two main benefits, it is easy to connect solar cells to the system and in case of blackout DC power from battery keep the lighting on. The control system of the lighting operates also on 24V DC current. It is based on CAN-bus and has flexible programmable functionalities: wireless user interface, automatic operation based on presence detection, timers, automatic dimming, day-, evening- and night status etc. The power consumption of the LED's is measured and send to the database. The next biggest change was made to the electrical system of the flat. The fuse panel was replaced with intelligent one providing remote controllable on/off switches for the household electronics including kitchen and bathroom. The fuse panel has now an Ethernet connection to the mainframe computer. This makes it possible to measure and control and cut down the energy consumption of the apartment. The information collected from the apartment can be used for instance to study the consumption profiles and differences between different users. Ass well it will be used to analyse the energy balance between power plant E-car and apartment.

Figure 6 VTT's test apartment.

6. Smart Grid

Smart Grid is currently very popular research topic. It can be defined in the following way:

"Smart grid is a next generation electric power network that incorporates information and telecommunication technologies into an electric power network that enables real time, two-way communication exchange to power suppliers, the electric power markets, and consumers"

The existing technology used in power distribution networks creates several problems and challenges which need to be tackled before real applications can spread to the market:

- Applying distributed energy sources to current electricity production in large scale
- Providing reliable and smooth demand-response control methods
- Improvements required in energy storage technology (unit price too high)
- New automation in energy delivery networks needed
- Controlling the Smart Grid requires new communication system with features that has not been implemented anywhere so far
- Amount of data will be huge
- Smart Grid enables new business models for different players: a whole set of totally new services may appear
- Electricity and energy networks are critical infrastructures; no compromises allowed in security and reliability.

VTT's testing environment will serve also as a tes tbed for Smart Grid research projects. The next steps include database management and user access to the system in order to let the project partners to get to the system for testing and data analysis.

7. Project Status

The roof of VTT's research environment holds a 5.5 kilowatt wind power plant and around 20 square metres of solar cells generating 4 kilowatts. Together, they produce enough electricity for living and running an electric car. The test apartment is used as accommodation for visiting scientists, and it is located at VTT Oulu premises.
The apartment is equipped with normal, energy-saving household appliances and other equipment. Lighting is optimised, based on a low-voltage network using 24 VDC . The resident can affect the energy consumption through his or her choices.
VTT is collecting data of the apartment's consumption and production and the choices made by the residents in its database. Consumption data is stored in the database at one-minute intervals. VTT's research scientists utilise the data in designing future forms of living and sizing the new systems. The test apartment helps VTT to study what are the benefits of energy self-sufficient living for the consumer.
At the moment the system is running and in full use. At the moment the energy production has been lower than expected:

Solar Energy (February 2012-November 2012) 2959 kWh
Windmill (December 2011- November 2012) 1783 kWh

Solar panels did not produce any energy in December and January. The solar inverter was optimised for 10 kW panel supply. For this reason another 4 kW set of panels will be added during the spring. The control system of the solar inverter did also broke down in June and one month's production was lost. Windmill was stopped for maintenance for two months in the spring. The steel pipe was suffering of resonance vibrations and tis problem was fixed by adding a stabilising mass to the pipe. On December 2012 the windmill suffered some damages by ice packing to the rotating blades.

8. Future Steps

In the future, the consumer will monitor and control the electricity consumption of his or her living and transportation, and can even sell electricity to the network. This is made possible by the development work on intelligent electricity networks, improving the efficiency, flexibility and dynamism of old-fashioned electricity distribution systems.
VTT is using the energy self-sufficient apartment to study, for example, how much the resident can reduce the energy consumption peaks and how much the energy consumed by living can be

reduced.
In-house local power plants could be located in, for example, office buildings, commercial buildings and residential buildings. With advanced control and monitoring system the consumption and production can be locally justified and this local control will be essential part of future energy distribution network.

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Estimated Energy Consumption of the Finnish Building Stock Using Representative Building Types

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Summary

The energy consumption of different building types in the building stock was estimated using a two-fold modelling approach. First representative buildings of various types and ages were modelled to establish their heating energy consumption using dynamic modelling. Then the cumulative energy consumption of these building types was calculated based on the modelled development of the building stock using the REMA model at VTT. According to the estimate produced by the calculation for the year 2012 the building stock will consume 73000 GWh of heating energy (including electricity for heating) and in 18600 GWh of electricity (excluding heating). For 2020 a similar calculation suggests a consumption of 76900 GWh of heating energy and in 19900 GWh of electricity for the whole building stock. The results fit reasonably well within the variation present in past calculations, with somewhat higher consumption in single-family homes than other studies have suggested.

Keywords: Energy, Energy consumption, Building stock, Modelling

1. Introduction

The objects of the Finnish SPF (Seasonal Performance Factor) project are to define a national seasonal performance factor calculation for heat pumps and to estimate the energy saving and renewable energy potential of heat pumps on the Finnish building stock. The project duration is from 1.3.2011 to 31.12.2013 and the project is financed by the Finnish ministry of employment and the economy, the Finnish ministry of the environment and SITRA. This paper presents results from Task 2 “Energy use of the Finnish building stock”, where the energy consumption of the Finnish building stock was estimated using standard building types (detached house, apartment building, office building and summer cottage) for different decades.

The energy consumption of different building types in the building stock was estimated using a two-fold modelling approach. First representative buildings of various types and ages were modelled to establish their heating energy consumption using dynamic simulation tool IDA-ICE. Then the cumulative energy consumption of these building types was calculated based on the modelled development of the building stock using the REMA model at VTT. The results were compared with the national statistics [1] and previous estimates ([2], [3], [4]) and four rounds of iteration were completed resulting in calibrated building types, a new estimate for the composition of energy consumption in the building stock and a forecast for expected changes in energy consumption.

2. Methods

Four model building types where chosen to represent the major building types that constitute the building stock: detached houses (about 38 % of the total floor area in the stock), apartment buildings (31 %), commercial and public buildings, represented by an office building (26 %), and holiday homes (5 %). The model building types are presented in Figures 1-3. The living area of the detached house was 134 m^2, the living area of the apartment house was 814 m^2, the net area of the office building is 2 695 m^2 and the living area of the cottage was 134 m^2.

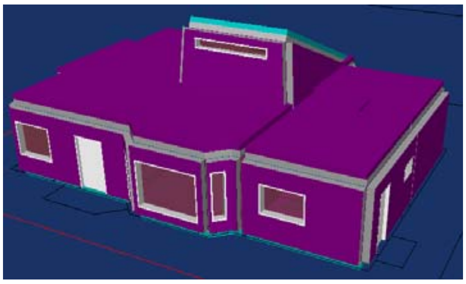

Fig. 1 Model building type for the single-family house and the summer cottage

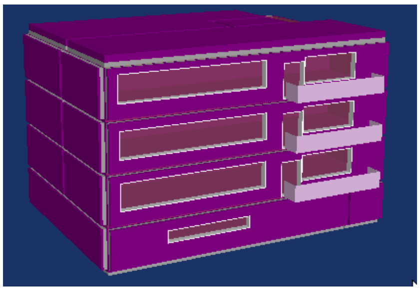

Fig. 2 Model building type for the apartment house

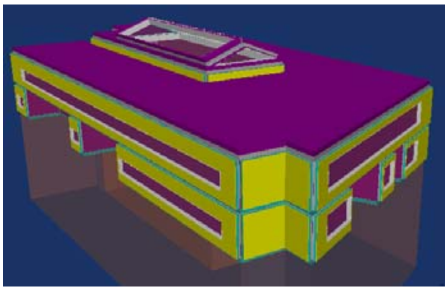

Fig. 3 Model building type for the office building

The buildings were further divided into four age groups and individually modelled: buildings built before 1960 (subgroup A), between 1960–1979 (subgroup B), between 1980–2000 (subgroup C1), and between 2001–2010 (subgroup C2). The building stock in the year 2010 is presented in Table 1. Future construction was modelled as norm buildings built according to 2010 regulation (subgroup D1), low-energy buildings (subgroup D2) and very low-energy buildings (subgroup D3). The air-tightness of the building envelope is presented in Table 1. For houses with natural ventilation (*) the air-leakage through the envelope is included in the air-change rate. The heat loss values (U-values) of different structures are presented in Table 2.

Table 1. Air-tightness of the building envelope n50, 1/h

Subgroup	Detached house	Apartment building	Office building	Cottage
A	*	*	*	*
B	*	2.3 [5]	2.3 [5]	*
C1	4.0 [6]	1.0	1.5	7.9 [7]
C2	3.5 [6]	0.9 [7]	0.9 [8]	5.8 [7]
D1	2.0	0.7	0.5	5.8 [7]
D2	0.8	0.6	0.5	0.8
D3	0.6	0.6	0.5	0.6

The detached house is heated and ventilated constantly. The apartment building is also constantly heated and ventilated, but in apartment buildings with mechanical exhaust ventilation system the ventilation rate is 50 % of the full rate during 18:00 – 7:00 and 9:00 – 16:00. Subgroups D1, D2 and D3 have a mechanical cooling system in the case of detached houses but not in the case of apartment buildings.

Table 2. Heat loss values of the buiding structures. OW = outer wall, UF = upper floor, BF = base floor, W = window

Sub-group	Detached house	Apartment building	Office building	Cottage
A	OW 0.69 [10] UF 0.41[10] BF 0.48 W 2.2[10]	OW 0.83[10] UF 0.42[10] BF 0.48 W 2.2[10]	OW 0.83[a] UF 0.42[a] BF 0.48 W 2.2[a]	as detached house in subgroup A
B	OW 0.42[10] UF 0.24[10] BF 0.48 W 2.2[10]	OW 0.47[10] UF 0.29[10] BF 0.48 W 2.2[10]	OW 0.47[a] UF 0.29[a] BF 0.48 W 2.2[a]	as detached house in subgroup A
C1	OW 0.28 UF 0.22 BF 0.36 W 1.6[10]	OW 0.28 UF 0.22 BF 0.36 W 1.6[10]	OW 0.28 UF 0.22 BF 0.36 W 1.6[a]	as detached house in subgroup B
C2	OW 0.25 UF 0.16 BF 0.25 W 1.4	OW 0.25 UF 0.16 BF 0.25 W 1.4	OW 0.25 UF 0.16 BF 0.25 W 1.4	as detached house in subgroup C1
D1	OW 0.17 UF 0.09 BF 0.16 W 1.0	OW 0.17 UF 0.09 BF 0.16 W 1.0	OW 0.17 UF 0.09 BF 0.16 W 1.0	according to Finnish building code, part C3 (2010), log wall U-value 0.4
D2	OW 0.14, UF 0.08, BF 0.12, W 0.9[11]			as detached house in sub-group D2
D3	OW 0.08 UF 0.07 BF 0.09, W 0.7[12]			as detached house in sub-group D3

Table 3. Set indoor temperatures

Subgroup	Detached house	Apartment building	Office building	Cottage
A	21.0 °C [1]	22 °C [2]	21.5 °C	21.0 °C
B	21.0 °C [1]	22 °C [2]	21.5 °C	21.0 °C
C1	21.0 °C [1]	22 °C [2]	21.5 °C	21.0 °C
C2	21.0 °C [1]	21.5 °C [2]	21.5 °C	21.0 °C
D1, D2, D3	21.0 °C [1]	21.0 °C [3]	21.5 °C	21.0 °C

[1] bathroom and sauna set temperatures 21 °C, [2] cellar and staircase set temperatures 19.0 °C, WC and bathroom set temperatures 23 °C, [3] cellar and staircase set temperatures 17.0 °C, WC and bathroom set temperatures 23 °C.

The office building is heated continuously. In subgroups B and C1 the ventilation is on during week-days between 6:00 and 20:00. In subgroups C2, D1, D2 and D3 the ventilation is on during week-days between 6:00 and 20:00. In other times only the social spaces are ventilated with the ventilation rate of 0.15 $dm^3/s,m^2$. Subgroups C1, C2, D1, D2 and D3 have a mechanical cooling system operating during weekdays between 6:00 and 20:00.

The recreational cottage is a private free-time home used annually an estimated typical length. Heating and ventilation is on during the usage time, outside the usage time there's a base heating load. The usage time is whole July, every weekend in June and August, and every third week-end from September to May.

The indoor temperature set-values are presented in Table 3. The ventilation systems are presented in Table 4 and the ventilation rates in Table 5.

The warm service water usage is presented in Table 6. The device electricity use of the different building types was according to the Finnish Building Code, part D3 (2012).

Table 4. Ventilation systems. NV = natural ventilation, ME = mechanical exhaust ventilation, MSE = mechanical suppy and exhaust ventilation, HR = heat recovery (temperature efficiency)

Sub-group	Detached house	Apartment building	Office building	Cottage
A	NV	NV	NV	NV
B	NV	ME	ME	NV
C1	ME	ME	MSE + HR (50%)	ME
C2	MSE + HR (60%)	MSE + HR (60%)	MSE + HR (80%)	ME
D1	MSE + HR (60%)	MSE + HR (60%)	MSE + HR (80%)	MSE + HR (60%)
D2	MSE + HR (80%)	MSE + HR (80%)	MSE + HR (80%)	MSE + HR (80%)
D3	MSE + HR (85%)	MSE + HR (85%)	MSE + HR (85%)	MSE + HR (80%)

Table 5. Air-change rate, 1/h

Subgroup	Detached house	Apartment building	Office building	Cottage
A	0.41 [13]	0.62 [13]	0.62 [13]	0.41*
B	0.41 [13]	0.43 [14]	0.43 [14]	0.41*
C1	0.46 [13]	0.5 [15]	0.5 [15]	0.46*
C2	0.40 [6]	0.56 [6]	0.5 [16]	0.40*
D1	0.5 [17]	0.5 [17]	0.5 [17]	0.5*
D2	0.5 [17]	0.5[17]	0.5 [17]	0.5*
D3	0.5[17]	0.5[17]	0.5 [17]	0.5*

* during usage time, in other times only air-leakage through the envelope.

Table 6. Warm service water consumption

Sub-group	Detached house, dm^3 /pers,day	Apartment building, dm^3/pers,day	Office building, dm^3/rm^2,a	Cottage
A	42 [18]	64 [19]	100 [20]	According to the usage profile
B	42 [18]	62 [19]	100 [20]	According to the usage profile
C1	42 [18]	59.2 [19]	100 [20]	According to the usage profile
C2	42 [18]	57.6 [19]	100 [20]	According to the usage profile
D1, D2, D3	42 [18]	56 [19]	100 [20]	According to the usage profile

3. Results

The energy demands of the different standard building types and subgroups were simulated using IDA ICE 4.2 dynamical simulation program with the test weather data 2012 of Jyväskylä, Central Finland (Kalamees 2012). The heating and cooling energy use is presented in Table 8 for the detached house, in Table 9 for the apartment house, in Table 10 for the office building and in Table 11 for the cottages.

Table 8. Heating and cooling energy net demands of the detached house, kWh/m²

Sub-group	Space heating	Space cooling	Inlet air heating	Warm service water heating
A	242	0	0	21
B	189	0	0	21
C1	157	0	0	21
C2	98	0	10	21
D1	68	2	9	21
D2	53	3	2	21
D3	38	4	2	21

Table 9. Heating and cooling energy net demands of the apartment house, kWh/m²

Sub-group	Space heating	Space cooling	Inlet air heating	Warm service water heating
A	200	0	0	49
B	125	0	0	47
C1	51	0	0	45
C2	22	0	17	44
D1	11	0	15	43
D2	8	0	4	43
D3	4	0	3	43

Table 10. Heating and cooling energy net demands of the office building, kWh/m²

Sub-group	Space heating	Space cooling	Inlet air heating	Warm service water heating
A	232	0	0	6
B	135	0	0	6
C1	105	12	27	6
C2	52	20	5	6
D1	41	16	6	6
D2	33	23	6	6
D3	25	27	5	6

Table 11. Heating and cooling energy net demands of the cottage, kWh/m²

Sub-group	Space heating	Space cooling	Inlet air heating	Warm service water heating
A	94	0	0	11
B	91	0	0	11
C1	63	0	0	11
C2	61	0	0	11
D1	39	0	1	11
D2	22	0	0	11
D3	17	0	0	11

The cumulative energy consumption of the whole building stock was calculated based on the modelled development of the building stock using the REMA model developed at VTT. The simulated energy demand results of each standard building type and subgroup were used as an input for the REMA model to calculate the total energy consumption of the building stock in each year, taking into consideration the estimated changes in the future development of the building

Table 1. Modelled size of building stock in 2010 according to the REMA model, in millions of m^2. Inconcistences in totals are due to rounding.

Subgroup	Detached houses	Apartment buildings	Office buildings	Cottages
A	50	19	24	10
B	40	51	30	6
C1 + C2	57	49	47	5
Total	147	119	100	21

stock

According to the estimate produced by the calculation for the year 2012 single-family houses will consume, in terms of delivered energy, 32600 GWh of heating energy (including electricity for heating) and 5200 GWh of electricity (excluding heating), multi-family buildings consume 23900 GWh in heating and 5600 GWh of electricity, commercial and public buildings 20000 GWh in heating and 7500 GWh of electricity and, finally, holiday homes 2800 GWh in heating 300 GWh of electricity, totalling in 73000 GWh of heating energy and in 18600 GWh of electricity for the whole building stock.

For 2020 a similar calculation suggests that single-family houses will consume 31900 GWh of heating energy (including electricity for heating) and 5600 GWh of electricity (excluding heating), multi-family buildings consume 23200 GWh in heating and 5800 GWh of electricity, commercial and public buildings 19100 GWh in heating and 8100 GWh of electricity and, finally, holiday homes 2700 GWh in heating 400 GWh of electricity, totalling in 76900 GWh of heating energy and in 19900 GWh of electricity for the whole building stock.

4. Conclusion

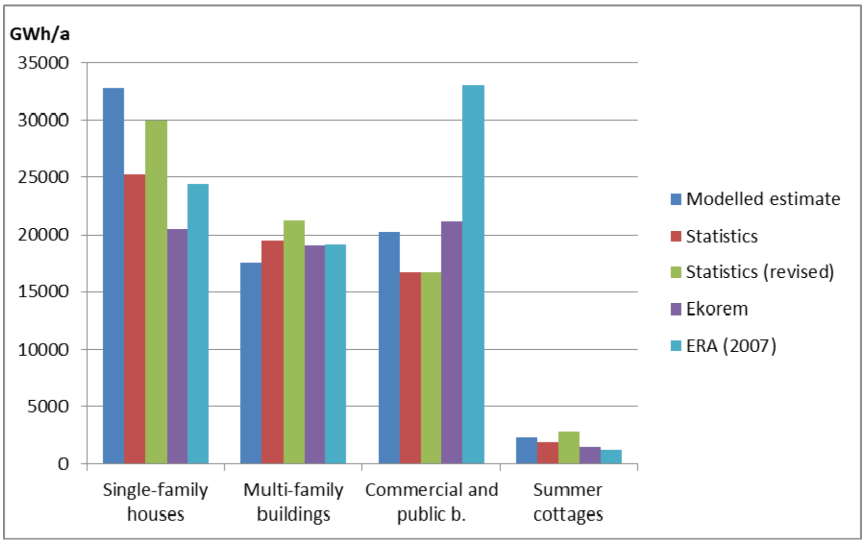

Fig. 2 The results (Modelled estimate) compared to Statistics Finland [1], revised statistics [2], Ekorem project [3] and ERA project [4].

The numbers correspond to an increase of 5 % in heating energy consumption and 6 % increase in electricity consumption in the building stock by the year 2020. This is in agreement with a slowing growth of energy consumption with a growing emphasis on electricity consumption.

The results fit reasonably well within the variation present in past calculations, with somewhat higher consumption in single-family homes than other studies have suggested. This might be because a significant part of the single-family home stock might be underused or in disuse and thus kept in lower than comfortable temperature.

A major benefit of the approach chosen here is that each type and subtype of buildings is individually modelled and therefore their contribution to the total energy consumption can be traced to the modelled physical characteristics of the buildings. This allows the study of individual building modifications and their effects to energy consumption on a large scale.

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Study on Life Cycle Carbon Minus House Part2:

Design of demonstration house

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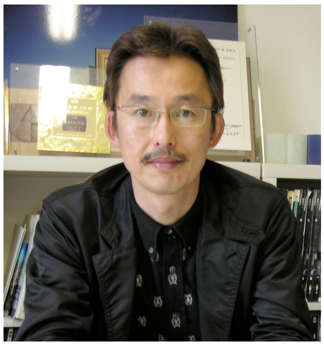

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Summary

The LCCM (life cycle carbon minus) house is a detached house that consumes low energy. It also generates energy and its amount is same as or more than its energy consumption by using on-site renewable energy systems (ex. photovoltaic). This project has started in 2009 and a demonstration house was constructed in Tsukuba in 2011. Part 2 shows design strategies of the LCCM demonstration house.
In 2009, we started to design the LCCM demonstration house. To realize the goal of LCCM, in every design phases, we considered not only energy-saving operation, but also reduce the amount of CO2 emissions during construction. Furthermore, we considered the amount of CO2 offset that is achieved by using renewable energy systems. This concept needs severe balance between CO2 emission and CO2 offset through a lifecycle of house.
Design of the demonstration house was proceeded with detailed predictions, such as the estimation of embodied CO2 that are emitted from various building materials during construction, the calculation of energy consumption and generation during dwelling. To achieve appropriate balance of CO2, the demonstration house is designed on the concept of " the house changing to different set of clothing for seasons." It means this house has the mode change system for its environmental control.
The principal design strategies are 1) stripe planning, 2) multi layered sectioning, 3) multi layered windows, 4) mode change system responding to various seasons and human activities, 5) the use of natural energy, 6) spatial composition and thermal environment responding to human activities.
Construction of the LCCM demonstration house started in 2010 and was completed in February 2011. After the completion, the verifications of its actual conditions and effects are ongoing.

Keywords: LCCM (Life Cycle Carbon Minus), LCA (Life Cycle Assessment), CO2 emission, Embodied CO2, Renewable energy, Detached house, Mode change System, Passive design, Multi Layered Composition, Human Activity

1. Introduction

The LCCM (life cycle carbon minus) house is aiming to ultimately reduce CO2 emission impact through a life cycle of house. Its goal is to achieve that the balance between CO2 emission and CO2 offset by using renewable energy systems shows surplus for the amount of CO2 offset thorough its life cycle. It means that the LCCM house is quite different to other usual ecological houses on its concept. Because many ecological houses in the past mainly focused on reduction of environmental impact which these houses emit during dwelling, whereas the LCCM house aims to reduce both CO2 emission during construction and dwelling. The aim of the LCCM demonstration house is verification of possibilities and problems of the LCCM house and spread its concept through its actual construction.

2. Design concept of mode changeable house

Realization of the concept of LCCM needs conditions such as 1) the construction methods and building materials are low CO2 emission, 2) the building performance and equipment allow low energy consumption for hot-water supply, heating, cooling, ventilation and lighting, 3) the house has the equipment which can generates energy or use renewable energy, and moreover, 4) people who live in it know how they should behave to utilize its building environmental performance.
These conditions sometimes conflict each other, such as day lighting and sun shading. The LCCM demostration house solves this kind of problems by its design methodology of "the house changing to different set of clothing for seasons". For environmental control, the house has the mode change system which can responses to various requests from seasons and human activities. It suggests a flexible way to control building environment, just like wearing the cloth. This shows a big difference comparing with the way which defeats nature by force. (Fig.1, Photo.1, 2)

Fig.1 Design concept of the LCCM demonstration house (left)

Photo.1 Exterior (right above), Photo.2* Interior of 1st floor *photos by Koichi TORIMURA*

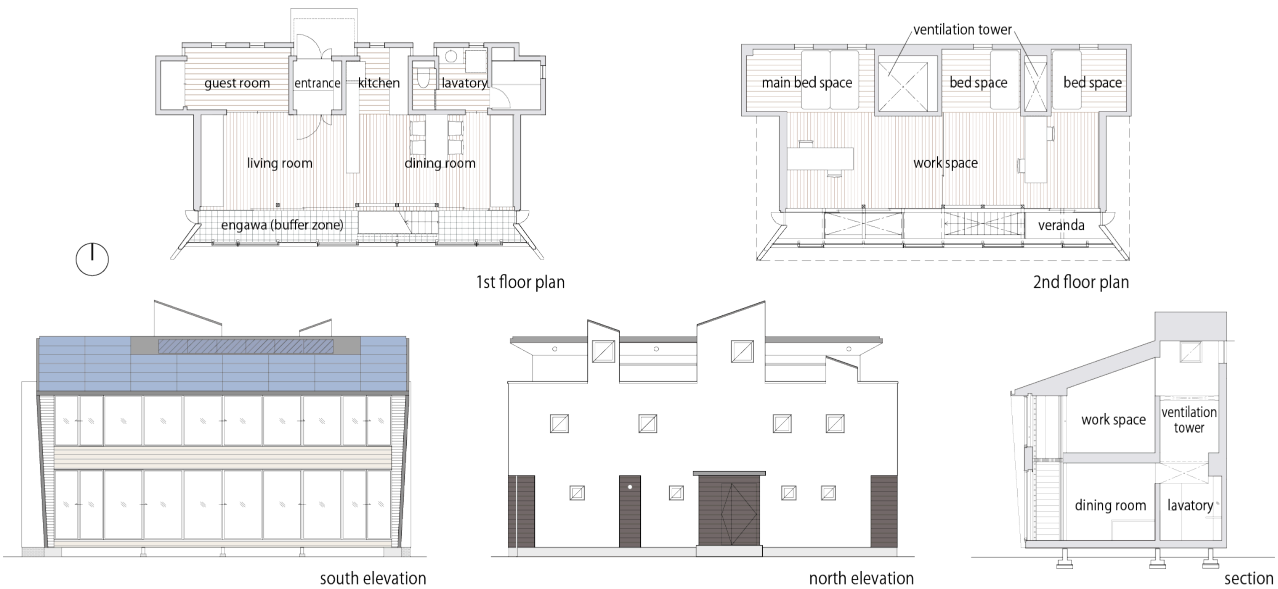


Fig.2 Drawings of the LCCM demonstration house

3. Principal design strategies

3.1 Stripe planning

The LCCM demonstration house is a two-story detached house (Fig.2). Entrance, living room, dining room, kitchen, lavatory and guest room are on the first floor. Three small bed spaces and two workspaces are on the second floor. The shape of floor plan is long from east to west. Its form allows to maximize solar gain from the south and to reduce negative effect of sunlight in summer.
The floor plan is composed of three zones arranged in stripe pattern (Fig.3). Southern zone is "BUFFER ZONE". This zone has engawa or veranda that are open to the south for facing sun. Northern zone is "STATIC ZONE". This zone is closed for protection against a north wind. Central zone between these is "ACTIVE ZONE". This zone is spacious with high ceiling, to stimulate lively human activities (Photo.3).

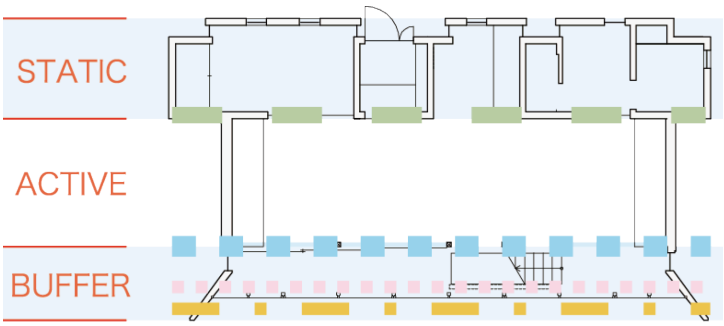
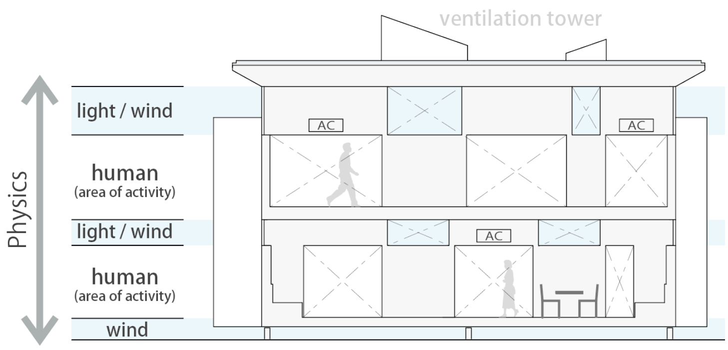


Fig.3 Stripe planning (left), Photo.3 View from ACTIVE ZONE to BUFFER ZONE*

3.2 Multi layered sectioning

The structure of this house is timber framework method that is ordinary in Japan. But in this case, its normal two-story height is differentiated spaces for human activities from spaces for environmental elements, such as light and wind. These different eight spaces are stacked alternately, therefore the section shows multi layered composition (Fig.4, Photo.4).
This sectioning made possible integration of design methods to reduce CO2 emission during both construction and dwelling. For example, the foundation is the lowest layer. Its form is continuous footing and raised-floor style. The edge of floor is cantilevered. This shape aims to reduce the volume of concrete. This means reduction of CO2 emission during construction. Furthermore, it allows natural ventilation by using floor inlets of engawa (Photo.4).



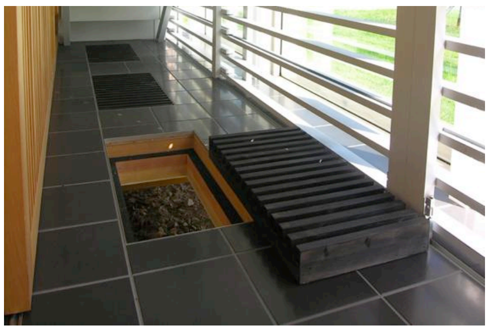


Fig.4 Multi layered sectioning, Photo.4 Floor inlets of engawa

3.3 Multi layered windows

This house is equipped with many windows that have various different functions. These windows are arranged in multi layered way for passive and active environmental control in daily life. According to different requests from seasons and human activities, they can be used in various combinations (Fig.5, Photo.5, 6).

The functions of each layers are as follows: 1) insulation and airtight layer of wooden window, 2) solar control layer of wooden louver, 3) insulation layer of honeycomb screen, 4) compartment air conditioning layer of wooden door and honeycomb screen, 5) gaze control layer of roll screen. Furthermore, deciduous trees and grasses planted around the house act as the natural layer to control sunlight and radiant heat from the ground.

Residents can customize the indoor environment by combinations of ON/OFF of these layers according to climate and their life style.

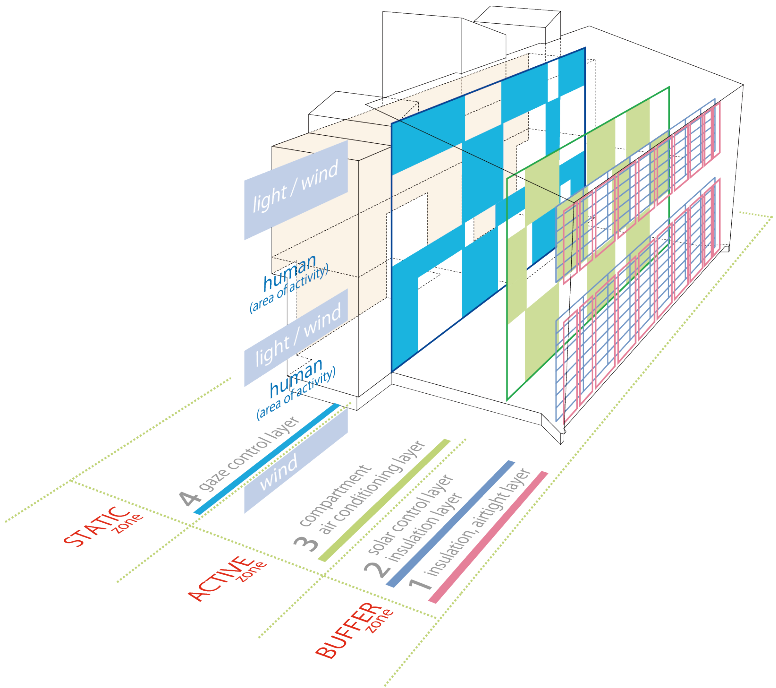


Fig.5 Multi layered composition diagram (left)

Photo.5 view from engawa, Photo.6* view from main bed space*

3.4 Mode change system responding to various seasons and human activities

These characters of this house keep in close cooperation, this house has the mode change system responding to various environmental differences, such as seasonal, day and night, human activities and their lifestyles. Fig. 6 shows basic six modes that are based on the methodology that separately uses or integrates passive and active ways in the right place.

In a calm season, "natural ventilation mode" creates comfortable breezed and shaded spaces. In summer night, "night purge mode" is ready for taking in the cool air. While the mode is in these cases, the ventilation towers in northern zone are open to encourage smooth airflow. And the southern windows as the insulation and airtight layer are also open, it creates big semi-outdoor spaces under the eaves by transforming engawa and veranda. In winter sunny day, "direct gain mode" gives maximum use of solar energy. Southern windows are closed, engawa changes into an interior space just like a sunroom.

These modes mentioned above are mainly in passive way, whereas "cooling mode" in summer daytime and "heating mode" in winter based on active control. In these active modes, multi layered windows are closed to achieve low energy consumption by minimization of interior spaces that are air-conditioned.

"Absence mode" is ready for cases when residents are out. This mode allows to avoid situations which high-insulated and air-tight houses sometimes overheat caused by shutting all windows while resident's absence. The idea of this mode is like "the standby mode" of home electronics or "the sleep mode" of personal computers. It gives quick and effective air conditioning after resident's return.
After the completion of construction of this house, various verifications are on going. Trough experimentations of inhabitants, new modes are found and verified in addition to these basic six modes.

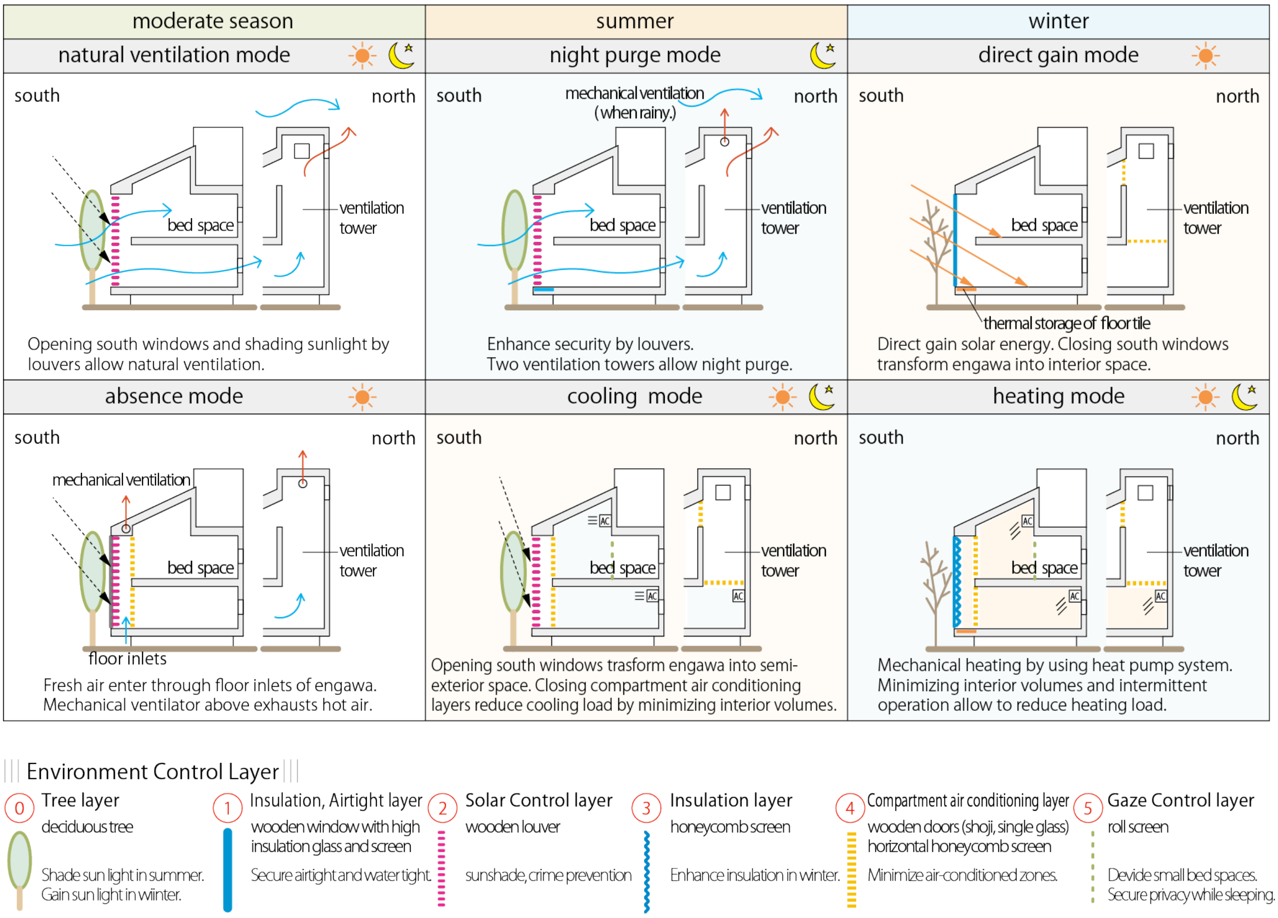
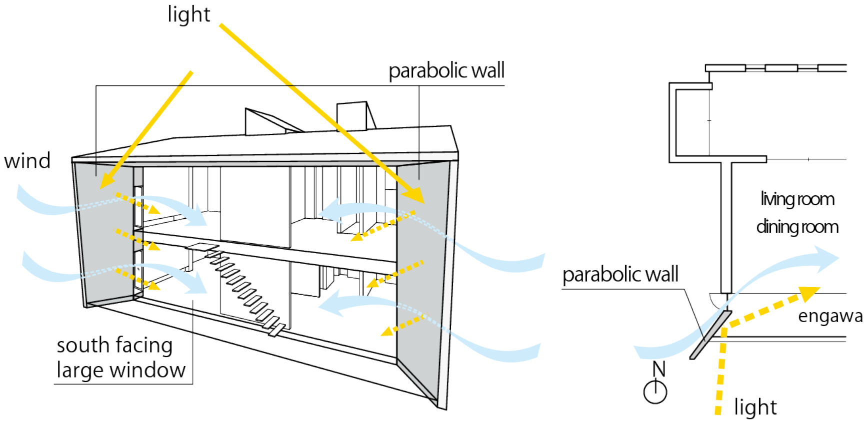


Fig.6 Basic six modes of environment control

3.5 Parabolic wall and ventilation tower

The south façade of this house was intend to be open to gain solar energy, therefore the shape of walls of east and west has become parabolic (Fig.7). This form allows to increase the amount of solar gain and the area of photovoltaic panels on the roof. In addition, these walls serve as the wind-catcher because they create gaps of air pressure around them that are useful for natural ventilation.
In northern zone, two towers are located in the position sandwiched between small bedrooms (Photo.7). They also create gaps of air pressure above roof, create the airflow from bottom area to towers. To avoid the backward flow that causes intake of negative hot air, the angle of roof and the position of windows of towers are decided with CFD simulations. In addition, these towers act as the day-lighting device. Therefore they serve natural brightness to the northern zone where it tends to be darker in general.



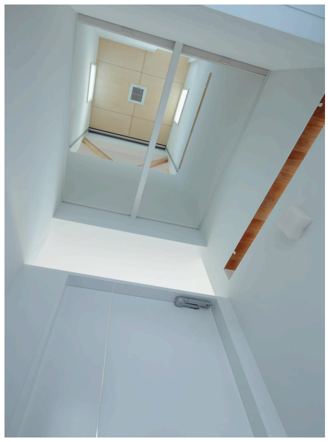


Fig.7 Parabolic wall, Photo.7 Ventilation tower*

3.6 Wooden sunshade louver

In general, the sunshade on the outside of window is more effective than inside. But this type of sunshade needs to resist weathering. In this case, aluminum blinds are employed, whereas they emit high CO2 during their manufacture. And the season when the sunshade plays an active roll is the period when the natural ventilation is also prominent. It means that the strength against wind is also necessary for the sunshade.
For reasons above mentioned, this house has wooden sunshade louvers on the inside of southern windows. Wooden louver is weaker than aluminum against weathering. But it has a big advantage of embodied CO2. In this house, wooden louvers are protected on the inside of windows and under the roof. Their dimension (depth, thickness and interval) is decided according to the prevention of unnecessary sun light during summer and the strength against wind while natural ventilation mode. Moreover, they are movable to allow that solar gain and sunshade are compatible (Fig.8).

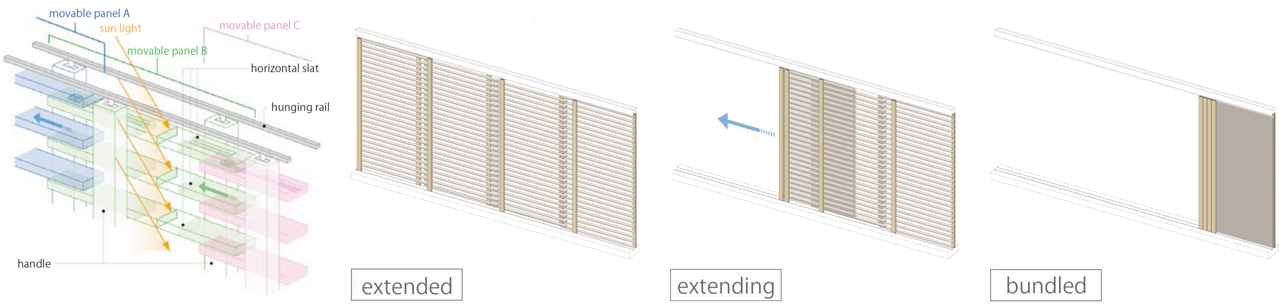


Fig.8 structure and mechanism of wooden sunshade louver

4. Conclusion

The LCCM demonstration house is for realization of the latest concept of ecological house as LCCM that targets on ultimate reduction of CO2 impact. Through the design and construction of the demonstration house, many kinds of subject are discussed. Therefore, various verifications including experimentations of inhabitants are on going.
This is a demonstration house, not a model house. In other words, it means diverse possibilities of design on the LCCM concept are left.

Study on Life Cycle Carbon Minus House Part1:

Summary of LCCM Housing Project

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Summary

The LCCM (life cycle carbon minus) house is a detached house that consumes low energy. It also generates energy and its amount is same as or more than its energy consumption by using on-site renewable energy systems (ex. photovoltaic). To realize the concept of LCCM house, this project has started from 2009 and was processed for 3 years by focusing on four WG. In part 1, Summary of LCCM housing project will be introduced.

The LCCM house is consider as the Japanese top runner house. We aim to spread the ideas widely by constructing the demonstration house and displaying its efficiency. LCCM house is aimed to reduce the CO2 emissions in a lifetime which includes the production, construction, operation and discard phase. At first, we planned to create an energy-saving house with the high-efficiency equipment, and also introduced passive technology depending on natural ventilation. Secondly, we planned to use the renewable energy, such as photovoltaic and solar thermal, for minimalizing the amount of CO2 emissions during operation time. In addition, it is assumed that CO2 emissions during construction could reduce as much as possible by using recycled materials. In this manner, it is important to note that during operation as well and take into account up to the reduction of CO2 emissions during construction.

As research and development projects of the Ministry of Land, Infrastructure and Transport, and Building Research Institute and Development Committee has been continued "research and development life cycle cabon minus house" (Chairman Shuzo Murakami) which is provided in the Japan Sustainable Building Consortium general. In the end, we consider about the verification of operation, construction method study of technology, the development of LCCO2 assessment tools, the design and construction of the demonstration house.

Keywords: LCCM (Life Cycle Carbon Minus), LCA (Life Cycle Assessment), CO2 emissions during Operation, CO2 Emissions during Construction, LCCO2 assessment tool

1. Introduction

Recently, the necessity of energy saving has much importance in residence part of Japan. Not only the movement to higher the minimum standard of entire houses, but also new concept is required as a top runner. In this situation, the consept of life cycle carbon minus(LCCM) house, which

surpasses energy-saving or zero-energy houses, and changes CO2 emission to minus level through a life cycle of house, is considered.
To realize the concept of LCCM house, this project has started from 2009 and was processed for 3 years by focusing on four WG. In part 1, Summary of LCCM housing project will be introduced.

2. Concept of LCCM house

LCCM house means a house that thoroughly reduces amount of CO2 emission from entire procedures of production, construction, operation and discard, and generates energy by using renewable solar energy, solar heat, biomass and others, and could decrease amount of CO2 emission to minus level. (Fig.1)

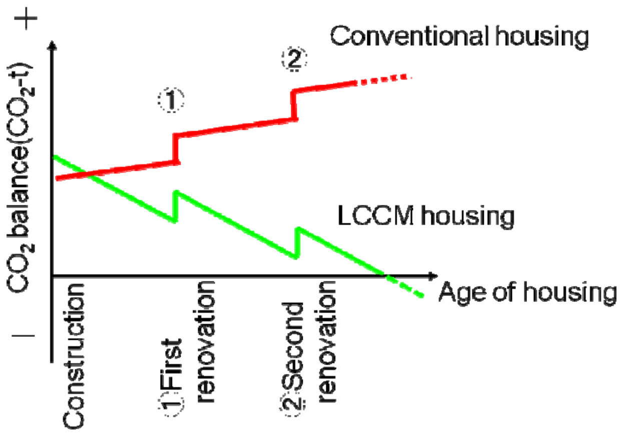

Fig.1 CO2 balance throughout life cycle (image)

The features are divided into three. First is to thoroughly adapting advanced energy saving technology, second is to generate energy that exceeds CO2 emission during operation, and lastly, third is reducing CO2 emission during construction or improvement to achieve LCCM. Although certain technology developments of these three are on the process, it is very difficult to be entirely realized in one house. Development of various technologies to apply on the house by this new concept is purpose of the LCCM house research development project.

A variety of developments on the concepts of zero-energy house, plus-energy house, zero-carbon house and others has been carried out overseas, such as BedZED of UK that aims for zero-carbon and “Plus-Energie Haus” of Germany which allows selling electricity generated from solar power. The concept of Japan is difference from other nations which attempts to decrease the amount of CO2 emission to minus level during a building lifecycle.

To make the amount of CO2 emission become minus, the reduction of CO2 amount during construction is also the focus to be experimented. The two approaches for reducing the amount of CO2 emission during construction are: One is to select members of framework and materials that are produce low CO2 emission on manufacture and transportation. The other is to choose the members and materials which are longevous. To reduce the CO2 amount by the first approach is to reduce the carbon footprint from each stage of manufacture, collection and transportation of materials. To reduce the CO2 amount by the second approach is to extend the period of material lifecycle. For example, the CO2 emission amount will become half through extending the lifecycle years from 15 years to 30 years. Therefore, not only choose the low CO2 emitted material, but also consider using the materials for longer period. A LCCM house is required to be energy-conserved and long life cycled. The requirements are the same as the goal of Japanese housing development.

3. Study of the research systems and plans of development

As mentioned above, various technology developments are on certain level of process. However, for accomplishing and popularizing the idea of LCCM, it is necessary to realize carbon-minus as gathering all technologies together but it is very difficult. Therefore, the construction of demonstration house is in order to identify the various issues for accomplishment of LCCM house and to verify its effectiveness. (Fig.2) The purpose of this house is to prove each technology and produce data for popularization trough this residential construction.

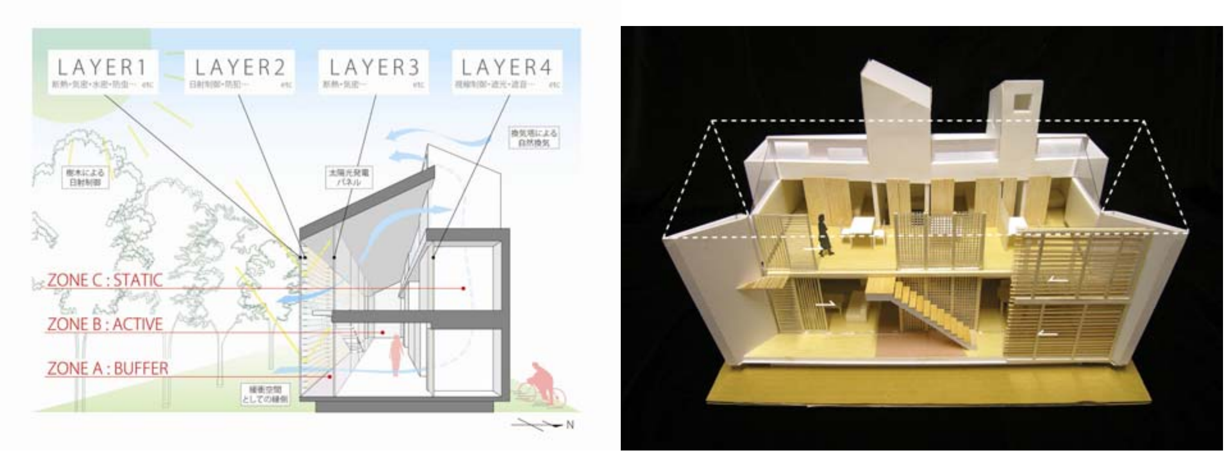

Fig.2 Image of LCCM housing

To realize LCCM house, the basic concept on early stage is as follows:

1) Clearly separate the modes in summer, winter and the season between with an awareness of seasonal differences (Type of housing and lifestyle are variable corresponding season)
2) Develop and disseminate the constructer techniques including various hardware or software to achieve the technologies of energy conservation and energy generation.
3) Integrate software technologies and the hardware technologies for multi-objective optimization and integrated design
4) Examine various demonstrated houses.
5) Develop the production technology and social systems for promoting and popularization

As research and development projects of the Ministry of Land, Infrastructure and Transport, and Building Research Institute and Development Committee has been continued "research and development life cycle cabon minus house" (Chairman Shuzo Murakami) which is provided in the Japan Sustainable Building Consortium general. In the end, we consider about the verification of operation, construction method study of technology, the development of LCCO2 assessment tools, the design and construction of the demonstration house.
And, to achieve the above concepts, the research development was processed for 3 years since 2009 by focusing on following four Working groups. In 2010, the residential model was constructed in Tsukuba City. From 2011, experiments for verification is proceed in the demonstrated house.

1) LCCO2 WG (chair : Toshiharu Ikaya, Keio University)
   : Concept design and establishment of a calculation system of LCCO2 in housing
2) Energy and building equipment WG (chair : Yasuo Kuwasawa, Building Research Institute)
   : Development of various environmental technologies and equipment to reduce CO2 emissions
3) Construction technology WG (chair : Tsuyoshi Seike, the University of Tokyo)
   : Development of construction methods to reduce CO2 emissions
4) LCCM housing design WG (chair : Masao Koizumi, Tokyo Metropolitan University)
   : Design of LCCM demonstration house and creation of building design manual

4. Study of CO2 emissions during operation

During a lifecycle of residential building more than 30 years, the period that emits the most CO2 is during the operation, and the amount is about 70% of total emission. The issue becomes the first step to be considered for a LCCM house. To save energy completely, use not only high-efficiency air conditioning and water heating equipment, but also natural energy. Therefore, it is necessary to well combine equipment with ventilation in summer and solar radiation in winter. (Fig.3)

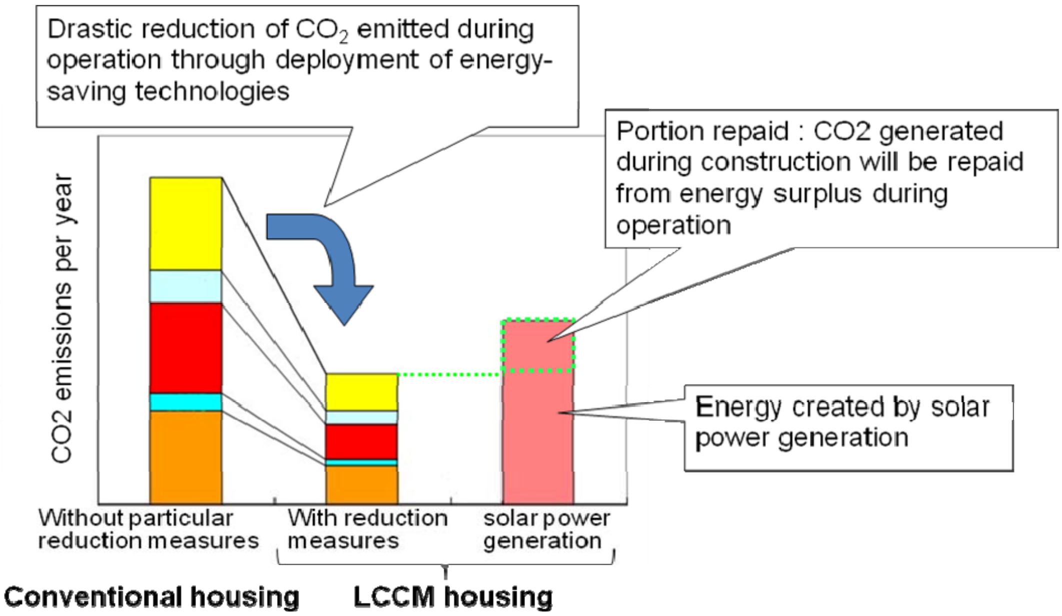

Fig.3 Achievement of carbon minus through energy saving and energy creation
(Image with a focus only on the operation stage)

LCCM house is a complex which is properly operated as important as well designed. Therefore, we simulated a variety of equipment related to the environment; the result of the simulation became the reference for designing the demonstration house.

Especially, the way of HVAC system usage will relate to an architectural design. To implement the passive design and utilize natural resource, the composition of building opening and the interior space have to be well considered. It takes time to find the best design combination by simulating. However, it might be difficult to do such comprehensive discussions and simulation studies for most housing design projects. If design tools could be developed, the idea of LCCM would become possible to apply on all housing design.

We assume the equipment such as performance of the water heating and the lighting dominants the result of the energy conservation; the optimum operating condition of high-efficiency equipment has been studied. The method for energy generating we chose is solar power system and fuel cell. The electricity is generated efficiently by installing solar panels on the south roof of the demonstration building. The point we are focusing is not only the simulation result of the equipment operation, but also the appropriate equipment selection.

5. Study of CO2 emissions during construction

In order to achieve the goal of LCCM, energy conservation and CO2 emission reduction during operation are basic requirements. However, the situation might happen that the amount of CO2 can’t become minus during building lifecycle by only meet the requirement. In such case, to reduce the CO2 emissions during construction is also important. Hence, we examined the amount of CO2 emissions during both design and construction phases for the LCCM demonstration house.

Furthermore, wooden structure is chose to build LCCM house because of its small amount of CO_2 emission.

The CO_2 emission amount of LCCM house is larger than the amount of conventional house during construction, because that the higher performance element are used. After reducing the quantity of concrete by changing the shape of the foundation, the CO_2 amount is decreased.(Fig.4) The elements which can control the amount of CO_2 emission during construction are the choice of materials, the distance of transportation…etc. However, the goal to achieve high performance is more important than to reduce CO_2 emissions only during construction.

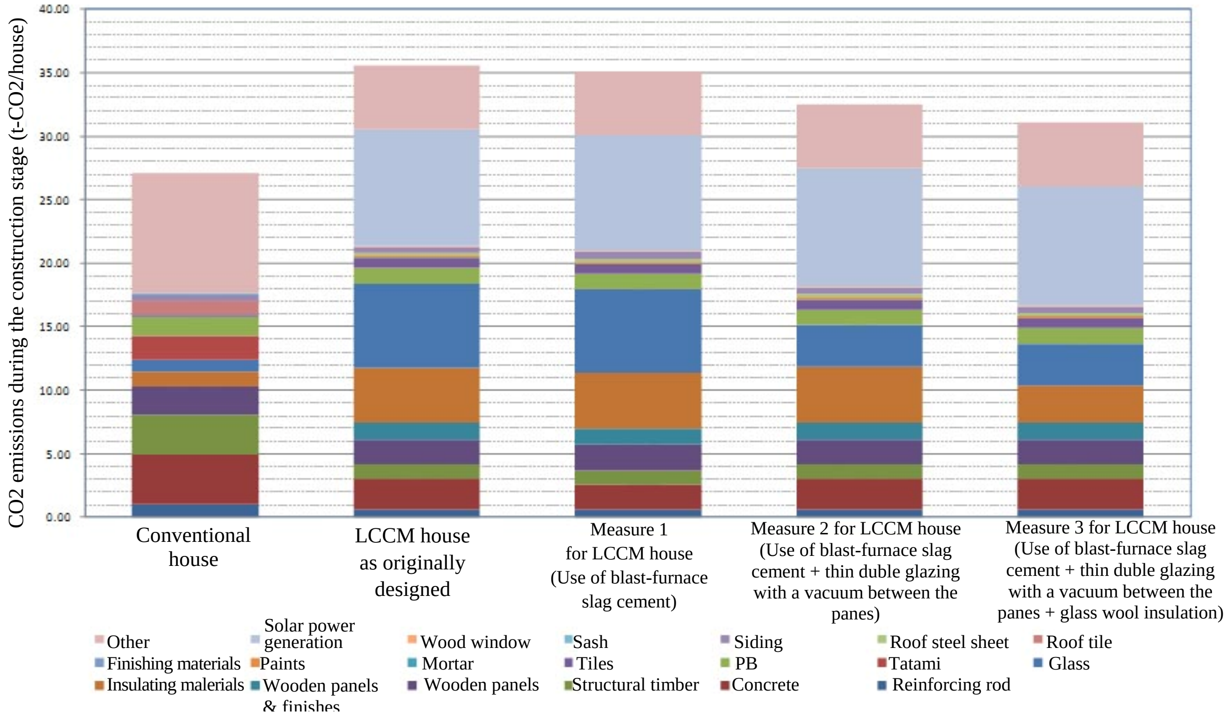

Fig.4 Proposed measures to reduce CO_2 emissions during the construction stage

By current design technique is still not able to complete the process of LCCM design, because of the lack of data for assessment. Therefore, the development of database for simulation and assessment tool are important.

Furthermore, to accomplish the goal of LCCM, it is important to develop a tool of calculating the CO_2 emissions during construction and also the database. However, there is not enough information to make the data. To popularize the concept of LCCM house on entire social environment, the database should be developed and completed.

6. Development of LCCO2 assessment tool

To realize a LCCM house, we have to ascertain that the house design meets the requirement of LCCM; an evaluation tool is needed. The evaluation tool of LCCM house is able to calculate the amount of CO_2 emissions in lifecycle of the house. The developed tool can evaluate each stage of LCCM housing lifecycle such as material production, construction, operation, renovation and reconstruction; especially it can evaluate the wood materials locally, transportation and circulation process detailly.

On the other hand, to evaluate LCA in detail needs lots of works. The evaluate approaches are difficult to be follow for constructing a detached house. Therefore, a simple version of the tool should also be develped; local builders and designers can easily use the tool for assessing the construction and design of detached houses. The tool is planed to be inculded in ‘CASBEE for Detached Houses(for New Construction)’.

The most construction evaluation will become easy to be calculated for detached houses through “CASBEE(Comprehensive Assessment System for Built Environment Efficiency)”. In present “CASBEE for Detached Houses(for New Construction)”, we can easily evaluate LCCO2 and the result is certificated by the number of green star. The highest score is five stars. However, the evaluation items of ‘CASBEE for Detached Houses’ are limited and fixed. There are only basic results can be knew such as general energy-saving and energy-generation. For CO2 emission result during construction, the parts material lifetime and maintenance are only showed in ‘CASBEE for Detached Houses(for New Construction)’. Therefore, the future plan is to develop an evaluation tool which is simple to be use and cover more evaluate items such as the choice of low CO2 emissions material.

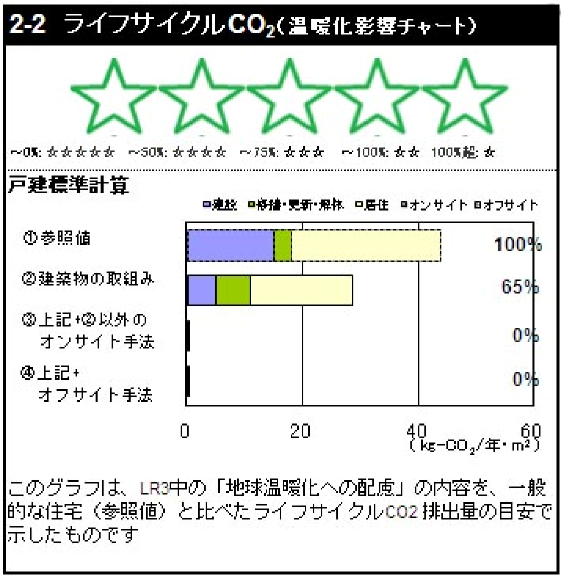

Fig.4 LCCM housing of five star

7. Conclusion

The LCCM house project is aim to become a demostration for the house which is concerning the environment and energy conservation. To achieve the goal, the study results are comprehensively examinating and organizting. And also, by using ‘CASBEE for Detached Houses(for New Construction)’ to implment energy-saving houses and environmental-conscious houses is the start for the popularization of LCCM house.

On the other hand, although the concept of LCCM is easy to be understood, the evaluation of LCCO2 is difficult. Especially when we calculate the amount of CO2 emission at construction, the amount cannot be summed up precisely because of data is various. Furthermore, when the data used for design might be huge different from real situation. To popularize the LCCM house, the problems should be conquered. Therefore, developments and results of the research will be continually proceeded in the future.

Natural wastewater polishing treatment, cold crystallisation and wetlands

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Summary

Modern biochemical wastewater plants produce high quality treated wastewater. To further improve end-product quality, natural processes such as wetland passage or snowmaking can be used as a low-cost polishing treatment. These two treatment methods have different annual optimum working periods and thus combining them could be an effective solution at high latitudes.

Keywords: Wastewater, wetlands, cold crystallisation, snowmaking, polishing treatment, wastewater treatment, municipal wastewater, BOD-removal, phosphorus, nitrogen

1 Introduction

With the current tightening of environmental regulations, there is a need for improved wastewater treatment. The final stages of wastewater purification to make the last percentage reductions in contaminants are costly in terms of Euros/kg impurities removed. The conventional method for enhancement of wastewater treatment is by making process changes or by adding a finishing treatment after the process, e.g. flotation or filtration. An alternative way to improve the effectiveness of municipal or industrial wastewater treatment is to use natural processes for polishing the water leaving the wastewater plant. Potential natural polishing treatments include e.g. passage through wetlands and snowmaking from treated wastewater [1,2].

In northern areas of the world the population density is usually low and there is often sufficient land available for using wetlands for polishing treated wastewater. Wetlands are used for wastewater polishing at four sites in northern Finland. In cold climates, the winter cold can also be exploited in wastewater purification, by producing artificial snow from treated wastewater. This cold crystallisation or freeze crystallisation method is based on the fact than when water freezes, ice crystals of pure water grow, while impurities are concentrated in the remaining phase. The impurities trapped in the snow evaporate when the snow ages (nitrogen in the form of ammonia gas) and the flocs of impurities formed in the snow ageing process are adsorbed in the soil when the snow melts. This system is used at some sites in the USA and Canada and has been tested in Kuusamo, Finland [3].

2 Finnish experiences of wetlands

The soil layer has long been used for wastewater purification all over the world. For example, infiltration of municipal wastewater to marshland (seepage trench technique) was applied in many places in northern and eastern Finland in the early 1970s. Overland flow or wetland treatment is now used in Finland as a polishing treatment after municipal wastewater treatment, or as a treatment for mining effluent and for water leaving agriculture, forestry and peat harvesting areas.

The Finnish experiences of using wetlands for polishing treated municipal wastewater are mainly from natural wetlands, of which four are currently in use in northern Finland. The number of population equivalents (PE) served by the associated municipal wastewater plants varies from 4 500 (Mellanaava) to 36 000 (Lakeus). The Ruka wastewater plant serves 15 000 PE and the Siikalatva plant 9 300 PE. The first three of those wetlands were built in 1990 and that at Siikalatva in 2007. The older wetlands are generally very basic and simply use an existing wetland area without additional earthworks or plantings apart from water-conducting ditches and isolation ditches and dams around the area (Figure 1).

Fig. 1. The multi-element Siikalatva wetland, Rantsila, Finland (left) and the very basic natural Ruka wetland , Kuusamo, Finland (right).

The four wetlands are quite different in nature. The Ruka wetland was originally a pine swamp, the thickness of the peat layer is 0.5-1.5 m, there is no open water and the wetland area is 0.6 ha (Figure 1) [4]. The new Siikalatva wetland, in which production in the whole area started in 2010, consists of three parts, a 3 ha natural wetland, 4.5 ha reed canary grass and 17 ha of old peat harvesting area (Figure 1). However, the latter does not yet have a satisfactory vegetation cover and slightly weakens the wetland's purification efficiency in terms of BOD and COD.

The Mellanaava wetland is 5.4 ha and the vegetation is sparse (Figure 2). The thickness of the peat layer is 0.7-1.0 m [5]. The Lakeus wetland has a water depth of 0-1.1 m and the amount of open area is 30%. The soil is a dense glacial till and the vegetation consists of cane-grass and willow. The original area of the wetland was 4.4 ha, but in 2011 it was enlarged to 17 ha (Figure 2).

Fig. 2. Mellanaava wetland (left) and the new expanded Lakeus wetland and associated municipal wastewater plant (right).

The purification effect of all four wetlands is quite good (Table 1). There has been no deterioration over the years, although adaptation of the vegetation might further improve the purifying effect slightly over time.

Table 1. Purification effects of four Finnish wetlands used for polishing water leaving municipal biochemical wastewater plants. BOD_7=biological oxygen demand, P_{tot}=total P, N_{tot}=total N [6].

Reduction (%)	Mellanaava	Ruka	Lakeus	Siikalatva
Suspended solids	45-50	80-86	64-68	95-99
BOD_7	16-25	60-65	60-80	55-60
P_{tot}	10-15	64-90	60-80	0*
N_{tot}	2-18	13-30	18-30	27-70

* Outflow of P from wastewater plant only 0.1 mg/L.

3 Cold crystallisation

The freezing process can be exploited in many ways for concentration and purification of fluids, for example for freeze concentration of fruit juices, desalination of sea water, sludge dewatering and wastewater purification, as described by many studies in this field [7,8,9]. Freezing requires a lot of energy, but at high latitudes the natural winter cold can be used for this purpose. The purification effect in cold crystallisation occurs during many phases: spraying and freezing, snowpack ageing and finally when the snow melts and the meltwater flows over the soil surface (Figure 3).

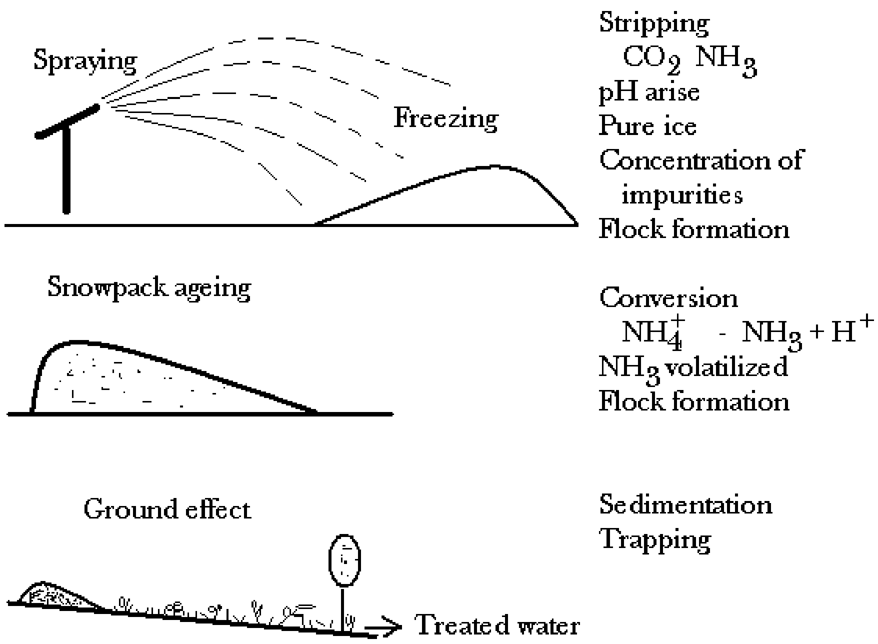

Fig. 3. Wastewater purification in cold crystallisation happens in many stages of the process [10].

In the spraying phase, up to 10% of the water disappears due to the evaporative requirement of the heat transfer process [11]. Small amounts of gases such as ammonia (NH_3) and hydrogen sulphide (H_2S) are also removed. Freezing then starts from outside the sprayed droplets. There is some degree of sublimation from the surface of snow flakes, perhaps up to 20-30% [12]. A considerable amount of CO_2 is also removed from the water, raising the pH of the water by 1.5-2.5 units. When the pH rises, ammonium (NH_4^+) is increasingly converted to ammonia gas (NH_3) [13]. The concentration of impurities in the liquid phase of snowflakes assists floc formation and precipitation. The reduction of ammonium also assists phosphate precipitation, because phosphate readily binds with ammonium ions to form highly soluble ammonium phosphate. When the amount of ammonium decreases, the phosphate reacts with calcium and precipitate [7]. The ammonium reduction starts in spraying and continues progressively as the snowpack ages. During snowpack ageing, contaminants travel downwards and there is some diffusion and gas exchange with the surrounding air. Light, UV-radiation, rain, temperature changes and microbial activities also alter the snow. When the snow melts, the flocs formed remain on the soil surface and there is also some adsorption of soluble impurities to soil on the surface and at deeper levels. After melting of the snow, growing vegetation uses those impurities and thus nutrients remain in the snowmaking area.

4. Studies on cold crystallisation at Kuusamo

The cold crystallisation method was tested at the Ruka biochemical wastewater plant in 2006. For this, 6 700 m^3 of treated wastewater were made into snow using hybrid snow guns. Total snow production was 10 000 m^3 (Figure 4).

Fig. 4. Snow made from treated wastewater in the melting stage at the Ruka wastewater plant (left and centre). Impurities left on the soil surface in the melting area are available for vegetation (right).

The average quality figures for the treated wastewater in the snow storage area were: chemical oxygen demand (COD) 17.3 mg/L, BOD_7 6.9 mg/L, P_{tot} 56 µg/L, N_{tot} 9.4 mg/L, pH 6.8, colour 150 mg Pt/L. Thus the reduction in nitrogen was very high but the reduction in phosphorus and organics (BOD_7) was somewhat lower (Figure 4). The energy consumption was 1.12 kWh/m^3 and the snowmaking area required was 0.37 m^2/m^3 wastewater [3].

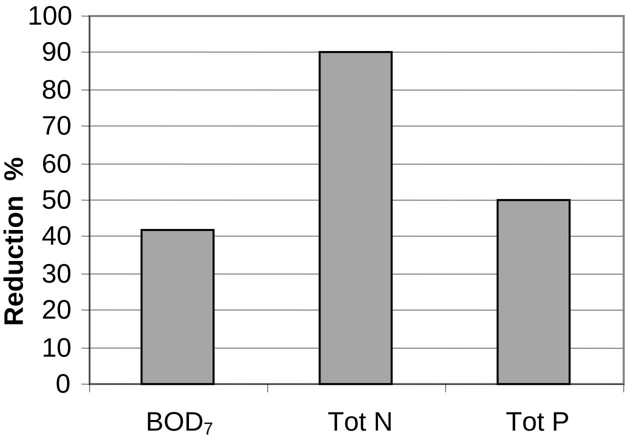

Fig. 4. Purification effect (% reduction) of cold crystallisation on biochemically treated municipal wastewater at the Ruka municipal wastewater plant.

5. Combined methods

Wetlands work somewhat less efficiently in wintertime than in spring or summer. The main vegetation in the wetlands consists of annual species and they grow in warm spring and summer conditions. They gradually extend their roots and build up new filter/substrate/adsorbent every year. Chemical reactions and biological activity are also much lower at a temperature of 2 ˚C than 20˚C. Although these affect the efficiency of wetlands in winter, wetlands still work moderately in cold weather.

In wintertime the coldness of nature can be exploited for the cold crystallisation method. The only energy needed is for pumping the snowguns, as nature supplies the rest. The greatest requirement is for a sufficient land area for storing the snow. This should not be near housing areas or other regularly used areas, because the fog produced by the snow guns covers a wide area. Although it is possible to include for example UV-light disinfection before snowmaking, the fog is not very pleasant to breathe. One possibility to improve the quality of this fog is wetland treatment before UV-disinfection and snowmaking. Wetland pre-treatment is also a good method for lowering the temperature of the water before snowmaking.

6. Results

There is long experience in Finland of using wetlands for polishing treated municipal wastewater and good purification results have been achieved with a small capital investment. The purification effect of wetlands is greatest in spring and summer, although they work moderately well in winter. The cold crystallisation method is not as well-known as wetland treatment, but experiences to date are positive. Cold crystallisation exploits the natural cold, so is only possible in winter. However, if there is sufficient land available, these methods can be combined so that the winter load of wastewater is sprayed to form snow and the cold crystallisation method partly purifies the water. In spring and summer, when wetlands are at their most effective, the meltwater from the snow spraying area is then conducted to the wetland for further purification before release to the recipient. In wintertime, wetland treatment before snowmaking would remove some of the pollutants and lower the temperature of the water.

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BIM and sustainability concepts in construction projects: A Case Study

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Summary

Even though the need of integration of BIM and sustainability as emerging concepts in the construction sector has been discussed, there are some barriers to a functional inclusion. This paper focuses on the current state of BIM in sustainability as well as other factors affecting the success of sustainable construction projects by performing interviews with the Turkish architectural firms participated in certificated sustainable projects in order to find out the key indicators for better integration solutions. Fuzzy-set qualitative comparative analysis (fsQCA) is used for evaluating the results due to its availability to provide the relations between the factors examined. Each impact of the variables on the sustainable projects is discussed in the conclusion.

Keywords: Building Information Modeling, BIM, fsQCA, integration, sustainable construction.

1. Introduction

Building Information Modeling (BIM) and green building market are the two current and growing movements in the architecture, engineering and construction (AEC) industry [9]. BIM, one of the most important developments promising in the construction sector, is a new approach to design, construction, and facility management in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format [15]. It is a methodology to manage essential building design and project data in digital format throughout a building's life cycle. One of the key advantages of BIM over drawing methods, either manual or computer-aided (coordinate-based software, knowledge-based or object oriented systems), is its ability to prevent possible conflicts during construction process by providing accurate project drawings and construction documents on time and fast. Moreover, BIM provides users with a consistent method of conveying project information, which prevents errors or conflicts caused by lack of coordination within the project teams. BIM is developed for the needs of collaboration, getting improved outputs, minimising the risks, time loss and cost. It also aids in the development of buildings less harmful to the environment in addition to providing better visualisation and project integration.

The term BIM was coined in the 1970s by Charles Eastman and has been used in academia in various studies [4, 5 and 8]. The importance of design and construction integration has increasingly been realised in recent years and the value of BIM technology has been understood since the early 2000s in the construction sector and in academic studies related to construction. It has also been developed by computer-aided design (CAD) suppliers such as Autodesk, Bentley, Nemetschek and Graphisoft.

The strong growth of the green building market can encourage BIM adoption in the design and construction industry [10]. Moreover, their integration has a great impact and importance on sustainable construction. However, it is difficult to mention about a thoroughly integration in the current situation due to lack of measured sustainable strategies' direct access into BIM models. Data needs to be exported to another application or imported from a data source [9]. In some cases a team may need to import information to the BIM model from an outside source, such as a database of weather data or material properties. Better and more seamless integration between BIM and sustainable design will come with time as the industry continues to standardise file formats, as data sets are developed, and as owners, clients, and designers begin to demand more from application developers [9].

Accordingly, the research presented in this paper focuses on the impact of BIM usage in sustainable construction projects' success in order to provide a basis for the integration of BIM and sustainability. The main purpose of the study is to determine the state of completed sustainable construction projects. This is achieved via conducting semi-structured interviews with the participants involved in the design process of the sustainable construction projects. The findings are considered to be useful indicators for the integration of BIM with standards of sustainable construction.

2. Sustainability and green building rating systems

The sustainability concept has been frequently encountered in the construction sector as in many other industries over the last two decades. The term of green in building design and construction started with the formation of Building Research Establishment (BRE), the American Institute of Architects (AIA) Committee on the Environment (COTE) and the U.S. Green Building Council (USGBC) and in the early 1990s [9]. World Commission on the Environment and Development, also known as the Brundtland Commission (1897) defined sustainability in construction as:

Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.

Moreover, when other factors such as global warming, pollution and rapid consumption of energy resources are taken into consideration, sustainability is becoming increasingly important in today's construction industry. Therefore, various stakeholders including research institutes, governments and other non-profit establishments have discussed the sustainable solutions. In this context, green building rating systems play a key role in the dissemination of sustainable projects. This section examines BRE Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED), giving a brief explanation of each system. The named criteria-based assessment and certification systems are addressed in this study due to their common usage in Turkey.

2.1 BREEAM

BREEAM, the oldest assessment method developed by BRE in the United Kingdom as a tool to measure a building's environmental performance, addresses wide-ranging sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other initial parties [2].

While the original version of BREEAM was limited to the office buildings, it has been developed and is available in a range of building types including existing buildings. The main areas in the assessment system are Management, Health and Well-Being, Energy, Transport, Water, Materials, Waste, Land Use and Ecology, Pollution and Innovation (added in 2009 version) respectively. Credits are awarded in each area according to performance and then added together through a combined weighting process in order to rate the building on a scale of Pass, Good, Very Good, Excellent or Outstanding and finally a certificate is awarded to the project [9]. Furthermore, BREEAM International, BREEAM Europe Commercial and BREEAM Gulf are the other categories developed for using aside from the UK.

2.2 LEED

LEED was developed by USGBC in 1998 for the purpose of sustainable buildings via measurement standards [14]. LEED system, initially introduced for new construction (NC), has been developed over time in various versions for different types of buildings such as LEED for Core and Shell Development (CS), Commercial Interiors (CI), Existing Buildings (EB), Homes (H), Schools (S), and Retail (R). Under the LEED-NC system, buildings are judged via a credit system in five categories of environmental performance and one additional area for innovative strategies, which are Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality and Innovation and Design [9]. The final score is obtained by adding the credits from each category to determine the level of certification awarded to the project. The LEED levels of certification are Certified, Silver, Gold and Platinum based on the points.

The process of certification can be said as the main difference between the two methods. While BREEAM trains assessors who assess the evidence against the credit criteria and report it to the BRE that validates the assessment and issues the certificate, there is a credit available if an accredited professional (AP) whose role is to help for gathering the evidence and advise the client, is used in LEED system [3]. The evaluation is examined and certification is issued by USGBS.

3. Fuzzy set – Qualitative comparative analysis (FSQCA)

As fuzzy set qualitative comparative analysis (fsQCA) is intended to evaluate the results, it is useful to mention about the analysis briefly.

The qualitative comparative analysis (QCA) is a set of systematic ways of studying causality in a simple data table of binary or ordinal variables which is mainly used in comparative research, or with qualitative data, or as part of case-study research methods [11]. Fuzzy set qualitative comparative analysis (fsQCA), on the other hand, is a software that uses combinatorial logic, fuzzy set theory and Boolean minimisation to work out what combinations of case characteristics may be necessary or sufficient to produce an outcome [7].

A data matrix, a simple qualitative table of data made up of rows and columns, is the data-handling mechanism. The cases are listed as rows where in the columns; case characteristics are not 'variables' in the usual sense, but degrees of membership of a defined category. The column elements can be binary (yes/no), ordinal, or scaled index variates. QCA is best suited for small to medium-N case study projects with between 3 and 250 cases. Following the data matrix, construction of a truth table is generated. While crisp-set QCA uses only binary variates for its truth table, fuzzy-set QCA also uses ordinal variates [for further details, see 7, 11, 12 and 13].

4. Background

4.1 State of research and practice

As an emerging trend, Green BIM has been increasingly discussed for more sustainable outcomes in various studies [for further details see, 6, 10 and 16]. An online survey designed by McGraw_Hill Construction for 2010 Green BIM Study is conducted with a range of industry professionals who use BIM tools to assess the level and scope of use of BIM tools to help achieve sustainability and/or building performance objectives as well as the expected level and scope of use in the future. The results of the study show that BIM is considered as an essential tool for green construction and expected in extensive use of green market in the near future. The report also makes a list of the areas that are key to the potential growth of Green BIM and its impact on the green building marketplace as follows: Software Integration, Integrated Output from Different Building Systems, Modeling Standards, Increasing Use of BIM for Small Green Retrofit Projects, Using BIM for Building Performance Monitoring and Verification and Greater Use of Integrated Design. On the other hand, EU-project STAND-INN addresses new manufacturing processes based on IFC standards [1] and performance-based standards for sustainable construction with objectives of creating new and more efficient business processes in the construction sector. The main objectives are to facilitate the integration of open standards into business processes, provide the integration of open standards into the design of new products and services and stimulate innovation through reference to standards in public procurement. Moreover, [16] proposes a 3rd party web service relying on BIM as the information backbone to facilitate the LEED documentation generation and management.

4.2 Problem Statement and Objectives

Even though the importance of Green BIM is recognised in the literature, there are some barriers to the BIM adoption in sustainable construction such as lack of functional tools and complex structure of the existing tools. However, it is obvious that there is a need for integration of BIM and green building market. This study aims to examine sustainable construction projects for setting up a substructure to fill the gap of BIM integration with standards of sustainable construction by conducting a case study. In accordance with this purpose, having interviews with the firms carrying out the projects in question and getting their prescience are intended. Not only the importance of BIM usage is investigated but also other factors affecting the success of a sustainable construction project are addressed.

5. Methodology

For an effective response to the research objectives, the research methodology includes four main steps (Figure 1): (1) Preparing the main topics to be discussed and the questions, (2) Determining corresponding participants to conduct the case study and interview (sampling), (3) Performing the interviews and data collection and (4) Data analysis and evaluating the results.

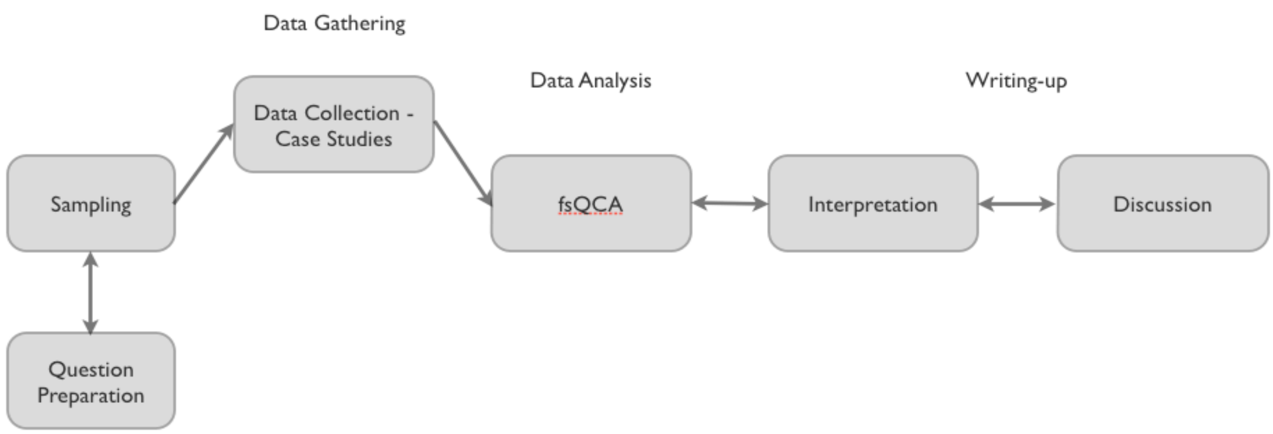


Fig. 1 Proposed method (Adapted from [11])

Firstly, the main topics and questions in order to examine the current state of sustainable construction projects in Turkey are determined. It is tried to avoid preparing very detailed, tedious and long questions, conversely, making a point of getting real data from more general but also key questions are intended. The questions vary from the sustainable project decision making to the future of sustainability in construction projects (Table 1).

The scope of the study is limited to the Turkish architectural firms that undertake the design of BREEAM and LEED certificated buildings in Turkey regardless of their ratings (levels) and scores. Therefore, the next step identifies these firms and determines the related participants. 35 firms are identified and 30 of them are contacted for interview request in total. 12 of them accepted to interview and/or answer the questions electronically. Following this step, the interviews are performed for gathering the data.

In the last step, the results obtained from the firms are used as the input data for fsQCA (http://www.compasss.org/). Firstly, the responses of each variable are calibrated (Table 2).

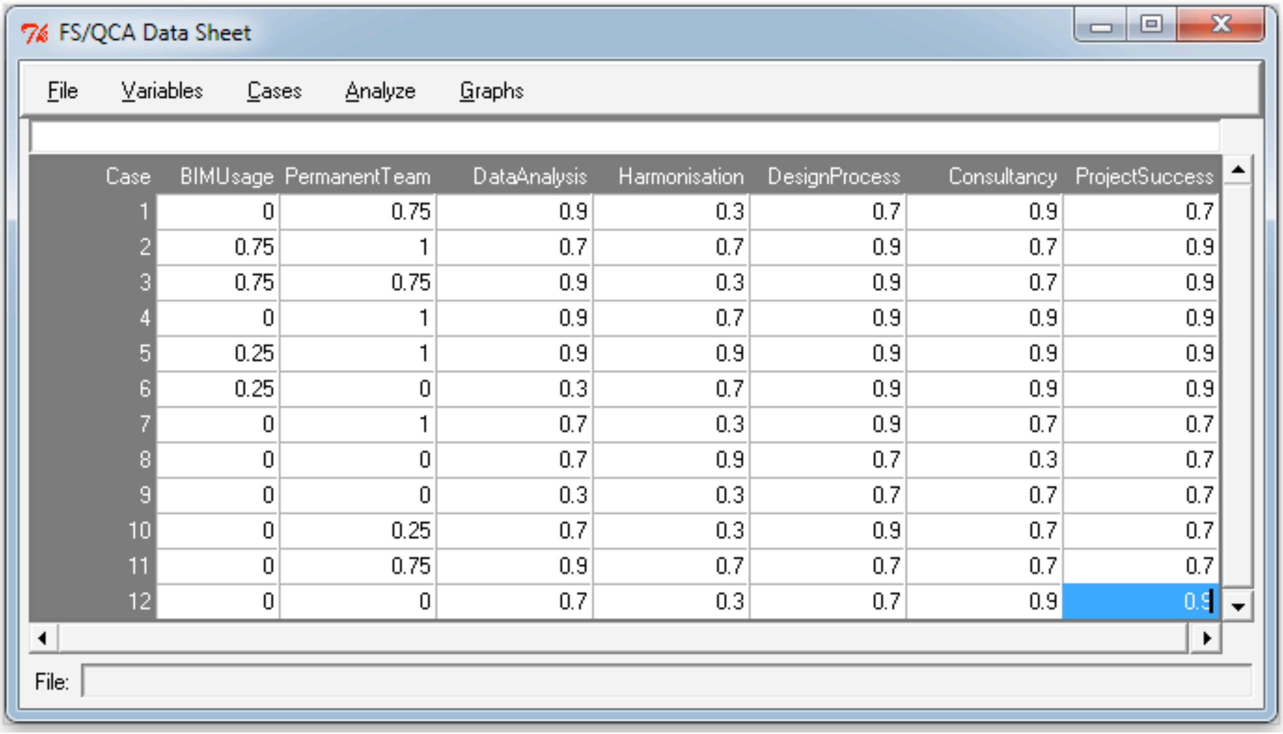
Table 1 The main topics of the questions

Topic	Research Question
Sustainable project decision	How is the sustainable project decision made? Who gives the decision? i.e. Owner demand or firm suggestion.
BIM usage	What is the current role of BIM in the sustainable construction projects? Are any BIM tools used in sustainable projects? If so, in which phases of the building production process?
The impact on fees	Is there any additional charge for generating sustainable and/or BIM projects?
Existence of a standard team	Is there any standard team for sustainable and/or BIM projects?
Sustainable data analysis	Which resources are used for selecting sustainable data?
Harmony of the data	How the harmonization between the data related to the sustainable construction and sustainable construction projects are provided?
Design process of sustainable construction projects	How does the design process progress? What are the differences from other projects?
Green consultancy service	How are the consultancy firms integrated to the building production process?
Project performance	What is the rate of your success?
Future	What is your prescience for operability? How do you see five years later?

Table 2 Calibration of the variables

Variable	Fuzzy Set	Values
BIMUsage PermanentTeam	4 Value Fuzzy-set	1= fully in 0.75 = more in than out 0.25= more out than in 0= fully out
DataAnalysis Harmonisation DesignProcess Consultancy ProjectSuccess	6 Value Fuzzy-set	1= fully in 0.90 = mostly but not fully in 0.70= more or less in 0.30= more or less out 0.10= mostly but not fully out 0= fully out

The collected data is converted into a table with the cases as rows and variables in the columns, presented in Figure 2. The variables are BIMUsage, PermanentTeam, DataAnalysis, Harmonisation, DesignProcess, Consultancy and ProjectSuccess.



Case	BIMUsage	PermanentTeam	DataAnalysis	Harmonisation	DesignProcess	Consultancy	ProjectSuccess
1	0	0.75	0.9	0.3	0.7	0.9	0.7
2	0.75	1	0.7	0.7	0.9	0.7	0.9
3	0.75	0.75	0.9	0.3	0.9	0.7	0.9
4	0	1	0.9	0.7	0.9	0.9	0.9
5	0.25	1	0.9	0.9	0.9	0.9	0.9
6	0.25	0	0.3	0.7	0.9	0.9	0.9
7	0	1	0.7	0.3	0.9	0.7	0.7
8	0	0	0.7	0.9	0.7	0.3	0.7
9	0	0	0.3	0.3	0.7	0.7	0.7
10	0	0.25	0.7	0.3	0.9	0.7	0.7
11	0	0.75	0.9	0.7	0.7	0.7	0.7
12	0	0	0.7	0.3	0.7	0.9	0.9

Fig. 2 Data matrix

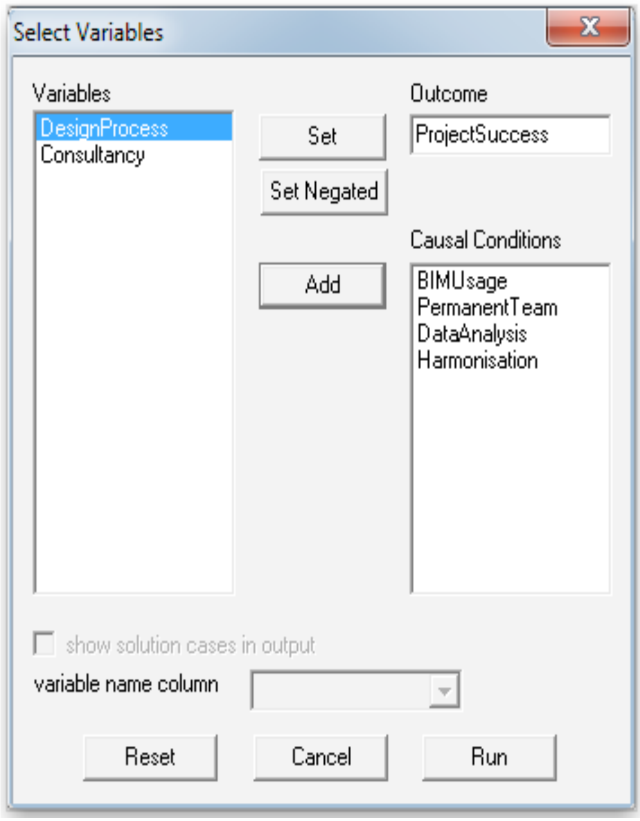


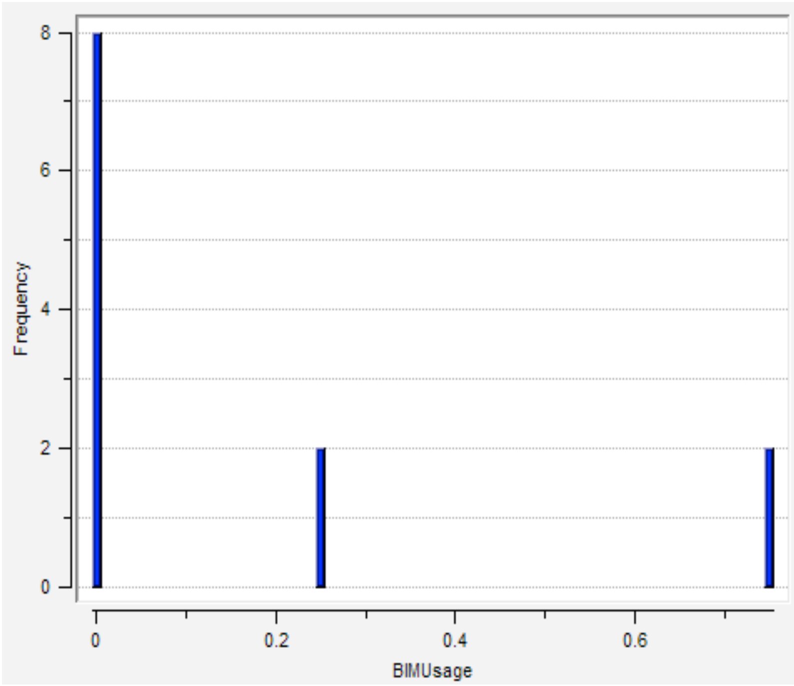
Fig. 3 Selection of the variables for Truth Table

Fuzzy Truth Table Algorithm is operated to construct the truth table. ProjectSuccess is set as the "outcome" and other variables are added to "casual conditions" (Figure 3).

In order to obtain the completed truth table, configurations are classified by removing the number of cases with smaller than 0.5 memberships in each configuration shown in the number column. Then, the configurations that are consistent subsets of the outcome from those that are not are distinguished. Values below 0.75 in the consist column indicate substantial inconsistency. Therefore, 1 is entered to ProjectSuccess columns that match the threshold and 0 for the rest. The output data of the analysis are presented as histograms and interpreted.

6. Findings and discussion

The results of the analysis are pointed out in this section. Key findings are depicted and interpreted using histogram and XY plots. While Figure 4 shows the frequency and weight of BIM usage in sustainable construction projects, the impact of BIM on project success is presented in Figure 5. BIM tools are used by 33% of the participants, however, that is not a thoroughly usage. Therefore, their impacts on project success are low.



The results show that permanent project teams have a positive effect on the project success with the exception of one case (Figure 6).

Detailed data analysis and integrated design process are the other important indicators for sustainable construction projects.

Figure 7 shows the mostly positive impact of data analysis in the predesign and design phases of the building production process. Similarly, it can be easily said that there is a direct proportion between integrated design process and project success. The more integrated design process, the more project performance gained (Figure 8).

Fig. 4 The frequency and weight of BIM usage

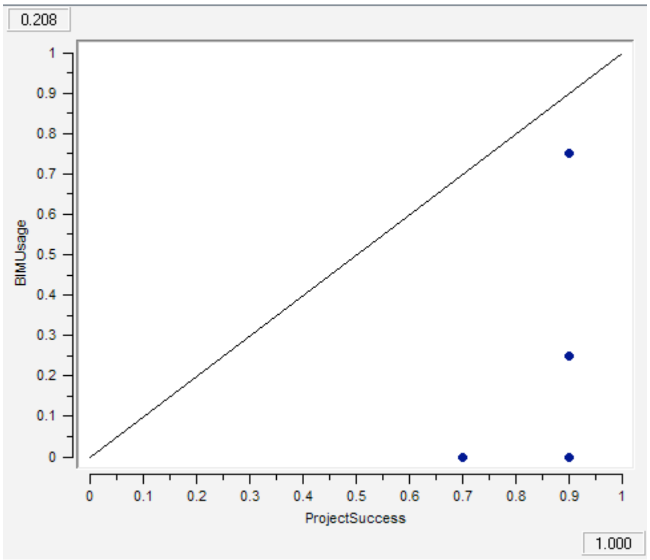


Fig. 5 BIM Usage – Project Success

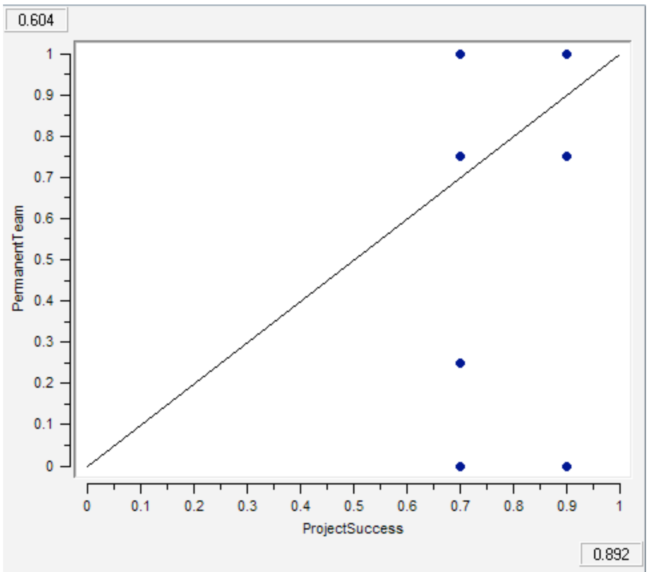


Fig. 6 Permanent Team – Project Success

There is a direct proportion between consultancy services and project success to a large extent as shown in Figure 9. The early participation of green consultants to the design process has a great importance for the success of sustainable projects. On the other hand, Figure 10 compares data analysis and design process. As might be expected there is linearity between the two variables.

It is also necessary to mention about the conceptions of the other topics not listed as conditions in the analysis such as impact on fees and the future of BIM and sustainability. Most participants indicated that they do not charge additional fees due to carrying out sustainable and/or BIM projects. Although the general view of sustainability in Turkish construction industry in the near future is positive, there is a long way to make the sustainable projects by legal regulations and the certificates cease to be an advertising tool.

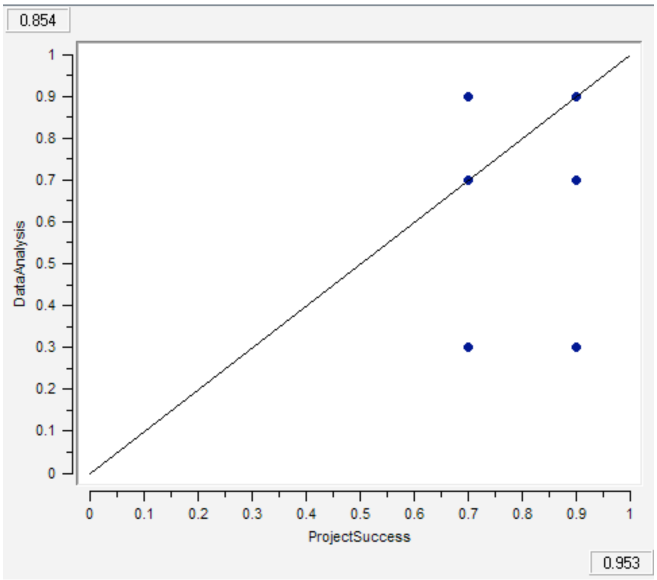


Fig. 7 Detailed Data Analysis – Project Success

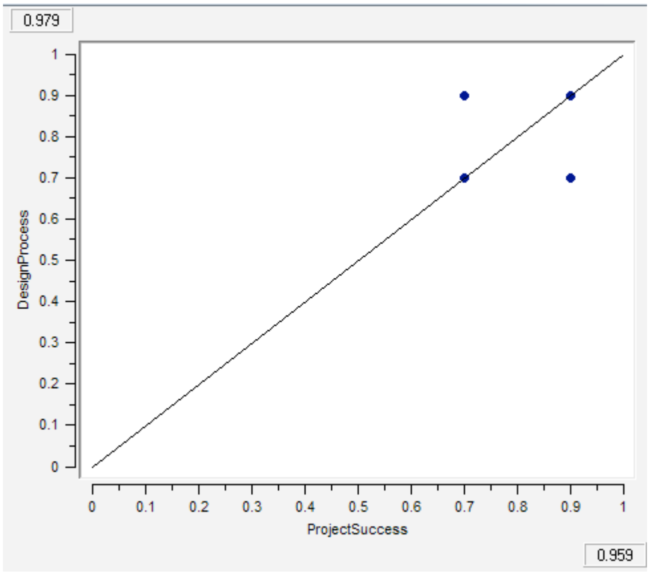


Fig. 8 Integrated Design Process – Project Success

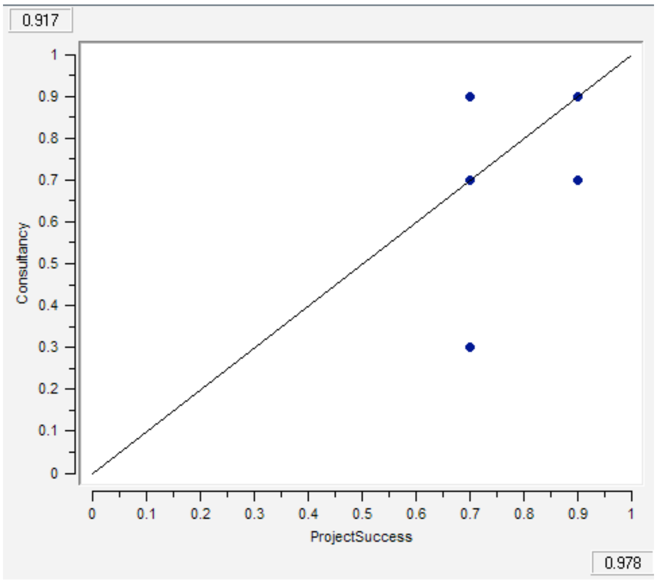


Fig. 9 Consultancy – Project Success

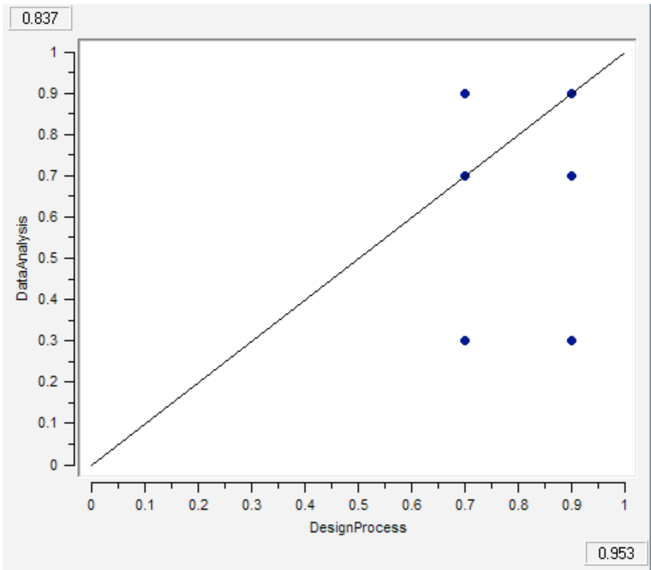


Fig. 10 Detailed Data Analysis – Integrated Design Process

7. Conclusion

The understanding and acceptance of BIM and sustainable construction integration has increased in recent years, however, it is difficult to mention about a perfect incorporation for obvious and accessible solutions. This paper finds out the relationship between BIM and sustainable construction projects as the first step of a functional model for this integration by examining the status of the firms that carry out sustainable projects in Turkey. Other factors such as sustainable data analysis, design process and consultancy services are also analysed via fsQCA besides BIM usage in order to point out their impacts on sustainable projects. The results of the analysis show that BIM is not used thoroughly for sustainable projects including all building production processes due to lack of allocated budget for efficient BIM usage and qualified staff. The benefits provided by BIM software in the design process are not yet realized by the designer, contractor and owners.

On the other hand, detailed data analysis, integrated design process with green consultants and having a permanent project team have great importance on the success of sustainable construction projects. Moreover, the difficulty of developing sustainable material and IFC database and the limitation of using current standards in Turkey can be listed as drawbacks of BIM and sustainability integration. This study is limited due to these factors. However, detailed analyses addressing new variables are needed for future studies. Similarly, the substructure for BIM integration with standards of sustainable construction should be presented at the end of a broader perspective analysis.

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Determining and visualizing regional energy usage and greenhouse gas emissions of housing

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Summary

Generally, energy demand in the building stock represents a large share of the final energy consumption in western countries. This paper presents a study on energy usage and greenhouse gas emissions in a case district in Finland. We use national registered building and dwelling data and employ a bottom-up model for calculations. With the aid of building locations, we assess the results in spatial form using GIS program. The results indicate that it is possible to analyse regionally residential stock and obtain practical information about the energy usage and greenhouse gas emission. This kind of information is useful in the decision making, especially when planning the energy system of the region accounting for both production and consumption.

Keywords: housing, energy use, renovations, greenhouse gas, emissions, GIS

1. Introduction

Housing and different buildings cause roughly one third of greenhouse gas emissions in Finland. The emission targets set by e.g. the European Union encourage seeking efficient paths towards improved energy efficiency and thus reduced greenhouse gas emissions (GHGE) in all sectors. Residential building stock simulations on a national level are a common practice in order to evaluate energy usage and greenhouse gas reduction potentials (see e.g. [1]). However, the demand is increasing for modeling energy performance of housing on sub-national and regional levels due to municipalities and cities setting their own targets for energy savings and emission reductions. Furthermore, it is important to identify the most cost-efficient ways to improve the energy efficiency at each region. For these purposes it is essential to model regional patterns of energy use [2, 3].

2. Materials and Methods

In Finland, the urban structure monitoring system (YKR) offers unique data to analyze in detail the built environment on both national and different sub-national, and regional scales. The system uses the Population Information System's data of buildings and dwellings and population data [4]. The registered real estate information includes, among other parameters, the location of the building in Finland, volume and floor area of the building, originally registered heating system and the year of construction. In addition, the occupancy information of buildings can be obtained from population data base.

In our study, the energy consumption of residential buildings is modeled with the aid of the physically based bottom-up EKOREM model that makes use of the National Building Code of Finland [5]. The main modeling parameters are thermal transmittances of structural elements in the stock, cooling and heating degree days, fuel mix used for heating, number of dwellers and volume and area of the stock. Since the model also allows ex-ante analyses of the residential stock, the benefits of urban infilling can be assessed.

Fig. 1 Residential stock volume by decade of construction in case district.

We analyse the energy use and GHGE of a case district within the city of Tampere in Finland called Kaukajärvi. It has about 11 000 habitants, and the total volume of residential stock in Kaukajärvi is about 1.6 million cubic meters. More than half of the residential stock consists of apartment houses and uses district heating. We show the residential stock's distribution of construction decades in Fig. 1. Most of the stock has been built after year 1960.

3. Results

In Fig. 2 we present the emission intensity, i.e. aggregated annual GHGE per square meter (floor space) for all residential buildings in Kaukajärvi. In addition, figure includes the gross energy consumption by different heating sources (GWh/a as bar charts). For clarity, we show the results in generalized form, i.e. in 500 m x 500 m grid. From the figure we see that the emission intensities are higher (darker cells) in the North-East corner, near the lake, where there are mostly detached houses that use electricity and light fuel oil for heating. However, the absolute energy consumption is rather small in these grid cells, as there are only few houses there. The smallest emission intensities are mostly in cells in which the district heating is the dominating heating source.

The age of building stock affects both emission intensity and need for renovations, and can easily be printed for the district. This is illustrated in Fig. 3, in which the average emission intensity has been presented for different house types built in different decade. From this figure we can see that the emission intensity of detached houses has decreased towards newer houses, whereas the emission intensities of attached and apartment houses have been on the level of about 40 kg

CO_2e/m^2 for later than 1980 constructed buildings.

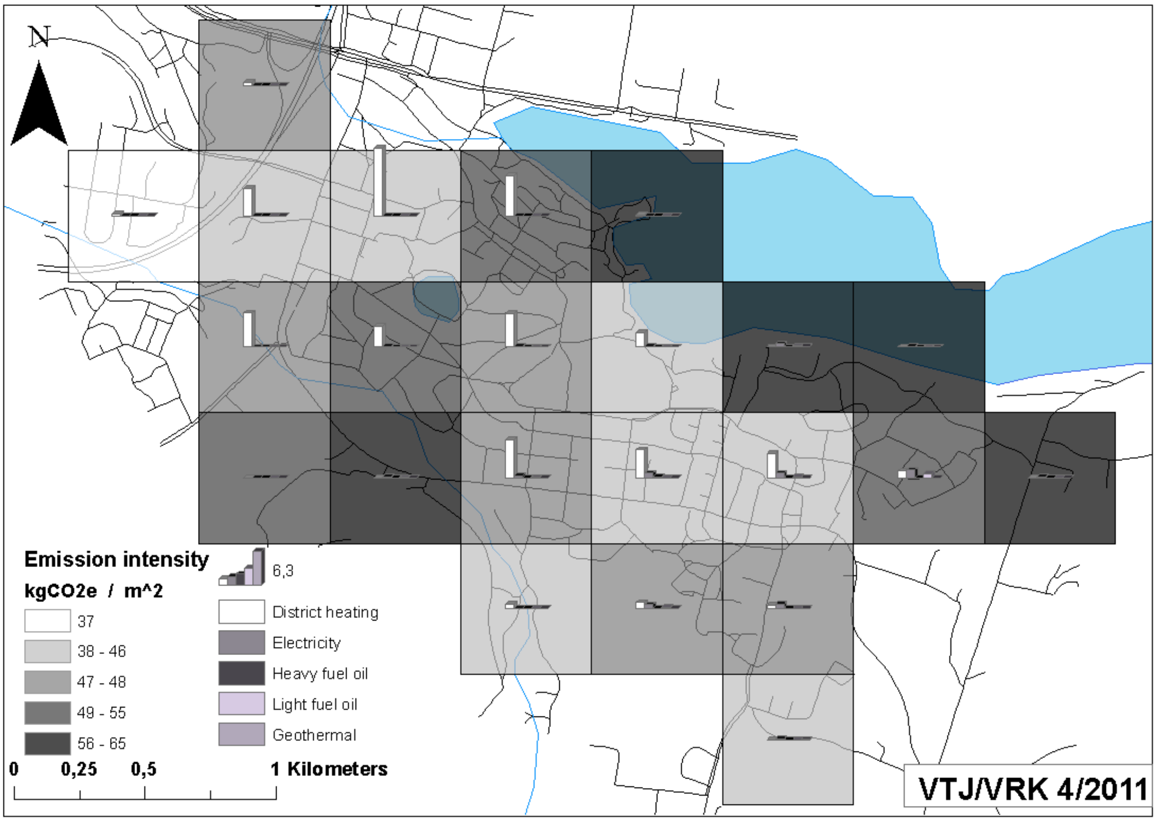

Fig. 2 Emission intensity (color grid) and the gross energy consumption by fuels (bar charts) in Kaukajärvi district. Input data for calculations from [4].

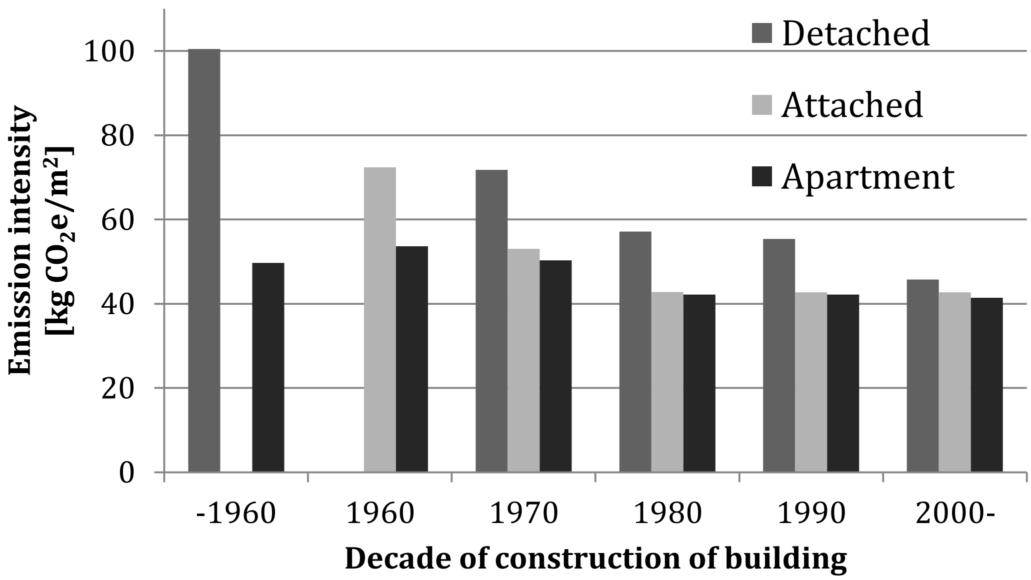

Fig. 3 Average emission intensities for the three house types from different construction decade.

4. Discussion and Conclusions

By combining physically-based building stock model and GIS data about buildings we are able to study regional characteristics of energy use and greenhouse gas emissions. Our results indicate that it is possible to analyze both rather small and large regions and obtain practical information to support energy policies. This kind of information is useful in the decision making, especially when planning the energy system of the region accounting for both production and consumption. Aspects like the availability of renewable energy sources and the needed infrastructure can be well taken into account. Additionally, using information about age distribution and types of buildings, we are able to assess the renovation needs and impacts regionally. This allows policy makers to plan cost effective measures for CO_2 savings.

5. Acknowledgements

The funding from Academy of Finland for LAICA project is gratefully acknowledged.

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Environmental assessment methods and tools at the district scale: review and analysis

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Summary

Developing new urban planning approaches and eco-district design able to help reaching equilibrium between environmental, economic, social and cultural issues (sustainable development principles) is an increased demand at international level. In response, several countries and organizations have developed new environmental methods (e.g. BREEAM, LEED, Green Star, HQE, etc.), action plans and assessment tools (e.g. ECOPT, ARIADNE, HEKO, NILIM too, RFCS prototype, etc.) to favor eco-aware design, environmental quality of architectural and urban planning and to promote sustainable development emergence. The role of environmental assessment tools is to highlight useful elements to support decision and to improve quality of design process by establish a comprehensive or summary diagnosis of urban projects design and cities management. They identify strengths and weaknesses of projects and show path to reduce their negative impacts.

The work presented in this paper has two objectives: firstly, to identify published methods and tools and secondly, to undertake a review of the quality of these tools, in order to provide a solid background for future researches. Environmental methods and tools were identified thanks to a systematic search in scientific databases (e.g. Science Direct), standardization databases (national standardization associations such as AFNOR), thesis, research report and websites. The initial search strategy generated a total of 44 references. After assessing data availability, nature of tools (monocriterion or multicriterion), 29 multicriterion tools were selected for a critical analysis, environmental assessment strategy, indicators, etc. By going deeper into their scientific robustness and terms of use, we have identified three main families of tools. The first family includes assessment tools "scientifically robust" (for example: method ADEQUA and ARIADNE). The second family includes assessment tools "scientifically simplified" (NEST, OptiCité for example). The purposes of these two families is i) to estimate impacts of a project for a selection of themes, in particular related to nonrenewable resources management and to comfort of open spaces, ii) and to support optimization of design by having recourse to modeling and to simulation calculation. The last family includes Sustainable Development tools to monitor impact of design and, later, of urban management for different sustainable issues (sustainable (e.g. Sustainable Development Checklists of Paris, Rennes, CASBEE, LEED). This family of tools is widespread.

After having described these three families, this paper present the results of analysis which we led to bring to foreground scientific questions for future developments...Finally, in conclusion, we present our opinion on the issues that should be dealt with in future research in order to work out either relevant or operative environmental assessment tools for district scale.

Keywords: Environmental assessment, district scale, simulation tools, monitoring tools

1 Introduction

In France, the building sector is the most consumer of the energy in front of transport with more than 40% of national energetic consumer. It generates 123 million tons of CO_2 per year or 23% of greenhouse total issued annually in the hexagon [1]. Face to French objective to reduce its greenhouse emissions by four in 2050 compared to 1990, focusing to building and urban sectors appears as evidence.

The need to develop a new mode of construction and planning 1) emphasizing the importance of reducing greenhouse's emissions, 2) optimizing use of exhaustible resources (energy, water, material), 3) able to control pollution and 4) strengthening biodiversity, is more and more highlighted in design steps and urban planning documents. This movement is accompanied by various European initiatives and national regulations such as the European Directive 2001/42/CE1 and national laws such as those related to implementation *Grenelle* Environment Forum.

For decades, city has been at the center of reflections concerning operational declination of sustainable development principles (e.g. Aalborg and Leizpig charters). In this panorama, operational urban planning projects as the "eco-district" or "Sustainable districts" offer opportunities for variation, in the limited perimeter, and contribute to overall performance of territory. In that sense, assessments represent an obvious interest to help choosing best solution and verify respect of environmental stakes.

Indeed, assessment of eco-districts can even lead to increased use of certification or labeling schemes (HQE-aménagement™, certified from Certivéa, future EcoQuartier label from Ministry...). These initiatives are based on an assessment for the consideration of environmental stakes or, more widely, the sustainable development principles. Different types of assessment can exist, be characterized by various deepening degree, and cover different purposes, such as: promote integration of fundamental objectives concerning environmental protection and sustainable development, measure environmental acceptability of project and finally inform decision makers about environmental consequences, etc.

Although, practices are emerging and sometimes embryonic, various observation show us interest and increasing demands about urban planning assessment according to sustainable development principles. Therefore, environmental pillar constitutes a domain where several initiatives have been undertaken and it can constitute the first core of reflection to establish robust assessment approaches.

We present in this article non-exhaustive analysis of several tools and methods appropriate to the urban scale that have been identified in France and Europe. First, tools and methods selected were sorted into several families according to their scientific degree and her integration criteria. Presentation of tools of each family and their development methodology is detailed afterwards. The strengths and weaknesses of each family's tools were also analyzed. This analysis was strongly impacted by amount of information found in the literature and the number of tools that characterize each family. Finally, we discussed some questions as the researchers can rise in a process of assessment tool elaboration adapted on urban scale.

Nomenclature	
SD	**S**ustainable **D**evelopment
SDC	**S**ustainable **D**evelopment **C**hecklists
LCA	**L**ife **C**ycle **A**nalysis
NEST	**N**eighborhood **E**valuation for **S**ustainable **T**erritories
Heko	**H**elsinki Eco-efficiency Tool for Urban Development
LEED	**L**eadership in **E**nergy and **E**nvironmental **D**esign
BREEAM	**BRE E**nvironmental **A**ssessment **M**ethod
CASBEE	**C**omprehensive **A**ssessment **S**ystem for **B**uilt **E**nvironment **E**fficiency
RFSC	**R**eference **F**ramework for **E**uropean **S**ustainable **C**ities
SméO	**S**ol, **m**atériaux, **é**nergie et Eau
HQE	**H**aut **Q**ualité **E**nvironnementale
AEU	**A**pproche **E**nvironnementale de l'**U**rbanisme
OSE	**O**util De **S**uivi et D'**E**valuation des performances d'un aménagement urbain
ENVI	**ENV**ironnemental **I**mpact
INDI	**IND**icators **I**mpact
NILIM Tools	**N**ational **I**nstitute for **L**and and **I**nfrastructure **M**anagement **T**ools
NQU	**N**ouveau **Q**uartier **U**rbain
CBDD	**C**arnet de **B**ord **D**éveloppement **D**urable

2 Descriptive analysis of existing methods and tools concerning urban scale

Since the beginning of the 90s, several countries' organisms worried about the environmental quality of their architectural and urban production and they developed assessment approaches according to a prospect of sustainable development. On the one hand, these approaches aim at ensuring integration of environmental parameters and sustainable development in the process of urban design and on the other hand, at estimating the environmental, economic and social quality of built districts. At present, these approaches constitute a good answer to help urban and architectural design to obtain respectful projects of their environment.

We present in this article, an analysis of 29 methods and tools of environmental and sustainable development assessment used in France, in Europe and in United States. These were spotted through various researches bibliographical in the published work, Web or having been the object of communication by their developers. Let us specify that the results of this analysis remain valid just for the methods and tools selected and which are presented in table 1:

Developers	Research Laboratory	assessment and environmental engineering department	assessment and monitoring engineering department	public agencies + Europe + State + community	Attesting witness
Tools Name	**ADEQUA Method**	**INDI-RU**	**TENDEM® empreinte**	**Sustainable Development Checklists of:** Paris, Lille, Rennes, Montpellier, île de France et @d AD®	**LEED®**
	ARIADNE	**OSE**	**CBDD®**	**SméO**	**BREEAM®**
	NEST	**Ecosphere**		**RFSC+ HQE Aménagement**	**CASBEE®**
	ECOPT	**ENVI or Silene**		**EcoQuartier label**	
	OptiCité			**Appel à projet NQU**	
	Heko			**AEU®**	
				NILIM Tools	

Table 1 Classification of various tools and methods listed according to their developer

Before beginning the analysis, we established a classification of the various tools and methods according to their scientific robustness and the taking into account of SD criteria. This classification allows us to gather tools and methods in three big families (fig. 1):

1. Assessment approaches that we call "scientifically robust"
2. Assessment approach that we call "scientifically simplified"
3. Sustainable Development Checklists

We shall rest on this classification to approach this analysis. So for every family, a global presentation of functioning principles will be detailed.

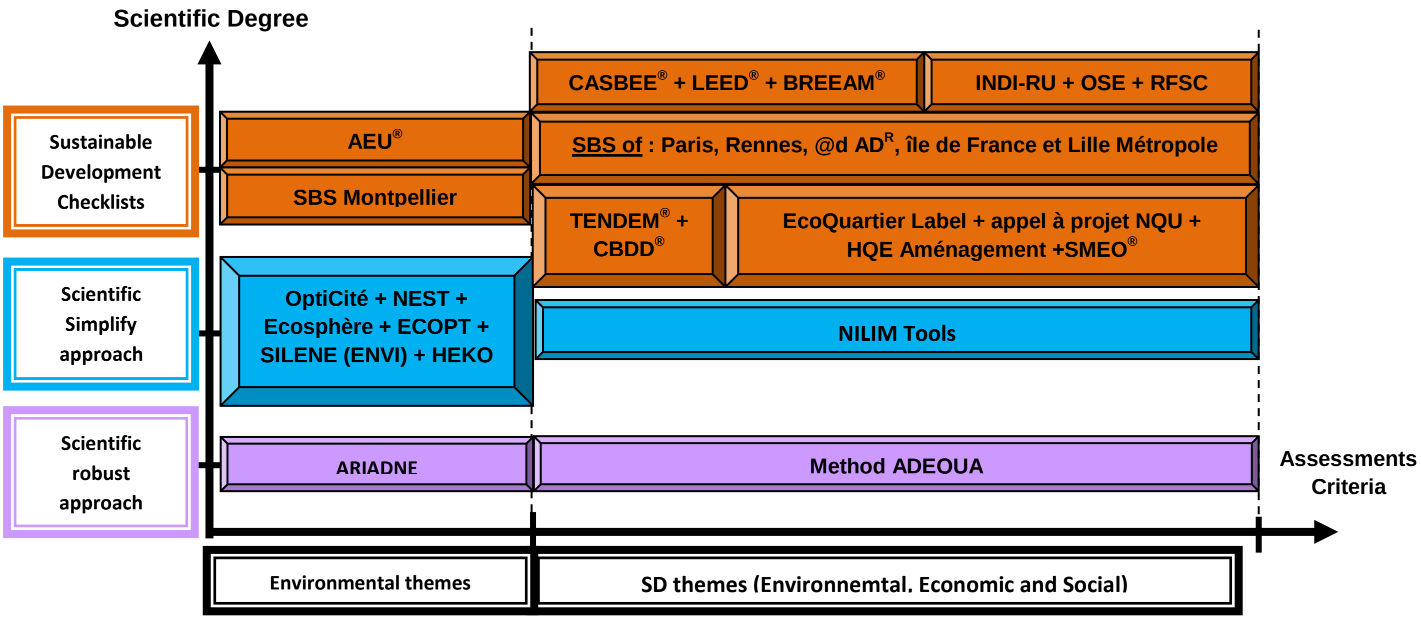


Fig. 1~~2~~ Classification of assessment approaches and tools listed according to their scientific degree and SD criteria.

2.1 Assessment approaches that we call "scientifically robust"

Assessment approaches "scientifically robust" (e.g. ARIADNE and ADEQUA method) represent only 6% of identified tools. The elaboration arises, in the case of ARIADNE, from a long route of research and development or, in the case of ADEQUA method, from collaboration between several private organisms (GTM[1] and TRIBU [2]) and research centers (ARMINES[3], LEPTAB[4], and CERMA[5]). ADEQUA method leans on interactive computing tools, from data stemming from simulations on numerical tools "free-service" (Solene for calculating of duration of sunshine period and Sound-plane for acoustic simulation), commercial (EQUER for LCA) and physical indicators, to obtain district profile in the form of radar diagrams presenting assessment results. ARIADNE tool is based on a chaining (Fig.3) between different tools modeling and numerical simulations which they are presented below:

1. **ALCYONE** - the 2d-3d modeler used to transfer the architectural data to the building thermal simulation tool COMFIE.

2. **COMFIE** - once a building model is defined in COMFIE interface or imported from ALCYONE, the simulation is performed using hourly meteorological data. The program calculates the energy loads of the building (heating, cooling and lighting) and generates hourly temperatures of the different building thermal zones (the building is decomposed into volumes called zones, assumed to be at uniform temperature). The building envelope, defined by its materials and their quantities, and the energy load, are then saved on a text file. This file is then transferred to the building life cycle assessment tool EQUER.

3. **EQUER** – according to the LCA methodology, the substances taken from and emitted into the environment are accounted (inventory) and evaluation indicators are derived for four phases of a building life cycle: construction (including the extraction of raw materials, production and transport of materials), operation (including heating, possibly cooling, water consumption, domestic waste treatment etc.) renovation (replacing of components like windows or painting) and end of life (demolition and waste treatment). A life cycle inventory includes:
   - used resources (e.g. rare materials, energy),
   - emissions into air, water, ground (e.g. CO_2 into air, ammonia into water, metals into ground),
   - Produced waste (e.g. inert, toxic, and radioactive).
   - …

[1] http://www.gtm-batiment.fr/france/gtm-batiment.nsf/web/construction-neuve.htm
[2] http://www.tribu-concevoirdurable.fr/index.php/qui-sommes-nous-.html
[3] http://www.armines.net/mission_45.php
[4] Laboratoire d'Etude des Phénomènes de Transfert et de l'Instantanéité : Agro-industrie et Bâtiment
[5] Centre de Recherche Méthodologique d'Architecture

4. **ARIADNE** which completes the tools chain and allows to define the various buildings present in the concerned area, taking into account to the surrounding environment (impact masks) It also takes into account the different types of public spaces (green spaces, roads ...) to evaluate different component of district.

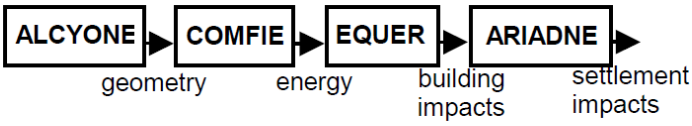


Fig. 3 Data transfer between assessment tools.

2.2 Assessment approaches that we call "scientifically simplified"

Assessment approaches "scientifically simplified" represent 24% of the identified tools. They are divided into two categories:

1. **The tools based of urban LCA attributional kind that we call "adapted":** this category includes models: OptiCité, ECOPT and HEKO which are based on a flexible assessment method and require a simplified mode for collection data. To proceed with data collection on a particular district, a triple approach is often used:

    - <u>A top-down approach from city to district:</u> for example, data on waste quantities reported in district, consumption of energy for roads and public spaces. This mode of processing data allows integrate data known only to the scale of the city or community or on the perimeter of intervention of section manager.

    - <u>A detailed approach</u> by decomposition of an object into sub-elements and successive aggregations. This step allows the integration of accurate data that we know: exhaustive collection of materials and products, water and energy consumption, pollution associated…

    - <u>A simplified approach</u> by integration of magnitude orders by object or element when it is too difficult to have a fine approach or when a big precision is not necessary.

2. **Tools based on "complex" indicators**: this category includes tools Ecosphere, ENVI and NULIM Tool where assessment is based on quantitative indicators in form of physical and mathematical equations and which require technical and aggregated information (e.g. floors surface, albedo, number of occupants, green spaces surface) concerning district area.

Developed by research organizations (e.g. EIFER, Technical Research Center of Finland) or energy managers (GDF-Suez, EDF), assessment approaches "scientifically simplified" aim at making a summary or exhaustive diagnosis of environmental and sometimes economic and social (e.g. NILIM Tool) features of urban projects. They are used in design phase and diagnostic results are made compared with a reference case or to other alternative scenarios.

The tools of family assessment "scientifically simplified" are also intended for evaluation of urban projects. With exception of NILIM Tool which offers advantage of a multicriteria evaluation, rest of tools measures only environmental impact (water, energy, waste, travel and possibly biodiversity). This character "monocriterion" limits the field of intervention of these tools with regard to the other SD stakes. A district which is the object of a simply environmental evaluation does not deserve the naming of "sustainable district" but rather environmentally district. It is for that, the majority of tools of this family would deserve to be enriched by indicators concerning comfort, social and economical aspects, so that evaluation includes more SD themes.

Other lifted question, concerns the way of functioning of tools in particular those with simplified LCA. Indeed, use of several approaches: fine, simplified and aggregated into the same time for collection of information to implicate relevance and quality of assessment results. However, it is necessary to underline that this flexibility would constitute at present only solution to allow going out of paradox of conception process theorized by Luc Adolph [2] (Fig.4)

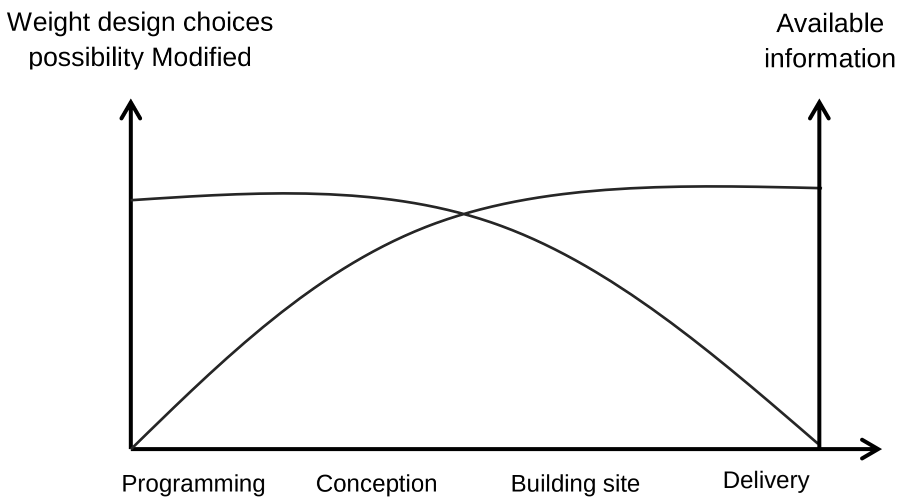


Fig. 4 Assessment in design phase: resolving the paradox of the design process (Adolph, 1991)

Indeed, data available on a project in design phase are approximate and shifting. In this context tools are required to work with big hypotheses and to adapt itself to type of available data. in spite of this simplicity, the method "urban simplified LCA" remains complex for a product as moreover for a district. The latter presents a heterogeneous character. In fact, every building is unique and present different formal and functional characteristics and, moreover other urban components such as: public road networks, infrastructures, green spaces and travels should be taken into account.

2.2.1 Main strengths and weaknesses of assessment approaches "scientifically simplified"

Tables 1 and 2 below synthesize questions which developers and practitioners have to face with to design and / or implement an evaluation process of urban projects. They allow identifying, according to the reserved choices, the main strengths and the weaknesses of assessment approaches "scientifically simplified". It is very important to identify needs and tools use, as well as nature of user, in order to adapt the approach shape (An approach or a too complex tool, for example, is generally incompatible with a regular and quasi-daily use. Conversely a too simple approach can be counterproductive and can be likened to a simple administrative procedure allowing to legitimize projects which are not sustainable).

Number of criteria, indicators, time of use?	
Complexity	
Advantages	**Inconvenience**
• Exhaustiveness of environmental themes ; • Physical and mathematical indicators used to calculation ; • More accurate results according to data availability.	• Complicated to manipulate and to instruct • Many data used in Input ; • Difficult to systematize ; • Rather reserved for an acute public or assessment expert.
Simplicity	
• Suppleness in data collection and information gathering ; • More operationally ; • Easier to systematize to help users from the very beginning ; • Can take decisions when the data are less numerous or difficult to collect.	• Results less pertinent provided by tools and difficult to verify and validate ; • Little exhaustiveness on some environmental themes as that: biodiversity, urban heat island, air quality for example.
Tools use	
Systematic use	
• Educational aspect for actors progressive handling with more scientific methods (LCA AFME ...) ; • Assessments more relevant and representative of the environmental issues complexity.	• Require a lot of will (time and means).
Occasional use	
• Progressive and perpetuity processes improves from feedback experience, evolution of stakeholder needs, geographical context, challenges of each region or country and continual improvement of results processing.	• Risk of abundant tool or process longish financial returns.

Table 2 Analysis of assessment approaches "scientifically simplified" according to number of criteria, indicators, time of use.

The graph below (Fig. 5) shows the degree of approaches complexity (criteria numbers, indicators, data and time required for evaluation) determines in part the user type or nature. Thus, a complex approach tends to be reserved for expert user. An approach with Intermediate complexity is appropriate for an "acute public " or "technician" (alone or in small groups). A collective appropriation of the approach (by stakeholders for example) requires more simplicity of the approach.

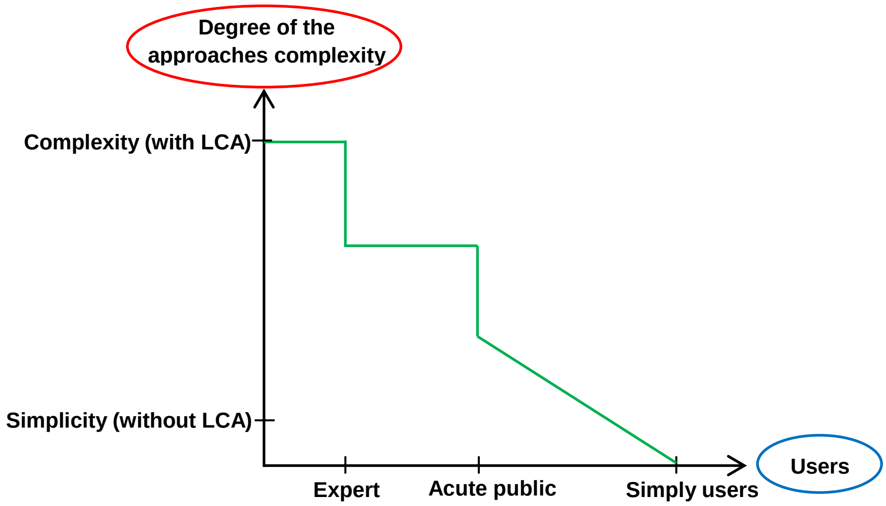


Fig. 5 The degree of tools complexity according to the user's type or nature

Strengths, weaknesses tools, key questions to ask	
Opportuneness	**Blockage**
• Scientific methodology that provides 1. Opportunity for urban planning actors to justify their choices; 2. Compare design scenarios between them or in comparison to a reference case; 3. Reassure stakeholders with quantitative results and visual graphics more representative of the impacts assessed 4. A practical concept translating environmental themes on thematic assessment and quantification indicators 5. Change ways of thinking 6. Create debate, reflection especially after the feedback.	• **Operational point of view** 1. Complexity of assessment methodology and data collection; 2. Ambiguity and vagueness that surrounds the method to ready operational actors. • **Competitive point of view** 1. Establishment of Certification Rules more representative of sustainable development thematic, easy to handle, cheaper financially to use and basically politically (city of Paris, ministry, urban agglomeration...). • **Politic point of view** 1. Absence / weakness of political support 2. Afraid to projects fail or enter into conflict with urban planning actors with their traditional logic of construction.

Table 3 Main strengths and weaknesses of assessment approaches "scientifically simplified".

2.3 The Sustainable Development Checklists (SDC)

Often called " Sustainable Development Grids» or “Politics and projects’ questioning and analysis tools with regard to sustainable development” by Boutaud [3], these tools are very composite objects appeared for the most part of independent way and sometimes in a way disconcert in the French administrative and urban landscape. They represent 70% of studied approaches. SDC takes the shape of a railing of analysis multicriterion in arborescence, declining the various dimensions of Sustainable development (economy, environment, social, governance and the other principles) in several themes. Generally, these themes appear in the form of quantitative or qualitative indicators or in the form of open or closed questions which examine politics or urban project. Developed by local communities (city of Paris, Rennes, Lille metropolis) or environmental and consulting engineering department (Egis concept, Syntec Engineering, LesEnr ...), they aim at evaluating, analyzing, or simply questioning an urban policy or project in relation to sustainable development requirements.

SDC tools are not in priori intended systematically for evaluation but they are considered as checklists that help not to forget sustainable issues at necessary stages of a procedure. Majority of these tools support decision-making at upstream stage of projects [2].

2.3.1 Main strengths and weaknesses of Sustainable Development Checklists

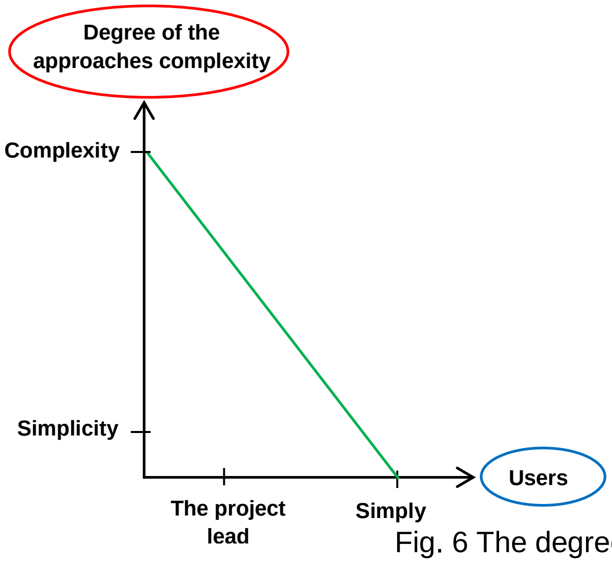
The main strengths is weakness of SDC tools will be presented and analyzed in the same way as the steps of assessment evaluation scientifically simplified (see tables 4 and 5).

number of criteria, indicators, time of use?	
Complexity	
Advantages	**Inconvenience**
• Exhaustiveness of Sustainable Development (SD) themes • Respect of the SD complexity • Less risk of subjectivity in the answers provided by users (many quantitative indicators more accurate and detailed)	• A little heavy to handle • Risk of discouraging actors • Difficult to systematize • Approach reserved for "technicians actors"
Simplicity	
• Easy to educate, disseminate and easy to understand as LSA analysis tools • Easier to integrate and systematize upstream of the decision; • Easily manipulated by users in a group (collective use)	• Approach frequently superficial or leaving room for various interpretations • Exhaustiveness on some SD themes as that: biodiversity, social interaction for example.
Degree of tools use	
Systematic use	
• Enables to develop reflexes, constant updates and taking into account SD in all levels	• Requires a lot of collective will (time and financial mean) • Risk of manipulation result because tools used are often simplified and generic

Occasional use	
• Enables to look into each thematic detail, refinement of questions and dedicate more time for processing results.	• Risk of tool abandon and a sectorisation of SD requirements at the regional scale of or the conglomeration area.

Table 4 Analysis of SDC according to number of criteria, indicators, time of use.

The graph below (Fig. 5) shows the degree of approaches complexity (criteria numbers, indicators, data and time required for evaluation) determines in part the user type or nature



- A complex certification rules tends to be reserved for use type “technician” and the project lead.
- A collective training of project (stakeholders, for example) usually requires a simple certification rules.
- Complexity use constitutes the sum of "certification rules complexity + organization needed to use."

Fig. 6 The degree of tools complexity according to the user’s type or nature

Strengths, weaknesses tools, key questions to ask	
Opportuneness	**Blockage**
• Adopt the SD concept, make concrete and pragmatic, the OQADD can: 1. Create a shared vision among those responsible for work on the issue of SD questions and reflection 2. Reassure stakeholders by making practical concept and translating the vague SD pillars on assessment thematic and indicators quantification. • Changing ways of thinking 1. Create debate, reflection especially after the feedback 2. Emergence alternatives solution in construction sector	• **<u>Administrative point of view</u>** 1. Lack of resources and time available. • **<u>Politic point of view</u>** 1. Absence / weakness of political support 2. Afraid to projects fail or enter into conflict with urban planning actors with their traditional logic of construction.

Table 5 Main strengths and weaknesses of SDC

3 Analysis and Discussion

Analyzed and identified assessment approaches find out several differences in terms of purpose, operating method and degree of integration of sustainable development criteria. The nature of each approach depends deeply on the developer institute. In fact, we noticed that the scientific assessment approaches are mostly developed by techniques researches organizations such as NOBATEK[6], ARMINES and HEKO while approaches like "SDC" are often shaped by political and administrative bodies (Ministry, Agglomeration, City, Province ... etc.). Furthermore, through this analysis and by the quantity of information found, we tried to explain the principle of operation, development, advantages and disadvantages, strengths and weaknesses of each approach as we considered necessary.

Other strategic, scientific and operational issues deserve a deep analysis. The issues are classified according to the following priorities:

At which design stage assessment tools should interfere?

Major approaches of scientific simplified assessment interfere at projects' design phase. According to Grace Yepez [4] who had held several exchange meetings with engineering consulting and urban design firms before working out NEST model: contractors can incorporate changes based on the results and recommendations raised by the evaluation at design phase. Luc Adolph, find out the paradox of the timing of the evaluation and the impact of its role in the design process as shown in Fig. 3.

We believe that the design phase is the appropriate one. In order to adapt the assessment process, it would be appropriate to determine nature of technical data, architectural and geometric information of urban project available at this stage. Afterwards, what are the environmental issues that we can assess with the fewest assumptions? At this stage of assessment, what are the SD issues that actors are mostly sensitive with: environment? Economy? Social? If environmental issues prevail, what are the priority questions? And at which stage of the project, economic and social issues should be taken into account?

What are opportunities and blocking of LCA method?

Tools and methods based on LCA are quite complex given the technical nature of the used method (field of engineering). Consequently, either on the practice of software or on the interpretation of results, scientific knowledge is required.

Conducting an LCA requires a large number of data that are often difficult to obtain or may be impossible to obtain in full for one person or institute working alone. For this reason, databases inventory are frequently used to modeling all or part of the life cycle. Though, these databases are generally designed to model life cycles corresponding to a particular region of the world. The use of a database to model the activities of another region is therefore likely accompanied by a certain margin of error in the assessment of life cycles impacts.

[6] http://www.nobatek.com/structure.html

In addition to these disadvantages, the LCA method completes the results of technical studies typically conducted for development projects (environmental impact, carbon footprint, etc.). The opportunities offered by this method are both technical and pedagogical. LCA can also broaden the debate beyond energy issues and beyond the single phase of building use. In addition, it offers an integrated study of the building area which used to obtain quantitative information facilitating communication and consciousness [5].

Finally, it should be noted, that the current practice of LCA, called "attributional" might evolve into a LCA called "consequential", taking into account the consequences of the decisions in relation with the system studied in the background system. The use of LCA may, indeed, in some cases lead to the development of a technology which induces a change in environmental impacts considered as starting hypothesis for background processes [6]. For example, the carbon footprint at a building system (studied) incentive to develop electric heating, but this development lead to a high demand for electricity, which changes the electricity generation system (the background) and therefore the impact. As a result, it is suitable to evolve the models to take into account these dynamic effects.

Which urban component of the neighborhood should be taken into consideration?

We found out that tools based on LCA method, break down the neighborhood into several urban bricks (residential and tertiary buildings, green space, moving urban infrastructure and roads, public planning ...). It is highly important to take all these bricks in the evaluation process, but it would be very appropriate for a first development of this kind of tool to determine the degree of impact of each component on the environment to take into account the essential impacts. Thus we can get the following questions:

What are the components of such a development: eco- district type? What are the components, activities and services that impact the more on environment?

4 Conclusion

The assessment of urban design, as in other domains of public politics, is today in France and Europe little disseminated and generally badly apprehend. Frequently, assessment is confused with technical and statutory conformity control, or still with follow-up of project.

Furthermore, the increasing pressures on the public finances, and diffusion culture of practices management from Anglo-Saxon companies in public sector, tend to assimilate assessment to an audit of budgetary performance of an action or a service. Only financial aspect seems to be able to show, see sense, and give evidence irrefutably of legitimacy or not the performance of urban design.

Many SDC approach still claims appellation of assessment tools while the majority of these tools arise from the "copy and paste" and completely short-circuited the logical chain of elaboration of an assessment device, which should cross by a definition clear, formalized and shared by the objectives of the project or some politics (via a tree of objectives), then in the definition of evaluative questions concerning various registers. So, most of SDC approach save this reflection and are used to follow-up of the implementation of actions, via indicators giving information of what has been done and not on obtained results.

LCA constitutes a tool for eco-design, which still has to evolve according to the improvement of the knowledge. It allows mutualizing a large number of data on products and processes implied in construction, to encircle better cause and effect relationship between decisions, choices of conception, and the impacts for example. On the other hand, new construction represents only approximately 1 % of the existing park a year, which thus constitutes an essential stake in a long-term politics. Indeed demolition concerns every year only of the order of 0,03 % of the park [5], which is renewed so much more slowly as that of the vehicles for example. It is not thus enough to act on the new construction to reach objectives as the reduction by 4 of the greenhouse gas emissions in horizon 2050. The LCA can be applied then very usefully to the rehabilitation projects.

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On cooperation of companies, public actors and educational bodies towards energy efficient buildings. Case Oulu energy efficiency quarter

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1. Introduction

The energy efficiency of buildings and their use plays a key role in aiming to decrease energy consumption in construction sector as a whole. This is based on the European objective of decreasing energy consumption and as a result to decrease greenhouse gas emissions significantly by 2050. One of the challenges faced by the construction sector is how to get individual house builders involved in the promotion of energy efficiency in their own building projects.

Official guidance requires that they possess in-depth understanding about energy efficiency with regard to both structures and equipment technology. This is where educational institutions and research institutes enter the picture as a cooperation partner of authorities in the role of educators of normal builders as well as experts in the industry. The entire construction operating chain must be positively involved, since otherwise the guiding procedure will not produce a good end result. Even this case, the end result is determined by the weakest link. In Finland, approximately 70% of one-family houses are constructed as prefabricated deliveries, so it is crucial to involve the industry in the guiding procedure, since the actual energy efficiency of the building is determined in the end by their product.

Designers and authorities in the construction industry must also be successfully included in the guiding procedure, which means that these cooperation partners of typical one-family house builders will gain new knowledge and vision about how to guide builders towards choosing more energy-efficient and environmentally-friendly solutions.

In addition to education and induction, example sites and clear development activities are needed to demonstrate the functioning and usability if the new more energy-efficient solutions to builders. In order to ensure these issues, the actors in the Oulu region are participating in an international project as a part of which a diversely monitored energy efficiency quarter will be built in Oulu.

2. The role of building supervision in Finnish construction activities

2.1 Building supervision as a part of Finnish energy efficiency

Each new building in Finland requires a building license for building supervision. In other words, building supervision is in contact with each builder even before they start the actual construction. Consequently, building supervision can give information it considers important to the builder and guide the design of the building as well as the whole process. The obligation based on the Land Use and Building Act (Maankäyttö- ja rakennuslaki 132/1999) [1] is to ensure that the building is constructed in accordance with the building instructions given by the municipality, which include also obligations related to the environment. Each of the 330 Finnish municipalities have a building supervision office.

Furthermore, it is recommended that the building supervision office gives advice and guides the builder towards achieving better energy efficiency and eco-friendliness as well as longer service life for the building. Due to building supervision resources and practices, many building supervision offices have to settle for minimum steering and monitoring required by legislation. A building license includes, among other things, determination of computational efficiency value (E-value), that comments on, for example, on the air tightness of the building in addition to the energy efficiency of the structures. [2, 3]

2.2 The role of building supervision in the City of Oulu

Building supervision in the City of Oulu has created new practices by emphasizing the guiding role of the supervision especially during the design phase of buildings, when the most effective choices and solutions are done with regard to the technical and spatial functionality of the building. The construction phase of the building is also guided and the builders are assisted to ensure the attainment of the objectives at the completion phase as well as to update the real situation of the building plans.

The aim of the City of Oulu Building Supervision Office is to provide added value both to its customers and the City of Oulu by:

- assisting the customers in their construction projects
- giving advice enhancing the customers' design work
- promoting sensible cooperation between parties in designing the building
- taking advantage of media in communications, incl. local newspapers
- developing cooperation between designers, builders and educational/research instituitions
- creating and promoting networking between local and international actors.

The Building Supervision Office has implemented all the above aims during the last ten years. The results have been excellent and they provided a demonstration of how significant an effect the guiding approach to building supervision can have in the quality of construction as well as other general development of construction in the Oulu region in specific and Finland in general. The Finnish Ministry of the Environment has started supporting the activities so that they could be spread to other Finnish municipalities as well. [2]

A precondition for attaining results is close cooperation between various parties in construction industry. The Oulu Building Supervision Office cooperates with companies, educational institutions and research organisations, the most important of which are the Oulu University of Applied Sciences (OUAS), the University of Oulu and VTT Technical Research Centre of Finland.

At practical level, the Oulu Building Supervision Office has organised seminars and information events both to construction experts and regular builders. During the last ten years, the overall number of education events has increased to approximately 10,000 person days. For example, each one-family house builder is invited to a guiding training held three times a year after they have received their construction plot. This enables the commencement or construction guidance as soon as possible before the builder has even started designing the building. An interactive online application (www.pientalonlaatu.fi) [4] assists in this guidance, which allows a regular builder to perceive that effect of various factors in the completed building while ensuring the clear choice of the desired quality level. Factors to be taken into account include humidity resistance, the quality of inside air, energy consumption and environmental effects. In addition, the Building Supervision Office has published quality cards on its website describing, for example, what issues are important to building an energy efficient one-family house.

3. The activities of construction companies in ensuring energy efficiency

3.1 Prefabricated house industry cluster in the Oulu region

There is a strong cluster of prefabricated house industry companies in the Oulu region, who are mostly specialised in the production of wooden one-family houses. For structural solutions the companies use normal element deliveries (large and small elements), pre-cut deliveries in which the timber is delivered at the work site alongside other construction materials and log houses for which ready-processed logs are delivered on the worksite where they are assembled as a house. Increasingly popular among customers are ready-to-move deliveries, in which case the customers purchase from a company ready-built house on their plot.

Companies are interested in energy efficiency and they are in constant dialogue with other actors in the region, the most important of which are the Oulu Building Supervision Office and the Oulu University of Applied Sciences. Pre-fabricated house industry produces the majority of one-family houses constructed in Finland (approximately 70% in 2012), so the industry plays a key role in the quality level and energy efficiency of new buildings. The share of ready-to-move deliveries will be approximately 30% in 2012. In these houses, the solutions offered by the industry will determine the energy efficiency. [5]

3.2 The role of prefabricated house industry in energy efficiency

The building energy efficiency requirements have changed in Finland three times within the last ten years, which has brought great challenges to construction by extension to house industry. At first, the U-values of structures changed significantly and stricter requirements were introduced in building technology, for example, in heat recovery. The latest change entered into force in July 2012, when the energy source used was entered into the mix as well as the consequent energy sources coefficients (e.g. district heating 0.7, electricity 1.7). E-value requirements were also set for the overall energy consumption of buildings. The energy consumption classification will be reformed in 2013 so that it will fulfil the new regulations and be in harmony with the EU-level statutes. [6]

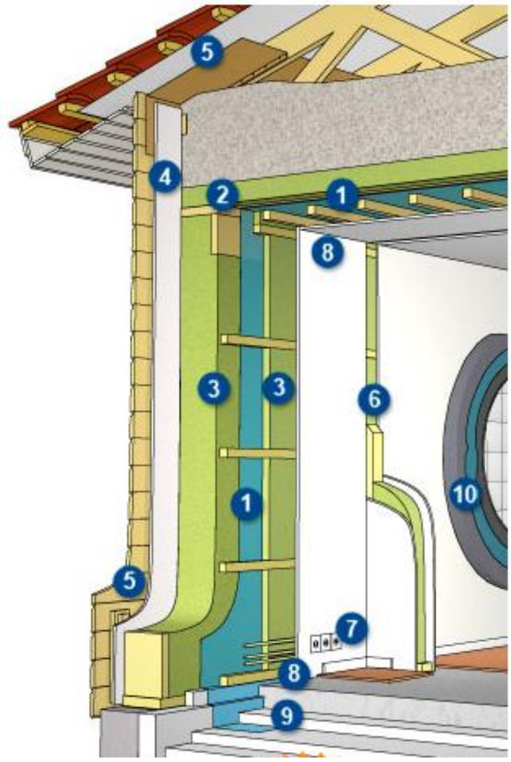
In the new building code an E-value (energy efficiency value) will be determined for the heated net floor area, describing the annual total energy consumption (kWh/m^2). This value cannot be exceeded. These values are the maximum values as a prerequisite for the building license. E-values are classified by building type and are valid in every part of the country (no climate zone differences). E-value includes energy used by heating, ventilation, domestic electricity and lighting. [7]

For instance, E-value of

- new apartment house 130-204 kWh/ (m^{2}a), (depending on the size of the building)
- office building ≤170 kWh/ (m^{2}a),
- commercial building ≤240 kWh (m^{2}a).

According to prior regulations, it was enough that prefabricated houses fulfilled first and foremost the thermal insulation requirements (U-values). The choice of heating system and building technology equipment was largely up to the builder, that is to say house owner. According to the new code, the overall energy consumption of buildings has to be taken into account, which means that the energy source used (electricity, district heating, renewable sources, etc.) as well as building technology solutions will have to be taken into account in calculations in addition to the thermal insulation of the structures. This has presented prefabricated house industry with numerous challenges.

The construction-physical functionality of enclosing structures providing improved thermal insulation must be ensured throughout the life cycle of the building in its entirety. The energy source used must be known and taken into account in the overall energy review. In addition, for example, the heat recovery of ventilation that plays a reasonably large role in the E-value achieved must be investigated. Even though a house factory may not necessarily have to comment on all above issues in cases where it only makes partial deliveries, non-professional builders often have to be guided in these choices. When a house factory delivers prefabricated houses with ready-to-move principle, all the above issues must be solved before delivery. House industry already uses energy efficient structural solutions (fig. 1).



1. Seamless and intact air inclusion
2. Tight seam between the roof and the wall
3. Double frame of external wall
4. Tight windshield all the way up
5. Well-functioning ventilating slots
6. Sound proofing of partitioning walls
7. Draught-free wall sockets
8. Nailing strips for battens
9. Tight and thermally effective seam between the floor and the wall
10. Reliable wet room wall structures

Fig.1 Structure section of a prefabricated house and portions affecting the energy efficiency and functionality. [8]

4. Significance of education and research in the energy efficiency of buildings

Traditionally, the energy efficiency of buildings has discussed first and foremost from the perspective of the thermal insulation provided by enclosing structures. In this case, contributing factors have included the thermal conductivity of the insulation material as well as the thickness of the insulation layer, which have enabled the attainment of the desired U-value. The tightness of the structure has also been a consideration in order to eliminate air leaks and as a result to ensure the construction-physical functionality.

The Oulu University of Applied Sciences (OUAS) has utilised in its teaching information produced by research institutes, which is supplemented with its own applied development projects. In teaching, structural engineering, building technology, electricity and automation technology have been kept separate, which is naturally reflected on the design of buildings. This fact has been attempted to rectify in teaching by, for example, introducing energy efficiency and structural physics as well as building technology in the teaching of structural engineering with a variety of calculation and simulation software. At the same time, companies have been assisted by engaging in applied cooperation with them and ensuring that experts graduating from the OUAS have a sufficiently varies competence in the construction of energy efficient buildings. [9]

The new energy efficiency regulations have significantly increased the pressure to continuously update teaching in order to ensure the sufficient level in the construction sector both in new building and renovation of old building stock. It is reasonably easy to ensure the competence of experts to be graduated but the great challenge is and will be the updating of the professional competence of experts in the working life to correspond to the new regulations, which the building code has now introduced in the industry. It is also challenging to widen the perspective at the EU level, where regulations should approximately similar. In this, cooperation over borders is of great help and enables finding out about differences between different countries, for example with regard to energy efficiency regulations and guidelines [10, 11].

Research and development activities in the industry must also be increased at all levels, since we need have sufficiently accurate information about the functionality of structures and solutions complying with the new regulations in order to avoid possible problems. Major challenges in Finland include the humidity-technical functionality, especially if possible climate change is taken into consideration. These issues have now started being discussed in research and development projects in universities and other higher education institutions [12, 13].

5. Improvement of energy efficiency in buildings and ensuring the functionality of buildings through multidisciplinary cooperation

5.1 Energy efficiency research project

Increasing Energy Efficiency in Buildings (IEEB) is a three-year (2010–2013) Nordic co-operative project, with the main funding coming from European Union Interreg 4A program called NORD. Lead by Oulu University of Applied Sciences Finland, the project consortium includes partners from Norway (NORUT Narvik, Norcem AS, Betong&Entrepreneursenteret AS), Sweden (Luleå Tekniska Universitet, Umeå University) and Finland (Oulu Building Supervision Office BSO, eight construction companies). [14]

The target of the IEEB project is to develop new solutions and promoting energy efficiency in buildings. Finding new ways to plan and build more energy efficient and technically workable buildings, contributes towards proactive sustainable development of the environment. This will be made through Nordic network among academia, research, industry and society.

The IEEB project develops new competence and expertise in measurements and methods for advanced design of energy efficient buildings, picks up and documents the best practices and recommendations based on real-life information. The project transfers all the accumulated knowledge to building professionals and industry representatives, local building authorities and citizens, educators, equipment manufacturers and system providers.

5.2 Construction and monitoring of energy efficient houses

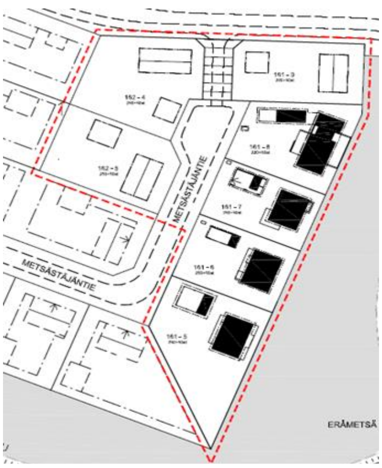


Fig. 2. Five one-family houses will be constructed in the Oulu Energy Efficiency Quarter, the functionality of which will be monitored with diverse measurements.

A part of the IEEB research project is to study the construction methods of energy efficient buildings and how their functionality is ensured in real-life sites. For this purpose, an Energy Efficiency Quarter (Oulu EEQ) has been established in Oulu. Companies participating in this project construct low-energy houses (fig. 2).

In co-operation with the city of Oulu (Building Supervision Office), the project will create an opportunity for participating prefabricated wooden house companies (Kastelli-talot Oy, Kontiotuote Oy, Puutuomela Oy, Lammi-Kivitalot Oy, A Vänttila Oy) to use a building site as a common platform to build a low-energy family house. Other Finnish partaking companies in IEEB-project are Lappli-Talot Oy, Kannustalo Oy, Pyhännän Rakennustuote Oy, NCC Construction LTd. and SRV Rakennus Oy. [14]

5.2.1 Buildings in the Energy Efficiency Quarter and measurements performed on them

Oulu University of Applied Sciences (OUAS) is focusing total monitoring, measuring and measuring methods verification of low-energy buildings. Monitoring consist energy efficiency calculation, building physical monitoring and analyses, air tightness and thermo camera measurements, energy consumption plotting and analyses and focused indoor air quality measurements.

Building design in Energy Quarter was done during the summer 2011 and 2012. The minimum level of energy efficiency of buildings conforms to 2012 Finnish regulations. The IEEB project will equip dwellings with high-end measurement devices (approx. 40 sensors in each building), which gather data continuously the first one years of living in the dwellings and it will continue in some houses till 2018. Measurement topics include e.g. these parameters [14]:

- Air-tightness of dwellings (tightness measurement and infrared camera monitoring during the construction process)
- Building physical parameters in construction elements and buildings
  - Humidity in elements from side to side (profiles)
  - Temperature in elements from side to side (profiles)
  - Inside air pressure in various rooms, compared to outside air pressure
- Energy consumption and its allocation
  - Distribution of energy consumption between various sources (household equipment, heating etc.)
  - Water consumption (cold, warm)
- Air change rate
  - Monitoring leak air flow with tracer method (pre-test)
- Local weather parameters (temperature, wind, air pressure, humidity etc.) measured by a weather station in the quarter
- The quality of inner air by sample measurements
  - Temperature and humidity of inner air
  - Amount (percentage) of carbon-dioxide
- Other measurements (contaminants, drains etc.)

Fig. 3. A wooden house being constructed in the Oulu Energy Efficiency Quarter.

As mentioned above, the dwellings on the Energy Efficiency Quarter have been manufactured with various methods: using concrete blocks, using a pre-method at the worksite, using large elements that have been assembled at the worksite and using a structure assembled on site (fig. 3). Heating systems vary from normal district heating to a full-scale hybrid heating (ground heat, solar energy and wood-heated fireplace), in which case the dwelling has not been connected to the district heating network at all.

Fig. 4. Monitoring results from the Oulu Energy Efficiency Quarter are monitored on BuildMeOn online platform.

An online platform has been constructed for the presentation of the monitoring results, through which public data, such as weather and general site-specific information, are disseminated (fig. 4). Companies participating in the project also receive more detailed measuring data and analysis of data through a confidential intranet website for their own development work. [15]

5.2.2 Measurements, results and analysis

The monitoring of the dwellings has only just started. It will provide data on the building physical functionality of the five dwellings and accurate distribution data of energy consumption. This data will be used both in the research and development activities of companies as well as updating the official guiding information in Oulu. The IEEB project will last until summer 2013 and the aim is continue measurements until the end of 2018, which would enable reception of extremely interesting data on longer term functionality of the dwellings.

The following figures (figs. 5 and 6) present examples of the measurement sensors and their placement in the structures. Sensors have been places in the foundations of the dwellings, which gives good information about temperatures in thermally-insulated structures and possible frost risks. With regard to structures, sensors have been placed in external walls and roofs so that moisture and temperature profiles can be received for various places on the walls. These measurements enable monitoring and analyses of the building physical structures of the structures and, if needed, launch clarifying calculations

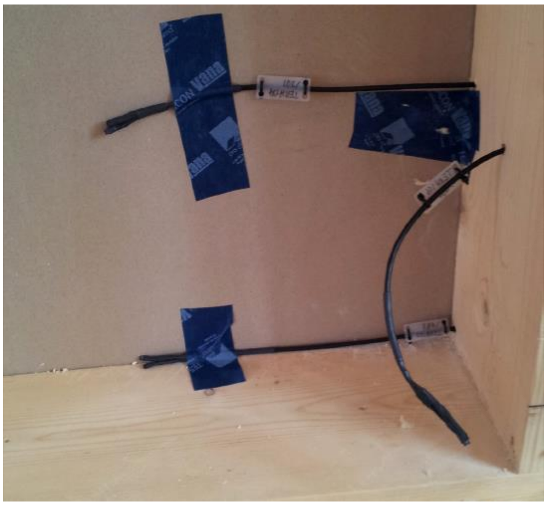


Fig. 5. Installation of humidity and temperature sensors inside the external wall before the wall is thermally insulated and enclosed.

Fig. 6. Installation of sensors in the roof of a dwelling.

Construction work has been monitored during the construction to gain information how the achievement of set energy efficiency in endures and finally confirmed. An important tool in this has been tightness measurements that have been performed 2–3 times during construction work. The first measurement was performed when the air inclusions of the dwelling had been installed but internal surface sheeting had not yet been performed. The tightness level of these measurements (n_{50}) was in the region of 0.4 – 1.2 1/h. Based on the results, tightness was improved in order to ensure the attainment of desired tightness level. In most cases, only smallish leaks were found in the dwellings, which could easily be fixed. The final measurement will be performed once the dwellings have been completed. As an experiment, two different measurement equipment provided by research partners (Minneapolis Blower Door and Retrotec Blower Door) were used in the tightness measurement of one of the dwelling, the results of which were found to be identical within the perimeters of measurement accuracy (fig. 7).

Fig. 7. Performance of tightness measurement in a low-energy dwelling in the Oulu EEQ by Finnish and Swedish experts.

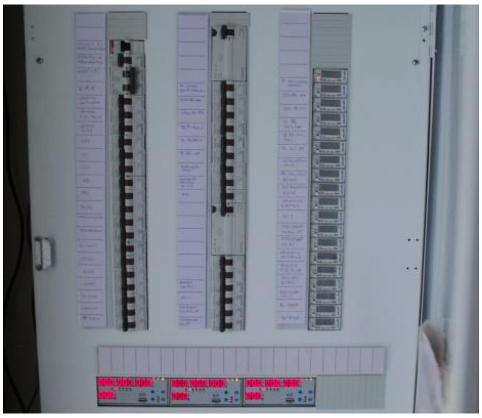
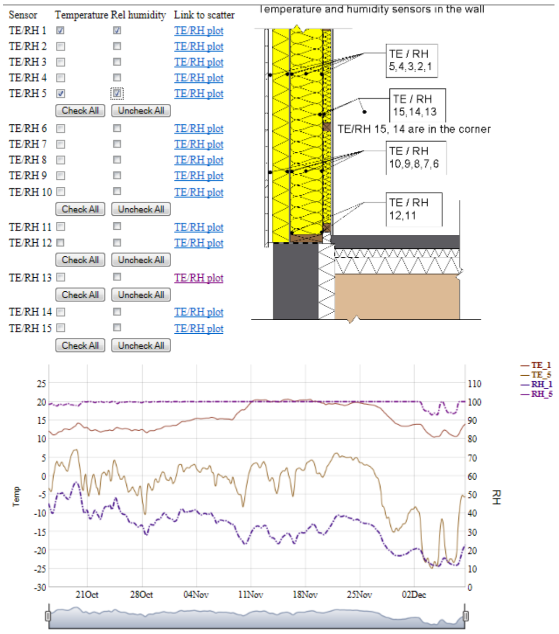


Fig. 8. Energy meters have been placed in the equipment room, where they are wirelessly connected with the online measurement website.

The measurement results are collected with a wired connection on a notebook, from where they are sent using a radio signal to BuildMeOn online platform. On the platform, the results are displayed for the project partners as basic time function monitoring charts (temperature-relative humidity) and as an accurate distribution of energy consumption (figs. 8 and 9). In addition, the results are analysed by comparing them with maximum humidity ratio (g/m^3), which provides information on possible condensation of humidity. Based on monitoring one of the dwellings for a few months, the results have been as expected and remained in an acceptable region. More information will be received later, after which the analysis can be clarified further.

The results of measurement points were also placed on the mould index as they were, which enables analysis if the results start to exceed limit values set for the mould index (fig. 10). The analysis method used is very simple and as such is clear for screening risk values. If values are starting to be on the risk area, a more detailed analysis of them can be made by determining the actual mould index. The mould index is based on research conducted by Hannu Viitanen [16, 17].



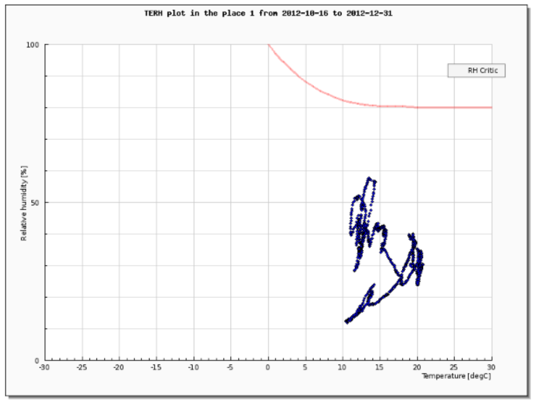


Fig. 9. Example: The temperature and relative humidity measurement points in the wall structure and display of measurement results by ticking the places desired.

Fig. 10. Example: Displaying the desired relative humidity point in the mould index chart. If the index value exceeds the limit value curve (red curve), the point can be used for making a more accurate separate calculation.

6. The significance of cooperation in energy efficiency

Cooperation between building supervision, construction companies and educational and research institutions is demanding but also extremely rewarding. At a communal level, the building service office is the ley actor, since it is in contact with all builders, who are seeking a building licence for their site. In Oulu, the aim has been to establish a guiding connection with the builder as soon as he or she has acquired a building plot. In Oulu, a one-family house plot is usually acquired from the city, because the city first procures the land for itself and only after that provides a city plan for turning it into building sites. In each Finnish municipality, the opportunity to affect starts at the latest when building licence is sought.

When the building supervision office cooperates with construction companies, it can affect what kinds of buildings will be offered to builders in general. In Oulu, the aim for years has been to ensure that buildings offered by prefabricated house industry clearly exceed the official requirements in energy efficiency. This has been achieved through builder guidance and cooperation with companies. It is important to note that this is a question of shared, deeper than normal vision, not forcing, because from the point of view of construction, mere compliance with official requirements would suffice.

The role of the Oulu University of Applied Science in this cooperation has been to commission student work on various subjects of interest to various stakeholders as well as construction and implementation of research projects with regard to the energy efficiency theme in cooperation with the Oulu Building Supervision Office and most of all the business community in the region. OUAS is one of the main educators in the construction sector in Finland, so this cooperation plays a major role for future construction industry experts. The students have the opportunity to delve deep into the core problems in energy efficient construction. At the same time, the views and needs of companies can be included in the teaching and the teachers will have the opportunity to keep up with the latest information through research projects. In short, a higher education institution can effectively implement its social core duty and distribute its own expertise among other bodies through this kind of multidisciplinary cooperation.

The IEEB project is a great example of the power of tripartite cooperation (authorities, companies, education and research), which even possesses an added international dimension. Experiences from this cooperation provide an impetus for strengthening and developing the activities further in the future. The aim is that the concept could be used to solve larger and smaller pinpointed problems when they are highlighted by various parties. For example, the City of Oulu's on-going Resca project [18] utilises experiences from previous cooperation projects and partly even same subjects, which enables the strengthening of shared research and development infrastructure. The Resca project develops the steering of hybrid heating system implementation. Other new projects on the subject matter have also been launched.

With regard to construction industry, the realisation of the development objectives requires increasing cooperation between various parties to construction. It is obvious that companies, authorities and educational institutions need to adopt "Oulu model" cooperation but municipal city-planning authorities also would need to be included in the cooperation. Wide-ranging cooperation could spread the sustainable construction perspective locally at the quarter level, in the spirit of the Oulu EEQ project, and later at the level whole districts. In Oulu, the next extensive forum of cooperation will be the new Hiukkavaara [19] district, where the project will be studied at the level of community.

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Possibilities Of Green Due Diligence In Real Estate Investment

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Summary

Green DD service has been developed at Pöyry and it takes into account the environmental management systems point of view in the invested property due diligence. Due diligence has been used to define and analyze possible technical and environmental risks and defects of the property usually for the sales situation. The best known environmental management systems for buildings are European standard instructions, Finnish national building evaluation system PromisE (that has been lacking updating) and more widely used international systems LEED (Leadership in Energy and Environmental Design, origin from US) and BREEAM (Building Research Establishment Environmental Assessment Method for buildings, origin from Great Britain).

Green DD has been developed based on the information gained from Pöyry's Green DD projects. Green DD is a system for building sustainability assessment. It includes criterion in categories that best describe environmental, social and economic aspects for buildings. Green DD research includes specific information on energy consumption levels, costs and measurements compared to similar buildings and similar comparisons for water use and monitoring, material conditions and risks, generated emissions and effects on the health and well-being of the tenants. Green DD answers also to the questions how the site is used and what ecological values there are, how the building is managed and how the maintenance is performing, how the users are able to travel to the building and what kind of transformations are available for the building spaces.

The state of customer awareness in these issues is growing according to the research of Pöyry´s Green Market Study (GMS). Green DD gives more information as in an ordinary DD with almost the same effort as done previously. The results show that by using Green DD-system, more information is gained and therefore the risks are covered in wider aspects than previously. The triple bottom line aspects of environment, social and economics considered in Green DD are the same as considered by the tenants and with Green DD the new owner gains information that answers directly to the market demand.

1. Introduction

Real asset investments such as real estate have traditionally been popular investments due to the better risk avoidance against uncertainties in the investment markets. Real estates are good long term investment instrument with yields from increased real estate values and rental income. Cash flows (both positive and negative) are usually assessed very carefully when considering buying or selling. Value of a real estate is in most cases based on the revenues and therefore the expectations and risks related to those are important. Usually the site location and building condition are the most important elements. Value can be increased with good connectivity and sufficient maintenance of the investment property. In sales situation it is important to minimize all possible risks that might have an effect to the real estate value. Due diligence investigation is used to define and analyze possible technical and environmental risks and defects of the property. Investigation includes owner's repair and renovation costs and property's maintenance costs. Besides the basic investigation report, the due diligence can also contain other property specific reports concerning the findings.

One new view point in due dilligence is the investigation of fulfilling the specific aspects that are considered when property is certified for an environmental management system. This aspect is considered as Green DD. The main reason for doing so, is to gain information e.g. on energy efficiency, building maintenance and connectivity to the surrounding community. This information is usually very valuable for the user of the building. Additionally, different nations have committed to energy- and emission reduction measures. For Finland, the green house gas reduction target for real estate sector is set to 16 percent below 2005 levels by 2020.[1] However, the target varies by nations and different sustainability aspects are considered. For example according to Paula J. Posas the driving forces such as CO_2 vary a bit for different areas. In Britain the main drivers for core strategies adopting more environmentally sustainable, climate-friendly behaviors are mandatory Strategic Flood Risk Assessments, emissions targets, and requirements for higher energy efficiency standards or percentages of renewable energy in new developments. [2]

European standard instructions, such as ISO 14000 -series environmental management standards, offer tools and techniques to value environmental aspects in a commonly accepted way. Instructions are well known and by referring to them it is easy to tell to others that the work is done well. The above mentioned environmental management standard gives instructions to organizations for more efficient use of raw materials and other resources, energy efficiency, process and distribution chain improvement, waste management and amount reduction and materials reuse. Besides the ISO 9000 - series gives instructions for quality assessment. However, these instructions are not directed especially for building industry, but with the help of CEN/TC 350 sustainability of construction works standard series, a lot of information about energy efficiency and environmental assessment is gained. However, there is still lack of evaluation for different environmental aspects which could lead into investments for issues that are less important in the building value chain. [1]

Environmental assessment field is broad and it is difficult to give a value e.g. between which is more important, water use minimization or flexibility of a building. Therefore, it is more efficient to concentrate on environmental assessment based on instructions such as Finnish building evaluation system PromisE and more widely used international systems LEED and BREEAM. The systems are concentrating to the topics that are most important in the evaluation of environmental efficiency in building sector. Additionally, all of these methods have instructions for existing building and new build sustainability evaluation as well. The international environmental management systems also gives building a certificate (LEED and BREEAM) covering environmental, economic and social responsibility. The certificate requires documentation for third party inspection and therefore ensures that topics are assessed as instructed. Additionally, the certification is an easy way to demonstrate that we have used the international best practices that have been recognized by the certification institution for this building and we have a certification for that. [4][5][6][7]

2. Sustainability assessment in real estate investment -Green DD

2.1 Basic due diligence

The due diligence investigation includes in regular basis the investigation of technical aspects such as structures, HVAC-system and electrical system. Additionally, very important part of investigation is real estate maintenance, maintenance costs and responsibilities, both written in the contracts and implementation as discovered with interviews at the site. Besides maintenance contracts, also contracts for the connections to the infrastructure are checked by the DD team. Those have a big influence e.g. to the energy efficiency which is also investigated. Additionally, the official inspections done by the authorities are checked. These include zoning and land-use development and building permits and easements.

2.2 Green due diligence added value

The added value of sustainability investigation in the due diligence includes investigation of possibilities of fulfilling the criteria to gain environmental management system certification (PromisE,LEED,BREEAM) and criteria fulfilment. The sustainability criteria are valued in the scheme for example with limit values or descriptions of the sustainability content that is necessary and can be achieved by selecting a certain design option. Similar valuation is necessary in order to get a "green" assessment for the Green DD checklist. [4][5][6][7]

The basic criteria are considering the following issues:

- Energy and water consumption level compared to base level of similar buildings (BREEAM: base level based on energy statement and water consumption per person and LEED: base level based on Ashrae standards or energy star evaluation and water fixture water flow/consumption PromisE: energy consumption per net square meter)
- Materials condition and risks (LEED: maintenance management instructions/reports and procedures, used refrigerants BREEAM: condition surveys and implementation of duties, maintenance policy, fire risk assessment, Security, PromisE: conditional survey, moisture risk protection measures)
- Waste management (LEED /BREEAAM/PromisE: Waste sorting and reporting)
- Health and well-being (LEED: Indoor air quality, VOCs, thermal controllability, daylight and views, satisfaction surveys, refurbishment policies, cleaning policies, BREEAM: Daylight and views, ventilation, Acoustic performance, drinking water provision, refurbishment policies PromisE: Lighting levels)
- Land use and ecology (LEED: Light pollution control, green areas at the site, rainwater capturing and protection measures BREEAM: ecological survey, biodiversity action plan, flood risk management plan and procedures, green roofs/ecological design options, water pollution control PromisE: natural site protection, land contamination prevention,
- Maintenance procedures from the user organization and environmental management plans (LEED: Existing building commissioning, environmental management plan, sustainable purchasing BREEAM: operating manuals, building user guide, environmental management plan, Maintenance procedures and plans, Risk system maintenance procedures PromisE: electronic service manual, Radon risk assessment)
- Transport and connectivity (LEED: Proximinity of amenities, Public transport access, commuting parking BREEAM: Proximinity of amenities, Public transport access, cyclist facilities, pedestrian safety PromisE: Proximinity of amenities, Public transport access, pedestrian safety and cyclist facilities)
- Space flexibility and accessibility (BREEAM: Accessibility, PromisE: accessibility, space flexibility, Pöyry specific criterias: efficient space use, technical system maintenance possibilities)

The evaluation scheme structure is developed mainly based on BREEAM, but a lot of issues are considered are from LEED and PromisE, that are not necessary considered in the BREEAM scheme under the same headline. Additionally there are parts specifically implemented in Pöyry Green DD that have been considered important issues in the field. Therefore the topic might have more included in Green DD than in the BREEAM certification system.

2.3 Greenness affect for building financial value

One reason for greenness evaluation in the building due diligence could be the possibility to increase the financial value of the building. There have been publications that indicate that certified buildings have a better rental and capital value and also publications that show that there is not. As an example, F. Fuerst and P. Mc Allister found that "*there was no evidence of a strong relationship* *between environmental and/or energy performance and rental and capital value*". However, they also said that the small number of BREEAM-rated assets had an effect on the results. [8] On the other hand, in another study they found that "*office buildings with Energy Star or LEED eco-labels obtain rental premier of approximately 3–5%"* and *"Dual certification produces an additive effect with rental premia estimated at 9%*". Additionally, the certification has an effect on sale price "*premia for Energy Star and LEED labeled office buildings are 18% and 25%. The sale price premium for dual certification is estimated at 28–29%*". [9] Both studies are from year 2011. Other sources give different results such as study by Piet Eichholtz, Nils Kok and Erkan Yonder study of the "*effects of the energy efficiency and sustainability of commercial properties on the operating and stock performance of a sample of US REITs, providing insight into the net benefits of green buildings"* during 2000–2011. In their study the results showed that "*the greenness of REITs is positively related to three measures of operating performance – return on assets, return on equity and the ratio of funds from operations to total revenue*". [10]

3. Results of using sustainability assessment in due diligence - Green due diligence

3.1 Investing sector market perceptions

When Green due diligence was first developed, it was recognized that the energy consumption information is the most important issue to be further developed in the due diligence. Energy consumption was investigated already in the earlier DD scheme. The investigation included energy costs and system functionality. However, the most important sustainability aspect for energy consumption, the "green added value", includes now the comparison of the energy consumption level with similar buildings and the review of the energy certificate. The review includes comments for the calculation of energy consumption figures for heating and electricity use (both building electricity consumption and consumption by user activities). Investigation was further developed based on the instructions in LEED (comparison of the building with Energy Star Tool [7]) and BREEAM (comparison with national energy certificate). The comparison of consumptions gives a certain idea of how big the energy consumption costs are corresponding to other similar real estates.

To get an answer from the clients about the necessity of sustainability investigation and to recognize more of these important aspects Pöyry conducted a survey for potential clients. The questionnaire was send for real estate owners/investors, users, construction agencies and managers, public sector and it contained questions about current state in sustainability assessment, use of certification in the real estates, driving forces for sustainability issues in the companies and other relevant sustainability issues. Study is called Pöyry Green Market Study (GMS) and questions were send to 607 respondents. Additionally the questionnaire was available in Pöyry's Internet page and 106 answers were delivered to Pöyry. The respondents can be considered sustainability forth runners for 40 % of the respondents answered that the organization they are currently working for is already a member of national green building council. Only 24 % of the respondents did not know that there was such an organization. [11]

3.2 Driving forces related to sustainability

One of the aspects considered in the GMS was the driving forces of sustainability. When building owners were asked to answer what were the driving forces for sustainability, two topics were recognized to be very important in the sustainability related decision making. As it is presented in the figure below, potential savings in energy and maintenance costs and better controllability over energy and maintenance costs has been recognized to be very or even extremely important issues. [11]

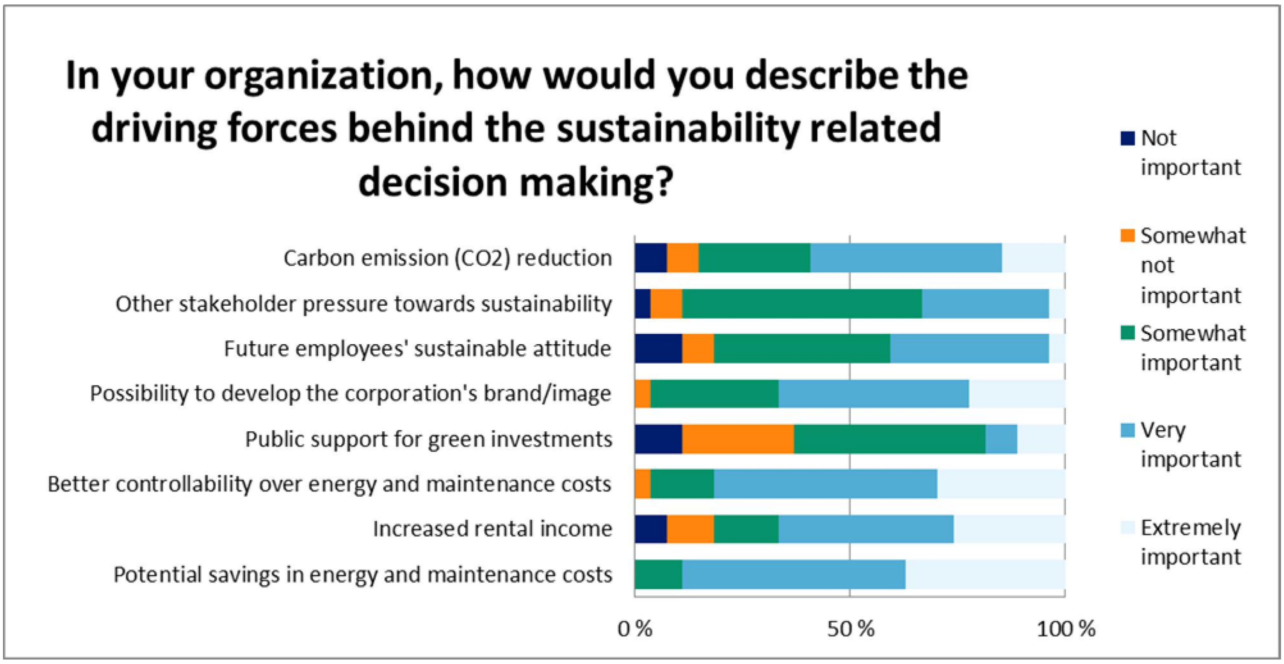

Figure 1. Pöyry Green Market Study results 2012 for question about driving forces behind the sustainability assessment in the decision making at real-estate investment field. Question for owners/investors. [11].

Maintenance costs and savings are included to the basic due diligence and also in the building environmental management/certification systems (LEED, BREEAM, PromisE). The “added green value” about building management and maintenance in Green DD is included to the sections maintenance procedures from the user organization and environmental management plans. Issues considered are e.g. existing building commissioning, environmental management plan, sustainable purchasing, real estate operating manuals and building user guide, possible risk system maintenance procedures and radon risk assessment. The green DD evaluation illustrates what are the sustainable procedures behind the maintenance management and the basic due diligence presents the costs related to the management (divided into different maintenance cost flows). From the Green DD the investor can see how the building is managed and see if the costs for the management are in line with the management duties. Additionally, now in the greenness evaluation investor can see the sustainability issues considered (or not) in the management.

3.3 Sustainability awareness development in real estate market according to the Pöyry GMS

The Pöyry GMS was conducted also in 2010 and the results were compared to results on year 2012. It was noticed that, the owners saw more value in the environmental aspects in 2012 in the real estate sales and leasing situation in all the categories than previously in year 2010. In 2010, 60 % of the respondents believed that sustainable buildings are more easily sold. In 2012 the figure was over 80 %. Additionally, 2010, 70 % believed in a better rent ability of sustainable buildings and figure increased to over 80 % in two years. The results do not show great differences in lease costs or contract lengths if sustainability aspects are emphasized in the building. However, the survey results showed that people are more familiar with the tools to improve sustainability than 2010. This can be seen from the number of “I do not know” - answers that were greatly diminished especially for BREEAM, ISO standards, Green Office (tool from WWF), Green Lease (contract for green buildings) and carbon footprint calculations. This indicates that in future, respondents might be more willing to pay and investors could expect higher rental incomes and longer lease contracts from real estates that are considered to be sustainable. The awareness of real estate industry field and sustainability aspect understanding has increased substantially in two years. [11],[12] On year 2012 all respondents (users, owners, construction agencies, managers and public sector) answered that important sustainability related issues were energy efficiency, spatial flexibility, connections to public transportation and quality of the indoor environment. The less or somewhat important sustainability issues were considered to be the site ecological values, water efficiency, possibility to use renewable energy sources, carbon footprint calculations and environmental rating of the building. [11]

4. Conclusion and Discussion

4.1 Sustainability aspects in risk minimization with due diligence

As it was said in chapters 3.1 and 3.2, the GMS results show that some of the real estate owners expect higher rental income from real estate that is considered to be sustainable. Additionally, the results indicate that respondents expect sustainability assessment to ensure better controllability and potential savings for the building. Therefore it can be said that sustainability assessment can be considered as a risk assessment for gaining better information about the building and possibility to react to deviations. As stated by C.L. Reichardt "*there is good evidence to suggest that the companies that are most successful are those who are willing to take on risk but employ rigorous enterprise-wide risk assessment and mitigation processes*". [13] The risk of company sustainability brand deterioration is also a risk that should be avoided and for that purpose the Green DD acts as a tool.

4.2 Sustainability assessment importance evaluation has a link to financial value

The results from the survey here don't indicate changes to the sales or rental prices that can be saved by operating sustainable. However, the results show what the most important sustainability measures are and what are less important in Finland and in the Nordic countries. The important sustainability related issues were energy efficiency, spatial flexibility, connections to public transportation and quality of the indoor environment. These all have a specific impact also to the buildings financial value.

The respondents indicated that the less or somewhat important sustainable related issues were site ecological values, water efficiency, possibility to use renewable energy sources, carbon footprint calculations and environmental rating of the building. This could be due to the fact that in Finland and in northern countries water is cheap and readily available, site ecology has no specific value due to thinly-developed areas with a lot of nature near by, renewable energy source cost are on same level as non-renewable and carbon footprint calculations and environmental rating systems do not have any financial support from authorities. If the weight of sustainability is wished to be transferred in to these issues, then authorities should change the driving forces such as compulsory CO_2 measures for Finland into these issues. That could be the case for renewable energy sources and also for the rating systems, because there has been changes in the legislation and the issues are discussed a lot in media by the politicians. The next GMS in two years could show already changes for these issues.

Although, all of the issues in the sustainability evaluation are not increasing direct cash flows or minimizing cost, those could lead increase of market value. However, as stated by C.L. Reichardt *"it is not realistic to expect that companies will decide to acquire projects on the basis of their outstanding environmental and socioeconomic risk management profile if the asset is not economically viable." [13]* But due to the possibilities of financial increase, some companies are "green washing" the brand image to increase sales. The use of certified third party environmental assessment tools prevents this. Additionally, with comprehensive life cycle analysis and focus to sustainability the tools can introduce new possibilities for the business. As an example of focusing into public transportation access to the building, new development concepts can be found and new customer groups can find the location of the business.

As an example of creating added value in with sustainability assessment, the business owner can find out in Green DD that there is a lack of public connections to the site, but the users would be very willing to use those. This could lead into negotiations with the local community of new access routes and new public connections to the site and in a best case scenario this could lead into new income and increase of business, increased efficiency and better communication with the stakeholders.

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Understanding Local Energy Initiatives and Preconditions for Business Opportunities

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Summary

More and more local bottom-up energy initiatives are emerging. Those involved encounter many barriers during the realization of their ideas. As the generation of renewable energy is mostly included, these local initiatives contribute to the targets set at regional, national & EU level. At the same time, they are an indication that end-users themselves want to be part of the energy transition. What are the reasons for citizens to organize themselves and start and initiative? What kind of barriers do they encounter? What does this mean for roles and responsibilities of professionals? And to what kind of opportunities does this lead for products and services? Answers to these questions provide a solid starting point to develop methods and instruments to stimulate, facilitate and upscale local energy initiatives.
This paper bundles the outcomes of three workshops and three additional interviews in the Netherlands as part of the European E-hub project. Conclusions can be drawn on needs and drivers, barriers, risks and solutions (lessons learned), possible roles for professionals and opportunities for new products and services.

Keywords: local energy initiatives, drivers, needs, roles, opportunities

1. Introduction

1.1 Context

In the past, there have been initiatives in communities to generate their own renewable energy. These were merely regarded as pilots or of no real importance to the rest of society since they were initiated by people with an ‘alternative’ lifestyle. In the recent years, the number of local renewable energy initiatives is increasing dramatically. To illustrate this: in the Netherlands there were about 50 of them in 2011, halfway 2012 there were 300 and end 2012 there are 1500 existing and starting initiatives known [i] (www.hieropgewekt.nl/initiatieven) and their number is still growing rapidly. More initiatives in other EU member states can be found on the website of the European Rescoop project (www.rescoop.eu) [1].
This development is triggered by changes in the market, ICT opportunities and new technologies, legislation regarding distributed energy generation, incentives and not to forget the crisis and rising energy prices. Furthermore, our energy system is changing towards a smart grid system. Smart energy systems require a new framework in which technological, societal and institutional innovation interplay. The current framework of institutions, organizations and technologies is built to facilitate the incumbent structure. Energy generation and distribution centrally managed by several large companies is the current practice.

At the moment new approaches are emerging that will determine the set-up of our future energy system. How will the intelligent energy grid look like from the perspective of bottom-up initiatives? What kind of products, services and support do we need from companies and public institutions to make this a success? What needs to be changed in order to make this happen?
Energy service companies, distribution system operators (DSO's) en transmission system operator (TSO), energy production and supply companies contemplate on their role and their opportunities. They are looking for ways to deal with the increasing imbalance in the grid due to the increase of renewables. Companies are investing in new products and experimenting with ESCo's. Do these fit in with the needs of prosumers and the new emerging local energy initiatives?

1.2 Research is part of the E-hub project

This research was executed as part of the E-hub project. The E-hub project (EU FP7; www.e-hub.org) is developing a new type of district energy infrastructure consisting of advanced systems for matching supply and demand of energy including advanced heat storage technologies such as TCMs (Thermo Chemical Materials). The E-hub concept will be demonstrated at full scale in the district of Tweewaters, Belgium. To achieve low energy or even energy neutral districts, the share of renewable energy must increase drastically. As still more renewable energy will be produced locally, both smart energy management systems and energy storage are necessary.
The objective of the E-hub project is to maximize the amount of renewable energy in a district while using the above mentioned technologies. For acceptance of such an innovative system, it is crucial to develop new business models and service concepts that are attractive to all stakeholders. An important element is the acceptance of such an advanced energy system by the end-users. The interviews and workshops used in this paper were part of the activities conducted to study the possibilities (and limits) of how that can be achieved.

2. Theoretical framework

The emerging bottom-up initiatives matter to both research and policy making [2,3]. They are seen as an important first step in active citizenship that is promoted as a solution to diminishing of public budgets [4,5]. They are seen as well, as a sign that society is changing under the influence of individualisation and digitalisation [6,7]. Parallel to processes of government, governance processes are appearing [8]. In governance processes all sorts of parties form partnerships, which can include government to realize public goals. The direct involvement of a government party is no longer a necessity. In the government model, the role of citizens was limited to test policy and co produce policy at special determined moments during procedures. With governance room in policy has increased considerably and citizens are able to get involved in the processes as an equal party. This leads to a network society in which organisation processes are increasingly of a bottom-up nature.
An outlook on how our energy future could look like has been described by Rifkin. Rifkin [9] argues that conjoining Internet communication technology and renewable energy technologies is giving rise to a Third Industrial Revolution. The entire system will be interactive, integrated and seamless. This interconnectedness is creating whole new opportunities for cross-industry relationships. And, Rifkin argues, the Third Industrial Revolution brings about a new era of "distributed capitalism" in which millions of existing and new businesses and homeowners become energy players.

3. Methodology

In the Netherlands, three workshops and three interviews were held by ECN and TNO in order to gain insight in barriers, drivers, roles and opportunities of various parties from both the demand side and the supply side. In the interviews, three cases were addressed located in The Hague (Couperus), Hoogkerk (PowerMatching City) and Culemborg (EVA-Lanxmeer). The workshops were held from the perspective of parties representing the demand-side and local bottom-up initiatives, parties involved in the production, distribution, transport and supply of energy, and a workshop dedicated to a local authority. To summarize:

1. Couperus interview
2. Hoogkerk interview
3. EVA-Lanxmeer interview
4. Supply-side workshop
5. Demand side workshop
6. Municipality workshop

3.1 Couperus interview (i1)

Interview with a technical consultant involved in the lay-out of a smart thermal network.

In the Couperus project in The Hague about 300 dwellings are involved. Heat pumps are used for heating in combination with ground source collectors. The heating demand of the whole system can be controlled by postponing the demand for a short period of time without the inhabitants noticing change in the comfort levels. This allows the balance responsible party to steer electricity demand of the heat pumps. It is possible to deliver heat to the coldest dwellings first. Agreements were made on preconditions and timeframe in which the demand can be altered. [10]

3.2 Hoogkerk interview (i2)

Interview with a consultant involved in the lay-out of a smart grid.

The PowerMatching City consists of 25 interconnected households equipped with micro cogeneration units, hybrid heat pumps, solar panels, smart grid appliances and electric vehicles. Additional power is produced by a wind farm and a gas turbine. The underlying coordination mechanism is based on the PowerMatcher, a software tool used to balance energy demand and supply. The aim is to extend this coordination mechanism in such a way that it can support simultaneous optimization of the goals of different stakeholders: home optimization for the prosumer, reduction of network load for the distribution system operator and reduction of imbalance for program responsible utilities. [11]

3.3 EVA-Lanxmeer interview (i3)

Interview with a Managing Director involved in the buying and extension of the thermal network of Thermo Bello

Residents that initiated the founding and construction of the sustainable neighbourhood EVA-Lanxmeer bought the thermal network from their water company. This thermal network provided their houses (170 dwellings), some companies and public organizations (5 additional buildings) with heat. The water company put the thermal network on sale since it did no longer fit in their corporate strategy. The residents worried that the new owner might increase the rates considerably. They decided to buy it in order to secure energy at affordable prices. It was decided that residents are free to financially participate in their new energy company. The network has already been extended to another neighbourhood. [12]

3.4 Supply-side workshop (w1)

This workshop was organized by TNO with representatives from energy companies (production & supply), energy service providers, a TSO company and DSO companies to reflect on possible scenarios for the network enabling bottom-up renewable energy initiatives.

Point of departure for this workshop was to think of a new set-up for the electricity system in the Netherlands in order to facilitate local bottom-up renewable energy initiatives. Goal of the setting was to explore the possibilities for steering while facilitating the development of regional and local networks and realizing the societal benefits of smart grids. Basic assumptions were that on a regional level, people should be free to make their own choices and that economic principles can be used to steer people to preferable outcomes. [13]

3.5 Demand-side workshop (w2)

A workshop organized by ECN and TNO with participants from different perspectives on the demand side. The participants represented housing associations, local energy companies, initiatives of citizens, lawyers, residents, research institutes and universities.

The workshop started with two presentations on the experiences of local energy initiatives in Hoonhorst (www.duurzaamhoonhorst.nl) and Texel (www.texelenergie.nl). Texel Energy is involved in solar power, wind turbines, manure fermentation, district heating on pruning and a smart grid pilot. Hoonhorst has initiated 17 projects which include solar power, district heating, fibreglass to facilitate e.g. care-to-the-home, bio fuels, biogas from manure, reduction & harvesting of waste, grey water system, village garden etc. Two parallel brainstorm sessions were held; one with people from the perspective of people in local initiatives and one session from the perspective of parties supporting or facilitating local initiatives. Objectives were to explore desirable scenarios and to make an inventory of needs, opportunities and possibilities for products and services in a future intelligent energy system. [14,15]

3.6 Municipality workshop (w3)

The workshop was organized by TNO with representatives from different departments in a local municipality.

At this workshop, departments for climate policy, environment, construction & housing, and e-mobility were present. The given municipality has formulated ambitious environmental goals for 2025 and is looking for ways to realize those. Workshop objectives were the further clarification of interests, role of the municipality and identification of new opportunities. [16]

4. Results from the interviews and workshops

The conclusions of the workshops and the interviews are clustered under the following headlines: needs and drivers, roles and responsibilities, risks, barriers and solutions (lessons learned) and opportunities for new products and services.

4.1 NEEDS & DRIVERS

Needs and drivers for parties in the supply chain are addressed in the report Business Models for Smart Energy [17] produced for the E-hub project. These drivers are not repeated here, only those of consumers or end-users, bottom-up initiatives, municipalities and housing associations.

4.1.1 Changing consumer needs

There is an emerging tendency among consumers to invest in private energy generation. (i3, w1, w2). Around 10% of end-users are interested to own energy generation equipment (w1).

4.1.2 Reasons to start local bottom-up initiatives:

- concern about energy prices or exploitation costs for dwellings in the future (w2)
- to improve the quality of life for the community (w2)
- to improve social cohesion (especially in areas with declining population) (w2)
- the urge to do something together (is considered great fun!) (i3, w2)
- as a means to jointly save energy (i3)
- control over own energy supply (i3)
- concern about the environment (w2)
- People are not satisfied about how large energy suppliers work. One pointed out that during the liberalization of energy market, a lot went wrong. Companies were not used to clients changing over to other suppliers. (w2) Now that these companies have become anonymous entities driven to maximize profit, some people feel the need for an alternative which allows people to get involved (i3).
- A group has more power than an individual and energy supply for a group can be more efficient. (w2)

Formulating mainsprings is important. In the Hoogkerk project, the mainspring is “Green”. A partner from Germany, MVV Energie, has “Innovative” as a mainspring. In Mannheim, were the headquarters of the company is located, the mainspring is: “MVV is our company”, because employees have shares in MVV Energie. “Sustainable” could be a mainspring, too. In Hoonhorst, the mainspring could be “Proud of Hoonhorst”. (w2)

4.1.3 Municipalities
Many municipalities are setting additional goals regarding sustainability and climate. The municipality used to formulate environmental goals as a separate policy line. The experience was that this made it very difficult to involve other departments of the municipality and other stakeholders. It is not possible to realize the set of environmental goals on your own as a municipality. These environmental goals are now an integral part of other policy plans. Environmental goals are reframed to sustainable liveability, sustainable health and sustainable safety. Support within the municipality has grown considerable as a result. (w3)
Question remains how to mobilize companies and citizens to increase sustainability goals in their own organization or household. (w3)

4.1.4 Housing associations
Housing associations often wish to distinguish themselves from their competitors and to address the most important driver for tenants: affordable living expenses. In the future, energy bills are expected to rise, therefore solutions are sought to control these costs. (w2) It needs to be explored how tenants can be actively involved in the realization of energy goals. (w2)

4.2 ROLES & RESPONSIBILITIES

Decentralised energy generation requires a much more active role of different parties who have remained passive up to now. New parties are also joining in. (w1) Each stakeholder needs to redefine its own role. (w1)

4.2.1 New parties
Local bottom-up energy initiatives are emerging. Local energy production brings about advantages for conventional energy companies (DSO's, TSO's and energy retailers) like possibilities to support consumers in energy saving, decentral balancing and reduction of transport costs due to the fact that generation and consumption of energy will take place at the same location. (w1) It turns out that successful initiatives are often from close small communities. At the heart of these initiatives are often one or two enthusiast leaders who can mobilize the community to realize local ideas. These close communities stick to their own surroundings and people usually are prepared for more sacrifices for their village, quarter or ward than people who do not have a bond with the locality where they live. This leads to a kind of urge to do things themselves as much as possible, with little external interference. People prefer not to be patronized by organisations or the government and be dependent. Instead they want to decide themselves on matters that affect their surroundings and they like to decide on ways to take action. People wish to be involved in the decision process already in the early stages. Furthermore, an important element is increasing community spirit. (w2)

Parties supporting local initiatives and new businesses will emerge e.g.:
- Usually new players are small businesses that operate locally (decentralised) and on a small scale. They sell solar modules, for example. These new players often find a position between the end user and the energy supplier/grid operator (w1). Texel Energie, for example, has contracted out the grid balancing. (w1)
- Decentralised generation can lead to congestion on the grid. If this is not solved by the grid operator, the consumer may even end up paying more than before. The grid operator can also contract this out to new parties. (w1)

4.2.2 Existing parties in the supply chain

Current developments lead to changes in roles and responsibilities of existing parties that use, create maintain, operate and manage the current electricity system. Ideas and thoughts that emerged from the workshops and interviews are mentioned below.

Network management and production are divided in the Netherlands, this makes optimization difficult. Splitting up of these two activities was imposed by law some years ago (with a corresponding resistance of the energy companies), but apparently these parties still prefer the old situation since the question was posed: Can we think of providers able to combine both functions?

(w1) There is infrastructure available, but balancing should be organized regionally with the responsibility and alignment with the national grid. (w1)
National distribution grid should remain under the responsibility of the Dutch TSO, TenneT. Regional networks should ideally be under the responsibility of a regional public party. Underneath the regional party, several commercial parties can reside. (w1)

The grid operators need to change the way they are monitoring and react to new developments (such as to the mentioned congestion on the grid which can be solved by placing batteries for storage to prevent congestion). The grid operator needs to identify a suitable business case, but cannot pass the risks to the end users. The grid operator is allowed to hire another party to take care of the grid management. For example, another player could start exploiting a small line. This does require different business models. Frictions may also arise between current cooperating companies since roles will change and current ways of collaboration will have to be redefined. (w1)

There is a difference between social ties in a village and social cohesion in a town or a city, which usually is not as tight. In a town or a city, the local lower authorities or housing associations could or should get involved. (w2) The roles they can or should take on are not clear yet. On the lowest administrative level (e.g. city council) support for local initiative could or even should be organized. The city council could or should create financial instruments in order to support local energy initiatives. Furthermore, provincial institutions dedicated to environmental goals could support the initiatives through their web sites. Using the community spirit is also important. (w2)

Possible roles of the municipality:

- When commercial parties take initiative or are prepared to do so in order to achieve certain environmental goals, the role of the municipality is mainly one of a facilitator. (w3)
- The municipality chooses to take on the role of an initiator in order to realize strategic ambitions formulated by the city council. This municipality for example, sees opportunities related to electric mobility. (w3)
- Creating incentives to stimulate people to get involved in local bottom-up initiatives. Financial incentives should be created or facilitated by municipality. (w3)
- Setting an example. People dealing with sustainability see energy saving measures and renewable energy technologies in the municipalities' property portfolio as a way of setting example for other stakeholders. (w3)

Possible roles of housing associations:

- Facilitating. To help organize. For example to arrange excursions in order to learn from other local initiatives and promote knowledge exchange (w2)
- To provide choice for tenants (w2)

There are still a lot of questions concerning the role of housing associations in this respect.

4.3 RISKS, BARRIERS AND SOLUTIONS (LESSONS LEARNED)

4.3.1 Risks

The risks involved are related to very different aspects, as the overview below shows:

- Insufficient support from residents.
  In the Power Matching City pilot 1 (PMC 1), so-called 'technology push' was conducted. Within 2-3 days all households were equipped with smart energy technology. The action was prepared through a number of meetings with participants. In retrospect, the technical team responsible for the implementation of the Power Matcher would no longer choose a technology push approach, but would prefer instead to find out first what participants want. They are convinced that a lot of attention should be given to inform people involved in the pilot. It should be taken into account that simple things may not be clear and are too complex to grasp for the residents. They also recommend launching a project only when there is social support. Information meetings are important. You can also start a blog where people can

exchange experiences and ideas. They should be free to say whatever they want. It is useful to look into this blog and to respond if necessary. (i2) End-users should also be allowed and encouraged to participate actively in the process. This was also done in the second pilot (PMC 2) project. (i2) to avoid resistance due to the technology push approach as occurred in the first phase of the project (PMC 1).

- The available social support structure can collapse.
  In the first stage of the Power Matching City pilot project (PMC 1), the initiators had no idea about possible responses of the participants, the end users. The project team first contacted the local authorities to find a suitable location. Hoogkerk was soon identified as a suitable location, because a sustainability committee was already active with various projects in the district. Through the residents' association, the idea was brought about. Unfortunately, the sustainability committee has later been discontinued. (i2) In stage 2 (PMC 2), things were approached differently. Groene Power – a SME that sells solar modules – has been contacted. Groene Power is used to contact residents in the area. (i2) Another communication channel in stage 2 was the residents' association. There, they were able to convince people to install solar modules that feed-in into the existing grid. (i2)

- Difficulties to measure progress.
  An incomplete overview of the situation at the start makes it difficult to indicate progress made in the project. Tip – start with the recording of important parameters at the start to set a reference. (i2)

- Teething troubles with new technology.
  When experimenting with new technology equipment, the question emerges how to deal with the guarantee for appliances. Have they been tested? Are they functioning properly? In the PMC project, household appliances worked with the Energy Service Gateway (ESG) system for 'Automatic Meter Reading', i.e. measuring of gas and electricity use. The communication with ESG did not function well because the system was not equipped for this. As a result, people were pulling out. The producer was aware of the problem, but nevertheless, it was applied. This is a potential risk. (i2) At the time (2009) there were no smart meters that met the requirements of the project. (i2) Tip – pay enough attention to problems people may have with the appliances and ensure that the technology is functioning well, otherwise participants will pull out. (i2)

- Legal issues.
  Legislation lags behind with the development of innovative solutions. Care should be taken that the innovative solutions tested do not break the law. In some cases it is unclear whether this would be the case. When conducting a pilot project that might raise legal issues, the consortium needs to take full responsibility for this risk and should not transfer it to the participating residents. (i2) Tip from local energy initiatives: when your plans not fit in the rules and laws, do it anyway. It will expose existing regulations that hinder the future intelligent energy supply. When exposed these rules and regulations can be criticized. Make sure you keep politicians posted of your actions when you do. (w2)

- Participants can feel unheard.
  Participating end-users need to be convinced that they have influence on the process. It should be made clear to what extent and on what elements the participants can have influence. If this is not the case some people will become unsatisfied because they will develop the impression that the consortium did not have the intention to listen. (w2)

- Unclear benefits.
  Participants are not aware of the advantages of new solutions and business models. For end-users it is not always obvious whether or not a technical solution and business model is advantageous to them. Especially for local district heating projects where projects are set up in which dwellers have no choice, this leads to questions and feelings of uneasiness. (i1) An example is a project of dwellings with a local district heating system on solar energy. Residents have a contract with the ESCo company, which is responsible for production and

distribution. It remains also unclear what happens in case of bankruptcy of the ESCo. Will the residents still be able to heat their houses? (i1)

- Fragmentation in the supply chain.
  The current fragmentation in the supply chain of the construction industry hampers innovation. Every next party in the supply chain can question the necessity of an innovative solution chosen in the project. Since innovation can influence the work of several parties involved, it can be difficult or almost impossible to introduce an innovative solution. (i1)

Some examples of risks for local initiatives:

- In local initiatives, the knowledge and / or competence of people that offer help can be insufficient. This can cause problems since it is difficult to tell your friendly neighbour that he or she is not suitable for a specific task. (w2)
- Some local initiatives feel it is very important to protect the companies founded by themselves from hostile take-overs. (w2)
- Local energy initiatives experience that the energy market is very complicated and it is not easy to earn money in this sector. (w2)
- The current economical and social system is not tailored for local initiatives. The process needs to be facilitated and people need guidance, but this cannot be enforced. Developments in solar modules, for example, are progressing so rapidly at the moment that it is difficult to facilitate the dissemination of information from a central system. These new developments require continuous updates of the available information. (i2)
- An important success factor in the development of local energy initiatives is the influence of enthusiast individuals. This is immediately a big risk too, since when this person stops or moves, the continuation of the initiative can be in danger. Sharing responsibilities with more people can lower the risk. (w2)
- Authorities have a different pace. They also have different interests to look after. A representative of a local energy initiative therefore recommends that authorities should not be involved directly. Another initiative advises to develop good relationships with local authorities instead. (w2)

4.3.2 Barriers

There are multiple reasons why one would like to start a bottom-up initiative, but there also are several barriers:

- Difficulties with legislation, regulations and the granting of permits

Most desired change is in the field of legislation and regulations. The current legislation is tailored to yesterday’s situation in which the interests of households and small companies have to be protected against those of large energy companies. (i3) Legislation and regulations therefore do not correspond with the needs of local initiatives. (i3) As a result the government is more a barrier than a facilitating factor. There is a little overview of possibilities (“There is no one to answer questions” and “everybody says something else”). Further, due to circumstances and (subsidy) regulations changing frequently, many things are unnecessary unclear. Therefore there is an overall wish for a related policy that is continued for several cabinet periods. (w2) Granting of permits can be problematic because of insufficient knowledge of civil servants and officers. Especially in small municipalities the local energy initiative is usually the first to ask whether a biomass production unit can be installed or a wind mill. (w2) It is interesting that housing associations prefer residents to come with ideas rather than imposing the ideas top-down themselves. Housing associations see the legal requirement that 70% of residents has to agree with the proposed measurement as a big barrier. (w2)

- Lack of information, problems of getting the necessary information combined and lack of intermediary parties.

Another barrier is that often there is a lot of knowledge of procedures or technical issues necessary. This information is scattered around, not accessible by consulting one person and usually it is not clear where it can be found. (w2) A lack of intermediary parties is experienced. For example some tenants think that the lessors should take the initiative. (w2) Little research is available in the field of social innovation and there are only few instruments to help you with what you should do and how you should do it. (i2)

- Difficulties defining suitable business cases

During one of the workshops an example was given of a Science Park. Here it was difficult to construct a business case. Earning back the necessary financial investments proved difficult due to split incentives. (w2) Companies often cannot afford to set up renewable energy projects out of idealistic reasons. There must be a business case and a proper return on investments. A reasonable pay-back scheme and a suitable business models are important.

- Most residents do not take energy costs into account when assessing the rent

Another problem is that end-users often do not understand that due to energy efficiency measures, the rent rises while energy costs diminish. (w2) This is, however, not unavoidable, there are business models where the tenants do not notice any change in their energy bills and rent (like paying the energy efficiency measures by savings in energy, or higher rent only for the new tenants…)

- The obligation for gas and electricity connection for every address and the socialization of the associated costs.

The question is whether or not a gas and electricity connection should remain an obligation. The costs to connect everyone to the grid are socialized while the residents or companies involved might not be using them. This might hinder innovation. For example a greenhouse equipped with an energy generation plant still needs to connect to the gas network. In the past, 20% of the costs had to be paid by the entrepreneur, now all the costs are socialized while it is not sure whether the given end-user would use it. There are however some exceptions emerging, for example in the housing project Hoogdalem in Gorichem. (i1)

- A lack of suitable financial arrangements and no direct access to information on how to apply for finance.

Access to information on how to apply for financing should improve. And there is a need for new financial constructions. It is very difficult to get banks involved in the financing of local initiatives (i3, w2). These initiatives become more dependent on private equity (i3). The investments necessary are relatively small. This is a problem for most banks since they are not equipped to manage these small loans. How can we bundle these loans? (i3) Municipalities and housing associations do not have the expertise either (i3, w2).

A lot of unexpected barriers will rise when starting an energy initiative. A local energy initiative representative therefore recommends: Just start, do not let them blow you away! (w2)

4.4 OPPORTUNITIES FOR NEW PRODUCTS AND SERVICES

The arrangements in the (future) energy market should be attractive for commercial initiatives. This means there should be enough room to explore different opportunities amidst all regulations to generate interesting business cases. On top of that, there should be a level playing field for different parties. What commercial parties take on and what not is not for the government to decide for. (w1) Ideas for products and services emerging from the workshops and interviews:

- New products and services based on value propositions.

We should not so much look at different types of energy production if we hope to find innovative products and services. An overview is needed whereto the end-user requires energy: light, power, heat, mobility, cooling, and comfort. This opens opportunities to formulate value propositions. Also information has value. This leads to new products and services: charge-my-car, ESCo-services etc. (w1)

- Differentiation in packaging of energy services.

A minimum energy package for everyone with agreements on flexibility of supply could become a possibility soon. It means that the end-users agree that energy is not available on certain moments. A commercial party could offer additional energy services against additional fees. Now there is no choice. The commercial party can also divide the capacity between different users. (w1)

- Shares in renewables.

Shares in the energy production can be bought instead of paying the bill based on the amount of energy used. As a result, the investor reduces his energy bill and new capital will become available for investments in renewables. (w1)

- Case managers for local initiatives.

In some local initiatives there was a need for a case manager who would help to clarify how to deal with certain issues. He or she would advise and support the initiative, e.g. by searching for the right expertise and to help with procedures. An independent case manager is preferred, but it could also be someone coming from consultancy. (w2)

- Parties bundling different buildings into virtual balancing units

The TSO (transmission system operator) likes to have small units they can use to balance supply and demand. Especially in certain areas in the Netherlands where the net has more imbalances, like the Westland were greenhouses cause fluctuation in energy demand. This is the reason why there are several projects initiated to displace energy demand. Examples are the Couperus case (i1) and the FlexiQuest project, which investigates the possibilities to alter energy demand for warehouses and datacentres. (i1, w1)

- Financial services

Furthermore, there is a need for more flexible ways of financing of bottom-up energy initiatives and associated SMEs. There are many barriers in claiming finance, from banks as well as from the government. The financing should not be given too easily; the initiative should not get pampered. There should be, besides a profitable business case, some resilience and ability to manage itself. (w2) The desired support is therefore financial advice. Another opportunity would be to bundle small loans of several local initiatives for banks and other financial institutions as a way to make a new market available for them.

- Parties interested in delivering energy generation on peak hours and regulating local transport

The current rules are not written to realize the current district heating projects. (i1) The same holds true for electricity grids. (w1+3) Today's system is tailored to the large-scale energy market and not to decentralised generation. (i2) The current legislation is tailored to yesterday's situation in which the interests of households and small companies have to be protected against those of large energy companies. (i3) The current system leaves little room for local initiatives from locals to locals (i3, w1, w3). A mayor change can take place when the rules for grid management would be changed. The difference between transport and distribution will disappear. Rates will change as a result. How will the price for capacity be determined? For commercial parties it will become interesting to anticipate on scarcity. That is very different from now, at least at local level. Transport capacity will become available for everyone. Consumers might not be interested, which means commercial parties will have a role here. (w1)

Economic principles should be embedded into the energy system. Incentives to improve the system are lacking since costs are socialized. For thermal grids, as was claimed, the best performing party determines the standard. This sounds as a good thing, but in reality this means parties are taking each other hostage and do not dare to make step change. (i1) Basically, the electricity system is a physical and an economical system. First, it was mostly considered as a physical system. There was central planning, which was later discarded. Now the system is also seen as an economic system. Through liberalization the system started to change accordingly. Infrastructure and production were disentangled. It became possible for consumers to choose their own energy provider. Liberalization turns out to be a slow process. At the moment a lot of costs are socialized like: distribution, other network costs, pollution, etc. This means incentives are crocked. When looked at from an economic perspective, you want people to pay for the costs they inflict in the system. This would lead automatically to the best thinkable system. (w1)

When implementing smart grids, users should get the possibility to access the market. Now, the risks (profit and loss) are covered by the energy supplier who, for example, does not pass the price fluctuations on. (w2)

In case energy prices increase dramatically, the entire system will change. Only then options that are now pioneering will become interesting, like timing the wash machine with automatic means. Price incentives are too low at the moment. (w1)

5. Conclusions

Local energy initiatives are emerging in still larger amounts. There is an important enabler for this phenomenon; the impressive progress in development of information and communication technology (ICT) and renewable energy technologies. This creates possibilities for new mutual relationships on the energy market where end-users can become active players and start bottom-up initiatives. Local energy initiatives cannot be easily embedded in the current centralized large-scale energy generation and supply system, with the given legislation, regulations and traditional roles. This brings about a necessity to revise and adapt structures, systems and roles along the entire supply chain.

Drivers to set up a local energy initiative vary from a concern about energy prices, a desire to have control over the energy supply, a wish to jointly save energy, a concern about the environment, a wish to realize more efficient energy generation and to improve quality of life for their community and to increase social cohesion. Another driver is dissatisfaction with the energy services of large companies. At the same time municipalities are setting their own sustainability goals in which the local energy initiatives seem to fit.

As a result of the transition to the new energy system, roles for new and existing parties need to be (re)defined. Current developments lead to changes in roles and responsibilities of existing parties that form the current electricity grid. For example, outsourcing of an exploitation of a small line and management of congestions on the grid to another party. Furthermore, it is expected that many small businesses operating on a local level will emerge.
The role of the municipalities will be mostly facilitating. Creating incentives and stimulate others to get involved and setting an example with their own property portfolio is a part of their responsibilities. They can also initiate local projects, like e.g. electric mobility to promote local business. Roles of housing associations are also mostly facilitating and creating choice for tenants.

Many risks are present. In smart technology projects insufficient support from residents due to technology push can occur for example. The lack of understandable information on the applied system can form a big hurdle. The available social infrastructure on which a local initiative is based can collapse. A broad support should be ensured e.g. through local SMEs that already have access to potential participants. It can be important to show results. But it will be difficult to measure the progress of projects without knowing the status quo at the point of departure. Teething troubles of a new technology should be avoided because it can cause participants to pull out. Further, legislation does not follow the innovative solutions development with the consequence that sometimes in practice, breaking the law cannot be avoided. This can, however, also be seen as a manner to expose the shortcomings in the legislation and achieve that the authorities start considering the necessary amendments. Participants can feel unheard if it is not clear to what extend and what they can or cannot have influence. Also, they are not always convinced about advantages of new solutions and selected business models. Furthermore, the current fragmentation in the supply chain of the construction industry hampers innovation.

Some examples of risks for local initiatives are the competence of citizens who fulfil a role in the initiative or a protection of the companies founded by the initiative from hostile take-overs. Further, the current economical and social system is not tailored for local initiatives. The success factor is often the influence of enthusiast individuals. When these individuals quit these initiatives risk to come to a standstill. Sharing responsibilities with more people can lower the risk that the initiative collapses when the individual stops or moves.

Many barriers are encountered too. For example legislation and regulations, granting of permits, split incentive, missing knowledge of procedures or technical issues. Housing associations see the legal requirement that 70% of residents have to agree with the proposed measurements as a big barrier. Another barrier is that there is little research carried out in the field of social innovation and there are only few instruments to help citizens with what they should do and how. The socializing of costs and current obligation for gas and electricity connection could be a barrier for innovation.

This obligation should be reconsidered as the connections to gas of electricity will no longer always be used.

As for barriers, legislation and regulations can be mentioned, and the granting of permits, split incentives, missing knowledge of procedures or technical issues. Another barrier is access to finance. There is a need for new financial constructions. It is very difficult to get banks involved in the financing of local initiatives. One of the reasons is that the investments necessary are relatively small and the way banks are currently organized does not allow for the management of a portfolio of small loans. One of the solutions would be to somehow bundle small loans of several local initiatives. Housing associations see the legal requirement that 70% of residents has to agree with a proposed measure as a big barrier. A lot of unexpected barriers will rise when starting an energy initiative anyway. A local energy initiative representative therefore recommends:

“Just start, do not let them blow you away!”

On the other hand, this transition period brings about unknown opportunities for the end-users who can become prosumers, business opportunities for SMEs and, not to forget, new opportunities for the established large energy suppliers and distributors. New products and services like charge-my-car or ESCo-services are emerging. Differentiation in energy supply packages becomes possible, e.g. a minimum energy package for everyone with agreements on flexibility of supply. It means that end-users are compensated when they agree that energy is not available on certain moments. A commercial party could offer additional energy services against additional fees. Shares in the energy production can be bought instead of paying the bill based on energy used. As a result, the investor reduces his or her energy bill and there will become new capital available for investments in renewables. Other products and services will appear, too. Case managers for example, independent people or people coming from consultancy, who would support a local initiative by searching for the right expertise and help with procedures was needed. New services will emerge when smart grids are implemented. The users will eventually get the possibility to access the market. Now, the risks (profit and loss) are covered by the energy supplier who, for example, does not pass the price fluctuations on. This will create opportunities for intermediary parties as well. At the moment price incentives are still too low to quickly raise interest for smart solutions like timing the wash machine with automatic controls. But this can change quickly when energy prices increase dramatically.

The number of participants involved in the workshops and interviews held is for obvious reasons rather limited. And, of course, the parties involved represented only the Dutch situation. The expectation is, however, that this is enough to formulate the first preliminary conclusions. On this, a first draft of a framework can be build that is fit for the development of new products and services. In the continuing transition period, new research questions will unavoidably emerge.

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Trends in the Public Engagement Projects in Hong Kong: A Focus Group Study

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Summary

Purpose – Public engagement (PE) has been increasingly applied to the mega construction development projects by the government of the Hong Kong Special Administrative Region in recent years. There are totally 226 PE projects used in Hong Kong from 1997 to 2009. PE is a team decision-making process which involved multiple stakeholders at different stages of the project. It becomes a popular way of consulting the public, so as to integrate various opinions and gain the final support for the project implementation.

Although the PE projects are blooming, the PE development in Hong Kong is still in its infancy stage (e.g., the Western Kowloon Cultural Development, the Queen's Pier Demolition, and the Cross-Border High-Speed Rail Development). PE has long been queried whether it is a window-dressing or a manipulating tool used by the government. The paper aims to explore the current trends of the PE projects in Hong Kong by adopting a focus group approach. Based on the understanding of the current trends of PE development, some practical recommendations are also addressed in this study.

Design/methodology/approach – To investigate the current PE trends, two focus groups were conducted with different types of stakeholders engaged in each group: construction professionals and non-governmental organizations. To ensure the quality of data collection, purposive sampling was adopted. Participants eligible to join in the focus groups were those who had direct PE experiences (such as workshops, focus groups and public forums) and had been affected or influenced by the projects at the time when they filled in the questionnaire. Seven participants with a good mixture of disciplines, working experiences and PE experiences were invited to each focus group.

Having informed about the ground rules and confidentiality of the discussion, the participants were encouraged to write down their views on the PE projects and express their opinions freely. All of their opinions were collected in the form of audiotapes, worksheets and spontaneous note-taking to ensure the reliability. The qualitative data obtained from in-depth group discussion were analysed by adopting the contextual analysis method in order to identify the motivators and barriers of PE for the construction development projects in Hong Kong.

Findings –The results exposed the current trends in PE projects, including both motivators and barriers. Three motivators consisted of the governmental support for the PE development, multiple PE stages and diverse PE activities involved in the PE projects, whereas barriers were identified and classified into two levels: strategic and operational. Strategic level included three barriers, namely top-down consultation approach, short of PE standards and negative PE impression; while operational level consisted of both project barriers and stakeholder barriers. The project barriers were caused by insufficient PE experiences, inadequate PE publicity, unclear information, and insufficient time for the PE activities (such as workshops, focus groups and public forums). The two stakeholder barriers referred to unrepresentative stakeholders and inadequate sampling of stakeholders engaging in the PE projects.

Originality/value of paper – The study investigated the PE trends (including motivators and barriers) in the construction industry in Hong Kong by using the focus group study. Based on the findings, several practical recommendations are proposed. The government is suggested to support the PE development and use the bottom-up approach for the future PE projects in order to gauge public opinions widely for the long-term strategy. To standardize the PE application, there is an urgent need to establish PE guidelines indicating: who should be engaged, what the logical PE team decision-making process should be, and what PE activities should be adopted. To ensure that the public can understand the technical issues of PE projects in the discussion, sufficient information is expected to be prepared in simple language for laypeople. We would also recommend the PE organizers to reduce the presentation time in the PE workshop and extend the workshop time so that the public have ample time to exchange their ideas and identify the best solution among the multi-stakeholders in the workshop. In order to enlarge stakeholder sampling and allow more representative stakeholders from different disciplines and backgrounds, PE projects are thus expected to be more inclusive.

The findings of current preliminary study can be used as the initial stages of the comprehensive study on improving PE performance. The current study is expected to become the basis for a large scale quantitative questionnaire survey from which it is expected to investigate the complicated relationships in PE projects. The results are expected to benefit the development of PE in construction projects not only in Hong Kong but also for other countries world-wide.

Keywords: Barriers; Focus group; Hong Kong; Motivators; Public engagement

1. Introduction

As a popular method to gauge public opinions, public engagement (PE) has been increasingly applied in the Nordic countries, such as the impact assessment in Finland (Peltonen and Sairinen 2010), the nuclear waste settlement in Sweden and the GM food project in Netherlands (Hagendijk and Irwin 2006). Since 1997, Hong Kong citizens actively participate into the decision-making and policy-making process in order to ensure their voices are heard by the government and their benefits are maintained (Chen et al. 2007). In recent years, PE has been encouraged by the Hong Kong government, especially in the areas of urban planning, mega-construction projects and policy making (HKSAR Policy Address 2008, 2009). However, it is still blamed for various blunders and inadequate transparency in the decision making of certain mega-construction development (e.g., the Western Kowloon Cultural Development, the Queen's Pier Demolition and the Cross-Border High-Speed Rail Development). This paper aims to explore the motivators and barriers of PE application in the construction industry by using a focus group approach. Based on the understanding of the current trends of PE development, some practical implications are also addressed in this study.

2. Public engagement in Hong Kong

The number of PE in Hong Kong has increased rapidly, which is 226 in total from 1997 to 2009 (Cheung 2011). PE is a process which involves related stakeholders in the decision making of project investigation, planning, decision making and implementation (Chen et al. 2007). It has been popularly used in the construction projects for gauging public opinions (Rowe et al. 2008).

At present, the government encourages all large-scale public projects with high sensitivity to apply PE (HKSAR Policy Address 2007-2011). In consideration of the complexity of the construction projects, PE is generally divided into three stages: the envisioning stage, the realization stage and the detailed planning stage (CEDD 2009). Several PE activities are often conducted in the series of PE stages including exhibitions, site visits, workshops, focus groups, public forums, hall meetings so on and so forth (Planning Department 2009; Public Policy Research Institute 2010). The outcomes of PE are summarized in the final report and published to the general public for review purposes.

A number of representative stakeholders, who might affect or be affected by the projects, should be included in the PE process. To maintain an open and transparent environment, not only should PE include internal project teams, but also involves the relevant district councils, community groups, green groups and professional institutions (CEDD 2009). This paper thus conducts focus groups with different stakeholders so as to explore the current motivators and barriers of the PE development in the construction industry in detail.

3. Research methodology

Two focus groups were conducted in order to deepen the understanding of current PE trends in Hong Kong. To ensure the quality of data collection, purposive sampling was adopted (Adams and Schvaneveldt 1985). Participants were recruited according to their experiences in engaging in the PE activities (such as focus groups, workshops and public forums) and whether they had affected or been affected by the projects. Professional consultants were invited to the professional group (PG) and non-governmental organizations to the interest group (IG).

In this study, both the PG and IG have seven participants, with a mixture of participants that included directors (14.3%), project managers (7.1%), architects (7.1%), engineers (14.3%), surveyors (14.3%), environmentalist (21.5%), social workers (7.1) and district councilors (14.3%). Of which 14.3%, 28.6%, 35.6%, 21.5% of the participants have been working over 20 years, for 10-20 years, for 5-9 years, for 1-4 years and less than 1 year, respectively. Focus group participants who have engaged in 1 project (7.1%); 1-4 projects (43%); 5-10 projects (35.6%); and over 10 projects (14.3%).

At the beginning, the moderator introduced the purpose of the study and explained the ground rules (such as equality and without hierarchy) and confidentiality of the discussion. The participants were requested to write down their perception of PE projects on the worksheet according to their actual experience. Then the participants were to discuss freely about their opinions. Qualitative data was collected in the form of audiotapes, worksheets and spontaneous note-taking during the discussion to ensure reliability. All data were contextually analysed for the purpose of understanding the trends of PE application in the industry in Hong Kong.

4. Results of contextual analysis

Consistent with the wider literature, PE has increasingly developed in Hong Kong. However, focus groups' participants identified so many barriers in the current PE development have yet to be re-solved. The data collected from the two focus groups were summarized according to keywords and phrase identification (see Table 1). Table 1 presents a synthesis of current motivators and barriers in PE for construction development projects in Hong Kong.

Table 1 Summary of PE motivators and barriers identified by the focus group

Perceived motivators	Groups	Examples
Social		
Governmental support	PG:	Nowadays, PE is <u>widely used in</u> <u>large-scale</u> <u>governmental</u> projects.

		The government brought forward the concept of PE for several years.
	IG:	The government helped in conducting more PE activities.
Project		
Multiple PE stages	PG:	The current PE stages (i.e., envision, detail design, consensus building) are feasible. PE can be used in different project stages, e.g. planning, implementation, operation.
	IG:	PE involves in different levels and stages, e.g. Tseung Kwan O to Lam Tin Tunnel.
Diverse PE activities	PG:	Before the construction of the project, we met with DC members to discuss the project issues. The development of PE is required to collect opinions from different channels, including workshop, forums and meetings.
	IG:	I have joined different PE activities (e.g. focus group, forums, meetings, workshops). We attended the government briefings and joined some forums.
Perceived barriers	**Groups**	**Examples**
Strategic		
Top-down consultation approach	PG:	Not all policies could be formed as bottom-up. The government often uses the top-down method.
	IG:	The top-down approach of PE cannot resolve fundamental conflicts among stakeholders with different needs. The bottom-up approach is painful. The government told us the design drawing is confirmed without even listening to our opinions.
Short of PE standards	PG:	The government does not have a standard model. The government procedure/handbook/guideline for the implementation of PE is missing, that is, it lacks a step-by-step PE instruction booklet.
	IG:	Such guidelines are not found in Hong Kong. The PE approach is too simple (i.e., publication → survey → forum). It is not suitable for the complicated PE projects.
Negative PE impression	PG:	So many activities are politicized. At present, PE is conducted just for face-saving. (protection) The PE has been criticized as fake consultation and window-dressing activities. The current PE is too general and sketchy.
	IG:	The PE is necessary, but the government is criticized for its lack of foresight. The current PE is too superficial and impractical. At present, most of the PE projects are briefings without consultation. The current PE is always using the hard-sell technique.
Operation – project		
Insufficient PE experiences	PG:	At present, the government has yet to realise who should have a role in organizing the PE project. The current contract clause did not clarify PE responsibility. Some consultants are inexperienced in PE.
	IG:	The behavior of the government is very important. It is still in its developing stage. Current PE organizers do not know how to consult residents and to facilitate the whole project.
Unclear information	PG:	The public have no idea about the government policies and PE projects. Due to their limited knowledge, the public were not able to understand the complexity of these technical issues.
	IG:	At the same time, the solutions are always too technical for the public to

		understand. The PE presentation is too complicated, which often confuse the residents. In general, citizens did not understand the technical problems.
Insufficient time of the PE activities (such as workshops, focus groups and public forums)	PG:	Given only two to three hours, the duration for the whole PE process is too short. There is little interaction in such short duration. The time for public discussion is too short. Insufficient time for group discussion. Sometimes the information is voluminous and the presentation time is too long.
	IG:	The PE time-scale is not enough to prepare sufficient information. Most of the public forums are focused on the presentation.
Inadequate PE publicity	PG:	I think the PE projects' marketing is inadequate for the public. The public often does not know the schedule of PE activities. We need to plan well for the PE publicity.
	IG:	The government keeps the PE in low profile, that is, without publicity. The notices of PE projects are always published on the webpage. Unless the public has an interest on the PE, they will not know what the PE projects are.
Operation – stakeholder		
Inadequate sampling	PG:	I hope the government can broaden the scope of selected stakeholders. Stakeholders need to be all-inclusive. The grass roots are expected to be included. Stakeholders need to be randomly selected so as to expand the sample size.
	IG:	The sample size is small. Public opinions are not well represented e.g., the Hong Kong-Zhuhai-Macao Bridge. These questions then came around: how many Hong Kong citizens would participate in the PE; and whether the PE is representative for all Hong Kong citizens.
Unrepresentative stakeholders	PG:	It is difficult and tricky to invite the right representatives to attend the workshop.
	IG:	Stakeholders are not representative. The government only invites the non-governmental organizations which has good relationships with them.

Note: PG refers to professional group; IG refers to interest group.

5. Discussion

Participants discussed their opinions and individual experiences freely and suggested several common motivators and barriers as shown in Table 1.

5.1 PE motivators

Participants identified three PE motivators which are governmental support, multiple PE stages and diverse PE activities applied. In recent years, the Hong Kong government encourages the development of PE projects, especially in the large-scale and complex projects (such as the West Kowloon Cultural District, the Wai Chai Development and the Kowloon East Development). Many governmental projects use PE activities to collect end-users' opinions (PG) and to fully support the PE activities (IG).

Due to the complexity of the construction projects, PE needs to be conducted with multiple PE activities in several stages (CEDD 2009). Participants in both PG and IG mentioned that the activities they attended included meetings, briefings, workshops, focus groups, community meetings and hall meetings. Moreover, the current PE involves three stages – the envisioning, the realization and the detailed design /planning stages which tallies with the previous literatures (Elton Consulting 2003). PE is also applicable in different stages of the project, such as planning, implementation and operation stages (PG).

5.2 PE barriers

Participants identified PE barriers in two levels, namely the strategic level and operational level. In the operational level, project barrier and stakeholder barriers are further categorized.

In the strategic level, three barriers are categorised as the top-down consultation approach, short of PE standards and negative PE impression. Participants agreed that *top-down approach* was often conducted in the PE projects. However, this approach failed to 'resolve the fundamental conflict among stakeholders with different needs' (IG). Although the bottom-up approach is painful (IG), it is suggested to be taken into consideration for future PE projects (PG). On the other hand, participants of the two focus groups also suggested that current PE *lacks of a standard guideline* for practical PE procedures. To promote PE development in Hong Kong, PE guidelines need to clearly indicate 'who should be engaged at which stage and how to carry them out' (IG). Both PG and IG participants expressed their *negative views on current PE projects*. PE was considered as 'politicized, sketchy, window-dressing and face-saving acts' (PG and IG). The government often pretended to integrate public views which often resulted in objections (Petts 2008). Remedial measures for these situations were always criticised for its lack of foresight (IG).

Four PE barriers were categorized into project dimension at the operational level including lack of PE experiences, unclear information, insufficient time for PE activities and inadequate PE publicity. Although PE is commonly used in the governmental projects for several years, focus group participants often thought that PE organizers and consultants were *inexperienced* (PG and IG). PE organizers sometimes did not even know how to conduct effective consultations with local residents and failed to facilitate the whole project (IG).

Participants considered that the *information* provided by the PE organizers is not clear enough to understand the whole project (IG). Moreover, the information given was often too voluminous with many technical terms (Lloyd-Smith 2009). As the public are not knowledgeable about the information, they often fail to understand the technical issues of the PE projects (PG). In terms of the duration of PE activities, participants expressed that the PE activities including workshops, focus groups and public forums would generally take two to three hours. Such *short duration is far from sufficient* for the public to understand the project issues and to express their opinions (PG and IG). Some participants even expressed that they were not given the chance to speak out and discuss with other stakeholders (PG). This resulted in the negative perception of PE. In respect of PE publicity, participants in PG and IG considered that the current PE *publicity was inadequate*. The public often 'were not aware of PE activities due to the inadequate marketing and publicity of PE' (PG and IG). If the public have not informed about the PE activities, they would not participate and convey their needs (IG).

Inadequate sampling is one stakeholder-related barrier identified in the focus group study. PG participants expected that the PE organizers should 'broaden the scope of participants and establish a feasible sampling size'. The grass-roots should be included. Both PG and IG participants agreed that well suited stakeholder representatives were not involved in PE projects. Stakeholders involved in the PE projects should 'be more inclusive and not be limited to a few interest parties' (IG).

6. Recommendations

The findings identified a diversity of motivators and barriers for PE development. Several practical recommendations are brought forward in consideration of the current trends of PE development.

Firstly, the government is recommended to enlarge the support on PE development and consider *bottom-up approach* for the future PE projects. There is an urgent need for *standardized and detailed PE guidelines* to regulate who should be engaged, how and when PE should be implemented and what forms should be applied. For the complicated construction projects, PE can be divided in to several continuous stages and conducted by multiple activities.

Secondly, from the project aspect, it is expected that clear information could *be prepared in a suitable and layman language*, so that the public could understand the technical terms. In term of the short workshop duration, the PE organizers are suggested to *extend the duration of the whole workshop (e.g., a series of half-day workshops) and decrease the content of the introduction or presentation section*. The PE organizers are also recommended to advertise the PE projects via multiple channels, especially online forum, Facebook and Twitter, which can be used to encourage the youth engagement (Raynes-Goldie and Walker 2008). In consideration of inadequate sampling, it is suggested to enlarge the sampling scope. PE should be *more inclusive to engage representative stakeholders* from different disciplines and backgrounds.

The current focus group study aims to explore the current trends of PE development in construction industry in Hong Kong. This preliminary study describes the current situation (including both motivators and barriers) of the PE projects. The findings can be used in the further large-scale questionnaire survey which is expected to investigate the complicated relationships in the PE projects.

7. Conclusions

PE has increased its popularity in integrating public views for the construction industry in Hong Kong. This paper explores the current trends of PE by introducing focus groups which involve construction professionals and non-governmental organizations. By means of contextual analyses of the qualitative data, three motivators are identified, which are governmental support, multiple PE stages and PE activities. Nine barriers are also identified and classified into strategic level (e.g., top-down consultation approach, short of PE standards and negative PE impression) and operational level which is further categorized as project dimension (e.g., lack of PE experiences, unclear information, insufficient time for PE activities and inadequate PE publicity) and stakeholder dimension (e.g., inadequate sampling and unrepresentative stakeholders).

According to our understanding of current PE trends, several practical recommendations are proposed, such as the adoption of bottom-up approach in future, the establishment of PE standards, the supplying of sufficient and appropriate information, the extension of PE workshop duration and the expansion of stakeholder sampling. Hence, the PE organizers are expected to resolve the current problems, improve PE performance and satisfy representative stakeholders.

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An analysis of the factors that impact and define environmental sustainability in Nordic societies, in the context of urban structures and land use

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Summary

A society's ability to recognise and measure different environmental impacts and to compare them forms a basis for our understanding of environmental sustainability. Within the context of spatial planning and urban structures, environmental sustainability is typically associated with the material and energy efficiency of construction, the energy efficiency of buildings, the fuel consumption and the greenhouse gas emissions of traffic, and the waste management of urban societies. Actions that improve material or energy efficiency, or reduce emissions or waste are often seen as environmental improvements to urban structures. Unfortunately these improvements do not always support lifecycle-wide environmental sustainability on a global scale as many actions that are intended to reduce a particular kind of environmental impact can have even more environmentally damaging side effects. The purpose of this study is to examine how the general idea of environmental sustainability is defined in the context of urban structures and spatial planning in the Nordic countries. A literature review is conducted to examine the framework for the appliance of prevalent environmental aims, scientific knowledge, and available technology to local urban planning and land use in the Nordic societies. The creation and diffusion mechanisms of environmental knowledge, the European cohesion policy in environmental issues, the structure and characteristics of national land use planning systems, as well as the available environmental assessment criteria and evaluation tools are considered briefly. Furthermore, a concise survey was conducted to examine the needs of Nordic municipalities and construction companies and ascertain their priorities when it comes to developing tools that can be used in the assessment of the environmental sustainability of urban structures and land use. Laws, international conventions, national guidelines and local practices set a certain framework for environmental management and spatial planning. Furthermore, it is found that universities, research centres, private businesses and non-profit organisations have important roles in creating environmental knowledge, producing environmental evaluation tools and transferring the knowledge through both commercial and non-commercial activities. However, all environmental strategies, be they international, national or local, will also have elements that are influenced by public opinion or political interest, and comprehensive approaches to knowledge and technology are needed for spatial planning to become an important instrument in the development of sustainable cities.

Keywords: urban structures, land use, spatial planning, Nordic countries, environmental sustainability evaluation tools, assessment criteria

1. Introduction

The industrial revolution can be seen as having stimulated the greatest human migration in history – the still on-going mass movement of people from farms and rural villages to cities all around the world [1]. According to Bithas and Christofakis [2], in terms of environmental sustainability, cities should not be looked upon as environmentally sustainable systems but rather as parasites that, in order to exist and develop, cling onto rural ecosystems. Given that they rarely have the capacity to ensure their inner biological balance, in most cases, cities rely on neighbouring ecosystems obtaining the natural resources necessary for their economic growth from other areas [2]. It has already been stated 15 years ago that, given the causal linkage between concentrated local consumption and global ecological change, national and local authorities must assess the powers that could be devolved to the municipal level to enable urban communities better to cope with the inherently urban dimensions of environmental sustainability [1].

A society's ability to recognise and measure different environmental impacts forms a basis for our understanding of environmental sustainability. There is no such thing as a single unified philosophy of environmental sustainability, but this concept does stimulate major debates about the nature of sustainability, about the changes necessary to make our societies sustainable and about the tools and actors capable of facilitating these changes [3]. On-going discussion increasingly underlines the need to measure environmental sustainability based on sustainability indicators or environmental evaluation criteria [4]. However, the use of terms is still incoherent. Same words can be used to mean a wide divergence of views on the goals, routes and the methods of environmental sustainability [3].

Within the context of urban structures and spatial planning, environmental sustainability is typically associated with the material and energy efficiency of construction, the energy efficiency of buildings, the fuel consumption and the greenhouse gas emissions of traffic, and the waste management of urban societies [5]. Actions that improve material or energy efficiency, or that reduce emissions or waste are often seen as environmental improvements to urban structures. Unfortunately these improvements do not always support lifecycle-wide environmental sustainability on a global scale as many actions that are intended to reduce a particular kind of environmental impact can have even more environmentally damaging side effects.

According to Tanguay et al. [4], the selection, use and application of sustainability indicators is problematic because of (1) an overly broad definition of sustainable development that gives rise to multiple interpretations, (2) the absence of standard and universal classification methods or approaches to designing indicators, particularly at the municipal level, and (3) constraints caused by the accessibility of data that preclude their quantification and the specific qualification of indicators. Thus, current practices related to environmental evaluation criteria cannot meet standard objectives [4]. However, the environmental sustainability of urban structures and land use is constantly estimated in the Nordic societies with the evaluation tools and knowledge available. Unfortunately, the selection of assessment indicators is invariably subject to arbitrary decisions at any of a multitude of points in the planning process and by any of a number of differing stakeholders. [4], [6].

The purpose of this study is to examine how the general idea of environmental sustainability is defined in the context of urban structures and spatial planning in the Nordic countries. The precise aims of the research are (1) to briefly consider the creation and diffusion mechanisms of environmental knowledge; (2) to estimate the general effects of the European cohesion policy in environmental issues; (3) to examine, in a little more detail, the national land use planning systems in Iceland, Norway, Finland, Sweden, and Denmark; and (4) to briefly investigate the effects of the available tools and their criteria on the definitions of environmental sustainability, in the context of urban structures and land use planning in the Nordic countries.

The rest of the paper is structured as follows. Chapter 2 introduces the study design. Chapter 3 presents the findings. Findings are discussed in the Chapter 4. Finally, Chapter 5 concludes the paper.

2. Study Design

A literature review was conducted to examine the framework for the appliancation of prevalent environmental objectives, scientific knowledge, and available technology to local urban planning and land use in Nordic societies. The purpose of this study was neither to explore the actual understanding of environmental sustainability nor to explore the current trends of spatial planning in the Nordic countries. Rather, the research attempted to clarify how the concept of environmental sustainability is defined, in other words to identify the framework for bringing scientific knowledge into sustainability policies and planning practices in the Nordic societies.

Given that any sophisticated idea or implication entails knowledge, the first step of the analysis was to briefly consider the creation and diffusion mechanisms of environmental knowledge. Due to the strong globalisation of scientific knowledge and the increased availability of research findings, the issue was not considered as Nordic-specific. However, in the second part of the literature review the focus was set in Europe. The European cohesion policy in environmental issues was seen to affect the adaptation of global scientific knowledge into the national environmental guidelines and the formal systems of spatial planning in the Nordic countries. A few examples of European law were introduced to illustrate the issue.

The third part of the analysis focused further on national structures and characteristics of land use and spatial planning in Iceland, Norway, Finland, Sweden, and Denmark. The common structures and main differences in formal planning systems and the position of planning in the national policy environment were briefly examined to better understand the differences of environmental implications in the Nordic societies, in the context of urban structures and land use.

Finally, given that environmental knowledge is implemented in actual planning activities in the form of environmental assessment criteria and evaluation tools, the effects of the available tools and their criteria on the definitions of environmental sustainability were considered. Furthermore, a concise survey was conducted to examine the needs of Nordic municipalities and construction companies and ascertain their priorities when it comes to developing tools that can be used in the assessment of the environmental sustainability of urban structures and land use.

The survey was conducted as an open inquiry. A simple poll was sent to a little more than 100 people in Finland, whose work is related to spatial planning and the construction of urban structures, and they were asked to distribute it within their organisations. The aim of the inquiry was to investigate which features of the regional eco-efficiency evaluation tools are seen as important and significant for the users and which are given lower priorities. The number of the respondents was 35, of whom 25 were spatial planners, architects and project managers working for 7 Finnish cities and municipalities, and 10 were various specialists working for construction and consulting companies, research institutes, and the Finnish Ministry of the Environment. Given that the number of people that received the survey was not known, the exact response rate could not be defined. The responses were thus analysed as a directional sample.

3. Findings

Our understanding of environmental sustainability is based on the creation and diffusion of environmental knowledge. International environmental agreements and EU legislation set a certain framework for the application of this knowledge in the context of spatial planning. However, each Nordic country has an independent national land use planning system, and there seem to be important differences in the ways that Iceland, Norway, Finland, Sweden, and Denmark approach regional planning. The availability, usability and content of environmental evaluation tools and assessment criteria play an important role in how environmental sustainability is taken into account in national guidelines and local spatial planning. Rather reassuringly, the results of the study indicate that in the Nordic societies, environmental evaluation is seen more as an element of the actual planning process than as a final assessment or green wash.

3.1 Creation and diffusion of environmental knowledge

The roles of universities and research centres in the creation and diffusion of environmental knowledge are manifold. Given higher education institutions' broad field of environmental know-how on all levels; global, local or regional, they are valuable partners within regional activities for sustainable development [7]. However, the creation of environmental knowledge occurs not only in universities and research centres but also within private business and non-profit organisations [8]. Private organisations produce and disseminate environmental information such as management standards, codes of conduct, and detailed national or international certification schemes [8]. Furthermore, private institutions provide forums for deliberation and conflict resolution as well as opportunities for organizational learning, and thus an institutionalised response to intertwined environmental problems [8].

Academics engage in both commercial and non-commercial knowledge transfer activities [9]. Publications, teaching, and informal knowledge transfer represent non-commercial diffusion of knowledge, while patents, spin-off formation and consulting constitute the main forms of commercial knowledge transfer activities [10], [11]. Networking between higher education institutions and regional actors occurs through a combination of education, research, management, and outreach [7]. On the basis of education, important contributions to the definition of environmental sustainability can be made by promoting a certain understanding of sustainability [7]. In the field of research, networking activities with regional stakeholders are essential for universities to identify research demands within society and the region [7]. Nevertheless, independent and diverse research in various scientific fields, also without the involvement of society, is a priority in the universities for the sake of unknown challenges in the future [12]. Outreach and hence addressing societal needs present another task of universities [7]. In the field of management, universities can take multiple roles, such as (1) the leader that guides and actively shapes environmental development processes, (2) an independent actor that monitors and evaluates related processes, (3) a spokesperson that represents the academics and speaks with one academic voice [13].

A university engages in regional sustainability initiatives and networks mainly because of research (case) data availability, knowledge sharing, mutual problem solving, and for the possibility for students and graduates to find jobs in the region [14]. Such co-operation can bring about holistic and commonly reflected environmental solutions that are widely accepted among the various stakeholders [15]. However, such links between research and practice can bring about challenges for universities to open their research and engage with non-academic stakeholders at an equal level [7]. According to Peer and Stoeglehner [16] the only way for the universities to effectively contribute to local and regional development processes is to bring their research and education into informal learning environments and to collaborate with local and regional societies. Joint knowledge generation is needed to obtain shared visions, objectives and implementation of actions concerning environmental sustainability [16].

3.2 European cohesion policy in environmental issues

Given that the interrelationship between natural systems does not respect political borders, the decision-making sovereignty of states with respect to the natural resources and the environment of their territory is problematic – an activity within one state's territory can have consequences in another state [17]. Because of emerging global environmental issues, such as climate change and biodiversity losses, international environmental regulations are increasingly indispensable, and the challenge for international standards is to reconcile the fundamental interdependence of the environment with the fundamental independence of the sovereign states [18].

In 1991 the United Nations Economic Commission for Europe (UNECE) Convention on Environmental Impact Assessment in a Transboundary Context (informally called the Espoo Convention), was signed in Espoo (Finland) and entered into force in 1997. The Espoo Convention serves as a principal framework for the European countries to protect, in co-operation, the local, regional and global natural environment by (1) carrying out an environmental impact assessment on certain activities at an early stage of planning and (2) by notifying and consulting each other on all major projects under consideration that are likely to have a significant adverse environmental impact across boundaries [17]. In 2003, the Espoo Convention was supplemented by a Protocol on Strategic Environmental Assessment (SEA), which seeks to carry out an environmental assessment of plans and programs that require a higher level of planning in comparison to localized projects [17]. The EU directive on SEA entered into force in 2004, and was firstly implemented in land use issues.

The European cohesion policy in environmental issues is fundamentally linked to respecting and enhancing high-level policy objectives which seek to be consistent with EU sustainability objectives, as well as enhancing member states' national policies [19]. The maintenance of biodiversity through NATURA 2000 areas and the amelioration of water bodies according to the Water Framework Directive (WFD) are examples of such policies. However, each member country can choose to interpret the EU's environmental standards in its own way. The environmental planners in Sweden for example have argued that the WFD-related environmental quality standards lack a precise definition [20]. Sweden has recently failed to comply with the EU's air quality standards and, after the European Commission gave Sweden two warnings, the case has been taken to the European Court of Justice [20]. This example shows how far the EU is prepared to go to impose the European environmental objectives [20].

In December 2008 the European Parliament approved the European energy and climate change package that aims (1) to reduce greenhouse gas emissions by at least 20% compared to 1990, (2) to increase the share of renewables by at least 20% compared to 1990, and (3) to oversee a 20% reduction in projected primary energy use by improving energy efficiency [21]. The international Emission Trading System (ETS) is the central instrument for reaching these targets [21]. The Nordic countries share similar targets in their climate policies. According to the Nordic Prime Ministers' Declaration on Climate Change, research and development activities are emphasised as the key strategies in coping with climate challenges [21]. However, each country has individually assigned decisions to support energy production from a variety of renewable sources. The decisions are mainly determined by access to natural resources, industrial structure, political and cultural traditions and contexts, trading opportunities, public attitudes and joint international agreements [21].

3.3 Spatial planning systems in the Nordic countries

National legislation and guidelines on land use and spatial planning define not only certain quality requirements for the built environment but the spatial structure of the Nordic communities as well. Administrative structures and planning procedures aim to optimise land use and the allocation of other scarce resources, and this effort is connected to the need for societal coordination [22]. From a European perspective, the Nordic countries form a fairly homogenous group. They have in common a corporatist tradition and a relatively strong planning focus at the municipal level [23]. In particular, the Nordic dualistic concept of spatial planning (understood as physical planning and regional development) contrasts with the European concept that reconciles environmental and regional policies and physical planning [23]. However, a brief review of spatial planning systems in the Nordic countries also showed differences in the national planning environments. Furthermore, their adaptation to the challenges of European spatial planning was found to vary due to differences in national planning systems and the position of planning in the national policy environment [23].

3.3.1 Iceland

In many regards, Iceland presents Nordic planning issues and approaches in a nutshell [23]. The spatial planning system in Iceland is based on the Planning and Building Act and the national planning regulations [22]. In the Icelandic system there are three planning levels: regional, municipal and local, and plans covering the same area have to be consistent with one other [22]. All regional and municipal plans that must be approved by the Minister of Environment as well as all local plans adopted by local authorities are legally binding [22]. Even if there is no formal land-use planning at the national level, the Planning Agency has access to the plans prepared by public entities that apply for the national issues, such as plans for power structures, transportation, and nature conservation [22].

Iceland is not a member of the EU. Given that Iceland is located far away form the European continent, no other European country has the same extreme conditions as Iceland does [23]. However, it would be wrong to picture Iceland as an uninformed and isolated country [23]. Especially the emergence of regions and regional planning procedures indicate that Icelandic planning is becoming more and more compatible with other European planning systems [23]. In Iceland each municipality is responsible for having a municipal land use plan, and neighbouring municipalities may draft a regional plan to co-ordinate inter-municipal planning in cooperation with one another [22]. The provisions set in the municipal plans are elaborated further in local plans, where planning and construction requirements for a respective area are also described in more detail [22].

3.3.2 Norway

The Land Act and the Plan and Building Act frame the Norwegian system of spatial planning [22]. National guidelines, such as the guidelines on transport development in relation to land use and the guidelines on coastal land use in the Oslofjord area, carry strong planning implications [22]. In some instances laws may even be introduced to restrict construction in certain ways, as for example in 1999 when the Norwegian Government introduced a moratorium on the establishment of new shopping centres above a certain size. Even if the Ministry of Environment acts as the national planning department and has the overall responsibility for land use planning, most regional planning issues also involve the Ministry of Local and Regional Affairs and the Ministry of Labour and Administration [22].

Unlike Iceland, Norway often behaves as if it were a member state of the EU, keenly following European debates with regard to spatial planning and even fully participating at its own expense [23]. However, with regard to the system of the three planning levels, Norway seems to want to marginalize or abolish the regional level whereas the EU is actually opting to strengthen the regional level [23]. The scope, ambition and legitimacy of regional planning activities in Norway have been substantially devalued and subsequently changed over time [22]. Municipal councils are the main loci of spatial planning, being responsible for municipal master plans and zoning plans [22]. However, regional authorities have the right to make objections in relation to municipal master plans and if the planning parties fail to agree, municipal master plans cannot be adopted by the municipal council but must be sent to the Ministry of the Environment for a decision [22].

3.3.3 Finland

In Finland, spatial planning and land use are controlled by the Land Use and Building Act and are governed in more detail by the Land Use and Building Decree and by Finland’s National Building Code [24]. The Finnish hierarchical land use planning system has one level of national land use guidelines and three levels of land use plan. Higher-level plans steer lower-level plans, and the Finnish Government defines the national guidelines that must be taken into account and promoted in all land use decisions and spatial planning [24]. Among other issues, the quality of the living environment, governance of regional and urban structures, the use of natural resources, the energy supply and the natural heritage are covered under the guidelines [24]. The Finnish Environment Institute conducts environmental research and monitoring related to spatial planning.

Finland’s administrative set-up has been influenced by EU membership. Already before joining, the need to adapt to EU Structural Fund regulations encouraged Finland to strengthen its regional institutions [23]. Regional councils are responsible for regional land use plans that cover each of Finland's 18 regions, steering decisions on issues that are of a trans-municipal or regional nature and setting out a legally binding general framework for more detailed local plans [24]. Municipalities draft local master plans and local detailed plans that must be approved by local municipal councils [24]. The Centres for Economic Development, Transport and the Environment have the task of controlling municipal planning and construction within their respective regions [24].

3.3.4 Sweden

In Sweden, the legal structures of spatial planning consist of the Environmental Code and the Planning and Building Act. The national environmental interests, such as threatened natural environment and important natural resources, are defined in the Environmental Code [22]. Sweden shows a high degree of Europeanization in adapting to trends set by Community policies, and in Sweden the Strategic Environmental Assessment (SEA) is strongly integrated into legal structures [22], [23]. Both the Environmental Code and the Planning and Building Act include legal demands for SEA that apply to comprehensive plans and to detailed development plans, as well as to different sector planning activities – for example, infrastructure planning [22]. The Ministry of the Environment has the main responsibility for spatial planning on the national level, while the Ministries of Agriculture and Industry are also responsible for several planning related issues, such as agricultural policy and regional level transport planning [22].

Nevertheless, spatial planning is mainly decentralised in Sweden and is more of a municipal concern. Regional plans are made only if there are issues clearly concerning more than one municipality, and the plans are unbinding [22]. More formalised regional planning occurs only in the Stockholm region, and to some extent in the Gothenburg region [22]. At the regional level, land-use planning is relatively weak when compared to other Nordic Countries and the municipalities hold the "monopoly of spatial planning" [22]. Comprehensive plans typically cover the whole municipality, setting the long-term aims for land and water management, but these are not binding. Detailed development plans are the only binding land use plans covering varying parts of the Swedish municipalities [22].

3.3.5 Denmark

In the Nordic spatial planning context, Denmark could be described as being rather enthusiastic, being both active in the field of national planning and being involved in trans-national projects [23]. The main objective of the Danish Planning Act is to ensure that planning synthesizes the interests of society regarding future spatial structure and land use and to ensure that planning contributes to the protection of the country's nature and environment, safeguarding the sustainable development of society with respect to people's living conditions [23]. The national spatial planning reports represent a combined national and European perspective to urban development [23]. The Danish Ministry of the Environment and the Spatial Planning Act control land use and spatial planning and the Ministry of the Environment leads seven Environment Centres that control spatial planning in municipalities where there may be a connection with the interests of the overall state [23].

Compared to other Nordic countries, Danish physical planning has a strong position in the competition between planning and economically oriented regional policy [23]. Regional councils draft regional spatial development plans to set out the development vision for respective regions. Interestingly, from 2007, those plans are guiding documents with no binding power over the land use planning of municipalities [25]. Municipal councils, on the other hand, hold all responsibility for municipal plans that form the framework of detailed local plans [25]. The Danish planning system is closely linked with the political electoral processes, giving spatial planning both legitimacy and flexibility [23]. After each election, the Minister for the Environment publishes the new government's visions for future developments. Given that Denmark puts much importance on the national control on land use, the planning system in Denmark can be seen as being more similar to those of for example Germany or the Netherlands, as opposed to those of the other Nordic countries [22].

3.4 Environmental evaluation tools for urban structures and land use

Collaboration between research centres, universities, municipalities and construction companies is not unusual in developing environmental assessment criteria and evaluation tools. In a recent study, 40 eco-efficiency evaluation tools were suggested to have the potential to be useful for regional analysis in Finnish municipalities [26]. Nine of the tools (British BREEAM for Communities, American LEED for Neighborhood Development, three Japanese schemes: CASBEE for Cities, CASBEE for Urban Development, and NILIM tool, Australian Green Star Communities, and three

EU-based tools: ECO-City, Eco Label, and EU GPP) have been designed for international use, and may thus have a unifying effect on the definitions of regional sustainability in the Nordic countries [26]. Diligentia, which is one of Sweden's largest real estate companies, has already started to apply the British certification system, BREEAM for Communities, to urban development projects in Sweden, and the Masthusen development in Malmö is expected to become the first certified project outside of the UK [27].

On the other hand, however, the environmental assessment tools of urban structures typically have a strong linkage to the region for which they were developed to evaluate, and the effectiveness of their application is thus dependent on national standards, regulations, building codes, cultural heritage, and local ways of living [28]. The setting of local environmental goals may therefore rely on evaluation tools whose criteria may have a dependency on specific local social and cultural conditions. Given that municipalities need environmental evaluation tools and sustainability comparisons to support local decision-making processes, there is a certain contradiction between the need to obtain assessment indicators that allow comparison between jurisdictions and the desire to reflect local concerns in the evaluation criteria [4].

3.4.1 User perspective

According to the concise survey conducted, it seems that one of the highest priorities for urban planners and city developers is that environmental evaluation is on one hand based on reliable and credible scientific research and on the other hand produces understandable results through a transparent process. In contrast, the urban planners and city developers do not see international certification as an important element of environmental assessment. However, of the respondents who work for the public sector, one third had never used an environmental assessment tool. Within the public sector, environmental evaluation has been conducted mainly for research purposes and within pilot projects. In contrast, the respondents who work for construction companies were largely familiar with environmental assessment methods, and had utilised such international schemes as BREEAM and LEED.

According to the survey, municipalities and construction companies require regional environmental evaluation tools that (1) are based on credible, comprehensible and transparent calculations or criteria, (2) produce simple, clear and illustrative results, (3) are effortlessly available and easy to introduce, (4) can be applied to multiple levels of urban planning, (5) are based on scientific research, and (6) respond to the specific needs of local urban planning. Nevertheless, according to the survey, a good evaluation tool does not need to (1) be a part of a certification system, (2) be designed for the planning processes that local inhabitants and companies or other non-professionals can take part in, (3) operate in Finnish, or (4) operate as two different versions, of which one is lighter and quicker to use for rough preliminary analyses. Even if the effortless availability of the tools is seen as important and even if the evaluation results are wished to be simple and easy to understand, the use of English instead of Nordic languages is not considered problematic.

In general, active partnership with local business and public determination is often seen as an important dimension of sustainable decision-making [e.g. 3]. Nevertheless, the respondents do not consider having a tool that can be used in planning by non-professionals such as local inhabitants and businesses as being a priority. Internationally, the traditional view of the building industry is that it is a conservative business, dominated by relatively small enterprises that have typically very limited budgets for research and training [29]. However, in Finland, construction companies typically take part in research projects as sponsors and often provide valuable data for case studies and pilot projects. In Norway, some construction companies have even expressed disappointment over the lack of ambition in new building codes [30]. According to representatives of the Norwegian Ministry of Environment, many enterprises actually ask for stronger environmental regulations, as long as the norms are fair and that the new regulations have uniform implications on all other parties in the industry [30].

3.4.2 Assessment criteria

The assessment of environmental sustainability is commonly associated with the derivation of indicators that can be used as measures of the state of the biophysical environment [31]. According to Ratti et al. [32], urban efficiency can be divided into four intervention opportunities, corresponding to four fundamental scales that constitute urban structures: (1) individual behaviours, (2) systems efficiency, (3) buildings efficiency, and (4) urban morphology. Nevertheless, still no single model or calculation tool is able to take into account all of these four factors at the same time [33]. The available environmental evaluation tools and assessment systems are extremely diverse [33]. However, these schemes are used to measure and thus define the environmental sustainability of urban structures and land use in the Nordic countries. This seems to be problematic for three main reasons:

Firstly, most schemes take into account only a small proportion of potential environmental impacts. Therefore, many actions that are intended to reduce a particular kind of environmental impact can inadvertently have even more environmentally damaging side effects [34]. For example dense urban structures typically reduce the greenhouse gas emissions of traffic but increases the proportion of exhaust particles that are inhaled by inhabitants [35]. Secondly, different timeframes and geographical restrictions of environmental examinations may significantly affect the forthcoming results and conclusions [36], [37]. There is still no consensus on the appropriate timescale for which intra- and intergenerational sustainability should be considered. Environmental decision-making appears to impact not only over the timescale of single generations, but over multiple generations [17]. Similarly, given that consumption and production activities are increasingly geographically differentiated as a global phenomenon, it should be recognised as imperative to consider supply chain wide impacts in the assessment of environmental improvements – an improvement in one location may have the effect of causing more harm somewhere else [18].

Finally, it is immensely hard to quantify the term 'environmental damage'. Complicated systems, such as total environmental load, are typically broken down into smaller units of analysis for ease of evaluation and decision-making [17]. A selection of indicators is thus typically used as the basis for predictions of environmental impacts. However, although it is possible to measure things such as greenhouse gas emissions, emissions of ozone-depleting substances, air quality, pollution of water bodies, waste generation, biodiversity losses, and the depletion of natural resources, their relative weight and importance is often an entirely subjective matter. Weighting systems attribute a greater value or contribution to one indicator or index than another, and this approach has drawn much criticism [4]. Weighting is an arbitrary process and none of the systems can rationally justify the attribution of the weight given to an indicator [4].

4. Discussion

This paper was set to examine how the general idea of environmental sustainability is defined in the context of urban structures and spatial planning in the Nordic countries. A literature review was conducted to examine the framework for the appliance of prevalent environmental aims, scientific knowledge, and available technology to local urban planning and land use in the Nordic societies. The creation and diffusion mechanisms of environmental knowledge, the European cohesion policy in environmental issues, the structures and characteristics of national land use planning systems, as well as the available environmental evaluation tools and assessment criteria were considered briefly. A concise survey was conducted to examine the user perspective.

It was found that universities and research centres as well as private business and non-profit organisations create environmental knowledge, produce environmental evaluation tools, and transfer the knowledge through both commercial and non-commercial activities. Joint knowledge generation is needed for obtaining shared visions, objectives and implementation of actions concerning environmental sustainability. In the Nordic countries, where spatial planning seems to be first and foremost a municipal specialty, important contributions to the definition of environmental sustainability can be made by promoting a certain understanding of sustainability in the education of spatial planning professionals. However, urban growth and the trend for governmental mergers on the regional scale have generated a need for more integrated land use planning, especially in metropolitan areas, and a thus stronger dialogue between the state and the municipalities seems to occur in the Nordic countries [22]. Despite the virtual taboo that rests on radical land use solutions, stronger regional level decision-making structures seem to be emerging [23].

Even if the EU legislation sets a certain framework for the appliance of environmental knowledge into the context of spatial planning, vertical integration of environmental policies within the member states seems to be rather weak, and institutional arrangements vary across the countries. Rather surprisingly, even in the Nordic countries, laws can not only promote but also prevent environmental sustainability [11]. According to representatives from Norway's Ministry of Environment, there is a long list of barriers to the transition to low-carbon societies in Norway that require change in the Norwegian legislation [11]. The SEA has proven to be a rather successful tool for the integration of sustainability goals at the EU and national policy levels [19]. High-level policy goals have been implemented to affect reductions in greenhouse gas emissions, the preservation of biodiversity and the use of renewable energy resources [19]. Given that especially Denmark, Sweden and Finland have a long history of strong environmental appraisal, Sweden's recent failure in complying with the EU's air quality standards is an interesting case that reflects the incoherence of EU legislation and national policies, even amongst the Nordic countries.

Finally, the availability, usability and content of environmental evaluation tools and assessment criteria play an important role in how environmental sustainability is taken into account in national guidelines and local spatial planning. Even if the sample of the survey conducted was small, the results indicate that in the Nordic countries, environmental evaluation is seen more as an element of the actual urban planning process than as a final assessment or green wash. Therefore, given the absence of standard and universal classification methods or approaches to designing environmental indicators, particularly at the municipal level, the selection of environmental evaluation tools critically affects the appearance of environmental sustainability in spatial planning. International rating tools have in some cases been accused of being too rigid and not taking into account differences in local climate, and socio-political conditions. However, the creation of a regional BREEAM for Communities scheme in Sweden offers other Nordic countries an opportunity to observe how a British certification system works in a Nordic context [27].

Urban landscapes are ultimately managed to provide user benefits [38]. According to Sager [39] the aim of public planning should be to solve urban problems in such a way that people are treated as citizens with political roles, rights, and agendas. However, in the current environment of market-oriented planning policies, people are seen merely as consumers and are being served according to their abilities to pay for a variety of services [39]. As a consequence, environmental sustainability is supported only to the extent that people are willing to pay for a stable climate, a clean natural environment, and rich biodiversity [39]. Given that all environmental strategies, be they international, national or local, have elements that are influenced by political interest, individual decision makers will also exert some influence on environmental issues. According to Hopwood et al. [3], the managerial outlook dominates the present discourse about sustainable development.

Comprehensive approaches to knowledge are needed for spatial planning to become an important instrument in the development of sustainable cities [38]. This, in turn, can promote our understanding of the many complex issues related to land use management [38]. However, insightful spatial planning and sustainable construction may provide no more than a 50% reduction of residents' emissions [30]. Given that there is a certain limit to the extent to which state and municipalities can control lifestyles, the end users of the built environment – people – have to affect the rest of the change through their own choices [30]. Theories on rebound effects are also important to take into account when considering single environmental improvements. It may not be wise to incentivise sustainable lifestyle choices through financial means if monetary gains are spent on increased consumption [30].

5. Conclusions

Although sustainable development has become a principle that all Nordic governments, as well as the European Union, seemingly aspire to abide by, the environmental assessment models and evaluation tools for urban structures are extremely diverse at the municipal level. There is no such thing as a single unified philosophy of environmental sustainability. Multiple and diverse stakeholders play significant roles in defining the environmental sustainability of spatial planning in the Nordic countries. Environmental strategies can be created through different processes and based on different levels of knowledge, but proper understanding of environmental sustainability requires familiarity with lifecycle thinking, global supply chain systems and weighting philosophies. This brief review of the Nordic framework for bringing environmental knowledge into land use policies and spatial planning practises will hopefully serve as a starting point for continued work on understanding the many complex issues related to the environmental sustainability of urban structures and land use.

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Sustainable urban development as an interdisciplinary challenge

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Keywords: sustainability, urban planning, urban development, co-operation, working methods, multi-target optimization

Summary

Sustainable urban development is clearly moving towards more interdisciplinary directions where multiple requirements should be optimized. Such multi-target optimization requires new approaches and co-operation methods instead of traditional processes.

Pöyry Sustainability Studio is a method for target setting in an urban development project resulting in the holistic and sustainable outcome. Through the Sustainable Studio it is possible to achieve optimized principles for sustainable development including concrete solutions for implementation.

The method is based on a tailored workshop for different stakeholders of an urban development project for creating a common vision of the sustainability. Experts from different competence areas of urban development (land use, energy, water, construction, real estate, traffic, landscape etc.) form up the core team of Sustainability Studio.

1. Introduction

1.1 New approach is needed

The process of urban planning is indisputably one of the key factors in achieving the ambitious targets of sustainability. The decisions concerning the land use issues made today will be affecting our environment for centuries. There are increasingly many economical as well as political interests directed to land use actions. Global climate change challenge also requires comprehensive approach from the developers of the future urban environment.

The arguments for creating sustainable communities exist now more than ever before. Decision-makers in cities and municipalities already have a strong desire to create eco-efficient, functional and modern urban areas, neighborhoods or even entire cities and city regions. Existing reference areas worldwide demonstrate that eco-efficient technological solutions are already available on the market with competitive price. The significance of urban land-use planning is rising on a whole new level when intentions are changed from words to concrete actions. However the process and business models for implementing the visions of sustainable communities still requires further development.

No single profession is responsible for implementing sustainability in urban planning. It can’t be assumed that planners or designers are able to interpret and apply all knowledge from number of researches, environmental impact assessments and new technologies. A new kind of expertise is needed for combining the expertise of various sectors involved in urban planning project.

1.2 Urban area as a complex system

Due to the fact that a community is a complex system, the challenge of creating sustainable environment is not solved sector by sector. Collected data on qualities of an area, calculation results, different analyzes and impact assessments do not necessarily give required information for the performance of the whole system. Need for extensive interaction is emphasized in today's design and operational environments which are increasingly cross-sectorial.

Residents are nowadays involved in urban planning process as a common practice and therefore interaction methods for residents' participation have developed in recent years. Similarly, the interaction between various experts, researchers and decision-makers should be improved as ambitious targets for sustainability that require common creative ideas.

There is a rapidly growing demand for eco-efficiency evaluation methods in regional planning and construction projects. In Finland a wide range of different domestic and international environmental assessment tools and methods are in use. These tools and methods are also developed further in projects by research institutes, private companies, municipalities and other organizations. The primary function of the rating tools is to facilitate the measuring of environmental, social and ecological impacts of a complex system. On the other hand there is a need to identify the most effective sustainability factors in regional planning and construction projects. At the same time simple and practical tools are needed for sectorial organizations or experts responsible for specific issues in an overall regional project.

Even the best tool does not make value choices on behalf of the user. It is important to note that tools are often built on the basis of value choices or decisions of what and how to calculate and how different viewpoints are emphasized. The solution may vary depending on the selected tool due to the value choices included in the tool. Therefore the weighing system behind each tool should be clarified.

Tools are including value choices because of the fact that sustainable development factors are not all directly measurable ones. Weight coefficient for each sustainability factor is determined on the basis of how valuable, rare, critical or harmful the effect is considered. Tools are needed, but experts should know how to use them. In other words compatible tools should be used for appropriate purposes.

Planners and decision-makers might expect tools to compress a huge amount of data down to a single number or otherwise simplified results that should be easy to understand and to communicate. If such a simplification method is used, the underlying option values should be clarified and the limitations highlighted. Openness and transparency are the basic requirements for assessing impacts in order to clarify and to validate the results. This way tools can be used by experts in design teams for supporting the well-organized process without replacing the experts and processes.

Starting points for urban planning vary by location. In urban and rapidly growing areas challenges are different than in the areas with decreasing population. However, sustainability can be created anywhere despite of the economic structure or the density of population.

2. Method for multi-target optimization

2.1 Sustainability Studio

A holistic view for urban planning requires clear understanding of the process aiming to sustainable urban development. Based on Pöyry's project experience a working method called Sustainability Studio has been developed. This method is based on a tailored and well-prepared workshop for stakeholders of an urban development project to create a common vision of the level of sustainability.

A streamlined co-operation between different experts is essential as urban development is an increasingly interdisciplinary subject. Experts from various competence areas of urban development (energy, water, land use, construction, real estate, traffic, landscape etc.) form the core team of Sustainability Studio.

Each Sustainability Studio is a tailored event for meeting the needs of the client and facing the problems to be solved. Each building site has its own qualities; each project has its own features, own budget and each participant their own ambitions towards the project. These factors create a unique starting point for each Sustainability Studio case.

In Sustainability Studio the experts work together with project stakeholders to create a common vision for the site specific sustainability. This vision is documented and approved. The common vision forms a platform for the project.

Benefits of Sustainable Studio method are:
1) Flexibility to meet the needs of unique projects.
2) Genuine co-operation created between experts and project stakeholders to find most efficient solutions.
3) Realistic approach to sustainability. Economical and site specific limits of each project are fully considered and a framework created for possible sustainable solutions.

2.2 Each project is unique

Key point of the studio is to find the most crucial aspects of sustainable development in each separate case. Aspects of sustainable urban development are derived from international certificate systems (LEED and BREEAM). These certificates can be regarded as most acknowledged frameworks for sustainable development in green building context and as useful best practices. These international certificate systems also have weaknesses. Despite of the locally adjusted versions they are not very easily tailored or do not manage to meet all the site specific factors. From Sustainable Studio point of view a separate analysis driven by field experts is necessary to achieve a fully holistic and genuinely sustainable outcome.

As Sustainability Studio is each time a unique event, the outcome of the Studio varies from documented planning principles to complete strategic or implementation papers for the whole development project. The outcome of the Studio from the client's point of view includes the following dimensions:
1) Multidisciplinary and enlightening approach to the concept of sustainable development
2) Identifying the most crucial aspects of sustainability
3) Clear definitions of the objectives and the level of sustainability of the project which is to be agreed and committed by all participants and actors.
4) Step by step road map for the achievement of the objectives: defined action points, realistic timeline and responsible bodies for each operation.
5) Accurate estimation of the economic consequences of the actions implemented during the development project.

With Sustainability Studio, Pöyry has developed an in-house solution for increasing and demanding challenges of sustainable development. The involved experts have learned from each other and deepened their own expertise. This is also one of the key factors of the superiority of Sustainability Studio.

3. Case client UPM

3.1 Case area

Sustainability Studio was conducted as a part of a master land use development plan for a large woodland area owned by Finnish Biofore Company. The planning area was 31,6 square kilometers and it's located 135 km from Helsinki. Cities nearby are Heinola, Lahti and Kouvola. In the North the area is bordered by Heinola city center and in the South by the Sport Center of Vierumäki. The bordering line in the West is E75 motorway and railroads and in the East the planning area is connected to a large lake area called Konnevesi.

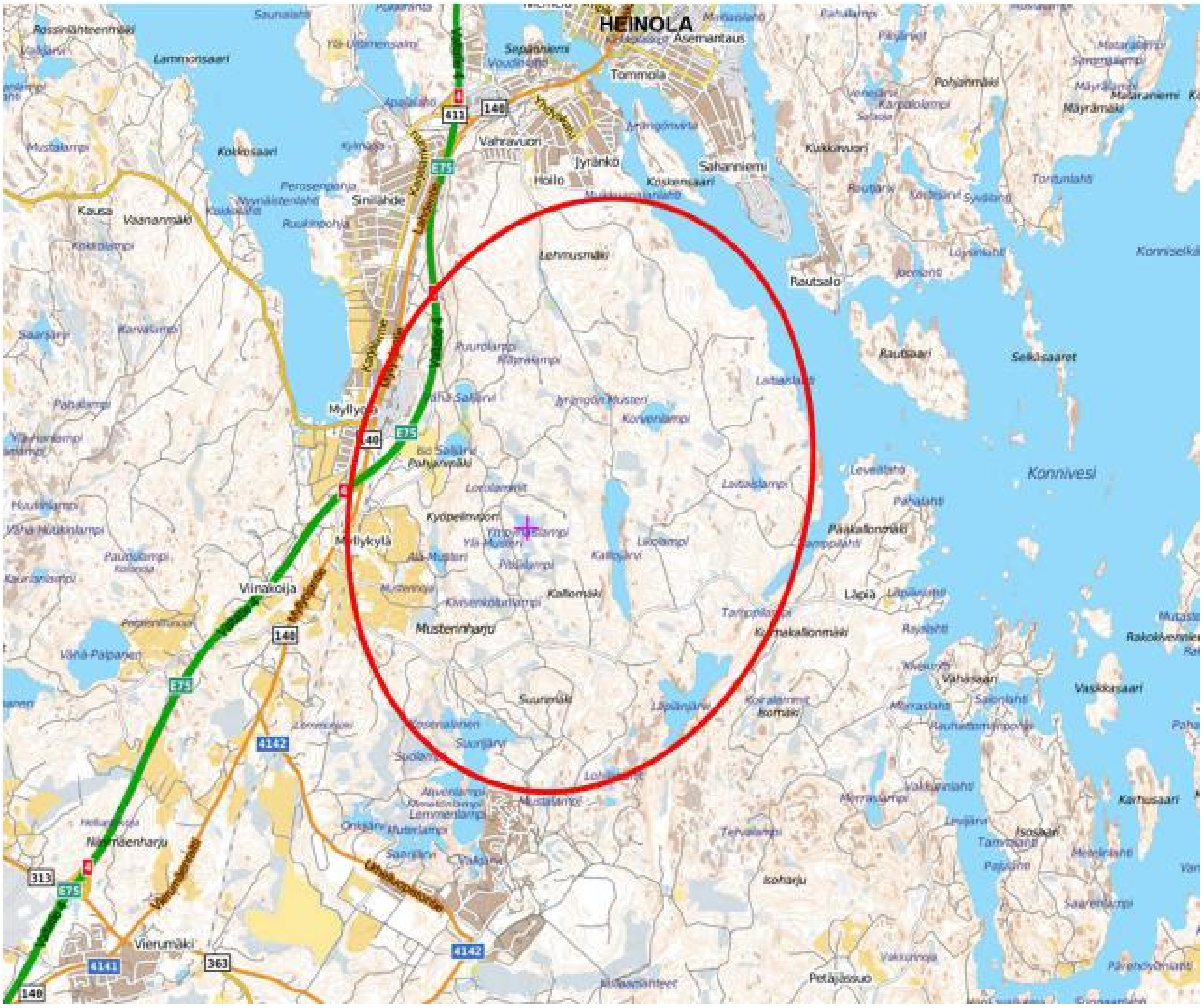

Fig. 1 Map of the case area

The site is rich with recreational possibilities. Within a radius of 40 km of the planning area there are a number of significant nature and hiking destinations. On the area and its immediate neighborhood there are two Natura 2000 conservation areas. In addition, the region contains an area of esker protection, valuable rocks and valuable ground water reserves as well as other nature and landscape values. There is a railway connection from Heinola to the direction of Lahti although there exists no passenger transportation at the moment.

The planning area will be indicated to tourism, well-being and leisure activities and services. These will support the existing leisure services offered by Vierumäki Sport Center. Ecological values are emphasized in future trends of tourism which is highlighted in the planning process. Another challenge will be the variation of different user groups with detailed needs. Seniors as well as families with children are increasing user groups.

3.2 Outcome of the Sustainability Studio

The principles of sustainable development of the area were identified with Pöyry Sustainability Studio. The Studio was completed in co-operation with bodies responsible for the project and resulted in tailored guidelines for future planning to support sustainable development.

The three key aspects enabling the sustainable development on the area were identified. These are 1) the flexibility of the plans, 2) sustainable transportation and 3) integrating the built environment as a part of the ecosystem.

Flexibility of the plans can be performed by zoning in the phases, leaving reserves for alternative purposes of use and promoting the development of new ways of implementation and creative solutions in future planning.

In order to decrease the dependence on private motoring, an assessment on traffic potentials will be carried out. Possibilities for different models of transportation within the area as well to the node points and services close by will be estimated.

Integrating the area as a part of the ecosystem can mean self-sufficient energy systems with renewable energy sources, material efficiency with closed loops, water efficiency and organic storm water management system.

Renewable energy sources and energy efficiency are crucial in targeting the environmentally friendly and self-sufficiency system. In the early planning phases it’s essential to anticipate the future solutions and the development of technologies.

Material efficiency will be put into practice by chosen building methods and materials. Use of wood as a local material will be maximized. When building infrastructural systems the balance of landmasses will be regarded and extra soil utilized locally.

The level of clean water consumption will be estimated and the possibilities to utilize lake water as well as grey waters as a part of water supply system will be studied. Water-saving technology will be used to minimize the water consumption.

4. Conclusions

Entwining different aspects and targets of stakeholders is an essential part of urban development. As economic and ecological demands indicated to projects are increasing, the significance of the co-operation and interaction between participants is emphasized. New information about environmental impacts is delivered constantly and should be taken into account and applied to local circumstances as a part of the urban planning and implementation process.

One can say that sustainable urban development is clearly moving towards more interdisciplinary direction where multiple requirements should be optimized. Such multi-target optimization requires new approaches and co-operation methods instead of traditional processes.

Pöyry Sustainability Studio is a method for target setting in an urban development project resulting in the holistic and sustainable outcome. Through the Sustainable Studio it is possible to achieve optimized principles for sustainable development including concrete solutions for implementation. As the final outcome of the Studio will be agreed on and committed by all interest groups, the process is easily made visible for decision makers and it simplifies image building and branding of the developing area.

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Exploring ways to successful resident-driven infill development: Lessons learned from two cases in Helsinki area

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Summary

The current study aims at understanding the factors which promote or hinder infill development project from residents' perspective. To reach the aim, altogether 10 theme interviews were held in two case commonholds located in Helsinki area, Finland. The findings of the study revealed four important factors related to infill development from residents' perspective: 1) project management, 2) third party information, 3) communication and 4) costs and benefits of infill development project. The study findings indicate that infill development is a complex phenomenon from resident's perspective requiring support from different actors. It also became evident that residents' decision making is not just rational calculation of financial gains and losses but it also involves emotional features (experiential and symbolic in nature).

Keywords: infill development, resident, commonhold, Finland

1. Introduction

The way of living is experiencing drastic changes. Number of people living in urban areas is growing which generates more demand for living space and denser cities. On the other hand, the trend demanding more eco-efficient way of living is growing (e.g. [1]; [2]). Together, these issues generate a need to develop more compact urban infrastructure.

One approach to tackle the need is infill development. Several benefits of infill development have been identified in literature. For instance, [3] state that infill development increases the population and generates more investments in the area. Also [4] identify several benefits of infill development. They notice that as the population increases, also companies are more interested in the area contributing to maintaining the already existing services and to offering new ones. Moreover, literature reveals that infill development has positive influence on reducing poverty and providing security to the residents living in the area [5], [3].

In addition to the several benefits attached to infill development, there also exist barriers hindering it. Some of the barriers are related to the society while others to the residents' disagreement with the infill development plans. As an example to the previous, [4] mention the pressure caused by infill development to provide more public services leading to a heavier taxation. It is also possible that the suitable land for infill development in the area is owned by several landowners making the process more difficult [6] or social segregation will increase due to the high price of infill development [7].

Anyway, among the most important barriers to infill development is mentioned to be the opposition of current residents in the area [4]. Some reasons for the residents' opposition have been recognised. For instance, [8] reported that residents are worried about loosing their parking plots due to the infill development and [9] stressed residents' concerns related to recreation areas such as parks. Also increased traffic caused by infill development has seen to worry residents [6]. These resident related barriers attached to infill development (and many other reported in the literature) show the importance of understanding residents and their wishes and fears to enable successful infill development projects. However, as typical in all housing consumption related literature, also studies regarding infill development are mainly focusing on monetary, neighbourhood or apartment issues (e.g. [10]). As [11, p. 1610] emphasises, housing studies: "typically preserve the central neo-classical assumption of a utility maximizing individual, while allowing the world in which the individual acts to be characterized by 'imperfections' such as non-market clearing, disequilibrium, uncertainty and government 'intervention'". The previous statement is in line with [12, p. 239] observation that "the (housing) purchase decisions were based on a few, very crude decision criteria working as guidelines for judging whether or not the alternatives considered were acceptable, while the final choice seemingly was made according to an affect-referral decision rule". This means, that it is important to notice that residents probably do not make solely calculative and money-related decisions but also emotional issues have effect on housing consumption. This point should be addressed in a context of infill development as well to understand residents more thoroughly. Thus, *the aim of the study is to understand the factors which promote or hinder infill development projects from residents' perspective*. To reach the aim, resident interviews were conducted in two commonhold cases in Helsinki area, Finland. The findings of the study are intended to contribute to management, planning and execution of future infill development projects.

2. Method, data collection and analytical approach

To identify the case commonholds, the City of Helsinki officials were met and requested to describe infill development projects conducted during recent years. Based on these discussions, two cases located in Helsinki were selected. In both cases, the main driver for the project was forthcoming water pipe renovation leading to a need for significant financial resources. The main idea behind the case selection was that the two cases should be different allowing as rich data as possible regarding the studied phenomenon and to lead to a detailed understanding of the success factors and drawbacks of infill development projects from residents' perspective.

In the first case, the infill development project was straightforward and finished in approximately three years (2004-2007). The case commonhold includes six separate 3–6 floors buildings (built in between 1951-1953) with altogether 116 apartments. All the buildings are located on a plot which is owned by the commonhold. During the infill development process, a separate plot was parcelled out for the new, infilled commonhold. The new building includes 18 apartments in four floors.

The other case was more difficult. The decision making within commonhold took several years (2005-2012) before the construction was initiated. The case commonhold includes two six floor buildings (built in 1959) with altogether 148 apartments. Both buildings are located on a plot which is owned by the commonhold. As in the first case, a plot was parcelled out and sold for the new established commomhold. The new building with five floors and 25 apartments is currently under construction and it is expected to be completed in 2013.

To achieve the aim of the study, semi-structured theme interview was selected as data collection method. In semi-structured theme interviews, the themes and questions are prepared beforehand but the interviewee has a freedom to answer meaning that no readymade answers are given to the interviewee [13]. This kind of procedure releases interviewee from researcher's perspective and gives room for interviewee's own perception, but at the same time limits the interview to the given topic. Semi-structured theme interview is also seen as suitable method especially when the study topic deals with issues the interviewee does not discuss or consider on daily basis (such as infill development) [14].

The themes selected to the interviews were based on the previous literature in infill development and housing. Also several brainstorming sessions were held among the research group to challenge the selected themes and revise the interview guide. As a result, the following three main themes were included:

1) **General description of commonhold and shareholders' meeting.** The main reason for this theme was to discuss about the commonhold and shareholders' meeting (e.g. what type of people live there, what is the condition of commonhold, what is a normal shareholders' meeting like) in general level to get background information on the case commonhold. The choice was made as in Finnish system, commonholds are considered as corporates in which each apartment entitles its owner to a certain amount of shares and right to vote in a shareholders' meeting. Shareholders' meeting is the deciding body of commonhold in which all the major decisions (such as infill development) are made.
2) **Description of infill development project.** Under this theme, the interviewees were asked about their perceptions on the commonhold's motives for the infill development project, current status of the project, management of the project, communication related to the project and their general perception on whether the project was conducted successfully or not. The idea of this theme was to capture the interviewees' general considerations regarding the project and activate their memory before going into more detail to the success factors and drawbacks of the project.
3) **Information processing.** This theme was about the interviewees' decision making related to infill development project. The idea was to capture the issues which interviewees' considered important while making the decision on whether to support or oppose infill development project. Thus, interviewees were asked about the source of information as well as the detailed reasons why they decided to either favour or oppose the project. To get into more details about the reasons, a theory of perceived value was adopted from marketing literature [15], [16], [17]. This theory proposes that individuals base their decision on calculations related to the perceived benefits and costs of decisions [18]. However, in addition to monetary benefits and costs, the theory also acknowledges emotional costs and benefits such as stress caused by the decision making or hedonic and symbolic value of the decision. Thus, this approach was deemed as suitable to go beyond the rational and monetary reasons for housing, or in this case infill development decisions.

The data was collected during 2012 (and is still ongoing). Altogether five interviews were held among the residents of both case commonholds. All interviewees had been living in the commonhold during the infill development project and were the owners of their apartments meaning they had right to participate in decision making in shareholders' meetings. Major part of the interviews concentrated on residents' perceived benefits and costs towards the project and the underlying reasons for those. The interviews lasted between 45 min to 90 min and were held in the interviewees' homes or in public places such as cafeterias. To ensure the completeness of the data and analysis, the interviews were tape-recorded and transcribed. Each interviewee was given a token worth of 30 euros for participating the study.

The data was analysed in a following manner: The transcribed interviews were read several times with emphasis on iteration. In this case, the iteration means a continuous movement between the individual case descriptions and the emerging understanding of the entire set of textual data. The reasoning behind this type of analysis is to develop provisional understanding, challenge it and further develop it through an on-going iterative process [19], [20]. The boundaries for the iteration were generated by the themes of the study. The analysis strived for developing more detailed and abstract categories which the residents considered important in terms of infill development.

3. Findings

This section reports the findings of the study. In general, the analysis revealed four main categories which emerged from the interviews and which the interviewees considered important from infill development perspective. These are:

1) Project management;
2) Third party information;
    a. professional information
    b. layman information
3) Communication;

4) Costs and benefits of infill development project;
    a. monetary costs and personal sacrifices
    b. functional benefits
    c. experiential benefits
    d. symbolic benefits

The content of the categories varied between the two cases. Thus, in the next sections the findings from both cases are reported separately. In conclusions, the findings from the two cases are contrasted in order to reveal the differences and generate additional understanding on reasons which, on the one hand, promote infill development process and on the other hand complicate the project from the residents' perspective.

3.1 Case area 1

The motive for the infill development project in case 1 was the need for monetary resources to conduct water pipe renovation. According to the interviewees, approximately one third of the expenses were covered by parcelling out and selling the plot for the new infilled commonhold. This naturally served as one reason for the successful project. What also became evident from the interviews was that the residents considered the project understandable and clear from their perspective. The reason for this was the *management of the project*.

According to the interviewees, both the chairman of the commonhold and the deputy landlord were active on the project. The interviewed residents described their work as focused and determined but also honest. What seemed to be important was that the interviewees considered that all issues brought up in shareholders meetings were well prepared and easy to understand which contributed to their positive expression on management. Basically, the only negative comments on management were that one interviewee considered that the managing persons had lack on both technical and financial knowledge and other interviewee was disappointed that the managers did not give the residents opportunity to influence on the design of the new building. Despite these lacks in management, it became evident from the data that the management of the project in general was successful from the residents' perspective.

"The then chairman of the board was very excited about infill development… He even planned some additional parts to the high buildings which would have been quite massive… And he planned the infill development and when the process moved on then nothing could have stopped it…" Male/case 1

The second main category identified in the interview material was related to *third party information*. From the residents' perspective, the use of professional third parties in the project was minimal or at least the interviewees did not remember well the parties which might have been involved. This indicates that the need of such actors was not considered relevant during the project. Anyway, one resident remembered that the construction company participated some shareholder meetings and presented its plans related to the new building, the easements allocated to commonhold's remaining property and what kind of shared functions the new and old commonhold will have. One resident also pointed that the city of Helsinki gave the permission for the project rapidly. On the other hand, one resident was of the opinion that the information given by the third parties was somewhat contradictory and was not helpful in decision making.

"I think some third parties were involved… but I wasn't in board at that time… I can't remember those who were involved, but I think there was some…" Male/Case 1

The other type of third party information was also identified in data. This information origin from *layman parties* such as friends, family and neighbours. Some interviewees told that they had had discussions about the infill development project with these parties. The main idea of these discussions was to interact with some unofficial party to reduce stress related to the project and also to monitor how the project is going on from other laymans' perspective. However, those interviewees who discussed about such behaviour mentioned that they did not want to have these discussions to support decision making but more like to "release steam".

”Well, we wondered the construction… you know what they are doing here and what will they do there. How you can drive to the garage via that hill when the road comes so high and you should drive down there. And how our garbage bins used to be down there and how they try to fit those in that corner…” Male/Case 1

The third category, *communication,* includes communication from different parties related to infill development project. In the case 1 commonhold, the interviewees did not remember well what type of communication they received during the project. Some interviewees remembered that leaflets were offered in bulletin boards and drawings of the new building were available on some website (the interviewee did not remember who was offering this information). In general, the interviewees did not consider that communication failed in any stage of the project and did not express need for more communication.

In terms of the *costs and benefits*, some monetary costs of the project were perceived by the interviewees. One interviewee stated that the commonhold lost some money as she considered that the price of the plot which was sold was relatively low. Also one of the residents who opposed the project, perceived stress and frustration during the project because he thought that the minority of residents who opposed the project were ran over by the majority and their concerns were not considered sufficiently. This reflects other type of cost, that is, personal sacrifices. Anyway, these costs were not considered as critical in terms of accepting the project which indicates that the costs in general were, at maximum tolerable, for the residents.

“A: One thing which came in to my mind was that the commonhold was not the only one which benefitted… Of course the constructor benefitted definitely and got a good business, but that how it goes..

Q: Do you think commonhold should have been paid better? When you saw the prices…?

A: Well, lets say that the prices of the new apartments could have been moderate…” Female/Case 1

“Of course then the decision making was stressing when we waited the voting and the results… even though it began to look like the others will run over us anyway…” Male/Case 1

Several *benefits* of infill development project emerged from the interviews. Some benefits were associated with the improved living surroundings and technical performance of the commonhold, that is, *functional benefits*. For instance, the monetary resources received by selling the plot covered almost one third of the water pipe renovation which contributed significantly to the technical functionality of the commonhold. The interviewees also mentioned that a right of first refusal on the new parking plots which were located in a parking hall under the new building was offered to those residents who suffered most harm related to the project (however, this right was not used by the interviewees and they did not know if some other resident had used it). All residents had also a right of first refusal on the new apartments, but the interviewees considered the prices relatively high leading them to refuse the opportunity. In addition to the previous, other functional benefits emerged as well. Some interviewees considered that the services in the area could be maintained due to the new building and increased population. At the moment, the services are adequate, but the interviewees considered that those are diminishing all the time and were afraid that at some point important services are no longer available (e.g. grocery stores, postal services).

“*Of course, without the project there would be all renovations and their costs so if there wouldn’t been the project the pipe renovation would still be pressuring… So in that sense you can say it was worth of it.”* Male/Case 1

Instead of only functional benefits, also other types of benefits were associated with the project. The interviewees mentioned that the living surrounding improved as the new building was located on an area which used to be untidy and without any real use because of the sharp cliff. The interviewees also considered that the townscape and the overall impression of their living area improved due to the new building. What was also considered important among some interviewees was that the new building did not diminish green areas or other recreational areas such as playgrounds. All these benefits refer to *experiental* benefits meaning that some aspect of infill development is related to more emotional than functional or monetary issues.

"*The area is now a bit more tidy what it was earlier when there was no building… It was quite a sharp cliff…"* Female/Case 1

3.2 Case area 2

The motive for the infill development project in case 2 was the same as in case 1; to gain financial resources for water pipe renovation. However, the potential monetary resources were significant compared to case 1. In the end, the entire water pipe renovation was financed by selling the plot for the new commonhold (and some were left over for future renovations). However, unlike in case 1, the infill development project was more difficult leading to a division of residents into groups either favouring or opposing the project. Also several official complaints and even disturbance and quarrelling between residents emerged. This indicates that the potential financial incentive (even significant one) available for commonhold planning infill development is not enough to enable straightforward process. The following paragraphs tackle the main issues the residents brought up which might shed light on why this particular project was a difficult one.

In terms of the *project management*, some residents perceived the management as determined and sufficient. The interviewees who favoured the infill development project considered that the chairman of the commonhold and the deputy landlord were the main actors who managed the project and their activities were considered as firm and determined. On the other hand, those who were on the opposing side gave strong criticism towards the project management. They considered that the project was forced and some decisions were made behind the commonhold administrative board's back (esp. by the deputy landlord) leading to a lack of trust in project management. This was also one of the reasons the opposing residents considered to be a source of quarrelling between the residents and the negative atmosphere in the commonhold. In addition to that, the opposing interviewees considered the planning of the project insufficient and they felt they did not have enough information to make decisions regarding the project.

"*The chairman of the board has been deeply involved with this… I know her… And I gave her a right to represent me by proxy when I wasn't able to participate the shareholders' meetings… And she has always informed me in very details what has been decided and what has happened… I have never considered that I need something more…* " Female/Case2

"*The whole process and management was forced, but now the new building is there as majority of the residents wanted*." Female/Case 2

"We didn't get much information… And perhaps the worst thing was that the deputy landlord had made some agreements about the road to the new building with the constructor behind the chairman's back… It decreased the trust." Female/Case 2

Case 2 included some *professional third parties* which assisted in decision making. The residents' opinions on these parties and their importance in infill development project varied. Some interviewees found the third party involvement as positive while some as negative and confusing. In comparison to case 1, the interviewees also remembered very well which third parties were involved (indicating that the project was more intense than in case 1). The third parties mentioned in the interviews were 1) lawyer from the Finnish Real Estate Federation (chaired one shareholders' meeting to control the decision making), 2) real estate agent who had evaluated the impact of the new building on the price of old building's apartment price and served as advisor in negotiations between the commonhold, city of Helsinki and constructor, 3) lawyers who reviewed all contracts between the commonhold and some other party (the reason was to avoid conflicts), 4) Helsinki city architect who presented the plans for the new building and 5) constructor which informed residents about the building project and its effect on residents' everyday life.

As mentioned, some interviewees considered the professional third parties' information positive. The main reason for this was that they found the third party involvement increasing trustworthiness of the project and made their decision making easier. They also found that as the decision making process within commonhold became more and more difficult, the third parties' involvement was necessary to avoid possibility of complaints related to formal errors which might lengthen the project (esp. the lawyers who reviewed the contracts were perceived very important from that perspective). On the other hand, third party involvement was perceived negative as well. Especially the city of Helsinki activities were perceived problematic by some interviewees. This was related to the traffic arrangements to the new building via the old commonholds' plot which did not pleased all residents (some interviewees even stated that the traffic arrangements were the main reason for opposing the project). The interviewees were slightly confused as they felt that the city of Helsinki did not have any reasonable justification for such traffic arrangements, but the officials did not want to listen residents' views and consider any other option. Another negative aspect of the third party involvement was the language and terminology the professionals used. It was not fully understood by some interviewees which caused confusion and frustration, thus the interviewees would have preferred written information which was rarely delivered.

"*We had real estate agent who was some kind of an expert. And then we needed, mainly due to the internal disputes, ask assistance from lawyers just to make opposition happy, so that all legal aspects have been noticed. And I think it was a good thing so that no one needed to question those anymore…* " Male/Case 2

"A: *It was just like that. Mainly I remember how those issues were handled…. There was always someone to give presentation and explaining things… But as I said, I didn't learn much in those meetings. At first, I tried to write everything down but then I always had difficulties to follow and in the next step I didn't understand anymore…*"

"Q: *Did you wish that the information would have been clearer?*"

"A: *Yes, as I said in some point, they could have delivered the information in written… or via Internet… just so that I would have been able to understand and not try to learn the terminology in the meetings…*" Female/Case 2

The interviewees also had discussions with *layman third parties*. Some of them had discussed about the project with their relatives and also with other residents. These discussions were considered positive. For instance, one interviewee had discussed about the project and the stress it caused with relatives. The interviewee felt that this had positive effect on his personal well-being as it relieved stress and contributed on his capability to continue with the project. The discussions with other residents served different purposes. In one case, the interviewee had discussed with her neighbours to understand what the professionals had presented in shareholder meeting. In other case, the interviewee told that he had discussions with other (favouring) residents regarding the opposing resident group. According to him, these discussions infused his belief into the project and that in one day the project will be finished.

Communication related matters emerged from the interviews. Some interviewees considered that the communication was sufficient and enabled decision making. According to them, the communication was handled via bulletin boards and also via direct interaction between chairman of commonhold and residents. Despite some positive evaluations regarding the communication, also negative ones emerged. Perhaps the main reason for negative evaluations was the lost trust in communication. Some interviewees mentioned that the communication failed as the content did not match the reality (e.g. dates changed, disturbance caused by the construction work was underestimated). Some interviewees were also confused as they did not have knowledge on who is responsible for communication and who they should address if they had questions. In terms of failed communication, especially the constructor was mentioned frequently. One interviewee stressed that the constructor had promised to communicate about the schedule of construction but never did so. Also the channel of communication did not please some interviewees. They considered that nowadays it would be feasible to use Internet for communication and gather all relevant information electronically, especially because the commonhold had its own web pages. This would have helped them to keep track on the project and found relevant information easier when the amount of different documents grew.

"Q. *How was the communication regarding the project?"*

"A: *Well, not very well. I didn't always know what is going on."*

"Q: *Why so?*"

"A: *Well, they didn't communicate at all… First they announced that it begins on that day… Well it didn't."* Female/Case 2

Interviewees discussed about the *costs and benefits* of infill development project. Due to the significance of financial resources received from selling the plot, no money related costs emerged from the material. However, the interviewees (both those who favoured and those who opposed) perceived several costs which were more psychological in nature including stress and anxiety. The reasons for psychological costs varied. One interviewee considered that the spirit within the commonhold was negative due to the constant quarrels between the residents. On the other hand, another interviewee perceived the uncertainty regarding the process outcome very stressful as she would not have had resources to finance the water pipe renovation and thus she would have had to move away from the commonhold in which she had lived for a long time. Other reasons for stress and anxiety included the difficulty to participate the decision making due to the lack of own competence (caused by the difficult terminology and insufficient communication) and the potential that the new building might include solely rental apartments (the interviewee was afraid of disturbance).

"*Well, yes it was somewhat stressful when such a small commonhold has two groups with such a different views… Of course you can have your opinions, but when it went so far that you didn't even say hello in the yard… That was somewhat stressful*." Female/Case2

In addition to psychological and personal costs, the interviewees were concerned that the infill development project will have negative effect on the functionality of their commonhold and the near area. Especially, the traffic arrangements via commonhold's front yard concerned several interviewees (both favouring and opposing ones) as they considered the increased traffic might cause danger to people and also the car lights might disturb those residents living in ground floor. The new building also generates difficulties for daily routines as the shortest (unofficial) road to a local mall goes through the new plot making the trip longer. Also the current location of garbage bins will be changed which caused concerns how the garbage truck can move on the yard during winters (there is a sharp and slippery road to the new garbage bins). Finally, one interviewee was not satisfied that the forest disappeared due to the project as she was concerned about the birds and their well-being.

"*The problem which we will have… you should have own road to the new building, not via our yard. Well, city was against it because it would have gone through a park. And now the road goes via our commonhold front yard… It stays as an easement to us. I don't think it's a good thing, because we have a big commonhold and already parking plots in the yard so the road increases traffic… It doesn't bother me that much because my windows aren't to the yard but those who have… It completetely changes it… I think that caused the quarrelling…"* Female/Case 2

In addition to costs, also *benefits* of infill development project were perceived among the interviewees. One major benefit was the financial support gained for water pipe renovation which was considered to improve significantly commonhold's technical functionality. Other functional benefit emerged as well. This was related to the increasing number of people in the area which was considered to contribute to maintaining the services in the area and also improving the public transportation. Some benefits which were more emotional in nature were identified in the material as well. Some interviewees considered that the living area will become more comfortable and attractive when the untidy forest with drinkers will be log. Also the new building was welcomed by some interviewees as they considered that they live in an urban area and the building will change the area more urban like. In addition to the previous experiential benefits, also some symbolic ones appeared. More specifically, the status of the area might be elevated due to the new building and the area will become more attractive in the eyes of the outsiders. Some interviewees also considered that the value of commonhold's apartments will rise due to the relatively high apartment prices in new building meaning that the new people moving in the area will in general be wealthier thus contributing to the status of the area.

"*Because those will be owner-occupied apartments and so expensive that there isn't many people who can afford those… So it's definitely a positive thing…"* Male/Case 2

4. Discussion, Conclusions and Acknowledgements

The current study aims at understanding the factors which promote or hinder infill development project from residents' perspective. To reach the aim, altogether 10 theme interviews were held in two case commonholds located in Helsinki area, Finland. To gain more holistic view on the issue, two opposite cases were selected with the help of Helsinki city officials. In case 1 commonhold the project took only few years without any complaints. Contrary, the other case took several years with several complaints and even quarrelling between the residents.

The analysis of the interview material revealed four main topics related to infill development which residents considered important: 1) project management, 2) third party information, 3) communication and 4) costs and benefits of infill development project. Based on the findings, it could be stated that the financial resources gained via infill development project is not in a key role to enable successful project from residents' perspective. In the straightforward case 1, the potential financial resources were minor compared to the difficult case 2. Thus, the reasons for successful project from residents' perspective probably lay somewhere else. Other explaining factor might be the geography of the area, that is, the new building simply does not fit in the townscape and residents cannot approve the plans. According to the interview material, this was not the case either as only few arguments was made for opposing the project due to lost views or recreational areas. Instead, in both cases the plot for new building was at least to some extent considered as wasteland.

Perhaps one explaining factor behind the differences in the two case areas was the project management. In case 1, the interviewed residents pointed only few minor shortcomings in management. In case 2, the situation was completely different as some interviewees considered the project management as adequate while others gave strong criticism towards it. This might have set up the flames between residents and led to the division of residents into two groups who either favoured or opposed the project. In the end, this led to quarrelling (and even harassment) between residents and continuous official complaints causing stress and anxiety and prolonging the project. Also communication regarding the project in case 2 was considered somewhat failed among some residents. What was important was that some interviewees considered that due to confusing communication their trust in the project decreased. Also the professionals who were involved in the project used difficult terminology which made some residents feel incompetent to make decisions.

Naturally, the shortcomings in communication reflect also managerial issues. As usual in Finnish system, the board of commonhold consists of regular residents whose primary profession might have nothing to do with housing, planning or construction. Even with the help of deputy landlord, preparing infill development project might be extremely difficult for layman actors. More demands for the preparation includes that infill development projects are not common in Finland meaning that the city officials or other professionals might also have difficulties to provide assistance or to estimate schedules leading to a residents' decreased trust in the project. Thus, it is imaginable that such a situation can easily lead to severe difficulties as was in the case 2. When the problems cumulate, the situation might finally go beyond residents' rational thinking and the nature of the entire project might turn into emotional one which manifests in quarrels and complaints without real justification.

Based on the study, it seems reasonable to consider the management issue more thoroughly. As the Finnish society encourages commonholds towards infill development, it means that managing such demanding project should be supported by officials. In finding the ways for successful support, it is important to understand that officials need to listen the residents carefully. In case 2, both favouring and opposing residents considered the city of Helsinki decision to plan the road to a new commonhold via old commonhold's front yard "foolish" and "stubborn". Neither the justification for the decision did convince the residents as they considered themselves more professional on their own area than city officials. As this was frequently mentioned to be the initiating factor for problems which then cumulated, it can be said afterwards that the decision should have been explained more thoroughly emphasising the need for true commitment to the project from officials as well.

The study findings revealed that infill development is a complex phenomenon from resident's perspective. It also became evident that it is not just rational calculation of financial gains and losses but the decision making also involves emotional features (experiential and symbolic in nature). Thus, it is important to understand these issues in future studies. It also seems that management of the project is in a key role. The limitation of this study is that managers and management per se were not on the focus but mainly how it was viewed by the residents. Thus, focusing on the complexity of management from managers' perspective would be valuable to understand the reasons for the problems and provide building blocks for management of future infill development projects.

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Managing Resources in a Sustainable Building Process

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Extended Abstract

Introduction

Managing resources efficiently in a building process is of great importance in a sustainable development. The framework in a building process contains legislations and rules from a societal perspective combined with demands of a more efficient way of working within the companies involved. The knowledge of all actors involved must be used in order to solve this complex task.
The quality of new buildings does not always match the expectations from the clients today so efforts must be done to improve the process. Another urgent issue is to deal with existing buildings. Participatory governance can describe the citizens' democratic right to participate in decision-making concerning building or renovation processes. The public sector in Sweden discusses the possibilities of working more systematically with the ambition to use all the resources in a better way and with an end-user perspective.
Today different processes seem to be parallel and do not always support one another. How can we achieve the best quality in the integrated process and in the end-product? Can a genuine dialogue and integrated processes be one way to achieve a better result? The case study evidence suggests that the primary focus of the logistics concept in construction is to improve coordination and communication between project participants during the design and construction phases, particularly in the materials flow control process.

Problem

The Building Industry faces challenges both in new building projects as well as when dealing with existing housing areas. The economical resources are limited and the regulations and restrictions are many.
Examples from the Swedish building industry show severe problems with quality and how to manage the financing of the damages. The knowledge and awareness ought to be within all actors involved in the process but the question is if there are obstacles for using it?
Where and when shall the resources be adopted to the process and which are the effect of a more integrated way of working? A gap can often be indentified between different processes and actors involved in this complex industry dealing with governing the built environment:

Theoretical framework

In the planning- and building process several kinds of flows are managed simultaneously. The flows are governed within and between the companies involved, the residents and the governmental framework of regulations and laws. If using a combination of theories from transport logistics, design methods and quality management maybe some of the existing gaps in the

process could be avoided. The challenge is to see the possibilities in new demands in services and products. New skills, competences and attitudes are required when working with processes. It is also of great importance to create an understanding and acceptance for the changes.
Starting with defining and focusing on the end-user in the process can be an important unifying force. Customer driven processes and a modern perspective on quality puts the end-users needs, expectations and requirements in focus.
Using theories from the design area one could start with looking into Architectural design where decisions influence the artificial environment in our every day life. The act of designing is a complex activity undertaken a close cooperation with many other actors. There is a growing recognition of the importance to think more creative and dynamic by adding values and culture into the process
If implementing the lean thinking philosophy and tools into construction industry one must include lean ideals and tools into the participating organisations. Eliminating waste and maximising value must be applied into the processes within the organisations as well as on site-based construction.
Logistics activities commonly involve movement and storage for the purpose of having the desired object of at the right place at the right time. Transport, storage and distribution are cornerstones of logistics and its most visible manifestations.
For the construction industry, logistics comprise planning, organization, coordination, and control of the materials flow from the extraction of raw materials to the incorporation into the finished building
Several Swedish laws emphasize the importance of the involvement of residents and end-users in the planning- and building process. Communication and knowledge transfer can be used as a tool for combining parallel processes. Digital communication networks offer the possibility of better links between clients, designers, construction organizations and suppliers

Case study results

Three case studies are used to exemplify different levels of collaboration and integration between parallel processes. Case I and II was part of a doctoral thesis and the third case is an ongoing research project not yet documented.

Case study analysis

Case studies on large scale projects in Sweden shows that working with the end-users needs and requirements in focus can support the complex building process. Working in a more integrated way can support the complex mix of technology, people and decisions involved.
Recourse logistics models and customer driven process methods can support the integration of parallel levels and phases in the process. The dialogue between the actors involved where experiences are shared can also give new and useful knowledge if it can be developed in a generous atmosphere.

Conclusions

Some experiences from three different case studies in Sweden shows that it could be possible to use more of logistic models and “Considerate Lean” models in the building and planning process. There is an opportunity to get long term sustainable housing by involving the residents and end-users and by using their knowledge in the process.
Logistics require that all involved processes are communicating with each other. If not, the lean model will be hard to apply. Lean is about taking away all waste that is not used in the value added process. It concerns time, products, costs, etc. If this is done in a proper way it is possible to make a shift to a more value added process i.e. storing activities can be used for more productive and value adding work.

Keywords: integrated processes, logistics, service logistics, lean renovation, sustainable process, communication, co-operation

Managing Resources in a Sustainable Building Process

Summary

Managing resources efficiently in a building process is of great importance in a sustainable development. How can we achieve the best quality in the process and in the end-product?
The framework in a building process contains legislations and rules from a societal perspective combined with demands of a more efficient way of working within the companies involved. The public sector in Sweden discusses the possibilities of working more systematically with the ambition to use all the resources in a better way and with an end-user perspective. A traditional building project contains different parts added in a chain of time like competence, time, money, and building materials. Traditionally the process is more like a parallel relay with a high risk of a communication gap between the actors involved. Involving the tenants supports the democratic right to be part of societal development and can also be used as a source of knowledge. Working in a more integrated way can support the complex mix of technology, people and decisions involved. Recourse logistics models and customer driven process methods can support the integration of parallel levels and phases in the process. The dialogue between the actors involved where experiences are shared can also give new and useful knowledge if it can be developed in a generous atmosphere. Where and when shall the resources be adopted to the process and which are the effect of a more integrated way of working?

1. Introduction

Managing resources efficiently in a building process is of great importance in a sustainable development. The framework in a building process contains legislations and rules from a societal perspective combined with demands of a more efficient way of working within the companies involved. All parts involved must be active and creative to develop new strategies and working processes. The knowledge of all actors involved must be used in order to solve this complex task.

Governance can be used as a term in industry to describe the processes needed for a successful project. New laws and regulations demands a more efficient way of using energy and a better availability in concern of people with difficulties in their mobility. These demands require large scale investments and urge a change of attitude and behaviour. New demands combined with the fact that many of the existing old houses need to be renovated due to poor building material that was used in the past, stresses the economy for the Real Estate owners in a bad way.

The quality of new buildings does not always match the expectations from the clients today so efforts must be done to improve the process. Another urgent issue is to deal with existing buildings. In Sweden today there is a great need of building new apartments and an urgent mission to renovate about 600.000 apartments from the sixties and seventies in a bad condition. Many apartments from the Million programme (built in 1960-1970) are generally owned by the communities and only a few by private companies. Many of the tenants in these housing areas have a low socio/economic status that also states the importance of using the resources in a considerate and efficient way. Several signals, from preferable young men, as burning cars and riots tell us that they don’t feel part of our society. This phenomenon creates a great risk to the social sustainability. The problem is shared by the individual, the Real Estate Company and the society.

Participatory governance can describe the citizens’ democratic right to participate in decision-making concerning building or renovation processes. Several Swedish laws and United Nations Convention on the rights of the child, states the rights for all individuals to express ideas and be part of decisions concerning their every day environment.
The public sector in Sweden discusses the possibilities of working more systematically with the ambition to use all the resources in a better way and with an end-user perspective.
Working processes involving the tenants supports the democratic right to be part of societal

development and can also be used as a source of knowledge.
Today different processes seem to be parallel and do not always support one another. How can we achieve the best quality in the integrated process and in the end-product? Can a genuine dialogue and integrated processes be one way to achieve a better result?

Frequently, the supply of building materials to the construction site is fraught with difficulties which can have a significant effect on productivity. Major productivity gains are possible, particularly if the building process is planned from a logistics perspective. The concept of logistics was developed initially within the manufacturing industry, and now constitutes an important management tool to ensure an overall strategic perspective on the flow of materials in the production process. This paper contends that logistics are relevant also to the construction industry, and describes the development of a logistics model to manage the flow of materials from suppliers to installation on-site and its application to a Danish house building project.
The case study evidence suggests that the primary focus of the logistics concept in construction is to improve coordination and communication between project participants during the design and construction phases, particularly in the materials flow control process. The logistics concept requires accurate scheduling of materials to programmed delivery dates keyed to actual site layout and storage arrangements. The logistics approach also involves a new role for materials suppliers, including early involvement in the design phase and overall responsibility for the flow of information relating to materials.

2. Problem

The Building Industry faces challenges both in new building projects as well as when dealing with existing housing areas. The economical resources are limited and the regulations and restrictions are many.
Examples from the Swedish building industry show severe problems with quality and how to manage the financing of the damages (*Fig 2.1 ,2.2, 2.3).* The knowledge and awareness ought to be within all actors involved in the process but the question is if there are obstacles for using it?

Fig 2.1 Building in Ystad collapsing two weeks before inauguration as "the House of Health"

Fig 2.2 Stucco facades with problem

Fig 2.3 Moisture damage

A traditional building project contains different parts and resources added in a chain of time like competence, money, and building materials. Traditionally the process is like a parallel relay with a high risk of a communication gap between the actors involved.
Where and when shall the resources be adopted to the process and which are the effect of a more integrated way of working? A gap can often be indentified between different processes and actors involved (*fig 2.4*) in this complex industry dealing with governing the built environment:

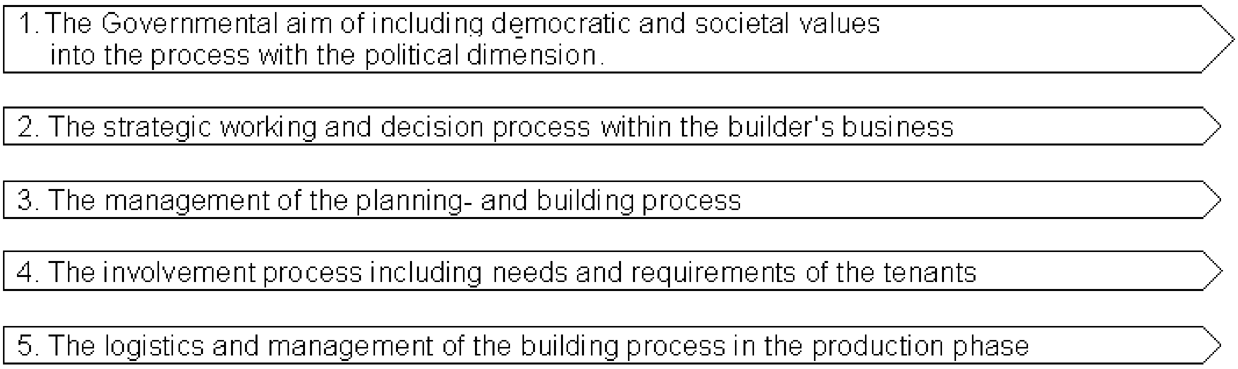

Figure 2.4. Parallel processes.

1. A problem with achieving a societal sustainability is that some residents do not feel that they are a part of society. Segregation and exclusion are accelerating in some neighbourhoods. The governmental aim to include the residents actively seems to have difficulties to be integrated into the planning and building process.

2. The builder can work with different goals and strategies but must always get positive results of their investments. The Municipal Housing companies in Sweden are governed by a law since 2011 to return profits of their operations. The conditions from regulations and the bad state of the existing housing are a challenge to deal with. Working with a traditional calculus bill does not always give a positive result and therefore requires an integrated accounting with a societal perspective.

3. Architects and Engineers and the other actors involved in the building process do not always share the same interpretation of the order from the builder/client. Digital tools and project portals with drawings and information seem to minimize the opportunities to discuss and understand the drawings.

4. Knowledge about economy and property management is not always a common focus and the tenant seems often not to be part of the process. A dialogue with the tenants is rare.

5. The production phase is supposed to solve all the questions expressed during the early phases in the building process. Drawings are handed over before they are properly investigated and discussed. The lack of time stresses the actors involved. At the building site when very few things can be changed lays all kinds of problems accumulated during the process.

3. Theoretical framework

In the planning- and building process several kinds of flows are managed simultaneously. The flows are governed within and between the companies involved, the residents and the governmental framework of regulations and laws. If using a combination of theories from transport logistics, design methods and quality management maybe some of the existing gaps in the process could be avoided.

"A *process is a repetitive used network in order of linked tasks that uses information and resources to transform 'object in' to 'object out', from identifying to the satisfaction of customers needs*". [1]
Increased competition on the market makes the companies work more efficient with a process-based business development. The challenge is to see the possibilities in new demands in services and products. New skills, competences and attitudes are required when working with processes. It is also of great importance to create an understanding and acceptance for the changes.
A process- based business must work with:

- A holistic perspective
- Customer focus
- Employee focus
- Strategy
- Flexibility and an ability to change
- Effectiveness
- Measurement
- Time

3.1 Customer driven processes

Starting with defining and focusing on the end-user in the process can be an important unifying force. Customer driven processes and a modern perspective on quality puts the end-users needs, expectations and requirements in focus. QFD, Quality Function Deployment can be described as a systematic way of working in order to achieve "quality of design" and do also support communication and participation [2]. Four steps are used when involving the end-users requirements into the process in comprehensive QFD:

- Product planning
- Product design
- Process design
- Production design

This method can be used both for products as well as for services and the positive effects are lower planning costs and much shorter time for the product development. As a bonus effect the customer also helps to identify weaknesses in the competitive companies that can be used when dealing with strategic decisions. Benefits from working with customer driven processes are mentioned as: better communication, better transferring of knowledge, more of consensus within the project team and better constructions. There are no negative effects mentioned by using the customer as a focus point. But if you lack of support from the management, lack of commitment in the project team and too few resources there can be a problem in achieving the goal [3]. In Kansei Engineering by Nagamachi [4] the management of the product development are assumed by client's statements and feeling about their experiences.

In order to achieve the best customer satisfaction a company can combine the strategy with Business Development and Business Performance Measurement and Balanced Scorecard [5] It is all about the Management's ability to evaluate the organization's efficiency and the manager's capability to take initiative for development. SIQ the Swedish Quality Award can be compared to TQM Total Quality Management is based on thirteen fundamental values. The goal is to create a strong driving force from inside for working with continuous improvements.

3.2 Design

Using theories from the design area one could start with looking into Architectural design where decisions influence the artificial environment in our every day life. The act of designing is a complex activity undertaken a close cooperation with many other actors. There is a growing recognition of the importance to think more creative and dynamic by adding values and culture into the process. The softer approach takes a new perspective on the process while moving away from the production line. Integrated teams and value-based techniques can be a better way of working in delivering the product and services to the clients.

"*Design is an expert activity that improves the usability, functionality and quality of the built environment, i.e. design adds value to our every day lives. Design is also a collective effort based on degrees of compromise and commitment, combining the skills and knowledge on a wide range of individuals to provide creative solutions to poorly defined problems"* [6]

Emmitt also states that when the project team strives to deliver value there is a constant and creative tension between the design and the production of buildings. He describes the construction industry as fluid and dynamic collection of specialists with temporary groupings of individuals and organisations with a very few established supply chains. Unlike the car industry with repeat building types lean production to the design and production of buildings may be misleading and inappropriate. Construction remains dependent on site-specific conditions despite the amount of off-site prefabrications. What's fundamental is the effectiveness of the relationship between the architects and the clients. It is important to discuss goals, opportunities, risks and values; the closer the interaction is the better the understanding. The creative tension helps stimulating innovation in product and process and makes it to a fascinating and challenging activity.

3.3 Lean

If implementing the lean thinking philosophy and tools into construction industry [6] one must include lean ideals and tools into the participating organisations. Eliminating waste and maximising value must be applied into the processes within the organisations as well as on site-based construction. Traditionally lean thinking philosophy is used in manufacturing processes and quality management work but it can be successfully used with modification in a construction project context. Using Information technology has transformed the way of working and there is a move towards more cooperative interdisciplinary work and using multidisciplinary teams. To reach real integration a social parity between actors is needed to achieve a more collaborative way of working. By improved interaction and communication the effect of these creative clusters can be knowledge transfer, feedback and constructive critical analysis which characterize good management. Trust, risk and uncertainty have to be handled in a considerate way in the process. Clear communications and identification of roles and responsibilities support this work. "*we don't trust an organisation per se; we trust the individuals working in the organisations with which we have contact on a regular basis* [6])"

Processes can always be improved and a pragmatic business approach can use "Six Sigma" as a strategic method [7]. The method is a formalised, systematic, heavily result oriented project- by-project improvement methodology to achieve improvements. If looking at three different key indicators of process performance it can form an improvement triangle for processes. The key dimensions are:

- Variation -How close to the target value?"
- Cycle time – "How fast?"
- Yield – "How much?"

Variation is the main key because a measurement can be applied to asses the performance of cycle time and yield of processes. Through improvement variation always affects the other two positively. Six Sigma was pioneered by Motorola in 1987 and consists of five steps : Define, measure, analyse, improve and control.

Four elements are embodied in a strong corporate framework:

- Top management commitment
- Stakeholder involvement
- Training scheme
- Measurement systems

Six Sigma is described as a long-term strategic initiative that requires hard work and close attention. “The primary reason for the success of Six Sigma is its rigorous pursuit of top line and bottom line results in all improvement activities associated with the initiative [7]”

3.4 Logistics

Logistics commonly refers to coordinating and organizing the movements of components, final goods and their distribution. It was first used systematically for military purposes but have been gradually spread to commercial endeavors, often referred as logistics management or supply Chain Management. The Council of Supply Chain Management Professionals (CSCMP) defines logistics management as: — “…that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption to meet customers' requirements.”

In reality, the scope of logistics issues for construction firms go beyond the —traditional tasks of physical storage and movement of goods because of its complexity. The concept covering this broader scope is Supply Chain Management (SCM), Business related logistics or SCM services which include customer service, demand forecasting, documentation flow, inter-firm movements, inventory management, order processing, packaging, parts and service support, production scheduling, purchasing, returned products, salvage scrap disposal, traffic management, warehouse and distribution centre management, and transportation. These services must be planned, coordinated and controlled to maintain the building process. This is today undertaken on an ad hoc basis and with a more integrated and planned process there are major potentials.

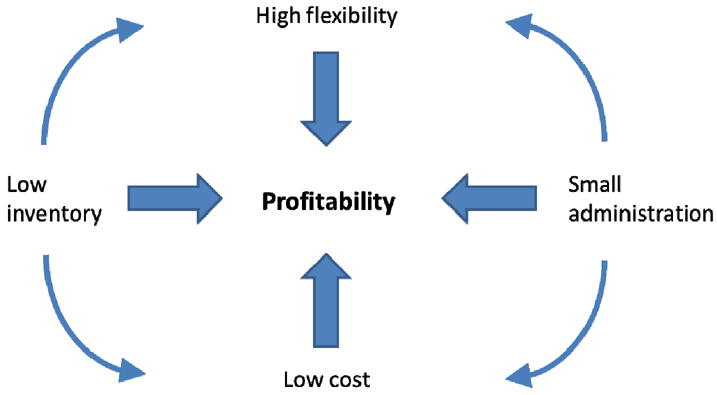

Figure 3.1 The benefit of using lean logistics in the construction industry

Logistics activities commonly involve movement and storage for the purpose of having the desired object of at the right place at the right time. Transport, storage and distribution are cornerstones of logistics and its most visible manifestations.

For the construction industry, logistics comprise planning, organization, coordination, and control of the materials flow from the extraction of raw materials to the incorporation into the finished building [8]. Some may argue that there is little difference between a logistics management system and an integrated materials management system. The former system is the means whereby the needs of customers are satisfied through the coordination of materials and information flows that extend from the building process, to the market place, through the resources and its operations and beyond that to suppliers [9]. It is broader in scope than the latter, and operates at the strategic level. The scope of logistics spans the total organization [10]. We can also find a close connection between integrated logistics and sustainable systems when applied in the building sector [11].

3.5 Governmental regulations

Several Swedish laws emphasize the importance of the involvement of residents and end-users in the planning- and building process. The Planning and Building Act PBL 1987:10 [12] regulates the planning process and the actor's responsibilities and roles.
The Swedish Government has established The National Council for Innovation and Quality in the Public Sector to improve the efficiency and quality of public activities in national, regional and local level.
The remit includes:

- describing government agencies' work on innovation, quality and business development;
- clarifying whether the current regulations imposed on government agencies for management, control and accounting support innovation and value creation;
- identifying the extent to which quality and efficiency analysis are carried out in different areas of the public sector and how these are processed to be translated into concrete improvements;
- assessing whether such analysis can be an instrument in efforts to achieve greater quality and efficiency;
- identifying areas, services or processes that are considered to have great potential for development and, in close coordination with voluntary participants, preparing development strategies for some of these areas;
- studying public sector organisations adopting the management philosophy known as 'Lean', looking at research into the use of 'Lean' in public sector organisations and, if deemed appropriate, supporting those public organisations that want to implement 'Lean'; and
- proposing measures to promote innovation and development in the public sector.

Efforts are done also by the Swedish Association of Local Authorities and Regions and
The Swedish National Board of Housing, Building and Planning to support a sustainable development.
Social sustainability is indicated to be our next challenge to deal with in urban planning and housing.

3.6 Communication, cooperation and knowledge transfer as a tool

Communication and knowledge transfer can be used as a tool for combining parallel processes. The communication process can be used to inform, coordinate and motivate people in the exchange of information, facts ideas and meaning [13]. Poor communication often results in low morale and low productivity and therefore analyzing communication behaviour is vital. Interpersonal and organizational problems can be related to poor communication skills. People must communicate effectively to develop goals, channel energy and identify and solve problems.
Examples of barriers that can reduce the effectiveness:

- Inarticulateness - can result in subsequent misunderstandings
- Hidden agendas - results in low trust and cooperation
- Status - distortion by perceptions of position
- Hostility – difficulties in sending and receiving a message
- Distractions – not focusing of the subject of the communication
- Differences in communication styles – listen less carefully because they are distracted
- Organizational norms and patterns of communication- may prevent questions and discussions

By coaching and mentoring the employees they can develop both reflective listening skills and communication skills that can improve effectiveness and enhance productivity.

Promoting a successful teamwork and cooperation is based on mutual goals that encourage trust and the ability to rely on others. Incompatible goals create suspicions and doubt and can lead to a communication break down [14]. In the process teams must be provided with adequate resources, with financial, staffing and training support. With a well defined task and both technical and group process assistance available, the performance can be better. It requires efforts from both individuals and the organization. The potential lies in the fact that that a whole is greater than the sum of its parts. The collective work of a group of people is more than its individuals could accomplish separately.

Digital communication networks offer the possibility of better links between clients, designers, construction organizations and suppliers [15]. These systems have the potential to provide the infrastructure for knowledge acquisition and accumulation, enhancing the possibilities of providing feedback and the potential to learn from previous experience. "*Conventional construction processes has usually involved sequential decision making, in which the decisions were passed from one group specialist professionals to the next, all of whom had to make inputs if overall project goals were to be realized. Decisions were transferred and translated in a process which changed semantics such the original intent could be lost or altered*." ICT technology systems change the type of involvement of each participant. With the new technology the timing, sequencing and hierarchy of decision making changed fundamentally. This could also offer customers value-added services with the intent of developing better user - producer relationships and give possibilities to improve overall performance. The linear- sequential approach changed into a interactive- integrated model of construction. Designer can use the information and communication technology to simulate and test design options and coordinate between different specialists. New design skills will be needed in the total design and construction process to produce complex buildings and social uses in a variety of different markets. "*Uncertainty remained high in most building processes, because of the ways in which they were organized with weak feedback loops and poor opportunities to learn from project –to – project. They needs to simplify processes, using modular component parts and standard interconnections were one response to growth in project complexity*" [15]".

The organizational learning includes some informational content like a learning product,
a learning process (acquiring, processing and storing information, and a learner (to whom the learning process is attributed).
There can also be a particular kind of learning that consists of unlearning when information leads to subtracting something from an organizations existing store of knowledge[16].
If treating an organizational entity as an impersonal agent is like adopting a machine language and seems to reflect the rising influence of the computer. Phenomenon that used to be attributed to thought, will, deliberation, feelings or habits have a tendency to employ computer language. There is a risk in this growing tendency to treat organizations as impersonal agents. It is important to come close enough to be aware of the individual interpersonal processes that underlie an organization's behaviour within which individuals think and act. Usually learning is used in a positive sense but Agyris & Schön also discusses that people can learn collectively to maintain patterns of thought and action that inhibit productive organizational learning. For example by responding to error by use of scapegoating, games of unilateral control, systematic patterns of deception and camouflage of intentions that keep critical issues undiscussable. This can be changed by using inquiries to let the organization explore and reconstruct the values and criteria's for the meaning of improved performance.

4. Case study results

Three case studies are used to exemplify different levels of collaboration and integration between parallel processes. Case I and II was part of a doctoral thesis [17] and the third case is an ongoing research project not yet documented.

4.1 Case I

The project Campus Östersund, an old military regiment was transformed into Mid Sweden University by Vasallen with the mission from the Government to: manage, to improve and then sell. New tenants with new activities demanded a total change of design but with the limitations of considering strict regulations regarding heritage buildings. Vasallen clearly stated the demand to all actors involved to involve the end-users' into the process and to work with continuous improvement. All the consultants and construction companies involved were educated in this spirit to fully understand the ambition in the project. Full scale rooms were built up in order to improve the possibilities to discuss the design of the indoor environment. When the tenants realised their opportunity to influence the process it was too late, the contracts were already written and the construction company were procured. This fact prevented the end-users from influence the result, the doors were closed. A positive effect with the full-scale room dialogue was the discussion and the exchange of experiences between Vasallen and the craftsmen. Details were designed that saved a lot of resources as time and material in the process. The craftsmen were also involved in daily information and planning throughout the building process. The tenants' satisfaction with the result was followed-up and dialogue and continuous improvement was one of the key-word in the process. All actors involved was content with the result and long term leases is one example as well as a tripled profit compared to the investment of about 35 billion Euros. The municipal planning was not supporting the process and at the end Vasallen purchased consultants to plan the surroundings meant for additional companies and activities. The plans were then presented for the political committee as a decision support without involvement of the City planning office. This is not the traditional way of working in the planning process but the understanding of Vasallens ambition was crucial for the total result and demanded this operation.

4.2 Case II

The project Maria Sofia, a multi-storey housing project in Helsingborg with 200 apartments built by the municipal real estate company (Helsingborgshem) with the mission: new apartments with the best possible quality with a predetermined cost ceiling. All actors involved took part of meetings and workshops in the early phases of the project in order to learn more about each other. The tenants were represented by people working in the very front line of the organization knowing a lot about how the tenants think and act. Priorities were made in order to get the most out of the resources. A lot of time was used in the beginning of the project that made everybody save time and money during the process. A common goal and efforts to reach the best quality for the end-users made everybody to work in a collaborative way. Experiences and knowledge were exchanged and even the craftsmen were involved. One apartment was made ready as a "role model" which could be the base for a discussion about and interpretation of the ordering. The quality of the end-product were discussed and understood of every actor involved. The City planning office was invited to the early workshops and discussions but they refrained to be part of the process. There were difficulties concerning the role as an authority to come close to one project because there were several parallel projects going on at the same time. The tenants were invited to visit the building site as soon as they signed the leases and they also attended the final inspection of their apartments. Technical details and questions about functionality were told at this occasion and gave effect on their preparedness as future tenants. Their knowledge of why things were as they were could be explained and their role in the process became clarified. The goal was to serve their demands and requirements and the results of the project were good. By using time, money and knowledge from all actors involved in the right way, the quality of the apartments became very good. A smooth process is not a common thing in the building process. Keeping booth time schedule and budget is even rarer. Sharing a common gaol and working with a joint ambition has this effect in this project.

4.3 Case III

The project Drottninghög in Helsingborg, an existing housing area with 1100 apartments from the Million programme (built between 1962-1972) owned by the municipal real estate company with the mission to: take care of both the tenants and the buildings and to double the number of apartments with a sustained energy use in the area. The working process so far has been using the same ambitions and common goal as case I and II. (Using resources and the knowledge of the actors involved in the best way to reach the best quality for the end-users)The big difference in this case is that the City planning office has been deeply involved in the early phases of the project. Dialogue with the existing tenants and learning from other projects in order to make the process better are ambitions that can give positive effects. Ongoing research and experiences done are used as well as other networks dealing with the same tasks. Developers and future property owners are not involved yet, but they are invited to workshops and meetings to exchange general experiences. Construction companies are not contracted so they are not part of the process yet. Qualities and values in the neighbourhood are indentified by using methods for dialogue with children and young ones from the school. These qualities and values are formulated and gathered and are now a part of the formal planning program determined by the political committee. The project will proceed in this spirit and can give more experiences of working in a more integrated way with the processes going on at the same time. The plans are now that the process to open up, connect and to densify this part of the city will go on for fifteen to twenty years. Long term thinking about both people and buildings are keywords with sustainability in a social, technical, economical and environmental perspective.

5. Case study analysis

Case studies on large scale projects in Sweden shows that working with the end-users needs and requirements in focus can support the complex building process. Working in a more integrated way can support the complex mix of technology, people and decisions involved.
Recourse logistics models and customer driven process methods can support the integration of parallel levels and phases in the process. The dialogue between the actors involved where experiences are shared can also give new and useful knowledge if it can be developed in a generous atmosphere.

Experiences from two case studies in large scale projects in Östersund and Helsingborg [17] shows that time and resources that are put in to a project, in order to increase the communication between the actors involved, can be considered as well paid investments. The time and the efforts made to communicate the goals, listen to the end-users requirements and to really understand these and use them as a resource, gives certain effects to the whole organisation and the quality of the product. Knowledge can be used and discussed, experiences from both end-user and craftsmen supports a process where problems are solved in the early faces of the building process. The same information about the project can be shared and discussed in order to make sure that everybody understands the meaning of the information. The discussions and conversations at the meetings with representatives from all actors involved can clarify questions and different perspectives are used to solve problems.

All the actors involved can use their energy to work with the issues that concerns a common goal instead of watching their back. Money can be saved due to less problems and obstacles in the process and at the building site. The efficient use of resources gave the product a better quality and was customized for the end-users requirements. Very little time were used to repair the negative effects of miscommunication that are the usual tradition. On the question to the persons responsible for the projects in both case studies: “Was it worth to put in all these time and effort to communicate in the early faces of the project?” the answer was “that is only a matter of how and when the resources are used in a project”.

Case I

Bad cooperation with the City planning administration – alternative ways gave good results anyway

Case II

Trying to cooperate with the City planning administration with bad success- but good result to the rest of the process-planning and production with a active co-operation with the construction company

Case III

Active and creative participation with a common goal for all actors involved (except the construction companies) – an ongoing project in the early phase of the process

6. Conclusions

Some experiences from three different case studies in Sweden shows that it could be possible to use more of logistic models and “Considerate Lean” models in the building and planning process. There is an opportunity to get long term sustainable housing by involving the residents and end-users and by using their knowledge in the process.

Logistics require that all involved processes are communicating with each other. If not, the lean model will be hard to apply. Lean is about taking away all waste that is not used in the value added

process. It concerns time, products, costs, etc. If this is done in a proper way it is possible to make a shift to a more value added process i.e. storing activities can be used for more productive and value adding work.
With a low integration in the building process it generates ad hoc activities. This can lead to two types of problem. First, some materials may be purchased just before they are required, resulting in delays, and interruptions to the working schedule. Second, other materials are procured in large quantities without complying with production needs on site. This can result in a waste of resources during stocking, handling and transporting. Responsibility for waste concerns all project participants. It concerns general management as well as site management; any solution to the problem should involve all parties, i.e. those who design the building, those who design the materials and components; and those who specify, describe and account for the work and the suppliers of materials. In selecting a method of handling building materials, the materials' characteristics (weight, vulnerability to damage, etc.), the method of packaging, the storage on site, the movement to the workplace and any obstructions, and the plant available and best suited to the task, are all aspects to be considered.
In the long term this will create a building process that will be positive for the environment as well as the final customer that will live in the building after it is finished.

This way of working requires a certain attitude towards the task and a fully understanding of the effect of genuine communication and dialogue. By using the dialogue, knowledge transformation can take place, but this needs a good leadership and a supporting organization to succeed. The most important resources can be summarized as time and competence. Responsible and considerate actors with suitable skills are required to create a safe and creative working atmosphere in which the best result can be achieved.

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A Multilevel Method to Manage the Complexity of the Sustainable Construction Works

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Summary

The nature of the sustainable **approach** is complex, because of the large number of components involved and relationships between disciplines, objects, phases of the **life cycle**, aspects and variables of any actual project or construction works process.
Complexity is one of the major features of the conceptual model on which the new European standard family of **CEN TC 350**, still in progress, is based. The approach for managing the complexity in construction works suggested by the standard family is **multidisciplinary**.
The future developments of the standards are expected to go more and more into the direction of the **integration** of the three major components: environmental, social, economic and their related aspects, impacts and performances, as actually declared: "In the future, the assessment methodologies within this standard framework may be part of an **overall assessment of integrated building performance**. The assessment methodologies may also be extended to an assessment of the neighbourhoods and wider built environment".
And yet, in the definitions, sustainability assessment of buildings is described as a "combination of the assessments of environmental performance*,* social performance and economic performance taking into account the technical requirements and functional requirements of a building or an assembled system (part of works), expressed at the building level".
The identification of a multi-scale **and multilevel strategy**, aimed at supporting the **decision-making process**, applied to the “Leonardo da Vinci Sustainable Campus” project in Milan, with respect to the energy, environmental, social and economic performances, is focused on **key objectives / criteria / indicators**.
The **holistic approach** and the involvement of the stakeholders in the method, supported by multiple criteria decision making (MCDM) models and methods, aims at giving transparent and shared answer to the search of the best technical solutions and strategies in a large sustainable perspective.

Keywords: Sustainable construction works, Integrated approach, CEN TC 350, Holistic, Multilevel, Multi-scale, Life cycle, Evaluation systems, Assessment tools

Introduction

The purpose of the research, whose title is “Sustainable management of construction works from the building to the context” is offering a contribution to the definition of methods and guidelines for the management of sustainability in constructions [1] [2], to support decisions by the actors of the construction process involved in the decision making stages (i.e. public and private managers, designers, developers, policy makers).

The case study is the "Città Studi Sustainable Campus" project (www.campus-sostenibile.polimi.it, Fig. 1), a multi- and inter-disciplinary intervention aiming improving the quality of campus life formed by Politecnico di Milano, Università degli Studi di Milano, including the up-grading [3] [4] of the building estate of Politecnico di Milano and the transforming of the university [5] district into a model part of the city in terms of quality of life and environmental sustainability [6] [7]. The building so-called "Nave" is in particular the case study selected for the application at the building scale. The project "Città Studi Sustainable Campus" is member of the ISCN (International Sustainable Campus Network www.international-sustainable-campus-network.org) and inserted in the European Peripheria framework (http://peripheria.eu).

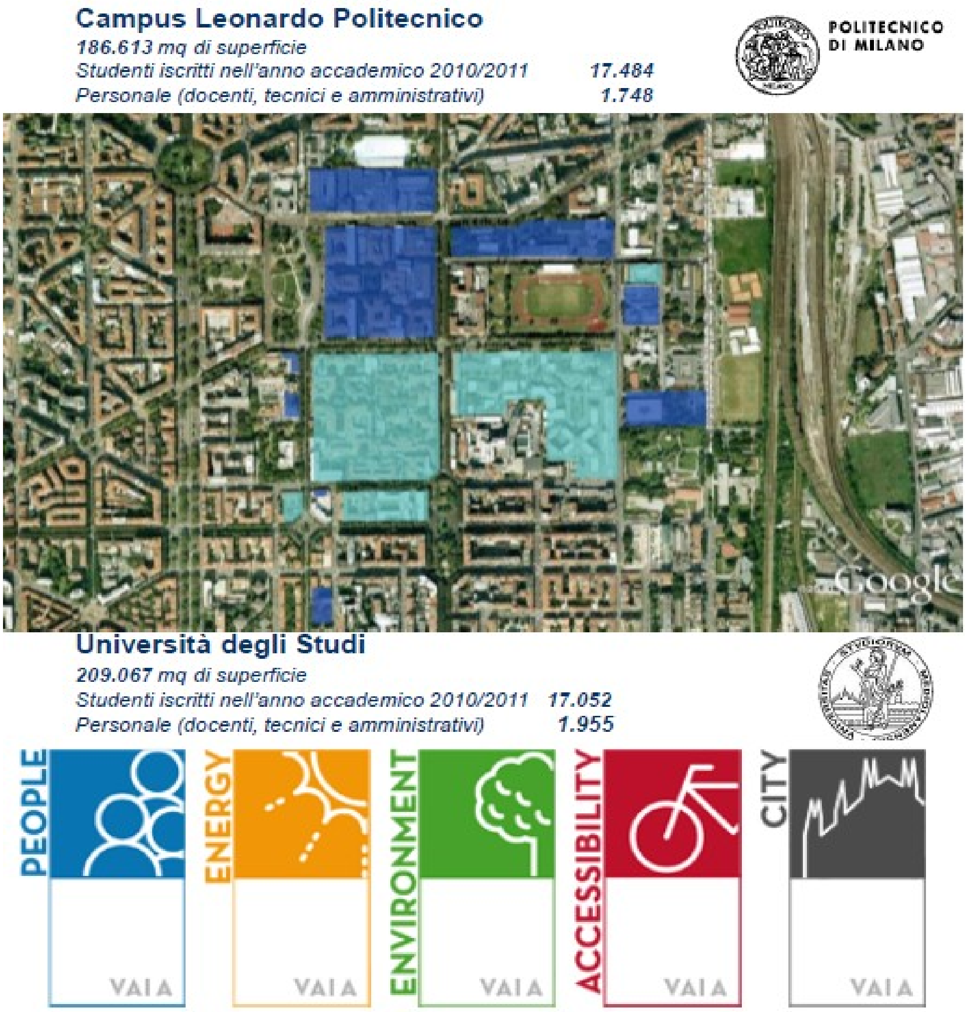


Fig. 1 Città Studi Sustainable Campus

Methodology

Initial Analysis

An analysis of the state of the art shows that for the assessment of sustainability of the life cycle [8] in constructions:

- The most commonly used tools [9] available today, such as development of the classical Multi-criteria Method, are national protocols related to their respective trade marks (of which the best known are Leed, Breeam, DGNB, CASBEE, Minergie, Itaca), using indicators (so called "of first-generation") and methodologies [10], generally inconsistent one with each other.

- At European level, there is an ongoing process of **harmonization by the CEN TC 350** [11] [12], in order to reduce the indicators to a shared set ("core") indicators (so called "of second generation"), identifying a common general approach (life cycle oriented), giving an innovative and strategic direction of approach.
- It is still under development the identification of sets of shared indicators, since some have been identified but there are others validated by research and which could be integrated in the next future.
- It is expected that, in the coming years, the **core indicators** and a common approach will provide inputs for the further development of the national protocols, which will receive them for alignment with the European standards.

The strategic guidelines declared in European standards aim substantially to:

- Manage the decision-making [13] processes aimed at optimizing sustainability [14] throughout **Aspects / Impacts / Performances** [15], described by **Indicators** [16]
- Move from a mono / multi-disciplinary approach as the current one, in which for each alternative are identified aspects / impacts / performances referred to environmental / social / economic [17] [18] areas, to an inter / trans - disciplinary approach in which the identification of relationships between the variables in the three above areas helps to predict cause-effect processes associated to design alternatives, expected to be aided by tools and methods "**multi-level**" or "**multi-layer**" in a so-called "**integrated**" **perspective** [19].
- Expand, in the assessment, the **boundaries of the system** in which we study the performances of the design options, that is, as already experienced in the field of LCA [20], beyond the building. The new approach "**multi-scale**" suggests, therefore, to examine the impacts of each project, in a larger scale, i.e. **territorial**. Still now, in the common decision-making processes the relapses / effects / impacts in wider scales are not considered, or even the decision makers do not have sufficient awareness of the boundaries of systems on which they are working.

In the area of international research, experiments of these strategies on real cases are still in the early, yet little explored. In particular, in the Italian context, a gap appears, between the use of sustainability assessment tools applied to the building and the existing territorial quality ranking systems, as the most known Ecosistema urbano, Legambiente-Sole 24 ore, EcoSistema Metropolitano Milano [21], moreover not directly considering the contribution of the buildings on the urban sustainable performances [22] [23] [24].
The present research aims at contributing to fill this gap.
In particular, applying them to the case study, the research attempts to understand:

- If the European core-indicators are sufficient.
- If the specific conditions that allow all three strategies approach indicated by CEN TC 350 (use of the new European harmonized indicators, **interdisciplinarity** and **integration**, multiscale approach) and above mentioned.
- How can they be implemented.
- Benefits of implementation.
- Implementation limits.
- Conditions of transferability of this approach to other situations and contexts.

Development Stages

Starting from the core indicators identified in the EN 15643-1-2-3-4 standards and in the related 7 Framework Program projects (Open-House, SuPerBuildings), a first panel of 43 indicators has been set (Fig. 2), grouped in environmental [25], social and economic [26] [27] indicators.
A deeper analysis shows that **many interrelations** exist between the three sets and this actually suggests an **integrated approach**, as by CEN TC 350 recommended.
Thanks to a further recognition in literature reporting the results of researches validating additional indicators, **an additional list of 12 indicators** [28] [29] [30] [31] has been selected (Fig. 2, 3).

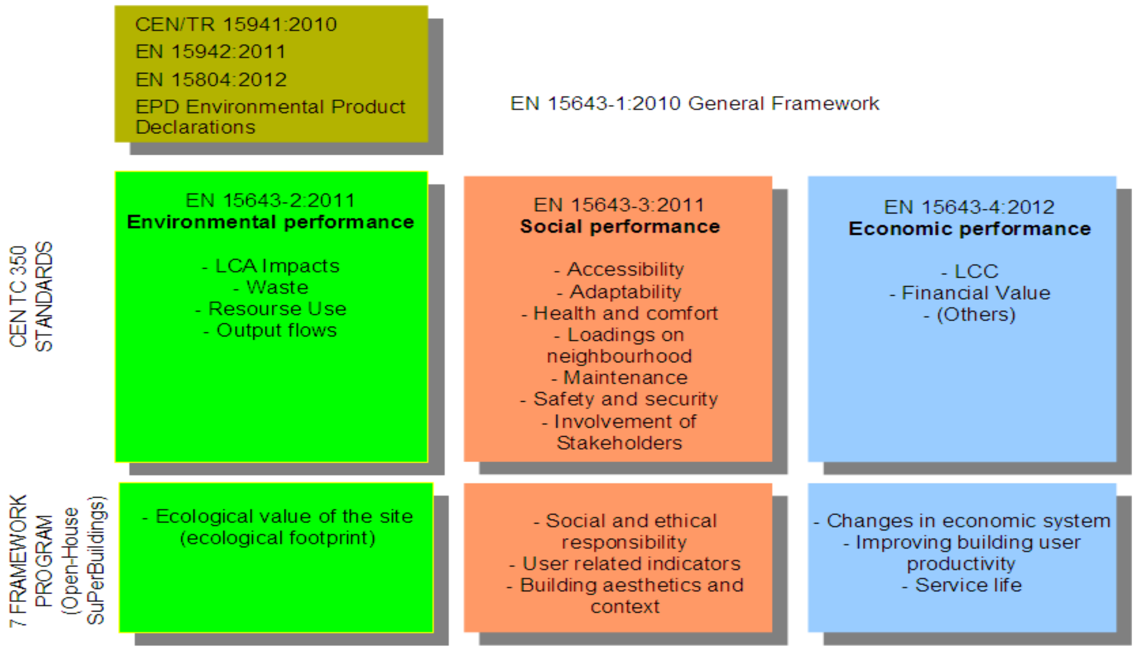
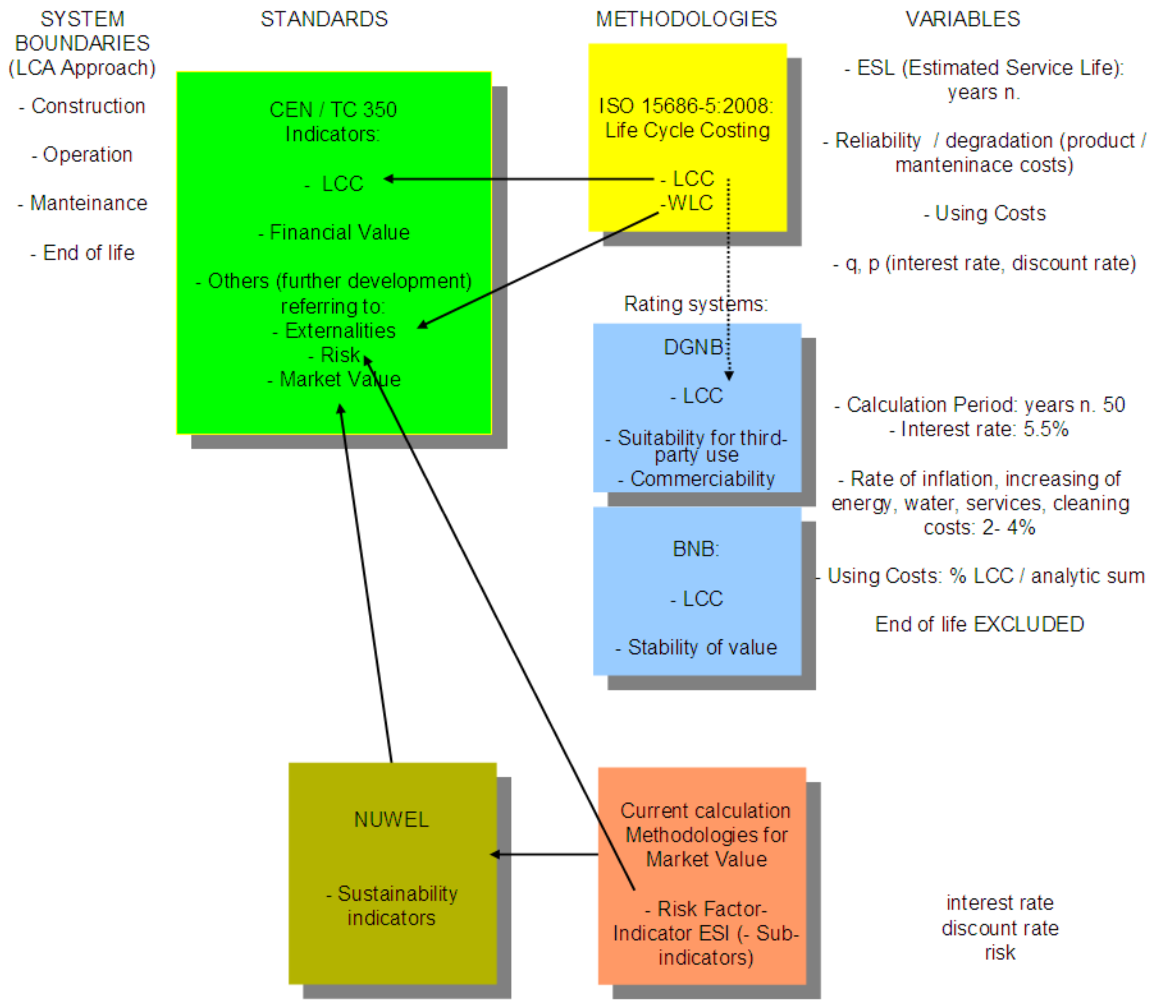


Fig. 2 CEN TC 350 "Sustainability of construction works" Family Standards: Overview of the sets of indicators. Fig. 3 Overview of the Economic indicators.



The second main step has aimed at identifying the boundaries of the territorial systems affected by hypothetical construction works on the building case study.

A **conceptual model** reporting the levels of the building, the campus, the city [32], the metropolitan area and the national-European framework has been built to study the territorial contextualization of the European indicators, describing aspects / impacts / performances (Fig. 3, 4).

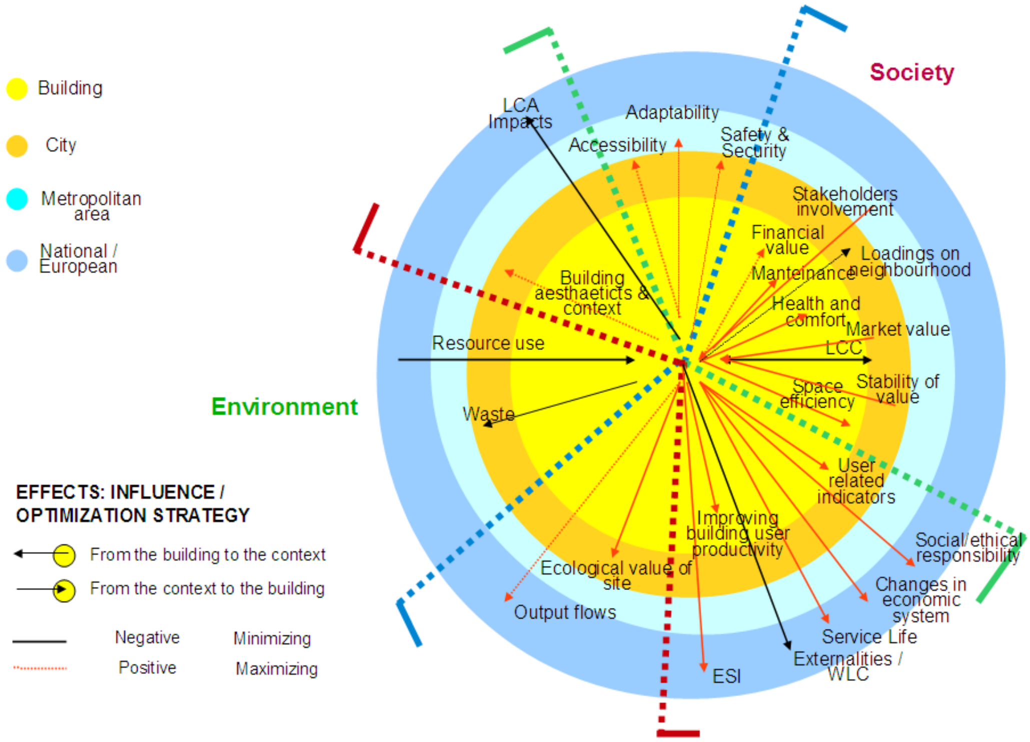
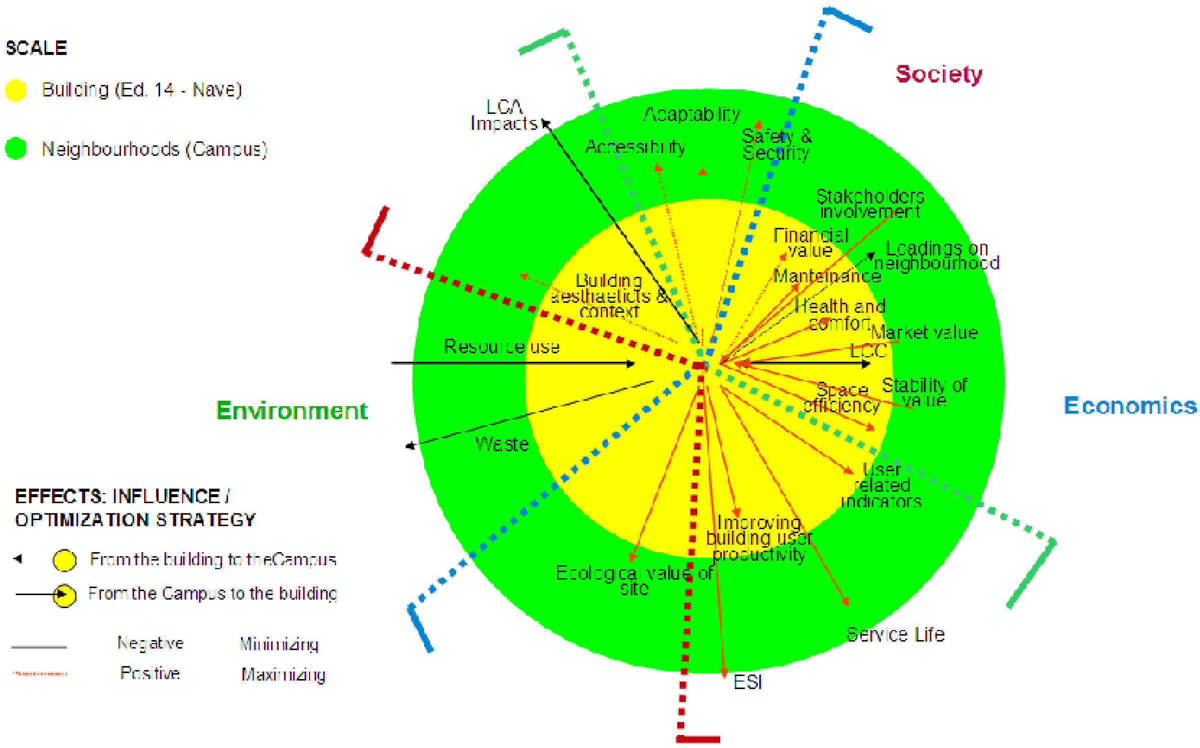


Fig. 3 Multi-Scale effects of construction works from building to the wider context described by the European Indicators. Fig. 4 Multi-Scale effects of construction works from building to the neighbourhoods (Campus) described by the European Indicators.



The following step has concerned to the identification of **existing evaluation systems at different scales** applied to the Milan area and the search of **interrelations** between the respective domains of indicators.
The comparison between the panels of indicators (the European one and and 3 territorial) has shown such similarities and congruences.
The set up harmonization tables will support the Politecnico di Milano management staff to plan future strategies [33] [34] creating **synergies** between interventions and policies implemented at different scales.

Moreover, some more applications of the so set up method have been done. In particular:

- The **association** of aspects / impacts / performances described by the building indicators related to a set of 40 design options and combinations thereof (including replacement of windows, insulation, heating [35] and air conditioning renovation, lighting installation) with the territorial scales involved, in order to introduce sustainability targets, referred to the territorial scales, in a multi-criteria analysis decision-making supporting.
- The **harmonization** of the different scales indicators sets with the guide set of ISCN with the European harmonized indicators. From this analysis it appears that the first sets are more accurate and the correlation of indicators belonging to the parallel panels of related systems at different scales can be strategic to achieve the performance of continuous improvement both at the level of campus and urban [36] which are the principles of the ISCN assessment and reporting.
- The **identification** of 10 sets of variables involved in decision-making, complex [37] in nature, aimed at building interventions in the context of the case study "Città Studi Sustainable Campus" and the possible relations, with particular reference to the areas of responsibility (environmental / social / economic [38]). A navigation matrix highlights the crucial nodes, characteristics and sensitivity of the decision-making processes and the areas most commonly affected, resulting a pretential management supporting tool for further decisions.

Results and Discussion

The results of the activities carried on evaluation systems and indicators [38] [39] applied to the case study show essentially that:

- The harmonized European panel of **43 core indicators** could be completed with **12 indicators** validated at European level but not yet shared to describe the impacts / performances of the building.
- **Interrelations** exist between the indicators belonging to different fields (environment / society / economy) [40].
- There is a relationship between the panel of European indicators of the **building** and the **territory**, namely relations with different scales (building, campus-area), due to the relapse of effects (impacts) produced by building operations and consequently affecting the territorial performances from a sustainable point of view.
- The study of the relationship between the building and the territorial scales **enlarges** the perspective of observation and evaluation of construction works in a sustainable key.
- In Italy and in the Milan area are available systems of sustainable territorial performance evaluation (ranking, reporting) interacting with the CEN TC 350 indicators system referred to the building.
- At this point you can select the **strategic key indicators** on which to **calibrate** building interventions that facilitate **synergies** to **improve** the sustainability of the **major scales**.

Conclusions and Acknowledgements

As one can easily see, the above suggested approach / method has potentially many possible applications and implementations.
These considerations could be, actually, usefully enhanced and integrated into the framework of an analysis / evaluation of sustainability aimed at a choice amongst alternatives, since this means that by acting on some **key performances** it can be more effectively to achieve improvements also on others (e.g. energy saving – LCC reducing) [26] [41], but also can improve the regional [42 [43] sustainability.
Making use of the MCDM techniques this result can be translated into logical and mathematical relationships between variables, defining hierarchies and constructing weight matrices of the indicators, according to a goal that **exceeds** the sustainability [44] [45] of each building / project alternative in an "absolute" or taken out of context way, but compare that to the **sustainability targets** of the territory in which the building is located.

Based on the above observations, the next steps of development of the research will include the selection of a restricted set of indicators TC 350 – "EcoSistema Metropolitano Milano" and analyse the interrelations between counterparts and/or interconnected indicators. After the identification of reference values, the development of methods of assessment of the indicators will aim to obtain, as a downstream of a MCDM analysis on a limited number of design options, the result corresponding to the "**most territorially sustainable solution**".

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Using FMEA and AHP methods to prioritise waste types in construction

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Summary

The construction industry sustains poor productivity, primarily because of the large quantities of waste generated during projects. Lean construction is considered to be an answer for better performance and from many industries the link between higher productivity and using lean practices have already been documented. The purpose of lean is to maximise the value to the customer and eliminate all non-value adding activities, otherwise known as waste. This study focuses on waste and its prioritisation. A literature review was carried out to define and classify different waste types relevant to construction. Then, a survey was made for seven Finnish construction practitioners to prioritise different waste types that occur in the construction industry. Failure mode effects analysis (FMEA) and an analytical hierarchy process (AHP), i.e. pairwise comparison, were applied to prioritise different waste types. Results show that poor communication and documentation is the most critical waste type in construction while non-physical wastes in general should be paid more attention to as they have similar negative impacts as traditional waste types but are more difficult to notice.

Keywords: Failure mode and effect analysis, FMEA, analytical hierarchy process, AHP, pairwise comparison, waste, prioritisation, lean construction.

1. Introduction

In Finland, as in many other countries, construction sustains poor productivity. Labour productivity in the Finnish construction industry has improved since the mid-1970s by approximately 0.5–1% per year [1,2]. Ineffective management practices, the growing emergence of subcontracting, and the lack of benchmarking are the factors affecting productivity [3]. The construction industry has a large impact on the Finnish economy, and improvement in construction industry performance would, therefore, have a major economic impact [1].

The concept of lean thinking has been successfully utilised in the manufacturing industry for many years. Lean manufacturing and higher productivity have been documented as being clearly linked, and lean manufacturing has been estimated to improve productivity by 15–40% [4]. Since the 1990s, lean thinking has been successfully applied in the construction industry [5]. Alarcon et al. [6] reported a 7–48% performance improvement after lean implementation in construction companies, while Forbes and Ahmed [7] also described cases of successful lean implementation.

The main purpose of lean thinking is to maximise value to a customer and eliminate all non-value adding activities, which are called ‘waste’. Lean thinking is a broad topic, so this study focused on waste elimination because of the large quantities of construction wastes; these are estimated to be between 30–70% of all activities depending on surveys [1,8–11]. A wasteful activity can cause many problems, such as schedule delays and cost overruns [12], so there is a considerable value to be gained by reducing the levels of wasteful activity. It is also a way to increase value generation for customers and to gain competitive advantage over competitors [13].

The concept of waste is reportedly not well understood by construction personnel [14,15], and this has led to problems in identifying and eliminating wastes. The main problem, in general, is the failure to recognise what constitutes waste [11] because there are no systematic [16] or adequate [17] measurement practices. Waste elimination is a main focal point on a daily basis in lean production. However, the waste elimination process is often misunderstood and is used only at the production level, without understanding the comprehensiveness of lean philosophy. Hence, there is a need to clarify the role of waste elimination in lean production.

Waste classification and prioritisation are important in identifying and eliminating wastes. Classification helps in recognising the different waste types, whereas prioritisation denotes the importance and ranking of waste types. This is important so that resources can be allocated appropriately, thus reducing the most remarkable wastes. Generally, resources are limited so focusing on the most important waste types is essential.

The main objective of this paper is to classify and prioritise wastes in the construction industry. In order to attain this objective, the following research questions must be answered:

- What is the classification of different waste types in construction?
- How waste types can be prioritised and what are the most important waste types in construction?

A literature review was carried out to define wastes and to describe the waste elimination process. Wastes were then classified based on information in the literature and previous studies of waste. Practitioners from various kinds of construction companies were then empirically surveyed in order to prioritise construction wastes and to obtain a comprehensive understanding of the matter. Finally, the results were analysed and their implications discussed briefly before concluding the paper.

2. Wastes in construction

Productivity, waste, and value are interdependent [18]. Productivity is often defined as a relationship between the output produced by a system and the quantities of input factors utilised by the system to produce that output. It is also closely related to the use and availability of resources as well as to value creation [2]. Therefore, it is possible to increase productivity by utilising resources, such as material and labour, more efficiently. Eliminating waste is a way to improve efficiency of resource usage. In lean value is defined through the customer. Value is what the customer wants, and a value-adding activity converts material or information to products or services needed by the customer [7].

In lean thinking, waste is linked to the term ‘a non-value adding activity’. However, it is difficult to identify waste if the value to the customer is unknown [19]. Womack and Jones [20] define waste as ‘any activity, which absorbs resources but creates no value’. More specifically, waste is any inefficiency that results in the use of equipment, materials, labour, or capital in larger quantities than those considered as necessary [21]. It also includes additional costs caused by both material losses and unnecessary work [22]. Monden [23] classified an organisation’s activities into three types:

- value adding activities
- non-value adding but necessary activities
- non-value adding activities.

The waste elimination process (Figure 1) consists of phases and support activities. The process starts with acknowledging waste and establishing a control system for measuring and identifying it. The idea of lean is to make waste visible, for example, by creating continuous material and information flows when waste and problems cannot hide in inventories. Instead, any stoppage on flow is a signal of emerged waste. However, making waste visible is the most challenging phase in waste removal because construction personnel generally fail to recognise it [11]. In addition, waste identification has not usually been systematically carried out in construction which further hinders its reduction [16].

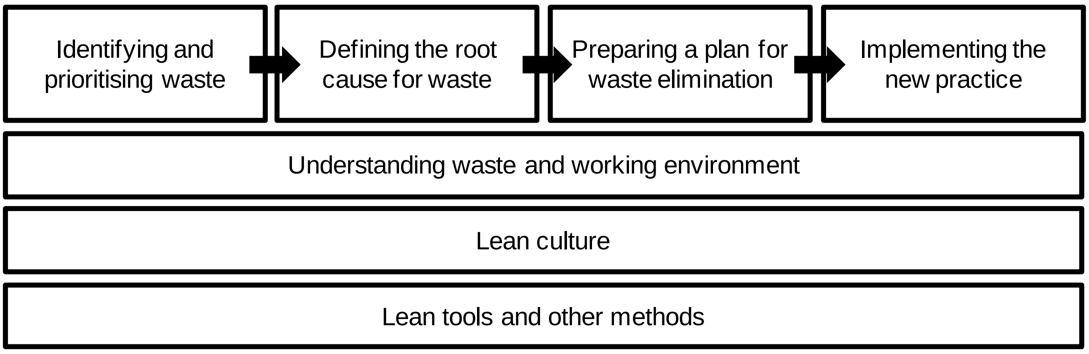

Figure 1. The waste elimination process.

In the following phase, waste can be identified by measuring or through expertise of individuals. Developing a systematic waste measurement system is important, because some of the wastes are not easily observable. The identification of wastes, analysing their causes, and measuring their level of importance provide useful information that allow management to act to reduce their negative effects in advance [14]. Yet, tools must always be selected to fit the problem at hand and the working environment they are used. The difficulty of waste elimination is that same problems tend to continually appear, which indicates that the root causes are not understood well enough [27]. Thus, it is important to identify the real causes of waste instead of just eliminating visible problem with obvious, but often non-optimal, solution. Only by eliminating the root cause can the visible problem be permanently removed.

Following completion of a root cause analysis, a waste elimination plan is prepared. There lean advocates obey consensus based decision making where different options and viewpoints are thoroughly considered before rapid implementation. To avoid making the same mistakes again and to make the improvement permanent, the new solution and working methods should also be standardised. This contributes to the building of a (lean) culture where problem solving and waste elimination become inherent to all employees.

Although lean tools can be used in many phases in the process, selecting and using the right tools for the given situation remains the most essential thing. Actually, the whole waste elimination process should always be formulated with the understanding of lean culture and methods, the type of waste and its impacts, and the working environment. For waste elimination to be successful, lean thinking must be adapted at the strategic level in a company’s management to understand and define customer value, and waste elimination must be institutionalised on an operational level [28]. This contributes to a complete strategy where waste elimination is not an isolated activity.

2.1 Waste classification

Wastes can be classified in different ways. One well-known classification is Ohno’s seven wastes: overproduction, waiting, unnecessary transportation, unnecessary movements, overprocessing, inventories, and defects [24]. Formoso et al. [21] revised these seven wastes to fit the construction industry. They also included weather conditions, theft, and vandalism. Subsequently, additional waste types have been proposed, such as making-do [18], poor constructability [22], making the wrong product or service [20], and behavioural waste [27]. Liker [25] mentioned unused peoples’ potential, overloading, and unevenness as waste types. Cain [29] proposed waste types, such as poor quality of work, poor material management, material waste, non-productive time, suboptimal conditions, and lack of safety. Inadequate methods [26], systems and structures [10], documentation [14], and inadequate information [30] have also been identified as waste types.

As a result of the literature review a classification with 15 waste types were made (Table 1). Some similar waste types were combined into one, which was perceived in waste definitions.

Table 1. Waste types in the construction industry.

Waste type	Definition
Overproduction	Producing material, products, or services beyond what is needed or too early, e.g. manufacturing products to an inventory [21]
Making wrong products or services	A customer's need is not understood and the wrong product or service is produced for the customer [20]
Unnecessary transportation	Transporting material, parts, tools, or information indirectly to the next working step, e.g. products or material are moved in and out of inventory between process phases [21]
Inadequate processing	Ineffective processing caused by unnecessary activities, defective working methods, or poor planning; producing overquality and underutilised capacity [21]
Inventories	Unnecessary storage of products, material, or work-in-progress [21]
Unnecessary movements	Unnecessary or inefficient movements made by workers during their job [21]
Defects	Includes quality defects, wrong working methods, and needing rework [21]
Making-do	Initiating a task without ensuring that all needed perquisites (material, workers, information…) are available [18]
Waiting	Products or workers have to wait for the next processing step, tool, parts, etc., e.g. because of a machine malfunction [21]
Overloading	Workload is too heavy for the worker or machine. This can cause defects and a decrease in safety and quality [25]
Poor constructability	Designing constructions that are difficult or inefficient to build [22]
Communication and documentation	Defective and poor communication, information, or documentation [14,30]
Safety	Working accidents, poor safety conditions, and dangerous working methods [10]
Peoples' unused potential	Underutilising peoples' creativity or skills. Workers' ideas and perspectives are not considered [25]
Other (weather conditions, theft, vandalism)	Waste of any other nature, such as theft, vandalism, or inclement weather [21]

3. Research methodology

A survey was carried out to identify the most important waste types in construction. From the literature review, 15 different waste types were identified and included in the survey. In the survey, practitioners were asked to rank waste types by importance. Because of the divergent nature of the different waste types (e.g. intangible and immeasurable waste types), the ranking was made by prioritising waste types as described below.

Two methods were used for prioritisation: failure mode effects analysis (FMEA) to calculate the waste priority number (WPN) and an analytical hierarchy process (AHP). FMEA is a technique based on identifying potential failures, analysing root causes, and examining failure impacts so that these impacts can be reduced [31].The AHP was established to aid in decision making for problems that involve multiple criteria [32]. Applying this concept entails a hierarchical formatting of the problem – establishing a pairwise comparison matrix in accordance with a pairwise comparison scale.

Within the context of the traditional FMEA, the degree of criticality of a failure mode is determined by calculating the risk priority number [31]. In WPN analysis, the idea is to evaluate the impact, frequency, and perceptivity of waste types by using a value from 1 to 10 and to multiply these values among the types. The WPN then illustrates the importance of the waste type. Impact refers to the effect of the waste in the operation, and the higher the number, the greater the impact. Frequency means how often the waste occurs; a value of 10 means continuous occurrence while 1 is very rarely occurs. Perceptivity refers to how easily waste can be identified; 10 means that waste is very difficult to identify and its root causes and consequences are hard to control within the current system. WPN is thus increased as occurrence of this kind of waste may have unpredictable and uncontrollable outcomes. A value of 1 means that waste can be easily identified by individuals or by the existing controlling system.

In the pairwise comparison, the respondents are forced to prioritise between two alternatives. By comparing factors, it is possible to identify the extent or ranking of the compared factors. A pairwise comparison includes several steps, starting with the construction of the matrix (size n × n). Then the respondent compares two factors at once by using the relative scale measurement shown in Table 2. Each alternative is matched one-on-one with each of the other alternatives. Reciprocals are automatically assigned in each pairwise comparison [32,33].

Table 2. Pairwise comparison scale [32]

Weight	**Definition**
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Substantially higher importance
9	Absolutely higher importance
2.4.6.8	Intermediate values
Reciprocals of above	Reciprocals (1/2 … 1/9) of the above weights can be used when necessary.

When all of the pairwise comparisons are made, the priority vectors (eigenvectors) can be calculated as follows: each element of the matrix is divided by its column total and then the priority vector can be obtained by finding the row averages. After that, the consistency of comparison is determined by using the eigenvalue (λmax) to calculate the consistency index (CI), CI = (λmax – n)/(n – 1). After that, the consistency ratio (CR) can be calculated by dividing CR with the appropriate value of the random index (RI), which is listed in Table 3. If CR does not exceed 0.10, it is acceptable, but if it is more than that, the judgment matrix is inconsistent and should be reviewed and improved [32,33].

Table 3. Random index (RI) values [34]

Size of matrix (n)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Random consistency	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54	1.56	1.57	1.58

Data were collected from seven interviews made during spring 2012. All of the interviewees worked at the managerial level in different construction companies (see Table 4). To obtain an inclusive overview of construction's wastes, interviewees were selected from different kinds of construction companies.

Table 4. Information of interviewees

Title	**Trade**	**Size of business unit**	**Work experience**
Project Engineer	Contractor	4	2
Executive Director	Design	4	3
Executive Director	Project Management	4	5
Account Manager	Design and Maintain	3	3
Consultant	Construction Consultant	1	4
Executive Director	Developer	1	5
Project Manager	Contractor	4	2

Size of business unit (employees): 1=0–10, 2=10–50, 3=50–200, 4=200+
Work experience (years): 1=0–5, 2=6–10, 3=10–15, 4=15–20, 5=20+

4. Waste priority in construction

4.1 Waste priority number

The results of the WPN analysis are presented in Table 5. Values of waste types are the averages of interviewees' answers. Communication and documentation, peoples' unused potential, defects, making the wrong product or service, and unnecessary movements are ranked the most important waste types.

Table 5. Results of the WPN analysis

Waste type	WPN	Impact	Frequency	Perceptivity
Communication and documentation	**328**	<u>8.0</u>	7.0	5.9
Peoples' unused potential	**251**	6.9	5.6	<u>6.6</u>
Defects	**238**	7.0	7.0	4.9
Making wrong products or services	**207**	6.9	5.3	5.7
Unnecessary movements	**201**	4.8	<u>7.3</u>	5.7
Inadequate processing	**187**	6.0	5.5	5.7
Making-do	**186**	6.4	7.0	4.1
Overloading	**176**	6.7	6.6	4.0
Poor constructability	**152**	6.7	5.3	4.3
Overproduction	**148**	7.1	6.6	3.1
Waiting	**146**	6.0	5.9	4.1
Unnecessary transportation	**144**	4.9	7.1	4.1
Safety	**51**	6.5	2.3	3.3
Inventories	**45**	4.3	6.2	1.7
Other (weather conditions, theft, vandalism)	**30**	4.7	4.8	1.3

Communication and documentation waste was the most important waste type. The interviewees described that type of waste as a basic reason for other wastes. Its impact was clearly highest, frequency third highest, and perceptivity second most difficult. The second most important waste type was peoples' unused potential which perceptivity was clearly the highest. In addition, the results showed a high frequency of unnecessary movement of both workers and material, but only a moderate impact of this type of waste made it less important than other wastes addressed above.

Often waste types are prioritised by impact and frequency. If ranked in this way, communication and documentation would remain at the top, but defects, overproduction, making-do, and overloading would all increase their importance. With respect to WPN, these waste types are in the middle of the rankings. This is caused by a low perceptivity value. In these circumstances, evaluation of perceptivity brings a new dimension to waste prioritisation. It is also a very important factor in the waste elimination process.

In the total averages, the average perceptivity (4.3) was lower than the averages of impact (6.2) and frequency (6.0). Perceptivity of wastes, therefore, is seen to be relatively easy. It could be that the interviewees knew about lean and were aware of large quantities of waste in construction.

There was no clear correlation in the interviewees' results. For example, in every result the most important waste type was different. This probably is a result of the interviewees' different activity fields. For example, design and construction have different situations with respect to safety, inventory, etc.

4.2 Pairwise comparison

Figure 2 presents the prioritisation of wastes made by pairwise comparison and shows the average of interviewees' answers. Presented values are relative weights and indicate the relation to other wastes. The most important wastes were making the wrong product or service, communication and documentation, overproduction, and defects.

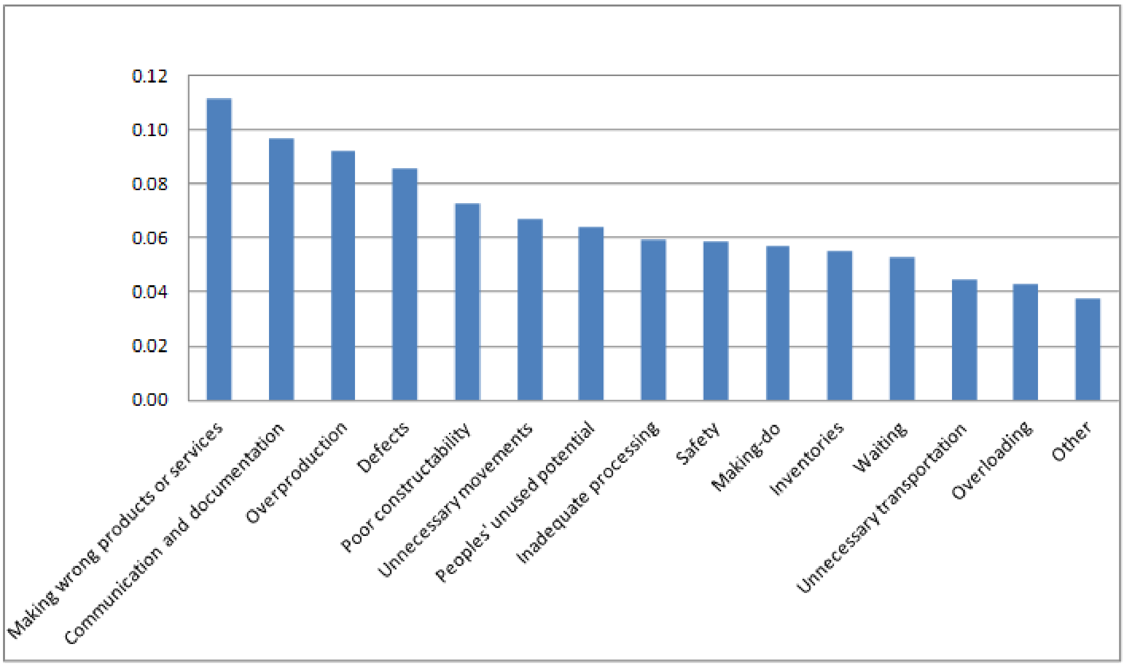

Figure 2. Results of pairwise comparison

There was no clear correlation in the results with the WPN analysis. Communication and documentation, making the wrong product or service, and defects rated highest with both methods. Overproduction and peoples' unused potential had the greatest difference in the top-ranked waste types. Overproduction was third highest in the pairwise comparison but ranked only tenth in the WPN analysis. Peoples' unused potential was second highest in the WPN analysis but seventh in the pairwise comparison.

Notably, the results of the pairwise comparison correlated more with the impact of the WPN analysis than the WPN itself. The pairwise comparison was made after the WPN analysis, and it is possible that its results affected the pairwise comparison. Interviewees' responses had no correlations with each other in the pairwise comparison or in the WPN analysis, which is probably due to the interviewees' different activity fields and different perceptions of waste.

5. Discussion

There is obviously a significant amount of non-physical waste in the construction industry. Often waste identification and elimination concentrate on physical waste like wasted or deteriorated materials or some of Ohno's seven waste types. The results show that concentrating on eliminating these seven waste types is not sufficient because the top five results included only two of those waste types. This study highlights that intangible wastes, such as communication and documentation and peoples' unused potential, need to be taken into consideration.

Interviewees noted that communication and documentation were defective. Communication was mentioned as also being a basic cause of other wastes. The construction industry is fragmented, and increasing collaboration could improve communication. One interviewee said that communication and documentation are ´no one's possession´ and therefore are not controlled.

Identifying waste is the most critical part in the waste elimination process because waste that is not seen cannot be eliminated. According to the WPN analysis, waste perception was considered to be easier than difficult (average 4.3). For example, the averages of impact and frequency were 6.2 and 6.0, respectively. Evaluation of perceptivity is challenging because it is relative and depends on the assessor. Therefore, independent and reliable data about perceptivity are difficult to obtain compared to measuring an impact or frequency using time or a monetary value.

The CR values of pairwise comparison, which measure the consistency of results, were over 0.10 in every interviewee's responses. Therefore, results of pairwise comparisons must be critically evaluated. If CR exceeds 0.10, it means answers are inconsistent. Saaty [32] noted that reviews and improvement are needed to improve consistency between answers if CR exceeds 0.10.

6. Conclusion

The construction industry suffers from a large amount of waste. Lean thinking provides an opportunity to reduce waste and improve productivity. This study concentrates on waste elimination and prioritisation in the construction industry. It also provides useful information in waste identification and elimination. Waste elimination is a process that includes acknowledging, identifying and prioritising waste, defining its root cause, and eliminating it. Waste elimination should not be an isolated technique but an inherent activity in daily operations.

In this study, a classification with definitions for 15 waste types, that were regarded central for construction, was made. In addition, a prioritisation was made for these waste types by applying FMEA to calculate WPN for each as well as by pairwise comparison. Results show that the most important waste type is communication and documentation, which stands out with both prioritisation methods. The study also highlights other intangible but important wastes, such as people's unused potential, that should be paid even more attention to than traditional waste types.

This research has some limitations. The sample was small and inconsistencies were registered in the results from pairwise comparison. Future research should include a more extensive collection of data and iterations to achieve consistency. Interviewees in this study worked at the managerial level, so a comparative survey could be made using workman and masters. Also, a study of communication and documentation problems and their reasons would be valuable.

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Development of assessment method of resilient capacity of urban energy systems: Verifying resilience assessment model with hypothetical systems

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Summary

This paper presents the latest accomplishment of an effort to develop an assessment method of resilient capacity of smart energy system at the distribution level that focuses on the relationship between the resilient capacity and, energy generation portfolio and demand response capacity. The assessment scope includes the distributed generation (DG) installed at the users' side and limits the application of demand response (DR) on building sector only. The assessment method is targeted to be used by policymakers and suppliers to make better decisions and investments. The objective of this paper is to show the development and verification of the resilience assessment model with hypothetical power distribution system. This paper begins with the background and motivation of the development of this assessment model which are followed with addressing of the concepts of sustainability and resilience. Resilience in this research context is defined as the ability of an energy system depending on its own responsiveness and vulnerability to maintain its energy-dependent functions at or above minimum desired conditions throughout any disturbances. The development of the assessment methodology which is primarily a combination of a conceptual framework, an indicator selection framework and a modelling framework is explained.

In order to verify the resilience assessment model, hypothetical power distribution systems were modelled in a simple scale and scenarios of disturbances at different scales were prepared. Disturbance expressed in the terms of the change of parameter values of components (generation, demand side and power network) in the system is applied to the hypothetical system model to run power flow analysis by using an analysis tool called the OpenDSS. The power flow analysis is aimed to add feasibility and reality of power system into the assessment result. The analysis outputs are used as the indicators of resilience attributes and system functionality which in turn are used to determine the resilient capacity of the system. The essence of assessing resilience is to compare the actual values of the indicators with their respective target or desired values. Scenario analysis was performed by applying disturbances at different scales to the hypothetical system model and then the same process was repeated to other model. The resilience assessment model is still under development. For this paper, the verification only covered the model behaviour in the aspect of vulnerability. Only the indicator performances of voltage stability index (VSI) and spectral gap were studied. Verification of the resilience assessment model was done by comparing and analysing the assessment results of those hypothetical system models to check if the assessment model was able to logically and reasonably reflect the resilient capacity of the modelled systems or not. The result of the limited verification shows that the VSI indicator did not differ much for all scenarios and the spectral gap indicator showed inconsistent changes during the analysis. Refinement of the modeling and analysis processes and research of more sensitive and consistent indicators are the considered to improve the assessment model. Verification and testing of the models need to be repeated to ensure that the assessment model behave reasonably before applying it to actual systems for validation and testing of hypothesis.

Keywords: resilience, assessment, power system, distribution system, distributed generation, demand response, development, verification

1. Introduction

1.1 Background

Energy especially electric energy is an important commodity in daily life and during emergency time. Recent disasters happening around the world such as the 2011 Tohoku earthquake and tsunami in Japan and the hurricanes in the United States have proved this situation. The physical components of a power system exposed to such destructive events like the transmission towers and lines, and distribution transformers and lines tend to be damaged and this situation consequently leads to the halt of power supply to affected areas. Modern societies that highly rely on energy supply for the living and various activities will then have to suffer the loss, inconvenience and discomfort resulting from the disasters. Not only large-scale natural disasters, disturbances to a power system also come from man-made activities. On one hand, there are intentional human sabotage, accidents and mistakes of command, control and communication to the operation of a power system On the other hand, sometimes the implementation of new technology meant for good turns into a cause of disturbance to the power system, for an example the renewable energy. The intermittent nature of renewable energy generation becomes an uncertainty to the total energy production and the balance of energy demand and supply. The fear of disturbing the stability of the power system when increasing the generation of renewable energy is one of the reasons why renewable energy is not used to fully replace the conventional energy.

Advancing forward from the traditional centralized generation is the adoption of the next-generation power grid system, which is popularly known as the smart grid system. A smart grid prefers distributed generations (DG) over centralized generations because of improved system reliability and power quality, and reduction of peak power, vulnerability to terrorism and land-use effects [1]. Another feature of a smart grid is the demand response (DR) which is a means to achieve efficient energy consumption through the interaction between the energy users and suppliers. In essence, a smart grid is an improved version of the traditional power system that aims to ensure continuous and good quality power supply to the end users.There are many terms used to describe the performance and properties of an energy system such as robustness, reliability, efficiency and so on. Among them, the term of resilience is often chosen to describe the ability or performance of an energy system during time of disturbances [2] [3] [4].

The research related to this paper addresses on the assessment issue of urban energy system, which aims to develop an assessment method of resilient capacity of smart energy system at the distribution level that presents the relationship between resilient capacity and energy generation portfolio and demand response capacity. The assessment method is targeted to be used by policymakers and suppliers to make better decisions and investments. This paper mainly covers the development and verification of the resilience assessment model.

1.2 Motivation

The major motivation behind this research is the anticipation that by providing information related to the resilient capacity of a power system the damages, loss and inconvenience caused by any disturbances can be reduced. Policymakers need to have insight of the outcome of a power system during and after any occurrences of disturbances so that they can make better decisions on how and where to improve the power system. Other than the policymakers, energy suppliers and electricity companies which are in charge of the generation, transmission and distribution of power supply can use a resilience assessment tool to assist in their design and planning of power systems. For an example, the suppliers can manage more efficient power dispatch and generation plans for an area with a given capacity of distributed generation without compromising the stability and quality of the power supply.

The idea of making generation portfolio and DR capacity as the decision variables of the resilience assessment is motivated by the authors' firm belief and also the opinions of many literatures of power system that the DG and DR are playing significant roles in the current and future power systems. The capacity ratio of centralized generation and DG is expected to have substantial change because DG especially the renewable energy generation is expected to have rapid growth and penetration in the near future. As a result, generation portfolio is a primary factor of resilience performance of a power system because the generation output of DG especially the renewable energy generation is relatively unpredictable and harder to control. The integration of information and communication technology into the smart grid system has enabled more diversified interaction between the supply side and demand side and among them DR is considered to possess unexplored potential to meet goals related to energy efficiency and climate change [5].

An assessment that covers the whole power system would be nice to have but at the same time it could become a complicated and tedious task. In addition, DG is more often installed near the demand area and DR is always linked to demand users. Therefore, the decision was made to develop the resilience assessment method by focusing on the power distribution system only.

1.3 Objectives

The objectives of this paper are to show the development of a resilience assessment method of urban energy systems which is a combination of a conceptual framework, an indicator selection framework and a modelling framework, and verify the assessment model with hypothetical smart energy systems at the distribution level.

1.4 Methodology

This paper contains the development of a resilience assessment methodology and the verification of a model made according to the developed methodology. For the development of the assessment methodology, intensive literature reviews about resilience, assessment indicators, power system and others have been done. Existing and relevant methodologies, models and concepts have been adopted and applied in the assessment methodology of this research. For the verification of the resilience assessment model, simplified modelling and simulation were done, and the consistency of the assessment model is observed and used for verification. At this stage, only simple and hypothetical models of power systems were used in the verification study.

1.5 Structure of this paper

The first section above introduces about the critical issues related to urban energy systems that motivate the authors to develop a resilience assessment method of smart energy system at the distribution level. The second section explains the definition of resilience used in this research and how it is different than other similar system properties and concepts especially the concept of sustainability. The third section describes the development of the resilience assessment model. The fourth section reports the procedures taken to verify the model and the fifth section presents and discusses about the result of model verification. The sixth section concludes this paper.

2. Resilience and sustainability

A very frequently quoted definition of sustainability is meeting the needs of the present without compromising the ability of future generations to meet their own needs which originated from the UN Brundtland Commission in 1987. The issues that the concept of sustainability has been used for to solve are the depletion of energy and natural sources, and the global warming. While efforts have been put to achieve sustainable development, many catastrophic disasters have landed on many countries and causing huge losses of lives and properties. The performances and survivals of various systems such as buildings, lifelines, infrastructures and transportation networks during such difficult hour have become the centre of attention. The term of resilience has since started gaining momentum in being the word to describe system performance during time of disturbances. According to Oxford Dictionaries, resilience is the ability of a substance or object to spring back into shape, or the capacity to recover quickly from difficulties. The authors have attempted to distinguish the resilience from other similar system properties and define resilience for this research context [6]. In this research, resilience is defined as the ability of an urban energy system depending on its own responsiveness and vulnerability to maintain its energy-dependent function at or above minimum condition throughout any disturbance. The concept of sustainability emphasizes on the way of doing things that aims to achieve efficient use of resources without compromising the environment quality. But then, the concept of resilience focuses on the ability to survive and sustain functionality during time of disturbances.

3. Development of resilience assessment model

The authors aim to develop an assessment method of resilient capacity of smart energy system at the distribution level that presents the relationship between resilient capacity and energy generation portfolio and demand response capacity. The assessment method is targeted to be used by policymakers and suppliers to make better decisions and investments. Besides assessing resilient capacity based on current and past events, this method can be used to assess for future events which is useful for design and planning. As some modelling and analysis procedures of the assessment process are simplified and therefore the analysis result does not represent the complete and real outcome of a power system.

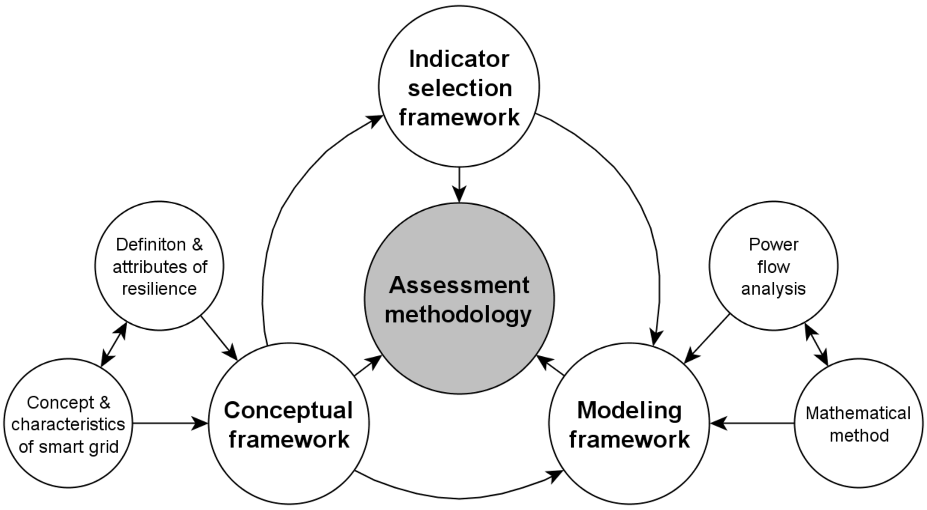

Figure 1 Structure of assessment methodology

The resilience assessment model contains three frameworks: conceptual, indicator selection and modeling frameworks (*Figure 1*). The conceptual framework handles the understanding of the mechanism of the emergence of resilience in a power system and derives definition and attributes of resilience for this assessment method. The indicator selection framework is aimed to determine and refine the selection of indicators of resilience attributes and system functionality for the assessment. The modeling framework asks for a power system of interest to be modelled and analyzed with a power flow analysis to obtain analysis outputs which are used as the indicators of resilience attributes and system functionality for the assessment. Further explanation about the three frameworks are given in the following sections.

A brief and quick look at the assessment process is shown in *Figure 2*. There are four types of inputs: the decision variables consisting of the generation portfolio and demand response capacity of a power system, other parameters consisting of information of the initial conditions of the components of the power system, disturbances input expressed in the change of values of components' parameters and decision variables, and constraints of the power system. All the inputs are used by a model of a power system at distribution level and the distribution system model will be used in the power flow analysis. In the end of the analysis process, the analysis outputs are used as the indicators of resilience attributes and system functionality. The indicators are used to make static or dynamic assessment of resilience depending on the timeframe used in the analysis. The essence of assessing resilience is to compare the actual values of the indicators with their respective target or desired values.

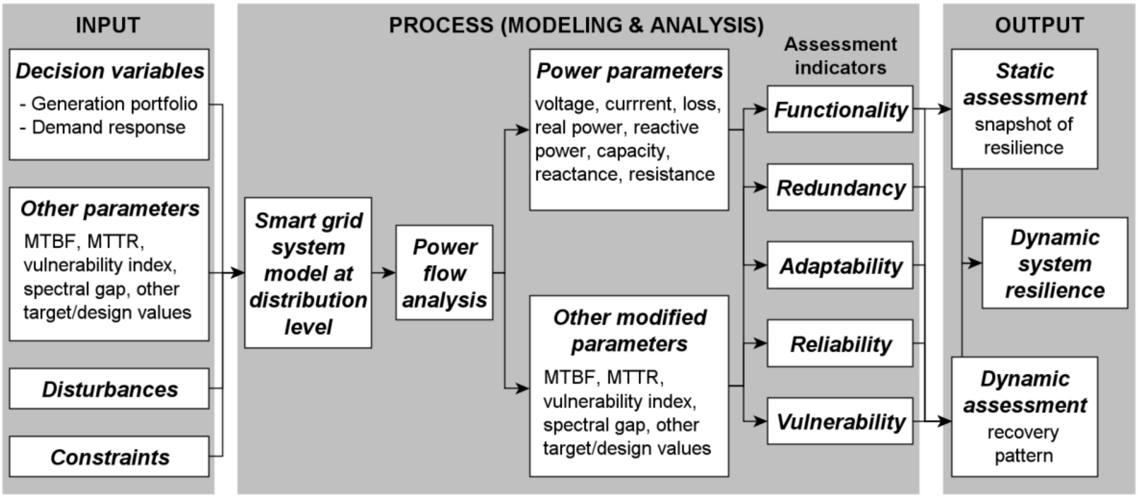

Figure 2 Input, modeling and analysis processes and output of assessment

3.1 Conceptual framework

Aside from defining resilience for this research the authors also have resolved the attributes of resilience for this research context through in-depth literature reviews about resilience and a series of analysis [6]. Functionality, responsiveness, vulnerability and disturbance are four significant elements to consider when the resilient capacity of a system is discussed. From there, the responsiveness which constitutes of adaptability, reliability and redundancy, and vulnerability of a system are considered as the most representative resilience attributes. The interactions and interrelationships among the four elements form the conceptual framework of the assessment method as shown in *Figure 3.*

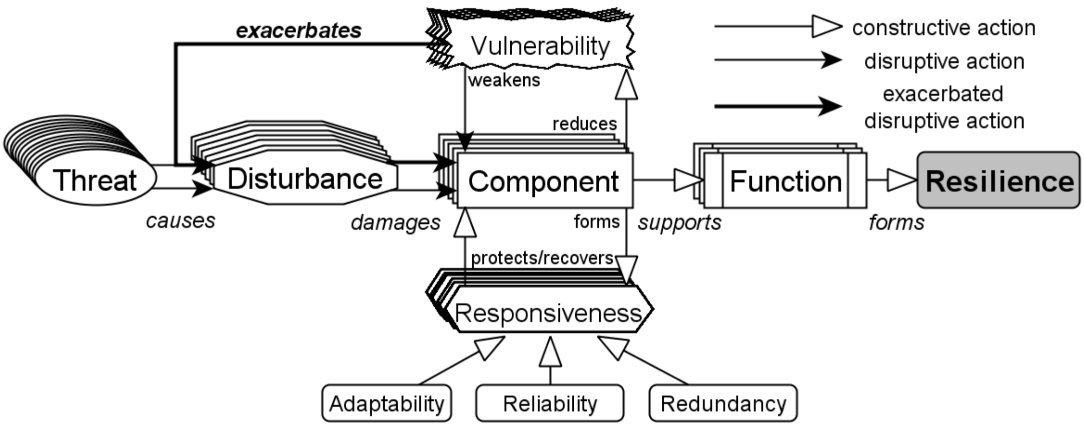

Figure 3 Conceptual framework showing interactions and interrelationships among resilience attributes (responsiveness and vulnerability) and elements related to system components (disturbance and functionality)

The conceptual framework also shows the mechanism of the emergence of resilience in a general system. On one hand, a system is always surrounded with indefinite threats and at certain time some threats manage to manifest into disturbances that cause damages to the system components. On the other hand, a system is made with many components in order to fulfil its functions and the degree of how much the functions are fulfilled is used to define the resilience of the system. For many systems serving similar functions and experiencing same level of disturbances, it is their respective vulnerability and responsiveness attributes that define their own resilient capacity. Higher vulnerability usually results in lower resilience because it exacerbates the damaging impacts come from the disturbances which will eventually reduce the system functionality. Higher responsiveness usually results in higher resilience because it enables a system to minimize damages and recover faster. Minimizing damages and faster recovery are two important characteristics of a resilient system. Vulnerability reduction and responsiveness increment can be achieved by hardening the system components.

Throughout understanding resilience and carrying out this research work, the authors accept and apply both the ideas of holism and reductionism, albeit with more weight on the latter idea. Resilience of a system is taken as a system ability that comes from the collective abilities of all the components of the system; that the system is the sum of its part. However, due to uncertainties and limitation (knowledge, cost, etc.) in real life, it is hardly possible to have a complete grasp of the mechanism of a complex system especially when unpredictable nature elements are involved. In this case, the authors agree with the idea that the system is more than the sum of its parts.

3.2 Indicator selection framework

The indication selection framework proposed by Maclaren [7] was used to select the indicators of resilience attributes. The indicator selection framework follows the following sequence: defining goals (objectives) for which the indicators are needed, scoping, choosing indicator framework (in this case, combination framework is used), defining selection criteria (representativeness, usefulness, relevance, scientific validity, analytic soundness, measurability and feasibility), identifying potential indicators, choosing a final set of indicators, analysing and reporting indicator results, and assessing indicator performance.

Matching the conceptual framework that bases on reductionism as well as holism, the authors adopted bottom-up approach for the resilience assessment method. Under this approach, a power system is considered to consist of three major components: the generation, demand side and network and that each component is assigned with an indicator for each respective resilience attribute, as shown in *Table 1*. The components each have different indicators than the other for the attributes of redundancy and vulnerability while all of them have the similar indicators for the attributes of adaptability and reliability. When the indicators of resilience attributes were selected according to system components, the indicators of system functionality were selected from measurable or quantifiable functions or objectives of a system, which in the case of a power system and according to the authors' choice are the power quality, energy saving and quality of life (*Table 2*). The indicators of resilience attributes and system functionality together indicate the degree of resilience of the system. When performing an actual assessment, actual values of those indicators are measured and compared with their target or desired values.

Table 1 Indicators of resilience attributes

Resilience Attributes	Indicators		
	Generation Component	Demand Side Component	Network Component
Responsiveness			
Redundancy	Available dispatchable capacity	Available demand response capacity	Available link capacity
Adaptability	Shannon's diversity index [8] [9] $H = -\Sigma_i p_i \ln p_i$		
Reliability	Availability $A = MTBF / (MTBF + MTTR)$		
Vulnerability	Vulnerability matrix [3, pp.91]	Voltage stability index [10] [11] $VSI_{m2} = \lvert V_{m1}\rvert^4 - 4.0 (P_{m2}X_{jj} - Q_{m2}R_{jj})^2 - 4.0 (P_{m2}R_{jj} + Q_{m2}X_{jj})\lvert V_{m1}\rvert^2$	Spectral gap [12] [13] $\Delta\lambda = \lambda_1 - \lambda_2$

Table 2 Indicators of functionality

Functionality Indicator	Equation
Power quality	$PQ = 1 - \lvert V_{actual} - V_{target}\rvert / V_{target}$
Energy saving	$ES = Saving_{actual} / Saving_{target}$
Quality of life	$QoL = 1 - (DR_{ancillary} + DR_{emergency}) / D_{total}$

**Note: V: Voltage, DR: Demand response, D: Demand*

3.3 Modeling framework

An assessment method is usually developed for more than just the purpose of assessing based on the current and past events. It is also often used to assess for future events which is useful for design and planning.

Therefore, a modeling framework is included into the resilience assessment methodology to account for such kind of assessment. The modeling framework asks for a power system of interest to be modelled and analysed with a power flow analysis to obtain analysis outputs which are used as the indicators of resilience attributes and system functionality for the assessment. The power flow analysis can be used to simulate the operation of the power system with predicted or imagined conditions and the results of resilience assessment can be used in decision making of what to do to improve the resilient capacity of the power system.

Feasibility and reality of the assessment result have been accounted for in this modeling framework so that the assessment method should be as scientifically sound as possible. For examples, the power flow analysis complying with the law of physics and principles of electricity is used and the negative impacts caused by disturbances are unambiguously translated into quantitative values that are expressed in the change of values of components' parameters, decision variables and constraints of the power system. As the modelling and analysis processes are performed with the primary intention to obtain outputs of some relevant parameters to be used as indicators, some modelling and analysis procedures are simplified and therefore the analysis result does not represent the complete and real outcome of a power system.

4. Model verification

4.1 Limitation and scope

The resilience assessment model is still under development. For this time, the verification only covered the model behavior in the aspect of vulnerability. Only the indicator performances of voltage stability index (VSI) and spectral gap were studied. The power flow analysis was done in a snapshot mode to obtain the parameters at that moment.

4.2 Hypothetical system models and scenario analysis

Two simple and hypothetical distribution system models used in the study are shown in as system A and system B in *Figure 4*. Three scenarios were prepared for each system models: normal scenario (A and B), moderate disturbances (Ai and Bi) and serious disturbances (Aii and Bii). Instead of indicating the type of disturbances, the impacts and damages caused by the disturbances were expressed as the malfunction of distribution lines. Affected distribution lines are marked with dotted line and the affected demand users (building users) were filled with grey and black colour. An open-source analysis software called the OpenDSS was used to run the power flow analysis and the analysis outputs were used to calculate the VSI values for each demand node.

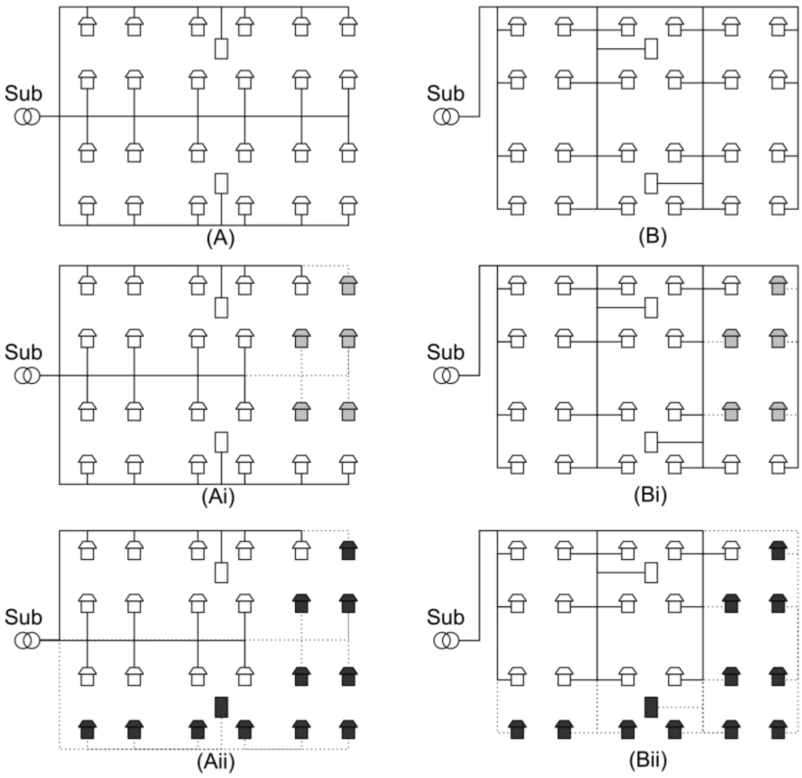

Figure 4 Two hypothetical system models and three disturbance scenarios

5. Result and discussion

The spectral gap values for system A are 0.2270, 0.2665 and 0.2297, and for system B are 0.1036, 0.0953 and 0.1561, in the order of normal scenario, moderate and serious disturbances, respectively. When a network receives more broken connections the spectral gap is expected to decrease but the result shows the problem of inconsistency. The possible explanation to this problem is that the spectral gap is more effective when used with meshed networks than radial networks. On the other hand, the VSI values for all connected demand nodes of both system A and B in all scenarios are showing insignificant difference. This insensitivity problem could be caused by oversimplification of modeling and analysis processes, mistakes and errors. Refinement of indicator selection, revision of modeling and analysis processes are necessary before verification of a complete model can be done.

6. Conclusion

This paper explained the original works of developing an assessment method of resilient capacity of smart energy system at the distribution level that presents relationship between the resilient capacity and, energy generation portfolio and demand response capacity. The developed model was verified with hypothetical distribution systems by using scenario analysis. At this stage, the resilience assessment model is not completely developed yet. The result of the testing and verification of the model shows that there are insensitivity and inconsistency problems with the vulnerability indicators. This model requires further refinement and verification.

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Local citizen initiatives and transitions to energy sustainability

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Summary

The energy transition requires the transformation of communities and neighbourhoods. It will have huge ramifications throughout society. Many cities, towns and villages have put together ambitious visions about how to achieve e.g. energy neutrality, zero-emission or zero-impact. What is happening at the local level towards realizing these ambitions?
In a set of case study's we investigate the following questions: How are self-organized local energy initiatives performing their self-set tasks? What obstacles are present in the current societal set-up that can hinder decentralized energy production?
In our cases local leadership, vision, level of communication and type of organisation are important factors of the strength of the 'local network'. (Inter)national energy policy and existing energy companies largely determine the 'global' or outside network. Stronger regional and national support structures, as well as an enabling environment for decentralized energy production, are needed to make decentralized sustainable energy production a success.

Keywords: decentralized energy production; energy initiatives; citizen groups; energy neutrality; sustainable energy; prosumers

1. Introduction

A relatively new phenomenon is that citizens take energy in their own hands, not only individually but also increasingly by establishing local energy initiatives. Indeed, a paradigm shift appears to occur in energy production and consumption, from large centralized fossil energy plants to diversified decentralized sustainable production. More and more consumers produce at least part of their own energy; the affix 'prosumers' is used to describe this development of decentralized energy production. Local Energy Initiatives foster and stimulate this development.

We study local energy initiatives in different research projects. The case studies presented in this paper are part of the following projects:
1. In the MACREDES project (workpackage IIb) we engage in several case studies of local energy initiatives, concentrating on organisation models, leadership and team effectiveness. We make an inventory of different organisation models of local initiatives.
2. In the Energy Plus Communities project we investigate the relation between social cohesion and the realization of community energy ambitions and evaluate differences in technical and spatial approaches.

The case studies primarily focus on the local energy initiatives, their ambitions, activities, and organization. The initiatives are all located in the north of the Netherlands. In the past two years fieldwork and interviews have been undertaken to investigate local energy initiatives. These community groups have diverse backgrounds, ranging from political parties, commercial ventures,

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and energy cooperatives, to Village Working Groups. However, they converge as to their goal of promoting local energy production.

A key concept in our theoretical framework is *agency* and what citizens can do to change a system. How can these initiatives be effective? What factors influence their success or failure?
The case studies are analysed with theoretical concepts derived from literature on the energy transition, non-profit organisation, teamwork and sustainable leadership. For example, we categorize the initiatives according to the model of Walker et al. who argue that degrees of 'collectiveness' and 'openness' are important factors influencing the acceptance of new sustainable energy production units. As such, we will ascertain if these factors can be witnessed in the Dutch energy initiatives as well. In addition, we focus on factors that determine if the implementation of sustainable energy measures has a chance to succeed. Here, we depart from Nijkamp´s 'pentagram for sustainable cities'. This pentagram points to the factors that have to be taken into account when implementing sustainability in cities. These factors are technology ('hardware'); communication ('software'); social conditions ('ecoware'); financial requirements ('finware') and organization ('orgware'). We combine the approaches of Walker and Nijkamp with actor-network theory in a conceptual model that is used to analyse local energy initiatives in the Netherlands.
In our model we identify 'local networks', where team effectiveness and the level of activities and communication are important factors. These local networks are embedded in a wider environment or 'global networks'. A supportive wider environment appears to be a crucial factor for the success of local initiatives.

2. Local Energy Initiatives: 20 case studies

In the past two years we followed the activities of 20 local energy initiatives in the North of the Netherlands. Fieldwork and qualitative interviews have been done to get in depth knowledge of the local energy initiatives. The interviews were transcribed, coded and analysed according to a coding frame. The coding frame was developed on the basis of the theoretical framework and first tried out in a pilot study. We also studied websites, documents and other communications of these groups.
We look at the initiatives as embedded and interlinked networks. The effectiveness of local energy initiatives we expect to be influenced by internal teamwork, activities on the level of the local project and the relations to the established networks on a regional or national level. On each level we focus on several factors that showed up prominently in our findings.

3. Discussion

In theory there are many technological options for decentralized energy production, however, the actual choice is rather limited. Due to earlier debates about landscape the regional energy policy is very strict on local windmills. Only large wind parks in designated areas are permitted. This means that local energy coops do not have the opportunity to invest in a cooperative village windmill, which would bring a considerable income for the community. Biomass installations are restricted to farmers, so again this technology is not within reach of most local initiatives.
Compared to Germany and the UK the situation in the Netherlands is very restricting for local energy initiatives. This leaves the local groups only solar power as promising technology. The recent fall in prices for solar PV has helped to bring 'prosumerism' within reach. However, the feed-in tariff in the Netherlands is so low that it is very unattractive to feed electricity into the grid. Small-scale biomass (wood pellets and woodchips) is another possibility on the individual level.
Due to fiscal restraints it is not possible to use electricity from a cooperative installation without paying taxes, including the former CO_2 tax (now called energy tax). This is a considerable barrier for local energy initiatives; it practically restricts their operations to the individual level.
Consequently, small-scale installations in and on private houses, combined with energy efficiency measures, appear to be the only viable option at the moment. It is therefore not surprising that the majority of initiatives in our study choose this route.

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1. Introduction

The societal transition to a sustainable energy system requires the transformation of communities and neighbourhoods. The transformation of energy production towards a more sustainable and decentralized system is progressing very slowly in the Netherlands. In Europe only Luxembourg has less sustainable production capacity installed. National fiscal policies are at present far from conducive to small producers; the national energy policy is one of the major barriers to change. Large energy companies argue that we have to wait with renewable energy. They fear that their recent investments in large coal fired power plants will not be economically profitable any more. Furthermore, they argue that an exorbitant growth of renewables will reduce necessary back up capacity.

Nevertheless, many cities, towns and villages in the Netherlands have put together ambitious visions about how to become energy neutral, zero-emission or low carbon. How to turn these ambitions into reality? In this paper we investigate bottom up approaches to realize local transitions to energy sustainability.

In this respect, a recent phenomenon is that citizens take energy production in their own hands. More and more consumers produce at least part of their own energy; the affix ‘prosumers’ is used to describe this development of decentralized energy production. Local Energy Initiatives foster and stimulate this development, but many go a step further by founding local energy cooperatives. Is a paradigm shift occurring in energy production and consumption, from large centralized fossil energy plants to diversified decentralized sustainable production? In our research we follow local energy initiatives to answer questions about their effectiveness and possible impacts on the creation of a sustainable energy society.

Our key question is: How can local energy initiatives contribute to a decentralized sustainable energy production system?

Sub questions are: What are the activities, motivations and ambitions of local energy initiatives? What determines their effectiveness? What are the barriers they encounter? In short, we aim to better understand the position and possibilities of these local initiatives.

With our study, we try to provide three contributions to the literature. First is that we try to expand teamwork literature by investigating the hitherto uncovered local energy initiatives. So far, most research on teamwork is carried out in formal organizations. Second is that we use Actor-Network theory to find out how local energy initiatives are related to more overarching networks. Third is that this is the first study after local energy initiatives in the Netherlands.

1.1 Energy policy and energy activism

The idea that an electricity network should rely on central production in large plants situated far from individual consumers has taken hold in the last decades. Started out as small, municipally governed production facilities, energy producers have become ever-larger companies. The recent mushrooming of energy co-operations on a town- or even village-scale is quite remarkable set against the background of the international energy system.

The governance of energy production in the Netherlands first has gone from the hands of local and regional governing bodies to international companies. (Wolsink, 2012) Consequently, the influence of consumers, local and regional politics on energy companies has become virtually non-existent. However, individual choice for green energy has at the same time become available. In the liberalized EU energy market consumers can freely choose their energy provider, so they can ‘vote with their feet’. Moreover, consumers can become producers or ‘prosumers’ by producing energy with solar panels or windmills. This has become an attractive option for a growing group of consumers.

The next step is to scale up from the individual to the community level and to establish an energy-cooperative, which distributes energy to his or her own community or region. This community option is witnessed by the already considerable and growing amount of local energy initiatives that has sprung up in several European countries in the past few years.

What are the drivers behind this surge of community activity? The provision and promotion of green electricity, the strengthening of social cohesion and the investment of revenues in the local community are strong motivations mentioned by these initiatives. In addition, many people encountered voice ideas about self-empowerment, wishing to become independent from large energy companies.

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This may reflect a latent wish for self-sufficiency or community autonomy. In the 1970s the concept of self-sufficiency was very popular in the environmental movement, but in the last 20 years this motive has not been very prominent in the Netherlands. However, Bomberg and McEwen mention it as a powerful motive for action in their analysis of Scottish energy initiatives.

1.2 Literature

Earlier research on community energy has been done in the UK, following the publication of a UK policy document entitled *Local Energy Communities*. Walker and Devine-Wright published several articles on this topic. ((Walker, 2008; Walker & Devine-Wright, 2008; Walker, Devine-Wright, Hunter, High, & Evans, 2010)). In Germany there has been qualitative psychological research by Schweitzer-Ries and Zoellner. (Schweizer-Ries, 2008; Zoellner, Schweizer-Ries, & Wemheuer, 2008). Citizen resistance to the siting of windmills attracted considerable interest as a research site; see for example Jolivet (Jolivet & Heiskanen, 2010).
Literature on advocacy groups, primarily in the United States, suggests that teamwork and internal democracy are important factors that influence the effectiveness of these groups. Our research takes up findings on leadership and teamwork (Salas, Sims, & Burke, 2005), which we apply to the Local energy initiatives. In teamwork literature, no research has (to date) been published on energy initiatives, as most research is carried out in formal organizations.

2. Theoretical framework

What theoretical approaches might help to explain the messy realities of energy policy and local activism? There have emerged several theoretical approaches that might help explain the realities of energy policy and local activism. For example, the concept of path creation seems promising to analyse barriers and incentives in the energy transition (Garud & Karnøe, 2003) However, we find that these approaches cannot fully account for the dynamics on the local level and the influence of citizens on the development and diffusion of technology. Moreover, we find these approaches lack a clear perspective on the role of moral agents, such as the members of the local initiatives in our study. Therefore we draw on concepts from Actor-Network Theory, which can help to explain local network dynamics as well as the possible impact of this phenomenon on the wider societal networks.

2.1 Creating new paths

Co-evolutionary theories draw heavily on the metaphor of a development path, which guides and restricts the development of technologies. Development paths are comparable with the ‘trajectories’ that Dosi postulated. Concepts such as path-dependency and lock-in describe the way in which it becomes more and more difficult to choose an alternative trajectory. This leaves open the question about the role of human beings in these technology paths. The concept of path-creation can be helpful to account for human influences. (Garud & Karnøe, 2003) ‘Path-creation’ is a metaphor to position activities that work to develop a new development path, especially geared to help new technologies become successful. To create such a new path involves a lot of risks in investing financial, human and knowledge resources in new technologies. How to foster and manage the development of a new path is described in Strategic Niche management, to which we turn in the next paragraph.

2.2 Strategic Niche Management

Furthermore, Strategic Niche Management (Verbong & Geels, 2007) (Verbong & Geels, 2007) (Verbong & Geels, 2007) (Verbong & Geels, 2007) (Verbong & Geels, 2007) could be helpful in analysing the impact of local actions on a system level. The route for influencing the energy system according to this theory is by protecting and managing niches or protected spaces. This is called Strategic Niche Management (SNM). In these protected spaces technical development is subsidized and regulations are set apart, until the products can compete on their own. This appears to be a top-down (policy) activity. Therefore, it is rather difficult to apply SNM to bottom-up or self-organized citizens groups such as local energy initiatives. ((Kirkman, 2009; Verbong & Geels, 2007)).
The concept of niches is in our view not appropriate for explaining self-organized initiatives on the local level. Therefore, to better understand how ‘agency’ can be mobilized to change the energy

regime in a sustainable direction we turn to Actor-Network Theory. In the next section we develop an approach, which can account for the bottom up path-creation by local networks of moral agents.

2.3 Networks of moral agents

'Agency' is a central concept in our framework, what can citizens do to change a system. Kirkman writes (Kirkman, 2009)that moral agents or citizens make ethical choices as an individual. However, these individual moral agents are hindered by 'limits of agency'; barriers are present both in cultural and political traditions and in the physical layout of our built environment. Moreover, the individual moral agent has little impact on his/her own. To gain more influence individuals could form a network:

'*form new centers for change, (...) building a network of like-minded human actors and alternative configurations of nonhuman actors in which the basic forms of more lasting and widespread changes might take shape*.' (Kirkman p. 254)

Drawing on Actor-network theory, local networks can be seen as being nested in global networks (Law and Callon 1992, p. 22-41), (Law & Callon, 1988). In their description of the development of a new aircraft in the UK, Law and Callon propose that the level of 'success' of a project is a function of the degree of mobilization of local actors and the degree of attachment of actors in global network. These attachments are not stable. A certain project or initiative can over time move around the figure when actors become more or less active and gain or lose attachments.

According to Law and Callon the degree of attachments that local actors have with the outside world or global network is an important factor that determines the success of the local project. Kirkman adds the possibility of linking up these local networks:

'*By carefully defining its relations to this global network the actors in the local network might safely lay the groundwork for a revolution*.

Another Actor-network approach uses the concepts of framing and overflowing. This framework is used to analyse resistance to wind energy in the Albi region in France. In our study we apply the literature about local networks to local energy initiatives. These initiatives are 'forming new centres for change', as Kirkman suggests in his contribution 'At home in the seamless web' (Kirkman, 2009). Kirkman expects that widespread changes can occur once local networks team up on a national or global scale.

So, instead of technological niches we propose to look at networks of moral agents as the locus of agency. In the next paragraph we discuss earlier findings on the factors that influence the activities and impact of local energy initiatives. We also incorporate recent empirical findings on local energy communities in our model.

2.4 Other findings on local energy transitions

An important finding of Walker ((Walker, Hunter, Devine-Wright, Evans, & Fay, 2007) is that the level of acceptance of energy production units is stronger when the unit is more open, participatory, local and collective. An important factor in this model is 'trust'; members of the local community have to trust the local initiative in order to support, or at least not oppose, the projects that this initiative wants to undertake. The absence of trust often leads to opposition to sustainable energy projects, as is shown in a number of studies into siting of windmills. ((Jolivet & Heiskanen, 2010)) Then, what factors influence 'trust'? A second finding of Walker is that the level of acceptance of energy projects is stronger when the unit is more open, participatory, local and collective. The notion of trust and the factors of openness, participation and collectiveness is included in our model, as discussed in the next section. A third relevant paper of Walker et. al. (Walker, 2008) presented an inventory of barriers and incentives to a successful outcome on the local level, see table 1.

Incentives	Barriers	Necessities

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Local income and regeneration	Legal conditions	Key committed individuals or entrepreneurs
Local approval en planning permission	Economic and technical viability	Supportive local and/ or regional institutions
Local control	Need for extensive liaison	
Lower energy costs en reliable supply	Lack of funding –	
Ethical and environmental commitment	Barriers to market entry and network connection	
Load management	Setting up of collective management, billing and metering arrangements	
	Planning permission	

Tabel 1

Nijkamp ((Nijkamp & Ursem, 1998)) studied policies to promote sustainable energy in European cities. He identified five factors that are crucial in attaining successful implementation of local energy measures: technology ('hardware'); communication ('software'); social conditions ('ecoware'); financial requirements ('finware') and organization ('orgware').
When analysing non-profit grassroots organizations we find that the challenges they face mirror the factors Nijkamp analysed on the level of cities: Local energy initiatives also face financial challenges, such as finding sufficient funding. Organisational challenges include safeguarding continuity, exercising effective team leadership, and attracting membership. There is also a need for regular communication with their local environment and securing municipal and/or regional support. Legal procedures can be rather complicated for non-experts. Also, the members of these initiatives have to familiarize themselves with technological options. When comparing the two approaches it appears that the barriers and incentives of Walker and pentagram factors of Nijkamp show a considerable overlap.
We combine the approaches of Walker and Nijkamp with actor-network theory in a conceptual model that is used to analyse local energy initiatives in the Netherlands.

2.5 Citizens initiatives as a network

For our analysis we worked out a tentative model. We look at the initiatives as embedded and interlinked networks. The effectiveness of local energy initiatives we expect to be influenced by internal teamwork, activities on the level of the local project and the relations to the established networks on a regional or national level. On each level we focus on several factors that showed up prominently in our findings.

Local network (degree of mobilization of local network)
Team effectiveness:
- local leadership
- organisation and participation

Project activities :
- vision
- activities

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- communication

Global network (degree of attachments to 'global' network):
- members' networks
- regional and national support system
- energy actors
- national policies (economic, legal and fiscal barriers)

According to literature, the *team effectiveness* will be stronger when the internal processes are functioning in such a way that trust and sustainable leadership are guaranteed (Salas, Sims, & Burke, 2005).
The project will be more effective if the level of activities and communication are higher, and when a strong vision is developed.
The *global network* (or wider environment) is more supportive if a regional support system is in place; energy actors are open to innovation, economic; and legal and fiscal barriers are identified and removed on a national level. Both actors in the energy system and political structures have to be in favour of small producers to create a stimulating wider environment.

3. Results of case studies and fieldwork

3.1 Method

In the past two years we followed the activities of 20 local energy initiatives in the North of the Netherlands. Fieldwork and qualitative interviews have been done to get in depth knowledge of the local energy initiatives. The interviews were transcribed, coded and analysed according to a coding frame. The coding frame was developed on the basis of the theoretical framework and first tried out in a pilot study. We also studied websites, documents and other communications of these groups.
The case studies primarily focus on the local energy initiatives, their ambitions, activities, and organization. This community groups have diverse backgrounds, but tend to converge as to their goal of promoting local energy production. They range from political parties, commercial ventures, and energy cooperatives, to Village Working Groups.
In table 2 we present an overview of the initiatives that form a part of our sample. In this section we present our preliminary findings, developed along the lines of the presented conceptual model.

3.2 Team effectiveness

3.2.1 Leadership

We found that in many instances the local initiators are individuals with a background in the fossil energy industry or the sustainable energy sector. Their motivation to act is the wish to contribute to the energy issues. Another common motivation is to preserve the local community and to foster social cohesion.
Local leadership was very important in the choice of vision, the level of ambitions, but also in the choice of organisation type. The initiators also for a large part determined the level of democracy within the initiative. For example, one local leader specifically set out to create an organisation with several working groups, actively including active local residents, such as schoolteachers, small businesses, and people with specific competences on communication, or finance. The initiator himself took up a modest role in the board of the initiative.

3.2.2 Organisation and participation

The initiators in the majority of cases formed a working group in close cooperation with the local village organisation. In some instances the organisational route was via a local political party.
Initiatives with active members, stimulating leadership and successful activities often went through a formalisation process after a period of 6 months to two years. The choice of formal organisations is between a society, foundation, a co-operative or a commercial business.
One of the initiatives grew in size from 5 to 25 active members in one year. This organisation set up a foundation, a more formal organisation. Although a co-operative is a type of organisation in which members can collectively own an energy company, which is attractive to many local initiatives, the financial risks and legal difficulties in setting up such a collective business is a

formidable barrier for many of the small initiatives in our study. The co-operations that were formed often chose to align themselves to a larger sustainable energy company, such as Greenchoice or Trianel. In one case, the commercial background of the local leadership stimulated the establishment of a BV, a commercial venture. In this case there is little internal democracy left, so it will be interesting to see if this organisation type will engender enough trust.

DEGREE OF FORMALISATION OF LOCAL INITIATIVES

- Working Group
- (attached to) Dorpsbelangen (village working group)
- (attached to) environmental groups
- (attached to) political party
- Vereniging
- Stichting
- Coöperatie
- BV

3.3 Project activities

3.3.1 Vision

The visions developed by the local initiative were different in scope and ambition. On the one hand the modest ambition was to stimulate the installation of solar PV panels in the village. After organizing one or two meetings in the Village Hall about the technical and financial aspects of solar PV, often resulting in a surge of installations in the village, the ambition was considered to be fulfilled and the group disbanded.
On the other end of the spectrum a local initiative has the ambition to become an energy neutral village in 2020. A tentative scenario of how to reach this ambition was developed.

3.3.2 Activities and communication

The level of activities on the local level has grown enormously in the past two years. Even in small villages meetings on solar energy or energy efficiency attract quite high numbers of people, ranging from 35 to 65 in villages of 100 to 1500 inhabitants.
Other activities are courses on energy efficiency, energy markets, and excursions.
The majority of the local groups create a website, a Facebook page, and often use other social media, such as Twitter.

3.4 Global network

The attachments of the local team to networks outside the local project may hinder or stimulate the local achievements. The challenge to the local network is to balance the global and local networks, such that their vision can become a reality. In a network approach there are no clear boundaries between 'levels', because every actor in the network is in turn part of other networks too.

3.4.1 Members' networks

In the local initiatives we studied it was apparent that many members were engaged in diverse networks and brought in knowledge and opportunities these networks provided. The other way round it is expected that the 'global' networks change when moral agents bring in views and experiences from local energy initiatives or other sustainable energy advocacy groups.
Some examples of relevant job activities on regional or national level of agents in our cases:

- member of municipal board
- director of energy advisory business
- civil servant in province, energy policy in job description
- engineer with energy research institute
- policy advisor with national gas institute
- employee at regional support organisation, with energy as main focus

The local or municipal level – outside the initiative itself – is also part of the 'global' network. Attachments on this level are of vital importance. In some cases there was considerable involvement from local businesses, farmers, hotels, camping sites or schools. These members can reach out to other small businesses, farmers, or the parents of schoolchildren to join the initiative and take part in activities. Other competences that members brought in were finance and communication.

3.4.2 Energy actors

The energy sector is dominated by a small number of large companies, primarily dependent on fossil energy. The interests of national grids are brought forward by the TSO's, also large companies. The existing lobbies of the fossil fuel sector prove to be very powerful and influential. Lately the discussion about the necessary modernization of the power grid has been framed as the 'fault' of the renewables. The view of the large fossil fuel sector is that would be wise to delay the growth of renewables. Another example of framing is to position the decline of the use of fossil fuels as a (lamentable) loss of tax income for the government, followed again by a plea to delay the growth of sustainable energy production. These views are not only put forward by the energy companies themselves, but also by presidents of Dutch national advisory boards – often former CEOs of large energy companies.
Sustainable energy actors are often smaller companies, specialised in one energy source, such as wind, biomass, or solar technology. These sustainable energy actors do not have the same resources for influencing national policies as the conventional industry has.

3.4.3 Regional (and national) support system

In our cases we actively worked together with regional support organizations. It is too early to draw conclusions from this part of our work. However, the activities of these regional organizations are very popular venues for local initiatives to meet each other, and to obtain information and advice. We expect that the better the local initiatives are supported, the higher the chances are that decentralized sustainable energy production can embed itself in the folds of the present central energy system.

3.4.4 National policies

Since a few years it is legally permitted in the Netherland to set up a new energy company. However, it is not easy for small local initiatives to do so. Furthermore, following the recent bankruptcy of the Dutch branch of Trianel, new rules have been implemented by the NMA. This caused all but one of the small cooperatives to discontinue their services. The only remaining co-operative is in the North of the Netherlands, where three provincial initiatives have founded a regional cooperative energy company, which can act as an umbrella organisation for small local initiatives. However, national fiscal policies still hinder the growth of cooperative ventures by levying energy (former CO_2-) taxes on co-operative sustainable production. On the other hand, many fiscal and economic policies subsidize fossil fuel activities.
At the moment a new energy law is being prepared. A few minor points are changed in favour of small and cooperative local production. However, in other respects the new law is (even) further restricting and will even introduce new levies on small producers, such as an extra tax for the use of the grid. The national union of local initiatives (E-decentraal) is actively engaged in commenting on the proposals for the new energy law and mobilizes local initiatives to get their views across to policymakers.

4. Discussion

In theory there are many technological options for decentralized energy production, however, the actual choice is rather limited. Due to earlier debates about landscape the regional energy policy is very strict on local windmills. Only large wind parks in designated areas are permitted. This means that local energy coops do not have the opportunity to invest in a cooperative village windmill, which would bring a considerable income for the community. Biomass installations are restricted to farmers, so again this technology is not within reach of most local initiatives.
Compared to Germany and the UK the situation in the Netherlands is very restricting for local energy initiatives. This leaves the local groups only solar power as promising technology. The recent fall in prices for solar PV has helped to bring 'prosumerism' within reach. However, the feed-in tariff in the Netherlands is so low that it is very unattractive to feed electricity into the grid. Small-scale biomass (wood pellets and woodchips) is another possibility on the individual level.
Due to fiscal restraints it is not possible to use electricity from a cooperative installation without paying taxes, including the former CO_2 tax (now called energy tax). This is a considerable barrier

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for local energy initiatives; it practically restricts their operations to the individual level. Consequently, small-scale installations in and on private houses, combined with energy efficiency measures, appear to be the only viable option at the moment. It is therefore not surprising that the majority of initiatives in our study choose this route.

Nevertheless, there is an active and growing group of local networks that can act as ‘centre of change’. They increasingly cooperate on a regional and national level. New modes of organisation are developed to realize local visions.
In the next years we will follow this development, and hope to witness a transformation of the centralized fossil energy system into a sustainable decentralized energy production system.

Location	Inhab.	Description
Balinge (Midden-Drenthe)	110	A small village initiative with local leaders set up a group aimed at installing a system with biomass heaters and sun thermal installation. The group volunteers with the nature agency to maintain and prune a certain strip of wood on a monthly schedule. The harvested wood is burned in the biomass heaters. Communication activities, such as energy education in schools are performed as well.
Wessinghuizen (Stadskanaal)	28	Successful small-scale initiative plans to supply houses with biomass from the direct environment. Pellet- or woodchip heating on individual level.
Oenkerk	1800	Village initiative started in 2011, developed a mission to become energy neutral in 2050. Plans include collective purchase of solar panels, promoting energy efficiency and founding of a co-operation to produce sustainable energy collectively.
Groningen	200.000	In the city of Groningen the organisation ‘Grunneger Power’ was formed in april 2011. Grunneger Power is a co-operation, so the decision power ultimately lies with the members. Any profit will be invested in sustainable energy projects. A new development is that other local initiatives can attach themselves to GP, as a local branch. This would provide smaller initiatives with the knowledge and juridical strength of GP, without giving up their local identity.
Oldehove (Zuidhorn)	1659	The region of Middag-Humsterland is a national landscape in the municipalities of Winsum and Zuidhorn. An initiative to start a Local Sustainable Energy Firm (LDEB) in the village of Oldehove, with the intention to supply energy in the whole of Middag-Humsterland. The focus shifted further to supply energy to a wider area, including the municipality of De Marne. The initiative attracted funding from the ECG to set up an organization. A board was formed with experts from the region. Recently the decision to form a (BV) was taken, to provide the new firm with a solid economical base.
Makkinga (Ooststellingwerf)	1039	SLIM- subsidized project for three years. Activities include building solar thermal installations, promoting solar panels, village kitchen garden. Plan to incorporate energy from biomass plant on farm outside village.
Pieterburen (De Marne)	375	Duurzaam Pieterburen was formed out of a protest group called ‘Pieterburen Tegengas’. Very active local leadership is performed, participating in Duurzaam Pieterburen, Dorpshuis Pieterburen.
Schouwerzijl (De Marne)	100	In the framework of the Village organization (Dorpsbelangen) a workgroup was formed, which organized a series of meetings about home insulation, solar panels and other new options to save energy and produce your own. The meetings were very successful and many installations of solar panels followed.
Westerveld (municipality)	19.176	A local political party, Progressief Westerveld, drives the initiative in the municipality of Westerveld. Recently a fund and action plan on community energy actions got adopted.

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Hooghalen (Midden-Drenthe)	940	In less than a year, the initiative in Hooghalen grew from a small group of enthusiast citizens into a formal ‘Stichting’ with a board and five workgroups. Stichting Duurzaam Hooghalen created a network of local citizens and also mobilized other actors such as the Village Hall, the municipality of Midden-Drenthe, the local school and the regional welfare organization. Activities included a survey, a course called ‘My insulation’, energy market and solar panel project.

Table 2

5. References

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[16]

Manage Smart in Smart Grid: Intelligent Energy Management and Control of a Smart Grid Connected Public Building

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Summary

Work from the project "Manage Smart in SmartGrid" is presented. This project has explored the potential that Smart Grid technologies offer in terms of energy management. A key point made is that energy management requires a holistic approach. Focus on the consumer side alone is not sufficient and is likely to yield suboptimal solutions. Smart Grid enabling ICT technologies will allow a broader approach that takes the whole supply chain into account. The need for a value or purpose oriented focus on energy management is also highlighted. Energy management is not only about reduced consumption. Energy must be directed to where it is needed at all times to sustain primary user needs. Focus on energy effectiveness as an additional dimension in energy management is therefore stressed. The paper addresses specifically consumer flexibility and prosumer orientation to achieve a balance between minimization of energy use and maximization of user benefits. A planning and control model is presented that takes this into account. This model incorporates an optimization part that seeks to balance user needs and user flexibility with a number of different concerns stemming from the supply side. An empirical part of the research is presented that give firm support to the ideas presented. Latent consumer flexibility is potent and can be used for the management purpose defined. A preliminary quantification of this potential is also presented.

Keywords: Smart Grid, intelligent energy management, system effectiveness, consumer flexibility

2. Introduction

In the project "Manage Smart in SmartGrid" we have investigated the potential that Smart Grid technologies offer in terms of energy management with specific focus on what has been defined as *consumer flexibility*. Consequently our scope extends beyond the traditional view on energy management whereby energy efficiency is translated into a reduction of kWh per square meter. A number of references on smart grid and associated technologies have been presented over the years [1],[2],[3]. Consumer or user flexibility is a term that is typically applied to describe the choice that a consumer has to manage and adjust his energy needs. This decision determines the response to the type, quality and quantity of energy offered, including what the user might supply by means of his or hers own energy producing resources. Smart Grid technologies encompasses and array of ICT-systems that can provide support both for long term planning and real-time control to help the user make the best choices and be as resonant with the state of the energy supply as possible. This pertains to our definition of prosumerism [4]. Ottesen [5] specifies three different kinds of flexibility: Load flexibility, generation flexibility and storage flexibility. The former addresses various ways to reduce the load and consumption that builds up over a shorter time span. Generation flexibility addresses different forms of dispatchable energy resources that can be activated or deactiviated as the user sees fit. Storage flexibility defines energy buffers used to balance supply and consumption better. But they can also be operated tactically in response to energy market developments, such as real time price and prediction on price the following hours. Consumer flexibility and prosumer orientation are both closely related to the philosophy that advocates zero-energy houses [6] and plus-house concepts [7]. However, one has a utility oriented perspective while the others are rooted in the building industry. With the advent of Smart Grid the customer end, including the building, the supply part of the energy market and the grid will come together and become more integrated along multiple dimensions [8]. Energy efficiency measures that have sole focus on the building and its inhabitants will therefore be too limited. Both the market and the grid are confronted with efficiency issues that are closely related. Smart Grid and its enabling ICT technologies will allow us to address these in a holistic manner. This suggests a systems approach to energy efficiency that must be complemented with reflections on effectiveness. We firmly believe that a systems approach like this is imperative to make the necessary advances required to meet the global climate goals and a sustainable future that hinges on energy efficiency and renewable resources.

3. "Manage Smart in SmartGrid" – The concept

In "Manage Smart in SmartGrid" the perspectives presented above have provided a basis for our research. Ultimately it is our goal to a create a computer based energy management model that can provide more intelligent control, smarter monitoring and better plans for energy use and supply in a building. Compared to former initiatives [9],[10] we will not limit focus to indoor climate parameters and local energy reduction, but address conditions that spreads beyond the walls of a house or a building. In our quest to optimize the benefit of energy we have set forth to include a number of different parameters and include this in our computer model. The idea is to direct energy to where it is needed, when it is needed and as efficiently as possible from the best resources available. The latter suggests a preference for renewable resources. This idea is especially important during prime time, namely the peak hours of the day when loads are high and aggregated demand is far beyond average. We will describe the overall model and its foundations which we have begun to test at a college in Norway. Other views on the research in this project have been described by Ottesen and Tomasgard [11] who address the issues of optimization and Simensen et al [12] who describes the human behavioral aspect in depth.

Our basic thesis here defines houses or buildings with its users only as parts of a bigger and more extensive infrastructure. This system includes the electricity supplier, the transmission system at different voltage levels and the consumers. The system may also include a number of other parties that we will not discuss here [4]. All of this is encompassed by the energy market. We hypothesize that it is possible to unify energy efficiency concerns related to supply, distribution and use to be optimized for the benefit of all three parties and the environment, simultaneously. Efficiency measures must be accompanied by actions driving energy effectiveness. The latter refers to how energy is applied and for what purpose. We ask the question whether a smart grid approach can help to manage production, distribution and use of energy so that resources can be preserved along the whole value chain while providing the necessary energy to fulfill the user needs. An obvious parallel here is the JIT-JE (Just-in-Time Just-Enough), a principle that has been applied in logistics and production plants for years to rationalize distribution of goods and reduce inventories while continuing to serve the interests of the customer. The idea is to deliver supplies and merchandise to the market when it is needed and in quantities that will be sufficient to satisfy customers at any point in time. While many plants have struggled with excessive inventories the power industry has had few possibilities to do the same. Electric energy must be produced in the instant the consumer demands it. But buffers are needed and consumer flexibility can serve such a purpose. Currently there exists an unexploited flexibility potential at the demand side. Unleashing the potential offered by consumer flexibility we can improve energy logistics and contribute to a leaner flow of energy, but also a flow directed to where it is demanded at all times.

Based on this we have created an overall model to prove our hypothesis. This model addresses all of the aspects presented above.

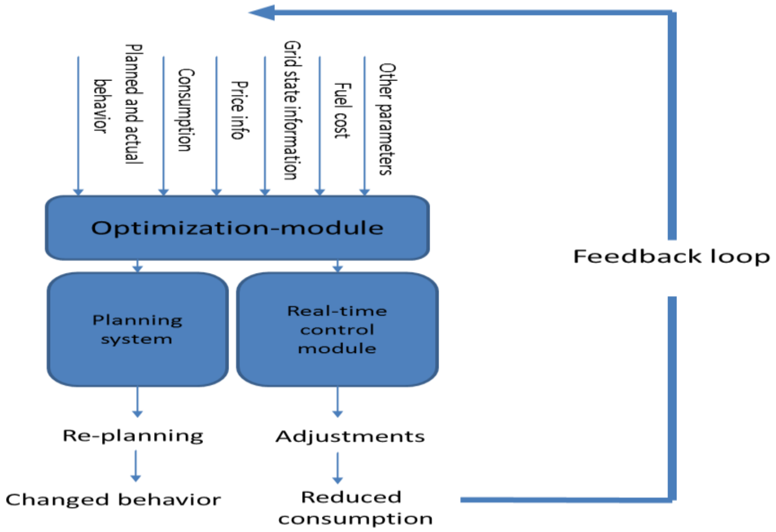

Fig. 2 The overall concept that is explored

The notion is that if different types of state information representing both the demand side and the supply side can be fused and processed it will be possible to optimize the use of energy for a given situation or period. This implies that the users and the building that they inhabit will maximize the utilization of available energy while energy supply will be minimized accordingly. This depends naturally on what constraints are imposed. Required information include planned and actual behavior on the user side (demand side), consumption data, price information (that reflects the state of the energy market, grid state information, fuel costs related to user side's dispatchable production and more. Eventually this can be used for real-time control and planning that seeks to yield efficiency rewards. An overall perspective of the optimization model is depicted in Fig. 3 below. The optimization process is driven by a stochastic programming method. Its aim is to determine the optimal daily dispatch of distributed energy resources for flexible consumers and prosumers participating in the retail side of the energy market. A general framework is designed to cover multiple energy input carriers i.e. district heat, sun, wind, oil and gas. The framework also distinguishes between energy systems for electricity, heat and cooling as well as the interconnection between them.

The rationale behind this split increases the latent flexibility by recognizing the possibility of fuel switching. The model encompasses also devices for energy storages and distributed energy generation. Demands for each separate energy system are split into three categories. One represents a consumer demand that cannot be altered. Another proposes a shift of energy use to another time where system conditions are different. A third simply crop the demand considering it superfluous or representing a secondary need that can be temporarily suspended. All prices are generalized and defined as a 3-part tariff. Understanding user behavior and user tolerances is prerequisite for this. More details on the optimization part can be found in [13]. A control system is also being engineered that will accommodate the model and the data feed required to drive the concept [14] The rationale behind this is to create an intelligent energy management system that can optimize the use of energy in buildings that constitute a part of the future smart grid.

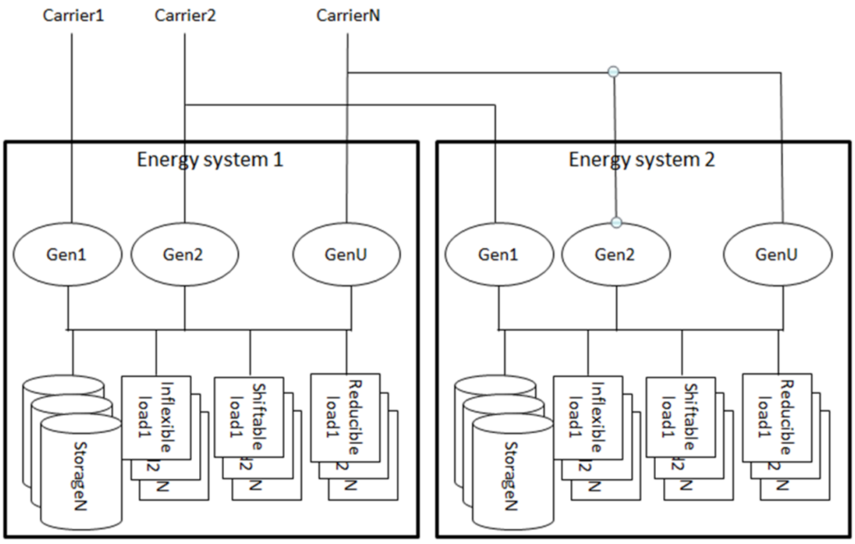

Fig. 3 The model of the internal energy system

4. Systems and value oriented approach to energy use

Energy use and efficiency of buildings is typically expressed in terms of *kWh per square metre* which is purely a technical parameter. It is the classic reference used to assess and benchmark the energy characteristics of buildings. In Bremdal et al [15] and Rønning et al [16] we advocate that the indicator is insufficient since aspects like the function of the building in relation to the users' needs, the buildings adaptability etc. have to be taken into consideration. Sustainable buildings require an approach and indicators for measurement beyond the traditional energy efficient focus that reflects on a goal to s*pend energy effectively when it is needed, where it is needed.* Similar perspectives have been expressed by Dooley [17].

Rønning et al [18] state that buildings are sustainable when they *function* optimally for its purpose over time, while using the optimal amount of resources. A sustainable building should:

- function according to intentions: The users' needs should be met effectively
- be suitable for its use
- be utilised optimally at any given point in time
- be flexible to adapt to changing needs and user requirements over time
- have optimal resource use, i.e. low material and energy consumption, low carbon emissions etc.

In other words emphasis is on what brings value to the user of the building and in what way energy management supports the purpose of the building and the value creating tasks that the users perform, hence our term "value oriented energy use". We have used the Power Utility Effectiveness (PUE) factor as an important guide. It is commonly used for optimization of energy use and power effectiveness of data centers [19]. PUE defines the fraction of the total energy feed that is used to support the value creating functions. The use of a PUE approach in our own project as well as for the building industry in general has been discussed before [15]. The essential idea is that the use of energy per zone (Z) expressed as the PUE for that zone at a given time (T) defines what fraction of the energy supplied to the zone is actually used for the value creating tasks. Consequently a distinction between primary and secondary energy needs per zone is required. Primary needs must be observed if the user experience is not going to be devalued. Energy for secondary needs can be relinquished in each zone without jeopardizing the primary functions. The PUE can also be used as a theoretical reference to determine a boundary between permanent and temporary reductions. The former refers to superfluous consumption and can be handled by standard efficiency improvement measures. The latter implies exploitation of the *consumer* *flexibility*. Thus an objective is first to eliminate superfluous energy feeds, exploit user flexibility while supporting primary needs necessary to sustain value. This can also be expressed as follows: *PUE(t) =(superfluous + secondary(t) + primary(t)) / primary(t)*. Another ambition we set forth to fulfill is to be able to manage non-discrete loads. Heating belongs to this category. More than 60% of the total energy in Norwegian homes is used for heating. A major portion of that is based on electricity[28]. Percentage reductions here will yield greater absolute gains. A standard procedure for saving energy for heating is to isolate building spaces and shut-off heating to these areas. Consequently these areas cannot provide the service they were intended for. Instead we try to establish a method that will allow us to manage this in smarter ways and during prime time when all areas are more or less in use. Aggregated net loads and prices are highest during prime hours when buildings are used, simply because the day is divided into distinct stereotypical patterns. Most people spend time at work during business hours. At other times the majority can be found in their homes. Being able to control energy use during prime time will not only improve energy efficiency at the premises of the user, but also improve the state of the market and conditions in the grid. Consequently efficiency measures at some hours are more meaningful and have more value for different stake holders than others.

5. User tolerance and consumer flexibility

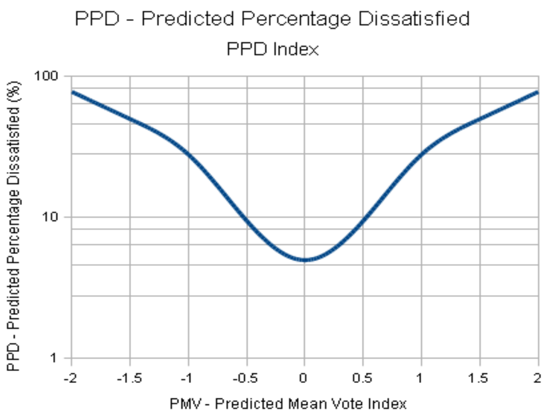

Fig. 4 The PMV index mapped against the population of predicted percentage dissatisfied (PPD)

The distinction between primary and secondary needs can be non-crisp. Primary needs are dependent on planned or intended use of zone and the tolerance of the people present there. Some people are very tolerant while others are not. Some people need a high temperature to feel comfortable. Others are happy if things are cooler. Simply put we may assume that there is common interval of intolerance that most people share. This interval must be avoided to maintain full value. This defines the minimum or primary needs of the user population. Secondary needs are related to climatic conditions where perceived comfort is more varied. People's perception of thermal comfort and temperature tolerance has been the subject of research for many years. Fanger's PMV Predicted Mean Vote index [20], [21] is a bearing beam in this respect. It defines the relationship between a person's metabolic rate and temperature tolerance. Factors like the physiological condition of the individual, her clothing and various climatic conditions, in addition to temperature are now a part of the PMV consideration. In our research we have been more preoccupied with the statistical relationship that relates the PMV index to the general user experience. This is shown in Fig. 4. The Predicted Percentage Dissatisfied (PPD) index can be mapped against the PMV. It produces a standard curve. The minimum defines a PMV value of zero. At this point only 5% of the population experiences discomfort. Ideally this also defines the set-point for indoor climate control. By setting a maximum limit for the percentage number of users that will be dissatisfied the upper and lower boundary for the PMV can be defined. Indirectly this will yield a metric for how much of the energy used for heating should be considered primary and what could be considered secondary. The higher the PPD that can be tolerated on a temporary basis the higher the offset from PMV=0 can be. Since cooling is not an issue in our case a PMV > 0 suggest that superfluous energy is being used. A permanent reduction of the thermal energy supply will in fact improve the satisfaction of the user population. A PMV < 0 is possible as long it is only temporary and well controlled. However, if the temperature is invariant to the reduction of load the PMV remains constant. This happens because we can have inertia. Inert systems where heat is conserved for longer periods make it possible to shed what is called "slow loads". These represent "low hanging fruits" that can be picked first. Such loads are essentially superfluous during prime hours. If it is possible to renounce energy on a temporary basis without changing the offset of PMV from 0 we can identify consumer flexibility as the amount of energy supply reduced

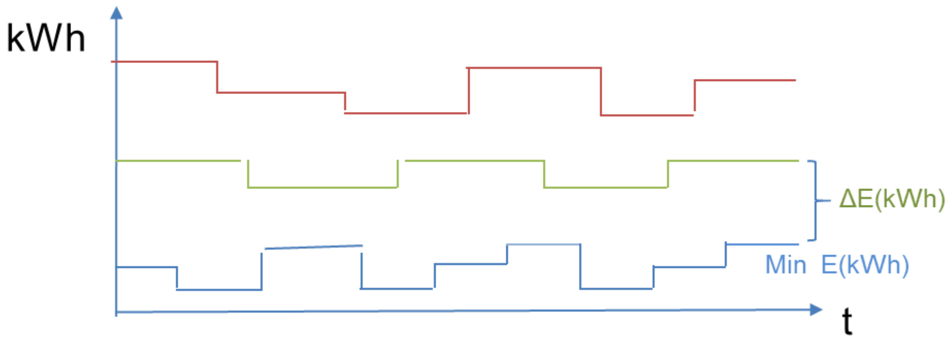

Fig. 5 Energy use and loads vary across time. The total consumption is shown as a red line. The blue line is what is required to maintain primary needs. The area between the red and the blue line is energy used for secondary or superfluous needs. The area between the green line and the blue represents the latent consumer flexibility.

and integrated over the period of reduction. Additional, secondary loads can be identified if we are willing to reduce the PMV. A negative PMV change of 0,6 will still be acceptable by most users (app. 90%). A negative unit change will leave around half the population unhappy. If a zone is not used the PPD will always be 0 and the PMV can be adjusted infinitely. The principle drawn out here also determines the extent of a periodic change. The higher the PPD, the shorter the time of PMV offset can be allowed. Formulated a little differently, the higher the PPD the higher the compensation for use of this tolerant behavior needs to be. This has also economic implications. One of the principal concepts that we have pursued can therefore be depicted as shown in Fig. 5. Energy use and loads vary across time, so does the fraction between absolutely required energy and what is actually supplied. Superfluous use can be removed permanently by means of traditional efficiency improvement methods. The green line represents the combined effect of primary (blue line) and secondary needs. The difference represents the latent consumer flexibility, ΔE. For practical purposes this flexibility must be determined on an hourly basis and related to other state parameters with the same time resolution i.e. energy prices, grid state, fuel costs etc. In practice, however, this flexibility can be hard to determine. Centralized heating and cooling systems generally provide an aggregate measure of energy produced and distributed. Simulators can be used to determine the distribution per zone. Our approach has been based on a new set of sensors and multivariate analysis [22] For planning purposes input based on real-time data gives a very narrow horizon. Our method therefore also applies forward commitment on room use as a means to determine future flexibility. Room booking systems, calendars and similar facilitate this. This also gives rise to operating rules like the examples shown below. Such rules can in turn be used for monitoring and control to maintain or improve the user experience and route energy to where it can truly be beneficial. Where X < Z < Y < Max we may write:

- **IF zone is pre-booked AND zone is in use THEN PMV = 0 PMV reduction of X% is possible.**
- **IF zone is pre-booked AND zone is not in use after 20 minutes THEN PMV reduction of Y% is possible.**
- **IF zone is not pre-booked AND zone is in use THEN PMV reduction of Z% is possible.**
  IF zone is not pre-booked AND not in use THEN full PMV reduction is possible AND max flexibility is possible

6. The Remmen Case

We have tested out the basic principles presented above at Campus Remmen in Halden, Norway. The optimization part of the model has been exempt from the first trials, but the basis for determining latent increase in effectiveness and consumer flexibility has been

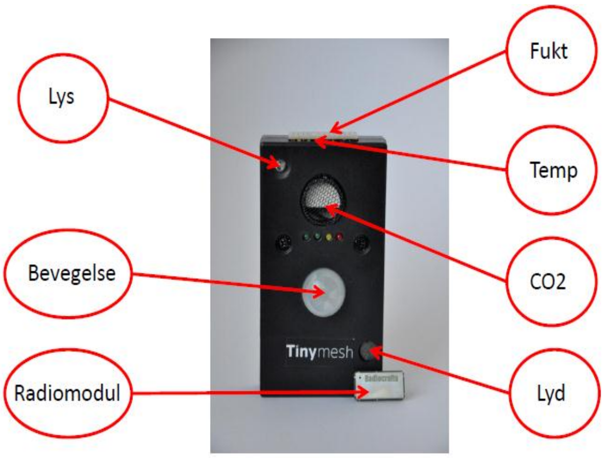

Fig. 6 The mesh based Building Lab sensor from Tiny Mesh. A new sensor was constructed and was integrated with the mesh network. Lighting, motion, moisture, temperature, CO2 and sound can be recorded with this wireless unit.

tested according to the model introduced here. Campus Remmen is part of Ostfold University College and is owned and facilitated by Statsbygg. The average energy consumption per year is 5400 MWh. Campus Remmen is tariffed according to peak load per quarter so initiatives of the type we have described here will have an immediate economic impact. Maximum peak load in the winter 2011/2012 was app. 3800 kW. The building has been divided into energy zones as explained earlier with focus on function, use and control. Zone resolution was modest. The primary idea was to identify at least one zone that we could isolate as much as possible. Consequently energy zone definition for the experiment had to be pragmatic, dominated by the design of the technical systems more than the specific use. However, after evaluating the various options we targeted what we called Zone 8 for our experiment. Zone 8 consists of four smaller energy zones that are used differently. The biggest one is the largest auditorium in the building which intersects two floor planes. Two lesser rooms are used by drama classes for rehearsal and dressing. A study for scholars represents the fourth sub zone. A primary objective was to determine the amount of energy supplied to Zone 8 and observe its use. We were also interested in determining the correlation between use and timetables and scheduled room bookings. Heating of the zone is airborne and waterborne. To determine the distribution of energy we combined our statistical approach with a new array of sensors. For this purpose a mesh network was established. The Tiny Mesh network [22] applies a wireless communication concept that allows signals to be relayed across a standard protocol and operate at different frequency bands for maximum customization and robustness.

The prototype sensor integrated with the mesh allowed us to observe the use of Zone 8 and measure climate conditions on a continuous basis. The sensor system records lighting, motion, moisture, temperature, carbon dioxide and sound (see Fig. 6). Carbon dioxide, motion and sound metering were meant to help determine the degree of zone occupation and use. It is also a way to correlate scheduled use with actual use. In conjunction with this we also exposed a population of students to the indoor climate to obtain an idea of the distribution of opinion and tolerances according to the combined PPD-PMV index. Here a poll was undertaken [12]. The thermal comfort part of the questionnaire was based on the Predicted Mean Vote index (PMV) described in ISO 7730 [24] for prediction of thermal comfort which again is based on Povl Ole Fanger's research (ibid). We utilised the seven-point thermal sensation scale (From hot (+3) via neutral (0) to cold (-

3)) in our design. The PMV method defines answers -1, 0 and 1 as satisfied. When investigating the perception on indoor air quality, the questions were based on another prediction calculation method by Shi and Tao [25] asking whether the students perceived air quality as good, acceptable, bad or very bad. In addition the students were asked if they thought it was satisfactory to work under the given conditions where the answer possibilities were yes, no and yes for a short period where they were to decide approximately for how long.

Five of the sensor prototypes were installed. Two were placed in the auditorium (lower part and upper part). The others were mounted in each of the different sub zones. Meters to measure the pulse of the electric circuits (4 of them) controlling the centralized heating and ventilation units were hooked up to the same mesh. This produced a composite set of time series that could be analyzed in different ways.

To analyze the data we applied multivariate analysis (MVA). The locations as well as the readings for the individual sensors are not independent. MVA is a powerful set of techniques for understanding the relationships between variables in large data sets, which classical statistics may not adequately identify or explain. MVA lets you understand, visualize and make predictions from your data. The CAMO Unscrambler®Software [22] was applied for Principal Component Analysis (PCA) and Partial Least Squares Regression (PLSR). The PCA provides visualizations of the observations over time. It helps to decide the importance of the sensor signals (variables) in describing the underlying structure. For modeling the energy consumption PLSR was applied. The main advantage with these methods is that they handle many variables and provide a consistent set of perspectives on the system that is being observed. E.g. if many temperature sensors are placed in vicinity of each other they will give the same information about the building's energy consumption as a function of time, thus the underlying dimensionality of the system is much lower than the actual number of sensors (variables).

7. Results

At the time of writing the experiment at Campus Remmen is still running and will be doing so until spring 2013. But data and observations for the fall have been recorded. An important observation made is that the 5 sensors can explain 65% of the energy supply for the whole building. Circuit 1,2 and 3 are co-variant with the temperature observed for both Zone 8 and the rest of the building, but circuit 4 displayed odd characteristics that could not be well explained by any of the observed parameters channeled through the mesh network. Still, based on this there are good reasons to believe that a denser set of sensors could improve the accuracy required to cater for the needs addressed in this discourse. **Feil! Fant ikke referansekilden.** shows the circuit loads on Oct. 3, 2012.

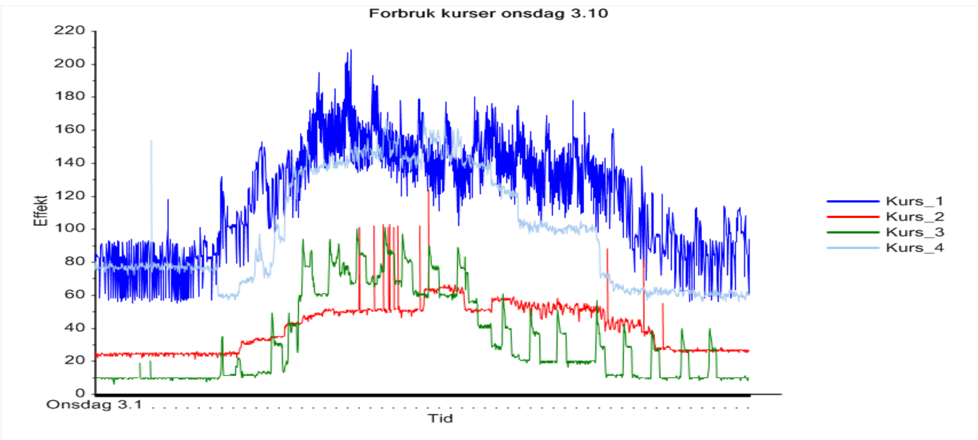

Fig. 7 Shows the observed load on the 4 circuits in the beginning of October 2012

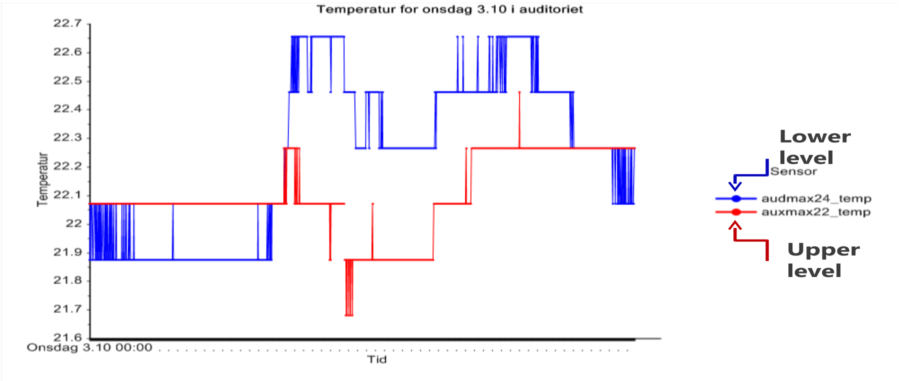

Fig. 8 Temperature recordings for the auditorium max. The maximum temperature recorded was 22,65 at the upper level while minimum was about a degree lower in the lower part an hour later.

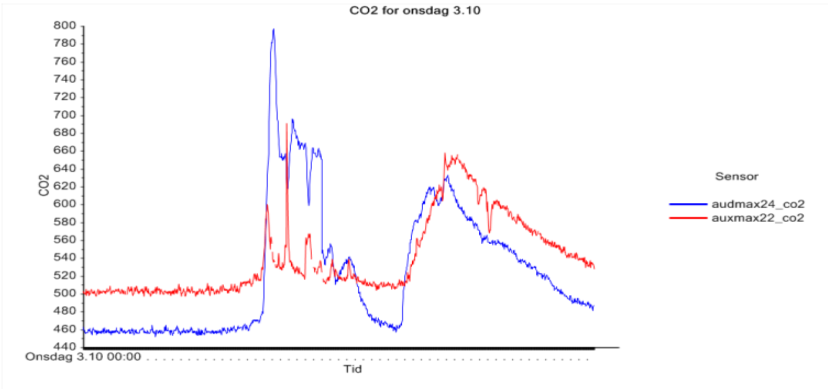

Fig. 9 CO2 recordings for the auditorium (upper and lower level) shows a typical rise midday and in the afternoon, due to classes being held both before and after lunch

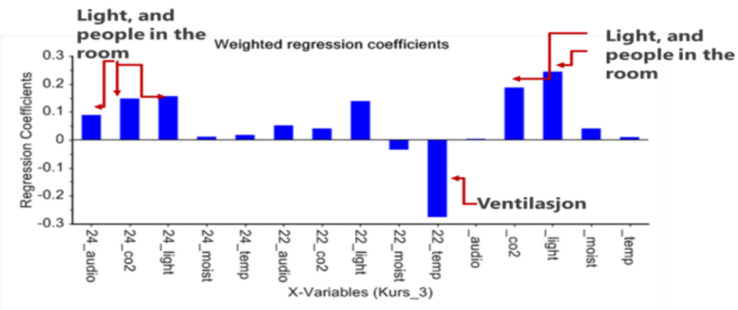

Fig. 10 Weighted regression coefficients from PLS regression. The first component accounts for app. 47% of the variations.

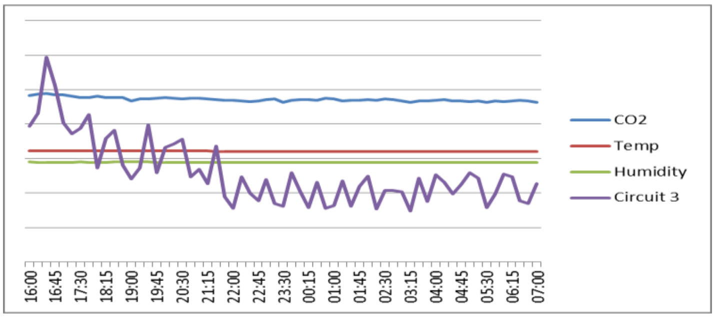

Fig. 11 Three climatic parameters in the auditorium of Zone 8 as the loads on circuit 3 are reduced. There are no people in the room.

Fig. 8 and Fig. 9 show variations in temperature and carbon dioxide on a normal day respectively. CO_2 has proven a good indicator of use, together with motion and sound. The regression revealed that two principal components account for 63% of the change of loads in Zone 8. 47% can be accounted for by the first component alone (see Fig. 10). The use of the room, represented by increased CO_2 -levels and lights have a noticeable impact on the electric loads generated. Zone 8 is generally supplied with energy supported by three electric circuits. However, during the test period circuit 2 was largely inert and heating was essentially supported by electric boilers hooked to circuit 3 and 1, where circuit 3 was the dominant one during the period reported here.

In Fig. 11Fig. 9 we have plotted the CO_2, temperature and humidity recorded in the auditorium in Zone 8 while the load on the actuating part of the system is gradually decreased over a period of 15 hours. The room is vacant. It is easy to observe the indifference of the climatic parameters to the changes of the energy output. Not surprisingly Zone 8 has accumulated so much bounded energy that there is only a -0,2 C average change over this time span. We have observed that the building as a whole requires a base load of 80-200 kW per hour per circuit. The variations observed are dependent on the outdoor temperature with a negative linear correlation of approximately 80%. As Zone 8 is located at the core of the building it is obviously less exposed to outdoor temperature changes than zones along the outer walls. The bounded energy in Zone 8 is therefore sufficient to maintain a stable temperature over several hours provided that steady state conditions have been established (stable long term operations, no dramatic change in outdoor temperature, no traffic through the area). We can see that the PMV = 0 is not threatened under such circumstances. Consequently latent consumer flexibility related to thermal comfort is significant. However Fig. 11 does not reveal whether the full difference between max and min can be permanently reduced. But the PUE is close to 3 in the late afternoon. However, it indicates very acutely that certain zones like Zone 8 can be used as thermal reservoirs. Consequently they represent a source for the kind of consumer flexibility that we are looking for. This in turn suggests that different zones should be operated differently and that their specific thermal signature and use should be taken into account. For Zone 8 a 10-15 hour suspension of the general load for heating is possible with a minimal drop in temperature. Based on this we have made some preliminary estimates of the potential for the full building by comparing the hourly loads in the four circuits between 18:00 in the afternoon and midnight. Only basic services and heat functions are maintained during these hours. We find that 80 kW's +/- 25% per circuit is possible. Theoretically this adds up to approximately 350 kW's. Peak hours in the net and energy market usually last for 2 -4 hours at a time. Suspending hourly loads of this magnitude should be possible. In practice this means that the control system should be responsive to external signals and invoke present afternoon or night routines during such hours to shed loads. As it is already practiced during weekends it should be a viable approach in practice.

Further analysis shows that humidity and CO_2 is important. As CO_2 and humidity builds up the indoor air is flushed and both ventilation and heating of the fresh air induce additional loads (see Fig. 10). One can observe the temperature shift in the lower part of the auditorium in Fig. 7 which yields a brief, bust significant drop in temperature as fresh air is flushed in. Consequently there is a strong relationship between the presence of people in Zone 8 and high power loads and energy output. CO_2 and humidity increase triggers a relative rapid exchange of air to improve indoor conditions. This makes the load on circuit 3 soar to assure a stable temperature and ventilate. By turning off all ventilation in the building we observed a load reduction of about 300kW. 1/10 of this load drop could be attributed to Zone 8.

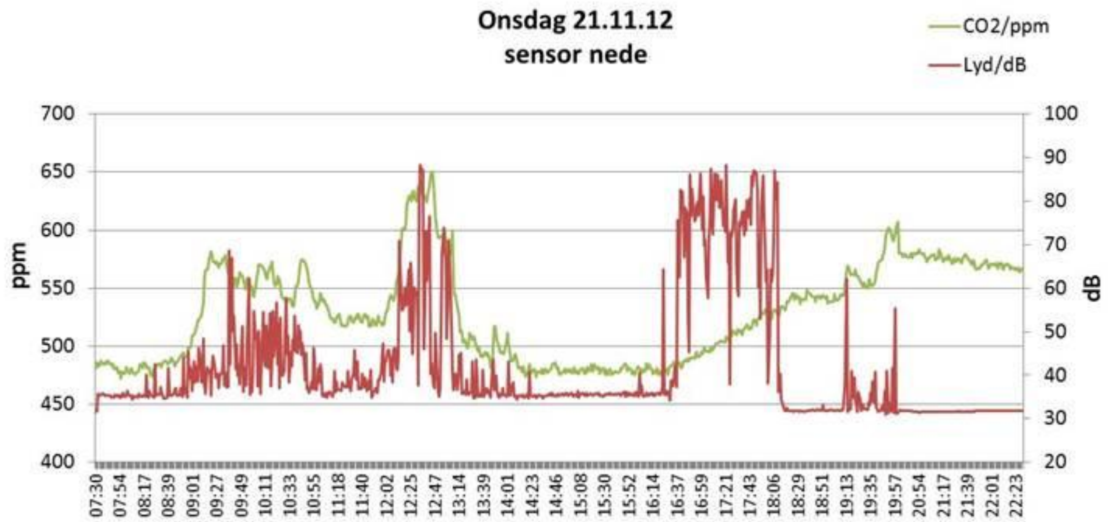

Fig. 12 Diagram shows CO_2 level developments during November 21, 2012. We observe that CO_2 levels are aligned with occupancy and activities of the room until 16:00 hrs. Then ventilation is shut off for the night.

Fig. 12 shows CO_2 level developments during in the largest auditorium on November 21, 2012. During regular hours class activities drive the levels up. When activities cease around 14:00 hours CO_2 levels are down to minimum as the control system has activated ventilation and flushed in fresh air. At 16:00 hours the ventilation is shut off for the night. Some minutes later the film club hosts a movie night in the auditorium. CO_2 levels rise once more. The CO_2 levels fall again when the evening event has ended. The diagram illustrates two subtle things. First of all it shows an expression of CO_2 tolerance on the account of the film audience. The 20% ppm increase during the two hour session did not trigger any complaints. We can also observe how the CO2 level is curbed without ventilation. From this we can infer that ventilation can be suspended for a shorter period during mid-day if the net demanded it, with minimal consequences for the audience in the room.

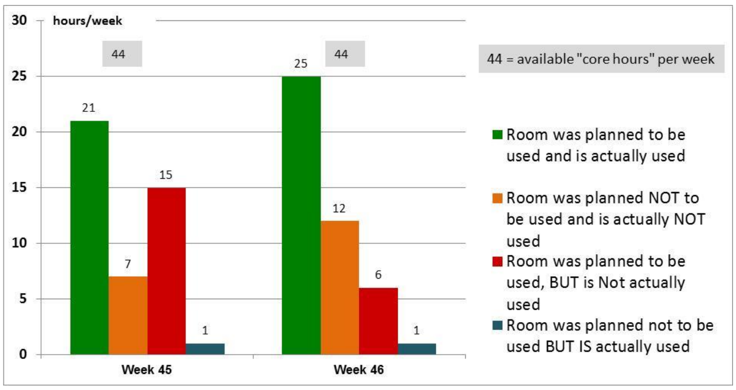

Fig. 13 Planned and actual use of the auditorium in Zone 8 in week 45 and 46.

We also wanted to compare the actual presence in the auditorium with class schedules and room bookings to find out whether the room as a material resource is utilised *effectively*. Two full weeks were investigated. Sound (dB) and changes of CO_2 concentration in the air (parts per million) were considered to be the best indicators for presence. The minute wise values of these two types of data were plotted and changes were identified manually and compared to the last updated version of the auditorium schedule that was obtained from the person in charge of planning at the university college. A more detailed description of this can be found in Simensen et al [12]. Fig. 13 indicates a fair consistency between planning and actual use (64% in week 45 and 84% in week 46). According to the strategic rules defined earlier this part of Zone 8 suggests that overall primary needs in 48% of operating time in week 45 and 57% in week 46. For instance, the green bars represent use according to plan while red bars represent the number of hours when the auditorium was reserved but no classes or events were held. In addition to this the auditorium was not in use more than 60% of a full working day. More importantly, however, is how the combined information on planned and actual use helps to frame the flexibility issues specified by the rules shown earlier. This investigation serves to determine how energy planning can better be integrated with class scheduling and room bookings. At the same time it shows how the sensors can provide us with information on actual use. Moreover, it underpins a control strategy that seeks to channel energy where it is needed at all times.

Two sets of samples were collected in late fall from two student groups during classes and group work with 66 participators and 43 participators respectively. During the first sample the auditorium had been in use prior to the class, while not in the other. The students were asked to fill in the questions on temperature and air quality four times during each sampling. The HVAC system was not manipulated by the project team during these samples. The following conditions measured by the sensors temperature, CO_2 concentration, humidity and light were stable all through the sampling and all except for Relative humidity in sampling one were well within limits of what is normally perceived as good indoor environment. Relative humidity during the first sample ranged between 28,6 to 29,5% and values below 30% are regarded as dry air[26] Results are shown in Fig. 14.

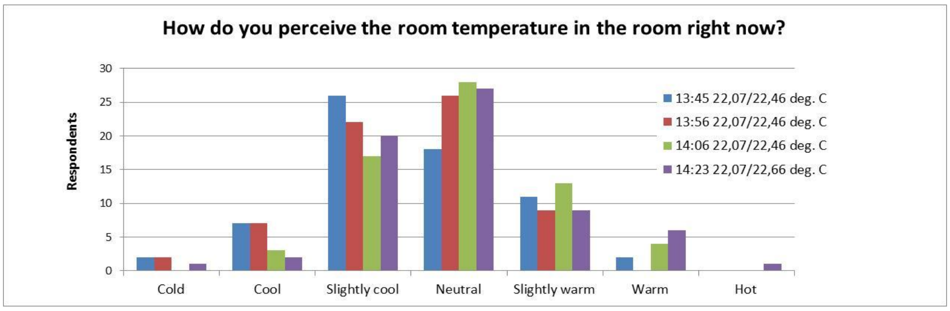

Fig. 14 How do you perceive the room temperature in the room right now? Answers at 4 different times. Temperatures are from two sensors placed high and low in the auditorium

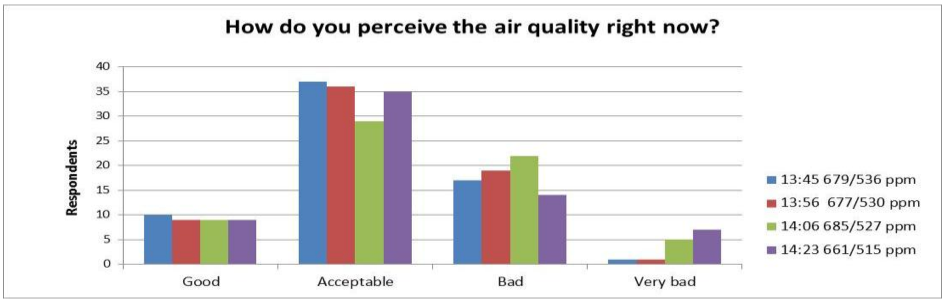

Fig. 15 How do you perceive the air quality just now? Answers at 4 different times

In Fig. 14 we can spot the contours of the PPD-PMV curve. The majority of the population asked finds the room temperature to be acceptable. However, we see that, regardless of the time of survey a significant fraction finds the auditorium a little cold. Using the PPD index as a guide it appears that the set point temperature represents a slightly negative PMV value. As the set point has been permanently fixed for this room it shows that approximately 60% of the users are unhappy, but tolerant. The answers given to the question shown in Fig. 16 indicate that the majority perceives conditions as tolerable, at least for a shorter period. However, we see here that net flexibility is reduced. It is unclear at this stage whether this is caused by a permanent decrease in set point or as a consequence of excessive chilling due to ventilation. By adjusting the set point upwards it is likely that the skewedness of the curve could be altered and people's perception of comfort would align with the ideal curve shown in Fig. 4. The fact that the present, non-ideal state is tolerated by most users suggests that there is latitude for manipulating the set point within a certain PMV limit. Temporary unit adjustments up or down would not change the PPD much. Consequently the ratio between happy and less happy would be approximately the same. Notice too the lower boundary between primary and secondary needs for thermal comfort during academic work. The groups "Slightly Warm", "Warm" and "Hot" experience excessive use of thermal energy. As temperatures are lowered the groups will gradually change their opinion. When all groups feel cold the PUE has decreased far below 1.0. Consequently a PUE = 1 is well aligned with a PPD of 5% as shown in Fig.3. Using the present records and the general PPD-PMV function, adjustments of energy supply is possible to improve both comfort and efficiency. By changing the temperature set point within an interval that corresponds to the PMV interval [-1,0] this can be achieved. In our optimization approach we would seek to maintain the median PMV value at zero and adjust on demand from this reference. With the thermal inertia displayed we would obtain improved comfort while take out the consumer flexibility when demanded. This will improve effectiveness, but also enhances the efficiency of the complete energy system during prime hours.

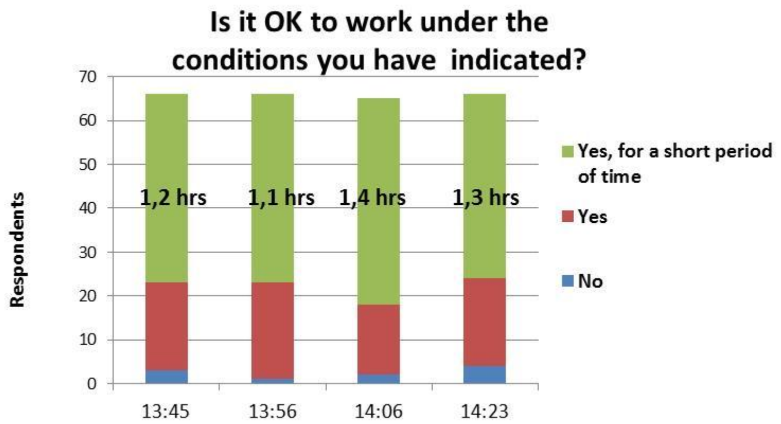

Fig. 16 When asked about working conditions the control group responded as shown above

Fig. 16 shows similar results for the air quality. Viewing this in the context of a PPD index for air quality we find that app. 70% of the group asked find it acceptable or good. Here the set point is obviously closer to the median. Applying the same logic as above there is leverage for similar adjustments. A definite test to prove this still remains to be done, but the present data helps us to define the latent flexibility and a basis for new energy management strategies. Also based on this it seems in this specific case that the CO_2 level places the strongest constraint on the latent consumer flexibility. Fresh air circulation induces a significant top load while air quality satisfaction is good. The bounded energy in the building creates a thermic inertia that can be easily exploited while air quality management is more demanding in terms of instant loads during actual use. Consequently there is a need to prognosticate use and to apply a proactive strategy of CO_2 concentration control.

8. Conclusive discussion

The work reported here yields strong support for the energy management model conceived in the project. The management model addresses energy issues related to the complete energy supply system using a building or house as an amendable unit to assure and balance energy needs in all parts of the system. To assure this we have advocated purpose or value oriented ideas that seek to assure that efficiency measures to do jeopardize the user experience. If properly exploited the people that use a building can be assured that their comfort, job and welfare related to energy supply can be assured while the total energy supplied through the grid is minimized and peak loads are reduced. Based on our empirical research we have found that it is possible to combine modern sensor technology with theoretic concepts so that latent consumer flexibility can be identified and estimated also for non-discrete loads such as heating and cooling even in what we call prime hours of energy use. The PPD-PMV theory helps to understand how primary and secondary energy needs related to thermal comfort can be identified. This can be used to delineate the potential flexibility related to thermal control. The results also show that there exists a firm robustness among the test population with respect to lower than ideal temperatures. This tolerance is the basis for the consumer flexibility that we are seeking. The results from the population of subjects monitored and interviewed responded in a way that reinforces our beliefs that the PPD-PMV model has general applicability. It will be a useful tool for the general purpose defined in this discourse. We also think it is worthwhile to pursue similar approaches for other climate parameters such as air quality/ CO_2 -humidity.

The results obtained from the initial field tests at Campus Remmen show that there is latent consumer flexibility that can be exploited by means of smart grid oriented concepts. We have shown here that the flexibility pursued can be pinned on three sources. These can be exploited alone or in any combination.

1. Energy zones that constitute thermal reservoirs
2. Improved class scheduling
3. User tolerances

Thermal reservoirs are typically zones like Zone 8 that have the capacity to absorb heat energy during off-peak hours and sustain preferred temperatures for long hours afterwards. Consequently we could question the practice of night time temperature reductions which is routinely used across the northern hemisphere. A more differentiated approach should be advocated whereby zones like Zone 8 at Campus Remmen should be heated, even over-heated, during off-peak hours between midnight and six o'clock in the morning. This would yield relief for the grid and the market during cold winter days and contribute to overall system efficiency and lower bills for the property owner and the tenant. Zone segmentation will be important.

For schools and offices energy management should be aligned with room and activity bookings. At Campus Remmen simple sensors record whether the room is occupied. This activates ventilation in many rooms and to some extent heating. More intelligence should be added to this. Room bookings combined with sensors that detect occupancy will be able to drive up the PUE for each room while temporarily shed loads for zones that are not pre-booked, but occupied or pre-booked, but not used. The accepted latitude here must be defined in accordance with accepted user tolerances. For Campus Remmen a 14% and 28% gain for week 44 and 46 would be achieved.

We have further shown that latent flexibility for Smart Grid demand side adjustments can be associated with user tolerances. Today set points are typically fixed. Based on our work we think that the PMV-PPD index could be used more actively to create an operational interval for both temperature and other climate parameters. The PMV-PPD approach also lends itself well to a fuzzy set expression. We have therefore initiated the building of a fuzzy set based control prototype to explore this. Unit changes of +/- 1 could be the norm for temperature. Corresponding liberation of loads for heating (and possibly cooling) for periods of 1-4 hours could surrender hourly loads in the range of 300-500 kW's and even more for buildings like Campus Remmen. We have also shown that a similar scheme is possible for CO_2 management. All three in combination could yield significant economic effects for consuming parties that are tariffed according to peak loads per period. For Campus Remmen such savings is worth €15 per kW. Smart and high resolution monitoring and control in a building like Campus Remmen could counter and reciprocate to morning peaks imposed by several hundred households in the local distribution net.

We also think that our approach indicate how affordable micro-production concepts can be applied, not as a principal energy resource as is commonly advocated, but as a load shedders. Based on our experiences thus far we believe the cost/utility for such could be quite attractive. To reduce the electric load battery packs or controllable fuel cell systems would be required. They could operate like UPS systems typically used as reserve energy in case of black-outs. This will be further explored [13].

9. Acknowledgements

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PLANNING AND PERFORMANCE OF AN ECO-EFFICIENT DORMATORY IN COLD CLIMATE AREA

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Summary

A public company, Senate Properties, is contracting multi-purpose dormitory building in the shore of Lake Inari in Lapland, Finland. The area is one of the coldest areas in the country. The building project will be realized in accordance with strict energy- and ecological requirements. In this paper the set requirements and planned actions to meet the requirements are presented.

Keywords: Eco efficiency, passive house, cold-climate building, demand controlled operations

1. Introduction

Senate Properties is a state enterprise with nationwide operations and a role as government-internal premises expert provides the central government premises with associated services. One of those premises is the Sámi Education Institute, a secondary degree school, which provides a variety of vocational training both in Finnish and Sámi, as well as promotes Sámi culture in the whole Sámi region. The Institute is located in the shore of Lake Inari in Lapland (figures 1[1] and 2[2]). Currently, Senate Properties is contracting a multi-purpose dormitory building for the students of Sami Education Institute in connection with the existing property. Due to Northern location and relatively hard weather conditions caused by the open Lake Inari as well as due to increased energy efficiency demand and fragile nature, Senate properties decided to realize the building project in accordance with strict energy- and ecological requirements. In addition, the environment as a part of Sámi culture adapted centuries with surrounding nature sets special demands for the project. During the seasons the dormitory is occupied by students and in summer times it can be used as summer hostel. Consequently, Senate properties decided to implement the project by using special commissioning procedures, in co-operation with VTT Technical Research Centre of Finland and subcontractors. This means systematic verification of the key performance indicators and owner´s project requirements in each stage of the building process.

Figure 1. Location of Inari community (source: Discovering Finland)

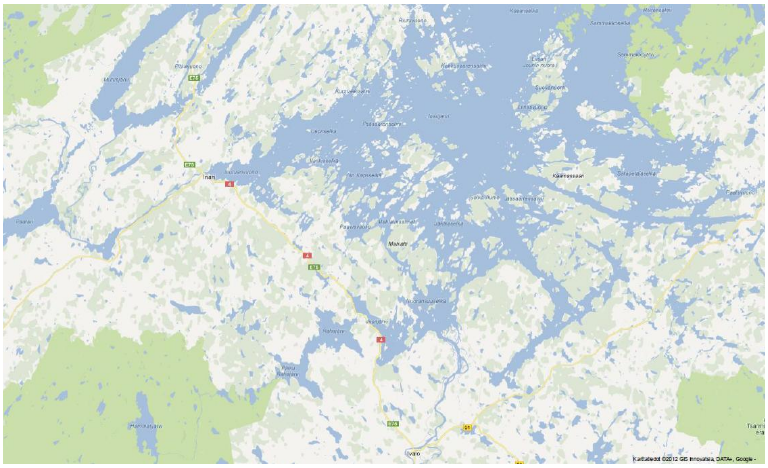

Figure 2. Lake Inari area (source: Google Maps)

In this paper we present the set requirements and different stages from pre-design phase to the construction stage. The building is due to be completed in 2013. The main idea of the paper is, anyway, to introduce requirements for energy, Eco technical efficiency and performance, as well as the design procedure and quality control steps to confirm the imposed goals. The HVAC-system will be based on geothermal heat pumps, but also solar panels and wind turbine will be installed. Insulation of the building envelope will be better than required. A special attention will also be paid to air-tightness. The building will be equipped with a detailed metering and control system in order to control the performance on-line. The nearby education center is heated by oil burner, and in the same connection the heating system of that building will also be renewed.

This kind of solution is very rare especially so in northern region in Finland. The goal of the contractor´s premises was to have an energy- and eco-efficient building equipped with an advanced monitoring and metering installation. The purpose of the extensive metering is 1) to verify the performance of the building (as designed) and 2) to be “a showcase” for possible similar buildings in the future. Because of a unique type of project there are no other reference buildings in the area or in the region available. The contractor´s aim is that a neutral research organization will verify the performance of the building. Due to the type of the contract, there was no possibility to study extensively other possible cases in semi-arctic region.

The implementation of the project has delayed compared with the original schedule, so no results are not in use at the moment.

2. Thermal conditions in the region

2.1 Background information

The municipality of Inari is the largest one in Finland (2012), area > 15 000 km^2. The water area is > 2000 km^2, of which the share of Lake Inari is approximately the half of it. The population of Inari is 6700 (31.12.2011) [3]. Inari is one of the strongest tourist areas in Lapland.

2.2 Thermal seasons

Thermal seasons [4] are determined on the grounds of daily mean temperatures. In Finland the longest thermal season is winter and the spring is the shortest. The change of thermal season is defined as follows:

- Spring begins when the daily mean temperature exceeds constantly > 0 °C
- Summer begins when the daily mean temperature exceeds constantly > + 10 °C
- Autumn begins when the daily mean temperature lowers constantly < +10 °C
- Winter begins when the daily mean temperature lowers constantly < 0 °C

In Finland the mean temperature may vary on both sides of the limits and the exact moment of the season is not always unambiguous. Nowadays the change of thermal seasons is based on the heat summation calculated of previous weeks/month. Traditionally, the winter begins when the average day temperature decreases constantly below 0 °C. For instance, winter begins from the next day, when the sum of mean temperatures, calculated from the beginning of September, reaches its highest value. Then one can see that temperature is constantly below zero even in single days the temperature could be above zero degrees. Winter started in Inari 17.11.2012.

2.3 Vegetation zones

Inari-area belongs to slow-growing forests zone [4]. In this north-boreal area the forests are sparse, slow growing and renewable only in the best summers (figure 3) [4].

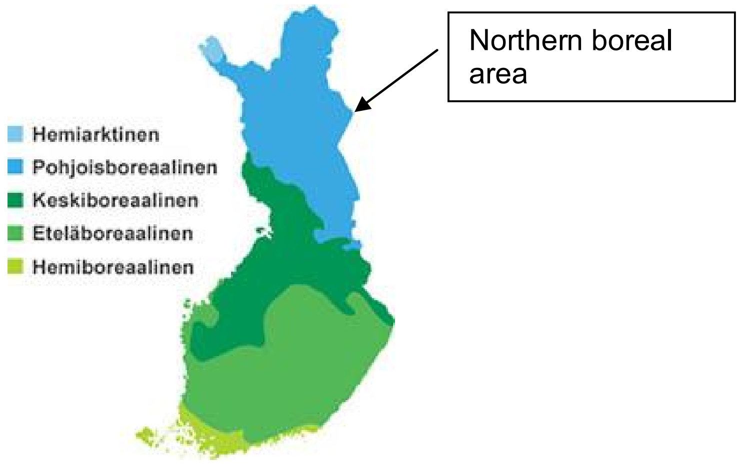

Figure 3. Vegetation zones

2.4 Building stock

The building stock in Inari region has mainly built after the war period and it is relatively new. There is nothing exceptional to build in northern areas of Finland; only outdoor temperatures have to be taken into account in the design criteria. There are not so many buildings in the community, anyway, which has been design based on sustainability and very high energy efficiency. Climate conditions due to the open lake and northern location will set some challenges for design, or, one must be very careful in planning details in order to meet set requirements.

According to the statistics of Association of Finnish local and regional Authorities [5], the volume of public building stock in Inari municipality is 136 500 m^3 (18 buildings), the average heating energy consumption is 53,4 kWh/m^3 and weather corrected consumption 45,2 kWh/m^3. The consumption of electricity is 17, 8 kWh/m^3 and water 118, 3 l/m^3. Savings of 5 % in energy consumption would mean 19 900 €/year and reduction of 2, 2 tons of CO_2.

3. General planning principles

3.1 Design intents

Finland has divided into 4 weather zones in terms of energy use in building design (figure 4) [6]. Inari region belongs to the zone IV. The monthly mean outdoor temperatures and sun radiation energies are based on four weather stations and on the test year 1979, the reference weather station for zone IV is in Sodankylä, south from Inari community. The normalized heating needs value based on degree days S17 is used by comparing the heating need with the heating need to other years or locations. Table 1 shows the weather data in weather zone IV (Sodankylä 1979). The heating need value for the whole year (used in calculations) is in zone IV 6317, when it is in zone I (e.g. in Helsinki) 4447. In case of Inari, the heating need values (degree days number) will be calculated using the local weather and heating need data which are represented in public sources.

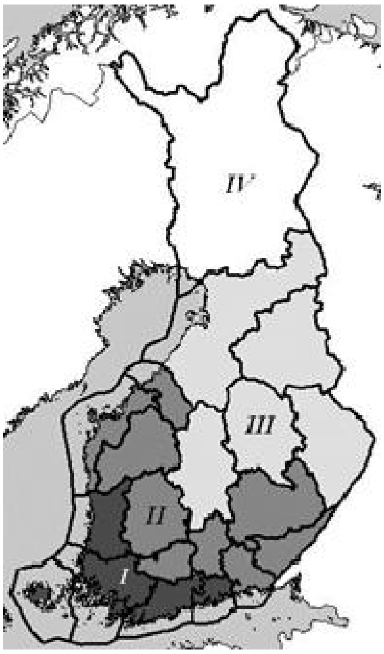

Figure 4. Weather zones for construction design

Table 1	Weather data	Sodankylä observation site	
	Zone IV	The total radiation energy of the sun, Grad, horizontal plane	Heating need value for normalizing the data
Month	Mean outdoor temp. °C	kWh/m²	S17, Kd
January	-18,3	1,5	1 094
February	-14,9	11,1	893
March	-7,03	43,8	745
April	-3,62	97,7	619
May	5,79	130,1	315
June	12,2	143,2	62
July	14,7	157,8	24
August	12,6	103,6	111
September	6,25	48,5	323
October	-3,1	19,7	623
March	-5,44	3,1	673
December	-9,97	0,3	836
Whole year	0,81	760	6 317

Table 1. Weather data used in energy calculations and design

3.2. Eco-efficient goals of the project

The goal of the construction project was to design and build an eco-efficient accommodation building in cold climate area, in Inari Finland. Additional focus of the building project was on energy efficiency and performance by pursuing passive house efficiency. Also life-cycle economy viewpoint for the entire project was adapted to guideline the planning process. The design complied with the Finnish building code regulations and guidelines. Passive house energy efficiency goals were set to as follows:

- E- ratio target value for purchased energy < 140 kWh / m^2,a (space program)
- Demand for heating energy < 30 kWh / m^2
- Demand for specific fan power for AHU < 2,0 kW/ m^3/s, (SFP-ratio)
- Annual heat recovery efficiency of AHU > 70 %
- Indoor conditions class S3
- CO_2 maximum value 1200 ppm in living rooms

Indoor classification is set according to indoor air classification ranges in Finland. S3 is the best range.

3.3. Method (process to achieve the goals)

During the planning phase analysis of eco efficiency and performance were made as performed and different solutions for fulfilling the objectives set by the client were evaluated. Already at the beginning of the project it was told to the whole design team that after the construction verification measurements will be used to evaluate the implementation.

In the design phase the life-cycle related guidance containing renovations and replacements, maintenance and energy efficiency was given to the designers. In the structural engineering attention was paid to placing the building services and to preparing for changing of HVAC equipment and piping (openings, enclosures etc. to facilitate operations) from the viewpoint of maintenance, repair and replacements. In the building envelope design phase the goal was to avoid high windows in low energy houses – to avoid the feeling of draft, to pay attention to routings and spaces for building services in order to avoid feed-through connections in the envelope and to reserve enough space for renovation of the building services. Also the goal was to avoid feed-through connections in electricity and ICT wirings.

The main focus was in selecting the energy supply and building services. Geothermal heating was selected as the main renewable energy sources after comparison it to pellet energy since pellet is unfavorable in low consumptions. In dimensioning of the geothermal energy 100% capacity was used instead of usually used 80 %. Boiler dimensioning and control, prevention of boiling and need for solar thermal collectors were also considered as were the use of photovoltaic panels and wind generator. Attention was also drawn to access to power grid and how to arrange power generation possibilities when disconnected. It was also realized if basic consumption is low then the investment payback time is longer.

3.4. Simulations

The main idea in building services is demand controlled operation (presence information) based on CO_2, temperature and humidity contents. Need for displays and controls in rooms, sub metering for lighting, air conditioning and water were seen important from the viewpoint of consumption. Five design cases were simulated with IDA Indoor Climate Energy simulator, namely:

- Accommodation according to Finnish Building Codes, parts D3/D5 (dealing with air exchange and energy efficiency, 2012) airflow and other regulations
- Apartment house airflows, loads and other regulations
- Reduced lightning energy consumption (LED)
- Reduced effect of structural cold bridges to one third according to the instructions as well as other system losses
- Target calculated including all changes by using Helsinki weather

Simulations showed that planning and implementation of air conditioning and equipment is crucial because of high energy consumption due to air flows in accommodations. If apartment house specifications are applied instead of accommodation ones the consumption falls to less than half. The same is also true with respect to the energy required by the illumination. Significant savings can be achieved with demand controlled ventilation and lighting. As a result energy consumption exceeds slightly the passive house consumption.

The challenge is that the passive energy level for the heating is difficult to achieve if the ventilation rate of accommodation buildings (dormitories belong to this category according to building code) is used. In real conditions it may be possible to use demand-controlled ventilation and hence decrease energy consumption.

3.5. Solutions

Focus was paid to large windows, feed-troughs, life-cycle viewpoint for renovations and replacements and verification by measuring the goals by giving a notice in the planning phase. It is important already from the beginning of the construction process to focus on eco efficiency, life-cycle use of the building and to verify the efficiency goals by measuring. Also it is important to pay attention to eco-efficiency from the structural engineering phase to avoid high windows and feed-through connections in the envelope especially in low energy houses. In the structural engineering attention has to be paid to placing the building services and to prepare for changing of HVAC equipment and piping (openings, enclosures etc. to facilitate operations) from the viewpoint of maintenance, repair and replacements. It is important also to reserve enough space for renovation of the building services. Also the goal was to avoid feed-through connections in electricity and ICT wirings.

As a result demand controlled lighting and air conditioning will be used (compare hotels). Part of lighting and electric sockets and room air conditioning will be connected to electric lock systems to switch them off when the occupant leaves and takes his/ her key card with. Building will also be equipped with information screen to show building energy consumption.

3.6. Planned measurements

3.6.1. Background

Indoor class 3 is accepted for indoor conditions. It means e.g.:

- Indoor air temperature in the summer +21 … +27 °C
- If mean outdoor temperature during 5 hrs. maximum period is higher than +20 °C, the indoor temperature can exceed it by 5 °C at most
- The air velocity in occupational zone in winter 0,19 m/s and in summer 0,3 m/s at most. During the boosted ventilation exceeding not more than +0, 1 m/s.
- Sound level of ventilation in the rooms must be not more than 28 dB (A). During the boosted ventilation exceeding not more than -10 dB compared with the reference value.
- Maximum concentration of carbon dioxide (CO_2) 1200 ppm in living rooms.
- The goal is the common automatism of electrical and HVAC-systems. The system must recognize the exceptional or wrong use of the building and prevent energy spending (e.g. open windows with simultaneous heating). By absence function one can switch off the ventilation in living rooms and control the temperature drops. The main goal is to create a developed and innovative system using the newest technology by reliable and energy-saving way.

Project will apply the Cx (building commission)-procedure (figure 5) [7]

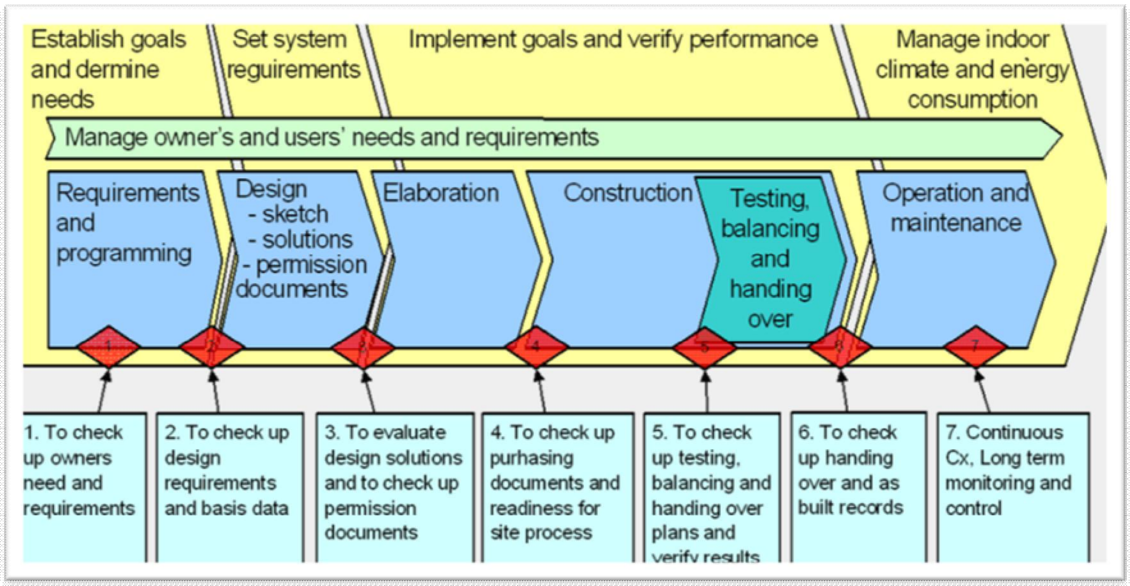

Figure 5. The schematic presentation of building commissioning procedure [7]

3.6.2. The aim of measurements

There are two main goals for the measurements:

1. To ensure the performance of the building and building systems and the proper use of them
2. To collect and analyze the data in that way that the performance of the building can be compared with the set requirements and goals

Except the basic instrumentation some additional fitted metering has been suggested (some of the measurements could be included in the basic instrumentation).

3.6.3. Structures

In customary solutions the temperatures of the structures are normally not measured. Because of pilot project, there is an opportunity to measure the soil temperature under frost protection (outside insulation) outside in both facades against the foundations. Also the corner temperatures in the joints of the wall and floor (inside) and across the wall structure (outside) can be measured. By these measurements one can see the real effect of thermal bridges and can also evaluate the heat flows from/to the ground. The local weather station to monitor outdoor temperature, wind speed and direction and relative humidity is suggested.

3.6.4. Indoor environment

The RH-concentration and CO_2-concentration of the exhaust air will be measured. Depending on the owners interest CO_2 could be measured also in some rooms. The indoor air temperature measurements belong to basic instrumentation.

Depending on HVAC-solution the exhaust air flows will be measured, too. The efficiency of heat exchanger (heat recovery) is a necessary measurement. The measurements of main supplied air and exhaust air belong to basic instrumentation. The pressure conditions will be measured separately in the connection of balancing of ventilation system. Draft measurements will be carried out if there is a need to do so.

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3.6.5. Heating system

The heating energy consumption of ventilation, heating and hot water is measured separately. The instrumentation of heat pump will be realized according to manufacturer´s basic instrumentation model.

3.6.6. Electricity

The electricity used by ventilation, heating system and lighting will be separately measured. The total consumption of electricity covers besides electricity consumed by ventilation, heating and lighting also other objects of use – the difference tells the distribution of other use. The consumption measurement of electricity should be realized in that way, that the evaluation of daily distribution of electricity consumption would be possible (an hourly average value is too sparse).

3.6.7. Building automation system and reporting

The realization of target values and key performance indicators (KPIs) will be verified by energy- and facility management software, which is based on the installed metering. The reporting model will be created separately. The orderer will determine the factors presented in reporting. The goal is a reporting system which serves users, owner and other stakeholders.

4. Lessons learned

It is important already from the beginning of the construction process to focus on eco efficiency, and life-cycle use of the building and to verify the efficiency goals by measuring. Make clear already in the design phase the goals and keep focus all the time on those goals. By running comparing design solutions in the simulator impact can be demonstrated clearly. Continuous focus on design goals resulted in several changes compared to ordinary design practices used. It was rather evident that passive house target and its verification by measurements caused a bigger rise in costs than it was expected. It must emphasize that the commissioning procedure should be started from pre-design phase and verify the owner´s project requirements in each stage very strictly, because in recent projects there are many subcontractors and actors, and in normal daily routine work the goals can stay for a secondary position for instance because of generally used technical solutions.

5. The recent stage of the project

The construction works are now in the skeleton stage. The builder is waiting the permission for ground heat pump system and acceptance for wind turbine. According to the original schedule the building should have been completed in the turn of 2012-2013 and the first measurements should be done in the spring season 2013. As a summary of the recent stage one can say:

- Rise in costs resulted in cost cuttings and delays.
- Finalizing of the planning still going on.
- Delay in construction close to one year.

This situation is not so unusual, especially if it is question about a little bit diverging projects compared with business-as-usual-type building projects. Also the requirements in proportion to the budget frame will cause some limitations.

6. Conclusions

The preliminary set requirements are not very different compared with the ongoing and planned passive house/near zero energy building projects. Special attention has been paid the performance of the building envelope, thermal bridges and air tightness which is also communicated to the design team. The structural details needed must be shown also in the working site and be presented in site meetings; even they are described in the design documents.

As a result of demand controlled lighting and air conditioning will be used (compare hotels). Part of lighting and electric sockets and room air conditioning will be connected to electric lock systems to switch them off when the occupant leaves and takes his/ her key card with. Building will also be equipped with information screen to show building energy consumption.

The systematic commissioning approach will be used during the building project. Cx (building commissioning)-procedure should ensure that the building performance and indoor conditions are "as designed".

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Study on the Existing Buildings Renovation for Energy Conservation in Taiwan


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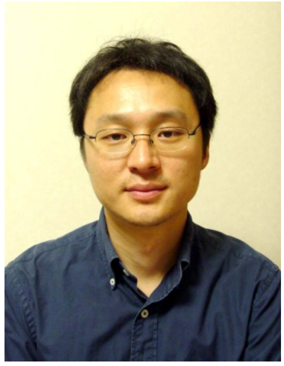
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Summary

Currently, existing buildings account for approximately 97% of the real estate market in Taiwan. Most of the existing buildings were designed and constructed before the establishment of green building regulations. Improper building design has caused the overheating of indoor spaces, while air-conditioning during summertime has led to electricity shortage. Concerning the environment, the Taiwanese government is promoting plans for improving the operational efficiency of existing buildings to reduce energy consumption. The purpose of this research is to find the difficulties of realizing energy-efficient approaches and suggesting solutions for popularization by examining practically retrofitted cases. In this paper, problems of existing buildings and relevant government policies will be analyzed and solutions for enhancing energy efficiency will be discussed.

Keywords:
Existing building, subtropical climate, energy efficiency, refurbishment of building envelope, heat insulation, sunshades

1. Introduction

Taiwan is located in a subtropical climate zone. The hot and humid climate enormously affects living conditions of the people. To maintain the living comfort, heavy consuming of electrical load and CO_2 emission have become the present issue for the environment. In general, buildings consume a lot of energy and emit huge amount of greenhouse gases during their long life cycle. Therefore, under the pressure of limited natural resources and the global warming phenomenon, enhancing the performance of both new and existing buildings is critical.

Like many other developed countries, the Taiwanese real estate market is saturated and newly constructed buildings comprise only about 3%. Meanwhile, the operation period of those existing buildings has been extended. Most of those buildings were constructed before 1999 when the “Green Building Regulation” was established. Those old structures with their inefficient features are not considered as environmental friendly. However, the comfort level of indoor living spaces has always been related to the outdoor environment. In this regard, a building design should always take into account the characteristics of the local climate conditions to improve the performance of new and existing buildings.

In Taiwan, 99.39% of the energy supply depends on import. Because of a natural resource shortage and city appearance enhancement, the Taiwanese government is promoting the improvement projects for existing buildings to reduce the energy consumption. Hundreds of public and private buildings have been upgraded with governmental support. Performance enhancement for existing buildings can be achieved through changes in three areas: external envelope, internal equipment and occupant's habits. Since the envelope is the outest layer of a building, outdoor environment affects it the most. In other words, the envelope part is the most important part to be improved. In this paper, Taiwanese governmental incentive schemes for renovating existing buildings and retrofitted examples will be presented. In addition, the difficulties and challenges found in the process of building improvement will be discussed. Thus, the aim of the research is encouraging energy-efficient refurbishment development.

2. Methods

2.1 The object

This study mainly focuses on the examples of energy-efficient improvements for buildings' envelope. The envelope includes the roof, wall and opening parts. The refurbishing approaches for improving those parts in a subtropical climate will be presented.

2.2 Research methods

Literature review and a filed study are utilized for this research. Reviewing literature is to gather the information related to up-to-date governmental policies and building standards for energy conservation. Through visiting the refurbished building and interviewing with occupants and experts, it was possible to understand the actual results of the renovation projects. The site tour was carried out in 2011 and 2012.

3. The circumstances of Taiwan

3.1 Climate

Taiwan is located in the coast area of East Asia and is classified as a subtropical climate. Generally, the climate is hot and humid. The climate types in Taiwan are: the subtropical monsoon climate and the tropical monsoon climate which is divided by the Tropic of Cancer. Furthermore, the country can be divided into three climate areas, the northern, central and southern zones, according to the Taiwan building design standards. Compared to the northern climate zone, the annual average temperature is higher and the sunshine hours are longer in the south. The weather data are as follows: the average temperature is approximately 29℃ during summer, the average sunshine hours per year is around 1788 hours, and the average percentage of humidity is about 77 percent.

3.2 Energy resources

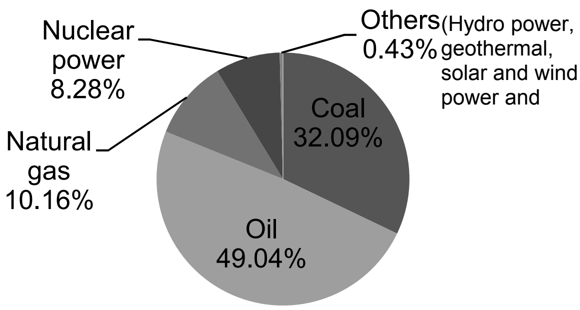


Fig. 1 Energy Source

The energy sources of Taiwan are coal, oil, natural gas, nuclear power, hydro power, geothermal, solar and wind power and solar thermal. 99.39% of the energy supply is dependent on import. The energy consumption for generating electricity was about 48.60% in 2010. The electricity amount for cooling and lighting accounted for up to 80% of electricity demand during summertime. Therefore, saving energy and reducing carbon emissions are crucial for Taiwanese economy and environment.(Fig. 1)

3.3 Current real estate market statistics

The amount of the new constructions and demolished buildings are decreasing during the last 20 years. (Fig. 2) About 97% of the existing buildings are in the current Taiwanese real estate market.

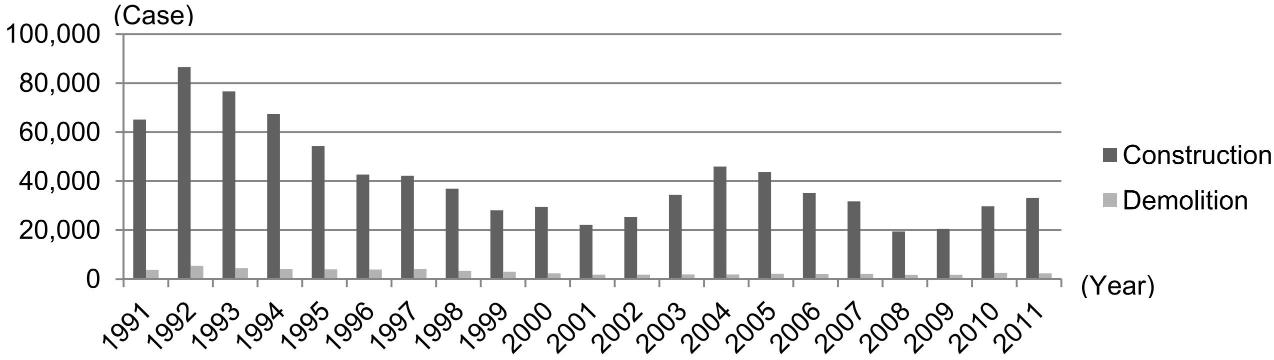


Fig. 2 Number of the construction and demolition (1991~2011)

3.4 Building material

In Taiwan, the most common material for building was reinforced concrete over the last two decades according to the statistics by Construction and Planning Agency. (Fig. 3)

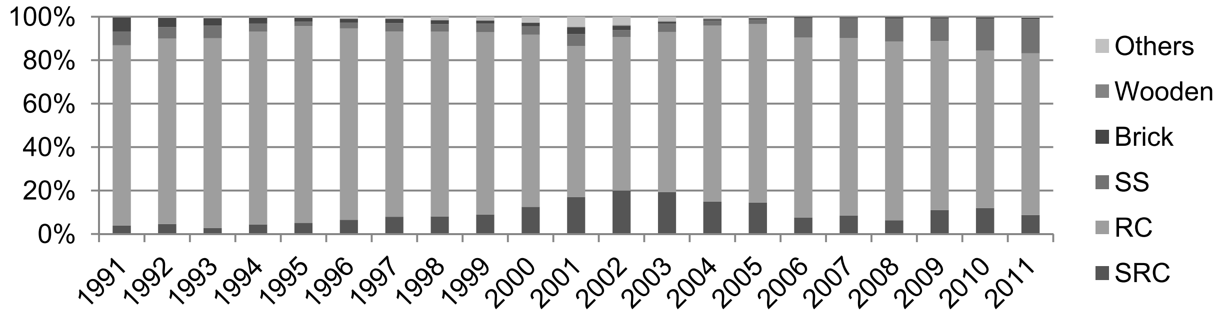


Fig. 3 Number of the usage license by building materials (1991~2011)

3.5 Standard for energy conservation design

3.5.1 Regulation for building techniques

According to the Taiwanese regulations on building techniques, based on climate conditions, three different design standards for energy conservation have applied to three separate regions: north, central and south. (Fig. 4 &Table 1) Furthermore, U-value, overall heat transfer co-efficiency, for external walls of residential building is 2.75 (W/(m²·K)) and 2.0 (W/(m²·K)) for others; the U-value for the roof is 0.8 (W/(m²·K)).

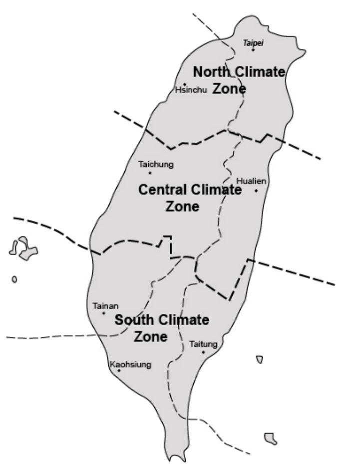


Fig. 4 Climate zones for building design standard

Table 1 Building design standards for energy conservation

Climate zone	Window opening ratio (Housing)	Overall sunlight receiving amount (School) kWh/(㎡·year)	Building envelope energy consumption standard kWh /(㎡·year)
North	<13%	160,000	Office: < 80,000 Retail: <240,000 Hotel: < 100,000 Hospital: < 140,000
Central	<15%	200,000	Office: < 90,000 Retail: < 270,000 Hotel: < 120,000 Hospital: < 155,000
South	<18%	230,000	Office: < 115,000 Retail: < 315,000 Hotel: <135,000 Hospital: <190,000

3.5.2 Green building rating system for renovation

EEWH-RN is a rating system for sustainable renovation applied for existing buildings in Taiwan. The system is applicable only for the buildings older than three years with the renovated area less than half of total floor area.

3.6 Governmental subsidy plans for existing buildings

Since 2002, there have been various national incentive schemes available for both public and private buildings based on the “Green Building Promotion strategy”. The subsidies have been eligible for commercial, residential and social welfare buildings. Renovated buildings became more sustainable with a refurbished envelope, high-efficient equipment and power generation system. In addition, local governments took the lead of several improvement projects for building façade refurbishment in Kaohsiung, Taipei and other cities. Five successful governmental incentive schemes related to sustainable refurbishment of building envelope are selected as examples in this research. (Table 2)

Table 2 Taiwanese Governmental incentive schemes

Name of the incentive scheme		Scheme A	Scheme B	Scheme C	Scheme D	Scheme E
		Green Remodeling Project for Governmental Building	Green Building Renew & Reform Project	Energy Conservation Improvement Project for Buildings	Green building demonstration project for private building	Kaohsiung building façade refurbishment project
Period		2002~2007	2008~	2002~2007	2004~2011	2006~
Building ownership & type		■Public: Business, Education, Health & Welfare	■Public: Business, Education, Health & Welfare	■Public: Business, Education ■Private: Business, Commerce, Education, Health & Welfare, Residential & care	■Private: Business, Education, Health & Welfare, Residential & care	■Private: Residential, Business, Commerce
Subsidy amount (TWD)		Unknown	≦500,000/per	Sunshade: ≦1,000,000 Roof Insulation: ≦500,000	250,000~2,000,000 and ≦ 49% construction cost	Primary area: ≦800,000 & 1/2 construction cost Secondary area: ≦500,000 & 1/3 construction cost
Project number		98	80 (till 2011)	Sunshade:116 Roof Ins.:220	109	224 (till 2011)
Subsidy content	Site	◎	◎		◎	
	Equipment	◎	◎		◎	
	Opening	◎	◎	◎	◎	◎
	Roof	◎	◎	◎	◎	
	External wall					◎

4. Field cases study

4.1 Problems of the existing buildings

Although the difference between building interior and exterior might not be obvious, exposure to sunlight is the main cause of overheating of the buildings. However, the buildings in Taiwan are mostly constructed with reinforced concrete. The concrete block easily absorbs and maintains heat during the day, and radiates the heat out at night. The improper design on most existing buildings leads to the results of overheated interior space, overexposure of sunlight and poor ventilation.

Those problems occur in buildings where the windows are always covered with shades, or the second roof layer was added on the rooftop to reduce solar heat gain. (Fig. 5~7) Furthermore, situations like air or water leakage which affects not only the appearance but also performance of the buildings are found in most of the disreputable constructions are. Enhancing the level of living comfort in such hot environments requires huge energy demand for cooling. Overconsumption of electricity and increased CO_2 emission are affecting current living conditions.

Fig. 5 Building appearance, Kaohsiung

Fig. 6 Windows shades, Taipei

Fig. 7 Secondary roof, Taipei

4.2 Approaches to building improvement

Internal heat radiation, outdoor hot air and heat gain on building envelope are the three main sources affecting the indoor temperature and energy consumption. When enhancing the building envelope performance to reduce the energy consumption, both heat insulation and sun shading should be considered equally. The function of the heat insulation layer is to insulate the thermal transfer heat of the building envelope; the function of the sun shading is to control the solar heat gain through the building envelope.

The below cases study are categorized by three parts of the building envelope: the opening, external wall and roof.

4.2.1 Opening

I will choose four private renovated buildings as the example. The most common improving techniques for opening parts in Taiwan are as follows:

(1) Add sunshades
Using sunshades to reduce the solar heat gain through the window is the most efficient techniques. About 15% of the electricity demand for cooling can be reduced. Moreover, the performance of the external sunshade is better than internal devices. Several types of sunshades are applied according to the building orientations. Generally, the horizontal overhangs are used on the south side, the vertical fins are on the east or west side, and the vertical and horizontal mixed types are on the southeast or south west side of the buildings. Those sunshades can also be installed by fixed or adjustable types, and both advantages and disadvantages are listed below for “Case 1” and “Case 2”. (Table 3)

(2) Move the window backward
The windows are moved backward about 45cm to create a shading space which can be seen on “Case 3” and “Case 4”. (Table 3)

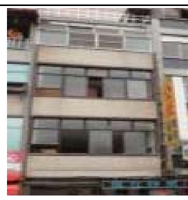
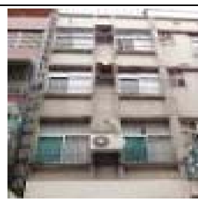
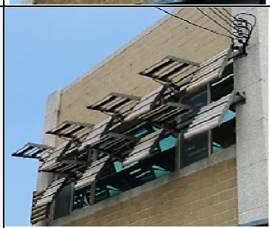
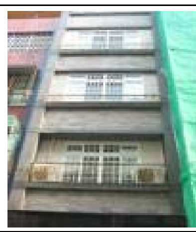
(3) Change the material of the window (Glazing + Sash)
Single clear glazing with aluminum sash is a common combination for the windows on existing buildings. To reduce solar gain, the windows are frequently changed to tinted, coated or add secondary glazing with PVC or stainless frames. In “Case 3” and “Case 4”, the windows were replaced by double green glazing window with PVC covered steel frames. (Table 3) Although Low-E glass is the best glass type to insulate the solar heat, the cost is too high to be afforded and is usually used on public buildings.

(4) Shrink the opening size
Take the office buildings in Taipei for example; the ratio of the opening area can affect 49% of the energy consumption. Reduction of solar heat gain by shrinking the size of the openings can be seen in the case 3 and Case 4. (Table 3)

4.2.2 External wall

In Taiwan, the performance of the external heat insulation is better than the internal one. The techniques are often used include changing to lighter colors or applying high-efficiency materials to building façades, covering buildings in greenery and installing double walls. Changing to light colors or applying high-efficiency materials to building façades is the most popular approach to be seen. (Case 3 & 4) There are two ways to apply a new layer depending on the buildings condition. One is to remove the original layer and apply a new one, and the other is to add a new layer on top of the old one. The safety of the structures and the cracked parts should be checked and patched before applying the new layer.

Table 3 The cases study of the external wall and opening

		Case 1	Case 2			Case 3	Case 4
	Subsidy	Project D	Project C		Subsidy	Project E	Project E
	Use	Commercial	Educational		Use	Residential	Residential
	Retrofitted part	Opening	Opening		Retrofitted part	Opening External wall	Opening External wall
	Location	Taichung (Central)	Kaohsiung (South)		Location	Kaohsiung (South)	Kaohsiung (South)
	Built year	2007	2000		Built year	1963	1973
	Retrofit year	2007	2007		Retrofit year	2011	2011
	Face	South	West		Face	Northeast	Southewest
	View 1				Before		
	View 2				After		
Opening (sunshade)	Type	Adjustable Horizontal overhangs	Fixed Horizontal overhangs	External wall	Color	Changed	Changed
				External wall	Material	Tiles Changed	Tiles changed
Opening (sunshade)	Material	Wood fiber	Aluminum	Opening (window)	Place	-	45cm setback(2F)
Opening (sunshade)	Advantage	1. Can be adjustable to receive different amount of sunlight or needs. 2. Easy to clean the window 3. View is available	1. Easy to be installed 2. Low cost for producing and maintaining.	Opening (window)	Size	Shrink	Shrink
				Opening (window)	Sash	Aluminum→PVC covered steel frames	Aluminum→PVC covered steel frames
Opening (sunshade)	Dis-advantage	1. The joints would break easily. 2. Maintenance is more difficult.	1. Can't be adjustable for needs 2. Block the view 3. Hard to clean the window	Opening (window)	Glazing	Clear→Tinted semi reflective glass	Clear→Double tinted glass

4.2.3 Roof

The roof is the part which receives the most sunlight and solar heat of the building envelopes. Most frequently used approaches to improve heat-insulation are as follows:

(1) Shading
A roof is covered by a canopy, solar PV and solar heat device as a second roof layer can also reduce the solar heat gain on the rooftop. However, the weight of the additional structures should be counted before installing to make sure the safety of the building will not be compromised.

(2) Heat insulation layer
The heat insulation types often applied to roofs are greenery, elevated wood board and the slabs. The slabs could be made of concrete, concrete with PS board, rubber and aerated concrete. By using these approaches, about 11% of the electricity demand for cooling can be reduced at the top floor. Before adding the heat insulation layer, the waterproof function of the roof should be well examined. (Table 4)

Table 4 Cases of the roof applied heat insulation layer

	Case 5	Case 6
Subsidy Scheme	Project C	Support by Kaohsiung city government
Building type	Residential	Educational
Built year	1980	2009
Retrofit year	2007	2011
Location	Yilan (North)	Kaohsiung (South)
Approach	Heat insulation layer	Heat insulation layer
Material	Concrete with PS board	Greenery
		
		

5. Difficulties and Discussion

After the study, there are some challenges during the process of the improvement on existing buildings. The challenges are discussed according to three phases of the refurbishing process.

(1) Promotion phase:
Although Government began promoting the need for energy conservation by mass medium and subsidy support, the general public does not understand the importance of energy conservation and the approaches of improvement. The main reason of occupants renovating their buildings is the façade appearances or structural problems, such as the structural safety and water leakage issue on external walls or roofs. Most of the people cannot afford to enhance the building performance for energy demand reduction by using high performance materials or equipment. Hence, budget and lack of professional knowledge are the reasons that affect the occupants' decision making for refurbishment.

(2) Assessment and Design phase
It is more complicated to enhance the performance of existing buildings than new buildings. The entire structure condition should be carefully assessed before applying the refurbishment design. However, most of the people consider only part of the buildings in need of improvment and request the product seller or marker to implement the changes. The structure safety and operational performance improvement cannot be ensured without taking account of the assessment and consideration of the whole building.

(3)Construction phase:
The site conditions would limit the scope of existing building improvement. For example, narrow sites require design changes.

6. Final comments and conclusion

To conclude, the study is to investigate the practical retrofitted cases in Taiwan, as ways to find difficulties in putting energy-efficient approaches into practice and to suggest measures for popularization. The promotion of building refurbishment for energy saving in Taiwan started 10 years ago; hundreds of buildings have been renovated by government support. From the result of the interviews, most of the occupants whose buildings have been renovated are satisfied with the final results of improvement. The comfort level of the indoor living environment was enhanced; the interior temperature during the days has lowered and the electricity cost for cooling has decreased. However, the difficulties of building improvement mentioned above might challenge the possibility of popularization. Therefore, finding better promotion strategies and developing the industries should be future development goals.

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Experimental investigation of behaviour of timber beams under natural environmental conditions

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Summary

The current work is devoted to the investigation of relationships in creep of timber beams under natural (uncontrolled) environmental conditions and is aimed to define an appropriate mathematical model for the prediction of final deformation after some loading cycles. The presented creep model is a new version of the known Burger body concept. The proposed model has been numerically tested by estimates obtained from four-point bending tests in static loading of pine (*Pinus Sylvestris*) beams. There are two different loading regimes applied in testing: full load for 65 days (winter season) and half load for spring and summer seasons (220 days). It has been verified that the proposed model fits well with experimental results and may be used as appropriate for bending strain prediction in timber beams under natural environmental conditions with possible improvements in the future.

Keywords: Timber Beams, Bending, Duration of Load (DOL) effects, Creep

1. Introduction

There have been a lot of serious investigations devoted to load duration (DOL) effects in wood carried out by researchers in different countries up to now, and more extensive reviews on the topic have been written by Morlier [1], Hunt [2] and Dinwoodie [3]. Nevertheless an establishment of a plain mathematical model and/or definition of numerical parameters for the prediction of final deformation of timber beams correctly remain generally unproved. The prognosis of long-term behaviour of timber structures under service loads and environmental effects is one of the most discussed issues in research and design of timber structures, as deformations develop due to very complicated physical mechanical time-dependent effects influenced by a wide range of factors such as variable moisture and temperature, stress level, particular structure of wood and others that should be taken into consideration to predict deformations of timber structures more accurately for design purposes. Serviceability limit state of timber structures is seriously influenced by the increase of deformation due to creep of the material. During the last decades many rheological models have been developed by researchers (Burger body [4], models according to Torrati [5], Hanhijärvi [6], Mårtensson [7], Dubois et al. [8], Chassagne [9]) with the purpose to describe the time-dependent behaviour of wood. The creep model examined in this study has been developed basing on the known Burger body [4] composed by *n* Kelvin Voigt cells corresponding to loading cycles. The experimental deformation values are compared with the ones derived using the proposed mathematical model.

The aim of this study is to make some contribution to the investigation of relationships for the description of creep of timber beams under natural environmental conditions, to examine some a mathematical model and to define a range of parameters introduced in the prognosis of the final deformation under variable loads.

2. Background

As this study is aimed at the prediction of total deformation in bending under normal service stresses ranging no more than 50% of the ultimate stress limit, it is assumed that timber behaves as a linear viscoelastic material. Thereby the Boltzmann's principle of supperposition has been applied to predict the deformation after some loading cycles [3]. Creep behaviour of timber has been interpreted with the aid of a mechanical model comprised of a combination of springs (elastic component) and dashpots (to simulate the viscous component). Simple models using combinations of springs and dashpots do not correspond directly to the discrete molecular structures of materials, but they do aid in understanding how the materials will respond to stress/strain variations.

A mathematical model developed for the prediction of total deformation due to the effects of cyclic load and variable environmental conditions is composed basing on the Burger body mechanics [4]. The four-element Burger body represents the principal features of the time-dependent behaviour of wood as a natural composite using a combination of a Maxwell body consisting of a spring and a dashpot joined in series and a Kelvin body consisting of a parallel arrangement of the spring and dashpot elements (see Fig. 1). The displacement (u_B) of the Burger body after time t due to the action of force factor P_o has been expressed as the sum of the displacement of the Maxwell and Kelvin bodies [4] and given by the equation:

$$u_B = P_o\left[\frac{1}{k_e} + \frac{1}{k_{de}}\left(1 - e^{-t/\tau}\right) + \frac{1}{r_\upsilon}t\right] \quad . \tag{1}$$

The Maxwell body alone describes the elastic and viscous behaviour (constants k_e and r_v), and the Kelvin body represents the delayed elastic response (parameters k_{de} and τ).

Aspiring to develop the expression for the final deformation sufficiently adequate in results and not complicated in use the total strain ε_t expected to take place in the side fibers of timber beams expressed in terms of elastic constant, viscosity constants, bending stress value and affected by the proportion of strength limit used is presented in the format as follows:

$$\varepsilon_t = \varepsilon_e + \varepsilon_v + \varepsilon_c = \sigma\left[\frac{1}{k_W K_e} + \frac{1-\exp(-t/m)}{K_{dp}}\right] + \frac{\sigma}{K_{dc}} \times \frac{\sigma}{f_k} \times \sum_{j=1}^{n}\left[1 - \exp\left(-\frac{\tau}{\eta}\right)\right] \tag{2}$$

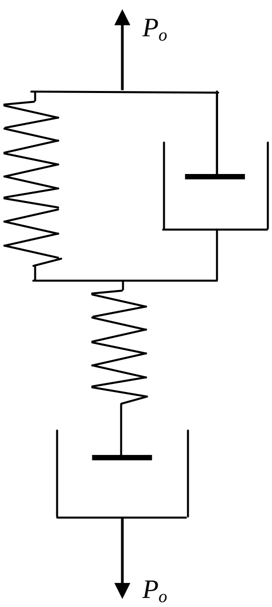

Fig. 1 Burger body representation

where:

ε_t – total strain at outermost fibres of beam after time t (in hours);
ε_e – elastic component of strain;
ε_v –strain component due to viscoelastic behaviour of material;
ε_c – additional creep strain component associated with accumulation of deformation during previous loading cycles;
σ – bending stress. Using the presented model two (or more) different loading cycles may be considered – lightweight simulating low season ($\sigma=\sigma_l$) and hard loading for high season ($\sigma=\sigma_h$);
f_k – characteristic bending strength of wood;
K_e – elasticity constant;
k_w – parameter associated with moisture content of wood;
K_{dp} – dashpot modulus describing the viscous behaviour;
K_{dc} – dashpot modulus describing the loading history;
m and η – constants;
τ – duration of load cycle in hours;
j - serial number of loading cycle;
n - number of loading cycles; $n=n_l$ for lightweight loading series and $n=n_h$ for hard load series.

3. Materials and methods

Twelve timber beams were tested under a long-term load in a four-point bending testing rig. The beams of pine (Pinus Sylvestris) were simply supported and loaded with two symmetrical forces to produce a constant bending moment in the middle part of the beams. The long-term test model is illustrated in *Fig. 2*. To simulate the real service conditions the tests were carried out in an unheated building with an uncontrolled microclimate. The building is located in Latvia, approximately 60 kilometers from the Baltic Sea.

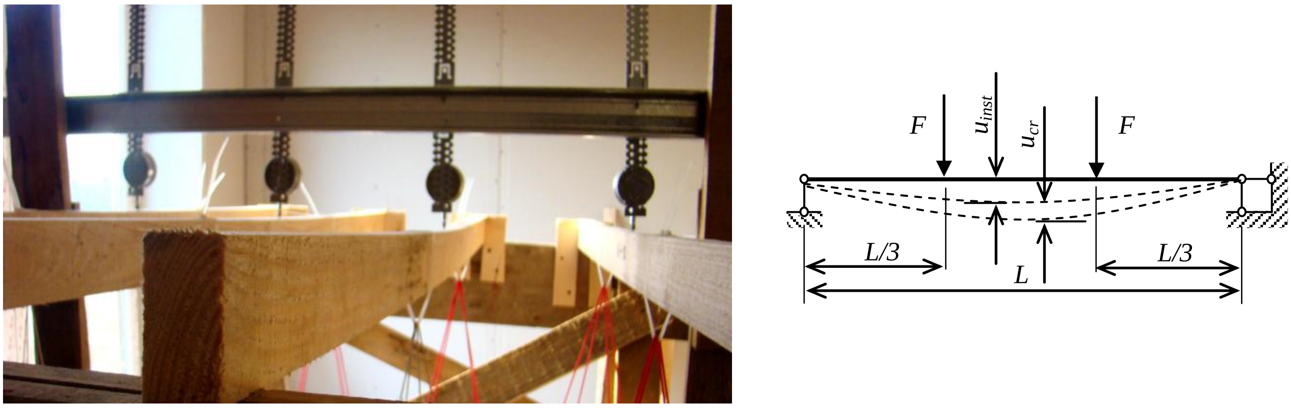

Fig. 2. Long-term bending test setup and static model

The maximal forces attached represent the load value corresponding to the total bearing capacity of a beam in accordance with the serviceability limit state condition u_{fin} = L/150, where u_{fin} is the prognosis of final deflection declared by Eurocode 5 (see Fig. 2 right for illustration of deflection components):

$$u_{fin} = u_{inst} + u_{cr} = u_{inst,g}\left(1 + k_{def}\right) + u_{inst,q}\left(1 + \psi_2 k_{def}\right), \qquad (3)$$

where $u_{inst,g}$, $u_{inst,q}$ - instantaneous (elastic) deflection values produced by permanent and variable load correspondingly,
k_{def} - deformation (creep) factor for permanent loading (k_{def}= 2),
ψ_2 - reduction factor for variable load to it's quasi-permanent value (ψ_2=0.5).

The timber beams were manually loaded with weights. Dial indicators for deflection monitoring of timber beams were fixed on a rigid frame and placed on the compressed side of the beams. The loading regime was created so as to simulate the service conditions of roof structures: full load acts for the winter season (about 65 days) and 50 percent attached for the rest period (no snow) of 220 days. Deflections in the middle of the span were measured after applying a full load (initial) and daily during the test. Moisture content of the wood was measured using a Wood Moisture Meter MD-2G. The temperature and air humidity both outside and inside of the room were fixed using a hygrothermometer Testo 605-H1.

Using experimental data the relative creep (known also as the creep coefficient) was quantified expressed as a percentage of the instantaneous elastic deflection (u_0): u_0= 100×(u_t - u_0)/u_0, where u_t is the deflection at time t. In order to transfer from the midspan deflection (u_t) measured to strain of the outermost fibres the geometrical relationships in bending has been used. See *Fig. 3* left. The radius of curvature (ρ) is expressed through the span and centre angle of curvature. The strain (ε_{el}) at the outermost fibre may be expressed by using Hooke's law and geometrical relationships in elastically deformed beam segment with simplification for straight sides (see *Fig. 3* right):

$$\varepsilon_{\mathrm{el}} = \frac{\Delta}{dx} = \frac{h}{2\{L/[2\sin(\varphi/2) + h/2]\}} \approx \frac{2h \times \sin[\mathrm{arctg}(2u_t/L)]}{L}. \qquad (4)$$

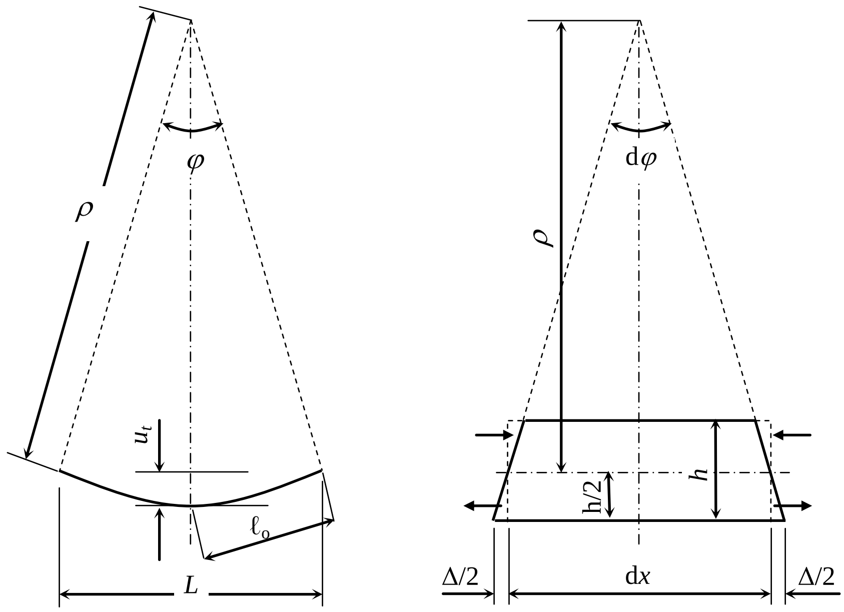

Fig. 3. Geometric illustration of bending shape

4. Results and discussion

In winter season (65 days) when a full load was attached to the beams the average air temperatures (TC) inside the building were +0.3 °C (±0.5 °C) with a range of variation of 15 °C and at the same period the outside average was -2.4 °C with a range of variation 24.1 °C. The average air temperatures for the rest period of testing while the beams were sustained under a decreased load, were 14.8 °C (outside) and 17.7 °C (inside) with a range of variation 24.7 °C and 30.8 °C.

In winter season the relative humidity (RH) of air inside the building varied between 48.6% and 81.7%, average 68.6% (±3%). The measured RH values for spring and summer time varied between 59% and 75.6%, average 67.5%.

During the testing the average moisture content (MC) of all timber beams decreased from 27.6% on the first day of the test down to 9.8% on the 285^{th} day. The average value of moisture content during the winter period was 20.5% and 11.6% for spring and summer time.

Relationships between relative humidity (*RH*), temperature (*T*) and relative deflection are shown in *Fig. 4*. In order to improve the readability of graphs the relative deflection displayed represents *u*/L value multiplied by 10^4.

Average relative creep (expressed in percentage) curve versus time calculated from all twelve timber beams is shown in *Fig. 5.* Average relative creep value for winter season was 24.3%, whereas for spring and summer period - 28.9%.

It is considered that the relative creep curve displayed in Fig. 5 represents viscoelastic, mechano-sorptive (MS), pseudo-creep and recovery as well. This is a complex phenomenon that has been extensively studied for half a century without reaching full understanding. The creep rate of timber is accelerated to a greater extent due to moisture variations, i.e. the timber exhibit mechano-sorptive creep. This process is very demonstrative in *Fig.5* observed between the 30^{th} and the 145^{th} day of testing. Timber beams were partly unloaded at the 65^{th} day of test taking off 50% of the full load responding to the end of winter season. Despite substantial reduction of full load, relative creep continued to increase up to the 145^{th} day of testing. On this day there was a margin where amplitude of RH and T fluctuations became much slighter.

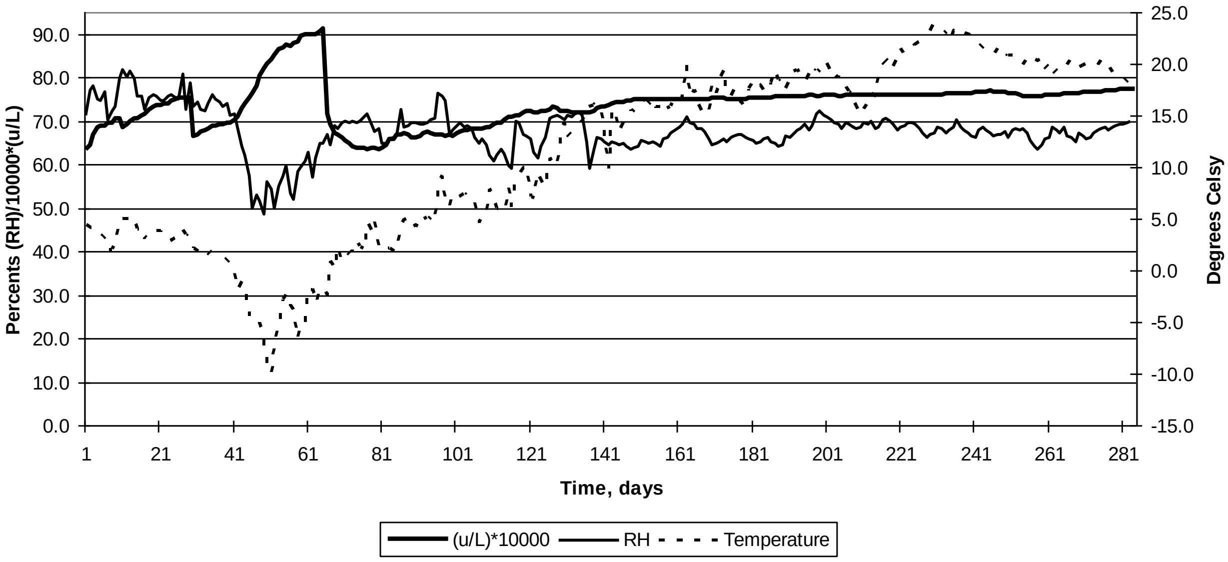

Fig. 4 Relative deflection (averages) of beams, relative humidity and temperature of air versus time

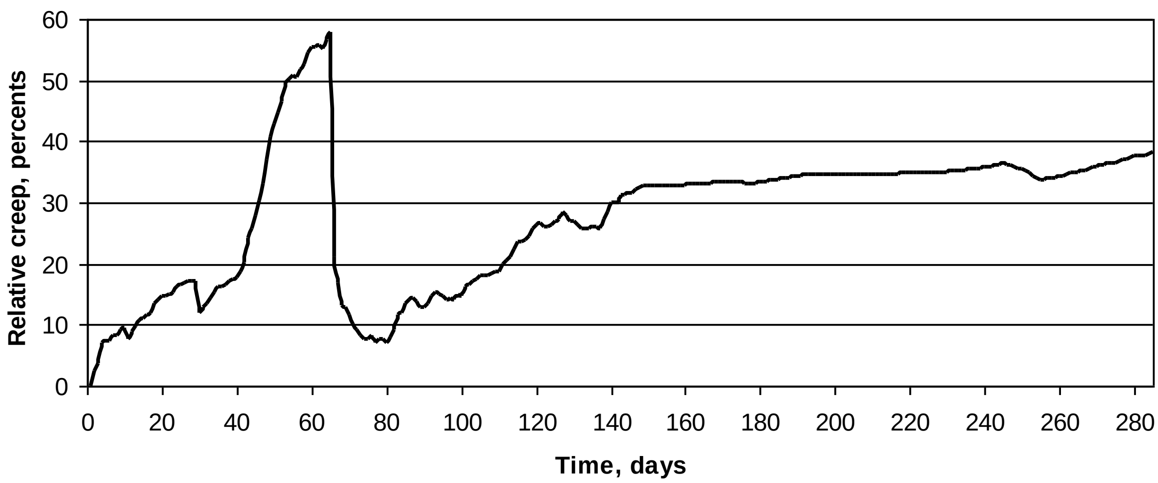

Fig. 5 Average relative creep versus time

The Burger model has been successfully used for predicting creep behaviour of wood [4], [10], [11]. Note that all applications have been carried out under constant or controlled climatic conditions. Because of this aspect, a modified creep model proposed in this study represents a reasonably accurate agreement with the experimental data. Based on the experimental results, the constants of the model parameters were optimized to achieve the best compliance. In Fig. 6 the strain curves produced using measured deflection values and the modelled one using Equation 2 are displayed.

It is found by examining experimental and model data for every beam tested that for some individual beams some discrepancy between strain values resulting from the mathematical model proposed and experimental data processed emerges. This difference can be explained by the fact that properties of timber beams differ in some degree, variation of moisture content of timber beams were significant for first forty days of testing while equilibrium moisture content was reached, and in addition density in the same way as width of the annual rings and amount of latewood varied too. Note that the compliance between model and experimental average values fits well.

It is proved that the Burger body model has been successfully used for the description of the creep behaviour under constant load and controlled temperature-humidity conditions. Natural environmental conditions involve some additional uncertainty due to the unforeseen mixing of affecting factors yet in a limited range. Discrepancy between experimental and model curve emerges in the time period from the 30^{th} day to the 150^{th} day of testing, directly during the period when climatic parameters (RH and T) present the marked variation. Average curve of experimental data and modelled curve in hours (see Fig. 7.) are reproduced to give the conception of deviation between average curves on a larger scale.

Creep deformations in timber structures depend on the season – variations in moisture causes fluctuations in creep curves. Relative humidity fluctuations and radical decrease of air temperature (indoor temperature decreased to minus 10º C on the 40th day of testing), accelerated creep rate that continued even when a constant increase of air temperature was observed. The creep development process in a period of fluctuating temperature and relative humidity (in winter) is much faster than it is in a more persistent temperature and humidity regime (in spring, summer). Small cross-section beams are influenced by humidity cycling more than large sections.

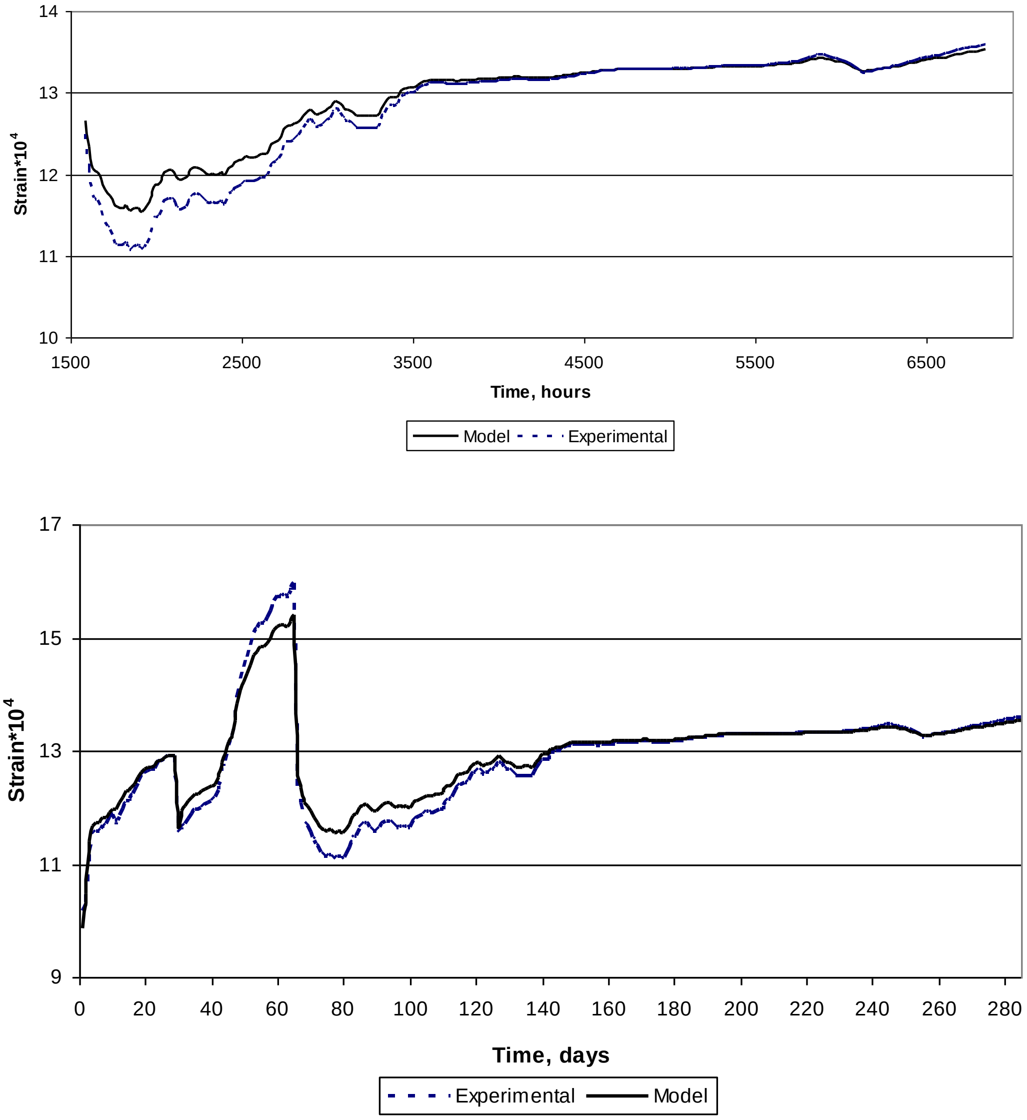

Fig. 6 Experimental and model curves

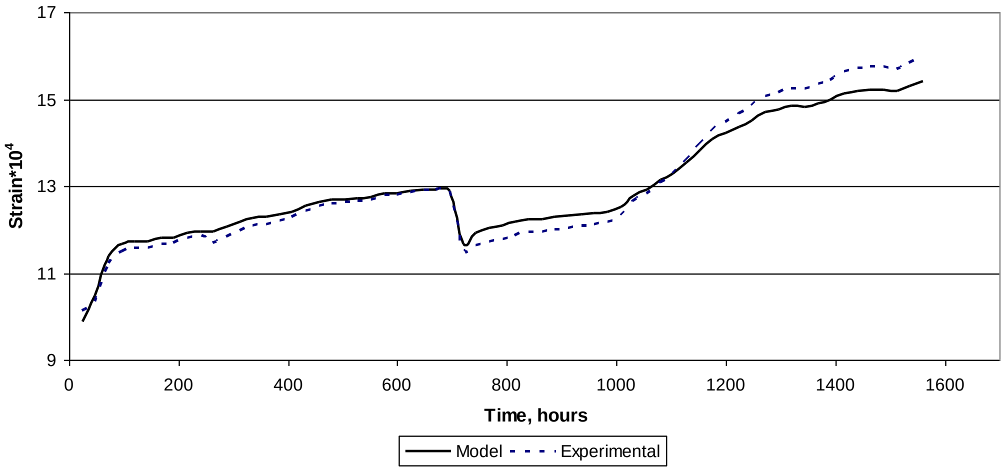

Fig. 7 Experimental and model curves

In order to examine the Eurocode conditions the numerical testing of Equation 3 was performed inserting the measured elastic deflection ($u_{inst,t}$) and the final deformation values ($u_{fin,t}$) detected in the process. Speculating for examination of combination factor ψ_2 recommended by Eurocode the factor C_t was worked out:

$$C_t = \frac{u_{fin,t} - u_{inst}}{k_{def} \times u_{inst}}, \qquad (5)$$

It is clear for test conditons described above that the deformation factor may be assessed as corresponding to 3-rd service class value (k_{def} = 2). The value of C_t factor detected by numerical trials may be assumed as representative of the quasi-permanent part of variable load producing the creep.

The average values of characteristics of beams in test series are presented in Table 1, where symbols are used as follows: σ - the bending strength calculated under assumption of elastic behaviour of material, L- span of beam, h - depth of section, E_{test}- modulus of elasticity found from elastic deflection equation in four-point bending, MC - moisture content of wood, Δ_{cr} – average increment of relative creep, generated daily.

Table 1 Average Characteristics of Test Beam Series

Mark	σ, MPa	L/h	L/u_{inst_t}	L/u_{fin_t}	E_{test}, MPa	MC,%	Δc_r, %	Prediction C_t
TB-1_...	5.6	40	200	105	11000	18.5	1.0	0.4
TB-2_...	9.0	22	180	120	10100	22.0	1.0	0.5
TB-3_...	9.7	22	210	130	9900	21.0	1.1	0.5

Notice that also the different standard models built-in the MS Excel were examined to describe the relative creep deflection (u_{cr}) relationship versus time (t) according to the test data [12]. For all that the best fitting between test curve and regression model may be obtained by exponential, logarithmic and polinomial curves, in this study the linear relationships (Equation 6) were found as sufficiently good approximators testified by the coefficient of determination values close to unity.

$$u_{cr} = a + b \times \mathrm{t}. \qquad (6)$$

5. Conclusions

This study provides background for future research trends with the purpose to establish a mathematical model suitable for the predictions of final deflection of timber beams after determinate number of loading cycles.

It is presumed by results of this study that the proposed mathematical model works well when fluctuations of relative humidity and temperature of air are negligible, and moisture content of wood remains constant while for higher ranges of humidity and temperature the strain values obtained on experimental basis and modelled ones differ in greater extent. A future research is needed for evaluation reliably in whatever degree any of model parameter represents the contribution to final deformation. Also more test beams and larger data samples are needed to prove plausible the proposed model.

Changes of relative humidity, temperature and subsequent variation of the moisture content of wood accelerated creep behaviour with following increment of deflection. It is illustrative that mechano-sorptive creep does not occur during steady-state moisture conditions.

6. Acknowledgements

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Situated Testing: Deploying Synergies between Sensing and Modeling for Case-specific Thermal Window Retrofit in Timber Buildings

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Summary

Timber building retrofit offers a particular challenge because of the variety in timber construction. Support for the role of architectural detailing innovation offers an opportunity to leverage this variation towards better in situ product performance and enhanced market uptake. This is predicated on developing new protocols for product assessment that foreground situated testing, a method greatly facilitated by exploiting synergies between sensing data and thermal modeling iterations. These new protocols are described relative to a specific case study of ancillary glazing.

Keywords: Thermal Retrofit, Timber Buildings, Ancillary Glazing, Testing Protocols

1. Introduction

Digital technology has been game-changing in product manufacture for its ability to permit slight but meaningful degrees of variation in a product solution. This has translated into the capacity to leverage a full range of solutions with very little additional overhead rather than accept the traditional trade-offs implicit in a universally applicable product. The use of digital technology in product *application* and *installation* has been less explored, but we claim can offer a similar scope of variation towards improved performance on site. This is particularly beneficial for retrofit of timber buildings; for retrofit because the negotiation between a lab-tested product and on-site contingencies is significantly greater than in new buildings, and for timber construction because of its inherent variability. This paper will argue that the introduction of digital technology in the form of modeling tools can transform the way product efficacy is tested by producers and communicated to users, ultimately, transforming on-site deployment for the better. We will describe a process, which we call ‘situated testing’. It exploits synergies between empirical testing protocols (“sensing”) and digital modeling. This promises a new approach to thermal retrofit of timber buildings by considering potential variations for on-site installation while maintaining a consistent product.

2. Variability in Timber Construction and Its Thermal Retrofit

2.1 Rule and Exception in Timber Building

Although timber construction strategies can be loosely categorized as ‘light frame’ or full-timbered, these categories do not capture wood’s capacity for variation. In fact, this ability for timber construction to assume a variety of forms and configurations contributes significantly to its popularity. Light frame construction especially can be manipulated to make almost unlimited shapes. In a method of construction so easily adapted to contingencies, the “rule” in timber construction is therefore usually no more than best practices, comprising rules of thumb for structural, thermal and life cycle performance. The “exceptions”, while ad hoc and legion, tend to occur at the junctures between vertical and horizontal or at apertures. These junctures play an important role in the work described in this paper because these are areas that significantly contribute both to a timber building's energy performance and architectural character.

Windows, doors, cornice and base--the more exceptional moments which are part of any building envelope--are much more difficult to categorize than typical wall construction. The area around windows presents a particular challenge because of wood construction's variability (sizing, shape, waterproofing, framing, existing window installation, etc.). Consequently, these areas are inherently challenging for optimizing product-based retrofit solutions for improved thermal performance. In the case of ancillary glazing units, the thinness of framed walls presents an additional difficulty, limiting the range in depth of likely installation techniques and placements. Because of these attributes, thermal upgrade via window retrofit in timber buildings presents difficulties not entirely addressed by factory products and "standard" installation guidelines alone.

The depth of a window in the wall, the resolution of the roof eave, the way a building meets the ground, are determinates of architectural expression. The delicacy with which such details are resolved proves particularly decisive in the case of building retrofit, where the mandate is not only improved thermal performance but also the rescripting of the building's connotations. In the projects depicted below, renovations offered the opportunity to rethink appearance and building envelope strategy, in both cases including new exterior insulation and rain screen facades in wood. Within the depth of the newly-installed facades, the placement of windows exterior or interior flush, and the treatment of junctures between vertical and horizontal planes lend the buildings entirely new qualities. While the standard façade detail remains consistent and typologically unremarkable, innovation occurs at apertures, base and cornice detailing. The uptake of new products and technologies for building retrofit is accelerated by innovative architectural thinking, and by finding affinities between what architects value and what energy managers value.

Figure 1: Timber Envelope Retrofits by Wespi de Meuron (l.) and Burkhalter Sumi (r.)

2.2 Thinking Parametrically about Architectural Detailing

In our earlier work [1], we have argued for an understanding of architectural detailing as a spectrum of potential solutions rather than a quest for optimization. Our prior case studies considered the location of a steel window in a concrete back-up wall with rain-screen construction; and cornice detailing in light-frame timber construction. In both cases, we demonstrated that the use of digital thermal modeling tools such as THERM/WINDOW, Energy Plus, WUFI and NIST can productively influence an iterative design process, leading to architectural hybrids. These may offer better performance and expand possibilities for new architectural expression. By highlighting weak points and quantifying trade-offs, the "X-ray vision" offered by digital modeling expands the traditional typological understanding of architectural detailing. Rather than limiting window installation to "exterior flush", "interior flush" and in the thermal "neutral" axis, for example, the window as standard product can be installed in an almost unlimited number of locations within the wall thickness. Digital modeling reveals the benefits of each possible installation quickly and without the resource intensity of the in-field testing over time that best practices represent. The potential to study at detail scale the reciprocity between product and context is the framework we designate as "situated testing."

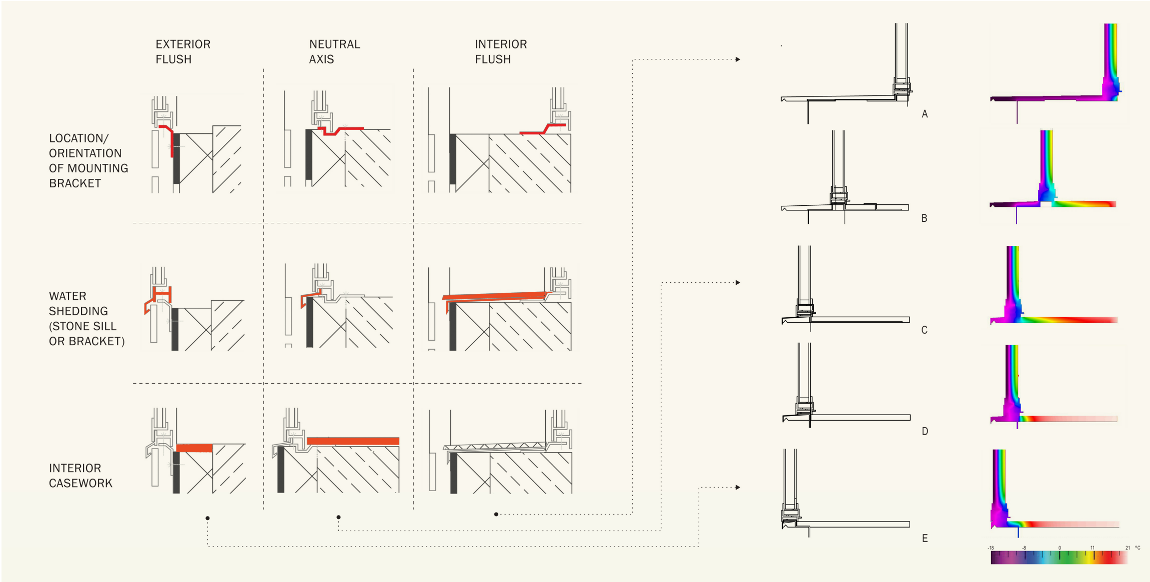


Figure 3: Ko, Widder, Window Installation as Typology v. Spectrum

3. A Case Study for Digital Thermal Modeling in Product Testing and Development

The advantages of situated testing with regard to thermal performance during the architectural detailing phase may productively be extended to the product testing typically conducted by manufacturers. Traditionally, manufacturer testing is often focused on product performance while holding constant the surrounding construction. [2] The results may not accurately predict actual in-field performance; recommended installation guidelines for timber building retrofit, which derive from this kind of testing, do not fully absorb the problem we identify, of the near-infinite variations possible in timber construction. The case study, an innovative series of studies conducted in timber buildings in Taiki, a particularly cold region of Northern Japan [3], offers insight into the benefits of situated testing: these studies introduce the contingencies of construction variation, user interface and alternate installation strategies into a fieldwork-based study of a particular product's performance.

3.1 Testing through Sensing and Modeling

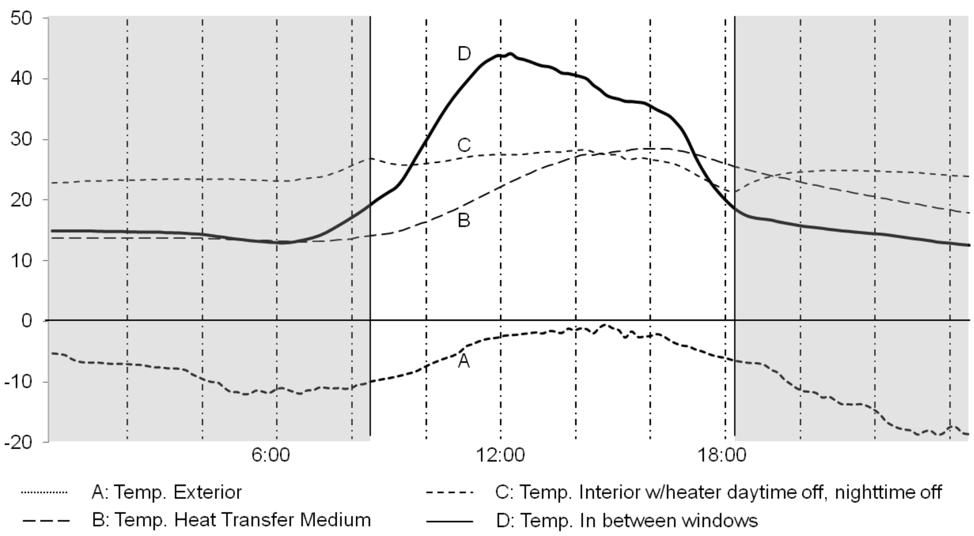


Figure 4: Noda et al, Sensing data from the Taiki prototype installation shows overall product efficacy in the region[4]

In the Taiki study, a standard ancillary glazing unit was installed inboard of existing windows in a series of light-frame timber houses from the 1970s in a single community. During year-long data tracking of ten houses, surface temperature readings were taken at the interior glazing of the original window and of the new ancillary window, as well as room temperature. Although the sensing data reinforced the new sash's efficacy, significant variation among houses also emerged, leading to a new set of questions about user interface and installation techniques. For example, the most energy efficient household was one that used the gap between the two sashes for thermal collection. This pointed to the importance of calibrating the gap between existing and retrofit window elements, and to the potentials of harnessing thermal gain between them. In response, a second generation of fieldwork studied exclusively the interstice between new and existing sashes for thermal energy harvesting and optimization. These kinds of potentials are suppressed in a typical testing environment, which aims at standardized specification. As a contextualized reading of fieldwork results, this study identifies advantageous local environmental parameters, which impact the installation of standardized ancillary window units [5] for better performance.

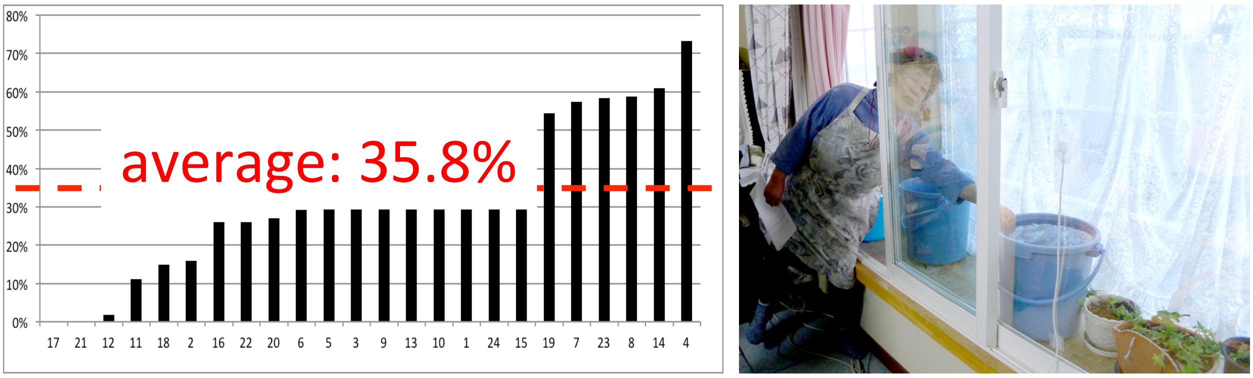


Figure 5: Morishita et al, Bar graph shows discrepancies in product efficacy across all houses (x axis shows house number, y axis shows percentage energy reduction [5]; photograph of occupants' interface with window interstice for energy harvesting using water [6]

Field testing is productive, but time and resource intensive. Because of the need to gather a full year's data as a benchmark, the second round of sensing in Taiki considered only one sash position and orientation. Within this kind of study, thermal modeling offers fast comparison of a variety of installation possibilities quickly, directing fieldwork towards more effective case studies.

3.2 Visualizing and Interpreting Ancillary Glazing Thermal Performance via Thermal Modeling

Modeling can identify a "point of diminishing returns", allowing researchers to locate the field-tested glazing unit for optimal data collection [7]. In addition, modeling can easily vary the installation of the ancillary glazing on the exterior, an undertaking that requires almost prohibitive intervention under field conditions. Reciprocity between data collection and modeling thus identifies a series of possible installation locations and can assess the trade-offs involved in each. The outcome is a more site-specific and responsive range of installation possibilities for a single, consumer-ready product, an outcome which earlier fieldwork has shown to be vital. Because of the need to evaluate product performance *in situ*, this use of testing and modeling to address installation promises more accurate knowledge of the product in context. The end result is better installed performance of the retrofit product, despite the infinite variation of timber construction, and improved detailing feedback for architects and installers, who can adapt various possibilities to their own specific conditions while understanding potential performance trade-offs shown through modeling.

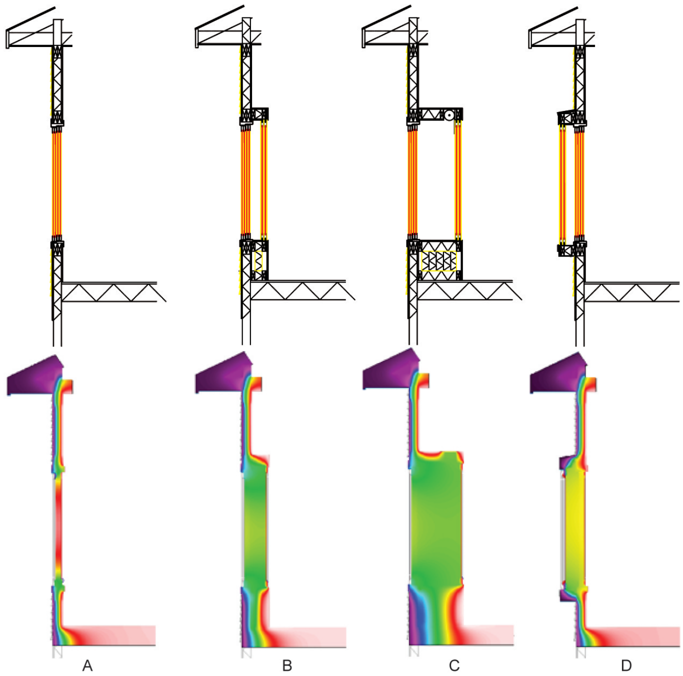
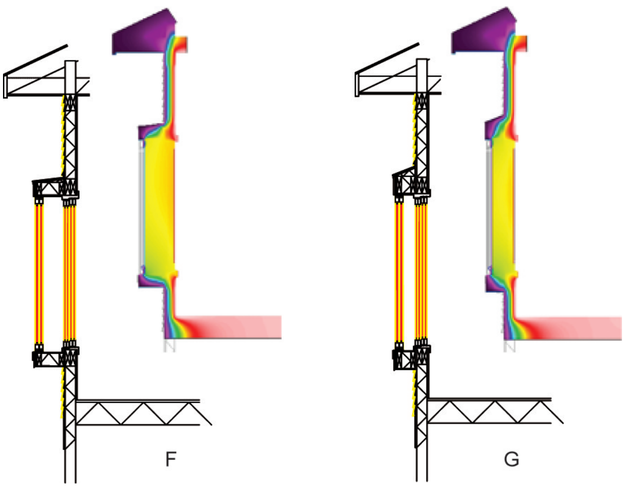


Figure 6: Three installation variations of a secondary layer of glazing compared to the base case shown at far left (A). Secondary layer placement from left to right: 10 cm to interior (B); 40 cm to interior (C); 10 cm to exterior (D). The false color scale ranges from purple (coldest) to pink (warmest) and shows thermal transmission at the framing around the window and at the sash. Exterior installation proves most effective; increasing still air between sashes from 10 to 40 cm has little impact. The images were produced in THERM/WINDOW.

Because of the ease with which installations can be changed in the space of a CAD drawing, we can quickly test the potentials of installing ancillary glazing on the house's interior and exterior. The results indicate the great advantage of an exterior installation, despite more extensive construction, which would discourage field testing; the problem of thermal bridging at the window frame is all but eliminated. Consideration of context through situated testing proves to be decisive for overall product performance relative to internal material thermal transmission and to surface temperature.

3.4 Iterative Design through Visualization



A second set of proposed design interventions responds to the insights provided by the "x-ray vision" which modeling allows. These refined iterations can additionally enhance the performance of ancillary glazing on the exterior and simultaneously give a sense of the architectural potentials inherent in the resulting bay window-like protrusion.

Figure 7: Variations on exterior installations. In (F), the depth of the still air gap was increased to 20 cm. In (G), the framing was increased from 2x4 to 2x6.

Thermal performance is improved in both cases to a similar degree: the air temperature in the gap reduces the speed of thermal transmission and the isobars at header and sill show thermal bridge mitigation. In architectural terms, however, the differences are much greater. In (F), the greater protrusion has potential for the façade's volumetric expression: because the pitch at the header is relatively flat, the protrusion will look more like a pure rectangular volume. In (G), the steeper slope at the header and thicker frame at the sill create greater continuity with the plane of the existing envelope, rather than emphasizing the protrusion as a discrete volume. Because architectural detailing is a driver of innovation, engaging the iterative process via situated testing by offering performance feedback on different design solutions improves product uptake and specifier feedback.

3.5 "Delaminating" Digital Modeling: Lessons Learned from Fieldwork

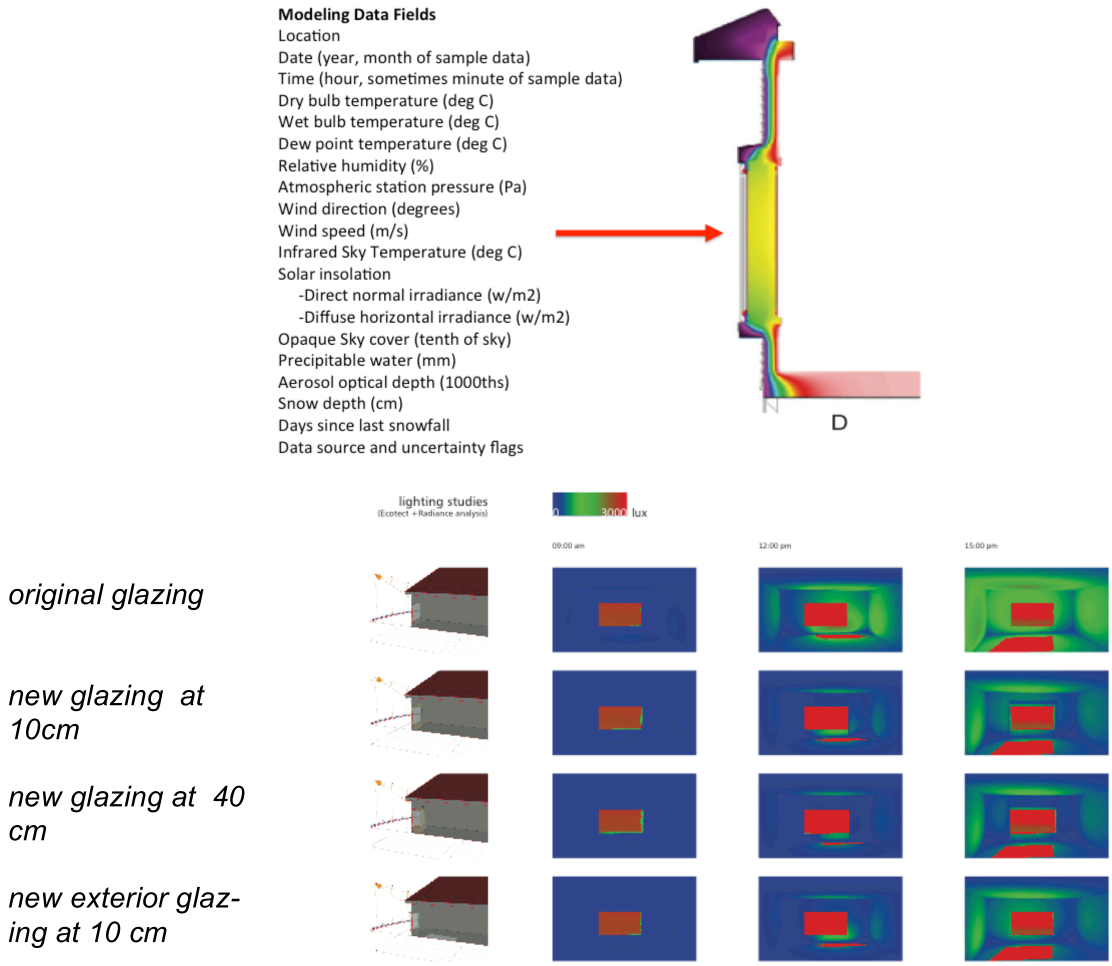


Figure 8: Some data fields embedded in THERM window (top); Ecotect results in false color showing how the original window and three sash installations impact insolation (bottom)

Situated testing encourages reciprocity between sensing and modeling because it highlights both differences and synergies in their methodologies. Just as modeling can contribute to expedited fieldwork by testing multiple construction variations and revealing intramaterial performance, fieldwork offers a precedent for dealing productively with unexpected outcomes in modeling. For example, the performance deviations at Taiki were empirically related to the occupant interface with the window interstice in order to generate a second generation of experiments. This same methodological flexibility is possible in modeling, but only if the parameters, which have been generalized for program outputs are revealed, or "delaminated." We offer the example of thermal gain through insolation, considered in Taiki to be a positive attribute of the window interstice.

Ecotect, a software designed to analyze daylighting, is used here to isolate the impact of the two interior and one exterior sash installation on insolation. Since the entry of sunlight into the interstice is desirable, quantification of thermal gain between the two panes is an important factor to consider in assessing installation trade-offs. The Ecotect outputs reveal subtle differences, particularly in the way incoming sunlight is reflected within the window embrasure and interior space. The 40 cm installation (third row from top), for example, shows the smallest quantity of light entering past the new sash. Although its thermal performance as modeled in THERM was only incrementally better than the 10 cm interior installation (second from top), significantly more sunlight is trapped in the 40 cm interstice. This first step in separating solar gain from overall thermal performance could sponsor another set of iterations, designed to maximize solar and thermal performance; this might be accomplished, for example, by installing the new sash at an angle to the existing window, for example, or by using the surfaces of the interstice to amplify solar gain.

4.0 New Protocols for Product Testing and Delivery

4.1 Deploying Synergies between Sensing and Modeling

An obvious response to the efficacy of modeling to deliver site-specific installation details might be a proposed consumer-friendly tool, which could generate details based on user input. This proposal underestimates the complexity of data that would be required, not to mention the invasive methods often needed to ascertain accurately the existing detailing at an aperture. Rather than insinuate modeling as an alternate to user agency and best practices, the synergy between sensing and modeling can be used to project a range of potential installations, which could be hybridized, varied and reinvented by the installer, with better knowledge of the trade-offs in performance. For a manufacturer, situated modeling promises better in-field performance and broader appeal to architects who understand their mandate in building retrofit as both managerial and cultural. Situated testing can translate into a far more elastic approach to product installation and to a built environment in which retrofit is seen as an opportunity for true innovation. At this stage of research, rather than stipulate a particular end-user or define a particular stage at which situated testing would be mandated, we are considering the characteristics, which, for a user or a process, might be used as indicators for the deployment of situated testing.

4.2 Outcomes: New Protocols

Our new protocol draws upon our work described above on the interface between detail-scale thermal performance modeling and the architectural detailing process, and on the potential reciprocity between sensing and modeling during in-field testing of standard ancillary glazing units. The protocol is not, however, conceived as an inflexible template for rote application. Instead, it suggests a flow of information and an interplay of physical and virtual media that support a more elastic, iterative decision-making process. In practice, the outcome would be a set of site-specific potential solutions to the problem of thermal upgrade (in this case, ancillary glazing), which can be more easily compared for their thermal, constructional and architectural merits.

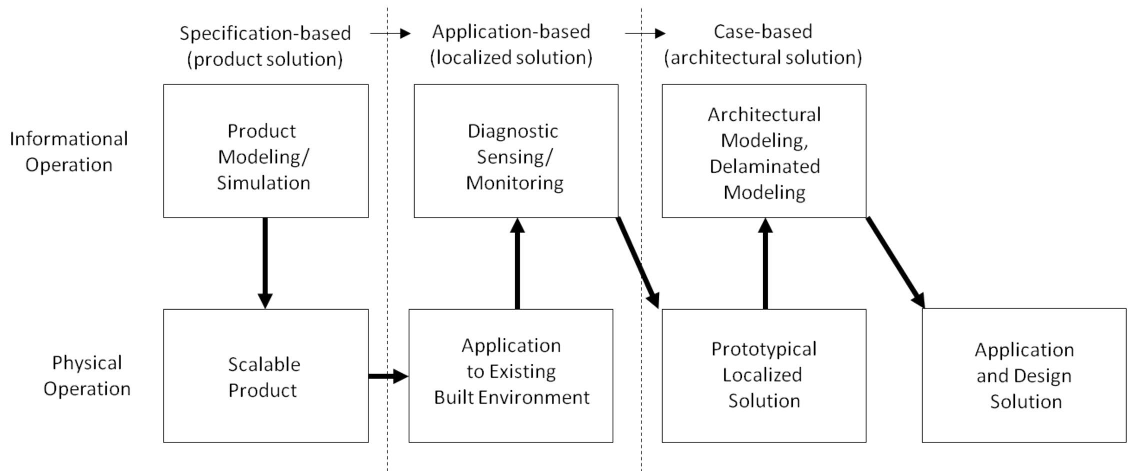


Figure 8: The roles of modelling, simulation and sensing to facilitate sustainable solutions: from product-based solution to integrated design.

4.3 Provisional Conclusions

Today, with the growing market in building retrofit, there has been fair amount of innovation in product-based solutions. Because these building components are highly specialized, it is typical that standardized details for product installation are part of the product contract upon which performance warrantees are predicated. However, in considering the performance retrofit at the scale of building details, this high degree of specialization must also accommodate localized climate differences, building culture, and case-based parameters. Through the sensing-modeling approach and its protocol, it is possible for these contextual parameters to become measurable factors for both the component-based solution and integration-based solution. The information produced acts as an interface among specializations. Thus, further study is expected to verify the role of this protocol in regards to its scalability. The challenge of scalability will in turn be the driving force within the production of this kind of information, and how can it be used as an effective tool to support thermal performance relative to different building cultures, construction types and architectural ambitions.

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Birmingham Zero Carbon House – Energy, Carbon and Economic Performance Analysis

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Summary

The Birmingham Zero Carbon House is a retrofitted Victorian house that has achieved carbon negative performance. The house has been under detailed instrumental monitoring, external and internal thermal imaging, and detailed simulation analysis. The aims of the paper are to examine the performance of this occupied zero carbon retrofitted house, through a combination of instrumental monitoring, dynamic simulation and economic analysis, so as to determine its energy, carbon and economic performance, and ultimately to determine the effectiveness of the retrofit strategies used.

Keywords: Zero carbon, Retrofit, Instrumental monitoring, Thermal imaging, Post-occupancy evaluation, Dynamic simulation, Energy analysis, Economic analysis

1. Introduction

Fig. 1 Zero Carbon House from the street side (left) and garden side (right)

The paper reports on the research work carried on zero carbon retrofit, using the Birmingham Zero Carbon House as evidence base (Fig. 1). The house was originally built 170 years ago, and it achieved zero carbon status recently, through retrofit. The house is in fact carbon-negative, as it emits less carbon dioxide into atmosphere than it absorbs. The house is occupied by its architect and owner, John Christophers and his family, and it is a living example that is ideal for analysis of zero carbon retrofit. The main features of the house are:

- High level of thermal insulation keeps the heat in
- High amount of thermal mass smoothens out temperature fluctuations
- Solar gain from south west reduces space heating demand
- High air tightness + heat recovery ventilation

- Natural daylight
- Solar photovoltaic system generates electricity
- Solar thermal system heats domestic hot water
- Additional heating: Wood burning stove used only in very cold weather
- Energy efficient lighting
- Rainwater harvesting
- Material recycling

The owners have given the Birmingham City University exclusive access for the purpose of experimental research based on monitoring and analysis of performance. The paper will first explain the experimental research method, consisting of instrumental monitoring, dynamic simulation, thermal imaging, and occupant survey. Subsequently, it will report on the main results on energy and carbon emissions performance, thermal comfort and economic performance. Variations of performance will be investigated using different occupancy conditions, and even different climate, by transferring the simulation model of the house from Birmingham to Rovaniemi, just inside the polar circle. This will be followed by a discussion of results and conclusions, looking at the impact of this work on a wider scale.

2. Method

In this section we describe the research method and how different components of the method are combined together to provide a holistic approach to the analysis of the Zero Carbon House. The underlying method for zero carbon design and retrofit is based on the work by Jankovic [1] in which building performance must satisfy energy, comfort and economic criteria in order to comprise a successful zero carbon performance. In the absence of other zero carbon retrofit houses in the UK and EU, and therefore without means for direct comparison with other projects, calibration of the simulation models on the basis of instrumental monitoring results, with set error criteria, will be the basis for ensuring accuracy and accountability of data.

2.1 Instrumental monitoring

The Zero Carbon House is instrumented with a system of wireless sensors (Fig. 2), sending information to he wireless data logger, shown in the lower right corner of Fig. 2.

Fig. 2 Environmental monitoring system in the Zero Carbon House

The monitored parameters include: internal air temperatures; internal relative humidity; carbon dioxide concentration; energy obtained from the solar hot water system; energy from the photovoltaic system, including generated, used and exported; energy imported from the electrical grid; energy obtained from the wood burning stove; energy used by the immersion water heater; solar energy falling on the roof surface; and external air temperature. A total of 20 parameters are measured every minute and sent to the data logger. The data logger is then accessible remotely over the Internet, for the purpose of visualisation of the monitored parameters and for data download.

2.2 Dynamic simulation

Dynamic simulation was carried out using IES Virtual Environment. The geometry of the model (Fig. 3) was built using architectural drawings and detailed measurements. The heat transfer parameters are based on detailed specifications obtained from the architect, and the occupancy patterns were obtained through occupant questionnaire and interviews. The Birmingham weather data file is obtained from a built-in library of the IES simulation software.

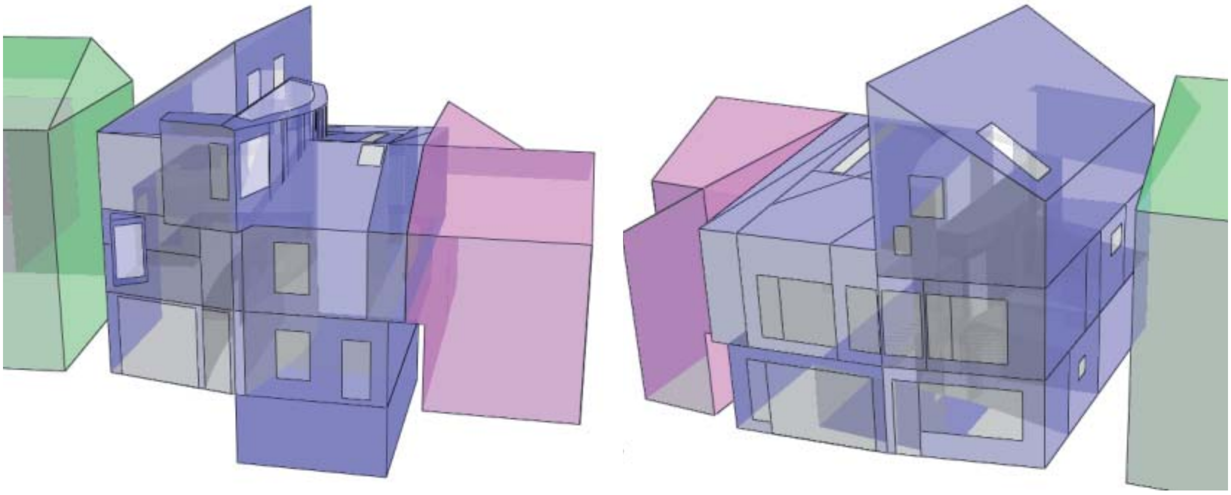

Fig. 3 Geometry of the IES simulation model of the Zero Carbon House

When it is first built, every simulation model contains a degree of inaccuracy, referred to as a ‘performance gap’. This is a discrepancy between the performance of the simulation model and the actual building [2]. In the case of non-existing buildings that are being designed, the performance gap can represent a real problem and can lead to over or under specification of the mechanical systems in the building.

This problem is however eliminated in existing buildings, which are being monitored as well as simulated. One of the purposes of the monitoring system described in the previous section is to provide information for calibration of the simulation model.

Calibration is a process of minimising the error between the simulated and actual building performance, by means of recursive adjustments of the simulation model until the error has reached the required level [3]. Two types of calibrations were carried out with the simulation model of the Zero Carbon House: 1) annual energy calibration; 2) temperature fluctuation calculation.

The objective of annual energy calibration was to achieve the error of less than 1% between the simulated and monitored energy consumption. The objective of temperature fluctuation calibration was to reduce the discrepancies between annual hourly temperatures between the simulation model and the actual building below 1 ^{o}C [4]. The result of energy calibration of 0.2% exceeded the target of 1% [1]. The result of the temperature calibration is shown in Fig. 4, where the cumulative number of occupied hours is shown as a function of temperature discrepancies between the simulation model and the actual house. The red curve in this figure shows that temperature discrepancies before the calibration were up to 8 ^{o}C in up to 3000 occupied hours. Temperature discrepancies after the calibration are represented with the blue curve, which is centered around zero error, and with mean square root error of 0.95 ^{o}C, thus giving a much more accurate and responsive model that closely corresponds to the actual building. After the calibration, the simulation model can be used with confidence to investigate what-if scenarios of the building performance under different conditions.

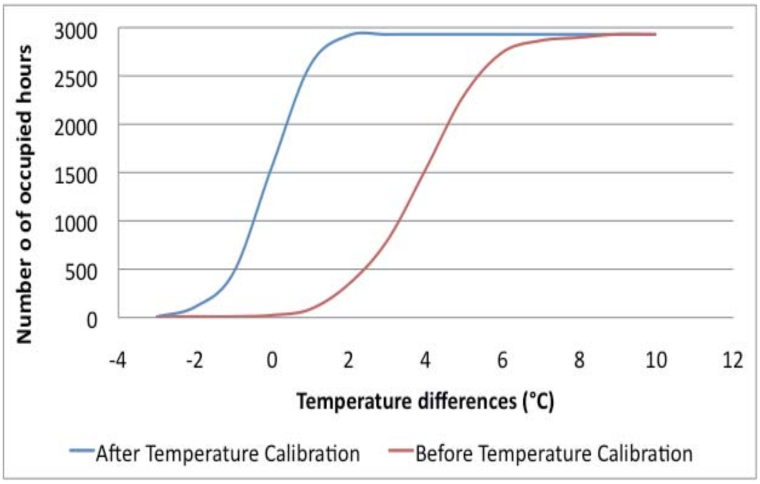

Fig. 4 Temperature calibration of the simulation model

2.3 Thermal imaging

Whereas the first two methods described above are quantitative, relying heavily on numerical procedures, the thermal imaging described in this section is more of a qualitative method. When used externally, dark colours represent lower heat loss, and bright colours represent high heat loss (Fig. 7). The reverse is the case in internal thermal imaging, where dark colours represent higher heat loss, and bright colours represent lower heat loss (Fig. 8). The thermal images will be discussed in more detail in the results section.

2.4 Occupant survey

Occupant thermal comfort is one of the key ingredients of zero carbon design [1]. The thermal comfort of occupants in the Zero Carbon House was established through a questionnaire and interviews. The main tool for establishing thermal comfort in this work was the seven point scale from Fanger [5]. Based on a number of responses from numerous volunteers, a relationship between the predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) people is established (Fig. 5). The meaning of zero vote is thermal neutrality – a 'Goldilocks' zone in which a person feels neither warm nor cold, but just right. Thermal neutrality is therefore the best performance that the designer can achieve for the building occupants, even though the PPD for thermal neutrality is 5%, meaning that there will always be at least 5% of people who are dissatisfied with thermal comfort conditions in a building (Fig. 5). The analysis of the occupant survey from this figure will be carried out in the 'Main results' section.

3. Main results

This section will discuss details of performance of the Zero Carbon House, including energy and carbon emissions, thermal comfort, and economic performance. All three types of performance must satisfy required criteria in order to declare that a building is a zero carbon building: the building carbon emissions must be zero or negative; the building occupants must be comfortable; and the building must be economically viable [1].

3.1 Energy and carbon emissions performance

The results of energy and carbon emissions performance of the calibrated simulation model are shown in Table 1. Thermal energy consumption is reduced considerably by the solar hot water system, so that the total annual thermal energy consumption is 5.56 MWh. The total electrical energy is negative (-1.31 MWh), as surplus, which is generated by the photovoltaic system, is exported into the grid. Therefore the grand total of the energy consumption is 4.25 MWh. As the house floor area is 206.8 m^2, the annual energy consumption per floor area is 20.55 kWh/m^2.

Carbon dioxide emissions are calculated using the energy consumption figures and applying the corresponding emission factors (Table 1) [6]. As the emission factor for grid displaced electricity is negative, the overall total of the carbon emissions is also negative, as shown in Table 1. This number is however slightly different from the corresponding number calculated by the simulation model of -661.6 $kgCO_2$/annum, as the former is based on a manual calculation, and the latter on dynamic calculation for every hour of the year, taking into account the electricity imported from the grid, the electricity generated, and the electricity exported back into the grid. This difference is very small, and either way the carbon emissions are negative, confirming the zero carbon, or indeed carbon negative, status of the house.

Table 1 Energy consumption and carbon emissions

	Energy (MWh/annum)	Emissions factor ($kgCO_2$/kWh)	CO_2 emissions ($kgCO_2$/annum)
Space heating energy	1.78	0.013	23.14
DHW heating energy	7.86	0.013	102.18
Solar thermal energy	-4.08		
Sub-total thermal energy	5.56	0.013	72.28
Electrical energy used	2.75	0.517	1421.75
Total electricity generated	-4.06	0.529	-2147.74
Sub-total electricity energy	-1.31		-725.99
Grand total thermal and electrical	4.25		-653.71

3.2 Thermal comfort performance

Thermal comfort performance will be analysed using information from Fig. 5. In summer, the predicted mean vote (PMV) is 0.09, corresponding to the predicted percentage of dissatisfied (PPD) of 5.17%. In winter, the PMV is -0.3 and the corresponding PPD is 6.87%. Taking into account that PPD for thermal neutrality is 5%, the PPD discrepancy from thermal neutrality in summer is 0.17% and in winter 1.87%.

It is important to emphasize here the meaning of thermal neutrality. This corresponds to a perception of an individual that he/she feels neither too warm nor too cold in a building, but just right. Designers should therefore aim to create buildings that provide thermally neutral environment for their occupants. As the diagram in Fig. 5 shows, even in a thermally neutral environment there will be 5% of dissatisfied people, and this number will rise exponentially as PMV gets further from neutrality. In the Zero Carbon House, the departure from thermal neutrality is minimal, thus confirming high level of thermal comfort.

3.3 Economic performance

Economic performance calculations are explained in detail by Jankovic [1]. The initial investment into retrofit of the original house was £47,345, and the annual return £5,752, resulting from energy savings and income from the feed in tariff. When these savings are amended in order to take into account the future value of money normalised for the current time, assuming the inflation rate of 3% and the actual investment interest rate of 3.05%, the financial returns vary from £5,581 in the first year to £5,517 in the 25th year.

As shown by Jankovic [1], not all zero carbon buildings are financially viable, and thus the process for zero carbon design must achieve financial viability as well as technical criteria for carbon-neutral or carbon-negative emissions and thermal comfort criteria for a minimum departure from thermal neutrality. Overall, the payback period is between 8 and 9 years, and the net benefit in 25 years time is £91,380 (Fig. 6). Taking into account the initial investment of £47,345, the return on investment, after all costs have been paid, is ROI = 193%. This is a significant figure. Although it will vary with inflation and the investment interest rate, it demonstrates high financial viability.

3.4 Results of thermal imaging

Thermal imaging was used as a qualitative analysis tool that complements other methods, such as instrumental monitoring and dynamic simulation. Examples of the results of external thermal imaging are shown in Fig. 7 and of internal thermal imaging in Fig. 8. Dark colours in external images and light colours in internal images indicate low heat losses.

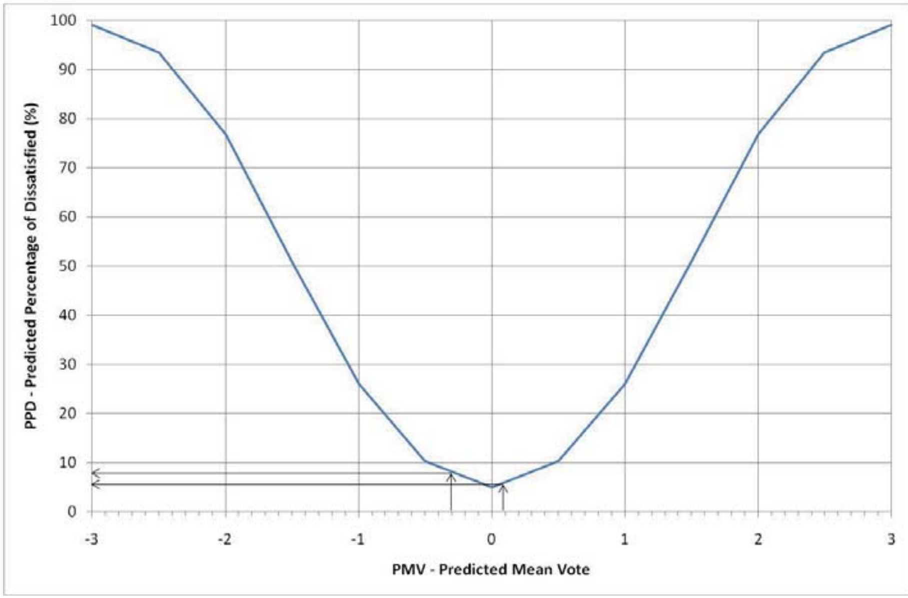

Fig. 5 Occupant survey using predicted mean vote and predicted percentage of dissatisfied

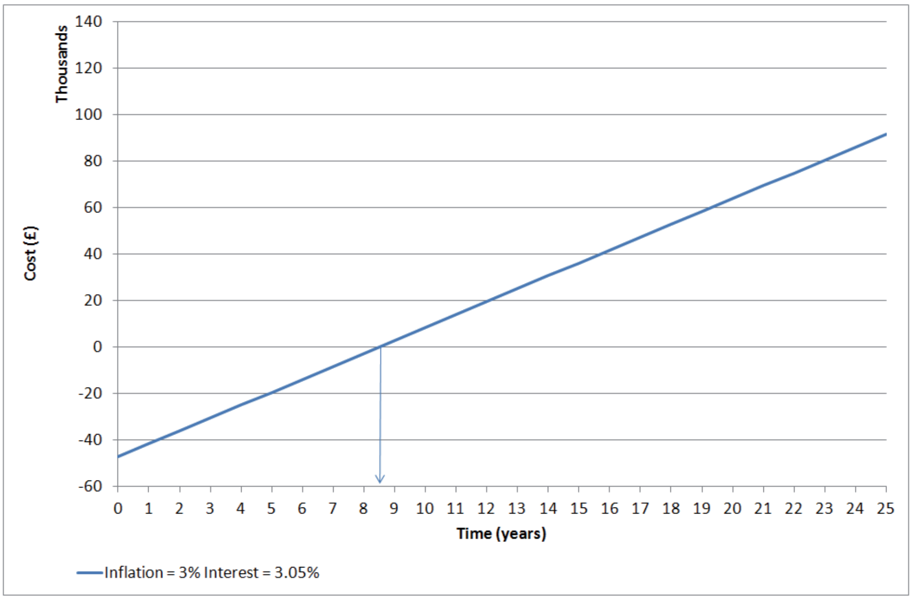

Fig. 6 Economic performance

The external thermal images show clearly which part of the image is the Zero Carbon House and which part is not. The left side of the street image is much darker than the right side, showing a clear difference between the Zero Carbon House and the next door house. A tunnel between the two houses glows red, indicating high heat losses, and a closer inspection revealed that these heat losses were coming from the conventional house next door. The high level of insulation in the Zero Carbon House is evident from darker parts of both street and garden side images. The garden side image also shows that the heat loss from the window of the Zero Carbon House is comparable to that from the external wall in the conventional house next door. These external thermal images provided an independent confirmation of the low energy performance of the house obtained through instrumental monitoring and dynamic simulation. Whereas external thermal images were used only as a confirmation the low energy performance, the internal images were used to detect any problems and to rectify them. These images revealed a crack between the wall and the ventilation duct (Fig. 8 – left) and a missing insulation on the door hinge (Fig. 8 – right), and this information was passed onto the developer for rectification.

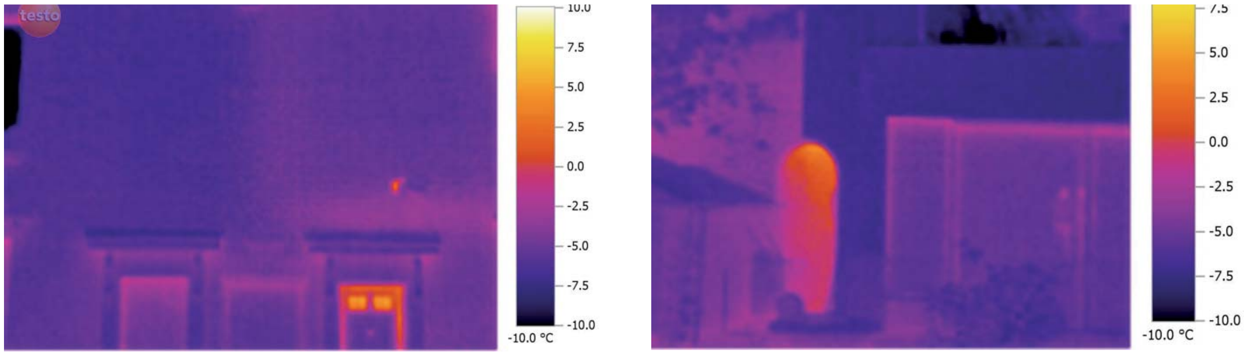

Fig. 7 External thermal images from the street side (left) and garden side (right)

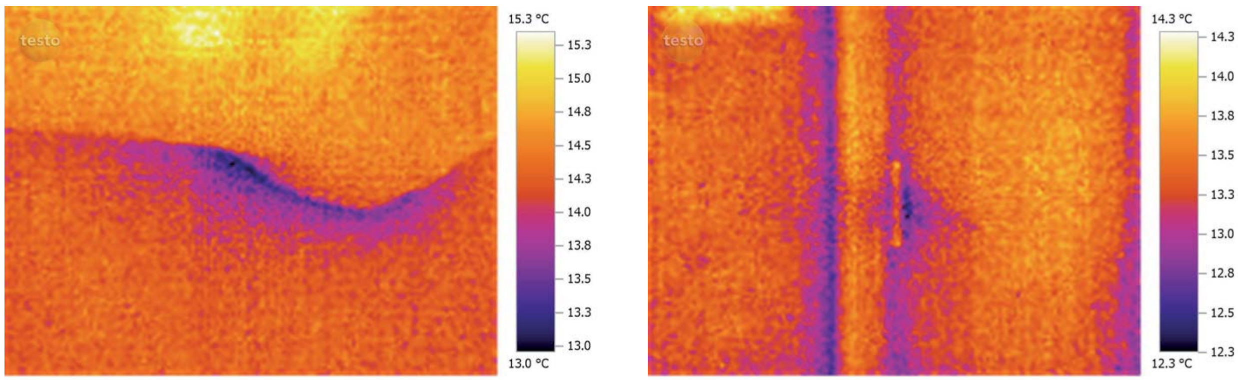

Fig. 8 Internal thermal images: a crack around a ventilation duct (left) and missing insulation on the door hinge (right)

3.5 Performance under different occupancy conditions

The calibration of the dynamic simulation model, explained earlier in this paper, resulted in a heating set temperature of 18.4 ^{o}C. A question can therefore be asked whether a different occupant who prefers higher heating set temperature would change the status of the house from zero carbon to non-zero carbon?

This possibility was investigated using the calibrated simulation model. The heating set temperature was increased to 20 ^{o}C and the simulation model was re-run. The resultant carbon emissions of -652.6 kg CO_2 were slightly worse than the original emissions of -661.6 kgCO_2, but still negative. The increased heating set temperature resulting from different occupancy preferences is therefore unlikely to change the zero carbon status of the house.

3.6 Performance in a different climate

Would a different climate and location change the zero carbon status of the house? Using the calibrated simulation model, the house was moved to Rovaniemi, just inside the polar circle, and the simulation was re-run with corresponding carbon emissions factors. The resultant emissions were -259.4 kgCO_2, demonstrating the suitability of this design for a much colder climate.

4. Discussion

The payback period, the net benefit at the end of the 25 year period, and the return on investment were calculated using the feed-in tariff and energy prices at the time of the original analysis. Although it is guaranteed for this house for 25 years, the feed-in tariff in the UK has changed since this analysis was carried out, so that newly retrofit houses would get much lower financial incentives, resulting in longer payback periods. Any future change of the carbon emission factors will result in changes to the actual carbon emissions from the house, although these are expected to be negative regardless of future changes.

The analysis of the Birmingham Zero Carbon House was carried out from the point of view of operational carbon dioxide emissions, without taking into account embodied carbon. However, most of the original structure of the house has been recycled, including bricks, timber in the roof and floor. Thermal insulation is partially made of recycled newspaper, floors are made of rammed earth and the internal rendering is made of lime and crushed recycled glass. All of this contributes to a considerably lower carbon footprint in comparison with newly built zero carbon houses.

5. Conclusions

The paper investigated the performance of the Birmingham Zero Carbon House, a Victorian residence built 170 years ago that has achieved zero carbon status through retrofit. The combination of instrumental monitoring, dynamic simulation, thermal imaging, thermal comfort analysis, and economic performance analysis confirmed that Birmingham Zero Carbon House is carbon negative, that it provides good thermal comfort for the occupants and that it is financially viable with high level of return on investment.

The robustness of this design was tested using a calibrated simulation model, with different heating set temperature and a different location and climate. It was found that under all these different conditions the house remained carbon-negative, and that this type of retrofit method is therefore widely applicable.

Considering that a large number of houses in the UK will survive till 2050 or beyond, zero carbon retrofit is increasingly being viewed as a necessary measure for reducing carbon dioxide emissions. Although this measure requires investment, the high economic viability of this particular design is very encouraging and it can be used as an example for the way forward.

In order to verify of the research method, the maximum errors between simulation and monitoring were set: less than 1 ^{o}C temperature error, and less than 1% annual energy consumption error. Both of these criteria were exceeded. As there were no other retrofit zero carbon houses in the UK or EU, this research could not be validated through comparison with external projects. However, as the instrumentation system had been calibrated before the installation, this provided the independent means for ensuring the accuracy and accountability of results.

6. Acknowledgements

Collaboration with Mr John Christophers of Zero Carbon House is gratefully acknowledged.

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Eco-efficiency and Environmental Rating Tools for Buildings


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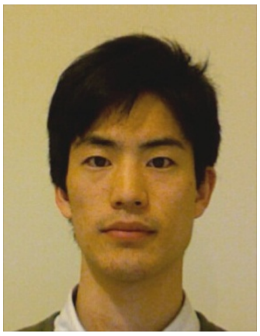
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Summary

This paper bridges the discussion between two independent fields of study; the environmental rating of buildings and nonparametric efficiency measurement. We will review the rating methods used in six different Environmental Rating Tools (ERTs) and will introduce an alternative approach known as Data Envelopment Analysis (DEA). In this context, we will call DEA type efficiency measures as eco-efficiency. We will first discuss some relevant methodological preliminaries of multiple criteria decision making and the production theory, and will show how they are implemented in different ERTs. The methods used in eco-efficiency and ERTs are similar, but in eco-efficiency the weights of environmental attributes are optimized for each building in turn - given the performance of reference buildings, eco-efficiency measure presents a maximum rating a building may get. Eco-efficiency can also take into account the fact that some of the attributes work as inputs for environmental quality, so that it is possible to model the impact of the level of operations on efficiency; usually implemented as constant or variable returns to scale. It is not seen as reasonable to use eco-efficiency on the sub-criteria level, but it could be justified to provide weights for the main sustainability categories. Weights that refer to actual possibilities that comply with all the pillars of sustainability can motivate the investor or designer more effectively.

Keywords: Green building, Environmental rating tools, Data Envelopment Analysis, DEA, Eco-efficiency.

1. Introduction

The development of different environmental rating tools (ERTs) has been rapid since the first release of BREEAM 1990 for non-domestic houses in the UK. Ding [1] lists 20 different new rating tools since 2006. Since then, the network of World Green Building Councils (WGBC) has more than tripled its members, mainly through national councils, to 89 by 2011. Even if the markets appear to be dominated by a relatively small number of original rating tools, WGBC lists a sample of six tools [2], they are usually differentiated nationally and by the use of buildings. Thus, the current number of individual rating schemes is likely to be well over a hundred.

The context of decision support needed in the building is usually highly structured [3], so that aside from building performance criteria it also covers the ranking of different designs with respect to their benefits and disadvantages. The rating rules are strikingly similar among the main ERTs; an additive multi-attribute value function seems to be the most common method. This straightforward method is the starting point for our discussion. Using a similar set of measures as those of current ERTs, we present here a new rating model known as Data Envelopment analysis (DEA) [4] that gives more flexibility in the criteria weighting. As it was originally developed to measure efficiency variations between the units that use multiple inputs and to produce multiple outputs, it makes accounting for life cycle costs and/or induced environmental loads possible and relates those to the environmental impacts of the building.

The goal of this paper is to create discussion about ERTs and the nonparametric efficiency measurement literature, known as DEA. We will begin by presenting the value function used in practically all the ERTs and theoretical reasoning about the use of the performance index. We will also review the use of these concepts in a set of current ERTs. DEA, or the eco-efficiency measure is presented in Chapter 3. We will close the paper by discussing how DEA type eco-efficiency measures could be used as an ERT for buildings.

2. Valuations in ERTs

2.1 Additive and qualitative value functions

Both from the decisions makers and environment's point of view the environmental rating of a building can be considered as a multiple criteria optimization problem. Criteria consist of categories that are measured with one or more attributes, e.g. a category related site, building material or operational properties. Considering that the attribute i is measured with a score of c_i .while the value of each score is measured by a value function $\upsilon_i(c_i)$. A genuine problem would be a joint maximization of value functions with respect to measured scores. This is usually not practical, and the literature of this type of multiple criteria optimization is broad, indicating that here is no single decision rule that applies. ERTs usually present problems as an additive multi-attribute valuation function [3, 5],

$$\upsilon(\mathbf{c}) = \sum_i w_i \upsilon_i(c_i), \qquad (1)$$

where w_i is the associated weight of the attribute value and $\mathbf{c}$ a vector of attributes.

Valuation of the attributes is an important research problem. When the environmental impact is directly measured with rational numbers, no further valuation (or transformation) is necessarily needed. However, environmental performance is usually a set of actions taken, and they are not necessarily measurable as such. A common specification of one-dimensional value function $\upsilon_i(c_i)$ used in these cases results in ordinal numbers between 1 and 5. The use of ordinal valuations in the additive multi-attribute function is generally not a feasible assumption, unless one assumes that the associated changes in environmental performance (or utility) between the taken measures are equal. This is a so called standard sequencing [5] assumption.

Aside from valuation, an equally important question is the way valuations enter into multi-attribute functions. A common problem for ERTs is the selection of appropriate weights, (w_i), that are expected to refer to the relative importance of the attributes. The weighting structure controls the overall result, making it one of the key issues in methodology. Although weights are usually set by a professional panel, the scientific reasoning behind weight distribution can appear unclear or even arbitrary.

The use of additive multi-attribute functions (1) is frequently criticized. Malmqvist et al [6] refer to [1,7-13] and summarize the criticism as indicating that each credit has different significance, inadequate transparency, a strong focus on 'simplified quantifications', hampering innovations, 'doubtful relevance of making national adaptations', dubious weighting, and may support 'points-chasing'. All these arguments are well justified. We skip the criticism concerning the relevance of the criteria, but will propose developments of the used scoring method and in the way the scores are used for environmental rating.

ERT developers have tried to solve the weighting problem either by differentiating the tools according to the use of buildings (fixed scoring) or letting weights vary within a reasonable range (flexible scoring). In fixed scoring, the weights within an ERT are constant. As the weights are incapable of considering the variation between the surroundings or the uses of the buildings, a new differentiated scheme is needed for each use and/or region of a building. In contrast, flexible scoring models the variations by tailoring weights within a set scheme.

Qualitative scoring responds to criticism by imposing different decision strategies instead of just adding up scores. The valuation of each attribute is given as a qualitative statement, e.g. excellent, good, fair, but the (sub) category rating is based on the mode or the worst/best rating within the category. To illustrate; if the quality of a building is measured as energy consumption, air quality, and material use, and it is rated as good, good, and fair respectively, then the quality of the building is rated good using mode criterion and fair if the worst rating dominates. It is not necessary to use the same aggregation rules for each category as the number of attributes and their contribution to building performance can be different.

It should be noted that qualitative scoring is a non-additive variant of the multi-criteria value function. It is usually assumed that each category has equal importance. However, it is possible to modify the weight structure according to the importance of key issues, i.e. dominance can be imposed so that poor performance in the critical issues will not be excused.

Both additive and qualitative rating strategies have their pros and cons, but they share one common problem; the level of the operation does not matter. For example, the low level of environmental impact can be justified, and considered as a good performance if a minimal amount of resources is allocated. On the other hand, a high environmental impact may be associated with a high social or economic burden. The main gain in qualitative rating is its transparency. The aggregate result always meets the set of minimum conditions in all criteria and the impact of a criterion is not hidden behind its weight. The evaluator, however, has to be familiar with the imposed decision strategy. Fixed scoring maintains the transparency of an aggregate score within a scheme, while better adapted flexible scoring suffers from the poor comparability of the resulting certificate. It is generally known how much it is reasonable to let weights vary.

2.2 Performance index

An additive function assumes separability and no interaction between the attribute values. Making the common assumption that the attributes' valuations are rational numbers, a simple alternative for the additive function is the ratio:

$$I_{ij} = \frac{\upsilon_i\left(c_i\right)}{\upsilon_j\left(c_j\right)}, \tag{2}$$

where the impact of numerator attribute(s) in i are dependent on the level of denominator attribute(s) in j , or vice versa. I_{ij} is the building's environmental performance. i attributes are called quality, and j attributes loads. Note that quality and load are not necessary environmental, but for example economy measures accounts for sustainability. The use of a performance index is illustrated in Fig 1.

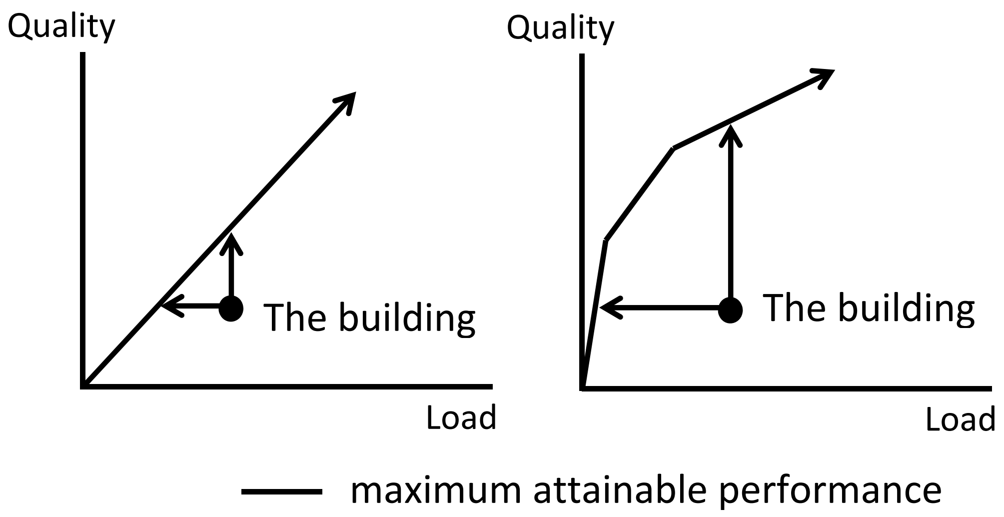

Fig 1. Performance index of a building

The index makes it possible to trade between the quality and load, as well as to relate the performance to the actual production possibilities. On the panel to the left, the ray from the origin keeps the quality/load ratio as well as the environmental performance constant. Let us consider it as a preferred, or maximum attainable performance. The building below the ray amounts to poor performance compared with the ray. The designer may consider three ways of improving the performance of the building; either by lowering the load, increasing the quality or both. Note that in relative terms horizontal (load) and vertical (quality) distances between the building and the ray are equal, regardless of the actual position of the building.

The panel on right presents a probably more realistic picture. It is usually easier to improve environmental quality first, but relatively higher load is associated with (or needed to reach) the higher quality. Thus, attainable performance decreases when we move right along the kinked line. A designer has the same options as with constant production possibilities (on left), but now the orientation matters. Relative horizontal distance (with a decreased load, given the current quality level) is shorter than relative vertical distance (increasing the quality but keeping the current load level). Which way the designer would like to go is a matter of local production possibilities; e.g. increasing the quality might be beyond the budget, favouring the load reduction approach.

In both panels, Fig 1 suggests that it is not necessary to measure absolute performance level, but the distance between observed performance and production possibilities can be used as a performance measure for the building. Also, unlike in additive and qualitative scoring, in a performance index framework, the low level of environmental quality can be associated with good performance if it is connected with relatively low load attributes.

The obvious problem in the performance index is aggregation. Environmental rating is always a multiple input and multiple output problem. We will generalize the performance index measure for the multidimensional case in Chapter 3. Before that, we will review how different scoring methods have been used in practice.

2.3 Valuations in current ERTs

In order to shed light on the above discussed valuation methods and their applications, we have selected 5 different tools, namely BREAM, LEED, DGNB, Miljöbyggnad and CASBEE, for a short review.

Table 1. Key characteristics of the environmental rating tools discussed here:

ERT	Origin	Valuation	Categories	Schemes/systems
BREEAM	UK (1990)	Fixed scoring	varies	6 main schemes in UK. Numerous sub-schemes.
LEED	U.S. (2000)	Fixed scoring	varies	9 rating systems in U.S.
DGNB	Germany (2007)	Flexible/fixed scoring	5 main categories and site quality	15, internationally
Miljöbyggnad	Sweden (2011)	Qualitative scoring	3 (areas)	1
CASBEE	Japan (2002)	Fixed scoring with index	25 qualities and 25 loads	4

BREEAM (BRE Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design) are probably the ERTs which are best known internationally. BREEAM was developed in 1990. With regard to the regional coverage, it is currently used worldwide with an emphasis on Europe. LEED dates back to early 2000 and the U.S. but the LEED International Roundtable currently has 21 member countries.

For both tools, the methodology is simple; a fixed scoring system that allocated points in several categories. The final score is weighted over categories. The number of differentiated schemes or systems is currently so large that it is impossible to give the exact number of categories or attributes, let alone to discuss their uses. A valuation of the attributes (indicators) used in BREEAM and LEED is somewhat different. The maximum number of credits is 100 for both and is based on compliance or measured performance in each attribute of a category. It seems that LEED relies more into the qualitative compliance of a rule or policy, while BREEAM relies more frequently on life cycle databanks, so credits are earned in reference to measured performance. In any case, additive multi-attribute value functions with fixed weights are used in both tools.

Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) was developed by the German Sustainable Building Council in 2007. It is relatively new and is supposed to be the ‘second generation’, giving a more holistic evaluation of the entire life cycle of the building. Even if it is a relatively new tool, the adapted schemes are already being developed in several countries worldwide.

Compared with BREEAM and LEED, DGNB features an explicit social and economic assessment of a building. In its scoring system, weights can vary from zero to three times (Bedeutungs and Anpassungsfaktor) depending on the system’s societal or political relevance and its importance for a specific use profile. Also, an important feature in DGNB is the explicit inclusion of economy, so that lifecycle costs and stability in value account for the certificate.

Miljöbyggnad has been managed by the Swedish Green Building Council since 2011 but dates back to its predecessor ‘Miljöklassad Byggnad’. While the ERTs discussed above are international, Miljöbyggnad’s target is to adapt to Swedish construction practices and code. It is also considerably smaller in terms of the number of categories (12 aspects) and attributes (15 indicators), divided in three areas. For each indicator, aspect and area, a qualitative valuation is given as: Gold, Silver, Bronze and Rated. Aggregation is based on dominance. “To aggregate results from indicator to aspect (step 1), a worst-class principle is used, meaning that if there are two or more indicators for an aspect, the rating is decided by the indicator with the lowest rating. To aggregate results from aspect to area (step 2) it is suggested that at most half of the aspects in the area are allowed to have one rating level below the area rating. [6]”. The building itself can be rated again according to the worst-class principle over areas.

The simplicity of Miljöbyggnad’s decisions strategy has gained favour among Swedish constructors. In [14], 3 out of the 4 Swedish constructors interviewed actually favoured its use. This type of qualitative scoring is rather transparent, especially if the worst-class principle is used, and could be well implemented as an element of any other ERT presented here.

A Comprehensive Assessment System for Built Environmental Efficiency (CASBEE) was established by the Japan Sustainable Building Consortium (JSBC) in 2002 in close cooperation with government agencies, academics, and the industry. CASBEE is only used in Japan, although it is meant to take into consideration issues and problems also in the rest of Asia. CASBEE has three tools for the different phases of the life cycle of the building: new construction, existing building, and renovation. Those can assess housing, industrial buildings, and even urban development and cities.

A CASBEE rating is called Building Environmental Efficiency (BEE). In our terminology, it is a performance index. The attributes are categorised into 25 building environment qualities (Q) and 25 building environment loads (L). BEE is the ratio of Q to L. Each L and Q attribute is first valued ordinally [1, 5], such that the highest quality is 5 and the highest load is 1. Next, the quality score is transformed as (valuation - 1) and loads as (5- valuation), so that both the highest quality and load value is 4. The inherent problem in CASBEE is how to aggregate loads and qualities; it is not reasonable to evaluate each of 25x25 ratios. The adopted aggregation rule is probably the simplest possible one; Q and L valuations are added together, so that the maximums of Q and L are 100 for both.

BEE expresses the balance between quality and load. BEE value 1 is usually not reasonable, as the building can probably still reduce the environmental load or increase quality, as discussed in Fig 1. To get the rating “very good’ requires BEE= 1.5 and ‘excellent’ requires BEE=2. The

“Excellent” rating additionally assumes that more than 50% of the quality scores are granted.

The goal of this review was to introducethe basic components that are used in current ERTs. In the next chapter, we will not introduce any new components, but will show new ways to use those for ERTs.

3. Eco-efficiency measure for ERTs

Data Envelopment Analysis (DEA) was developed to measure efficiency variations within a homogeneous group of production processes or companies, called units. Typically, the units produce and use multiple outputs and/or inputs that do not necessarily have explicit market value. The efficiency measure is the radial (equal proportionate) contraction of inputs or the increase of outputs needed to reach the maximum attainable performance (see Fig 1.). The idea was first introduced by Farrell [15] and was operationalized as a linear optimization problem by Charnes et al. [4]. Since then, the method has been applied to a large range of issues, from basic industry applications to efficiency of public services and environmental issues. The interested reader should refer to textbooks e.g. [16-18]. In this paper, we call the DEA measure as eco-efficiency.

The initial problem is similar to the one faced in CASBEE, the maximization of the ratio of virtual output to virtual input. To simplify the presentation, we need to drop the attribute value functions from formulas and assume that all the $m+n$ attributes, denoted as q and l for inputs and outputs respectively, can be measured in such a way that radial contractions and expansions are considered feasible. We will also rewrite output weights as u and input weights as v

$$I = \frac{\text{Virtual output}}{\text{Virtual input}} = \sum_m u_m q_m \Big/ \sum_n v_n l_n \,. \tag{3}$$

The index is a ratio of two additive multi-attribute functions. Without any further restrictions for the weights, this ratio will be unlimited. Note that in CASBEE $u_m, v_n = 1 \forall m,n$ was assumed. In economics formula (3) is called productivity. For our purposes it is enough, if we can identify how productivity is related to the maximum attainable performance. In economics literature, this concept is called efficiency.

Let us assume that the assessed buildings define exhaustively the set S. We rate each building *in turn* against these sample buildings. The building to be rated is usually called the Decision Make Unit (DMU), and is superscripted as $0, 0 \in S$. We try to find weights for the DMU that maximize its efficiency, given that no buildings rating (eco-efficiency) exceeds unity with those weights. Thus, we have to solve the problem:

$$\begin{aligned} &\underset{u_i, v_j}{Max} \quad \sum_m u_m q_m^0 \Big/ \sum_n v_n l_n^0 \\ &s.t. \quad \sum_m u_m q_m^s \Big/ \sum_n v_n l_n^s \le 1 \quad \forall s \in S \end{aligned} \,. \tag{4}$$

In (4), productivities are scaled to an observed maximum; i.e. they are expressed as efficiencies. (4) has multiple solutions, but we can use normalisation $\Sigma_n v_n l_n^0 = 1$, also recognising that that the objective will be linear. Also the constraints can be expressed in linear form, so that eco-efficiency measures for the buildings in the sample can be obtained by solving either one of the primal or dual problems in (5):

$$
\begin{array}{llll|llll}
\text{Primal} & & & & \text{Dual} & & & \\
\underset{\mu_m,\upsilon_n}{Max} & \sum_m \mu_m q_m^o & & & \underset{\theta,\lambda}{Min} & \theta & & \\
s.t & \sum_n \upsilon_n l_n^o & =1 & & s.t. & \sum_s \lambda_s q_m^s & \leq & q_m^o \forall m \\
 & \sum_m \mu_m q_m^s - \sum_n \upsilon_n l_n^s & \leq 0 & \forall s \in S & & \theta l_n^o - \sum_s \lambda_s l_n^s & \geq & 0 \forall n \\
 & \mu, \upsilon & \geq 0 & & & \lambda_s & \geq & 0
\end{array}
\qquad (5)
$$

Note that in this basic eco-efficiency model it is *not necessary* to give any particular value for any of the weights, but they are calculated so that the efficiency of each building is maximized in turn. It is also true to say that each building may have a unique set of weights, not shared by any other building. Perhaps a more intuitive interpretation of the eco-efficiency can be found in the dual problem, where it is necessary to search for a minimum value for parameter θ that contracts all the inputs equal proportionately (the second set of constraints). The first set of constraints defines a combination (λ_s>0) of the outputs (the qualities) of the reference buildings that is at least equal to DMU building in terms of each quality. These buildings with (λ_s>0) are called peers. The second set of constraints ensures that the inputs (loads) of the DMU building are not contracted below that of the combination of peers. If the minimum θ is less than unity, the DMU building is ranked inefficient. On the other hand, if the quality is of the building is higher or equal to peers and any contraction of inputs would follow lower quality than the peers, the building is considered fully efficient. The efficiency measure is illustrated in Fig 2:

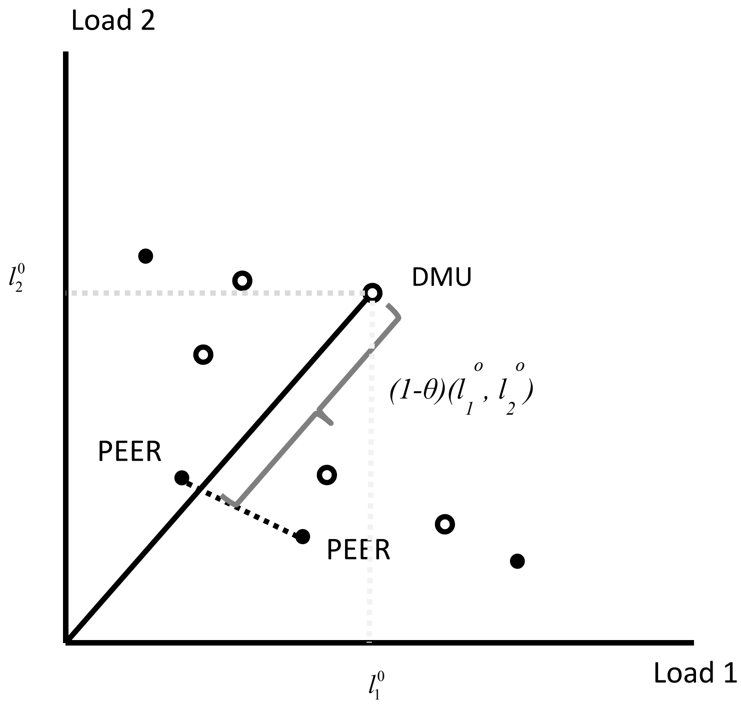

Fig 2. Eco-efficiency measure

In the Fig 2 two buildings are identified as peers. The DMU building could reduce its environmental loads to $\theta(l_1,l_2)$, while the constraints ensure that it could still produce the quality indicated by the peers. A similar radial contraction of loads can also be found for all the five buildings (circles) in the figure. Altogether 4 buildings (dots) are fully efficient and act as peers for the other buildings.

The measured eco-efficiency is always between]0, 1]. This is a conservative estimate, showing the building performance in its best possible light; given the performance of all the buildings in the sample. If this level of freedom in dictating the weights is not acceptable, weight restrictions can be set. The simplest option is the so called Assurance Region model - see [16, 19], where additional constraints to the weights are set as:

$$L_{mn} \quad \leq {u_m}\Big/{\upsilon_n} \leq \quad U_{mn} \quad m \in (1,\ldots,n), n \in (1,\ldots n), m \neq n, \tag{6}$$

where L_{mn} and U_{mn} are predefined constants. A more general Cone Ratio model [20] has also been used.

The DEA model presented above is the most simplified version, and is also known as the CCR input oriented model. When the normalization in (5) is carried out for outputs instead of inputs, the result is quantitatively equal but inversed; showing how much the DMU should increase the quality to reach the peers' level (the CCR output oriented model). The CCR models are characterized with constant returns to scale, so that the optimal ratio of environmental load and building quality is assumed to be independent of level of operations as in the panel left in Fig 1. Variable or non-increasing returns to scale (the case in panel right, Fig 1.) are known as BCC-model [21]. Technically the BCC model uses an additional variable (a constant term) to get the scaling of virtual input or output dependent not only on inputs and outputs. If variable returns to scale are assumed, the orientation, i.e. the contraction of loads or the increase of quality, will have an impact on the rating.

The DEA currently appears as a well-established methodology in several fields. Also, software tools have been developed. Non-commercial simple stand alone applications like DEAP [22] and spreadsheets supporting EMS [23] cover the basic variants of the method. Several commercial applications and textbooks with software exist. Also, regular optimisation software can be used; e.g. an advanced spreadsheet user should have no problems in implementing DEA models.

4. Discussion and conclusions

The goal of this paper was to show connections with current ERTs and the nonparametric efficiency measurement models known as Data Envelopment Analysis (DEA), and to discuss in what way the concept of eco-efficiency could be used in connection with ERTs. The choice of criteria in ERT and full characterization of DEA was beyond the scope of this paper.

Any of the current ERTs score attributes and give them predefined weights. Also, eco-efficiency uses scoring, but weights are defined with respect to the performance of other buildings used for reference. First, the algorithm identifies the set of buildings that can be judged as being fully efficient. They receive a full rating, and the rest of the buildings are rated with respect to them. The weights are optimal for each building in turn, so that given the building's performance relative to peers it is not possible to get a better rating. Even if subjective/professional information on the weights is not necessarily needed, they can be used as supporting information.

The full score in the current ERTs is usually not reachable, but the highest rating is reached with somewhat lower score. In eco-efficiency at least one building gets full score. If better performing new buildings are added to the sample (rating scheme) the efficient frontier shifts. A shift can lower the rating of (limited number of) previously rated buildings. This is also the case in current ERTs, where schemes are frequently updated, making any previous ratings obsolete. In eco-efficiency this is not necessary, however, as super efficiency technique [24] can be used; better performing buildings gets scores above 1, but are not used as peers.

Compared with the current state-of-the-art of ERTs, eco-efficiency does not introduce stricter requirements for the data. The same mathematical tools, additive multi-attribute value functions and index formula are used. This is not to say that current treatment of data in ERTs is always consistent; ordinal measures are used as rational numbers. This is also true for eco-efficiency, in that the most reliable results are given when attributes are measured as rational numbers. Ordinality can be used as information in eco-efficiency, however. The ordinal choices indicate kinks (see fig 1 right panel), where "quality returns" of induced loads change.

A division of attributes into qualities and loads is not necessary. The eco-efficiency model can be reduced to additive multi-attribute valuation by assuming that the same amount of single input is used for each building. This assumption may sound intolerable, but it is present in those ERTs that do not account resource usage explicitly. In our view, if resource usage should contribute to environmental rating, the index formula is obviously the better way to implement it. For example, if the building economy accounts for sustainability, the BCC type eco-efficiency model can be used to take account increasing the marginal costs of environmental impacts.

The DEA algorithm has its well-known drawbacks. A solution can be found for the cases where the number of attributes equals the number of buildings, but it does not necessary make a lot sense. Conservative weighting means also that efficiency improvements are searched aggressively. Thus, when the number of buildings is low, most of the buildings are rated as being fully efficient. Due to this type of multicollinearity, the model is usually not usable with the small samples (<20 buildings) and more than 10 attributes. In the case of ERTs, we could reliably design a model with at most 5-7 attributes and preferably more than 20 relatively homogeneous buildings. This would be enough to run the eco-efficiency model for the highest level of categories in LEED, BREEM and DGNB, i.e. allowing flexible scoring between the main categories of sustainability. Weights that refer to actual possibilities to comply with all the pillars of sustainability can motivate the investor or designer more.

Given that the scope of this paper was to bridge the discussion on ERTs and nonparametric efficiency literature, we have been able to give just a short review of the preliminaries of DEA. Several models have been developed to overcome the known difficulties is DEA and to adjust the method to new problem environments. In this view, more extended reviews are clearly needed. Given that data is made available, also real life tests and comparisons between current ERTs and eco-efficiency are already possible.

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Energy efficient Wall Element with Steel Frame and Polyurethane Insulation

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Summary

The aim of this work was to develop a wall element with steel frame and polyurethane insulation for small houses, examine its performance and develop the element further at a detailed level. The additional aim was to research the performance and usage of cold formed steel and polyurethane together in an external wall structure in general.

The element was developed for a passive energy level solution used in energy efficient buildings. The element was going to be produced in a highly automated factory. This was kept in mind during the development process, although the design of the automatic assembly line was not a part of this work. Particularly the cost efficiency and hygrothermal performance in Finnish climate were important factors, when developing and designing the element.

After some early stage brainstorming the projects workgroup had outlined over twenty different element types to choose from. The most interesting ones were examined closer and compared by thermal performance, material cost, and strength.

An element type with C thermo purlin was chosen. This solution was the best alternative of the most interesting element types when it comes to technical performance and possibilities in automated industrial production. This element type has 100 mm mineral wool between steel purlins and plasterboards on its both sides. Outside this load-bearing part is the 200 mm thick polyurethane layer and outer structures according to façade materials.

The steel frame was dimensioned with Rautaruukki PLC's ProfBeam software. Thermal performance was examined with HEAT software and using C3/2010, D2/2010 and D3/2010 sections from the National Building Code of Finland. Acoustics was examined with Heikki Helimäki Oy's ILPO software and hygrothermal performance with HAM software. Airtightness and fire performance were studied by using the National Building Code of Finland.

Thickness of almost every steel part and purlin is 1.0 – 1.5 mm in the final element. U-value of the element is 0.092 W/m^{2}K, total thickness 384 mm, and weight 64 kg/m^2. The airborne sound insulation capability is 51 dB and the material cost is ~60 €/m^2. The element can also be built as 356 mm thick with 0.088 W/m^{2}K U-value by using polyurethane and mineral wool with better λ-value. The element can be used widely in different small houses due to its versatile design and options. It can also be used as non-load bearing panel for multi-storey buildings.

Keywords: polyurethane, cold-formed, steel, profile, wall element, small house, passive house

1. Introduction

Buildings and construction account for about 40 % of all energy use and emissions. Improving energy efficiency of the buildings is an important part of climate and energy strategy of Finland. Finland has set the ambitious goal of reaching the nZEB energy efficiency level as a standard level by 2017. This rapid schedule of improving the energy efficiency sets the demand for completely new type of structures that are relatively thin without compromising the thermal resistance. Also the importance of the hygrothermal performance increases when the thermal resistance increases.

It is very typical to traditional structures and materials that when insulation level is increased, also the total thickness of the structure increases. This costs more in form of logistics and increased amount building materials in the whole building. Thicker structures can even weaken the tolerance of construction defects and environmental factors during construction, which can lead to unhealthy indoor environment.

When using in new ways more efficient materials, like steel and polyurethane, structures can be found with relatively thin total thickness and excellent insulation properties. This was the main idea of the project; to find new cost efficient and safe structures for the needs of energy efficient construction.

The work was carried out as a master thesis of Mr. Antti Viitanen and guided/observed by Mr. Pasi Käkelä from SPU Oy. The work was financed by SPU Oy and Rautaruukki Oyj. The complete master thesis in Finnish can be found from here: http://URN.fi/URN:NBN:fi:tty-201204121090

2. Structure and materials

2.1 Limit values of the structure

The aim of this work was to develop a new type of wall element with steel frame and polyurethane insulation for small houses, examine its performance and develop the element further at a detailed level. The additional aim was to research the performance and usage of cold formed-steel and polyurethane together in an external wall structure in general. There was no source material to be found about passive energy level steel framed external wall structures with polyurethane insulation.

The element was developed as a passive energy level solution used in energy efficient buildings. The element was going to be produced in a highly automated assembly line. This was kept in mind during the development process, although the design of the automatic assembly line was not a part of this work. Particularly the cost efficiency and hygrothermal performance in Finnish/Nordic climate were important factors, when developing and designing the element.

In addition to cost efficiency and good hygrothermal performance, the element was intended for fulfil these technical specifications:

- U-value ~0.09 W/m^2K
- Total thickness of the element from inner surface to façade outer surface ≤384 mm (this is the maximum thickness before the cost of logistic increases significantly)
- Simple structures and joints to ensure an air tight building, n_{50} ≤ 0.6 1/h
- Can be applied to one and two storey buildings as load-bearing wall
- Optimised amount of different steel parts and purlin types
- Optimised amount of building materials

2.2 Main building materials

The element was designed to be mainly insulated with SPU Insulation (PIR). Thermal conductivity (λ_D) of SPU Insulation –products are 0.023 (SPU AL) and 0.022 (SPU SP) W/mK [1]. With diffusion tight facings, SPU AL and SPU SP are completely gas tight and can be also used as a vapour barrier. Because of very low thermal conductivity of SPU Insulation, insulation layer can be kept thin without compromises in the U-value of the structure.

Steel frames and purlins from Rautaruukki Oyj have many advantages over traditional timber frame. Due to very high strength of the steel, load-bearing structures can be designed much thinner. With thermo holes of steel purlins, the thermal conductivity and cold bridges are reduced significantly. As an inorganic material, steel has great tolerance for different kind environments. Therefore it can be used freely all around the structure without worries of decay and mold.

Other materials used in the element are soft mineral wool for sound insulation and different building boards e.g. plasterboards.

3. Selection of the structure

3.1 Element types

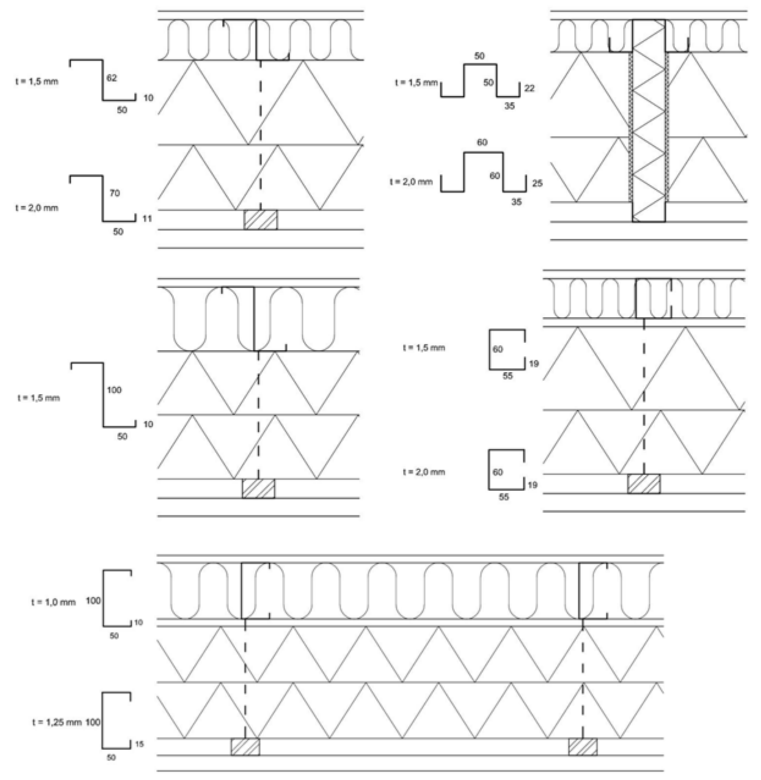


Fig. 1 Selected element types

The workgroup of the project consisted of experts from Rautaruukki Oyj, SPU Oy and Tampere University of Technology with many different backgrounds from marketing and sales to technical expertise from different fields. The development process started by innovating all kinds of different structures through many brainstorming sessions and meetings with smaller and bigger groups. The workgroup outlined over twenty different element types.

From these element types, the workgroup selected the most promising ones based on the knowledge and experience of the workgroup. The main focus at this point was manufacturability, cost efficiency and total thickness of the element. The horizontal cuts of the selected element types are presented in figure 1.

3.2 Comparison and selection

Typically the purlin type defined the rest of the structure and therefore structures were classified by the purlin type. The most suitable purlin types were Ω, Z and C, which Z and C –purlins were with and without thermal holes. These selected element types were examined closer and compared by thermal performance, material cost, total thickness, amount of steel and thickness of steel. In table 1 is presented the summary of the comparison. Structure types were rated from one to five points by the performance compared to other structure types.

Table 1 Structure comparison

Feature	Ω (rk)	Z (rk)	Z (rk) therm.	C	C therm.
Total thickness	5	4	3	2	1
Thickness of steel	1	2	4	3	5
U-value	5	4	1	3	2
Material cost	1	3	5	2	4
Amount of steel	1	3	4	2	5
AVG	2.6	3.2	3.4	2.4	3.4

At this point there was an innovative realization of the benefits of using partition wall steel frame structure type as a load bearing structure of the element. In partition wall the steel frame is between two plasterboards. When the both flanges of purlin are fastened to rigid boards, the load-bearing capacity is improved significantly. The sound insulation properties also improve with this structure.

If the load-bearing part is manufactured on one assembly line and insulation part on the other, all load-bearing and non-load-bearing partition walls can be also manufactured on the same load-bearing part –line. The structure of the partition wall and the load-bearing part of element is practically the same. This gives an advantage in cost efficiency, when all walls of the house can be built on the same production line, freight to the construction site and installed with same crane at the same time

An element type with C thermo purlin and partition wall structure type was chosen. The load-bearing part of this element type has 100 mm mineral wool between C thermo purlins and plasterboards on its both sides. Outside of this load-bearing part is the 200 mm thick polyurethane layer and outer structures according to facade materials. This element type is presented in figure 2.

This element type was the best or second-best in material cost, amount of steel and thickness of steel. The workgroup also felt sure that this element type had the most of possibilities in automated assembly line and industrial manufacturing.

When comparing this element type to other element types, this type was not at its best with the thermal performance in relation to total thickness of the element. However, the total thickness with the thickest façade structure and the U-value of the selected element type were within the limit values, so there was no reason not to continue the project with this element type. All benefits together of this element type made clear difference to other element types and therefore the selection was unanimous.

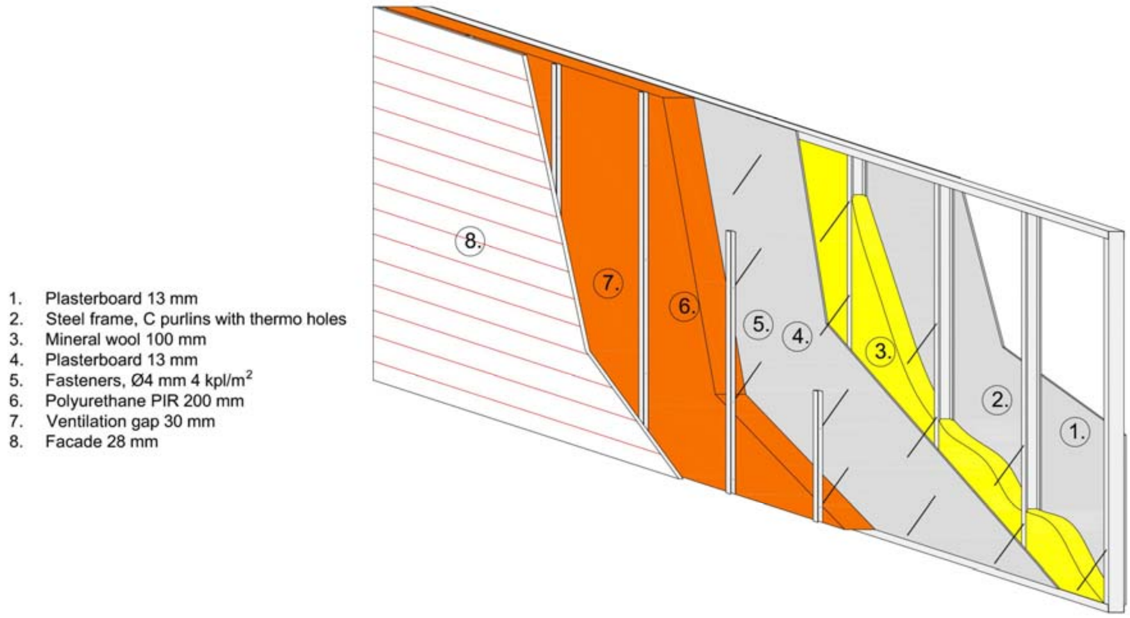


Fig. 2 The selected structure

4. Selected structure

4.1 Load-bearing capacity

The steel frame was dimensioned with Rautaruukki PLC's ProfBeam software. The dimensioning of the ProfBeam is based to Eurocode 3. Basically with typical loads (wind and snow) in one storied building 1.0 mm thick purlin is enough. In two storied buildings and cases with bigger loads the 1.5 mm thick purlin is needed. In any case, screws with drill bit can be easily drilled to 1.5 mm thick or thinner steel.

The C purlins are tied together from both ends with horizontal U purlin with thermo holes. The U purlin can be done in most cases with 1.0 mm thick steel. Rautaruukki Oyj has designed pre-fitted slots to the C and U purlins, so that the purlins fit right into each other and assembly of the steel frame is easy and fast.

4.2 Thermal insulation

Thermal performance was examined with HEAT software [2] and by using C3/2010, D2/2010 and D3/2010 sections from the National Building Code of Finland. The impact of the purlin thermo holes to thermal conductivity of the purlin was calculated separately with HEAT. The result of the heat conductivity of the purlin was then used in HEAT model of the whole structure.

The U-value of the element is 0.092 W/m^{2}K with regular SPU Insulation (SPU AL) and mineral wool (37). With better SPU Insulation (SPU SP) and mineral wool (33) the U-value is as low as 0.088 W/m^{2}K. As thermal insulation materials keeps developing, it possible in the future to get near 0.080 W/m^{2}K with same structure and insulation thicknesses. In the future it is also possible to keep the U-value fixed and make the element even thinner. Thermal conductivities of the materials used in HEAT software are presented on table 2.

Table 2 Thermal conductivities used in HEAT software

Material	Thermal conductivity (x- and y-direction) W/mK	Specific heat capacity MJ/m^{3}K
Plasterboard	0.2400	0.48910
Mineral wool 33	0.0330	0.03149
Mineral wool 37	0.0370	0.03149
Polyurethane foam (joints)	0.0300	0.05250
SPU AL	0.0230	0.05250
SPU SP	0.0220	0.05250
Steel	50.000	3.57700
Steel with thermal holes (6 holes)	9.1513	3.57700

4.3 Acoustics

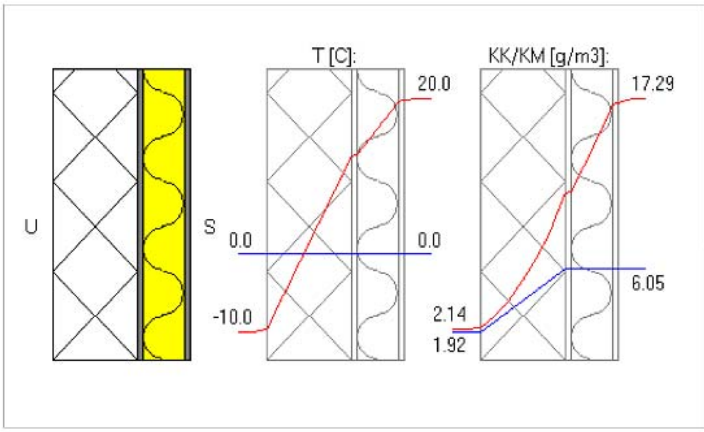
Acoustics was examined with Heikki Helimäki Oy's ILPO software. The ILPO software calculates the airborne sound insulation capability of the structure with good accuracy. When ILPO software results are compared to the sound insulation values that are measured from a real structure, the deviation is typically not more than ±1 dB and with very high probability not more than ±2 dB. [3]

The airborne sound insulation capability values of the structure are:

- R_w 51 dB
- R_w+C 50 dB
- R_w+C_{tr} 46 dB

4.4 Hygrothermal performance

The hygrothermal performance of the structure was evaluated by calculations made with DOF Therm and results of dissertation by Juha Vinha [4]. The critical point of the element, when it comes to hygrothermal performance, is the point where outer plasterboard meets the polyurethane layer. There was no condensation to be found in DOF Therm calculations. These results are presented in figure 3.



Piste:	T [C]:	KK [g/m3]:	KM [g/m3]:	SK [%]:	C [g/m2]:
U	-10.00	2.14	1.92	90.0	0.00
1	-9.67	2.20	1.92	87.5	0.00
2	12.50	11.00	6.05	55.0	0.00
3	12.64	11.09	6.05	54.5	0.00
4	19.53	16.82	6.05	36.0	0.00
5	19.67	16.95	6.05	35.7	0.00
S	20.00	17.29	6.05	35.0	0.00

Fig. 3 DOF Therm result (KK = Saturated humidity, KM = Humidity, SK = Relative humidity)

One of the results in the dissertation by Juha Vinha states that ¾ of thermal insulation must be outside of the vapour barrier. With the combination of 200 mm polyurethane and 100 mm mineral wool this is achieved easily. There were also calculations made with WUFI 4.2 Pro (HAM calculation program) from some other same kind of structures with timber frame where polyurethane is outside of the mineral wool. Also these calculations supported the idea that there is not going to be a condensation between outer plasterboard and polyurethane.

5. Joints and details

5.1 Element joints

Also different kind of joints and details were designed in order to attain a good comprehension of the element usage in real construction site. The work covers different joints between elements, window and door joints and details about how the element can be connected to other structures. Simple dimensioning examples of these joints and details were also made to make it easier for a designer to start planning a building with this element. All the joints in polyurethane layer are sealed with PU-foam. The joint can be also taped with aluminium tape from the outside if necessary. This way the polyurethane forms a solid and air tight layer around the envelope also at the joints.

Here are two examples (figure 4) of the details designed for the element:

- Window detail
- Detail of connection of the element and footing

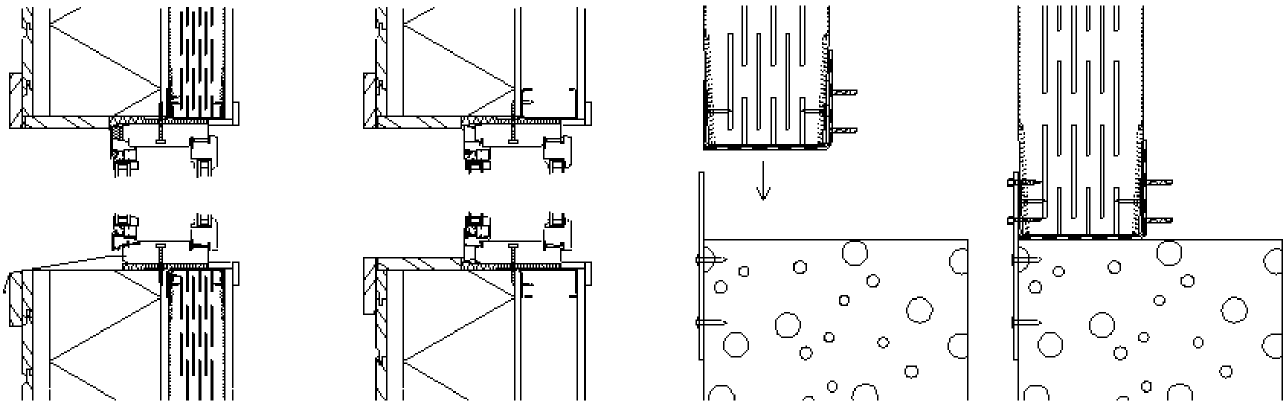


Fig. 4 Two details from the work: Window detail (left) and Footing detail (right)

Window is fixed to the steel frame with L purlin. The position of the window can be adjusted by adjusting the size of the L purlin. The cold bridge is minimal, because there are not any steel parts going through the whole structure. Element is fixed to footing with steel plate which is fastened to the footing before lifting the element in place. The element can also be fixed to the footing by replacing the steel plate with U purlin fastened on top of the footing.

All these details have dimensioning examples in the appendix pages of the master thesis. There are also many other details drawn and dimensioned, e.g. different joints between element and roof structures, joints to intermediate floor, joint to partition wall and vertical joints between two elements.

5.2 Façade options

There are many different façade options to choose from. The most common façade in small houses is probably wooden panel. This is one of the thickest façade structures and therefore it was the default façade when calculating the total thickness of the element. In wooden panel façade, the studding battens (e.g. timber 22 x 100 mm) are simply fixed to the steel frame with long screws with drill bit. Then the panels are fixed to the studding battens.

The wooden studding battens can be replaced with steel support studs that are fixed in the same way to the steel frame. There are many different purlin types available, e.g. Rautaruukki Oyj has CA1SS purlin system that can be used with many different types of façades. Façade material can be also steel, masonry or cement products.
It is also possible to use Rautaruukki Oyj's solar panels (Liberta Solar Panel) with CA1SS system. This gives interesting possibilities when building nZEB or Energy+ house. The amount of solar panels can be easily increased later if necessary. The house can be built now to a passive house level and later on update it into nZEB or even Energy+ house.

The excellent long-term durability and maintenance free living can be easily achieved with façade options without any organic materials, e.g. steel purlins and panels. This way all the materials (polyurethane and steel) exposed to outdoor environments are inorganic and therefore have excellent durability against moisture, cold, heat etc.

5.3 Handling and storage

It is very important make sure that the elements are handled and stored properly. Especially the protection against moisture is important. Almost every part of the element can be replaced in case of damage except the outer plasterboard. If the outer plasterboard gets damaged by moisture or some other factor, the whole element needs to be replaced. The outer plasterboard is between steel frame and polyurethane, so it cannot be removed. All other moisture sensitive materials are inside of the polyurethane layer and can be fixed or replaced indoors after installation of wall and roof.

6. Results

6.1 Technical properties

In the final element almost every steel part and purlin is 1.0 – 1.5 mm thick. U-value of the element is 0.092 W/m^{2}K and total thickness 384 mm. It is very difficult to achieve this U-value and total thickness with any other traditional building materials and solutions. The element can also be built with 0.088 W/m^{2}K U-value by using polyurethane and mineral wool with better lambda values.

The airborne sound insulation capability (R_w) is 51 dB. This is roughly at the same level than sound insulation capability of the traditional insulated concrete wall. Still the element weighs only 64 kg/m^2.

The material cost is around 65 - 70 €/m^2. The total cost estimate (incl. material and labour, excl. freight) for installed element is approximately 100 €/m^2 when using Finnish labour cost. Depending on the calculation method, the steel frame element cost is very close to typical timber frame element cost.

6.2 Applicability

The element can be used widely in different energy efficient small houses due to its versatile design and options. It can also be used as non-load bearing panel for multi-storey buildings. With many pre-designed detail, joint and dimensioning examples the element can be applied with ease to any real life building project.

There has been a pilot project in Sweden, where this element, with few modifications, has been used in multi-storey building as a non-load bearing panel. Building the element by hand has also been tested with different kind of tools and methods. The proto-type element is presented in figure 5.

Fig. 5 The proto-type element

7. References

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Wooden vs. Concrete Blocks' Structure - HAM and Mould Growth Analysis

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1. Introduction

New civil engineering projects are subjected to high requirements on esthetical clauses, energy savings, environmental protection, costs, comfortable and healthy living indoors, etc. One of the most important items which influence more or less all the conditions is selection of the materials which will be used in the building. The decision of the material selection usually depends on investors' taste. Some people prefer wooden houses because of the natural and warm feeling, and also due to costs, especially in northern countries where the wood creates accessible material for civil engineering projects. On the other hand, many people prefer brick or concrete houses because they give a feeling of stability and safety. Comfortable and healthy living indoors is influenced the most by air temperature and relative humidity. A certain combination of temperature and RH could indicate a danger of mould growing. According to moulds' extension in the structure or on its surfaces the moulds existence influences the reliability and lifespan of a structure and might also inflict allergy reaction on people living indoors. Mould is a result of biological processes where microscopic organisms assemble, so the reliability and lifespan of the structure depends especially on the sensitivity of materials used.

The aim of this paper is threefold. First, to analyze thermal features of walls' corners of wooden and concrete low-energy family houses located in Oulu/Finland via their numerical models, second to subject the structures to heat and moisture (HAM) transfer and third, with the obtained temperature and relative humidity data to analyze the mould growth risk in the corners to compare HAM transfer and mould growth risk properties of the houses.

2. Performed Analysis

Within the frame of the presented paper a heat transfer, heat and moisture transfer and mould growth risk analysis are performed. Thermal features of the structures are observed via numerical models of the exterior vertical walls' corners in the multiphysical FEA/FEM Comsol program created. The thermal bridge values of the structures are evaluated.

A next essential phenomenon for quality living indoors is combination of heat and moisture. Their certain amount might cause conditions which are favourable for mould growth. From this reason the numerical models of the structures were subjected to the heat and moisture analysis by the Wufi 2D program. The simulation was performed over a 2-year period where boundary conditions were taken from measuring of temperature and relative humidity in weather station at the Oulu University of Applied Sciences.

The temperature and relative humidity data were observed in points, located diagonally across the models' corners, in each time step (1 hour) of the HAM analysis for a period of one year. The obtained data from each analysed point and boundary condition were subjected to the mould growth analysis performed according to [1; 2; 3]. At first the HAM condition were analysed from the point of view of favourable and unfavourable environment for mould growth and then the mould index M_{index} which indicates the risk of mould growth stage during the simulated period was evaluated.

3. Summary of Obtained Results

The thermal bridge values in analysed structures show presumed results where lower thermal bridge was achieved in the case of wooden structure in 12,2% compared to concrete external walls' corner. The difference is predicated especially to thickness of used insulation and higher thermal resistance of wood in comparison to concrete.
The temperature and relative humidity data in the all analysed points, including internal and external conditions, obtained were subjected to the mould growth risk analysis. Analysed points which are closer to the exterior side of the model show favourable condition for mould growth. But the amount of the condition is very low that after evaluation of the mould index M_{index} value in all the analysed points are on the safe side from the point of view of mould growing. On the other hand boundary condition of the structures might change in the future which leads us to continue with the presented analysis. Little bit more favourable condition for mould growth inside of the structure is achieved in the case of concrete corner. But if the sensitivity of materials which are used in the structure is considered the mould growth risk would be lower.

4. Ongoing and Future Work

The presented numerical models represent real structures of low-energy family houses situated in Oulu/Finland. They are currently subjected to measuring by temperature and relative humidity sensors and also computers which control energy consumption. The sensors were installing during erecting of the houses which allows us to situate them without any damage of the structure. The aim of the work in the future is verifying the numerical models with measured data and follow changes in material properties in the structures. This allows us to control temperature and relative humidity in the internal and external environment and also conditions inside of the structure. By this there is possible to predict mould growing in the houses in future with high accuracy. The knowledge of thermal and humidity features of the structures can be then apply for analyzing of future structures to improve their energy efficiency and life-span.

5. Conclusion

The numerical models simulated corners of external vertical walls of wooden and concrete block low-energy houses located in Oulu/Finland are presented. The thermal conditions of the structures are observed. Heat and moisture analysis is performed to obtain required quantities for applying mould growth risk model. The mould growth risk analysis was performed in 9 points in concrete blocks structure and in 12 points within the frame of wooden house exterior corner. The obtained results do not show mould growth risk in any analysed point on or inside of the structure. Based on the performed analysis we assume the structures are safe from the point of view of mould in the analysed period.
The numerical models performed in this work represent an efficient initial step for the analysis of current and future building to control and predict problems from the point of view of mould existence and increase live quality indoors and extend life-span of the structure.

Wooden vs. Concrete Blocks' Structure - HAM and Mould Growth Analysis

1. Introduction

New civil engineering projects are subjected to high requirements on esthetical clauses, energy savings, environmental protection, costs, comfortable and healthy living indoors, etc. One of the most important items which influence more or less all the conditions is selection of the materials which will be used in the building. The decision of the material selection usually depends on investors' taste. Some people prefer wooden houses because of the natural and warm feeling, and also due to costs, especially in northern countries where the wood creates accessible material for civil engineering projects. On the other hand, many people prefer brick or concrete houses because they give a feeling of stability and safety. Comfortable and healthy living indoors is influenced the most by air temperature and relative humidity. A certain combination of temperature and RH could indicate a danger of mould growing. According to moulds' extension in the structure or on its surfaces the moulds existence influences the reliability and lifespan of a structure and might also inflict allergy reaction on people living indoors. Mould is a result of biological processes where microscopic organisms assemble, so the reliability and lifespan of the structure depends especially on the sensitivity of materials used.

Generally, there are three ways to acquire temperature and relative humidity data in a structure; taking measurements at a real structure, analyzing the structure or its element within the frame of lab tests, or subjugating a mathematical model of the structure to numerical computation by accessible program.

The aim of this paper is threefold. First, to analyze heat features of walls' corners of wooden and concrete low-energy family houses located in Oulu/Finland via their numerical models, second to subject the structures to heat and moisture (HAM) transfer and third, with the obtained temperature and relative humidity data to analyze the mould growth risk in the corners to compare HAM transfer and mould growth risk properties of the houses.

2. Wood and Concrete as Building Materials

Generally there are two main attitudes to build family houses from the point of view of used construction material. One is to apply heavyweight material and the second is use a lightweight material for load-bearing parts of a house. One of the most popular heavyweight material used in family houses besides bricks and stone is a concrete. The most widely used lightweight material in family houses is represented by wood.

2.1 Wooden Houses

The wooden houses are characterized by the load-bearing structure made from wood and its products. The most widely used wooden houses are timber frame houses and log houses, where the load-bearing structures in timber frame houses are created by timbers' panels. This type allows filling free spaces in timber frames by insulation to improve thermal resistance properties of external walls. By way of contrast the log houses are created by fully wooden walls. In this case the thermal resistance of external wall depends on thermal properties of used wood and quality of contacts between individual logs. Advantages of wooden structures consist in easy architectural design and forming individual elements, wood is relatively cheap and readily obtainable, lower demands on accuracy (small deviations in foundations are acceptable), easier adaptation, reconstruction, etc. On the other hand the wood inclines to defects by thermal and moisture conditions as torsion and bending. In comparison to other, inorganic materials, the wood is more sensitive to damages caused by mould.

2.2 Concrete Houses

Concrete is the most used material in civil engineering. Concrete is especially used in parts of buildings where high compression strength and durability is required, such as foundations, footings, columns, etc. Significant expansion can be seen also in building family houses which are erected by concrete external and/or internal load-bearing walls. Many variations of concrete structures are currently available in the market. Advantages of concrete houses consist especially in stability, durability but also efficiency from the point of view of thermal energy because of its ability to absorb and retain heat. Concrete is friendly to the environment from the beginning of production to the end of its life span.

3. Heat Transfer Analysis

Current market offers plenty of family houses' designs. Wooden houses are usually constructed as log or timber frame houses. Concrete houses are in most cases assembled from concrete blocks. One of the most popular blocks are two-faces' blocks filled by a certain thickness of insulation in dependence on given requirements. This allows applying insulation lengthwise of the entire wall against timber framed houses where the insulation is discontinued by load-bearing wooden studs. The first analysis in this work is focused on heat transfer differences between typical timber-frame wall and concrete blocks' wall. One of the most dangerous places in houses which are often exposed to thermal bridge and mould presence are corners between two external vertical walls. This let us to analyse difference between wooden and concrete structure in the corner. Thermal bridge values in corners of the structures, based on simulation by the Comsol program performed, are evaluated according to the following equation (1):

$$\psi = \frac{L_{2D}}{\Delta T} - U_1 \times l_1 - U_2 \times l_2 \qquad (1)$$

where Ψ *(W/m^2K)* is the thermal bridge value, l_1 and l_2 *(m^2)* are distances of walls on the interior side of the structure from the corner, U_1 and U_2 represent *U*-factors *(W/m^2K)* of both walls, L_{2D} *(W/mK)* is total heat flow on the interior side of the model obtained and ΔT is difference in outdoor and indoor temperature which is considered $\Delta T=1K$ in this analysis. The calculation of thermal bridge value in defined structures show presumed results where lower thermal bridge was achieved in the case of wooden structure. The difference is 12,2%. This is caused by thickness of used insulation and better thermal resistance of wood in comparison to concrete. The figures (Fig. 1) show temperature distribution in analysed elements.

Table 1 Thermal bridge properties

House	U (W/m^2K)	$l_1=l_2$ (m^2)	L_{2D} (W/mK)	Ψ (W/mK)
Wooden	0.061	1	0.309	0.187
Concrete	0.083	1	0.379	0.213

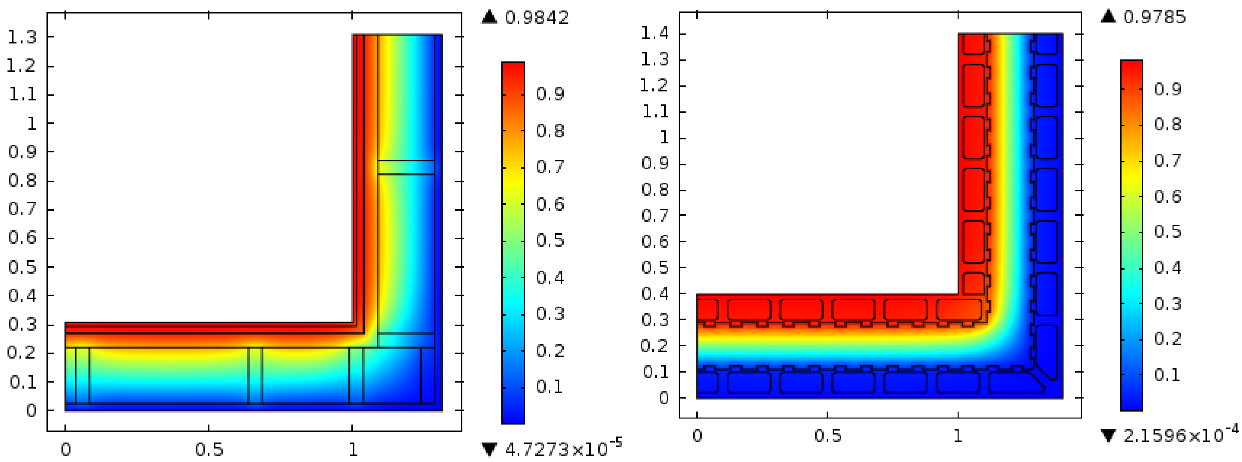

Fig. 1 Temperature distribution in wooden and concrete structure for ΔT=1K

4. Heat and Moisture Transfer

To analyse the structures from the point of view of mould growth risk the temperature and relative humidity values in dependence on time must be determined. This let us to simulate the structures by the Wufi 2D program which has been designated for heat and moisture analysis. The structures' geometry which was subjected to the heat and moisture (HAM) analysis is pictured in Fig. 2. They represent corners of vertical external walls where is one of the biggest assumption of mould presence. This is generally caused by temperature differences and less air movement in corners which leads to a higher risk of condensation. Boundary conditions of the models are defined according to data from weather station at the Oulu University of Applied Sciences obtained in period from beginning 2010 to the end of 2011. The Wufi program doesn't allow applying steady state simulation as initial point. From this reason two years simulation was performed to stabilize the HAM transfer in models in the first year and the analysis according to the second year is considered for the next step of the work. So, two years time dependent HAM analysis was performed in wooden and concrete structure separately.

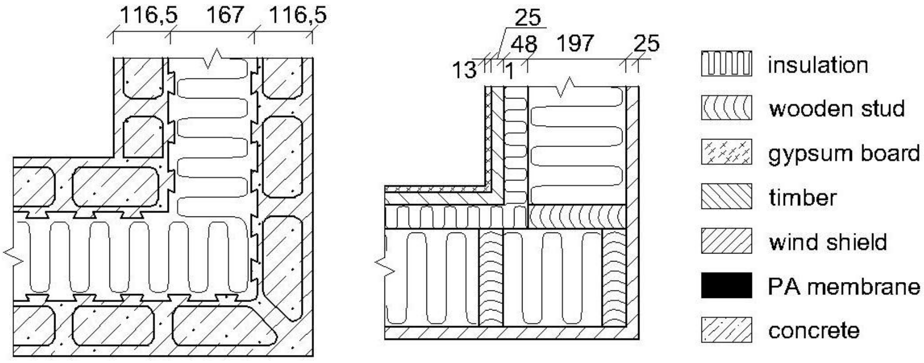

Fig. 2 Geometry of analysed elements

5. Mould Analysis

Mould growth risk analysis was performed according to mould growth model developed by Hannu Viitanen and Tuomo Ojanen [1]. A polynomial function (2) which describes barrier between favourable and unfavourable space for mould growth in dependence on temperature and relative humidity has been determined:

$$RH_{crit} = \{-0{,}00267 \times T^3 + 0{,}160 \times T^2 - 3{,}13 \times T + 100{,}0 \, when \, T \leq 20; 80\% \, when \, T > 20\} \qquad (2)$$

where T is a temperature. The range of thermal conditions for mould growth is limited by 0 ^{0}C to 50 ^{0}C. Graphical expression of favourable and unfavourable space for mould growth according to temperature and relative humidity values is pictured in the Fig. 3. Inconsiderable part of the mould growth analysis is exposure time. The mould growth risk (expressed by equation (3)) increases if the mutual relation between temperature and RH reaches favourable conditions for longer period and decreases if the conditions are in unfavourable area for period determined by relations (4). Then the mould growth risk is determined by six levels of mould growth [3], where 0 is for no growth, 1 for small amounts of mould on surface (microscopic), 2 for <10% coverage of mould on surface (microscopic), 3 for 10%-30% coverage of mould on surface (visual), 4 for 30%-70% coverage of mould on surface (visual), 5 for >70% coverage of mould on surface (visual) and 6 for heavy and tight growth with

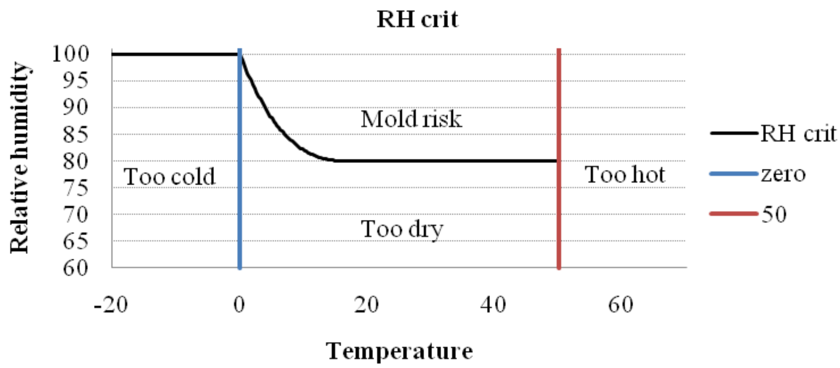

Fig. 3 Favourable and unfavourable area for mould growth

100% coverage. The mould index is evaluated by the equation:

$$\frac{dM}{dt}=\frac{1}{168\exp(-0{,}68\ln T-13{,}9\ln RH+0{,}14W-0{,}33SQ+66{,}02}k_1k_2 \qquad (3)$$

where W is timber species, SQ is surface quality, t is time and k_1, k_2 are coefficients for the growth. The presented analysis considers all the coefficients on the safest side of the solution. The decreasing progress in the case where unfavourable conditions are achieved is described by the following expression (4):

$$\frac{dM}{dt}=\begin{cases}-0{,}00133, when\_t-t_1\leq 6h\\ 0, when\_6h\leq t-t_1\leq 24h\\ -0{,}000667, when\_t-t_1>24h\end{cases} \qquad (4)$$

The mould growth risk analysis was evaluated in points, located diagonally across the models' corners (Fig. 4), in each time step (1 hour) of the HAM analysis for a period of one year. The temperature and relative humidity data in these points should lead us to obtain sufficient information about heat and moisture transfer in corner of the walls.

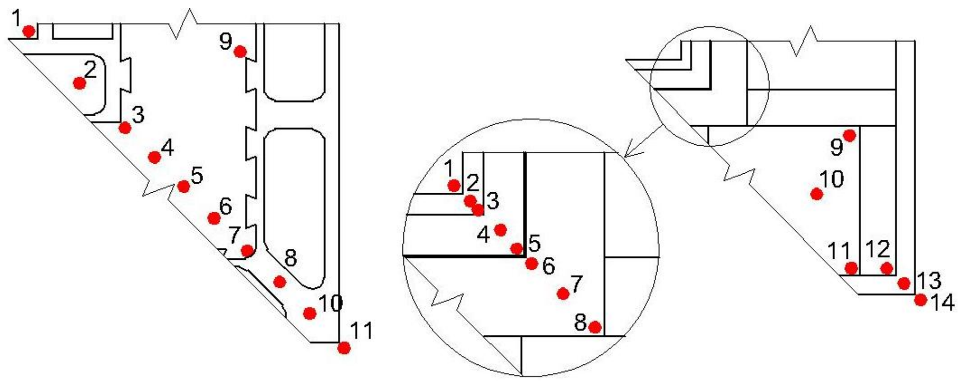

Fig. 4 Analysed points' location

6. Results and Discussion

The temperature and relative humidity data in the all analysed points (Fig 4) obtained, including internal and external conditions, were subjected to the mould growth risk analysis. The analysis was performed in each time step of the simulation. To achieve matching results for comparison of wooden and concrete structure the same boundary conditions were used. Exterior conditions which might lead to the mould growth on exterior surface of the house show 14,65% of time steps in favourable area for mould growing according to expression pictured in Fig 3. But after evaluation of mould index M_{index} which achieves zero value there is no mould growth risk on the outdoor surface. Very small value of M_{index} is obtained only if the decreasing process (4) is not included. The interior conditions achieve results where should not be risk of mould on interior side of the walls because only 0,1% of time steps reach conditions for mould growth in the favourable environment. Then going from the internal conditions through the structure

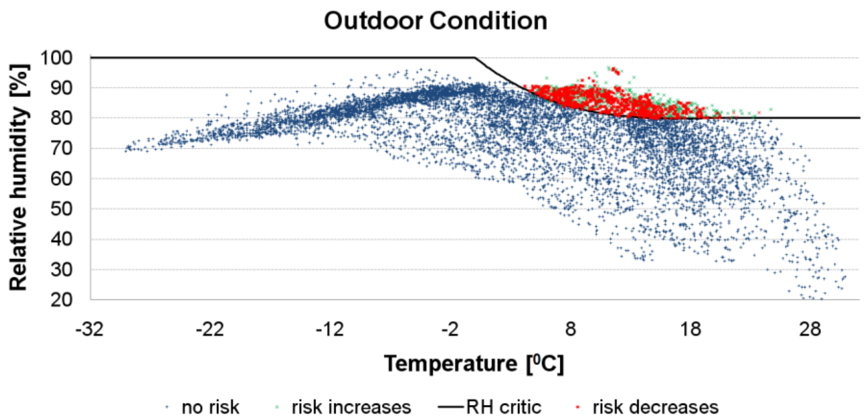

Fig. 5 Outdoor mould growth condition

toward exterior the mutual relations between temperature and RH achieve unfavourable environment for mould till point 10 in the wooden structure and point 5 in the case of concrete structure (Fig. 4). The following points already include conditions in favourable space for mould growth. For example graphical expression of the condition during the analysed year in point 7 in the concrete structure is pictured in the Fig. 6. If the condition reaches the favourable area the mould index M_{index} evaluation is needed to express the mould growth risk. The progress in this case is pictured in the Fig. 7, where the red curve shows the mould index progress in the case where decreasing (4) is not included and the blue one if the solution is evaluated within the frame of the risk decreasing. Summarization of all obtained results in the mould growth risk analysis is pictured in the Table 2. In the case where the decreasing progress (4) is included in the calculation all the analysed points achieve zero value of M_{index}. This leads us to assume there is no risk of mould growth in the structures. According to obtained results if the decreasing is not included a little bit higher M_{index} values were achieved in concrete structure but considering sensitivity of used materials in concrete and wooden structure for decay existence the risk is in the both cases neglecting. On the other hand by varying interior activities and usage inside the internal conditions might in the future change and also there must be assumption of varying outdoor condition. Other items which are necessary to follow are material properties. They also might change their features in time by an influence of ambient conditions.

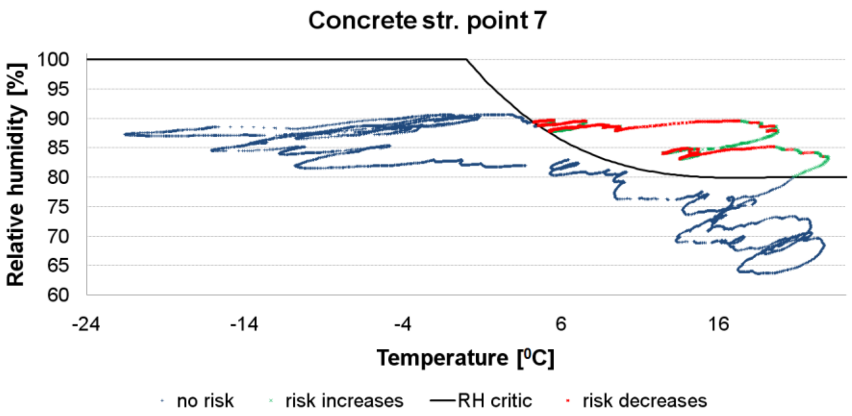

Fig. 6 Mould growth condition in point 7 of concrete structure

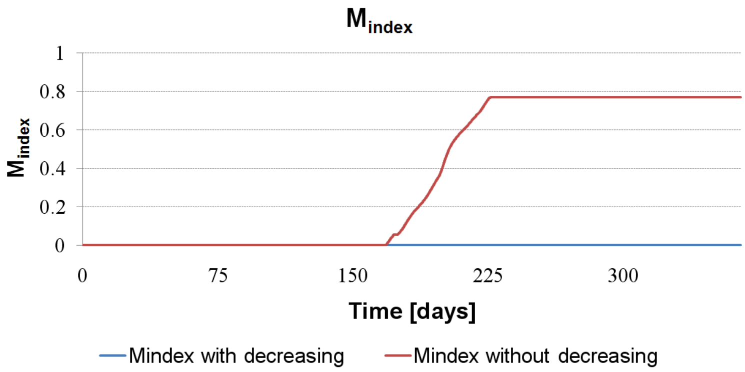

Fig. 7 Mould index progress in point 7

Table 2 Mould growth risk analysis data

House	*analysed point*	*unfavourable area [%]*	*risk [%] (decreases)*	*risk (increases)*	M_{index} *[-]*
Indoor condition	1	99,89	0,01	0,09	0,00 (0,01)
Wooden	2-10	100,00	0,00	0,00	0,00
	11	95,76	1.95	2.29	0.00 (0,12)
	12	92,22	3,54	4,24	0,00 (0,26)
	13	89,12	5,90	4,99	0,00 (0,39)
Concrete	2-5	100,00	0,00	0,00	0,00
	6	86,31	6,36	7,32	0,00 (0,51)
	7	84,36	6,87	8,77	0,00 (0,77)
	8	93,93	2,87	3,20	0,00 (0,22)
	9	99,81	0,12	0,07	0,00 (0,01)
	10	98,37	0,76	0,88	0,00 (0,04)
Outdoor condition	14 (w) 11 (c)	85,34	7,25	7,40	0,00 (0,62)

7. Ongoing and Future Work

The presented numerical models represent real structures of low-energy family houses situated in Oulu/Finland. They are currently subjected to measuring by temperature and relative humidity sensors and also computers which control energy consumption. The sensors were installing during erecting of the houses which allows us to situate them without any damage of the structure. The units measuring walls conditions are leaded along the wall at least 30cm through which the influencing of measured data by internal or external conditions is minimized.

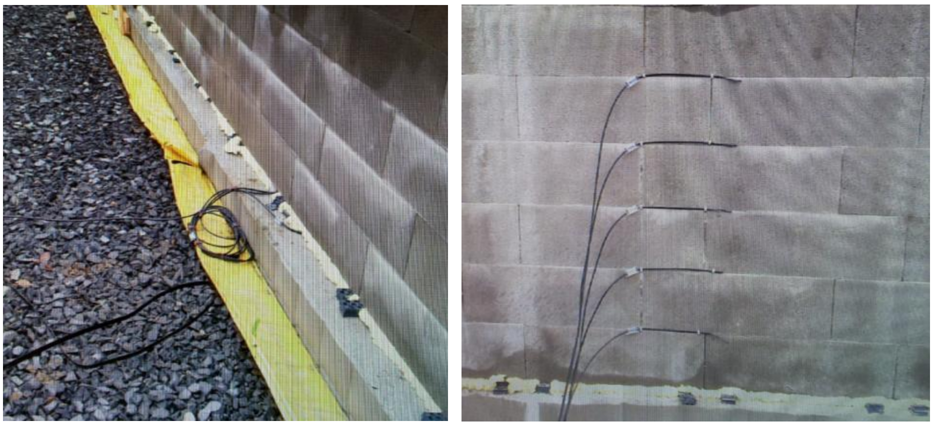
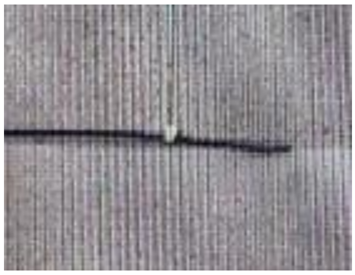

Fig. 8 Sensors in concrete house installed

The aim of the work is verifying numerical models with measured data and follow changes in material properties in the structures. This allows us to control temperature and relative humidity in the internal and external environment and also conditions inside of the structure. By this there is possible to predict mould growing in the houses in the future with high accuracy. The knowledge of thermal and humidity features of the structures can be then apply for analyzing of future structures to improve their energy efficiency.

Fig. 9 Sensors in wooden house installed

8. Conclusion

The numerical models simulated corners of external vertical walls of wooden and concrete block low-energy houses located in Oulu/Finland are presented. The thermal conditions of the structures are observed. Heat and moisture analysis is performed to obtain required quantities for applying mould growth risk model.

From the point of view of thermal features of presented structures the wooden analysed corner between two vertical exterior walls achieves lower thermal bridge value in 12,2% against the concrete blocks' corner. Considering the whole structures and their thermal properties the differences are insignificant and the results do not lead to single-value decision of more efficiency from the point of view of energy consumption.

The defined structures' exterior corners were subjected to heat and moisture transfer simulation following by mould growth risk analysis. The analysis was performed for two years period based on boundary conditions in weather station at the Oulu University of Applied Sciences obtained. The

structures were observed by temperature and relative humidity conditions in 9 points in concrete blocks structure and in 12 points within the frame of wooden house exterior corner. The obtained results do not show mould growth risk in any analysed point on or inside of the structure. Based on the performed analysis we assume the structures are safe from the point of view of mould in the analysed period.
The numerical models of the defined structures will be verified with data from measuring obtained which is currently in progress. With verified numerical models will be then possible to control any part of the buildings and by this to predict eventual problem and damages with high accuracy.
The differences between wooden and concrete structures in obtained results are neglecting so there cannot be specified definite decision which of the structures is more efficient from the point of view of energy consumption or mould growth risk. Within the frame of analysed structures the results achieved satisfying values in thermal and humidity conditions and the final decision of the most suitable load-bearing material depends on investors' taste.

9. Acknowledgements

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Green rating systems: an adoption of sharing layer concept

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Summary

The idea of the visualization of a building as six shared layers: Site, Structure, Skin, Services, Space and Stuff, each reflecting their different lifetime scales and subsequently, their different environmental damages. The division of the building to six-layer concept will result in more reliable green points allocation with accordance to the Israeli Green Building Standard, SBTool and LEED, is presented.

Keywords: Standardization, green building, sharing layer concept

1. Introduction

Since 1980 much interest has been devoted to decreasing building-related environmental impacts and promoting sustainable building-related activities. In general, rating systems have quite similar sustainable categories such as site, energy, water, materials, emissions, management, etc. Each category commonly includes together both credits for the site and structure that have long timescale influence as well as credits for the serving systems that have short timescale. Horvat and Fazio [1] suggested that “The relations between separate sub-systems within a building, and of the building itself with its surroundings is rarely linear. The performance assessing method needs to reflect that complexity”.

Shaviv [2] claimed "Energy efficiency in buildings, according to LEED can be achieved only by improving the mechanical, electrical and hot water systems. There is no need to improve the architectural design from bio-climatic and passive solar aspects." She stated that "The fact that all energy saving features are put in one basket...leads to the present situation". Moreover, "as the life expectancy of a building in Israel is about 50 to 100 years and that of the building systems is about 15 to 20 years only, the requirements for these two groups of the energy sub-categories should differ..." [3]. Therefore, she suggested dividing the energy category to two subcategories: Building energy performance and Building services systems. The separation procedure, which was initiated by Shaviv, is already embedded in the recent revision of SI 5281 [4].

In this respect it is appropriate to introduce “shearing layers” concept invented by architect Frank Duffy. The shearing layers concept separates a whole building into six layers [5]. The layers are: site (timescale: eternal), structure - the foundation and load-bearing elements (timescale: from fifty to three hundred years), skin - exterior surfaces (timescale: twenty to fifty years), services - communications wiring, electrical wiring, plumbing, fire sprinkler systems, HVAC, elevators and escalators (timescale: from ten to twenty years), space plan – interior walls, ceilings, floors, and doors (timescale: three to ten years) and stuff - chairs, desks, phones, pictures; kitchen appliances, lamps, hairbrushes (timescale: from daily to monthly).

This paper suggests adoption of the shearing layers concept to the green rating system. The idea of visualization of the building as six layers is due to their different timescales and consequently, due to their different environmental damages as well. Such a separation will allow allocating points to each sustainable building-related activities with an objective criterion of the life expectancy and the environmental damages. The paper will present how such a separation can be adopted to all subjects in each category of the Israeli Green Building Standard, in LEED, and in SBTool and how points could be allocated more objectively, based on such a separation that considers the timescale of each design parameter. In this study all examples are taken from: SI 5281 Part 3 for office buildings, LEED 2009 for New Construction & Major Renovations [6], and SBTool [7] average variant (focused the following variants of SBTool: Energy and Emission, Indoor Environmental Quality, Site Regeneration, Urban Design and Infrastructure, Social and Perceptual and Residential design issues, Design phase).

As consequence of rapidly developing of science and technology, the Standard Institution of Israel recognized the need for new revision of the Israeli Green Building Standard every three to five years period. The authors will propose the study of the adoption of sharing layer concept as an important point to consider for the further development of the Israeli SI 5281.

2. The Energy category of the Israeli Green Building Standard

Launched in 2005, SI 5281 was the first version of the Israeli rating system offering building sustainability. In 2011 the second version of SI 5281 was available [4]. The essence of the revised SI 5281 is to undertake various sustainable activities within nine environmental categories: energy, site, water, materials, health and wellbeing, waste, transport, and management and innovation. SI 5281 already has a separate approach for allocating points associated with the energy category (building and services sub-categories). In this paper the sharing layers concept was adapted to all environmental categories of SI 5281 while the separation procedure itself is explained in the Energy category.

Credits with their maximum of available points in the sub-category “Building”, were relocated to the relevant sharing layers. The Passive heating and cooling (1.1.1 Bioclimatic Design - Passive heating credit) intends to determine bio-climatic design strategies, ensuring natural ventilation of the building, and applying passive heating and cooling techniques. Design strategies for natural ventilation and passive heating and cooling techniques mostly depend on the design of the building skin, in addition to the building structural design [4]. Therefore, the points of 1.1.1 Bioclimatic Design - Passive heating and cooling were divided between Skin (3pt) and Structure (1pt).

The credit 1.1.2 Bioclimatic Design - Sun and shade (7pt) intends to maintain the solar rights of the planned project and of the buildings and open areas in its close environment. Thus, the credit was relocated under the Site sharing layer.

The Energy Efficiency (1.1.3 Energy Efficiency according to SI 5282 [8]) intends to achieve savings in energy consumption required for heating and cooling of the building, by designing the building as energy conscious one. Energy conscious building strategies mostly depend on the design of the building skin (insulation of the envelope, window size, type of glazing and shading of them, building thermal mass and night ventilation for passive cooling), as well as the design of the building’s structure (including the thermal mass of the structure, building geometry, compactness and proportions and window orientation) [3]. Therefore, the points of the credit were divided between Skin (13pt) and Structure (8pt).

The credit 1.1.4 Daylighting of public indoor areas (1pt) intends “to reduce energy for electric lighting in all public communal indoor spaces that are in daily use, like lobbies, stairways, etc.” [4]. The issue requires a certain minimum window area as 3% of the floor area of these spaces. Thus, the credit was relocated under the Skin sharing layer.

As the number of the total points allocated to the sub category 1.1 "Building energy performance" are 21, while all points allocated to all subjects summarized to 33, therefore, each point mentioned above in this sub-category should be corrected by a factor of 21/33.

All credits and their maximum available points of the sub-category “Services” such as: 1.2.1 Energy Lighting Performance (8pt), 1.2.2 Water Heating (1pt), 1.2.3 On-site Renewable Energy (2pt), 1.2.4

HVAC systems (6pt), 1.2.5 Sub-metering and control (1.5pt), 1.2.6 BEMS, Building Energy Management Systems (3pt), 1.2.7 Internal transportation systems (1.5pt), 1.2.8 Energy Efficient IT Solutions (0.75pt) were relocated under the Services layer due to the same expected timescale (from ten to twenty years) of these systems and appliances. Again, as the number of the total points allocated to the sub-category 1.2 "Services" are 16, while all points allocated to all subjects summarized to 23.75, therefore, each point in this sub-category should be corrected by a factor of 16/23.75.

In the same way the points of each category were allocated to the six shared layers.

3. Rating systems and tools

The sharing layer concept was applied to three systems, IS 5281, SBTool average variant, and LEED and the obtained results were compared. SI 5281 has nine environmental categories: energy, site, water, materials, health and wellbeing, waste, transport, management and innovation. SBTool average variant (design phase) evaluates seven issues: site regeneration and development, urban design and infrastructure; energy and resource consumption; environmental loadings; indoor environmental quality; service quality; social, cultural and perceptual aspects; cost and economic aspects. LEED estimates seven categories: sustainable site, water efficiency, energy and atmosphere, material and resources, indoor environmental quality, innovation and design process, regional priority credits.

To perform comparison of a sharing layer adoption to SI 5281, SBTool, and LEED systems, the credits and their relevant points of the systems were relocated to several generic sustainability categories that best represents their intent: energy, sustainable site, water, materials, health and wellbeing (H&WB), construction site management and innovations. It should be noted the LEED system has 110 points in total, while SI 5281 and SBTool are designed on a 100 points scale. Therefore the LEED points were standardized by a 100% scale. The results of a sharing layer adoption to SI 5281, SBTool, and LEED systems are presented in Fig. 1 – Fig. 4.

Analyzing the total percentages of Building and System layers, by summing all environmental categories (Fig. 1), SI 5281, SBTool (average variant) and LEED systems use different approaches for emphasizing importance of each of six building layers: SI 5281 focuses on importance of Building layers (Site, Structure and Skin) with a long timescale (from eternal to fifty years) and offers 60% of points to be achieved under these layers. SBTool (average variant) gives the same priority to both, Building layers (50% of points) and Service Layers (50% of points). Eventually, LEED focuses on the Service layers (Services, Space plan and Stuff) with a short timescale (from twenty years to daily) and gives 66% of points to these layers.

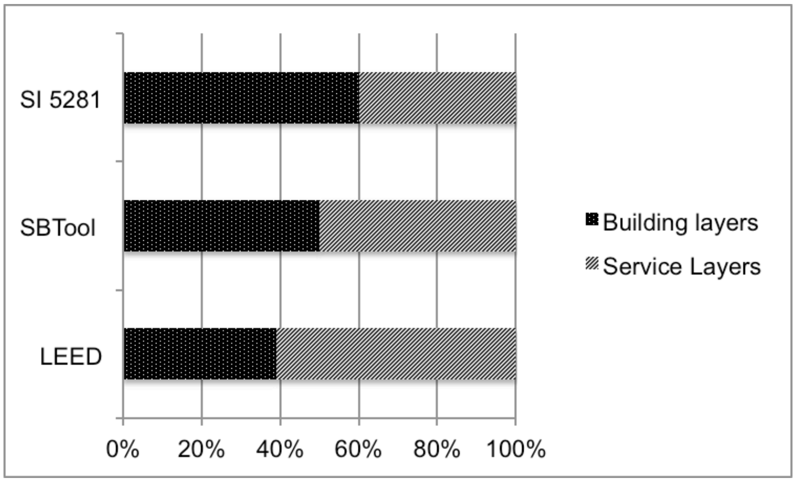

Fig. 1 SI 5281, SBTool (average variant), and LEED: Building layers vs. Service layers

Nevertheless it should be noted, SBTool variant focused on site regeneration, urban design and infrastructure (Site) issues devotes more attention to Building layers (59% of points), while SBTool variant focused on energy and emission (Energy) issues gives a little more priority (53% of points) to Service layers (Fig. 2).

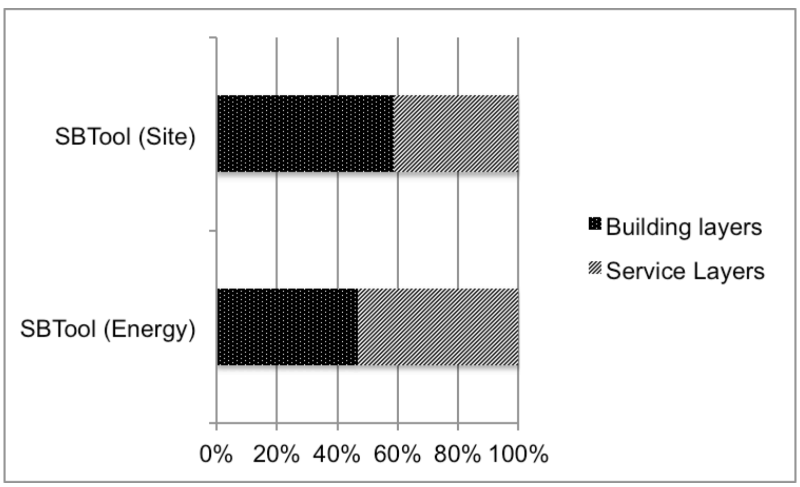

Fig. 2 SBTool focused on site and SBTool variant focused on energy: Building layers vs. System layers

While analyzing Building layers allowable percentages per each environmental category (Fig. 3), all systems pay much attention to sustainable site category. In addition, H&WB category is more significant for 5281 and SBTool (average variant) than for LEED system. Somewhat dissimilar attention deserve to site management, material and innovation categories: site management category has evident consideration in SI 5281 systems in contrast to both LEED and SBTool (average variant), while in material and innovation categories LEED and SBTool (average variant) implement better than SI 5281. However, SI 5281 in contrast to LEED and SBTool (average variant) considers energy and water categories as significant issues for Building layers.

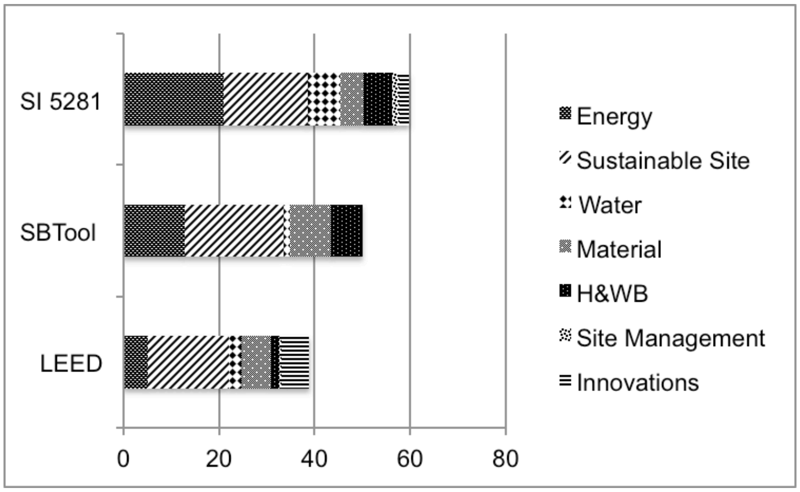

Fig. 3 SI 5281, SBTool (average variant), and LEED: Building layers by environmental category

While analyzing System layers allowable percentages per each environmental category (Fig. 4), all systems devote large importance to energy category. Also water category is meaningful issue for all systems. Slightly different consideration takes place in material, site management and innovation categories: in material category LEED and SI 5281 perform better than SBTool (average variant), while site management and innovation categories have certain attention in both SI 5281 and LEED systems. However, LEED in difference with SI 5281 and SBTool (average variant) considers sustainable site H&WB categories as important issue for System layers.

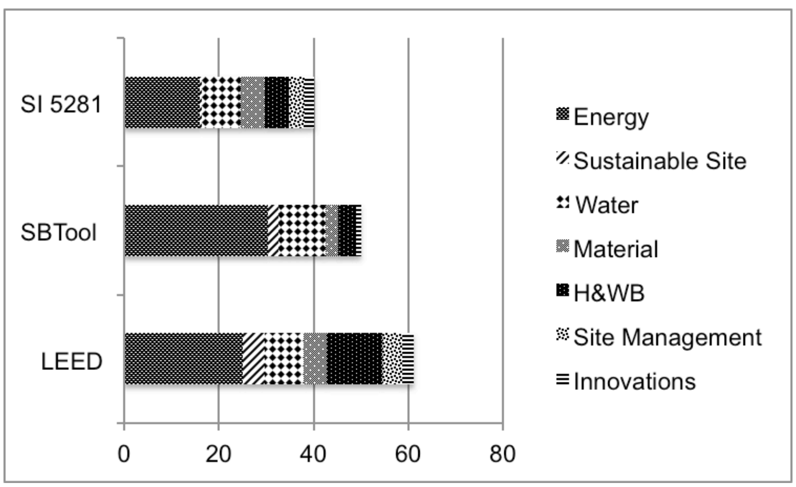

Fig. 4 SI 5281, SBTool (average variant), and LEED: Service layers by environmental category

4. Discussions

In order to fulfill the promise that Green Buildings will be designed as truly sustainable buildings, the adoption of a sharing layer concept to the Green rating system was suggested. Allocating points to each sustainable building-related activity with the objective criterion of the life expectancy and the environmental damages, the SI 5281 rating system was reshaped with accordance to the idea of visualization of the building as six sharing layers: Site, Structure, Skin, Services, Space and Stuff reflecting the different lifetime scales associated with them.

Furthermore, SI 5281 was compared with SBTool (average variant) and LEED, and these were also reshaped with accordance to the sharing layer concept. It was concluded that the current version of the LEED rating system is mostly out of compliance with the sharing layer concept. The system is not considers energy, water, and H&WB as important issues for Building layers. SBTool (average variant) adjusted better to the sharing layer concept. However the tool gives a little attention to energy and water categories within Building layers.

In contrast, SI 5281 is already on the road toward the application of the sharing layer concept, with only minor corrections to be suggested for the further development of the Israeli SI 5281 in the Structure and Services layers within the categories: material, site management, and innovation.

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Energetic life cycle cost of energy efficient building: French case studies

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Summary

This article presents an energetic life cycle cost analysis of four new French energy efficient buildings. As uncertainty is one of the main barriers to the spread of life cycle cost assessment, we narrowed the analysis to energetic performances and tested the sensitivity to the main parameters in order to increase the knowledge on the method's uncertainty. Although this type of analysis should be done on a larger number of buildings, first results seem to suggest that energetic life cycle cost does not depend on the type of energy used –electricity or gas- for French case studies but the cost distribution is different. Besides, parameters characterizing the investor –actualization rate and time horizon- are the most sensitive: a 50% shift for those parameters can lead to a 30% variation of energetic life cycle cost.

Keywords: life cycle cost, sensitivity analysis, energy efficient building

1. Introduction

Since the implementation of the first measures for energy saving and climate preservation, the building's energy efficiency is becoming a core issue in the climate and energy policy orientations, at the worldwide, European, national or local level. Indeed, this sector represents a large potential for energy savings and CO_2 emissions in the perspective of the implementation of cost effective measures.

The European Union set up three major directives during the last twenty years aiming at encouraging the Member States to apply minimal requirements on energy performance for the new and existing buildings. The Member States transposed these directives in national law by setting up action plans in order to achieve reducing targets in energy consumptions and GHG emissions.

In France, within the framework of environmental regulation (called the "Grenelle for environment"), a "Grenelle Building Plan" was created with the goal to cut down by 38% the energy consumption to 2020 in existing buildings and by 50% the GHG emission to 2050. Besides, a new regulation was set up for new buildings. From the 1st of January 2013, new buildings will have to consume about half the consumption of previous buildings for the five basic uses: heating, cooling, hot water, lighting and ventilation.
Due to the increase in energy prices, the interest of the building sector to life cycle cost analysis has highly increased in recent years. This cost approach integrates all future expenses in order to help the decision making process at the moment of conception. As energy is concerned, Lice cycle cost analysis are often made to study the profitability of an overinvestment leading to better energy performances [1] [2]. It can also be used to assess the green value potential of efficient buildings [3] as hedonistic studies can lead to high differences in estimation (see analysis of [4] [5] using the

same database) or to assess the optimal level of energetic performances according to current additional costs [6] [7].

The aim of this paper is to clearly establish a life cycle cost for four energy efficient buildings and assess the impact of hypotheses with a high uncertainty on life cycle cost analysis. The methodology developed in this paper will then be used to compare the different combinations of technical solutions often used in energy efficient buildings.

2. Methodology

The theoretical aspects of this approach in the building sector are discussed since several decades [8] and are clearly described in the French norm ISO 15686-5 [9]. But this type of reasoning struggles to spread amongst professional of the building sector. One of the major barriers seems to be its high uncertainty. In fact, many expenses will happen in the future and are sometimes difficult to forecast. Besides, life cycle cost analysis depends greatly on the inflation hypothesis and on the actualization rate of the investor, and those hypotheses are hard to estimate precisely. Our aim is then to set a clear baseline scenario, evaluate the energetic life cycle cost for our case studies and check the sensitivity of our analysis to the five main hypotheses and parameters.

2.1 Case studies

The four case studies were chosen on five main criteria. First criteria, they had to have a high energy efficiency, which means that they had to get a BBC label. In a nutshell, the BBC label characterizes buildings that consume less than 50 kWh of primary energy per square meter per year for the five standard uses, according to the regulatory energy consumption estimation software. Second criteria, they had to be built since no more than three years to be comparable, but since more than a year in order to get proper data for maintenance cost. Third criteria, they had to be reproducible, which means they were not using prototypical technologies. Fourth criteria, they had to be different from one another. On our four case studies, two are offices and two are collective housings. For each category, one building uses electricity as heating energy while the other one is using gas. And finally, the buildings had to be in the same climatic zone, which means they are exposed to similar climatic conditions.
Our four buildings are: a collective housing building, ten individual houses, an office building and a mixed activity building. For the mixed activity building, we only took into account the office part, as the other part is a warehouse with very specific activities.
The main characteristics of the buildings are presented in the table below:

type of building heating energy	office electricity	office gas	housing electricity	housing gas
construction year	2009	2010	2009	2011
surface (sqm)	891	600	1301	843
number of floors	2	2	4	2
estimated consumption (kWhep/m².an)	44	53	60	50

Table 1: main characteristics of the selected buildings

As the analysis highly depends on the selected buildings we also chose buildings that were roughly comparable in the sense of their size and their management. Our initial sample was composed of sixth buildings but one was too specific because of its size – about 10 000 sqm- and a second one was an office with very specific activities needing a specific thermal insulation.

2.2 The scope of life cycle cost

There are various definitions of life cycle cost analysis. According to the mission for quality of public construction gathering several ministries (MIQPC), there are three different level of life cycle cost analysis [10]. The first level is focused only on financial flows, the second level takes into account some externalities such as indoor air quality but the perimeter of this approach is only focused on the building. The last level has the wider scope and integrates other externalities as CO2 emissions or use of non-renewable resources. As there is currently a lot of uncertainty on the measurement of externalities such as indoor air quality or the impact of better working conditions on productivity, we chose to focus on the narrower definition of life cycle cost analysis, which is financial flows concerning the building. And as our methodology is strictly focused on energy performances, we only took into account expenses directly linked with this aspect.
We then took into account investment cost for energy efficiency, energy consumption, maintenance and replacement costs and the time spent by employees to control for the energy performances.
In investment costs, we took into account the cost of heating and cooling equipment, hot water equipment, ventilation system, wall, roof and floor insulation, and the additional cost of energy performances for windows.
For annual maintenance costs, we took into account the detailed maintenance cost for each equipment linked with energy performances. Those costs were provided by the building managers.
In our paper, we will not take into account the different taxes. Costs will be expressed in euros excluding taxes (€HT). Besides, life cycle cost will be expressed per square meter of floor space – sqm-.
In the remaining of this article, we will use the words life cycle cost or energetic life cycle costs to describe the evaluation described above.

2.3 Investment and maintenance costs

The building managers provided the detailed investment costs and the annual maintenance costs for each operation. Frequency and cost of additional maintenance, as example the change of a pump for a heat pump, were derived from discussion with contracting owners, CSTB internal material and literature [11].

2.4 Energy consumption

Energy consumption was provided by the building manager. The energetic consumption used for this life cycle cost estimation is based on the conventional consumption. Conventional consumption is an estimation of the future consumption for five standard uses: heating, cooling, hot water, lighting and ventilation. Those uses are the main uses directly impacted by the buildings performances. This estimation is made thanks to the regulatory software required by the authorities. The conventional consumption is only an estimate of the real consumption for those five uses but may differ from real consumption when the building is in use. But as it is conventional, this consumption does not depend on the way the building is occupied and the comparison between several buildings is easier.

2.5 Energy prices

Energy prices were derived using a national database developed by the ministry of Ecology called PEGASE. This database presents the evolution of energy prices for every type of actors and for every kind of contract. In France, gas and electricity prices are still regulated prices for the majority of customers [12] and do not depend on the type of production means. Additionally, competitors are basing their offers according to the regulated prices. Using a regulated price database seems therefore a good estimate to calibrate our estimation.
We chose June 2012 as the beginning of our baseline scenario. Therefore, every energy price at time zero is taken in June 2012.

French energy price is divided between a fixed cost associated with the type of energy contract and a variable cost depending on the amount of energy consumed. As the fixed part can play a major role in total energy price, especially if energy consumption is low, we took it into account. In our model energy cost is therefore composed of a fix price for each energy use and a variable price depending on the estimated building's energy consumption. The different types of contracts were identified according to the floor space of the building, the estimated consumption and the type of heating system.

2.6 Equipment lifespans

Lifespan hypotheses for every investment linked with energy performances are coming from the CEE card published by the Ministry of Ecology. Those cards provide lifespans for equipment and insulation action and are used in the frame of Energy Economy Certificates –CEE-. Those certificates quantify the amount of energy savings energy suppliers could benefit from in order to fulfill their obligations.

insulation action/equipment	lifespan (years)
insulation action	35
windows	35
collective thermal solar panels	20
individual thermal solar panels	15
heat pumps	16
individual condensing boiler	16
collective condensing boiler	21
heating floor	30
heat recovery ventilation system	16
mecanical ventilation	16
thermostatic control	12
radiators	25

Table 2: equipment lifespans according to CEE cards

2.7 Maintenance labour cost

The average maintenance labour cost is coming from the National Institute of Statistics and Economic Studies. This institute estimates labour costs for hundreds of workforce categories. In 2010, the labour cost for air conditioning and thermal equipment installation was 22 270 €/year.

2.8 Data characterizing the investor: Actualization rate

The actualization rate is a key parameter in a life cycle cost analysis. In our baseline scenario, the actualization rate is 4%. This is the current actualization rate for public investments, [13].

2.9 Data characterizing the investor: Time horizon

Time horizon of the investor represents the number of years that are taken into account in the analysis. The longer the time horizon is, the higher future expenses will be. In the CEE cards, life spans for equipment and thermal insulation are not higher than 35 years. We therefore choose the time horizon to be 35 years in our baseline scenario. Equipment's have in general a life span of about half this time horizon, while insulation actions last for about 35 years.

2.10 Inflation rates

Life cycle cost analysis depends greatly on different inflation rate hypotheses. Inflation rates of energy prices play a major role in life cycle cost estimations, but general inflation is also an important parameter.
For general inflation rate, we chose the long term target of the Central Bank of Europe, which is 2% per year. In our baseline scenario, the general inflation rate affects annual maintenance, additional maintenance and replacement costs and labor cost.
For fuel and gas long term inflation rates, we based our estimation on a 2011 International Energy Agency (IEA) report [14]. According to this study, the long term inflation rate for fuel prices is 2,79% per year, in constant euros. And the annual long term inflation rate for gas is 2,76%. With our hypothesis on general inflation rate, the annual inflation rates held in our baseline scenario are 4,79% for fuel and 4,76% for gas. Political decision regarding shale gas may have an impact on the inflation of gas prices but we are not qualify to estimate the extend of the impact.
As we do not have data on the different inflations for subscription and kWh prices, we will assume that they grow at the same rate. This assumption is very unlikely in a context of privatization of the energy sector but we do not have better estimates.
For electricity, we used a 2011 report published by the French Union of Electricity (UFE) [15]. This UFE report developed three scenarios on long term inflation for electricity according to the share of nuclear power in the electricity mix. As the middle scenario is based on a share of nuclear power which is consistent with the current goals of the government, we will use those hypotheses in our baseline scenario. In constant euro, annual inflation for electricity prices will be 2,55 % for enterprises and 2,05% for residents. And according to our hypothesis on general inflation, annual inflation rate for electricity prices will be 4,55% for enterprises and 4,05% for residents in our baseline scenario.

type of data/hypothesis	origin
actualisation rate	4%, actualisation rate for French public investments
lifetime horizon	35 years, the higher lifespan for equipment or insulation actions
investment cost	provided by building managers
annual maintenance cost	provided by building managers
Maintenance labour cost	22 270 €HT/men.year, National Institute of Statistics and Economic Studies (INSEE)
energy consumption	conventional consumption, independant from occupant behaviour
energy prices	fix price for subscription. Variable price: gas: 9,01 €HT/kWh for housings, 5,62 for offices. Electricity: 4,60 €HT/kWh for housings, 3,49 for offices. Regulated prices for primary energy (still largely used), PEGASE database
equipment lifespan	French Certificates of Energy Savings (white certificates)
additional maintenance cost and frequency and replacement cost	publication, internal material and discussion with building managers
energy inflation rate	gas: 2,76%/year. Electricity: 2,55%/year for offices, 2,05%/year for housings. Macroeconomic analysis reports, in constant euros
general inflation	2%/year, Central Bank of Europe's long term target

Table 2: summary of hypotheses and data

3. Results

Results are shown in the table below.

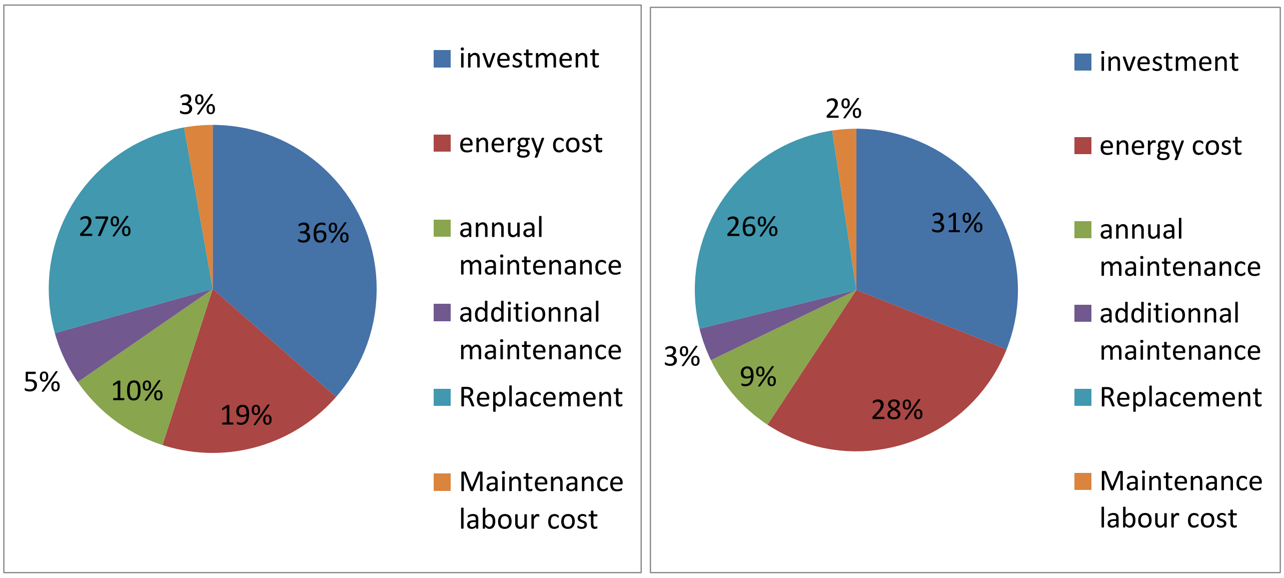
type of building heating energy	office electricity	office gas	housing electricity	housing gas
investment	255 €	218 €	281 €	247 €
energy cost	129 €	204 €	144 €	221 €
annual maintenance	88 €	64 €	65 €	64 €
additional maintenance	26 €	35 €	52 €	14 €
replacement	191 €	182 €	199 €	216 €
maintenance labour cost	19 €	29 €	22 €	7 €
TOTAL	**708 €**	**732 €**	**763 €**	**769 €**

Table 3: life cycle cost analysis of the four case studies (€/m² of floor space, excluding taxes)

Reading guide: the second building of our case studies is an office using gas as heating energy. Its whole energetic life cycle cost is 731 €/m², excluding taxes. Initial investment represent 218 €/m²; the cost of energy represents 204 €/m²; the annual maintenance represent 64 €/m²; the additional maintenance, such as the replacement of a pump on a boiler, represents 35 €/m²; the replacement cost represents 182 €/m²; and the time spent by the building manager’s team represent 29 €/m².

The average life cycle cost of our four case studies is 743 € per square meter of floor space, excluding taxes. As shown in table 1, the average variation from the average is 23 € HT per square meter of floor space. With our hypotheses, a first result of this analysis is that energetic life cycle cost is relatively independent from the use or the heating energy of a building. Energetic life cycle cost is a bit higher for housings -766 €HT/m²- than for offices -720 €HT/m²-.

The average energetic life cycle cost is 735 €HT/m² for buildings using electricity to produce heat, while it is 750 €HT/m² for buildings using gas. This small difference suggests that the type of energy chosen for the heating system does not play a major part in the overall energetic life cycle cost. But there is a difference in the cost repartition for those two types of buildings, as shown in figures 1 and 2. In fact, energy cost is more than 50% higher for buildings using gas as the heating energy rather than electricity. This 76 €/m² difference is mainly compensated with a lower investment cost -36 €/m²- and a lower average -15 €/m²- of the cost of maintenance, replacement and time spent to control the building. This difference might play a role in conception choices as the actors paying for the investment or the energy cost are not necessarily the same.



Figures 1 and 2: energetic life cycle cost distribution for buildings using electricity (left) and gas (right) as heating energy

The difference in cost distribution between electricity heated buildings and gas heated building can be explained by several factors. The French regulation for Building's energy consumption is using kWh of primary energy per square meter as unity of measurement. According to the official conversion ratios, a kWh of final energy for gas equals a kWh of primary energy, while a kWh of final energy for electricity equals 2.58 kWh of primary energy. This difference is steaming from the high heat losses to convert energy into electricity.

Consumption requirements are therefore harsher for electric buildings. In our sample, one of the buildings chose to use an expensive geothermal heat pump. The other uses a Canadian well and a highly efficient heat recovery ventilation system with convectors and had to increase the global insulation –tripled glazed windows, 30 cm of highly efficient lagging material for external wall insulation-. Besides, those highly technical combination of solutions have a higher maintenance cost.

On the other side, a condensing boiler, doubled glazed windows and a fairly good insulation – about 15 cm of lagging material for external wall insulation- are enough to reach the same level of performances in primary energy for gas heated buildings. This cheaper combination of technical solutions was in fact chosen by the two gas heated buildings.

On the other hand, energy cost in primary energy is cheaper for electricity heated buildings than gas heated buildings, and energy expenses are therefore much higher for gas heated buildings. This might be specific to France, as electricity price is about 30% lower than the European Union average [16].

4. Sensitivity analysis

As explained before, there is a high uncertainty in life cycle costs analyses. The uncertainty might come from several sources. Among them, the anticipation of the future plays a major role. To produce a life cycle cost analysis, future has to be predicted and maintenance cost, energy consumption, or energy prices have to be anticipated. And some of those key variables are highly uncertain. For example, the inflation of energy prices depends on major choices such as the place of nuclear power or the exploitation of new fossil fuels like schist gas, and the future answer to those questions is far from being clear at the moment. Future occupants' behavior and real energy consumption are also highly unpredictable. And there is a large debate on the actualization rate, which characterize the weight if the future for the investor.

We therefore chose to set a sensitivity test for the five main parameters of energetic life cycle cost analysis: energy price inflation, actualization rate, equipment lifespans, time horizon and real energy consumption. To produce this test, we increased or decreased each of those parameters by 50%. Results of the sensitivity test are presented in table 4.

	increase of 50% of a single factor	decrease of 50% of a single factor
energy prices inflation	11%	-7%
actualization rate	-21%	37%
equipment lifespan	-6%	16%
time horizon	27%	-29%
energy consumption	8%	-8%

Table 4: sensitivity analysis of energetic life cycle cost

Reading guide: If we increase the actualization rate of 50%, which means using a 6% actualization rate instead of a 4% actualization rate in the baseline scenario, the average life cycle cost of our four case studies will decrease by 21%. On the contrary, if we decrease the actualization rate by 50%, which means using a 2% actualization rate, the average life cycle cost will rise of 37%.

Actualization rate has a great impact on life cycle cost analysis and has to be defined precisely. With a higher actualization rate, the share of initial investment is larger as the investor cares less about the future. And with a 50% increase in actualization rate, buildings using gas as a heating energy have a lower life cycle cost than those using electricity, as investment is relatively lower for those buildings but energy costs, happening in the future, are higher.

Time horizon also has a deep impact on life cycle cost. It seems pretty natural, as more years taken into account brought more future expenses, increasing the life cycle cost and reducing the share of initial investment.

The impact of equipment lifespans is rather low, as an increase of 50% of the lifespans only reduces the life cycle cost by 6%. But equipment lifespans is the parameter with a high uncertainty, as no consensual database is set up yet.

Energy prices accounts for a large share of life cycle cost. Therefore, future inflation has a noticeable impact on life cycle cost, and an increase of 50% of energy prices inflation increases the life cycle cost by 11%. And as our case studies are energy efficient buildings, they are less sensitive to energy price inflation than common buildings.

Finally, a 50% rise in energy consumption increases the energetic life cycle cost of 8%.
A 50% shift in energy consumption or in energy inflation prices modifies the energetic life cycle cost of about 10%, while a 50% shift in parameters characterizing the investor have a much larger impact –about 30%-.

5. Conclusion

This paper presented a methodology to estimate the energetic life cycle cost of buildings, tested it on four case studies and set a sensitivity test to evaluate the impacts of changes in uncertain hypotheses.
This study is currently under prolongation, and we are willing to include a larger number of case studies to analyze the various technological combinations of solutions used to get high energy performances. The other aim of the prolongation is to specify contextual data –especially equipment lifespans- to reduce the uncertainty of life cycle cost analysis. In fact, according to interviewed contracting owners uncertainty is the main barrier to its massive development. Is it?

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Decision Making Pertaining to Sustainable Features of Building Design

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Summary

This paper presents methods by which the user may influence the sustainable features of a building during the design process. The presented methods are based on the idea that by using advanced modeling and calculation methods it is possible to produce information about important properties of buildings, and effectively generate alternative design solutions. Even though a lot of information exists and modern design softwares utilize building information modeling, the owner and the end user of the building only gain access to a very limited amount of information on the impacts of different design alternatives. The current practice requires that the client should be able to make decisions on the basis of sketch drawings and visualizations when a significant amount of information remains hidden. To achieve optimal solutions, all the relevant pieces of this hidden design data should be output in a form that can be understood by the client.

The problem is that the objectives of building design are typically non-commensurable. The common solution to this problem is that different quantities are converted to money to enable the comparison between different alternatives. However, if the comparison is performed on the basis of monetary values, the sustainable features of a building still remain hidden from the client.

In this study, multi-criteria optimization has been applied to generate alternative solutions where all the pre-set decision-making criteria are considered at the same time. By browsing the optimal solutions, the client can examine feasible values of a single criterion or find out the best compromise. At present, the main focus of the decision making seems to be on minimizing costs. By searching the design space with multi-criteria optimization, the optimal trade-off between monetary units and environmental measures can be found and used as a transparent basis for decision making.

Keywords: BIM, building design, decision making, multi-criteria optimization

1. Background

The European Parliament and the European Council defined in Decision No. 406/2009/EC their objective of reducing CO_2 emissions in Europe by 30 % by 2020 and by 50 % by 2050 compared to the 1990 level. The current view is that the energy consumption of residential and commercial buildings represents around 40 % of total final energy use in the EU member states. At the same time, it is responsible for 36 % of the total CO_2 emissions in the European Union. Thus, improvement of the energy efficiency of buildings offers great potential for significant energy savings and allows moving closer to sustainability. At present there is a large difference between the best and average practices in energy efficient building design and engineering [1, 2, 3], and new operational modes are needed to achieve the ambitious objectives regarding energy efficiency and sustainability.

Although energy efficiency is much talked about, it is only a part of the multiform problem field of decision-making in construction projects. Despite the fact that energy costs constitute a significant expense item from the viewpoint of life-cycle economy, and future pressures to raise rents can be restrained by improving energy efficiency, it would appear that energy efficiency nevertheless easily becomes overshadowed by other issues in planning. Thus, new type of planning process management will be needed to reach national and international energy-efficiency goals. It is widely acknowledged (e.g. [4, 5, 6, 7]) that the most important decisions are made, and the most significant commitments fixed, during the early stages of construction projects. During the pre-design phase the chances to impact are wide-ranging, but they tend to diminish abruptly later as the design process moves on.

At present, a common practice is that in the early design phases sketches are designed at minimum costs. The desired output is rather marketing material and cost estimation than a real comparison of different design alternatives. The prevailing practices do not lead to optimal solutions, and even if the end user or the owner of the building were interested in investing in sustainability, their possibilities of influencing on the final solution are inadequate.

During the design process, the room spaces are adapted to the needs of the end user. At present, one of the most important indicators for evaluating the quality of solutions is the amount of rentable area. All other features of a building may easily be compromised in order to save building costs. In general, a building is thought to be well-designed if it fulfills all official regulations. This kind of practice does not guarantee a sufficient level of sustainability and probably results in a final solution including unintended features. The features that are subject to the most significant improvements include maintenance costs, GHG emissions, energy consumption, life cycle costs, safety against structural damages, and quality of indoor air. Many of these features are linked to the concept of sustainability.

If the aim is to allow the end user or the owner of the building to make decisions pertaining to sustainability of the building, it is important be aware of that these decisions must be made already in the beginning of the design process. Designers are typically busy, and therefore any automation of the process is desirable. This can be performed by using parametric building information modeling. To enable finding the solution in each design case, it is important that the search space utilized in the modeling is large enough to contain all the feasible solutions. The comparison of different design alternatives does not require that all the design values are accurate, but it is enough that calculation process is able to provide reliable information on relations between different design alternatives.

When alternative solutions can be generated in an effective and economic way, the next step is to determine the criteria by which the quality of different solutions can be evaluated. Also sustainability should be included in those criteria. If the criteria are defined so that they can reliably and automatically be evaluated by computers, the proposed multi-criteria optimization techniques for design can be utilized. The multi-criteria optimization allows combining all the information in the search space and finding a set of *Pareto optimal* solutions. In the case of a Pareto optimal solution none of the criteria values can be enhanced without deteriorating at least one of the others, when moving from one feasible solution to another in the criteria space. Sustainable criteria of buildings have been applied in multi-criteria optimization for example in [8].

The purpose of this paper is to present an example of the design calculation environment utilizing multi-criteria optimization. Two test cases will be presented. The first case is concerning a single family house and the second one is concerning a large supermarket. The analyses were made using 4 to 5 criteria, and optimizations were performed using genetic algorithms. The conclusions are drawn on the basis of the examination of the criteria spaces.

2. Decision making during the design of a building

2.1 Early phase design

During the early phase design the main things to be decided are the appearance of the building and the number and area of spaces. In the case of single family houses, the client has a lot of alternatives and may be very actively involved in space planning. In other types of buildings, alternative solutions are usually created by the designer. To save costs the design of alternative solutions is performed only on sketch level. It is possible that a single alternative is selected quite quickly as the starting point of the design and a cost estimate is made only for that solution. The spaces may be reorganized later, but the form of the building can no longer be changed.

All the design work in the early phase is done at the risk of the investor. Therefore, design costs are kept at the minimum. This is despite the fact that important decisions on the features of the building are made in this phase. For example, the spans of the load bearing structures may be selected based on references without any calculations. A typical way of saving in design costs is to use same kinds of solutions that have been used before. However, changes on the market may have a significant effect on prices. For example, the prices of materials and products may have changed, the current production capacity may affect the delivery date, and the availably of professional building workers may be limited making prefabricated elements more competitive.

In some building projects important selections may have been made before the design has even started. For example, the materials of the building may have been selected without any cost comparison. Likewise, the orientation of the building to the cardinal points can be determined by the environment making it non-optimal from the point of view of energy consumption.

2.2 Design

There are three different ways for the client to take part in the decision making on building properties during the design process. The first one is the traditional method where the client sees only the end product. In the second and third cases the client can take part in the decision making.

A rental agreement for several years for at least 60 % of the spaces is usually required before the decision to realize a building can be made. Detailed design will not be started until this decision has been made. The main task of the designer is to ensure that the building is suitable for the planned use and meets all the regulations pertaining to the environment. The main idea of regulations is to ensure the safety of the building for both people and the environment. An example of that is the snow load, which the roof must be able to bear.

At the same time, the budget should be kept below the approved limit. This is difficult because architectural and engineering design programs do not have direct links to cost calculation. The price of the building must be estimated separately. The final investment cost is often established after getting tenders from constructors. If the price is higher than expected, something must be changed. As it is not desirable to reopen existing rental agreements, the only possibility is to eliminate something from the designed building to lower costs.

In the current practice, the role of the client in the design process is relatively small after the costs have been approved. From the perspective of the client, the design phase is a check list to ensure that all requirements have been met. The idea of check list approach is described in Figure 1.

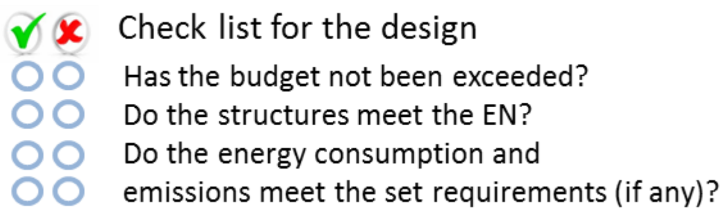

Fig. 1. Design based on check list.

To enable the client's participation in the decision making a sufficient amount of information is needed. The first task is to have methods and programs by which the current design could be analyzed interactively so that the effects of the changes can be seen. Otherwise, the possibilities to generate alternative solutions are limited by the design costs. If the design model should be transformed to a separate special program, which can be used only by a professional user, the analyzing is too expensive and slow before the actual detailed planning.

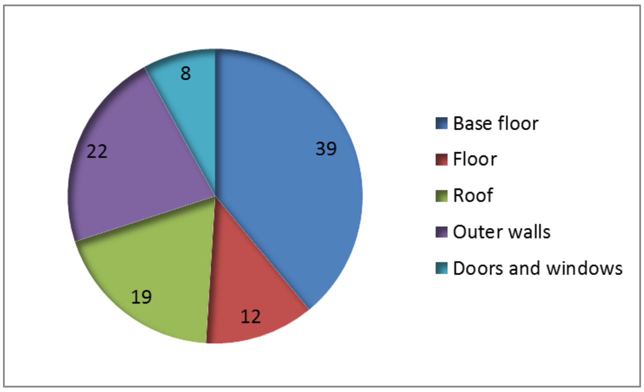

Fig. 2. An example of the breakdown of CO_2 emissions between building parts.

Automatic calculation cannot be as accurate as an analysis made by an engineer, but should be accurate enough to get reliable results. This kind of a calculation method is needed at least for energy consumption, emissions and structural behavior of buildings. For example, in cost calculation the problem is, how to link the design model to the cost database as automatically as possible. The real price lists must also be available. The output of these programs allows detecting the elements with the biggest impact on the final result. For example, Figure 2 shows how the global warming potential (CO_2 eq. emissions, calculated according to [9]) is divided between different building parts. The cost deviation from the initial value can also be presented in the same way.

The effective generation of alternatives requires using a parametric building information model. For example, it should be possible to quickly change materials, spans, building parts and their producers. Moreover, the properties of building parts should be editable. This enables, for example, calculating the effect of an increase in insulation thickness on the investment costs, life cycle costs, emissions and energy consumption.

The larger the group of alternative solutions, the more likely it is that the most promising alternative will be found. If automated calculation methods could be developed sufficiently, one single solution could be adopted as a basis of more detailed design. Yet, it is more realistic to think that decisions will always be made by a human and the role of computer programs is to provide suitable data for them.

Usually all criteria are compared to the costs. A comparison can be made to find out the most economical combination of building parts for realizing a building. From the client's point of view, the comparison can also be made between any feature and cost. The comparison requires that the cheapest way to reach a certain level of the feature has to be found in advance. This is not possible without calculating very many design alternatives. If a sufficient number of solutions can be analyzed, it is possible to draw a curve representing a given property against costs as presented in Figure 3.

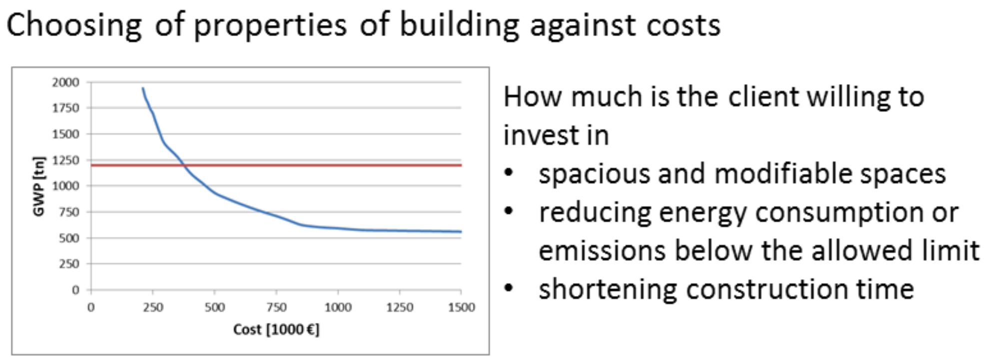

Fig. 3. An example of a curve presenting the relationship between investment costs and global warming potential of a building.

The calculation of life cycle cost is always more or less inaccurate because the development of prices and interest rates over the entire lifetime of buildings is unknown. Such calculations are needed because most of the costs of a building are incurred during the use phase. To simplify the life cycle calculation, some features of the building can be studied as a larger entity. For example, energy consumption can be considered as one variable in life cycle cost analysis without separately itemizing the consumption of heating and cooling energy.

If every feature of the building is in included in the calculation in its own unit of measurement without converting it into costs, the decision making becomes more complex. On the other hand, if only part of the features is included in the calculation process, it means that the rest of the features are assumed to be constants. In reality, most of the properties influence each other, and thus they should be examined simultaneously even if their units differ. Multi-criteria optimization techniques form a transparent basis for this. All the chosen criteria are minimized (or maximized) simultaneously and costs are only one criterion among others. Multi-criteria optimization produces a set of Pareto optimal solutions. This means that while moving from one solution to another, none of the criteria values can be enhanced without deteriorating at least one of the others. An example of what a Pareto curve could look like in a two-dimensional case can be seen in Figure 3. The visual representation method in Figure 4 allows the illustration of how four alternative Pareto optimal solutions differ from each other in terms of four different criteria. The figure should be interpreted so that the further the points are from the origin, the better the solution is.

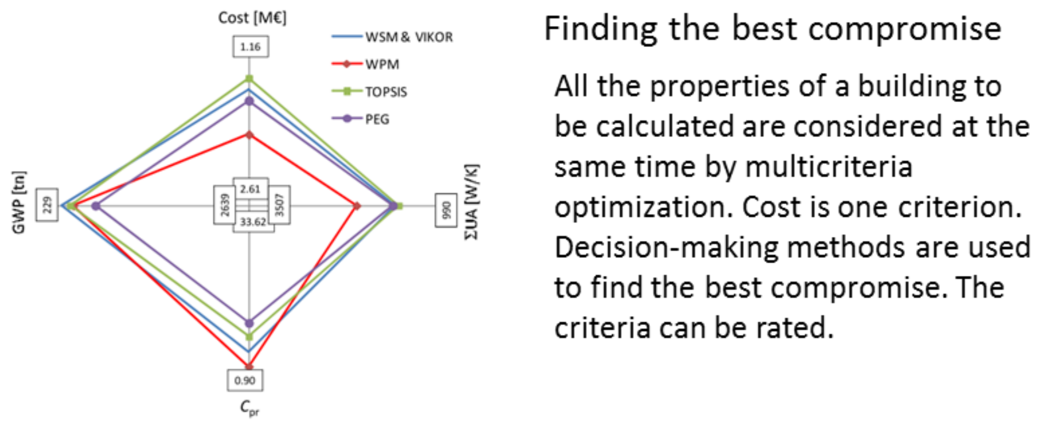

Fig. 4. An example of comparison of different solutions based on several criteria.

The found minimum and maximum values of criteria set the limits for feasible solutions. By a suitable program it is possible to arrange the solutions so that the effect of changing the value of one criterion on all the other criteria is easy to see. That allows examining the relationships between different features. Thereby, the criteria that could not be calculated mathematically can be added to the alternatives.

In this research a test environment to make optimization calculations was generated. The programming of the actual optimization calculation is not peculiarly time-consuming when a lot of ready-made programming libraries are available. A more challenging task is to determine methods to calculate the values that describe the features of the building. Non-linear structural analysis or energy consumption simulation of the building cannot be utilized because of the long calculation time of them. Instead, for example the right size of the cross-section of the beam can be selected from the pre-calculated tables. If calculation methods that are accurate and quick enough can be found, the optimization calculation can be realistically integrated to the planning process. In the planning process building information modeling (BIM) has a remarkable role in the effective generation of the input data.

When selecting the design alternative to be realized, the decision making methods might become useful. A comparison of six popular methods as well as an introduction to multi-criteria decision making can be found in [10]. Applying these methods to the decision making, enables the selection of the best compromise. The criteria can be weighted and, for example, costs can be given a dominant role. The decision making methods can also be applied without optimizations, as in [11].

2.3 Construction

Competitive bidding of constructors is often thought to minimize the investment cost. To win a deal, a constructor has to make several offers. The constructor also pays all the costs related to preparing the offers. They cannot afford a very detailed analysis to find out the cheapest solution for each offer. In fact, the best solution for the constructor is the one that provides the best margin. Thus, it is not certain that a process like this really reveals the best way to realize a building.

3. The test cases

3.1 Single-family house

Let's consider the rectangular single-family house in Figure 5. The preliminary design problem concerning such a house can be formulated as a multi-objective optimization problem with five criteria: construction work cost, construction material cost, construction materials' global warming potential, energy consumption, and client preferences. All of the criterion functions have relatively simple mathematical definitions (for details, see [12]). The evaluation of criteria related to sustainability, namely energy consumption and global warming potential, are based on standards [9] and [13], respectively. As soon as the design variables are known, the criterion values can be evaluated.

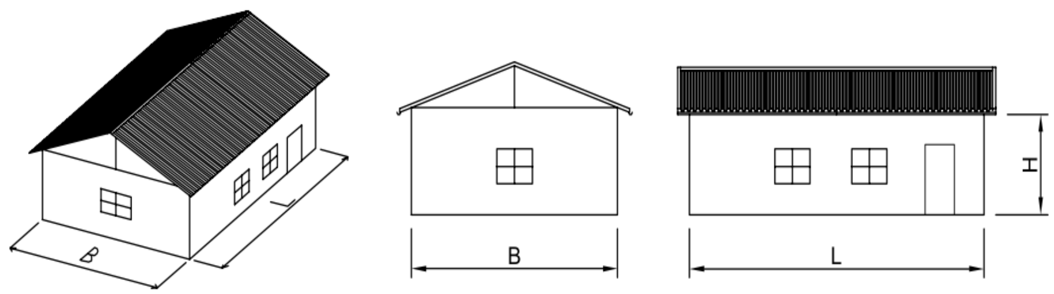

Fig. 5. Single-family house.

As a result, a set of Pareto optimal solutions is obtained which can be illustrated graphically. In Figure 6, the Pareto optima can be seen in the criterion subspace of construction costs and energy consumption. The front formed nearest the origin could be considered the Pareto curve for a two-criteria problem of cost and energy consumption. It depicts the conflict between the two criterion. The final choice depends on the client's preferences: whether he/she is willing to pay more for a more energy-efficient house, which is causing a smaller environmental impact.

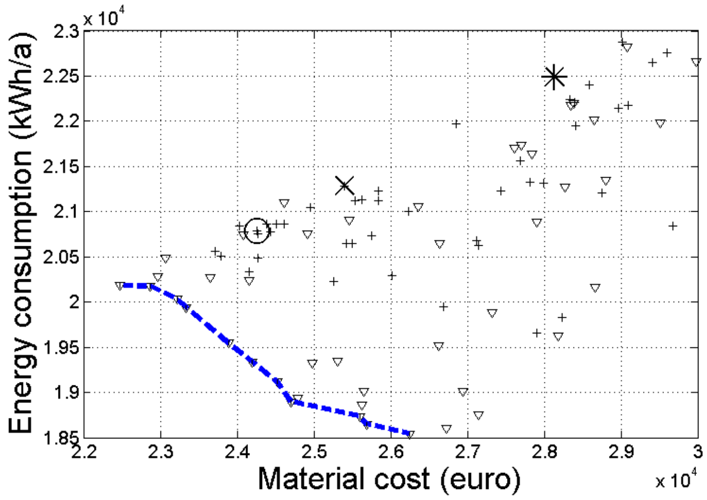

Fig. 6. Pareto curve of material cost vs. energy consumption. The other points are Pareto optimal for the five criteria problem.

3.2 Single-storey commercial building

Multi-criteria optimization was also applied to the single-storey commercial building in Figure 7. The design problem had four criteria: construction cost, energy consumption, GWP of construction materials and client preference (for details, see [8]). As seen in Figure 7, the search space included two different structural systems with different construction material options including typical steel, concrete and timber structures.

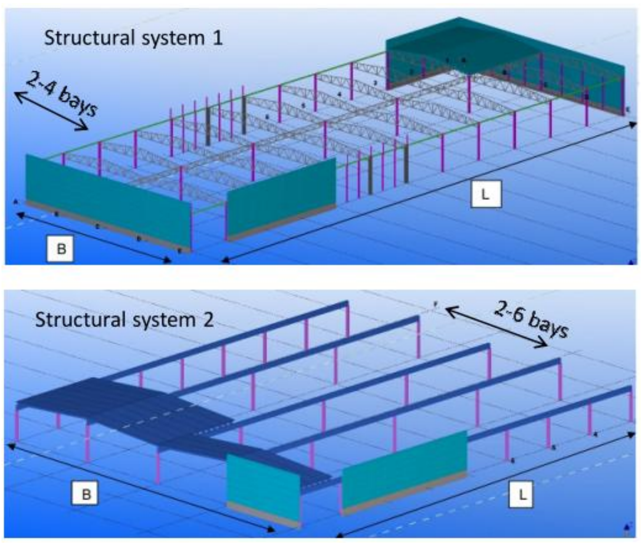

Fig. 7. Single-storey commercial building and two possible structural systems.

The results proved to be similar to the case of the single family house: there is a conflict between cost and environmental criteria. The illustration can be seen in Figure 8.

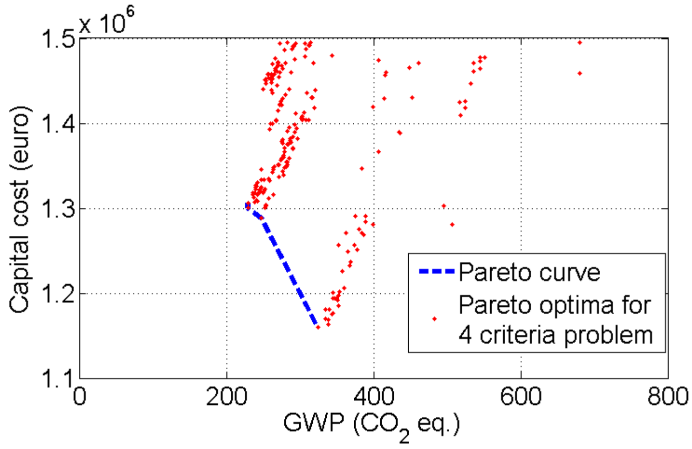

Fig. 8. Single-storey commercial building Pareto curves.

Of course, the measures of costs and environmental impacts could be different. For example, by aggregating the criteria with a suitable procedure it would be possible to form a two-criteria problem where the criteria would be life-cycle cost and life-cycle environmental impact (as in [14]). However, it is important to note that these design objectives are in conflict and the decision maker should be informed about it.

Discussion

To be able to apply the presented method to different design softwares considerable amount of recourses is needed. Nevertheless, the advantages of reducing routine design tasks and possibility of finding the best solution for the client could drive development towards this direction. Environmental authorities can also utilize the method, for example, to determine suitable limits for emissions.

The main problem with the presented methods is that many of the features of buildings are fixed during the early design phases. The authors propose an approach based on multi-criteria optimization. The approach enables the user to influence the design choices in the early stages. The approach was tested in the research environment with two test cases and was found usable. Despite the promising results, putting the approach to practice has a couple of obstacles. The first obstacle is that there are no existing software tools, and thus a certain amount of programming is needed to be able to implement the multi-objective optimization tool by using existing programs. The second obstacle is that the designer has to be familiar with the methods and their limitations. In order to make the proposed approach as a part of practical design process, an initial investment in both tools and training is needed.

Conclusions

This paper presents the principles of utilizing multi-criteria optimization to support decision-making in the early phases of building design. In the current practices of building design, the client has only inadequate information on the impacts of different design alternatives, and the main focus of decision-making seems to be on minimizing costs. By searching the design space with multi-criteria optimization, the optimal trade-off between monetary units and environmental measures can be found and used as a transparent basis for decision making. The approach significantly enhances client's possibilities to impact on the design process, which improves the probability of sustainable decisions.

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Improving Decision Making with Life Cycle Costing in Urban Development

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Summary

The battle against global warming questions our current urban development practices and challenges us to find improved methods and assessment tools. The initiative with this study is to compare different eco-efficient design solutions from a life cycle cost (LCC) perspective for an urban development. The urban development area subject to this research is situated in Tampere (Finland) and is approximately 190 000 m^2 according to the master plan design. This study was conducted by utilizing modelling and simulation programmes to attain an energy demand profile for the different design options of the urban area, after that, life cycle costing methodology was applied in order to gain a life cycle cost perspective. The evaluated design options (energy systems) were (1.) district heating (reference design), (2.) district heating with building integrated solar heat & power, (3.) ground source heat pump, and (4.) ground source heat pump with building integrated solar heat & power. The results indicate that the two most costly design alternatives are in fact the most life cycle affordable options, with a time period of 40 years with modest indexation and discounting rates. Additionally, by uncovering a design option with lower energy costs means lower energy consumption which promotes the environmental aspect of life cycle costing. Thus, by applying life cycle costing in an early design stage; valuable information for decision makers is revealed, information that illustrates the life cycle outcome of different eco-efficient design options. Life cycle costing (LCC) has to be taken into consideration when thoroughly developing sustainable urban areas in the future.

Keywords: Life Cycle Costing (LCC), Sustainable Urban Development, Energy-Efficient Design Solutions

1. Introduction

Decision-making in contemporary urban development is driven by economic figures and values, to be more precise, investment costs are accentuated. In most cases a life cycle perspective of alternative design options is not managed and utilized within decision-making, although, increase in sustainability has proved to add value during the life cycle [1, 2]. Urban development as a process has numerous stakeholders such as government, property owners, contractors, designers and users produce and share enormous amounts of information and have specific interests which make decision-making especially challenging [3].

The carbon challenge and its mitigation potential are strongly emphasized in present urban development. The existing building stock is accountable for approximately 40 % of the energy use and carbon emissions globally [4], of which the residential and commercial segments reduction ability is 29 %, in reference to baseline 2020 [5]. Thus, by combining existing knowledge and technology in urban development; energy demand and cost savings with a long term perspective is feasible [6].

By applying a life cycle perspective within urban development valuable information is attained which enables operational cost benefits to be assessed against initial (investment) cost decisions. If a life cycle perspective is neglected, the initial cost of different design alternatives remains the only economic criteria for decision-making which might lead to unaffordable decisions within a long-term perspective. By uncovering life cycle affordable design options in urban development lower operational cost levels are achieved, which represents a lower amount of energy purchased. According to a study made by McKinsey & Company [7] minor design changes have a payback-time close to zero for operational costs and correspondingly carbon emissions, therefore, significant savings during the operational phase can be achieved.

The initiative with this study is to examine the life cycle cost outcome of alternative energy system designs. The idea is to demonstrate that a life cycle cost approach can reveal valuable information for decision-making in developing sustainable urban areas in the future.

2. Research Methods

The research methods employed in this study was an urban energy simulation followed by life cycle costing. The results (energy demand) from the urban energy simulation were further used to create a life cycle costing model.

2.1 Energy Simulation

The energy simulation study was divided into three stages; building mass modelling, energy simulation and energy production simulation. For each stage it was essential to use specific computer based software and therefore use of individual software would not have been possible. The energy simulation research was conducted with Autodesk Revit Architecture 2012 [8], IDA Indoor Climate and Energy 4.2 (IDA ICE) [9] and Transient Systems Simulation Program [10].

The building designing was conducted with Autodesk Revit Architecture 2012. Revit Architecture is developed for 2D and 3D architectural designing and creating high quality architectural plans and documents [8]. In this research software was used in urban massing and to produce BIM models.

The urban energy demand analysis was conducted with IDA Indoor Climate and Energy 4.2 software. IDA ICE is innovative and reliable dynamic energy simulation software which can be used to analyze the indoor climate conditions and energy consumption of the building. The software is suitable for designing building geometry, structures, HVAC systems and internal and external loads. IDA ICE can import Industry Foundation Class -files (IFC) generated by Revit Architecture [9].

The renewable energy production analysis was conducted with Transient System Simulation Tool 17 (TRNSYS 17). TRNSYS 17 is a versatile and dynamic simulation tool for building and HVAC system modelling. The program includes TRNSYS 17 Simulation Studio tool which can be used to model renewable energy systems. [10]

2.2 Life Cycle Costing (LCC)

Life cycle costing (LCC) is an assessment method for comparing diverse building designs where investment costs are compared against operational costs in order to find the most life cycle affordable design alternative. The main idea is to cut operational costs from a life cycle perspective by applying a higher initial investment in the decision-making phase [11, 12]. A general definition of LCC is "a technique which enables comparative cost assessments to be made over a specified period of time; taking into account all relevant economic factors both in terms of initial costs and future operational costs" [13]. Flanagan [14] and Dell'Isola [15] has developed the LCC assessment method to include the following steps: (1.) Defining alternative strategies to be evaluated (functional and technical requirements), (2.) identifying relevant economic criteria (discount rate, analysis period, escalation rates, component replacement- and maintenance frequency), (3.) obtaining and grouping significant costs (in what phases and categories different costs occur) and (4.) performing a risk assessment (systematic sensitivity approach to reduce the overall uncertainty).

It is to be noted, that while LCC is not theoretically accurate, it uncovers a lot of benefits for the development process. The LCC analysis reveals which strategic (design) options to sincerely consider and obtain a deeper understanding. Through the LCC analysis a great deal of information is simplified to support decision-making from a life cycle perspective [11]. As an example, Eva Sterner [16] created a calculation model where LCC methodology is used to evaluate life cycle energy costs for buildings.

3. Research Process

The research methods employed in this study was an urban energy simulation followed by life cycle costing modelling. The results (energy demand) from the urban energy simulation were further used to create a life cycle costing model for the alternative design options. The research process is illustrated in Figure 1.

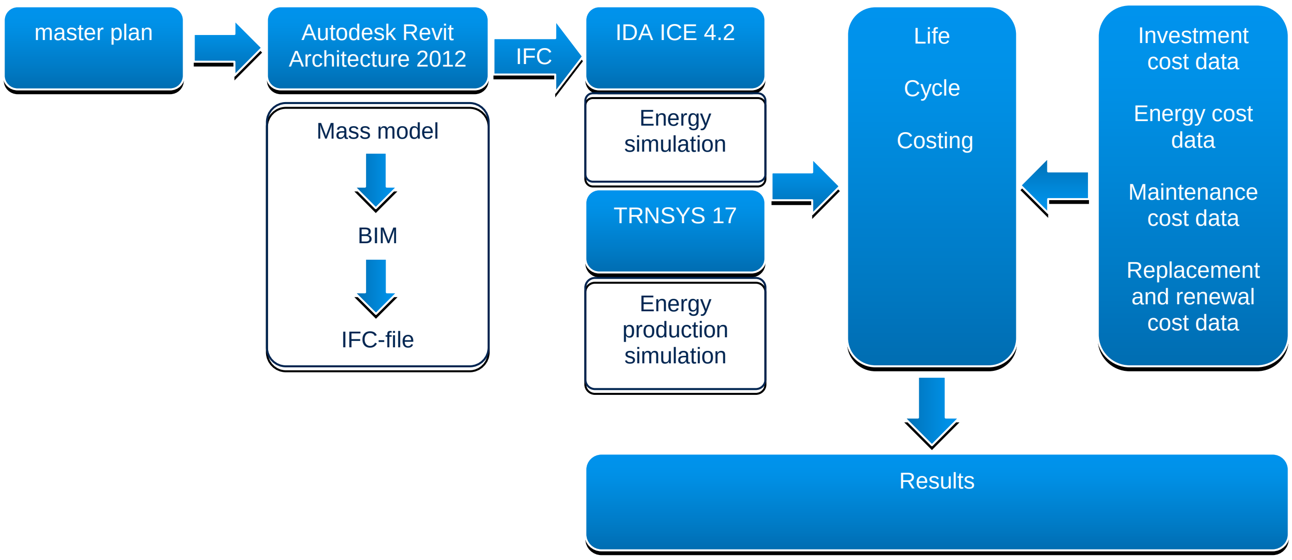


Fig. 1 Illustration of the research process

3.1 The Residential Development of Härmälänranta

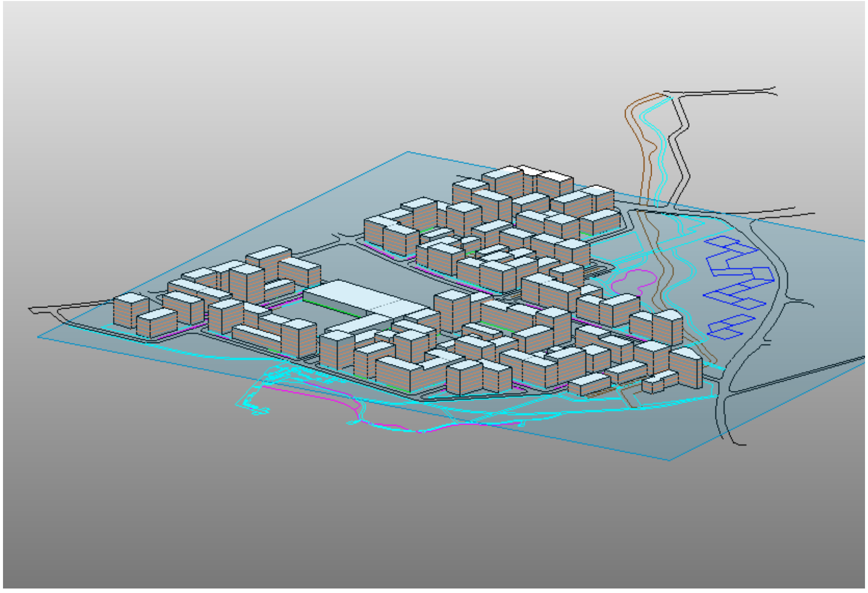
The residential development of Härmälänranta is located in Tampere, which is Finland's third largest city by population (approx. 211 000 citizens). The development site is situated about 5 km southwest from Tampere city centre with comprehensive public transport connections, for example, bus lines every 20 minutes. The residential development is divided in two phases which will be executed during the years 2007-2024. The second phase (2014-2024) of the development will be examined in this study and includes 15 residential blocks of approximately 190 000 m^2 (according to master plan). The area is designed for about 2000 apartments.

3.2 Energy Simulation

In the first stage, building mass modelling was conducted with Autodesk Revit Architecture 2012 software. An urban mass model was created which was used as a base for the building information model (BIM). The BIM model was further divided into 15 individual block specific BIM models in order to make interface possible with the energy simulation software. The models were converted to IFC file format which supports the energy simulation program.

In the second stage, energy simulation was conducted with IDA ICE 4.2 software. The block specific IFC files were imported into IDA ICE project to obtain fast and accurate building geometry in the energy simulation environment. An annual energy demand was simulated separately to each individual block. In the third stage, energy production simulation was conducted with Transient

Systems Simulation 17 software for solar heat and power system.



Picture 1 The building mass model of Härmälänranta

3.3 Life Cycle Costing

The energy simulation (chapter 3.2) provided data to construct a base scenario for LCC comparison. The following steps according to the LCC methodology [14, 15], is to define and design alternative design options to evaluate against the base scenario. The evaluated energy systems were (1.) district heating (base scenario), (2.) district heating with building integrated solar heat & power (10 %), (3.) ground source heat pump, and (4.) ground source heat pump with building integrated solar heat & power (10 %). Solar heat & power system consisted of 2000 m^2 solar collectors and 1500 m^2 PV modules, which produced 10% of the annual energy demand.

With the aim of completely executing a LCC model for these energy system designs, supplementary cost data was attained from the development company in terms of investment, maintenance, and replacement and renewal costs. The data used in the LCC modelling is presented in Table 1.

Table 1 Data used in the LCC model

Data category	Origin of data
Investment cost data	Cost estimation of the development company. For renewable energy sources the investment prices is acquired from the market.
Energy demand data	Comprehensive energy simulation of the urban area (see chapter 3.2).
Energy cost data	Local energy company for district heating and electricity (energy consumption and transfer costs) [17].
Renewable energy data	Investment costs (€/m^2), power generation, maintenance- and replacement costs were attained from design managers of the development company and literature source [18].

Maintenance cost data	Design managers representing the development company estimated maintenance costs (€/a).
Replacement and renewal cost data	Design managers representing the development company estimated replacement and renewal intervals and costs.

The following measure was to identify relevant economic criteria such as evaluation period, indexation- and discount rates. When applying these criteria it is important to understand what affect these parameters have to the LCC model. Still, including these economic parameters are essential in order to compare the different design options in a net present value context. If the indexation- and discount rates are given far too excessive values they can distort the LCC assessment results. Thus, a precautionary principle is utilized and these rates set to reflect a macro-economic stable outlook; indexation rate is set to 2.00 % (ECB inflation target [19]) and discount rate is aligned to 2.60 % (Finland's 10 year government bond [20]). The evaluation period for the LCC assessment is set to 40 years to reflect a buildings life cycle before major renovations are needed.

All the attained data is accordingly placed in a life cycle framework so that different measures are combined with the correct execution year and the indexation- and discount rates provide the life cycle perspective. Afterwards a systematic sensitivity analysis is performed to reduce the overall uncertainty of the LCC model.

4. Results

The results reveal that within the evaluation period of 40 years the two most costly design alternatives in the investment phase turns out to be the most affordable from a life cycle perspective. All the comparable design options obtain an individual distinct cost trend for the life cycle which intersects with each other during the first 10 years. During the first four years, the base scenario (1. District heating) is the most affordable options due to the lowest investment costs. At year 5, option 3. (Ground source heat pump) obtains life cycle affordability, and maintains it until the end of the evaluation period. The cumulative life cycle costs of the different design options are presented in figure 2 and net present cost (NPV) of different options are shown in table 2.

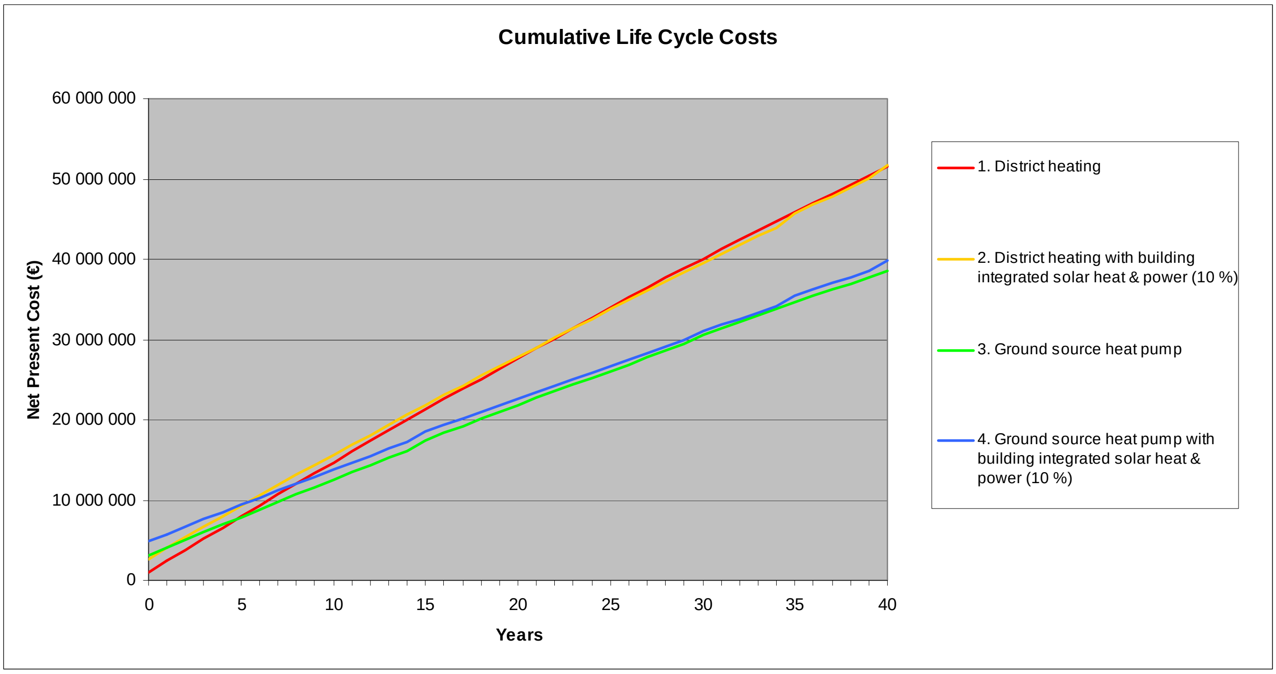


Fig. 2 Life cycle costs of the different design options

Table 2 Net Present Cost of different options

Net Present Cost (€)	Option 1. District heating	Option 2. District heating with solar heat & power	Option 3. Ground source heat pump	Option 4. Ground source heat pump with solar heat & power
Investment cost	956 593 €	2 682 497 €	3 104 160 €	4 830 064 €
Energy cost	49 887 597 €	46 831 045 €	33 716 821 €	31 877 289 €
Maintenance cost	540 732 €	697 544 €	793 073 €	949 885 €
Periodic replacement cost	197 041 €	1 419 109 €	889 531 €	2 111 600 €
TOTAL	51 581 962 €	51 630 195 €	38 503 586 €	39 768 838 €
Tot. NPC/m^2/a	6.72 €	6.73 €	5.02 €	5.18 €

Figure 2 illustrates how the design alternatives (options 2. and 4.) perform during the evaluation period. It is clear that the integrated solar heat & power technologies struggle for life cycle affordability due to heavier maintenance and replacement schedules. Option 2. (District heating with solar heat & power) acquires life cycle affordability against (option 1.) at year 23, whilst option 4. (Ground source heat pump with building integrated solar heat & power) never attains life cycle affordability against option 3. Furthermore, it is to be noted that these LCC results were acquired with chosen economic parameters (indexation 2.00 %, discount rate 2.60 %).

4.1 Risk and Sensitivity Analysis

When employing LCC, risk and sensitivity analysis are to be undertaken, according to ISO 15686-1 standard methodology [13]. By examining the affects of economic criteria a complete behaviour understanding of the model is achieved. The key parameters explored in this case are future energy escalation (indexation) and the discount rate.

Sensitivity analysis was performed by examining boundary values (in annual energy price escalation) when positions between the comparable options change. According to the results, option 3. (Ground source heat pump) acquires the life cycle affordable position year 5. Thus, in order for option 3 to reach life cycle affordability at year 4 the indexation has to be 6.46 % per year, and respectively year 7 the indexation would be -1.69 % (negative) per year. This indicates that the model is fairly stable to energy price adjustments (~+/- 4.0 %/a). As a supplementary procedure, a buffer area was created by adjusting the indexation to 8 % and discount rate to 0 % and vice versa. In this way, extreme future conditions were charted along with their affects to the outcome.

Naturally, when portraying the future there are multiple risks to be considered. For instance, the sufficiency (content and costs) of the energy options life cycle performance information (maintenance and periodic replacement etc.). Furthermore, production- and cost efficiency of renewable energy systems will probably develop rapidly in the future [21], which raises the question; why invest in renewable energy today when it is most likely even more profitable tomorrow.

4.2 Validity

Validity of the energy simulation study was highly dependent on the simulation software. IDA ICE has performed a number of standardized tests to ensure its quality and it is considered to be a reliable tool for building energy simulation [9]. TRNSYS 17 has been utilized in number of scientific researches that have been published in well-respected journals [10]. The energy simulation study is also dependent on the input data used in the simulations and user operation of the software. In order to eliminate errors made in the energy simulation study, reliability analyses were conducted during the simulations.

Validity of the LCC analysis is associated with the exploited input data. The origin of the data is presented in table 1. In terms of research set up, the data is relatively valid. It is also important to understand that the LCC process is the actual analysis and the urban energy demand simulation is a significant part of the input data. Moreover, it is substantial to mention that the absolute results of the LCC analysis are affected by the chosen economic criteria (indexation and discount rates) and access to reliable data [12].

5. Discussion

In this particular case, the relation between the initial investments and life cycle outcome of the comparable options are different. By making a greater investment in the beginning, significantly lower life cycle costs are obtained. In this case lower life cycle costs means a decreased amount of energy procured, thus, environmental emissions are reduced [7]. UNEP 2007 [4] states that 90 % of the energy demand in developing countries for the building sector is derived from residential buildings, hence, it is obvious where the focus should be in decreasing energy use (costs and emissions).

The results indicate that the renewable energy options (option 2. and 4.) have a relatively long payback time. From an investment payback point of view; the option seems unviable to invest in, from a user perspective. A study done by Emiel van der Maaten [22] insinuates that the majority (38 %) of homeowners want to postpone their investment in renewable energy because they assume that technology will improve. In the future, it appears, that production- and cost-efficiency of renewable technology will develop rapidly, thus, improving future prospects for renewable energy options [21].

Taking into account future prospects of energy-efficient construction and the development of building regulation it is clear that energy demand for buildings will decrease. This means that costs in the operational phase will decrease and the balance between initial investment and operational costs will change. As buildings become more energy-efficient, the demand for investigating plausible outcomes from a life cycle perspective increases.

Although, the LCC methodology bestows a number of risks and uncertainties, the approach still provides a computational basis for choosing one alternative over another, for strategic decision making [11,12]. LCC as an assessment tool has not yet obtained favour within present building development; reasons for the disregard could be lack of general motivation, restricting contextual factors, access to reliable data and methodological problems and limitations [12]. By providing and establishing a comprehensive framework for decision-making the role of LCC could be enhanced.

The buildings we develop and construct today will stand for at least 50 years, probably more. Therefore it is imperative to understand the affect design decisions have from a life cycle perspective. The maintenance costs and environmental impacts during the operational phase are to be accentuated and understood; applying LCC to the development improves the general understanding of the development and its outcome.

6. Conclusion

The results show that by applying LCC as an assessment tool in the early development process added value in terms of life cycle perspective for decision makers is obtained. Through the LCC approach design alternatives with lower energy costs are revealed, thus, creating lower environmental impacts. By applying a life cycle perspective for different eco-efficient design options, operational costs are accentuated in comparison to the initial investment that is conventionally employed in decision making processes.

In the future, renewable energy options are increasing within urban development. In order to evaluate their life cycle outcome LCC methodology should be utilized to uncover their actual potential.

By applying an economic life cycle perspective into the urban development process, life cycle leadership of the built environment is enhanced. Is there a demand for improved life cycle leadership in our current urban development practises in order to increase sustainability for the built environment? If there is, which stakeholder is to be responsible – private and public owners? There seems to be a strong interest for eco-efficient concepts in urban development from the public sector [23].

Considering further research; a framework for comprehensive life cycle assessments from both economic and environmental aspects should be created and examined in order to further emphasize the opportunities for sustainable viability in urban development.

Life cycle costing (LCC) has to be taken into consideration when thoroughly developing sustainable urban areas in the future.

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A Study of lifecycle management of housing using LCC as probability function

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Summary

In Japan, the value of housing on market, especially the existing one, is underestimated. In order to create a resource-circulation society and extend life-span of housing, assessment of existing housing needs to be improved for the market. How to manage our property with flexibility during the planning period is also a critical issue. This study focus on housing asset and LCC from the point of view with an approach of property values and economic life, propose a appraisal model for housing management by adopting both concept of LCC and ROA method. Differing from conventional testing model, this study evaluated LCC present value by using various hypothetical circumstances rather than limited, and simplified conditions. It also attempts to clarify the cost of various projections underlying uncertain factors for decision makers. This Study re-examined the applicability of LCC appraisal by analyzing different households. Based on the LCC simulation result, Ring-shaped LCC model is exhibited in the end of this study.

Keywords: Decision Making, Real option, Asset management, Uncertainty, DCF method

1. Introduction

This research focus on housing asset and LCC from the point of view with an approach of property values and economic life. However, the value and price of housing on Japanese market, especially the existing one, is underestimated because of lack of proper estimation tools. Since extending life-span of existing housing and creating a resource-circulation society has become the priority principles of residential policy for Japan government, Assessment of existing housing needs to be improved to smooth the circulation in property market. How to manage our property with flexibility during the planning period is also a critical issue.

1.1 Purpose of Research

The main purpose of this paper is to propose a alternative model to users which can analyze the lifecycle cost of different alternatives during the planning period, and help to manage their properties and make decisions at each step. According to users' different life stages and conditions, this model simulates various alternatives, and visualizes the present value of LCC and also compares the results of LCC simulation. This model also assumes the uncertain future, which puts uncertainty factors, (such as interest) into LCC equation and analyzes the probability distribution of each alternative. Finally, this study proposes a flow model for housing's life cycle management. It is based on a new approach to lifecycle cost, and is considered with the uncertainty of future. *(fig.1)*

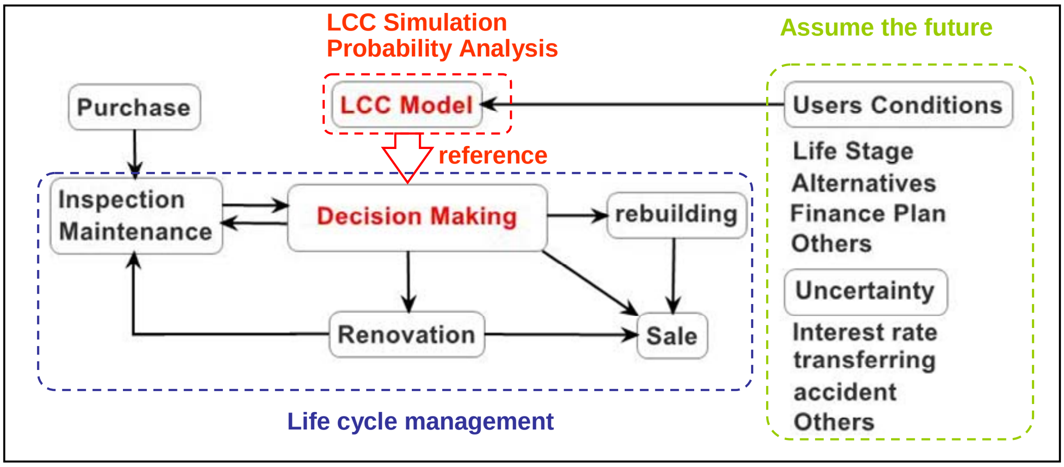

Fig. 1 The image of applying LCC Model to each step of decision making

1.2 Scope of Research

Lifecycle management of housing can be discussed by different terms such as physical life, functional life, economical life or social life, This research regards housing's property values from the economic point of view of economical life. This research focus on presuming the lifecycle cost of the existing housing in Japan, It simulates the LCC of alternatives during the planning period, and analyzes the effects by uncertain factors.

The scope of this research is considered with several aspects, which are:

a. Simulation object

  Existing housing, apartment building type,

  Built over 10years, Concrete construction.

b. Different household with different financial plan

  Single, Young couple, Nuclear family, Elder

c. Alternatives during the planning period

  Maintenance plan, renovation plan, rebuilding plan (based on users' life stages)

d. Uncertain Factors

Various assumed volatility of interest rates is added to anticipated items of uncertainty factors in the model.

2. Literature review and research contributions

This research focus on housing asset and LCC from the point of view with an approach of property values and economic life. No matter we buy a house for living or treat it as investment tools, housing can be regarded as merchandise. However, the value and price of housing on Japanese market, especially the existing one, is underestimated because of lack of proper estimation tools and inspection system. This is also the reason why the life-span of housing in Japan is much shorter then the UK, US and other countries. (MLIT,2011) Regarding to understanding of how to manage our house and treat it as asset, there are some research literature we need to review. They are: 1.evaluation method for property value. 2. the application of lifecycle cost on housing research. 3. asset management study concerned with flexibility and uncertainty.

2.1 Evaluation method for property values

Although housing can be regard as merchandise, real-estate market belongs to neither perfect competition market nor monopoly market. Pricing for real estate is a complicate system. In order to respond this particularity, different analytical aspects such as cost approach, sales comparison, income approach have been well applied in practice for building property. (JAREA,2011) However,

only sales comparison is applied to housing transaction even though it is not appropriate enough. In the process of housing transaction, asking prices are the only information we can have as benchmark, but even contract prices and registry prices are more substantial. The buying behaviour is also concerned with someone's decision-making. Therefore, the price on the market becomes more difficult to estimated, especially for the existing housing.
In Japan, some researchers attempted to explicate the pricing construction on the market by using hedonic approach. According to Shimizu's research (Shimizu et al,2011) , as constructing a housing price index, it is critically important to choice the data sources of house prices, and to proper tools among alternative methods of estimation. Although the hedonic approach can be use to compare housing price in conclusion, the difference between the distribution of house attributes and quality still remains, Hence, the hedonic approach need s to be adjusted in appropriate manner.

2.2 Application of LCC (Lifecycle cost) on housing research

The general definition of LCC is:
the sum costs over the full life span or a specific period of a good, service, structure, or system. Including purchase price, installation cost, operating costs, maintenance and upgrade costs and salvage value at the end of its useful life. (http://www.businessdictionary.com)
In the field of construction industry, LCC method is generally applied to appraise different plans while buying equipment or choosing a method of construction. An assumption of LCC could help owners (or users) to imagine the probable revenue and expenditure in the future. Considering their particular requirements or preference , decisions can be made in a more reasonable way. In Japan, there is a lot of studies discussion about LCC of housing from different perspectives. *(Table.1)*

Table. 1 Application of LCC (lifecycle cost) on housing research

Article	An Evaluation of Life Cycle Cost for a Detached House, Umeda. K et al, 2000	Study on Life Cycle Cost of a Resource Circulation House - Study on economical assessment of housing system for sustainable society, Igarashi.T	A Study of Housing to Reside in an Apartment House for Generations -Planning for Variable Living Space to Match Resident's Life Stages- Kubota. T et al, 2004	A Study on Material Selection Method and Repair Plan Method with Necessity Evaluation by AHP Moriya. K et al, 2000	
Object	Calculation and comparison of running cost of detached house	LCC present value comparison between resource circulation house and conventional house	a proposal of housing model for successive generation	verification of rationality in maintenance plan in terms of VI(value Index)	
Subject	A)wooden B)semi-fireproof C) fireproof	A)attached house B)apartment building	A)varaible space aparment B)two families	commercial facility	Compare the LCC advantage with several type of construction, Design layout,management,etc
maintenace cycle(year)	A) 35 B) 60 C) 100	15	50	3～4	necessary maintenance,repair, renovation or rebuilding for long-term use
Planning	100year	180year	100year	65year	
Initial Cost	◎	◎	◎	◎	Construction
Operating Cost	◎	◎	×	◎	repair,renovation,rebuilding cost
	◎	×	◎	◎	rental income(if any)
	◎	×	×	×	utility expenses(electricity,water,etc)
	◎	×	◎	×	tax, insurrance premium
Interest Rate	NA	1.96%	NA	NA	using real interest rate
	NA	◎	NA	NA	consider decreasing rate of material,labor cost
◎included in LCC calculation	×excluded	NA not indicated			

Moriya. K focus on examining the useful life of components in order to propose an appropriate maintenance cycle (Moriya. K et al,2000) . Igarashi (Igarashi et al, 2004) tries to test the feasibility of layout planning for variable living space which will meet different demands for every stage of users' lifestyle. ; Kubota. T scrutinize the economical advantage of sustainable housing which is designed in circulative and longevous resource. (Kubota. T et al, 2004) . (Table.1) Most of these research have generally concluded that LCC prediction critically are applied with limited hypothetical conditions. Therefore, results are applicable only under assumed situations.
According to the inadequacy of previous approaches, we need more flexibility to manage housing property, while using LCC appraisal in order to avoid any unexpected situation in the future.

2.3 Asset management study concerned with flexibility and uncertainty.

Most of the research in Japan applied DCF (discount cash flow) method to calculate the LCC present value. Under many circumstances, asset value is underestimated in practice by using DCF method. The reason is that the discount rate of WACC (weighted average cost of capital) is set constant. Under the long-term prediction, however, it is inconstant in reality. During the planning period, to adjust management plans and strategies or how to reallocate budgets, is not included in the concept of DCF method, (Copeland et al,2002)
Differing from conventional financial options, ROA (real option analysis) provides more flexible options to undertake business initiatives and helps decision makers to be explicit about the assumptions under their projections. The option itself is the right but not the obligation. Decision making associated with uncertainty is much more reasonable resemble to real-life. Option value is explicit by using decision tree. Decision makers can modify their plan at any time of any step. (Mun,2003)Although ROA as been increasingly employed as a tool in business strategy formulation at the present, in Japan there are a few studies which applied concept of ROA in the research of housing asset management.

2.4 **Research contributions**

This research is to propose a appraisal model for housing management by adopting both concept of LCC and ROA method. Differing from conventional testing model, this research evaluated LCC present value by using various hypothetical circumstances rather than limited, and simplified conditions. This model analyzes various scenarios and projections which underlying uncertain factors in the future. It also attempts to clarify the cost of each choice for decision makers

3. LCC analytical method and theoretical model

3.1 LCC analytical method

most of the LCC studies in housing management are considered with simplified situations without alternatives. Decision is also be made at only one specific point of time without flexibility.. When analysing the LCC present value through conventional way, decision makers have no other options such as "call option". This research attempts to consider more complicated situations, and put different conditions into simulation, in order to re-examined the applicability of LCC appraisal by using DCF (discounted cash flow) method.

3.1.1 Simulation of various households and real interest rates

As a parameter, composition of household has been divided into four types: a)Single (late twenties) b)Young couple (early thirties) c)Nuclear family (early forties) d)Elder (late fifties)
Except for different composition of household, other simulation conditions are under the same setting. *(Table 2.)*

Table. 2 Simulation conditions

Subject Background	
Apartment building	Concrete construction
Age of building: 30years	Once renovated
Data resource: リフォーム支援ネット http://www.refonet.jp/csm/case/theme/0_2_1_26.html	
Hypothetical Conditions	
Planning Period	32years with maintenance plan
Specification of repair work	Refer to database of ″建築物のライフサイクルコスト(平成 17 年版), 2005″
Assumption Operating Cost (Utility expense only)	Refer to database of Statistics Bureau, Japan
Real interest rate	a) 0% b) 2% c) 4%
Composition of household	a)Single. b)Young couple. c)Nuclear family. d)Elder

3.1.2 LCC Simulation result analysis

Operating cost occupies the highest ratio in LCC. *(fig.2)* Depending on the setting of cycle and maintenance plan, LCC present value have obvious difference even if all the other conditions are same. The composition of LCC in housing is very relevant to different household. Not only because of different number of family member but also have relevance to how they operating it *(fig.3)* (Comparing with b and d type family) According to these results, it is verified that user's different life stage or way of operation have critical influence on LCC assumption.

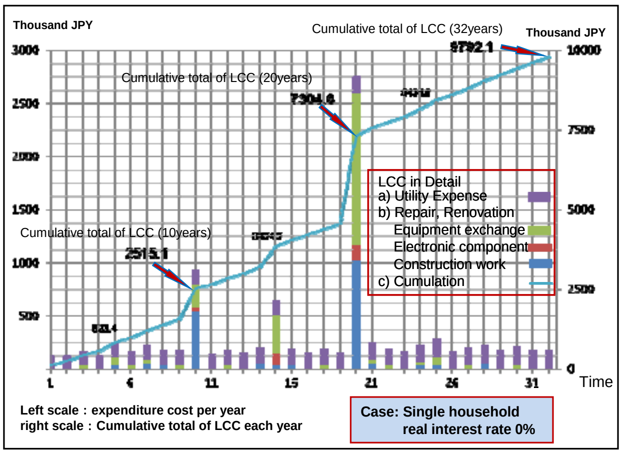

Fig. 2 The Composition of LCC by year

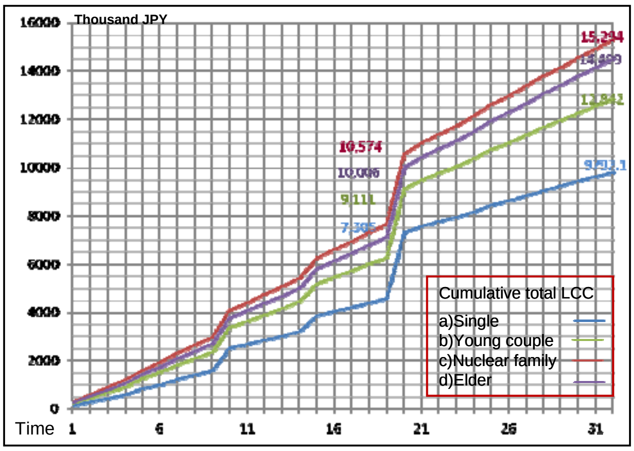

Fig. 3 LCC Comparison of four type households

3.2 LCC Model for decision making by using probability distribution

This research proposed a hypothetic LCC Model which can be applied to decision making when user enter the next life stage or face an important change. Considering the probability of uncertain events on time series, this model analyzes various scenarios and alternatives for decision makers, and help them choosing their favorite way (route) to manage their property.

3.2.1 Optimization model with uncertainty

The basic conception is analogous to optimization model with uncertainty, we can simulate every alternative and analyze the LCC result through this process (fig.4) (Mun.J.C,2003)

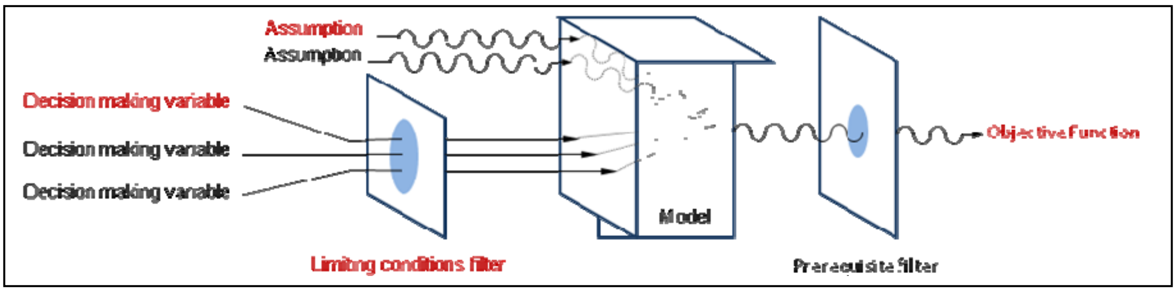

Fig. 4 Optimization model with uncertainty (Mun.J.C,2003)

However, optimization is not the purpose in this research. Since each selection of decision maker is "right" but not "obligation", this study prefer using "choose a favorite route" rather than "optimize the LCC" as main purpose. The variable setting in this study is showed as *table.3*

Table. 3 Variable setting in LCC model

Decision making Varialbe Options Alternative	Continuing	Repair Renovation rebuild	Energy Saving Barier Free Layout Change Performance Upgrade Others
	Moving Out	send it on lease sale	
Limiting Conditions Background Setting	Life Stage Household	Member Change Child's Growth Second Life	
	Homeowner Association Management	Common Element proprietary element Inspection,Repair Schedule	
	Finance Plan	LCC Target Loan(repayment) Management cost Maintenance fee	
Objective Function LCC Probability Function	Comparison of Alternatives		
Assumption Uncertainty Factors	free risk rates inflation rates technology improvement	Utility Expense Construction Cost commodity prices	
	Job transfer Accident Disaster	Change of living style Financial adjustment	

3.2.2 Ring-shaped LCC model

the flow below will explain how LCC model is established.
a)step1: Making LCC probability tree *(fig.5)*
set up first planning period named T1. Length of time depends on user's life plan.
Input the volatility of real interest rates which reflects the uncertainty of future. Larger volatility means that uncertain future is hard to predict. (It's zero in DCF method) A,B,C....D represent the probability of events and route. For example, if we presume the real interest rates be up and down with 20% every year from now on, after 9 years the rates will become A,B,...D in certain probability.

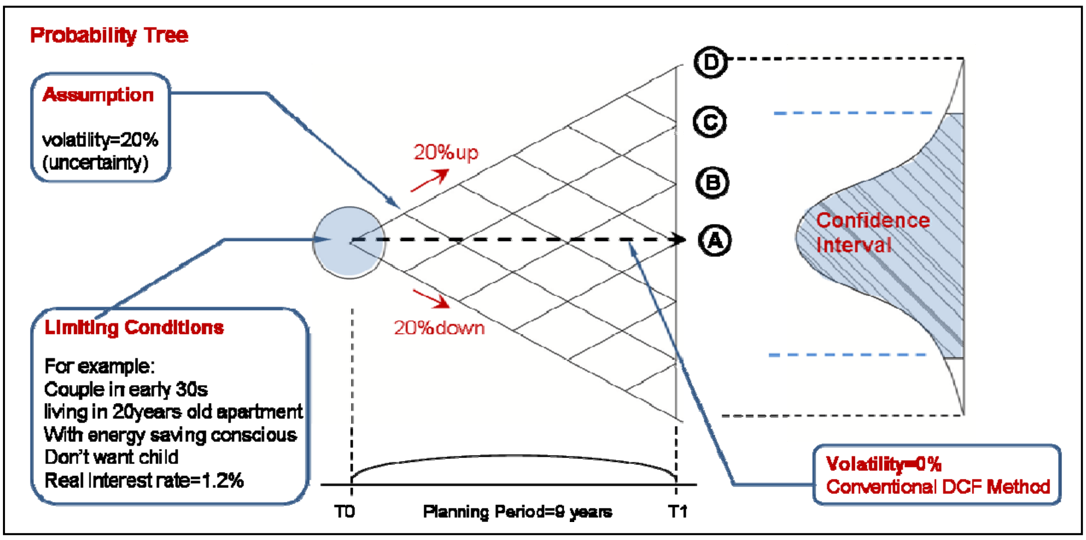

Fig. 5 Making probability tree

b)step2: Making LCC decision tree *(fig.6)*
Set up second planning period named T2, and complete LCC probability tree from T1 to T2. When the time comes to point T1, user has opportunity to re-examine the original plan and target then make decision: **continue, adjust it, or choose a new plan**. Depends on user's different decision making, simulation result of LCC might become X,Y...Z at T2. For example, a couple have 9 years old child at time point T1, they might consider converting their house into appropriate living space for child's growth in next 9 years. At route c , everything happened as they have expected at point T0, they can continue original plan. Then the LCC might be Z 9 years later. They can also choose a new plan, such as extending additional space or change the layout.

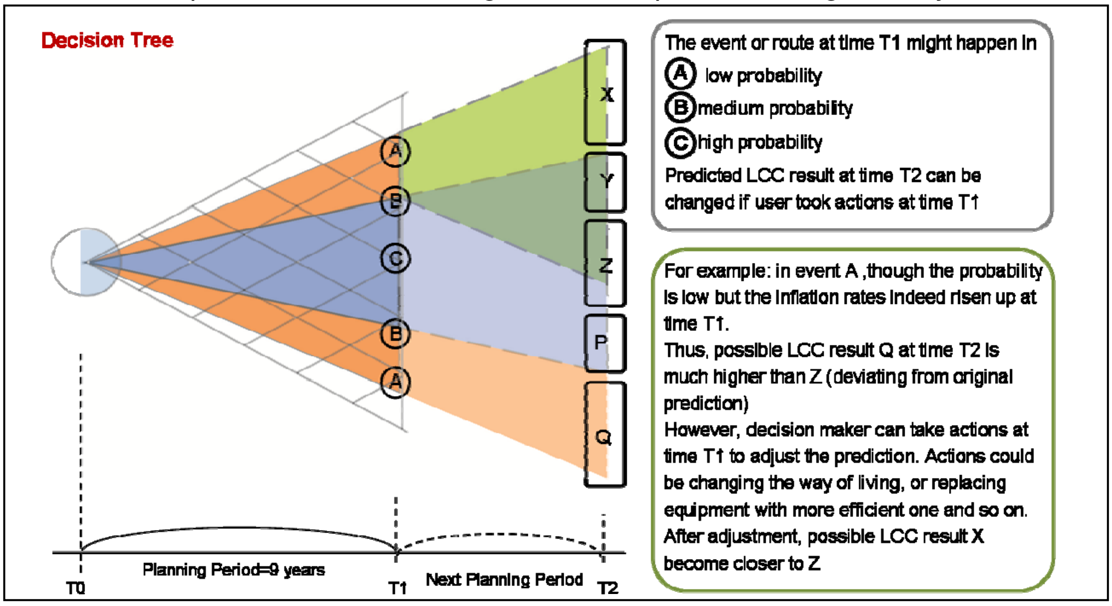

Fig. 6 Making decision tree

c)step3.Making Ring-shaped LCC model *(fig.7)*
Triangle represents the original plan. It grows up with time which also means that the prediction of future becomes more uncertain. only decisions like repair, renovation or maintenance cycle adjustment are allowed in original plan. Mirrored triangle with dotted line represents different alternatives (new plan) at different point of time (T1,T2...Tn) decisions like moving out, rebuild are defined as alternative (new plan) . A project (plan) starts from the center and spread outside with time by adding various triangles (alternatives) from time point T1 to Tn (important point of life stage) Finally, ring-shaped LCC model is established.

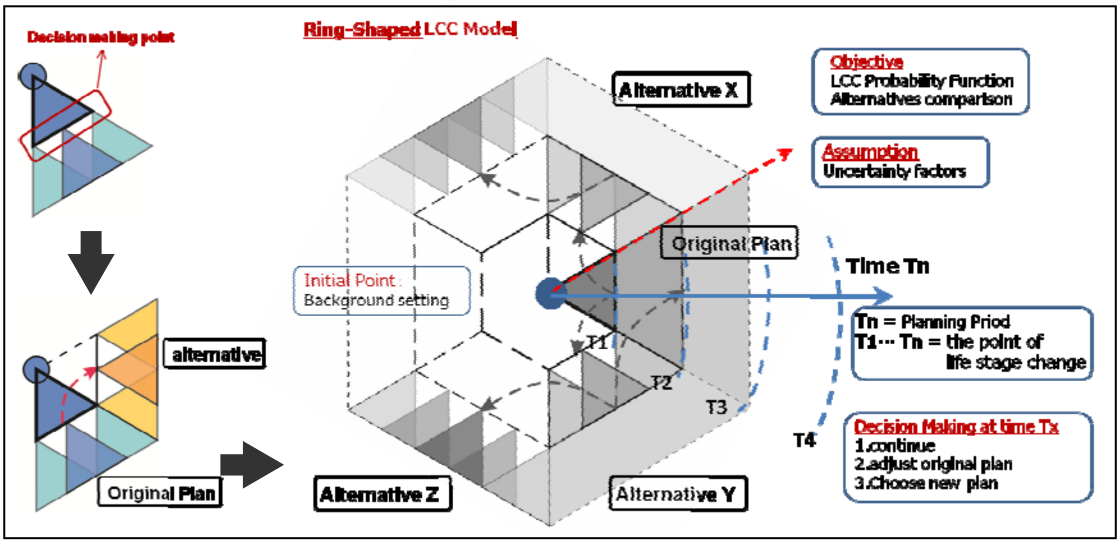

Fig. 7 Ring-shaped LCC model

4. Conclusion

Although DCF method is a conventional way which is generally conducted to estimate housing's LCC present value, the limitation of prediction only under single situation without alternatives, lacks of flexibility to face the uncertain future. This Study re-examined the applicability of LCC appraisal by analyzing different households with more complicated conditions. The result that operating cost occupies the highest ratio in LCC shows the same tendency with previous research. Number of family member is also very relevant factor to operating cost estimation. User's different life stage and way of operation have critical influence on LCC assumption. Even under the same conditions, simulation object's appearance on LCC changes when the setting of maintenance cycle is adjusted. Ring-shaped LCC model which exhibited in the end of this research is a hypothetical model at this stage. It is based on the LCC simulation result of various type of household. So far in this study, we can assume the LCC for different life stage from T0 to Tn by using probability function, then complete a triangle (original project) . However, in real life there are more alternatives such as moving to a new place or rebuilding which have not been assumed yet in this study. To complete the Ring-shaped LCC model, these alternatives should be considered and put into LCC probability function in further study. The reliability should be verified as well.

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Moisture safety in wood frame constructions – What do we know today? – A literature overview

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Summary

This paper intends to offer an overview of current knowledge in practical moisture safety in wood frame house. Books, journal articles, reports and other documents at different levels regarding moisture and moisture safety in different aspects are summarized. Possible gaps and flaws in existing knowledge, such as, lack of blind verifications of moisture safety calculation tools, the need to separate quantitative and qualitative issues in the moisture safety design processes and the fact that mould growth model handle the influence of duration in different manners are reported.

Keywords: Moisture safety, mould growth, wood frame constructions, literature overview

1. Introduction

1.1 Background

The interests of using wood frame constructions have increased during the last decade depending on the intention to build more carbon dioxide, CO2, efficient houses [1]. In Northern European countries there is also a tradition of wood frame houses and plenty of wood as raw material that can be used in buildings [2] [3].

Regardless what materials or design system is used there is a need to build moisture safe constructions. Moisture damages are linked to negative consequences, extra costs and cause sickness and bad health because of inadequate indoor climate and Sick Building Syndrome [4].

Today, there is a relative good basic knowledge in the area of building physics, moisture transport and factors affecting mould growth [5] [6] [7] [8] [9]. However, since moisture related damages still is common and cause high costs and bad indoor climate it may be questioned if there are areas with lack of knowledge and if or how knowledge in the moisture safety area are implemented in the building industry [4] [10] [11].

1.2 Aim

The aim of this paper is to give an overview of current knowledge in the moisture safety area in wood frame constructions. The intention is also to present new insights into underlying factors, results from field studies and strategies to avoid mould and moisture damages as well as to discuss mould models and calculation tools that can be used to predict mould and moisture damages in wood frame constructions. Furthermore, the paper aims to show weaknesses and gaps in existing knowledge and research in the moisture safety area and suggest direction of further research.

1.3 Limitations

The paper does not include a complete review of all knowledge in the field and it is instead more a kind of “state-of-the-art” that overviews and presents the latest knowledge. The study does not aim to discuss and evaluate basic building physic knowledge. Furthermore, it is limited to focus on wood frame constructions. Material data and boundary conditions are not considered. Additional steps have been taken to especially present literature that is useful and applicable to applied research and possible to use in real building constructions, without any further development. Some references are given in national languages such as Swedish, Finnish and German.

2. Literature search method

This paper consists of studies and research documents at different levels. The connection between and effects of qualitative and quantitative factors also make it necessary to include studies at different levels. Therefore the study includes doctoral theses and international reviewed journal articles as well as national institute reports, conference papers and master- and bachelor theses.

Initially, searches in open access data bases in the area were carried out, but mostly with poor results. The only open database that showed relevant and reasonable hits was Google Scholar. This may depends on that the topic of applied building physics seem to be primarily published for national use since the construction sector is strongly national. In the area of mould and moisture, the local climate has a big influence, and, consequently, only Nordic research is useful in the Nordic area. Furthermore, the construction sector acts conservatively and in a closed manner [10] [11], i.e. findings and knowledge are not supposed to be spread to competitors. Instead of a random literature search on Google Scholar, references and authors in known documents were used to find new relevant documents. A risk with this kind of search is that critical articles may have been excluded.

Furthermore, conference proceedings from the latest conferences in the area have been used and scanned. This has given both an overview of the present knowledge level and a good picture of the most recent research results that have been published.

The fact that some research in the area is connected to national experience or local conditions and traditions have made that national institute reports and master’s and bachelor’s theses also have been studied. In addition, the SP Technical Research Institute of Sweden database was used.

3. Summary of studied representative papers, articles and documents

Below are important facts from several studied journal articles, conference papers, thesis and other documents summarized in different groups depending on their content. A more detailed description of total 146 documents is shown in a separate report [12].

3.1 Laws, Rules and Regulations, Enquiries and National Investigations and Reports

By studying building laws, rules and regulations concerning mould and moisture in some European countries it seems that there is variation in demands, structure and limitations. Some countries focus on qualitative limits and some connect mould and moisture risks to inhabitant’s health. Furthermore, there are countries that give recommendations, qualitative or quantitative, how to avoid mould and moisture related damages. In general, studied laws, rules and regulations seem to be underdeveloped compare to regulations in other building areas such as statics, availability, fire safety and energy use [13] [14] [15].

Furthermore, studied Swedish national investigations show that there is a lack of knowledge in the moisture safety area and unclear responsibilities [10] [16]. Verified methods and calculation tools to predict and avoid moisture damages are also required [4].

3.2 Moisture Safety Design Mehtods

Different moisture safety design processes and methods to avoid moisture related damages have been found. Some methods concern qualitative issues, i.e. practical or basic knowledge, and some quantitative issues, i.e. measurable [12]. Only one moisture safety design method that concern both qualitative and quantitative issues and cover the entire building process has been found [17]. Studied quantitative methods focus on a maximum relative humidity with respect to duration limits to avoid mould growth in buildings [18] or use statistic methods calculating the risk of mould growth [19] [20]. There are also moisture safety design methods that focus on qualitative issues [21]. General guidelines in order to achieve high quality timber buildings where moisture related questions are briefly discussed have also been found [22].

3.3 Mould Growth Models

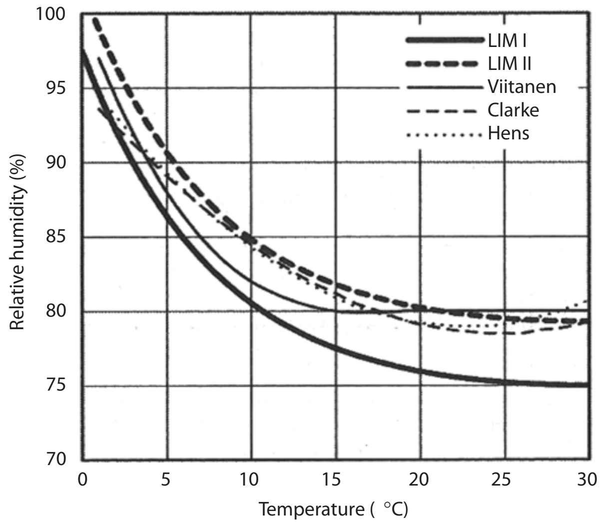

Fig. 1 Example of different mould growth models dependent on relative humidity and temperature [23].

There is a broad agreement that different material has various sensitivity to moisture and that temperature, relative humidity, and duration are the main factors affecting the risk of mould growth [23]. Several of mould growth models have also been invented based on those facts, as shown in Figure 1. However, the models have a number of different theories and models about reducing, if this is at all possible, the amount of mould growth during non-favourable mould growth climate conditions. Furthermore, different critical levels with regard to the effects of duration are presented and none of studied mould growth model include the influence of short time climate variations [24] [25] [26] [27]. The mould growth models mainly show if there is a risk of mould growth or not, without presenting underlying factors affecting the risk of mould growth and possible actions in order to avoid or reduce the risk of moisture damages [28].

3.4 Water Proofing Membranes in Wet Rooms/ Bathrooms

Bathrooms, and other wet rooms, are pointed out as an area where mould and moisture damages have high cost [4]. Many bathrooms with exterior walls made of wood in Nordic European countries have three different vapour resistance membranes. To avoid damages, the interior waterproofing membrane in bathrooms has to have a higher vapour resistance compared to the other vapour membranes in the wall. Studies show that many waterproofing membranes has to low vapour resistance compare to other vapour retarder membranes in the wall. Therefore penetrating vapour become locked in, between the interior waterproofing membrane and the vapour retarder, and creates mould damages [29]. Acceptable vapour resistance of weather or wind resistive barrier in the outer part of the wall depends on the vapour resistance on the other membranes and the exterior climate. Furthermore, the vapour resistance is often given by a test method that neglects the influence of high relative humidity. Unfortunately, waterproofing membranes have shown significantly higher vapour diffusivity if there is a high relative humidity, which naturally occurs in bathrooms. This increase the risk of moisture related damages in exterior bathroom walls [30].

Many damages also occurs dependent on detailing errors. Several waterproofing membrane systems have been tested for leakages in or close to installations, pipes penetrations or other details with bad results. None of the systems had acceptable solutions for detailing [31]. The influence of detailing errors is also shown in damages investigations where the main cause of damage was poor sealing around or close to the floor drainage point. An interesting result from a limited study shows that “amateur” work appeared to be better than work carried out by professional workers [32].

3.5 Airtightness in Buildings

The quality of airtightness in buildings mainly depends on good detailing and a building design or building system that allows good joints between airtight membranes. Plenty of examples with constructions detailing and solutions of how joints can be put together and sealed have been found, both as literature and in forms of mounting instructions from material industry [33] [34] [35]. There are also validations made of different sealing methods [36]. New materials, especially membrane tools for joints and detailing, seem to be constant developed by the industry. Furthermore, methods handling air tightness during the entire building process, including verifications, have been found [37].

3.6 Rendered Non-Drained and Unventilated Facades

It is well known that rendered non-drained wood frame walls without a ventilated cladding, so-called ETICS design, are a risk construction [38]. A great number of moisture damages have been found in houses with this design [39]. The main causes of damages are detailing error, poor workmanship and leakages of penetrating driving rain. Suggestions of possible moisture safe repairs for damaged walls [40] as well as studies showing the positive effects and importance of a well-ventilated air gap behind the claddings have been found [41] [42].

3.7 Moisture Risks During the On-Site Construction Phase

Recent Swedish field studies show that mould growth are noticed in wood frame houses that have become exposed to only one rain during the on-site production of wood element, even in cases where the mounting have been completed in one day. The risk of mould growth is highly dependent on the prevailing weather conditions during the on-site production until the house is made weather tight [43]. Furthermore, laboratory studies show that if sills or studs become exposed to rain during the construction phase they also become damaged by mould growth [44]. However, there are general and detailed methods, descriptions and measuring methods of how to control and handle moisture in wood material during the on-site construction phase [17] [43] [45].

3.8 Well-insulated Wood Frame Houses

Well-insulated constructions are generally more sensitive to mould- and moisture damages compared to less insulated constructions [46]. This depends on several factors such as higher amount of initial construction moisture, longer dry out times and a higher amount of cold parts in the construction. To build moisture safe well-insulated wood frame houses there have to be a well-ventilated and drained air gap behind the cladding, the influence of driving rain have to be considered and organic materials in the outer part of walls have to be protected by mould resistant thermal insulation. Furthermore, there is a need of an interior vapour barrier in cold climate and the outer parts of walls have to have vapour diffuse open materials to facilitate the dry out process of in-leaking water and initial construction moisture [8] [47]. However, the risk of increased moisture damage is not significantly higher in newly build Swedish cold attics since they are already normally well-insulated [48]. The influence of long wave radiation and the air ventilation rate in cold attics also have a major influence on the risk of mould growth damages in attics [49].

3.9 Air Flow Rate in the Air Gap in Ventilated Cladding

Different studies establish the need of a well-ventilated and drained air gap behind the cladding for several moisture safety reasons. The service life of the facade is positively affected of a well-ventilated air gap [50]. The dry out potential from both the façade and the wood frame wall on the inside of the air gap increase if the air gap is well-ventilated [42]. In case of a brick façade with a wood frame construction behind the air gap it is even more important to establish a proper air flow in the air gap, which gives a high air ventilation rate, in order to achieve a moisture-safe building [51]. A 25 mm wide air gap behind wood façades and a 50 mm wide air gap behind brick façades is suggested [42] [47] [52]. Furthermore, the importance of a well-ventilated air gap increases in well-insulated wood constructions. A well-ventilated air gap with vertical or perforated battens also has positive effects on drainage and decreasing the air pressure difference over the cladding [47].

3.10 Moisture Calculation Programs

There is a need of reliable and user friendly calculation tools that could be used to predict and avoid moisture related damages [4]. Several moisture calculation programs with coupled heat- and moisture transport have been found [12]. Most of the programs use forward differential equations methods [6] [53] [54] [55] [56]. The availability of using forward differential equation method in real cases has been known since the 70´s. However, it has not been possible to apply this knowledge to real conditions because of the lack of computer capacity [53]. Some programs based on the finite element calculation method have also been found [12] [57]. Many programs seem to be based on the same general equations and then further developed from each other. Most of the programs also seem to be made for research purposes. Three, WUFI, DELPHIN and COMSOL, of eleven studied programs seems to be user friendly and could be used as moisture safety tools in the design phase by the industry. COMSOL is based on the finite element method [12]. COMSOL and DELPHIN are also perceived as more complex compare to WUFI. More complex two-dimensional versions also exist of some programs. There are plenty of studies where calculated values have been compared with measured values. Both independent and dependent comparisons made by the developer were found [6] [53] [58] [59] [60]. However, none of over 50 known studies seems to make blind comparison between measured and calculated values, i.e. not knowing measured results before the calculation is made [12]. Furthermore, some studies show the importance of using appropriate boundary conditions to get reliable results, such as air flow in the air gap and the influence of driving rain [40] [47] [58] [61] [62].

4. Summary, discussion and conclusions

The summary, discussion and conclusions intend to point out examples of relevant knowledge and to give examples of gaps where there is a lack of knowledge and suggest further research. Based on the studied journal articles, conference papers, dissertations, theses, standards, books and other documents, knowledge could be summarized and several conclusions could be established based on the contents of several documents.

In general it is obvious that there is lot of Swedish knowledge that only is national published and not widely spread to the international research society. It is also obvious that basic knowledge exists in the area of heat, moisture, moisture transport and mould models. However, there are several documents that establish the need of further research in the area since moisture related damage is common and has a great effect on both financial and health issues. Furthermore, the construction industry needs to carry out further work with regard to moisture protection in existing construction systems. Investigations also show that attitude, unclear responsibilities and deficiencies handling moisture safety issues in the industry are a part of the problem.

There is broad agreement about the main factors affecting the risk of mould growth. However, possible ways of reducing mould growth and its influence on health need to be further investigated as well as critical levels with regard to the effects and duration. The effects of short-time variations between critical and non-critical conditions also have to be further studied. Mould models also need to be further developed to direct or indirect show possible actions how to reduce or avoid the risk of mould growth in critical constructions.

Moisture safety design process is needed to reduce the risk of mould and moisture related damages. It is established that both qualitative and quantitative issues need to be considered in the moisture safety design process and it needs to be in focus and dealt with from the planning phase, throughout the entire building process.

New waterproofing membranes and systems with high quality joints in bathrooms need to be developed. There is also a need to ensure the vapour tightness when the membranes are in contact with high relative humidity. The difference in vapour resistance between different membranes in exterior bathroom walls also needs to be handled in the design and construction phase.

Generally there are good materials, tools and detailing solutions to build airtight constructions. It also seems to be a positive ongoing developing process with new materials and new tools in the material industry. However, it is always best to try to find design solutions with good opportunities for easy made airtight joints and membrane connections.

Experience and studies from rendered non-drained and unventilated facades with wood frame walls, so-called ETICS constructions, could be summed up with that those kinds of constructions should be avoided in order to build moisture safe wood frame constructions. The importance of a ventilated air gap behind the façade in order to reach a long service life is also established. No matter the design the influence of driving rain have to be considered, which can be made by a well-ventilated and drained air gap behind the façade.

It is possible to build wood frame constructions with high thermal resistance, but there is an increased risk of mould and moisture damage. A number of specific factors affecting the moisture safety of well-insulated wood frame houses have been identified and must be considered. For instance, the organic materials in the outer part of the wall needs to be protected, preferably by a mould resistance vapour diffuse open insulation board. Furthermore, the importance of a well-ventilated air gap behind the façade cladding increases with well-insulated wood frame walls.

Wood frame houses cannot become exposed to rain during the construction phase in order to safely avoid the risk of mould growth. By build under tent or concentrate the on-site construction to a day without rain in case of building element houses, this risk could be neglected. This is especially important in well-insulated houses which are more sensitive to moisture.

I order to predict and avoid moisture damage it is also shown that there is a need for user-friendly and reliable moisture calculation tools and methods. User-friendly tools exist but do not seem to be widely spread in the construction industry. However, none of the studied moisture calculation tools, no matter if they are commercial or used for research, seems to be verified to real conditions by blind comparisons.

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Integrative Design Approach for Buildings in Kazakhstan

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Summary

There is a distinct lack of building design literature specific to the Central Asian region. This perhaps, could be one of reasons for the only slight improvement of new building designs and construction. One does observe the highly glazed buildings are a particularly popular feature here in Astana, as like anywhere else in the world. However, excessively glazed surfaces combined with the weather extremes leads to adverse internal conditions and skyrocketing energy bills. In the present context, low energy buildings' refers to buildings inherently low energy consuming by careful passive design, utilizing intelligent building technologies to automate building services and minimize wastage of energy and by incorporation of renewable technologies for its energy supply. Demonstration of improved environmental conditions and impact on energy savings will be outlined through a case study incorporating application of passive design approach and detailed computational fluid dynamics analysis for an existing building complex. The results indicated that there is a considerable influence of passive design and orientation on energy efficiency, wind comfort and safety.

Keywords: building orientation, CFD, energy efficiency, low energy design, wind comfort

1. Introduction

Construction sectors arguably one of the most resource-consuming and environmentally impacting industries. Buildings account for nearly 40% of the end-use energy consumption and carbon emissions worldwide [1]. The construction and maintenance of the buildings cause great deal of pollution which in turn creates air quality issues in urban environments contributing to climate change. Low-energy buildings design is seen as a viable option to reduce the negative impacts of the increasing energy consumption of construction and maintenance processes. This design approach is the resourceful exploitation of the building form and envelope with the intent of saving energy. The above could be complemented by employing renewable technologies to supplement the power requirements. The synergistic integration of inherently low energy building design, intelligent systems and renewable technologies (sustainable) gives rise to a truly energy efficient building. When analyzing or designing low energy buildings, the following aspects are normally examined. It should be noted that in the current work the authors will only outline the possible and practical renewable energy sources and in future work the result of the integration will be presented.

1.1. Low energy design

Analyzing the site features such as its layout and orientation, surrounding land and climate, prevailing winds, solar resource, adjacent buildings and access to infrastructure are all predominant factors which have a direct bearing on the building shape and orientation. Sometimes, as in urban environments, adjacent buildings provide shading from the sun to the advantage or disadvantage of the building. These factors can be utilized, by careful design, for the benefit of the building, in light of energy consumption [2].

Building Shape: An optimum shape of a building is one which transmits the least amount of heat from the interior to the outside during the winters and admits the minimum amount of solar radiation during the summers.
The envelope is a highly crucial factor in the design of buildings as it performs several functions of protection from the external environment, noise, pollution and provides comfortable interiors. But most importantly, it determines the rate of flow on energy within the internal and external environment of the building. The efficiency of the envelope has a direct influence on the energy consumption of the building. It could lead to unnecessary over-sizing of the mechanical equipment, if not designed carefully. However, a proper design could help reduce the mechanical load to great extents.
All-glass façade buildings seem to be extremely popular with architects and property developers all over the world. No doubt, its sleek and polished appearance is quite attractive and greatly enhances the overall aesthetics of the building.
Designers tend to include large areas of glazed surfaces, in the form of huge atriums, skylights, all-glass walls and larger windows. Such features can result in intolerable internal conditions, glaring and exorbitant electricity bills for cooling [3]. In the past, windows were inefficient and hence some restrictions were imposed on the allowable window area. Technological improvements gained in the glazing technology have been wasted on larger window-areas rather than increased efficiency. The three parameters one needs to take care of while choosing window glazing types are the solar heat gain coefficient SHGC, visible transmittance VT and U Value. SHGC is to be kept to a minimum. Other common types of window glazing are reflective-coated, low-e coated, tinted and the double or triple-glazing [4]. Daylighting. Shading: shading by means of external or internal devices can be utilized.
External shading devices are more effective compared to internal devices such as internal roller blinds, venetian blinds etc. External shading devices may be in the form of overhangs, louvers, vertical blinds and the more complex ones will be operable which is more preferred [5].
Incorporating natural ventilation into today’s air conditioned commercial buildings is a tricky and the least straightforward. In extreme harsh climate it is normally difficult to integrate natural ventilation. Mixed mode ventilation, if at all, is only possible during the four winter months [6].

Low energy building design must be approached from a system point of view. As such, integration of renewable energy sources with the building design and construction is necessary. There is no real advantage in installing renewable energy technologies in an improperly designed building apart from the eco-friendly image. It would play the role of a mere ornamental addition to the building at a heavy cost. On the other hand, when renewable energy is integrated in an inherently low energy building, the benefits are many-fold. In the following an outline of possible renewable additions to buildings are discussed.

1.2. Renewable technologies

1.2.1. Photovoltaic

Photovoltaic is one of the examples of such technologies. Integration of photovoltaic systems in commercial as well as residential buildings is easy as it does not require additional areas for installation. They can be easily installed on the flat or sloped roofs and vertical surfaces of the buildings. Flat roofs allow for favorable orientation and inclination of the panels. Sloped roofs and vertical surfaces facing south are more preferred for installation of the PV panels [7]. Technological improvements in this field have allowed PV application in various colours and forms such as solar tiles, arrays of solar modules, roof-mounted and façade-mounted, bifacial solar panels, transparent modules and so on. Advanced systems come up with motorized features that allow for tilting the module to follow the sun path during the day. Building integrated photovoltaics BIPV are PV systems incorporated during its construction or planning stage. Photovoltaic modules also come in form of shading systems and are known as shadow-voltaics [8]. The possibilities to integrate PV systems into buildings are endless. Apart from roofs and facades, transparent modules which allow natural light to pass through are suitable for skylights.

1.2.2. Wind turbines

Another type of technology for creating a truly sustainable building is wind turbine. Integration of wind turbines in commercial and residential buildings is relatively uncommon but has been attempted. The Bahrain World Trade Centre BWTC located in Bahrain (Fig. 1) is the world's first integration of large wind turbines in a building. The sail-like structure of the BWTC consists of two 50m towers supporting three wind turbines of 29m dia in between. The structure is designed to increase the wind velocity between the towers to maximize the wind energy output. Each of the three turbines supplies about 350 MWh annually [9].

Fig. 1. Bahrain World Trade Centre during its construction phase

1.2.3. Integration of energy management systems

Energy management systems, in its more common form of building management systems have been very popular in many countries and all major buildings possess these systems. However, there have been repeated reports that these systems do not function as claimed. The complex system does not reap the benefits as desired due to increased and unnecessary complications arising as a result of improper system design, insufficiently trained operating staff, the sensitivities of sensors, lack of calibration of sensors, inability to access sensors for maintenance, improper commissioning and testing. Evidently, building owners even shut off these systems as they perform erroneously. This is a mere picture of the true situation in some cases. BMS is, at times, ornamental to the building and do not produce any benefits and further complicate matters due to above mentioned reasons. Inspite of its several anomalies, automation by careful design in a low energy consuming building could bring about even greater energy saving benefits. Few of the available energy management systems are lighting control systems, variable frequency drives for pumps, timers and sensors. Lighting control systems can be designed to employ timers, occupancy sensors, photo sensors etc., and switch on/off depending on either time, occupancy detected by sensors, dimming up/down depending on photo sensors. Variable frequency drives may be utilized for pumps and fans and allows for substantial energy savings as the pumps do not function continuously. They are switched on/off depending on demand and hence they experience less operational life loss. Energy management systems/devices avoid wastage of energy by automating and performing based on demand and occupancy.

2. Building descriptions and technical characteristics

Housing development used in this study is the Dostar micro district which is located in one of the intensively developed urban areas of Astana, shown in Fig. 2. This district was selected due to the fact that significant majority of the housing construction in Kazakhstan takes place in this area [10].

The Dostar is the largest district in the capital not only in size (21 hectares), but also in terms of a record number of apartments, it has over three thousand flats of varying size.

Fig. 2. Dostar micro district. General view

This work focuses only on one of three identical residential blocks as they are all built in the same manner and the same technical specifications. It is assumed that results of CFD analysis of one complex can be applied to other as they are all will encounter similar climatic and physical conditions. To analyze the behavior of an average high-rise building while standing alone and when is a part of a complex (surrounded by other buildings) the Dostar 2 residential complex was chosen. This complex consists of 7 typical buildings. All buildings are 9 floor buildings and six of them joined together create a «П» type box surrounding a single standing building in the center (Fig. 2). Dimensions of the buildings are as follows: length #1 – 30, 6m, #2 – 52,8m, #3 – 52,8 m, #4 – 55,8m, #5 - 52,8m, #6 – 52,8m, #7 , 58,8m, widths and heights are the same in all 7 cases and are 12,8 m and 27,5 m respectively. Although Fig. 3 obtained from Google map (satellite view) shows six buildings seen as one block, in fact, they are separated by thermal and settlement joints. Thus, their foundations and frames are completely independent from each other. Neighboring objects are located in a remote distance from the considered complex and therefore were intentionally missed out of the area of analysis.

Distance between building #7 and two adjacent buildings #1 and #6 is 20m. The yard side of the complex contains three large playgrounds and a small square. Given the importance of the yard as a central leisure space, a good wind flow is important. The absence of a building which would play the role of an obstacle protecting the buildings and a yard side from the predominant winds from North-East direction would be investigated. Moreover, the study will also assess how changing the complex orientation can impact air flow pattern and overall behaviors.

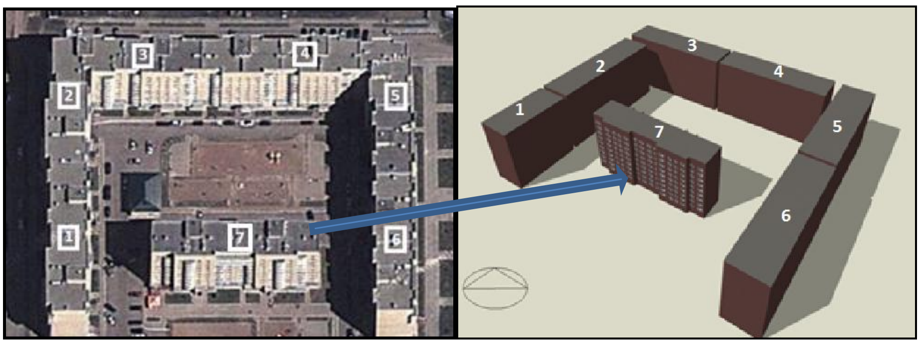

Fig. 3. Dostar 2. Satellite view (left, plan view) and CFD computational model (right, actual orientation).

3. Description of climate

Astana is located on the northern part of Kazakhstan, and situated on the zone of steppe. Hydrographical net of the city is presented by Esil (Ishim) River and its branches. The relief of the city territory is low terrace above flood-plain. Climate of Astana is acutely continental and distinguished by hot, dry and extreme cold weather conditions. In winter time, arctic cold air mass predominates, and clear frosty weather is set due to the branches of Siberian anticyclone. In summer, hot and dry tropical masses invade from south-west [10]. According to the code of reference [11], the climate zone is 1B (average temperature in January -14 - (-28)0C; in July 12-210C). The temperature profile depicted in Fig. 4 reveals that the highest average temperatures occur during the months of July with an average temperature of 20.8°C. The lowest average temperature occurs during January with temperatures as low as -14.2°C.

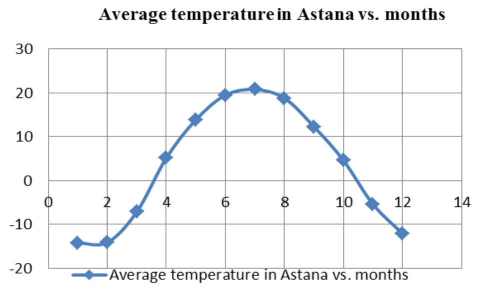

Fig.4. Average Temperature profile - Astana, Kazakhstan [9]

Values of normal, monthly minimum and maximum precipitation are plotted in Fig. 5. The normal value of the annual precipitation is about 318 mm.

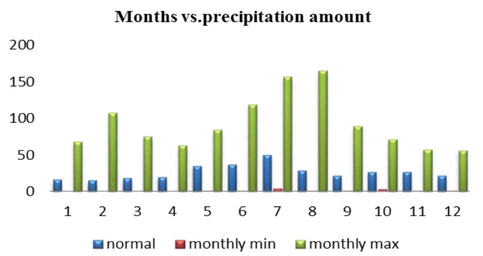

Fig. 5. Monthly precipitation profile - Astana, Kazakhstan [9]

The monthly average relative humidity values are plotted in Fig. 6. Humidity levels can reach as high as 80% Rh and the lower extents are around 53% Rh.The monthly average wind speeds lie in the range of 2.8 m/s – 4 m/s (Fig. 6). The average wind speed over a year is just 3.4m/s. The data does not specify at what height the speeds were measured. It is assumed that the given wind speeds are at sea level.

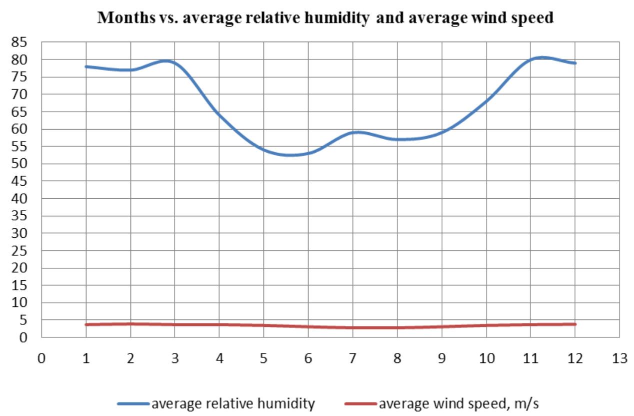

Fig. 6. Average Wind Speed and Relative Humidity profile - Astana, Kazakhstan [12]

Average values of total solar radiation (MJ/m2) on to vertical surfaces depending on the cardinal directions during the heating season are presented in Fig.7 below. According to [13], heating season in Astana is considered to be 216 days.

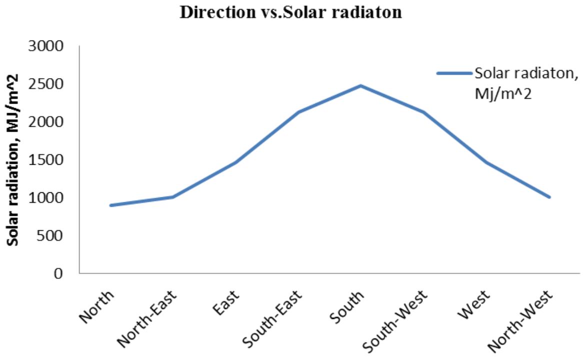

Fig. 7. Averaged solar radiation profile depending on the cardinal directions during the heating season - Astana, Kazakhstan [13]

From [13], the amount of total solar radiation onto vertical surface on a cloudless July day is taken as maximum as 778 Wt/m2 and as daily average as 190 Wt/m2. As shown from Figure 7, south facing side tends to receive the largest amount of the radiation.

4. Results overview

The boundary conditions has been set as initial velocity values in X, Y, Z (correspondingly u, υ, ω) direction and ambient outdoor temperature which are constant through the domain; and final conditions are automatically built-in as pressure equals to atmospheric pressure. So, overall boundary conditions can be expressed as following:

$$\begin{cases} u = const = 5{,}9 m/s \\ \upsilon = 0 \\ \omega = 0 \\ T = ambient\ outdoor\ temperature(winter) \\ p = p_{atm} \end{cases}$$

The application of CFD for pedestrian – level wind studies was initiated by the early, more general research efforts in which CFD was applied to study the wind-flow pattern around isolated (single standing) buildings [18]. In order to develop further, this paper attempted to establish correlations between orientation and configuration of a building(s) and its wind system behavior. In order to find out how the above mentioned aspects affect the wind flow distribution around the considered objects, it has been decided to run simulations separately for both configurations: a single standing building and a complex (several blocks).

A. Multiple buildings configurations

Inaccurate placement of buildings with respect to each other, inappropriate distance between two adjacent buildings as well as their orientation with respect to the dominant wind direction can sometimes cause severe adverse effects. Durgin and Chock [19] proved that uncomfortable wind conditions have been destructive to success of new buildings. For instance, Wise [20] reports about supermarkets built-in in one of the blocks were left without visitors due to windy environment. Lawson and Penwarden [21] reported that dangerous wind condition has led to death of a couple of elderly people after they were blown over by sudden wind drafts near a high-rise building. It is often encountered situation in Astana when people are drawn back by wind and are not able to go through passing spaces (arches) between adjacent buildings [22].

CFD simulations for this model were completed for five main orientations: 0˚, 35˚, 90˚, 180˚, 270˚; with original direction of the target building (the one in the center of the complex) and the whole complex - 35˚ towards the North-East. As the complex currently exists, it was aimed to compare actual orientation with other potential alternatives. As it can be seen from the CFD images in the Figure 10, the wind flow pattern between the buildings when they are located in a box-shaped form is quite satisfactory. Images present the plan view of the computed velocity and pressure fields around the buildings at 1,35m (pedestrian level) and 20m (middle of the domain height) from the ground level for normal wind conditions. Values of wind velocity and pressure are distinguished by color and are indicated on the scale.

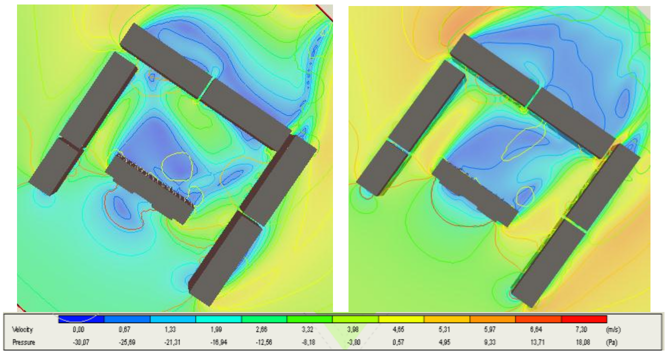

Fig. 10. Wind and pressure distribution around the complex at 1, 35 m and 20 m height levels. Direction - 35˚ (initial position)

However, changing the orientation of the complex has shown that there are setups that provide more favorable wind conditions. For instance, turning the object to 180˚direction has allowed reducing the wind speed and pressure inside the “box”. High wind speed and pressure values noticeable in the initial position (Fig. 10) dropped down as the surrounding buildings started to hamper the effect of winds from predominant winds direction (Fig. 11)

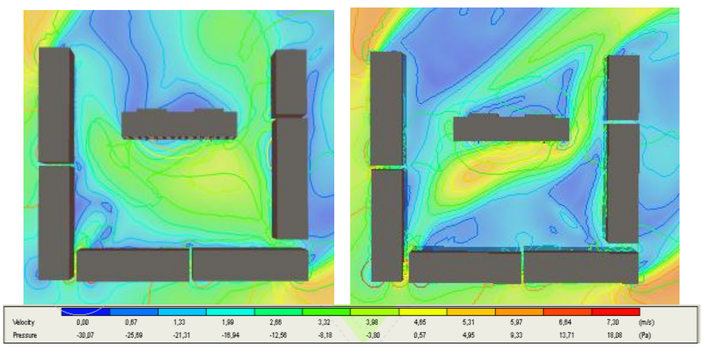

Fig. 11 Wind and pressure distribution around the complex at 1, 35 m and 20 m height levels. Direction - 180˚

Thus, simulation results also show that complex with the same configuration model can create different wind environments given different orientations. Comparing snapshots for different orientations (degrees) the study concluded that all simulated directions have different effects on the local flow development.

B. The Single Standing Building Model

Unlike the previous treatment, this model was simulated for twelve orientations of the target building: 35˚, 80˚, 125˚, 170˚, 215˚, 260˚, 305˚, 350˚ (eight directions with increment of 45 degrees and starting with the initial orientation 35˚) and the main four directions 0˚, 90˚, 180˚, 270˚ (the latter ones were taken intentionally in order to compare with the previous model results and only they are presented in the table).

This type of arrangement is also one of the often encountered arrangements in Astana. Usually people living in such isolated buildings complain on lowering of indoor temperature due to winds continually blowing on the external walls and windows. The outdoor conditions are also reported to be uncomfortable mainly due to open space around a building. In fact, neighboring buildings do not provide protection from intensive winds typical to Astana if they are not surrounding the considered building [23]. This model is also characterized by a relatively high level of nuisance as ventilation systems joining with outdoor wind flows can create drafts in the apartments and lift shafts [24].

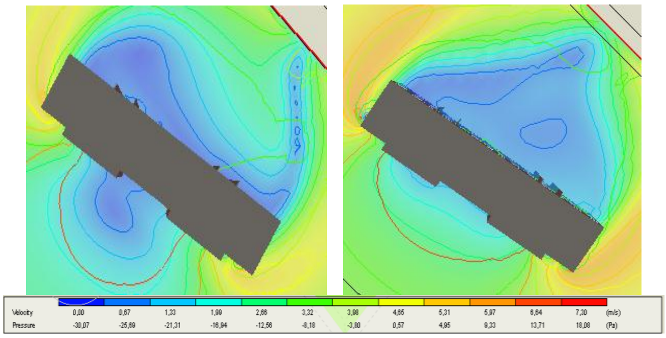

Fig. 12. Wind and pressure distribution around the single standing building at 1, 35 m and 20 m height levels. Direction - 35˚ (initial position)

Simulations have shown that the initial orientation of the considered building is the best fit (Fig. 12). In contrast to other directions current orientation is found to be providing more comfortable environment. The yard side of the building has the lowest level of wind speed and pressure. Whilst almost all other orientations create smaller comfort zones as, for example, in case of 270˚ (Fig. 13), the initial direction allows creating larger propitious wind environment including the rear side of the building.

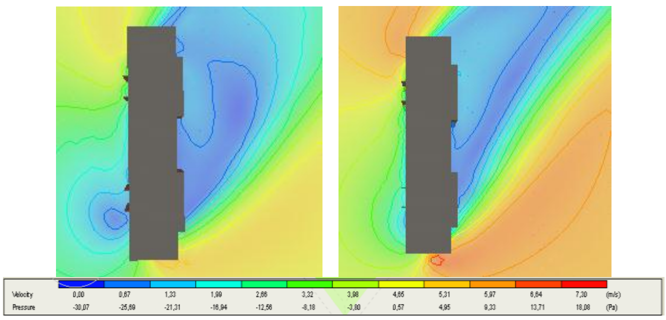

Fig. 13. Wind and pressure distribution around the single standing building at 1, 35 m and 20 m height levels. Direction - 270˚

5. Comparative Assessment

Comparison of two cases shows that multiple buildings configuration as expected, provide moderate and controlled conditions in terms of wind velocity and pressure levels than the stand alone single building model. Although there are areas of turbulence but they do not seem to be excessive in nature (within the stated conditions). Fig.13 shows that the single standing building, in turn, is characterized by quite high speed wind flows around it and noticeable high pressure levels at the corners of the building. With regard to orientation both models seem to have the best fit degree with respect to North and wind direction. In the case of the building complex, most desirable conditions are created when it is turned to 180 degrees direction. It seems to be obvious as orientation of complex close to this value creates “blocking effect” to the predominant winds. The inner area seems to be protected from winds by surrounding buildings. The yard side can be categorized as sheltered. In case of a single standing building the best fit orientation is considered its initial orientation (35˚). As the wind direction (225˚) and the building’s façade (yard) are in the same directions they are most likely to create the most quiet and safe environment among all.

The optimal building orientation and configuration based on the results of simulations should be considered carefully and validated by on-site measurements. As this study employs a specialized code, a proposal of the most optimal features of two different models will be purely based on the analysis of CFD results. According to the above presented comparison, it is suggested to consider the multiple buildings configuration (a box-shaped in this case) rather than a single standing building while designing future housing developments. Other types of multiple building configurations should be studied too. With respect to buildings’ orientation it is recommended in case of a complex model to turn the fully surrounded side of a “box” opposite to the predominant wind direction (180˚ in this case). In the latter model, a building should be located with the rear side opposite to the wind direction (35˚ in this case).

6. Conclusion

The paper provides a brief overview of external flow distribution on building performance. The influence of orientation and configuration is discussed with reference to energy efficiency and associated wind comfort and safety.The effect of these aspects on energy consumption and comfortable wind environment has been assessed using CFD analysis and proved to be positive. According to our comparison it could be concluded (as expected) that the multiple buildings configuration has better wind conditions rather than a single standing building. With respect to orientation the former one should be modeled with the fully surrounded side of a “box” opposite to the predominant wind direction whereas the latter one should be located with the rear side opposite to the wind direction.

The findings are particularly important as the study covers a very sensitive aspect of the country’s economy and general well-being of future building design development in Kazakhstan capital. Provision of comfortable wind environment and safety as well as making cuts in energy consumption by means of well-planned passive design are believed to lead to financial savings as well as environmental benefits**.**

7. Acknowledgment

The authors would like to thank Nazarbayev University for the research funding, “BI Group” Construction Company for making available data on building complexes and Associate Professor of Mechanical Engineering Desmond Adair for his invaluable advice and guidance throughout this study in the area of CFD simulations.

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Measured Effects of Shading a North-facing Wall with External Horizontal Slats of different reflectances at Latitude 33'53"South

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Keywords: Shading walls, direct solar radiation, effectiveness of reflectances of shades.

1. Introduction

The shading of walls relates to the sustainability of building materials in the context that shading has been shown to reduce the temperature of the face of a wall during the day and reduce heat loss at night. As such this may be equated to a quantity of thermal insulating material being either low emissive (e.g. reflective foil insulation) or bulk thermal insulating material. Most thermal insulating materials have a high embodied energy. Thus, achieving the effect of thermal insulation by using, for example, a low embodied energy shading system may be seen to be sustainable because the quantity of high embodied energy thermal insulating material may be reduced.

Interest in shading walls as an energy conserving measure is shown in the literature. Cook [1] states: "In modern construction the various means of heat avoidance are by far the most economical energy conservation methods in spite of the availability of many technical or mechanical solutions". Papadakis et al [2] found shading from plants to be efficient for solar control by comparing surface temperatures of a shaded and an unshaded wall. Sandifer [3] took readings from walls shaded with vines in an effort to quantify the amount of heat gain avoided by different thicknesses and varieties of vines, in comparison to an unshaded wall. Okba [4] presented a checklist for building envelope design options that included shading walls. Abou-El-Fadl [5] combined the effects of shading and night ventilation to reduce summer thermal load. Parker [6], Heisler [7] and others published on the benefits of shading walls to reduce heat gain.

Throughout history architects have used vegetation, external colonnades and roof overhangs to shade walls in an effort to avoid excessive heat gain. Although most papers mentioned in the preparation for the present research involve the use of trees, for taller buildings it would be difficult to shade with any kind of vegetation. Also, buildings located in arid regions where vegetation does not thrive would benefit from passive shading devices. There is a case to investigate more thoroughly the performance of external shading devices for walls for which plants are not suitable.

The series of experiments presented in this paper report on the effect of shading a north-facing wall in a southern hemisphere location with horizontal slats of different reflectances compared to an unshaded wall. Data recorded at 10 minute intervals were analysed to indicate which reflectances were more effective in shading the wall panels.

2. Experiments

2.1 Test panel array

The experiments were carried out at latitude 33°53'South and longitude 151°11"East, on the roof of the Wilkinson Building at the University of Sydney, in an effort to avoid external objects casting shadows on the panels. The sun's altitude at noon in this latitude is 81° at the summer solstice (December 21st); 57° at both of the equinox days (March 21st and September 22nd); and 33° at the winter solstice (June 21st).

Three separate experiments were made. All were performed with the same setup, consisting of two identical reinforced concrete panels 500mm high x 500mm wide x 50mm thick. These panels were physically linked to a table using thin metal fixtures, so as to minimize thermal conduction with the table. Both panels were installed inside a protective wooden box custom-built for the purpose of the experiments, in order to protect the edges and back surfaces of the panels from direct and diffuse solar radiation, as well as rain and wind (Fig. 1). The front surfaces of both panels were placed vertically facing the northern sun.

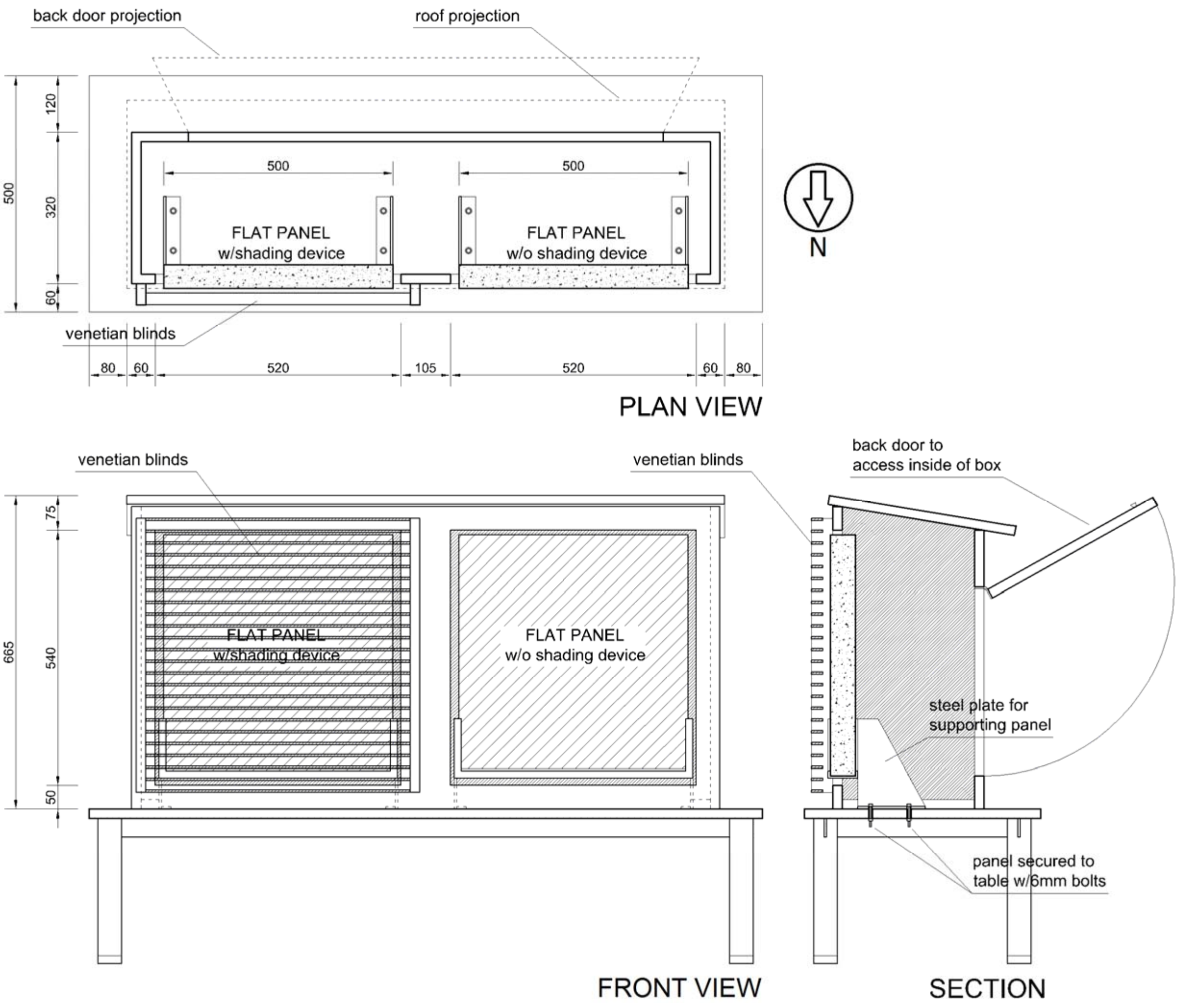

Fig. 1 Diagram of the test panel array

Each of the two panels was fitted with 7 thermocouples (Fig. 2): two on the front surface, four on the back surface and one suspended inside the box for air temperature control, not in contact with the panel or the box. Each of the two groups of 7 thermocouples was connected to a 7-channel high resolution data logger that recorded temperatures every 10min for 144hrs. Calibration, setup, and data recording were performed according to the logger's manufacturer specifications.

2.2 Data Logger Calibration

Both 7 channel data loggers were identical: Smart Reader Plus 6 by ACR Systems Inc., with a 128kB memory. The thermocouple cables used were Type J (Range: -50°C – 600°C, Resolution: 0.3°C). The calibration was done by fixing equal lengths of cable to each of the channels and submerging the ends of the coupled cables in icy water with a known temperature. The loggers were then connected to a computer using TrendReader (software bundled with the data loggers). All channels were re-calibrated in real time using the low reference temperature while the ends of the cables were still submerged. Once calibrated, the thermocouple cables were fixed to the panels (Fig. 2) and the calibrated loggers were reset. An initial test was performed on both panels unshaded, in order to verify their physical similarity by confirming that their respective back and front surface temperatures were similar: results were satisfactory with mean deviations of no more than 0.3°C indicating that the loggers were adequately calibrated and that all 14 coupled wires were firmly connected.

2.3 Thermocouple fixing method

Ø1.5mm x 8mm perpendicular holes were drilled into the panels at the locations shown in Figure 2. The coupled wires, of an approximate diameter of 1.6mm, were cut 5mm long and fitted inside the holes. Silicon was then applied around the hole to prevent the coupled wires from sliding out and to protect them from wind and humidity (Fig. 3).

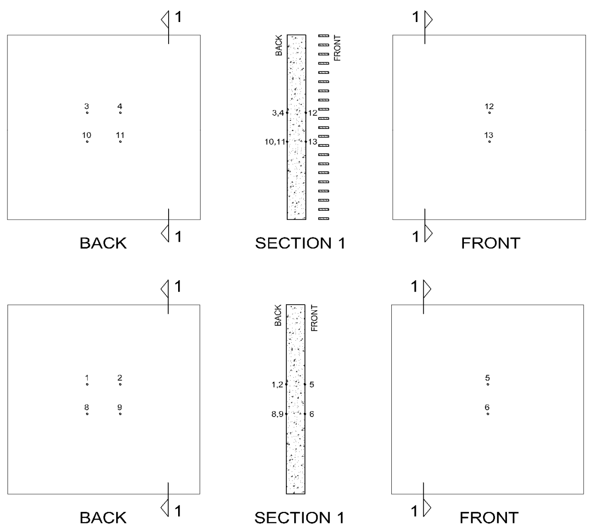

Fig. 2 Thermocouple locations

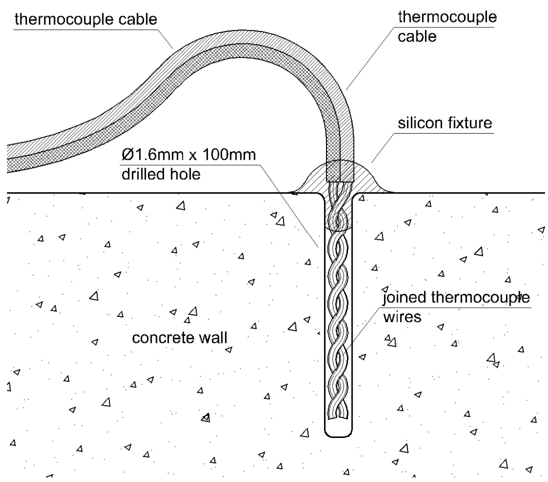

Fig. 3 Thermocouple fixing method

2.4 Experiment Setup #1 – White Slats

In the first experiment, an external shading device with horizontal slats painted white (approximately 70% reflectance) was installed in front of one of the concrete panels. The shading device was fixed to the wooden box to eliminate physical connection to the panel, avoiding thermal conductance. The loggers were set to record temperatures every 10min for a period of 144hrs of predominantly clear skies. The dates recorded were Feb26/2009 through Mar02/2009. The sun's average altitude at noon during these dates was approximately 68°.

2.5 Experiment Setup #2 – Grey slats

In the second experiment, the external shading device was painted medium gray (approximately 50% reflectance) and temperatures were recorded every 10min for a period of 144hrs of predominantly clear skies. The dates recorded were Mar02/2009 through Mar08/2009. The sun's average altitude at noon during these dates was approximately 62°.

2.6 Experiment Setup #3 – Black slats

In the third experiment, the external shading device was painted black (approximately less than 5% reflectance) and temperatures were recorded every 10min for a period of 144hrs of predominantly clear skies. The dates recorded were Mar24/2009 through Mar30/2009. The sun's average altitude at noon during these dates was approximately 55°.

3. Results

3.1 Front Surface Readings

Figures 4, 5 and 6 show the temperature difference (Δt) between the front surface of the unshaded panel and the front surface of the shaded panel. Table 1 summarizes the results.

Table 1 Front surface temperature differences (Δt) between the shaded and the unshaded panels

Experiment	Panel	24h average temp. (°C)	24h average Δt (°C)	Daytime Δt At the highest point in the graph		Nighttime Δt At the lowest point in the graph	
				(°C)	Date	(°C)	Date
#1: White slats	Shaded	24.6	1.2 (shaded is cooler)	9.0 (shaded is cooler)	02Mar 13:20	-0.9 (shaded is warmer)	27Feb 05:20
	Non shaded	25.8					
#2: Grey slats	Shaded	24.0	1.5 (shaded is cooler)	10.0 (shaded is cooler)	05Mar 13:40	-1.2 (shaded is warmer)	05Mar 05:40
	Non shaded	25.5					
#3: Black slats	Shaded	24.6	2.0 (shaded is cooler)	11.1 (shaded is cooler)	28Mar 13:30	-0.8 (shaded is warmer)	28Mar 01:20
	Non shaded	26.6					

3.1.1 Maximum daytime temperature differences between front surfaces:

On March 2nd at 1:20PM the white slats produced a temperature on the shaded panel that was 8.8°C cooler than the unshaded panel. On March 5th at 1:40PM the grey slats produced a temperature on the shaded panel that was 10.0°C cooler than the unshaded panel. On March 28th at 1:30PM the black slats produced a temperature on the shaded panel that was 11.1°C cooler than the unshaded panel.

3.1.2 Maximum nighttime temperature differences between front surfaces:

On February 27th at 5:20AM the white slats produced a temperature on the shaded panel that was 0.9°C warmer than the unshaded panel. On March 5th at 5:40AM the grey slats produced a temperature on the shaded panel that was 1.2°C warmer than the unshaded panel. On March 28th at 1:20AM the black slats produced a temperature on the shaded panel that was 0.8°C warmer than the unshaded panel.

3.1.3 Average temperature difference over a 24hr period between front surfaces:

Over a 24hr period (daytime and nighttime readings combined), the front surface of the panel shaded with white slats was on average 1.2°C cooler than the unshaded one; with grey slats 1.5°C cooler than the unshaded one; and with black slats 2.0°C cooler than the unshaded one.

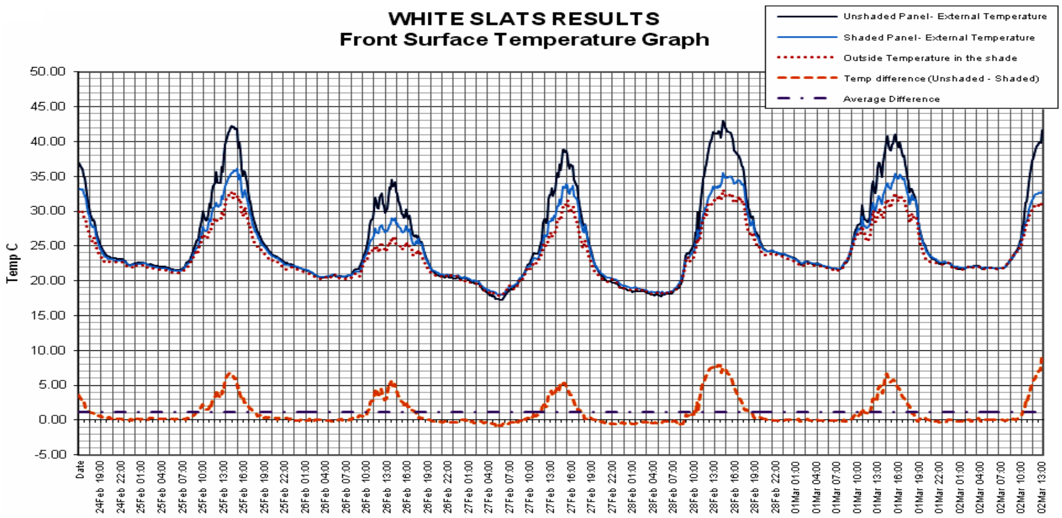

Fig. 4 White slats: Front surface Δt between the shaded and the unshaded panels

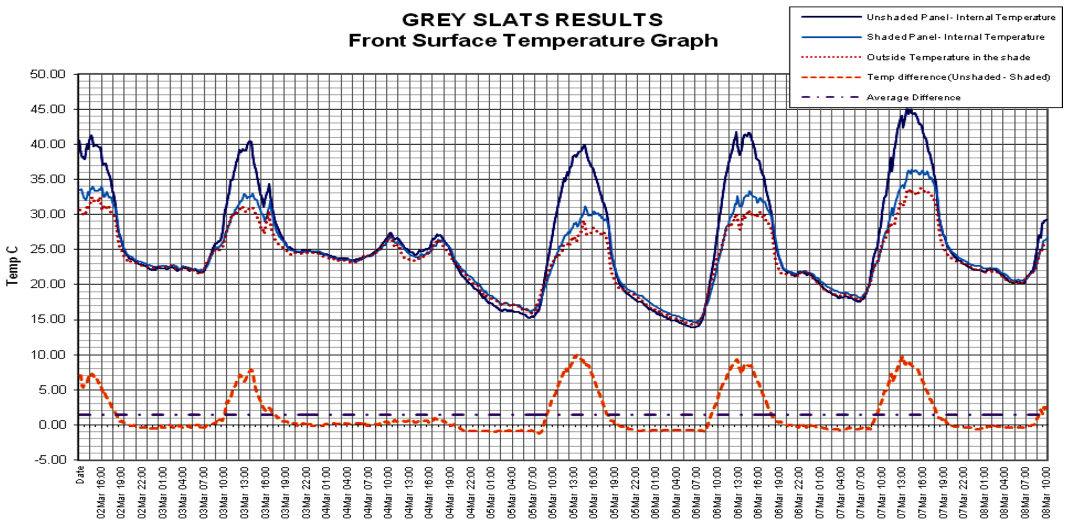

Fig. 5 Grey slats: Front surface Δt between the shaded and the unshaded panels

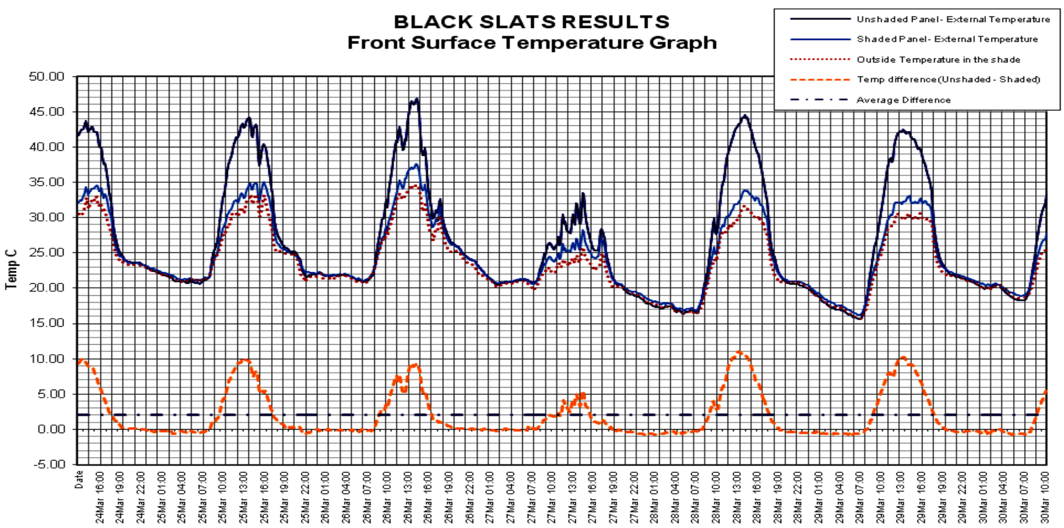

Fig. 6 Black slats: Front surface Δt between the shaded and the unshaded panels

3.2 Back Surface Readings

Figures 7, 8 and 9 show the temperature difference (Δt) between the back surface of the unshaded panel and the back surface of the shaded panel. Table 2 summarizes the results.

Table 2 Back surface temperatures differences (Δt) between the shaded and the unshaded panels

Experiment	Panel	24h average temp. (°C)	24h average Δt (°C)	Daytime Δt At the highest point in the graph		Nighttime Δt At the lowest point in the graph	
				(°C)	Date	(°C)	Date
#1: White slats	Shaded	24.2	0.8 (shaded is cooler)	6.1 (shaded is cooler)	28Feb 14:10	-1.0 (shaded is warmer)	27Feb 05:00
	Non shaded	25.0					
#2: Grey slats	Shaded	23.7	1.1 (shaded is cooler)	7.5 (shaded is cooler)	07Mar 13:10	-1.1 (shaded is warmer)	05Mar 06:50
	Non shaded	24.8					
#3: Black slats	Shaded	24.3	1.5 (shaded is cooler)	8.2 (shaded is cooler)	28Mar 13:20	-0.8 (shaded is warmer)	28Mar 02:00
	Non shaded	25.8					

3.2.1 Maximum daytime temperature differences between back surfaces:

On February 28th at 2:10PM the white slats produced a temperature on the shaded panel that was 6.1°C cooler than the unshaded panel. On March 7th at 1:10PM the grey slats produced a temperature on the shaded panel that was 7.5°C cooler than the unshaded panel. On March 28th at 1:20PM the black slats produced a temperature on the shaded panel that was 8.2°C cooler than the unshaded panel.

3.2.2 Maximum nighttime temperature differences between back surfaces:

On February 27th at 5:00AM the white slats produced a temperature on the shaded panel that was 1.0°C warmer than the unshaded panel. On March 5th at 6:50AM the grey slats produced a temperature on the shaded panel that was 1.1°C warmer than the unshaded panel. On February 28th at 2:00AM the black slats produced a temperature on the shaded panel that was 0.8°C warmer than the unshaded panel.

3.2.3 Average temperature difference over a 24hr period between back surfaces:

Over a 24h period (daytime and nighttime readings combined), the back surface of the panel shaded with white slats was on average 0.8°C cooler than the unshaded one; with grey slats 1.1°C cooler than the unshaded one; and with black slats 1.5°C cooler than the unshaded one.

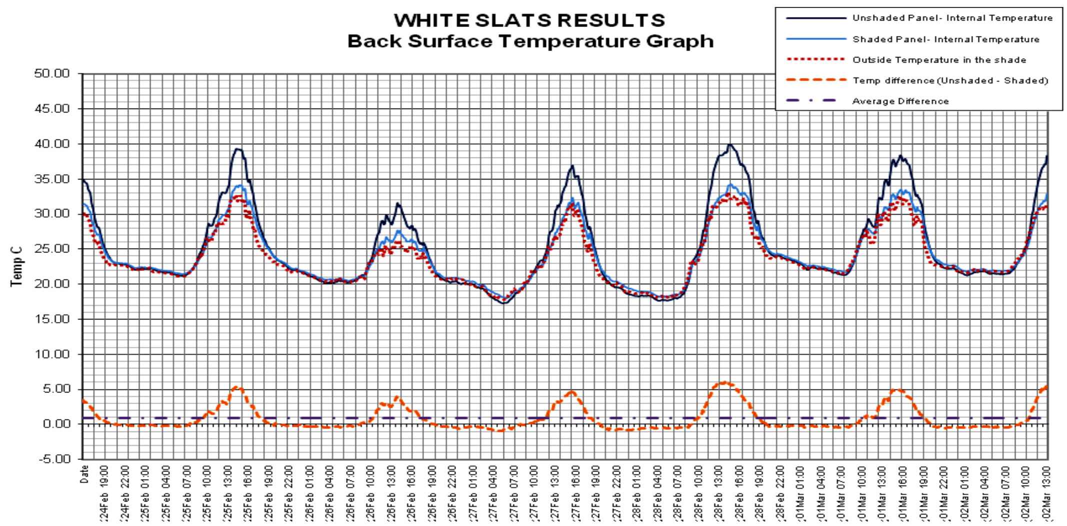

Fig. 7 White slats: Back surface Δt between the shaded and the unshaded panels

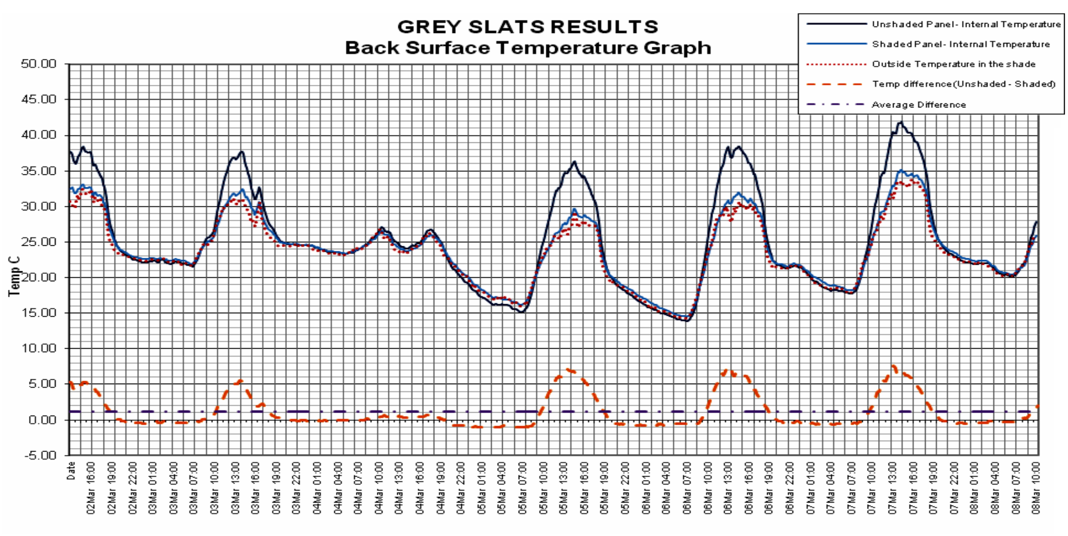

Fig. 8 Grey slats: Back surface Δt between the shaded and the unshaded panels

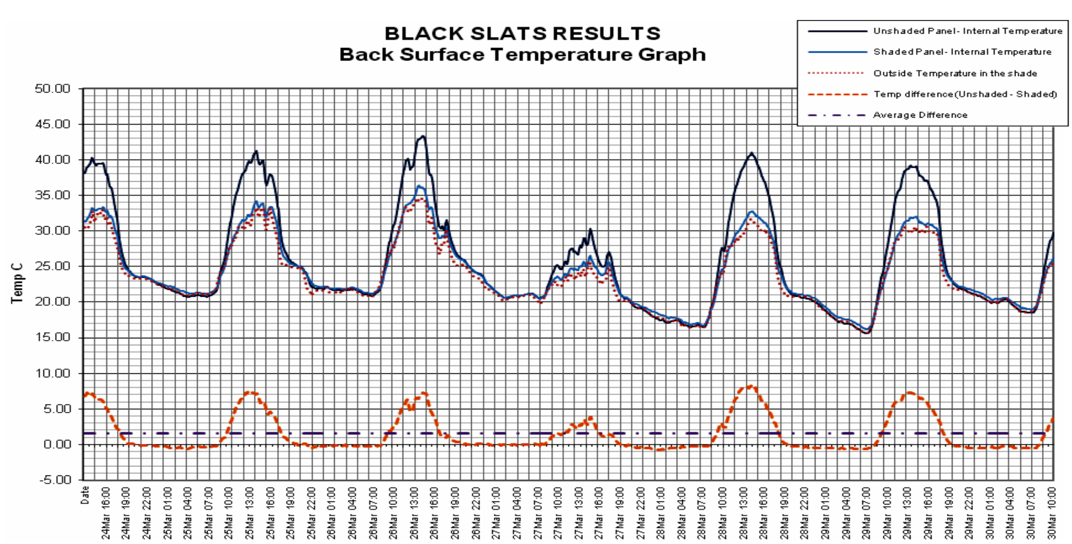

Fig. 9 Black slats: Back surface Δt between the shaded and the unshaded panels

3.3 Performance on overcast/cloudy days

Solar irradiance on a completely overcast day would be up to 100% diffuse. Other days may have various proportions of direct and diffuse solar radiation due to passing clouds. This affects the slats' ability to reduce the surface temperature of the panels.

On March 4th the skies were mostly overcast, except for short periods of clear skies in the morning and afternoon. The temperature difference (Δt) between the shaded and unshaded panels reached a daytime maximum of just 1.0°C on the front surface with grey slats, compared with an average of 10.0°C on a sunny day. On the back surface the Δt between the shaded and unshaded panels reached only 0.8°C.

On March 27th (Fig. 10) passing clouds resulted in an intermittent exposure of the shaded and unshaded panels to direct solar radiation throughout the day. The daytime maximum difference on this day was 5.5°C, compared to 11.1°C on a sunny day.

Conversely, on both dates the nighttime maximum temperature difference did not vary significantly, although the shaded panel still remained slightly warmer than the unshaded panel.

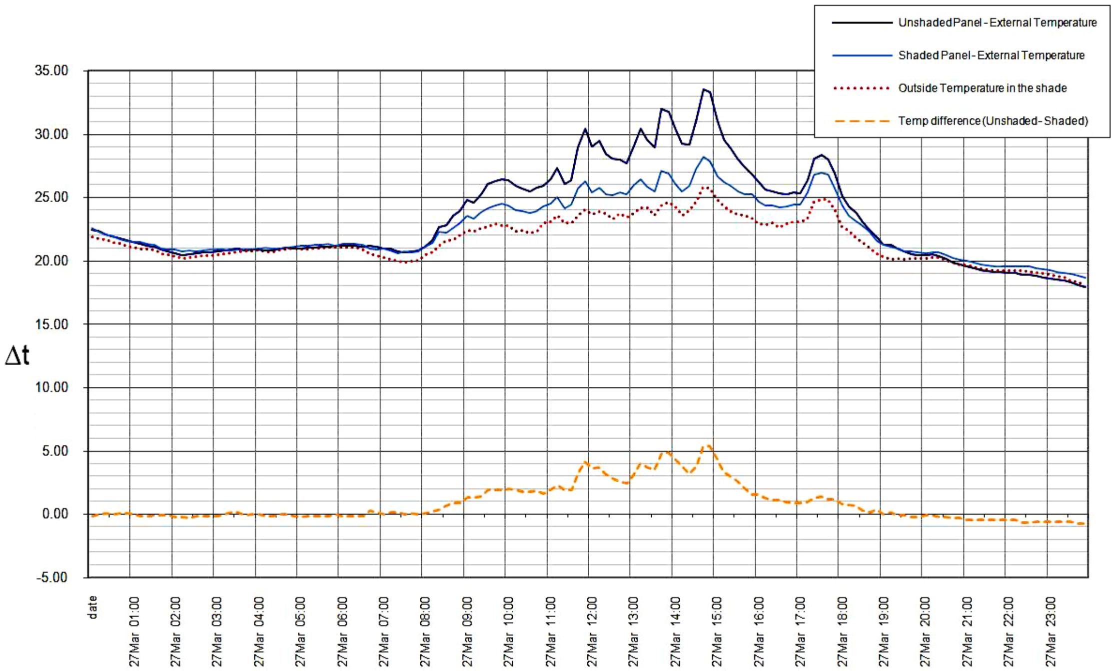

Fig. 10 Front surface Δt on a day with partial direct solar radiation

4. Discussion of results

Data collected from the three experiments showed that during the daytime, darker coloured slats were more effective in preventing the shaded panel from gaining heat than lighter coloured slats. Regardless of the colour, the ability of the slats to prevent heat gain on the shaded panel during cloudy days was dramatically reduced. On cloudy days the Δt between the shaded and unshaded panels was less than 1°C at any time, which indicates the significance of shading against the direct component of solar radiation under clear sky conditions.

Figure 11 shows the Δt between the front surface of the shaded and unshaded panels over a 24hr period of clear skies. To produce this graph, data from the four hottest clear days was averaged. By avoiding most of the direct solar radiation with the horizontal slats, the Δt reached an average peak of 10°C on the front surface and almost 8°C on the back surface using black slats.

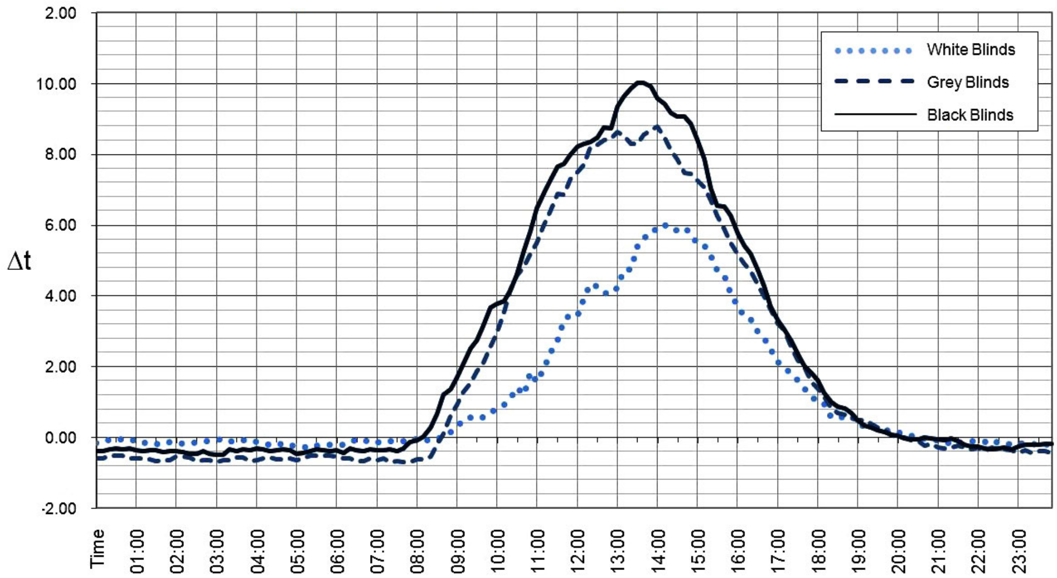

Fig. 11 Front surface Δt between shaded and unshaded panels over 24hrs of clear skies. (This graph averages of the four hottest clear days and compares results of all three experiment setups: white, grey and black slats)

It was also found that during nighttime the shaded panel remained slightly warmer than the unshaded panel. The temperature difference between the wall and the slats, being less than between the wall and the heat sink of the sky at night, would result in less long wave radiation being emitted from the wall protected by the slats. This may have also reduced wind speed on the panel's front surface, reducing the amount of heat lost by convection.

The Δt between the back surfaces of the shaded and unshaded panels was less than the Δt of the front surfaces; the reason being that the thermal mass of the panels caused the temperature curve of the back surface Δt to flatten slightly in comparison to the front surface Δt. Temperature differences were calculated in both cases, as shown in Tables 1 and 2.

5. Conclusions

Shading a wall reduces the external surface temperature of the wall as a function of the reflectance of horizontal shading slats. Shading systems also reduce the rate of loss of heat at night.

White horizontal slats were less effective than grey and black slats because the white slats reflected more shortwave radiation onto the surface of the wall. The presence of the slats reduced the panel's area that could emit long wave radiation directly to the heat sink of the night sky.

Black slats resulted in a front surface temperature reduction of up to 11°C, while grey slats achieved 10°C and white slats achieved 9°C, compared to an unshaded wall.

This makes a case for using dark coloured low mass shading systems for shading walls, particularly in hot climates with clear skies.

Slats are much less effective on days with clouds. During cloudy days a larger percentage of the total solar irradiance is indirect, being up to 100% on days with overcast skies. During cloudy and overcast days the outside temperature of the wall is lower due to lack of direct radiation.

By being much more effective at blocking direct rather than diffuse solar radiation, slats enable the wall to be significantly cooler on sunny days. Slats can be designed to provide more shade in summer than in winter by modifying the geometry of the shading device (e.g. slats could be designed to allow some direct solar radiation during winter, when the sun's altitude is considerably lower).

6. Further investigations and experiments

The ability of darker coloured slats to maintain lower temperatures on the exterior surfaces of walls than lighter coloured slats is not yet well understood. Further experiments may produce more precise results, in which thermocouples could include surface temperature readings of the different coloured slats themselves, both on their upper and lower surfaces. This would shed some light on how solar energy is being reflected, transmitted and emitted by slats with different reflectances. Installation of additional monitoring equipment could include:

Installation of thermocouples in several parts of the different coloured slats, in particular the upper and lower surfaces. This which would help explain where and how the energy is being dissipated in each different coloured set of slats.

Wind velocity measurements with anemometers near the surface of the test panels would also help explain how wind influences the overall results.

Include data from nearby meteorological stations (e.g. temperature, relative humidity, wind velocity). This would provide useful information necessary to draw conclusions about how external factors influence on the overall results.

Measurement of global and direct radiation intensity would provide information about how changes in solar irradiation affect the results, as well as providing reliable information about sunny, cloudy and overcast days.

Further work could include developing slat designs for other orientations and latitudes, as well as the development of commercial products that could be retrofitted on existing buildings that suffer from excessive solar gain on windowed or windowless walls exposed to the direct component of solar radiation. Reflectance selection for any shading system could significantly affect cooling loads in buildings.

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Value Stream Engineering – A case study of process optimization for the supply chain of window installation

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Summary

The Value Stream Mapping (VSM) approach has originally been developed for the automotive industry for series production with limited variant number. Many case studies show the optimization of processes using the VSM methodology. The traditional VSM approach was extended to be used in single-part and small batch production with high diversity of products and variants in the manufacturing industry. The new approach was called Value Stream Engineering (VSE).
The case study presented in this paper was executed within the joint research project "build4future", which is managed by the Fraunhofer Innovation Engineering Center (IEC) in Bolzano (Italy). The mentioned research project is composed of 12 small and medium sized enterprises (SMEs) situated in the province of Bolzano. The main target of the cooperation project is to optimize the process inside the enterprises as well as an integration of the value chain in building projects, targeting shorter lead times and lower costs without losing on quality and individuality.

To this goal the case study aims on evaluating a standardized methodology for analysing and redesigning processes in the construction industry by means of a supply chain analysis for window installation. This standardized methodology consists of an adapted VSE approach to the needs of the construction sector. For the case study a project scenario has been chosen consisting of a hotel with an overall building cost of around 3 Million Euros and with 120 windows to be installed. The current processes for the glass supply, the window manufacturing and the installation on site were mapped using the VSE methodology. In addition, lead times of different processes were registered. As a result, interfaces between the supplier, the manufacturer and the installation on site were studied in detail identifying sources of waste in the construction supply chain.

In traditional construction projects wrong materials on site are the main concerns of project supply, causing losses in construction quality or large material stocks creating high fixed costs. Therefore, in the case study based on the current state analysis, an innovative methodology for an efficient supply, manufacturing and installation of windows on site will be presented. The concept developed in the case study is different from the prototypical applications of "Lean Thinking"

concepts in construction up to now, because it is worked out in an integrated manner. This means that the coordination on site is integrated in the internal process optimizations of the involved companies.

As a result, a standardized methodology is shown, which serves as a best practice for analysing and optimizing every process in the construction industry using the VSE approach. Furthermore, four guidelines are presented, which should allow to design and align the supply, manufacturing and installation of different crafts to the building site.

1. Introduction

The South Tyrolean building sector is well known for its innovative and high quality standard. It is one of the key industries for the local economy. However the building industry is composed of small and medium sized companies that struggle the price competition in a globalized market. Therefore the research project “build4future”, which is currently managed by the Fraunhofer Innovation Engineering Center (IEC), was launched to build up a platform, composed of twelve companies from different businesses in the construction industry. The target is to develop an industrialized, integrated and intelligent approach in planning and construction method to help each project member sustaining and strengthening its market position.

“Build4future” is organized as a cooperation project between South Tyrolean construction companies and research institutes like Fraunhofer IEC, the Free University of Bolzano, TIS innovation park and the KlimaHaus Agency. Facing problems of different sectors in the same industry by different research partners allows an integrated view of the whole process.

In South Tyrol labour costs are relatively high and enterprises do not have a strong negotiation power to reduce them. So, the only way to influence costs is to work on reducing waste in processes. Traditionally, construction companies focus on their core competences and only a few years ago they started to consider redesigning process flows to reduce waste [1]. The main goal of the project “build4future” is to optimize the value chain in construction in order to get lower costs and shorter lead times without losing on quality. Thence, the existing processes of the partner companies were analysed using the Value Stream Engineering (VSE) approach. On the basis of the current processes, the applicability of lean concepts derived from other industries, for example the automotive industry, were considered and their adaptability on the construction business were studied. In addition, process models were developed to make these concepts applicable to wider project scenarios. The case study validates some of these concepts on basis of a supply chain analysis for window installation.

2. The Value Stream Engineering Approach

“The construction industry still continues to under-perform, generally due to a continued lack of design and construction process integration, a lack of focus on quality and customer value, poor contractual relationships and a general lack of understanding as to why poor performance continuous or how improvements might be achieved” [2]. Thus, a methodology has to be provided, which visualizes in detail the different processes occurring during a construction project. The Value Stream Mapping (VSM) approach as described by Rother and Shook in [3] has not been diffused in the construction industry. In fact, few case studies exist, which only show the optimization of sub-processes introducing Lean Production methods to construction. The interaction between different stakeholders is analysed only superficially without a systematical approach. This leads to the consideration that the VSM methodology introduced by Rother and Shook is not suitable for studying processes with high diversity of product typologies and variants, like in the construction industry. Therefore, the Fraunhofer Institute for Industrial Engineering (IAO) developed a further evolved and adapted version of VSM, which is called Value Stream Engineering (VSE). This methodology allows to design work-processes with embedded Make-to-Order Process chains. “VSE contains a toolkit with design options, process templates and methods for design of a firm specific industrial engineering approach in enterprises with customer driven work processes” [4]. This methodology describes the process in a holistic way, which means that it starts with the order

from the customer and finishes with the delivery of the final product or service to the customer. So, all participants in the planning, production and logistic process are included. Furthermore, the process chain is represented by a flow graph starting at the customer order and ending at the delivery to the customer. In conclusion, interfaces to downstream or upstream process stages can be depicted in detail, identifying sources of traditional problems in construction supply chains.
In this case study, an adaptation of the VSE approach to the construction industry will be presented.

3. Process analysis

Based on a problem analysis carried out within the project “build4future” in traditional construction projects wrong materials on site causing losses in construction quality, or big material inventories creating high fixed costs, emerged as main concerns of project supply. Therefore, in this case study, the optimization of management and control during construction execution will be described in detail. The supply chain is composed of a tier one supplier and a tier two supplier. The tier one supplier delivers his products to a building site for assembly. In the following paragraphs the current state of this window installation supply chain will be studied. The supply chain of the window manufacturer was analysed because of its significant participation in total building costs. Production and installation of windows constitutes around 10% of total building costs [5].

The analysis starts with the tier 2 glass pane supplier continuous with the tier 1 window manufacturer and finalizes with the installation of the windows on site. After a brief description of each company, the suppliers’ processes are analysed using the VSE approach and a connected lead time analysis is worked out. Due to confidentiality reasons the names of the considered companies are not shown.

3.1 Process analysis of the glass pane supplier

The company produces multifunctional insulating glasses. More in detail, it doesn’t fabricate the glass by itself but it purchases prefabricated glass panes. The core business of the enterprise is in the building sector. There, it acts in a business to business supply chain, where the customers are window manufacturers, carpenters, facade constructors and interior furniture manufacturers (joiners).

The VSE-map is shown in Appendix A. First of all, the information flow, which is shown with thin lines, is explained:

- The window manufacturer sends a customer order which is acquired in the *order processing centre*.
- Afterwards, the order is forwarded to the *job scheduling department*, which plans the used machines and the time necessary to produce the requested order numbers. Moreover, it determines a list for tailored glass panes which should have the task to minimize the offcuts. This means that from one raw glass pane different production orders from different customers are tailored. In a next step, the *job scheduling department* forwards a production order to the *production planning department* which splits the assignment in sub-orders and arranges the time scheduling for elaborating the capacity planning. Finally, the *production planning department* sends a *purchase requisition* to the *purchasing department* which organizes the needed materials.

In the following paragraph the material flow is explained:

- The glass panes are delivered directly to the glass inventory which is installed into every automatic cutting cell. Due to the great handling effort a quality control before the storage is not done. The production process is triggered by the enterprise resource planning (ERP) system. The first process stage of the company consists of cutting the glass panes.
  Next, the tailored glass panes are commissioned and stored in an intermediate buffer. This intermediate storage is needed because the tailored pieces have to be rearranged/ resorted according to the different customer orders (Fig. 1).
- In a next step, the tailored and sorted glass panes are transported manually to the *insulation glass line*. Within the insulation glass line, firstly, the glass panes are seamed, secondly they are washed and afterwards an automatic quality control by a so called quality

scanner is performed.

- Contemporarily to the previous process steps the glass pane frame is prepared. To ensure a sufficient cover of glass pane frames the company uses an intermediate buffer with the size of one shift. Next, the frame is mounted on the glass panes and simultaneously a visual quality check by one employee is performed. After this process stage the glass panes pass through a second automatic quality controller. In the last stage of the *insulation glass line*, an automatic sealing takes place and after this stage one employee moves the insulated glass panes from the production line to so called *A-rack* charge carrier. The finished glass panes require a drying time of 1 working shift. In conclusion, the *A-rack* charge carriers are then commissioned and stored in the warehouse for shipping to the customer.

Fig. 1 Intermediate storage glass pane supplier

In Figure 2 the lead time analysis was performed based on the VSE-map. The glass pane supplier works with two shifts, therefore one time interval corresponds to one shift (Fig. 2). Firstly, at the *proposal process stage* the sales division gets a request for proposal and in collaboration with experts an offer is forwarded to the customer. Secondly, in the process called “*Customer*” the insulation glasses are produced and delivered to the client. This process has a delivery time range of 1 to 8 labour days. In Fig. 2 it is evident the small amount of value adding time of 0.5 days (Cutting, Insulation), and the large amount of time consumed by the order processing centre (50% of the delivery time).

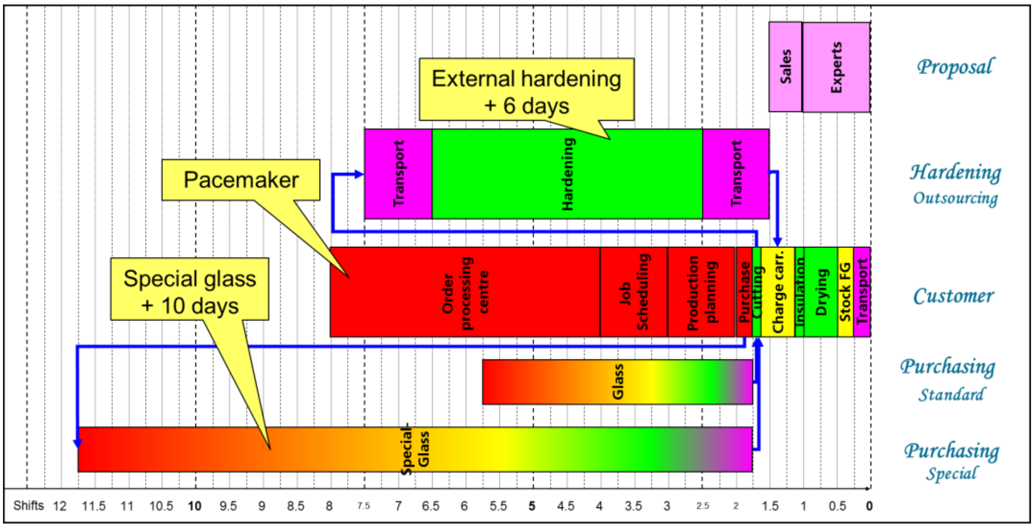

Fig. 2 Lead time analysis Current State glass pane supplier

The identified types of waste can be described as follows:

a) *Long lead time in the order processing centre:* the lead time of the order processing centre amounts at 4 days, which corresponds to 50% of total lead time. This because every order passes through the order processing centre, causing queues, even if a technically feasibility is not necessary.

b) *High work in process and long searching times:* The intermediate buffer used for rearranging the tailored glass panes (charge carrier) contains an average duration of one shift. In other words, the buffer is used not only for sorting the tailored glass panes, but as an intermediate storage too.

c) *Production is pushed:* The glass pane supplier processes large batches of items and moves them from the cutting cells to the insulation glass line. Moreover, the bending line for glass pane frames produces an amount required for one shift in advance regardless of the actual pace of work in the insulation glass line.

3.2 Process analysis of the window manufacturer

The company manufactures primarily wooden and aluminium windows. In addition, it supplies and installs front doors, roller shutters, window shutters and fly-screens. The company has 25 sale consultants in the north and in the middle of Italy and 15 assembly operators, to install the products on the construction site.
The VSE-map is shown in appendix B and the description is divided in 4 sub-processes.

Proposal stage process: The customer of the window manufacturer is usually an architect or the owner of the planned building, who generates a request for proposal (RFP) to the *sales department*. The sales people record this RFP, using a configurator, and forward it to the *sales management department* which controls the price and the technical feasibility. If the sales management approves the RFP, the vendor generates an offer and forwards it to the client.

Project-contract award process**:** If the customer approves the offer, the vendor forwards the conceptual plan to the *job scheduling department*. Afterwards, a non-definitive production order is forwarded to the *production planning department*. In this department, the resource planning and the production sequence planning is done in a backward analysis. The *production planning department* fixes a target completion date and books the needed production time in the ERP-system. Furthermore, the *production planning department* organizes the supply chain. Consumable supplies, like aluminium profiles or iron fittings are stored in the stock receipt of the window manufacturer. “On-demand” supplies like front doors are delivered directly to the commissioning zone of the window manufacturer. Glass deliveries are not stored in the stock receipt though, whereas they are delivered directly to production, i.e. to the assembling line.

Window subframe manufacturing and installation**:** When the shell construction of the building is completed the contact person of the construction site (the architect, the construction supervisor or the owner) contacts the vendor by a phone call. Then, the vendor goes to the construction site and takes the detailed measures of the structural opening, which means the allocated space for windows, roller shutters or front doors (Fig. 4). With this information, the *job scheduling department* configures the computer aided manufacturing (CAM) data to steer the machinery park. It is only now that the window subframes can be produced.
At the same time the *job scheduling department* places an order at the *assembly schedule department* for the installation of the subframes on the building site. Furthermore, the *assembly schedule department* places an order at the installation team for mounting the subframes on the building site (Fig. 3).
When the window subframes have been installed the vendor goes to the construction site and takes the exact measures of the installed subframes. Now, the vendor forwards the exact measures to the job scheduling for the computer aided manufacturing (CAM) data to steer the machinery for producing the final windows.

Fig. 3 construction site installation of a window shell frame

Window manufacturing and installation: The windows are produced in the plant of the window manufacturer according to the booked date of the *production planning department*, which is explained in the project-award contract process stage. The production start is set by the ERP-system of the window manufacturer. The window production process is done in a flow line. In the last manufacturing step, which is called “Glass Pane Assembly” the glass panes are installed in the casement (Fig. 4). The glass panes are delivered on *A-rack* charge carriers directly to the final assembling line. The manufactured windows are packed to special

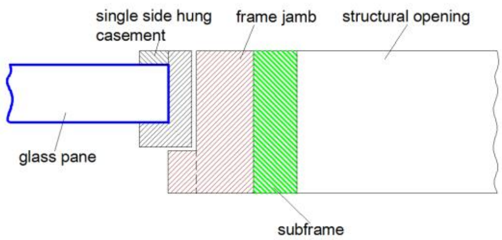

Fig. 4 Cross section single window – modelled after [6]

charge carriers and sorted according to the different building sites. This is done in the commissioning zone of the manufacturing plant. Finally, the windows are transported from the production site to an intermediate stock.
For the final installation at the building site, the site manager contacts the *assembly scheduling department* which places a pick order in the intermediate stock, where the windows are stored. Furthermore, it places a supply assignment to a local freight company to transport the windows to the installation site. Finally the *assembly schedule department* places an order to the *installation team* for assembling the windows on the building site. The value stream map is shown in Attachment B.

Lead time analysis (Fig. 5): As explained before, the case study consists of a hotel with an overall building cost of around 3.0 M€ composed of 120 windows and one front door (external door). The proposal process stage has an average duration of six days. The manufacturing and installation process stage of window subframes has an average duration of 15 days. When the window subframes are produced, the site manager takes the measures for the window production and for the ordering of external doors. Only at this time, the ordering of external doors and the manufacturing of windows can commence. This process stage is called “Purchase and production windows” and it has an average lead time of 48 days.
External doors are delivered directly to the commissioning zone of the window manufacturer where they are commissioned with other products, like windows etc., for the delivery to the intermediate stock. The window production is booked by the ERP-system in a backward analysis with the aim to have the produced windows and the supplied external doors at the same time in the commissioning zone. The windows are produced in one batch which allows a production lead time of four days. External doors are outsourced and have a lead time of seven weeks. Therefore the supply process of external doors is the pacemaker for the entire process. The commissioning of windows, external doors or roller shutters has a lead time of four days. Sometimes, a defective glass pane is found only when the windows are commissioned. Therefore, the window manufacturer considers a time buffer of four days, which corresponds to the average reordering time of glass pane supplies. In this case, the quality of glass supplies influences directly the lead time of the entire process. The final process stage “Window installation” takes place with a lead time of 18 days.

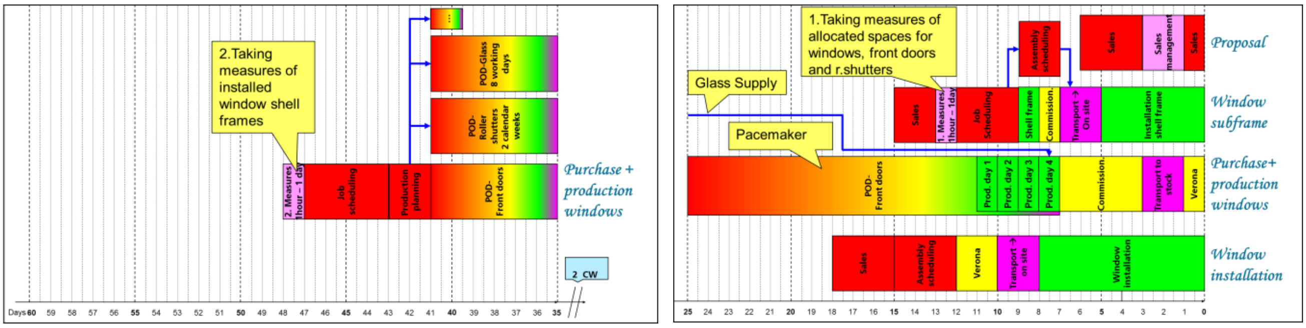

Fig. 5 Lead time analysis Current State window manufacturer

The identified types of waste are described as follows.

a) *Production is not connected to construction:* Manufacturing is triggered by the ERP-system, and therefore the order penetration point (OPP) is placed too early. This means that the trigger point for a customer order is set too early and so a just in time (JIT) deliver to the construction site is not possible.
b) *Insufficient quality from glass supplier process stages:* The glass supplier company produces and delivers with an error rate ranging from 0.5% to 2%. Therefore, the window manufacturer has to consider a time buffer of four days in the commissioning zone. This means that the reorder time for the replacement of a glass pane has to be considered. It extends the window lead time.
c) *Large handling effort of glass panes:* The glass supplier delivers the panes in a sequence according to their dimensions, from small to large. Therefore, the window manufacturer has to rearrange the glass pane order within the final assembly process. This leads to high searching

and handling efforts, which represent waste activities. More than 50% of the work needed for the glass installation is spent for searching and sorting [5].

3.3 Process analysis on the construction site

When the shell of the hotel-building was completed, the window subframes were installed. In the next process stage the wall plastering was done and afterwards the windows were installed on the basis of the subframes (Fig. 4). In this case, the painting of the internal and the external walls was done after the window installation. The site manager of the window manufacturer acts like a project manager in the traditional definition. Normally, he visits the construction site up to four times. The first time, he takes the measures of the allocated spaces for windows, roller shutters and front doors. The second time, when the roller shutters or the window subframes are delivered to the construction site the site manager instructs the window installer about technical details. The third time when the window subframes have been installed, the vendor visits the construction site and takes the detailed measures of the installed subframes. As mentioned before, the detailed measures are forwarded to the *job scheduling department* for preparing the machinery park. The fourth and last time, when the windows are installed, the site manager visits the construction site for the acceptance inspection with the owner.

Fig. 6 Installation of a window

The site manager decides when the subframes and the final windows can be mounted on the construction site. He communicates, normally by phone, with the manager of logistics when the installation team can be booked for the construction site.

In the following paragraph the installation on site is explained in detail: 1) the windows are delivered on special charge carriers to the construction site; 2) the provisionally covering in synthetic material is removed from the structural opening; 3) the window subframe is cleaned with a brush; 4) a sealing gasket is plastered on the frame; 5) a silicone stripe is plastered onto the subframe; 6) the frame is mounted based on the subframe and the single side hung casement is latched into the frame (Fig. 6). In conclusion, the window has to be adjusted and a silicon stripe has to be plastered into the fugue between the frame jamb and the wall inside and outside the building. After 5 to 6 months a final setting-up of the installed windows has to be done by the window installation team.

The identified types of waste are:

a) *Wasting quality assurance in the construction process:* The masonry process (upstream process stage) delivers insufficient accuracy in the wall construction – structural opening. The disadvantage of a subframe system is that small dimensional tolerances of the structural opening are allowed. If the sales agent does not take the measures (2 times) on site, the window subframes or even in the worst case the windows have to be reworked on the construction site.
b) *High amount of work due to low quality of upstream companies:* The insulation and the plastering process are not carried out according to the specifications. This means that the finishing coat is spread over the window subframe. Moreover, the insulation cover is plastered over the window subframe. The window installation team has to clean up the subframe which corresponds to non-value adding activities.
c) *Weak coordination of window installation – high work in process:* The site managers have the authority to decide when the windows should be mounted on the construction site, trying to push the window installation. Therefore, the windows are often installed too early, which causes damages deriving from other companies.

4. Approaches for process optimization

On the basis of the previous analysis optimization approaches are discussed. Every optimization corresponds to a problem listed in the previous section.

4.1 Optimizations for the glass pane supplier

a) *Optimization of the information flow:* The glass pane supplier works with two different categories of customers. One customer group orders products with special requirements, whereas the other one orders standardized products, where a technical feasibility is not necessary. The window manufacturer has concluded a master agreement with the glass pane supplier. Therefore, the order from this type of customers can enter directly in the *job scheduling department* bypassing the *order processing centre* (Appendix C). So, the average lead time of glass pane supply will be reduced from 8 to 4 days (Fig. 10).

b) *Reduce work in process*: In the current state, after cutting/tailoring of glass panes an intermediate storage is used. The main objective of this buffer should be rearranging/resorting the tailored glass panes according to the different customer orders. The average lead time of this buffer consists of 1 shift. The reason of this high work in process is that the buffer consists of two different parts. One part is composed of semi full charge carriers, whereas the second part contains charge carriers with complete customer orders. In this case, the flow is disconnected by the intermediate buffer. In order to reach a continuous production flow, only the buffer for sorting the tailored glass panes is needed.

c) *Link production with construction:* According to the authors Rother and Shook production must be planned just at one point of the value stream. Moreover, in the future state the pacemaker should be driven by the external customer orders [3]. This guideline was adapted in the development of the future state, where the trigger from the construction site enters directly into the first process step which stands for tailoring the glass panes.

To achieve a pulled production from the construction site, the insulating glass frame production system should be optimized. The bending, threating and preparing process has to be integrated into one production cell. In the current state the ERP-system triggers the tailoring process and the bending process. Otherwise in the future state, only one trigger starts the production line.
To reach a production flow, in the future state the cutting cell triggers directly the bending production system by sending a scheduled assignment. More in detail, the cutting cell delivers information about which customer order is completed first, according to the cutting list. Therefore a just in time delivery of insulating glass frames to the insulation glass line is possible.
In conclusion, the cutting cell stands for the pacemaker process. As shown in Appendix C glass pane production is triggered directly from the building site. This allows eliminating demand amplifications upstream the value chain.

4.2 Optimizations for the window manufacturer

a) *Link production with construction:*
At the moment, the window manufacturer books the production start by the ERP system. More in detail, the production end of window manufacturing is set at the same time as the delivery of front doors or roller shutters. Thus with the aim that outsourced product groups can be commissioned with manufactured windows without unnecessary storages. Therefore, in the current state the supply of front doors sets the pace for the entire system. On the other hand, in the future state the supply of front doors is disconnected from the window manufacturing, because Production on Demand (POD) components are delivered directly to the site. In this way, the commissioning is moved from the factory to the construction site. So, the supply of POD-components and the manufacturing of windows can be steered in an independent way (Fig. 7). This allows to trigger the production in the first process step, and the material can pass from the pacemaker

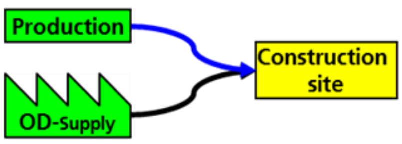

Fig. 7 VSE POD delivery on site

process downstream in a continuous flow. As a result, in the future state production will be triggered according to the construction progress. More in detail, in the future state two different production triggers are considered. The first interface stands for smaller building projects, where the building crafts are not synchronized with each other. In this case the production is triggered as before. The second production trigger is set by so called Weekly Last Planner Meetings with the aim to align the production start with the construction progress. In this case the production order is acquired in the same way as before, where the site manager forwards the technically information to the order processing center which controls the technically feasibility and organizes the supply chain of needed material or components. The difference in this case is that the production is not triggered by the ERP system but from the construction progress on site (Fig. 8).

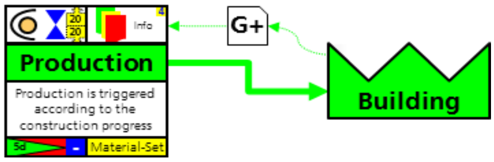

Fig. 8 VSE production pulled from site

b) *Introducing charge carriers which allow a loading JIS (Just-in-Sequence):* In the future state, the glass pane supplier delivers the requested glass panes according to the production succession of the window manufacturer. The window manufacturer organizes the production sequence according to an optimized installation on site. The existing charge carriers don't allow a loading in JIS due to structure problems and therefore the glass pane supplier developed a prototypically charge carrier (Fig. 9).

Fig. 9 Charge carriers allowing JIS

4.2.1 <u>Optimized lead time analysis</u>

In the case of the window manufacturer, the commissioning zone and the intermediate stock could be eliminated. In the future state the task of the production planning department was replaced by the triggering point derived from the construction site. After receiving the measures of the installed window subframes the job scheduling department prepares the machinery data CAD/CAM for the production facility and organizes the supply of POD components (i.e. glass pane supply). The manufactured windows are transported directly from the manufacturing facility to the construction site. As mentioned before, the window manufacturer works particularly in the north and in the middle of Italy, and therefore one day was considered for the transportation. In conclusion, three calendar weeks could be reached for the production and installation of windows (Fig. 10).

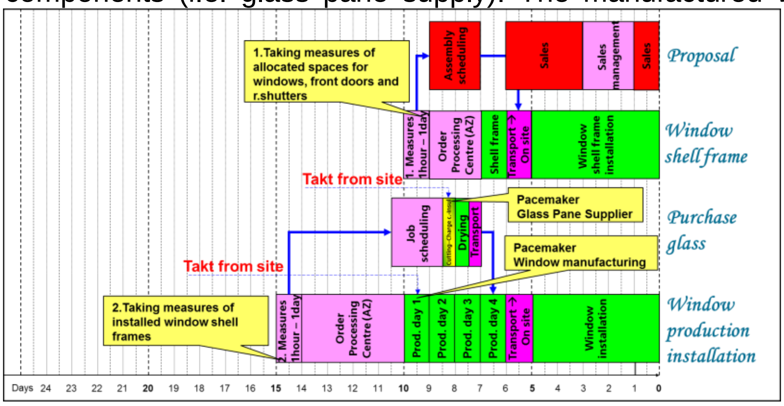

Fig. 10 Lead time analysis Future State window supply chain

4.3 Optimizations on the construction site

a) *Design of a reliable construction progress:* First of all, the building has to be subdivided into construction phases with separate processes. In Fig. 11 the Pitch-Lane defines the labour content in every construction phase for every involved company. In the manufacturing industry this is called "Pitching". In this context one Pitch means the work content for one craft per week in a specified Pitch-Lane (construction phase).

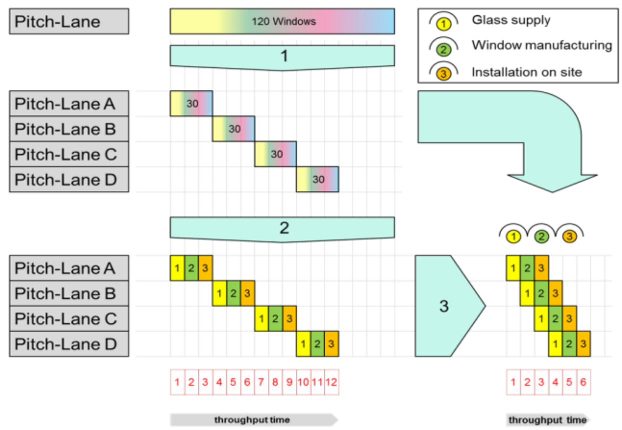

Fig. 11 Manufacturing and installation according to customer takt time

The foreman on the building site was replaced by weekly "Last Planner" meetings. In these meetings the foreman of the window installation team, the manager of logistics and installation and the foreman of the masonry should participate. Every three weeks a so called look-ahead plan is elaborated, where the work content of the window manufacturer and the glass pane supplier will be defined. In this context, "Pitch" means the work content for one craft per week in a specified construction phase. So, as shown in Fig. 11 a lean thinking methodology which is called "One-Set-Flow" can be introduced. During the first week, in Pitch-Lane A, the glass supplier delivers an amount of 30 glass panes. Next, during the second week the window manufacturer produces 30 windows with the glass supply of the first week. Simultaneously, the glass supplier can produce glass panes for Pitch Lane B. During the third week the window manufacturer installs the windows on site produced for construction phase A.
This methodology should be repeated for every construction phases (A, B, C, D). "One-Set-Flow" means in this case, that the total delivery of 120 windows is subdivided in 4 construction phases each composed of 30 windows. So, one set of 30 windows flows from the glass supplier to the construction site.

b) *Continuous quality assurance:* As mentioned before, during the weekly "Last Planner Meetings" the foremen of every participating craft discusses problems in the current week and at the same time an update of the weekly working plans is done. So, these meetings have a dual function: 1) by updating the weekly working schedules a reliable construction progress is reached. 2) at the same time a quality control is done. More in detail, if the upstream companies don't fulfil their work according to the specifications, during the weekly "Last Planner Meetings" rework assignments are given to the concerned crafts. In other words, the window manufacturer is allowed to access the site, until when the building project is ready for the installation of subframes or for mounting the finished windows.

5. Generalization and Standardization

In this paragraph, first of all, design rules for efficient customer oriented value chains will be described. In a second step, the identified process template developed for a better coordination of the involved companies will be presented.

The suggested design rules are:

a) *Let the customer order flow:* Identify the pacemaker process in the current state and separate it from other processes. Moreover, set the first manufacturing step as the pacemaker process. In the future state, the external customer order should trigger directly the pacemaker process. Upon this point, the production order should flow in a continuous way.

b) *Connect the order penetration point with the construction site:* In the automotive industry the Order Penetration Point (OPP) means a process stage where customer neutral production assignments transition to customer related production orders. In the case of the window manufacturer, the OPP was set too early in the current state and therefore a stock for finished goods is used. In the future state, the construction site should trigger directly the production of upstream suppliers.

c) *Connect value chain participants avoiding intermediate stocks or buffers:* In the current state, two different control loops exist for the window supply chain. One supply loop is set from the site to the window manufacturer and the second one from the window manufacturer to the glass pane supplier.

Otherwise in the future state, the delivery of glass panes and the manufacturing of windows are triggered directly by the construction site. In this case not only the production of windows is connected with the site but also the production and delivery of glass panes. Therefore, if delays occur on the building site, product buffers don't arise in the intermediate processes.

d) _Control a process chain in one place:_ The whole process, from glass supply, to window manufacturing to the installation on site is controlled in one point. This is done in the weekly last planner meetings, where the Plan Percent Complete (PPC) value is measured. So, production orders can be released to upstream companies according to the real construction progress on site using just one control point.

The mapping of a holistic construction process has to be highly flexible and adaptable in terms of product and process as construction firms are not able to operate on basis of a fixed target process because of the changing customer requirements from one project to the next [7]. Therefore, for every construction project the ideal coordination process is different. Using the VSE approach a customized integration of different lean process templates should help to develop an ideal coordination process with a minimum of effort. In the case study a process template for optimizing management and control during construction execution was developed, where concepts from Lean Production and concepts from Lean Construction, like the "Last Planner System" were used (Fig. 12).

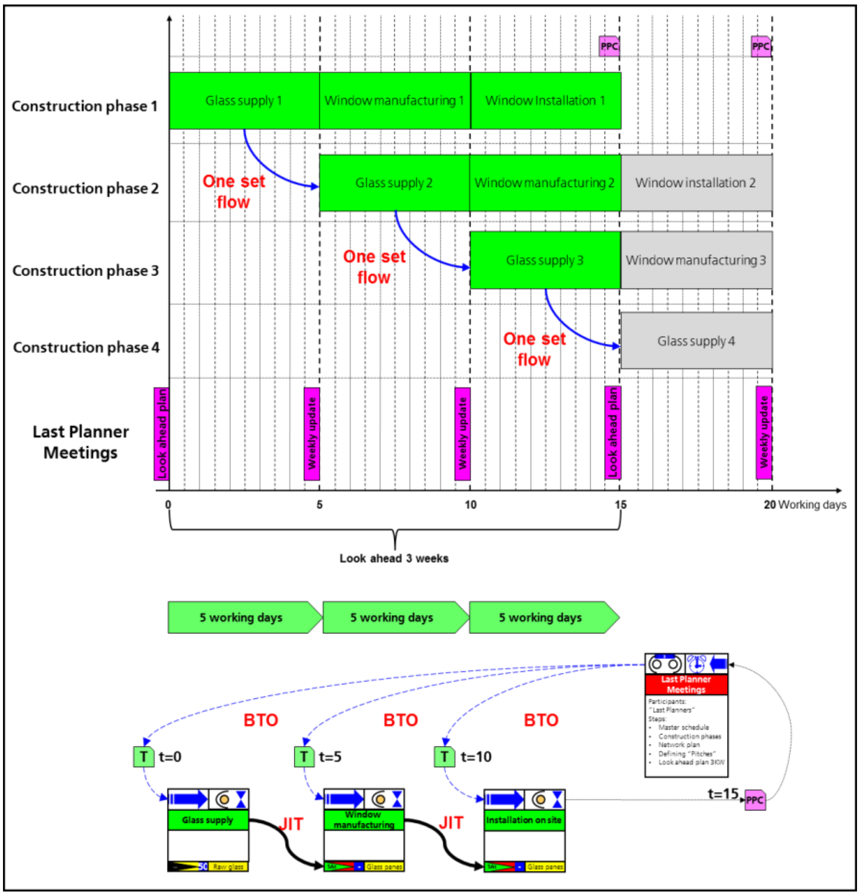

Fig. 12 Manufacturing and installation according to customer takt time

Build to Order (BtO): The producer builds products entirely to confirmed order rather than to forecast [8]. This should eliminate the demand amplification, registering the data back upstream the value chain. In the case of the glass supplier and the window manufacturer production starts until when the construction site is ready for installation.

Just in time (JIT): As shown in Fig. 8 production is pulled from the building site, allowing so to eliminate intermediate stocks. To synchronize the glass supply with window manufacturing and installation, "Pitches" have to be defined. As a result a continuous flow from the glass supply to the installation on site can be reached.

One set flow: Producing and moving a small and consistent batch of items at a time through a series of production steps as continuously as possible. In the case of the window supply chain a batch of 30 window panes is moved from the glass supplier to the window manufacturer, which moves than 30 windows to the site. This allows reducing drastically the lead time because a parallelization of the glass supply, the window manufacturing and the installation on site is possible.

6. Conclusion and Outlook

The concept developed in this case study is a new approach, which adapts well known concepts from the automotive industries to the construction industry.
In the case study, three different processes of the window supply chain were analysed with the VSE methodology where an adaptation to the construction industry was done. Processes like the acquisition of new orders (service processes) or the measuring for the final window production (production trigger) were added to the VSE toolkit.
Furthermore, process lead times of the current states were registered. On the basis of the current state analysis optimizations were identified and applied within the case study. The coordination on site was integrated in the internal work processes of the involved companies. As a result, the identified concepts were standardized. A process template including the mentioned optimizations was developed which can be used by other companies in the construction industry. Moreover, four guidelines for an efficient customer oriented value chain usable for every construction supply chain were discussed.
It can be concluded that the VSE methodology can be adapted for analysing and optimizing construction processes. To match the supply chain with the building site, the construction process and the mentioned “Last Planner” Meetings need to be studied in detail. This sets the goal for the future research activities within the “build4future” project framework.

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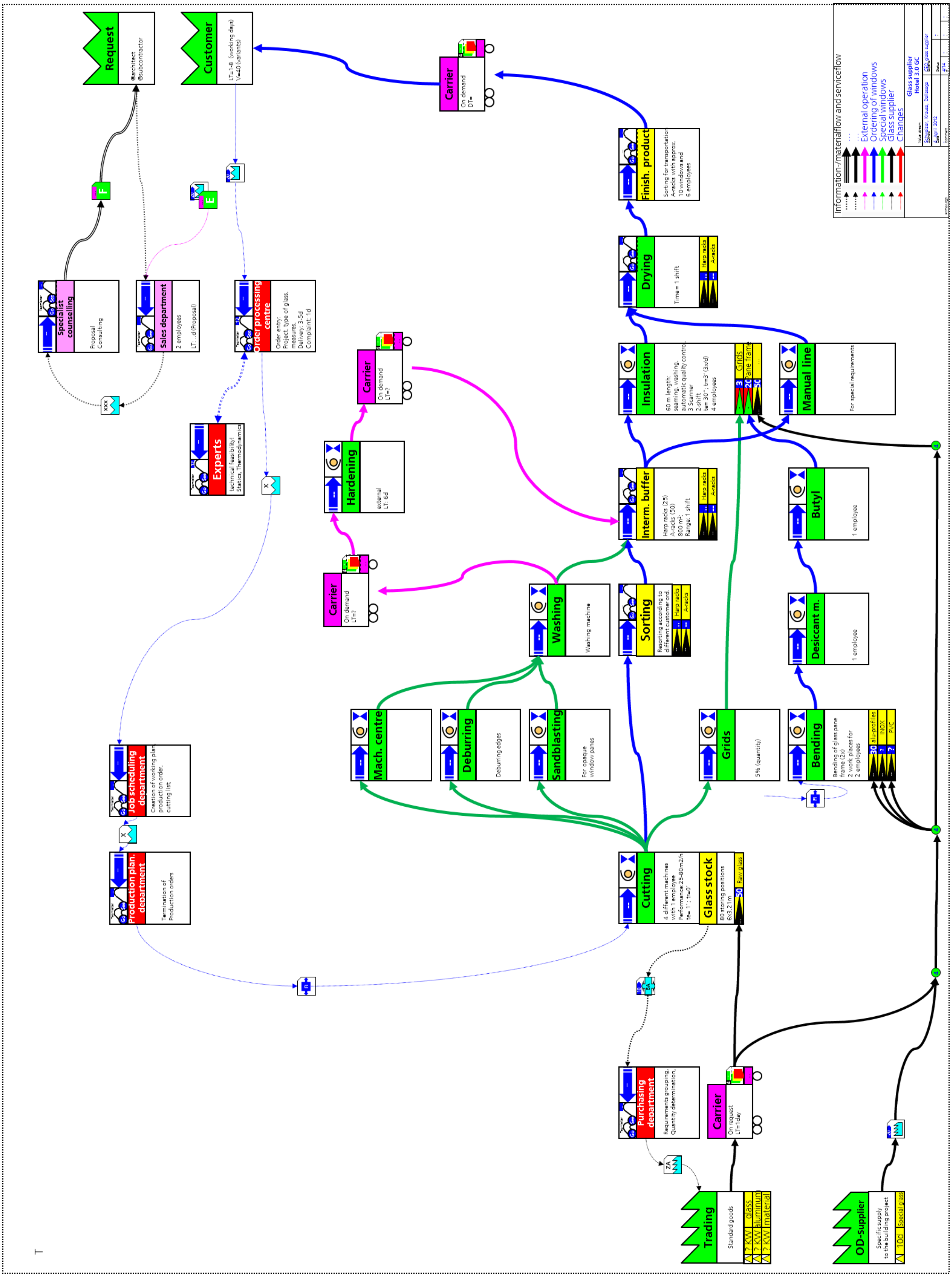
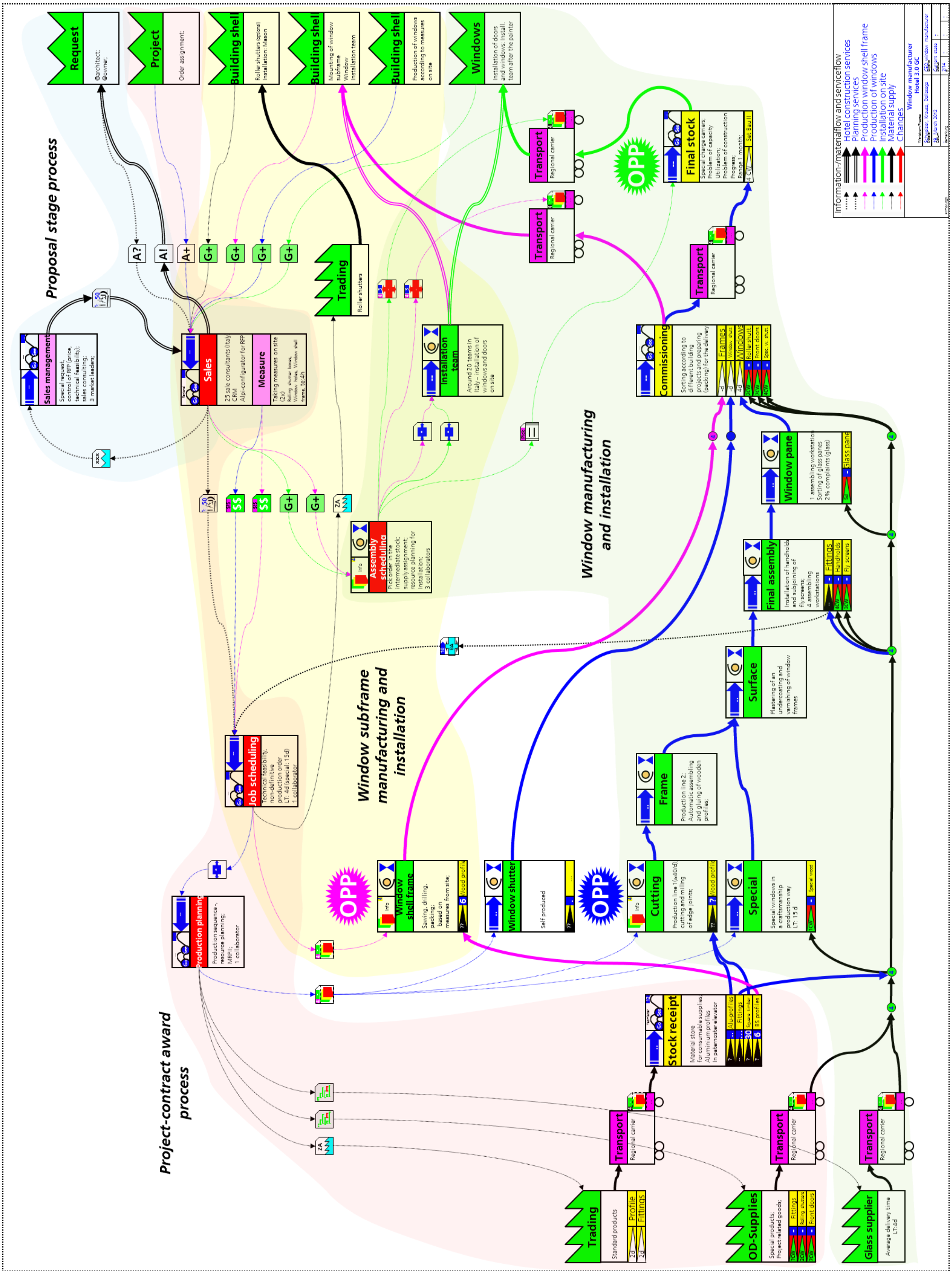
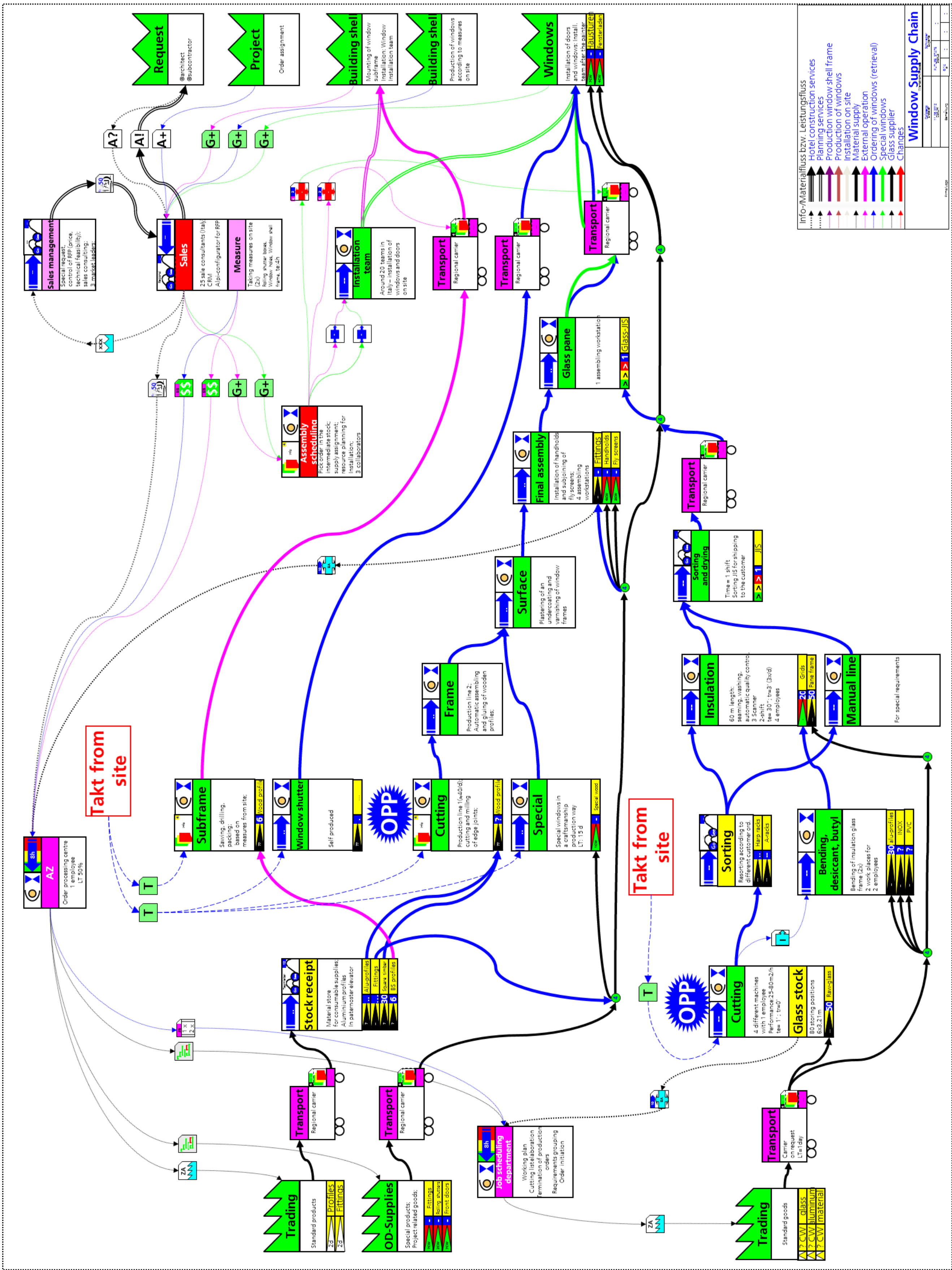


Appendix A Value Stream Map Current State glass pane supplier



Appendix B Value Stream Map Current State window manufacturer



Appendix C Value Stream Map Future State window supply chain

Reducing residential estates' heating costs in half – the case EEMontti

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Summary

There is a large market potential in Finland for renovating electrically heated houses that don't have a water circulation based heating system. Currently there are not that many examples where these kinds of houses are renovated, even though there is a potential to reduce the heating energy consumption in half. The service provided for the customer/house owner needs to be based on holistic and user-driven view. Good examples are needed for both, the customers and the service providers. EEMontti project implemented and documented such energy renovations and pointed out good cases and procedures of energy renovation services for apartment houses.

In EEMontti project three energy renovations were implemented and documented. In addition to these, a renovation concept for fourth location was developed, but the renovation itself was not implemented during the project lifetime.

EEMontti project showed that it is possible to cut the heating energy consumption in half and to achieve good profit for the capital invested. Energy renovation also increases the market value of the house. The market values of the renovated houses were evaluated by a real estate agent. The renovations increased the market value by 10 000-15 000 euro, about 50-65 % of the total renovation cost.

Keywords: energy renovation, energy efficiency, heating, heat pump, ventilation, heat exchanger

1. Introduction

The purpose of the EEMontti project was to implement, document and point out good cases and procedures of energy renovation services for apartment houses by organizing a competition for service providers. EEMontti (being an acronym from Finnish word meaning energy renovation) focused on four different houses that were typical Finnish electrically heated houses that didn't have water circulation based heating system. Houses were representing very common building types from different eras – being built in the 60's, 70's and 2000's. For each location among the entries, the jury designated for EEMontti competition selected the one that met the competition conditions in the best way. Three of the winning solutions were implemented during the project.

There are approximately 500 000 houses without water circulation based heating systems in Finland. These houses represent the largest building and energy consumption group in the building stock and also have the highest potential for energy saving. Single family houses' weighted average of delivered combined energy for space heating and domestic hot water in Finland is annually approximately 155 kWh/m². The effects of annually applicable cost-effective energy efficiency retrofits will accumulate to produce the annual savings of 2000 GWh by 2020 and 3000 GWh by 2030. In relative terms these savings represent approximately 10% by 2020 and 18% by 2030 of present heating energy consumption. [1]

The objective of EEMontti project was to find holistic, user driven and cost-effective solutions for energy renovations and implement and document them as example cases [2]. During the project also some challenges in energy renovation service market in Finland were discovered. In example in many cases the comparison of different solutions was demanding due unclear tendering documentation. In addition to this, the relatively small number of service providers capable of providing holistic energy renovation service in Finland was surprising for competition organisers.

Despite some unexpected limitations in the supply side, three energy renovations with ambitious energy saving goals were implemented during the project.

Also the hypothesis that energy renovations might increase the market value of the house was proven accurate in EEMontti locations.

2. Key conditions and the tendering process

The competition rules specified the following key conditions as the goal of the energy-efficiency improvement solutions:

1. 50% reduction of heating energy consumption (includes the heating of premises, ventilation and service water)
2. Renovation lead-time: three weeks
3. The alteration work must generate a profit of at least 14% for the capital invested in the heating renovation

The third competition rule was defined in order to demonstrate that these kinds of renovations could be seen as a profitable investment. 14 % was defined based on 7 year payback time.

In addition to these also some minor conditions were specified. When these conditions were met, the winning renovation service should also be commercially competitive and a significant demand for it could emerge.

The tendering process of EEMontti was the following:

1. A house condition survey with energy certificate was done for each location.
2. The tendering documentation was the condition survey report, the energy certificate and the competition key conditions.
3. Based on this documentation the competition was open for any solution that would meet the key conditions the best way.
4. An in-line investment calculation was made for each tender.
5. For each location among the entries, the jury designated for EEMontti competition selected the one that met the competition conditions in the best way.
6. The winning solution was recommended to the house owner, who made the investment.

3. Energy renovation solutions

EEMontti competition targeted on renovation of four residential estates located in Finland. Houses were representing very common building types from different eras – being built in the 60’s, 70’s and 2000’s.

The winning energy renovation solutions were:

- LOCATION 1, 351 m² house built in 1960’s: Geothermal heat pump and a water radiator heating system were installed leading into 60 % reduction in heating energy consumption of the house.
- LOCATION 2, 139 m² house built in 1970’s: Air handling units with a rotary heat exchanger and integrated heat pump were installed leading into 30 % reduction in heating energy

consumption of the house.

- LOCATION 3, 115.5 m² house built in 2006: a geothermal heat pump and a water radiator heating system were installed leading into 50 % reduction in heating energy consumption of the house.
- LOCATION 4, 2*103.5m² semi-detached house built in 2001. Concept for installing a geothermal heat pump and a water radiator heating system were created. Estimated saving potential of 65 %.

Locations 1-3 were renovated, location 4 was not due relatively high payback time of the investment.

3.1 Location 1, 60's house

The location 1 was 1960's house with 351 m². The energy consumption before the renovation was relatively high, 45 500 kWh.

Fig. 1 EEMontti-location 1, 60's

The winning solution for the house was installing a geothermal heat pump and a water radiator heating system. This led into 60 % reduction in heating energy consumption of the house.

The renovation investment was about 36 000 €. After the reductions (domestic help credit and ARA-grant) the net investment for the house owner was about 28 500 €. This led into about 3400 € annual savings in energy costs. The ROI of the investment was about 12 %. Detailed calculations are in Chapter 4.

3.2 Location 2, 70's house

The location 2 was 1970's house with 139 m². The energy consumption before the renovation was 31 000 kWh.

Fig. 2 EEMontti-location 2, 70's house

The winning solution for the house was installing an air handling units with a rotary heat exchanger and integrated heat pump. This led into 30 % reduction in heating energy consumption of the house, and clearly improved indoor climate conditions.

The renovation investment was about 19 300 €. After the domestic help credit the net investment for the house owner was about 15 500 €. This led into about 1150 € annual savings in energy costs. The ROI of the investments was about 7.5 %. Detailed calculations are in Chapter 4.

3.3 Location 3, 2000's house

The location 3 was a house built in 2006 with 115.5 m². The energy consumption before the renovation was 23 000 kWh.

Fig. 3 EEMontti-location 3, 2000's house

Initially the house was equipped with Legalett heating system (air circulating heating system with electrical heating unit). The winning solution for the house was installing a geothermal heat pump compatible with Legalett system, replacing the electrical heating unit. The energy savings achieved with the renovation were about 50 %.

The renovation investment was about 25 000 €. After the domestic help credit the net investment for the house owner was about 21 500 €. This led into about 1400 € annual savings in energy costs. The ROI of the investments was about 7 %. Detailed calculations are in Chapter 4.

3.4 Location 4, 2000's semi-detached house

The location 4 was a semi-detached house built in 2001 with two apartments 103.5 m² each. The energy consumption before the renovation was 34 350 kWh for the whole house. Unlike the other locations within the competition, this location was in rental use. This was also the only location that was not renovated during the project time.

Fig. 4 EEMontti-location 4, 2000's semi-detached house

The winning solution for the house was installing a geothermal heat pump and a water radiator heating system. The energy savings estimation was 65 % reduction in heating energy consumption of the house.

The investment to the renovation of the whole house (both apartments) was estimated to be 54 000 €. Since the house is in rental use, no domestic help credit was available for the owner. This would have led to the annual savings of 2800 € (for the whole building) leading into ROI of 5.2%.

This renovation was not implemented during the project time since the payback time of the solution was relatively high. There was no other renovation demand in the house, so the owned decided not to renovate the house at this point. The geothermal heating concept will be implemented though when the house demands some other renovation too, like redoing the floors.

4. Investment calculations

Table 1 Investment calculations of EEMontti energy renovation solutions

	Unit	60's house	70's house	2000's house	2000's semi-detached house
Contractor		Senera	Ensto	Pistoke	Halmesvaara
Total renovation cost	€	36 000	19 300	25 095	54 000
Domestic help credit (2011)	€	4 000	3 794	3 682	
ARA-grant	€	3 500			
Net investment	€	28 500	15 506	21 413	54 000
Energy costs	€/kWh	0.125	0.125	0.125	0.125
Energy price increase	%	3.00	3.00	3.00	3.00
Inflation	%	3.00	3.00	3.00	3.00
Energy consumption	kWh/a	45 500	31 000	23 000	34 350
Energy cost	€/a	5 688	3 875	2 875	4 294
Energy saving potential	%	60	30	50	65
Energy consumption after the renovation	kWh/a	18 200	21 700	11 500	12 023
Energy costs after the renovation	€/a	2 275	2 713	1 438	1 503
Savings in energy consumption	kWh/a	27 300	9 300	11 500	22 328
Savings in money	€/a	3 413	1 163	1 438	2 791
Return of investment	%	12.0	7.5	6.7	5.2
Payback time (4% interest rate)	years	8.80	14.40	16.30	21.70

All EEMontti locations' energy consumption baseline was defined in a house condition survey. The renovations and their results are documented by Metropolia University of Applied Science. The results will be available late spring 2013.

The adequate technical functioning in the cold climate of the heat pumps used in the renovation has been authenticated by field tests in the study "Field measurements to demonstrate the potential for heat pump systems in cold climates" [3].

5. Locations' market value increase

One hypothesis of EEMontti project was that energy renovation might increase the market value of the location.

Two of the renovation locations were evaluated by a real estate agent before and after the renovation, giving the evaluation of the market price in both cases. The results were following:

- **Location 2, 70's house:** Rising in the house market value caused by the energy renovation was 10 000 €.
- **Location 3, 2000's house**: Rising in the house market value caused by the energy renovation was 15 000 €.

The real estate agent also pointed out that in case of selling the house most likely these houses with smaller energy consumption and better indoor air quality will be sold quicker than similar houses in similar area with bigger energy consumption.

6. Conclusions

There is a large market potential in Finland for renovating electrically heated houses that don't have a water circulation based heating system. Renovating such houses is traditionally considered quite challenging. EEMontti project demonstrated three renovations that showed that there is large energy saving potential in these buildings and the renovations can also be commercially competitive. From contractor this though requires wide know-how, detailed planning and a holistic view.

Even the newer house type, built in 2000’s had a significant benefit from renovating the house. The locations renovated in EEMontti project benefitted from smaller heating energy bill, but other benefits emerged too. In the renovation of the 70’s house where the air handling units with a rotary heat exchanger and integrated heat pump were installed, an improvement of indoor air quality was an asset.

In addition to these, the project verified that the renovation increased the market value of the renovated houses. The rise of the market value was around 50-65 % of the renovation investment.

The project also revealed some shortcoming of current energy renovation service market of Finland. The service provided for the customer/house owner needs to be based on holistic and user-driven view. Good examples are needed for both, the customers and the service providers. The tendering documentation needs to be evolved into more comparable and user friendly form or the house owner should be able to get expert help in order to define the best solution to be implemented.

In general, by doing a holistic energy renovation, it is possible to cut the heating energy consumption in half and to achieve good profit for the capital invested.

The final, measured and verified results of energy savings in EEMontti locations will be published by Metropolia University of applied science during spring 2013.

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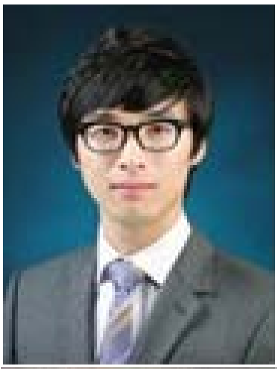
Assessment of pedestrian wind environment of high-rise complex using CFD simulation



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Summary

The outdoor wind environment plays an important role for pedestrian comfort. In general high-rise complexes, wind gust frequently occur due to the building form which has a complex airflow Therefore, when designing high-rise buildings, it is important to plan mitigation strategies for wind gusts which lead to pedestrian discomfort.
Pedestrian comfort is quantified by the outdoor wind velocity and the probability of an excess threshold velocity. The case study is carried out to generate the findings of pedestrian wind comfort in high-rise complexes. Firstly, the wind comfort of the high-rise complex was analysed by a CFD simulation, then mitigation strategies were established by a climate response design for the landscape plan. The results show that the mitigation works affect the climate response design plan, which could help Architects during the design phase.

Keywords: CFD simulation, Pedestrian wind environment around buildings, High-rise building, Climate response design

1. Introduction

Recently, many high-rise buildings have been constructed around the world with the development of building technology. This development changes not only the outlook of a city, but also creates local wind environmental conditions which are unpleasant and sometimes dangerous for pedestrians walking around the buildings. The discomfort of pedestrians is caused by strong winds which increase significantly during the winter.[1] The wind flow at pedestrians level around buildings is the result of the complex interaction between the wind(incidence, mean vertical speed gradient, turbulence) and the buildings themselves(shapes, sizes, setting etc.).[2, 3] Narrow gaps between buildings especially create a wind valley which leads to an increase of wind velocity and hence the discomfort of pedestrians. Designers should therefore consider these problems during the design phase in order to find solutions and apply them.[4]

In the last decades, Computational Fluid Dynamics(CFD) has been studied intensively as a tool for evaluating the indoor and outdoor environment of buildings.[5] Indoor Airflow Analysis has been studied and well established yet there are not many studies done on outdoor applications. Usually a wind tunnel test is used to analyse the outdoor wind environment. However, wind tunnel testing has some disadvantages for practical applications. They are expensive and difficult to model with errors built up as a result of the simulation undertaken on reduced scale models. Furthermore, only point measurements are obtained by wind tunnel experiments.
For these reasons, CFD simulations could be an effective alternative because it can avoid some of the stated problems with other procedures. In addition, CFD can modify the reduced scale model results to full scale effects and calculations. The possibility of full-scale modelling and the variety of results from single demonstrations are a significant benefit of CFD. However, to get accurate analytic results, many different factors such as boundary conditions, mesh properties and governing equations need to be covered precisely and carefully.
This study will show the winter outdoor airflow of three high-rise complexes by using CFD simulation analysis. The results of this analysis can be used to improve problems with outdoor airflows by proper planning followed by analysing the data. It is carried out with the following process : (1) Establish the building analytic plan by using the Wind data of the targeted area(base model); (2) Analysis of the air environment around the building using a CFD simulation at pedestrian level; (3) Finding an alternative solution model(alternative model) after determining possible problems from the simulation; (4) The consideration of improvements through the analysed alternative model.

2. Analysis of wind data

2.1 Wind criteria for wind comfort

Pedestrian discomfort occurs when wind effects become so strong and occur so frequently (say on time scales up to 1 h), that people experiencing those wind effects will start to feel uncomfortable, and will eventually act in order to avoid these effects.[6] The biggest influence on the wind comfort of pedestrians is the outside wind speed. The comfort criterion consists of the discomfort limit and the pedestrians’ acceptance of its probability. The comfort criterion has been demonstrated in numerous other pieces of research.[2, 6-9] Some have used the hourly mean wind speed as the relevant parameter to assess the human wind comfort whilst others use the gust wind speeds or effective wind speeds (integrating the wind-speed standard deviation).
In The Netherlands, the method used to evaluate the wind climate is prescribed in an official standard, the NEN 8100:2006 "wind comfort and wind danger in the built environment".[10] This standard allows the possibility of using both wind tunnel experiments and CFD to evaluate the wind climate. In the NEN 8100 code, the threshold for the mean wind speed is 5 m/s for all grades of

Table 1 Criteria for wind nuisance and danger according to NEN 8100

Probability of Exceedance $P(V_{loc} > V_{threshold;wind\ nuisance})$ in percentages of the number of hours per year	Quality-level	Activity-level		
		I. Walking, normal pace	II. Walking Leisurely-strolling	III. Sitting longer time
1< 2.5	A	Good	Good	Good
2.5 – 5	B	Good	Good	Moderate
5 – 10	C	Good	Moderate	Poor
10 – 20	D	Moderate	Poor	Poor
≥ 20	E	Poor	Poor	Poor
Probability of Exceedance $P(V_{loc} > V_{threshold;wind\ danger})$ in percentages of the number of hours per year		Qualification		
$0.05 < p < 0.30$		limited risk		
$p \geq 0.30$		dangerous		

wind comfort and 15 m/s for danger to pedestrians from wind forces (Table 1). The choice of the probability P(VIS45 m/s) in NEN 8100 is based on the feedback by clients, especially by developers of shopping centres. The code defines five grades of wind comfort from A to E.[11]
This study is completed on the outdoor wind environment around high-rise complexes at a 5 m/s threshold velocity.

2.2 Wind environment around the building

The analysis of the wind environment of the surroundings is the precedent to determine the CFD of a high-rise building complex.
The object building is located in downtown Beijing, China. Actual measurement data is being used to determine the wind environment of the actual plot. Fig.1 shows the wind rose which has been determined by the weather data of the winter wind environment (from Dec to Feb) mentioned earlier.
So the main wind direction for the winter season is North-West. This direction constitutes 15.66% of the winter wind. Fig.2 is the wind direction categorized by the wind velocity between 0~10 m/s. Up to 6m/s, the wind velocity contains 93.9% of the winter wind. If the wind environment is satisfied above this reference velocity, the probability of excess wind in winter V_{thr} is below 6.1%. In this study the wind environment of the building surrounding is analysed through the CFD simulation. The data is calculated in every 1m/s up to 7m/s of its wind velocity.

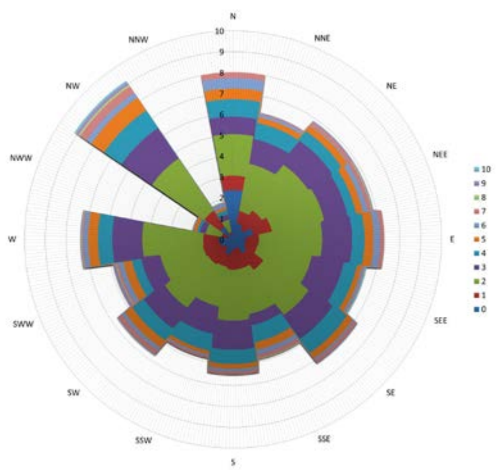


Fig. 1 Wind rose around building

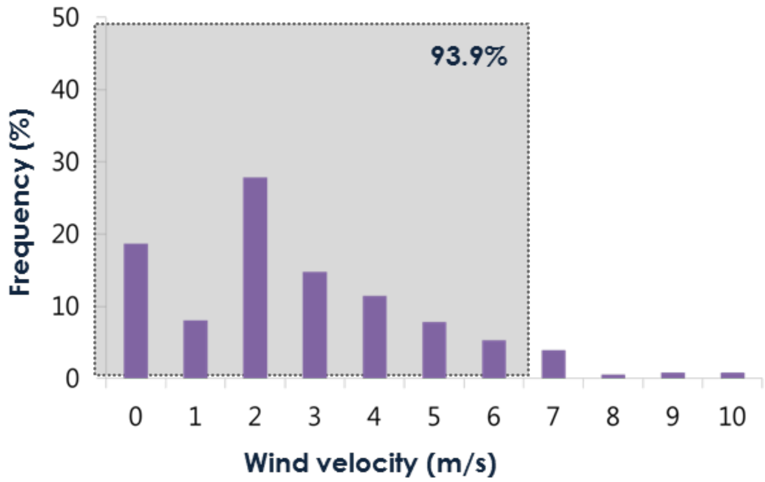


Fig. 2 Distribution of wind velocity

3. CFD simulation for outdoor built environment

3.1 CFD simulation method

The methods of analysing the wind environment of the external built environment are divided into two parts, Reynolds-Averaged Navier Stokes(RANS) simulations and Large Eddy Simulation(LES). RANS equations are appropriate when calculating a steady state solution due to their effects on the mean flow.
Steady RANS modelling with the k-ε model and other turbulence models has become quite popular for pedestrian-level wind studies. Several CFD studies of pedestrian wind conditions in complex urban environments have been performed.[5, 12-16] Almost all studies were conducted with the steady RANS approach and a version of the k-ε turbulent model. In this study steady state RANS equations with standard k-ε turbulent models are selected for calculating pedestrian wind comfort with the outdoor built environment.

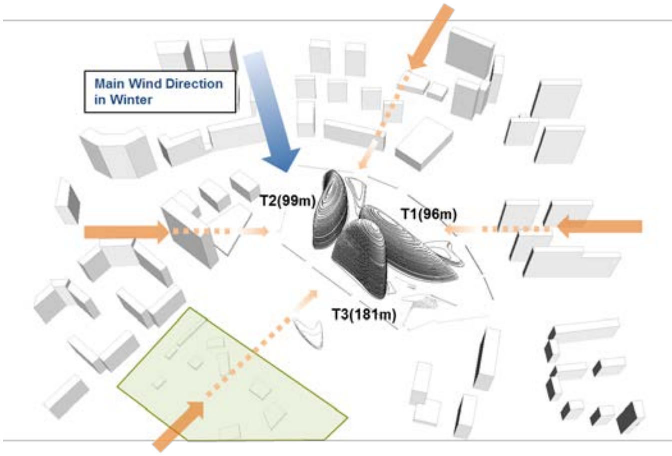


Fig. 3 Wind direction around building

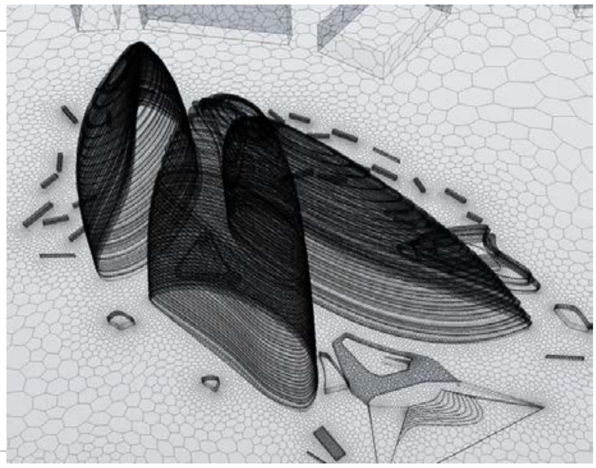


Fig. 4 CFD grid description

3.2 Simulation model

The simulation modelling of this study is based on actual high- rise buildings in Beijing which has office and retail use. There are three buildings on the total site area of 115,393m^2, two of them have 25 floors (96m, 99m high) and the other one has 45 (181m high) floors. The buildings are closely placed with narrow spaces between them it could lead to a very fast air flow speed. Furthermore, it can be expected that the sunken areas of the complex which is used for retail shops, also gives an impact of overall air flow in the basement.
Therefore, this study includes the conditions as stated above for the accurate simulation modelling. Based on these analyses, the object buildings were modelled as shown in Fig 3, Fig 4. Additionally, the form of the object building uses a very complex geometry (atypical shape) and every floor has horizontal louvers as well. Apart from this, an ellipse type floor plan can affect the air flow speed too. It is therefore necessary to consider all details for the simulation modelling.

3.3 Boundary condition for CFD simulation

The computational domain size is 2,000m*2,000m*500m. Using the automatic mesh generation system of the commercial CFD simulation program star ccm+, polyhedral mesh was selected for the complex shape of buildings. The mesh contained about 2,000,000 cells. The density of the grid was concentrated at pedestrian level and the space around the low level (1st~3rd floor) of the 3 main tower buildings. The size of the grid was the minimum 0.5m to the maximum 50m (surface growth rate was 1.3).

Table 2 Detailed boundary condition

Item	Condition
Turbulence model	Standard k-ε model
Scheme	1st order upward differential scheme
Inlet	Turbulence intensity : 0.01(Constant) Turbulent length scale : 0.1m
Outlet	Flow-split outlet Split ratio (0.5, 0.5) (South, East)
Wall	Log law(offset 9.0) Von Karman constant : 0.42
Number of mesh	About 2,000,000 polyhedral cells

To solve the RANS equations for the simulations, a standard k-epsilon turbulence model was chosen. The CFD calculation needs to be finished after sufficient convergence of the solution. COST suggests that scaled residuals should be dropped by 4 orders of magnitude.[17] However, the convergence criterion of each simulation was 3 times the normalized residuals over all the control volumes for all variables (energy, momentum, turbulent kinetic energy, turbulent dissipation rate) for the efficiency calculation.

The CFD simulation of wind flow was carried out for a North-West wind direction only for the winter, due to the climate analysis result in Fig 1 and Fig 2. The results are analysed for a wind velocity from 1~7 m/s.

The boundary condition of every wall is no-slip except the top wall of the domain. The detailed calculation conditions are shown in Table 2.

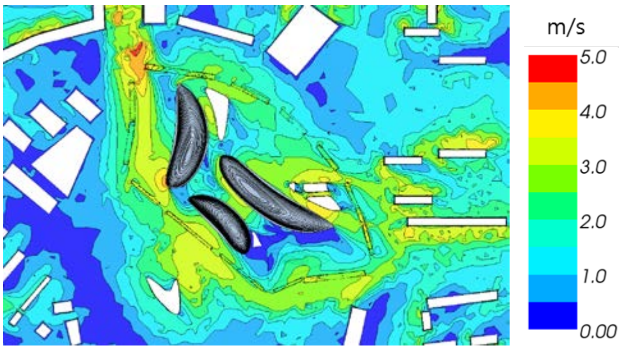
4. CFD simulation results

4.1 CFD simulation of base model

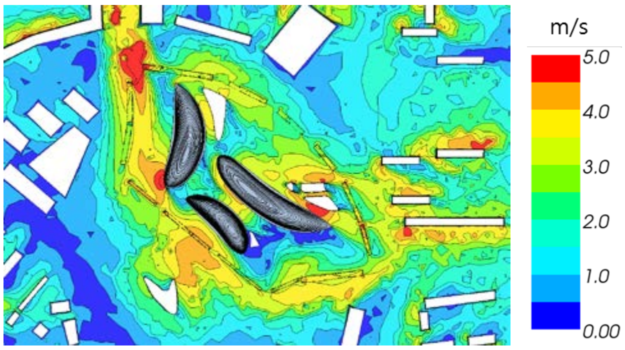
Fig. 5 shows the distributions of wind velocity at pedestrian level (1.75m) for each case under the CFD simulation. Fig 5 shows only 4 simulation results because when Uh is under 3 m/s, almost every part of the site remains in the comfort condition (velocity magnitude < 5m/s). High wind speed began to appear at the north-west side of the site when U_h is 5m/s.

Areas vulnerable to reduced pedestrian comfort (velocity magnitude ≥ 5m/s) were observed at U_h=5m/s. The red zone on the NW direction experienced high wind gusts at the site entrance because of the wide road. High wind velocity distribution could be easily observed at the narrow spaces, such as the space between the tower and the pavilion etc. It was thought that the pressure level drops because of the narrow wind way, and therefore the wind velocity was increased at this space.

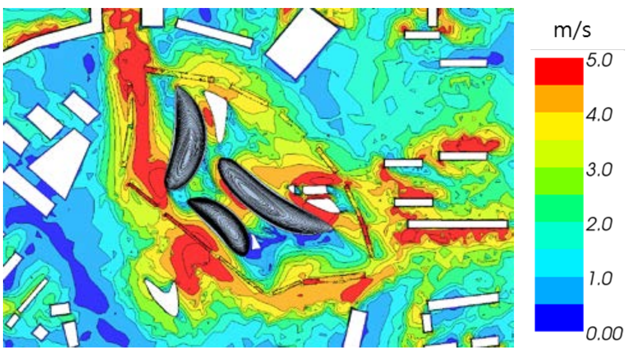
The vulnerable area at Uh=5m/s was 0.3% (220m^2). However its vulnerable area ratio increased sharply in accordance with the increase of U_h. When U_h is 6 m/s, the vulnerable area ratio is 3.5% (4,330m²) and 15.5% (10,920m²) with the U_h=7m/s. Therefore, design modification or special action is required when Uh > 5m/s.



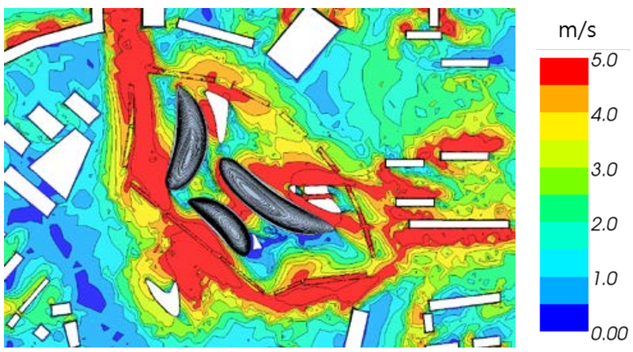
(a) U_h = 4m/s



(b) U_h = 5m/s



(c) U_h = 6m/s



(d) U_h = 7m/s

Fig. 5 Velocity distribution of wind speed 4~7m/s at the pedestrian level (1.75m)

4.2 CFD simulation of alternative model

For pedestrians comfort, low wind speeds are required for the outdoor wind environment. To decrease wind speed on site, special measures are required, such as planting trees and installing barriers at the middle of the wind ways.

In this project, two main measures were selected as mitigation strategies for strong wind. Fig. 6 shows mitigation strategies for strong winds by landscape design. Based on the wind way analysis, 61 evergreen trees and 19 wind barriers are installed at the critical wind way position. The wind barrier is a flat plate structure for defending pedestrians from strong winds.

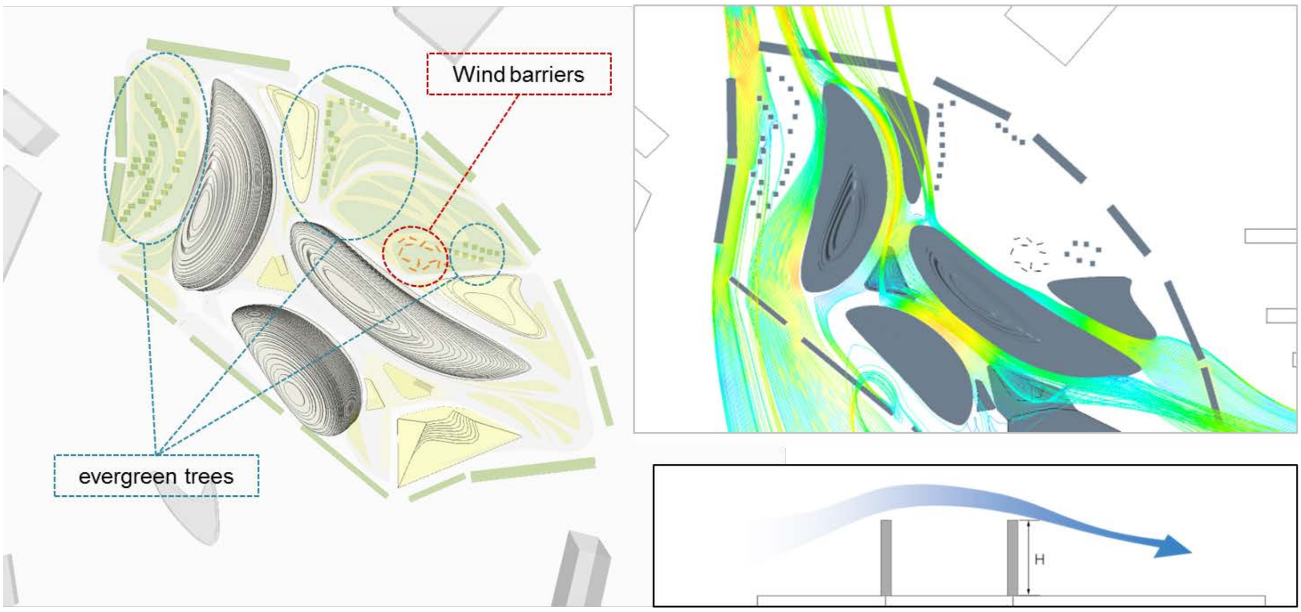


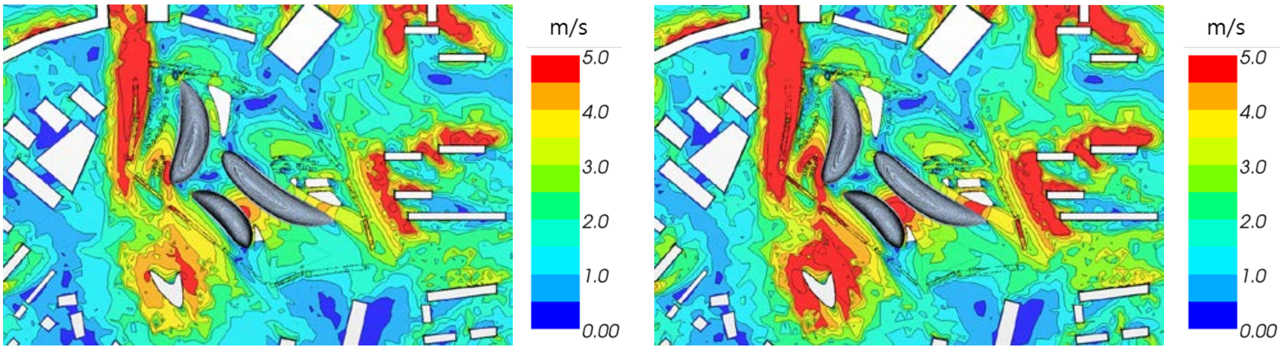
Fig. 6 Land scape design plan for mitigation of strong wind at pedestrian level

Additional CFD simulations are performed with the alternative model. Fig. 7 shows the wind velocity distribution of the alternative model with U_h=6,7m/s.

The overall wind distribution of the alternative model is improved over that of the base model. The most problematic locations were the main entrance (NW side) and the narrow space between the towers and the pavilions. Airflow from the main entrance is not fully mitigated. However, the wind distribution of the open space around tower 2 is considerably lower than the base model. It was thought that the wind stream is diverted from the SE direction (around the main street) to the SW direction (around the sub entrance) by the trees around the tower 2.

There are 6 wind barriers at the upper side of tower 2. These wind barriers defend strong wind from the main entrance. Wind distribution at the upper side of tower 2 improved in the alternative model, while there are much more vulnerable areas in the base model.

Although the wind distribution of the objective site was improved remarkably in the alternative model, the wind environment at the main-street (the narrow space between tower 1, 3) partially remains. Because of its use of space, it was hard to install any kind of structures or plants. Therefore, additional wind converting strategies could be helpful around the main street.



(c) U_h = 6m/s (d) U_h = 7m/s

Fig. 7 Velocity distribution of alternative model at the pedestrian level (U_h=6, 7m/s)

5. Conclusions

Pedestrian wind comfort depends on wind velocity and the probability of wind excess. Therefore, it is important that there needs to be not only wind distribution of site but also the probability of strong wind based on the weather data.

The objective of this study was to analyse the pedestrian wind environment of a high-rise building complex and provide useful mitigation strategies for strong wind. The outdoor wind environment around the buildings were calculated by a CFD simulation. A group of high-rise buildings was analysed for pedestrian comfort. The outdoor wind environment was analysed to satisfy comfort conditions above 90%. Then mitigation strategies were applied for improving pedestrian wind comfort. As a result of this study, optimized landscape plans for objective buildings were established.

The wind environment could change in accordance with the reference velocity. Therefore, the outdoor wind environment should be planned based on the probability analysis of weather data.

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Risk and Economic Analysis of Low Energy Technologies for Apartment Building

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Summary

This study evaluated the applicability of low energy technologies that have been developed for low energy consumption of apartment houses. The applicability of technologies was evaluated from two points of view. One is risk analysis and the other is economic analysis. Selection criteria and application method were presented to indicate possible development directions including the establishment of practical low-energy apartment house models and the future zero energy models.

Keywords: Risk Analysis, Economic Analysis, Low Energy Technology

1. Introduction

The world continues to preserve the environment and conserve energy in all sectors in order to overcome the energy crisis and mitigate climate change. About 40% of all energy is consumed in the building sector in the United States and the United Kingdom (UK) and 76% of the electricity is used in buildings [1]. In Korea, the energy consumption in the building sector is also increasing steadily [2] [3]. The Korean government is aware of this effect and has announced a plan to develop a zero carbon house by 2025.
Economics are the most significant issue in a consumer’s selection of a low energy house. Initial cost increases, energy bill decreases, and the payback period are the key elements of economic analysis considering building cycle.
Beside economic analysis, reviewing the barriers that limit construction of low energy house is also an important issue. The conservative characteristics of construction industries mean that a new technology takes more time to be applied in the market. Most construction companies tend to accept and spread a technology after the problems are solved and the performance has been verified by advanced companies.

In this study, the standards for low energy technology selection and integration method are suggested through evaluation of currently available technologies using risk and economic analysis.

These standard and methods are used to propose a practical low energy apartment model which is typical house type in Korea. Furthermore, these will provide directions to reach a zero energy apartment model.

2. Evaluation of Low Energy Technologies

As mentioned previously, the applicability of technologies was evaluated from two points of view.
One view assessed the risks; in other words, the problems that may occur during the technology application. Technologies were divided into 3 groups of risk: low, medium and high. The risk factors were then presented as the group in which the technology belongs.
The other view was based on economic analysis, which is widely used in applicability analysis. The economics of each technology was evaluated as a SIR (Savings to Investment Ratio) value, which was calculated with the energy reduction rate and the additional cost increase rate of each technology application. The energy reduction rate of each technology was calculated by energy simulation.
Any technology that had a low risk factor and high a SIR value was evaluated as a highly applicable technology.

2.1 Risk Analysis of low energy technologies

2.1.1 Barriers of the low energy house

The risks are defined as some factors which cause uncertainty and potential gains and losses expected by that factor in the construction market [4]. The problems that occur in the case of installing low energy technologies can be defined as risks.
There are four kinds of risk categories: technology, market, occupancy and policy.

Technical risks that affect performance occur when the technology has not been comprehensively proven through real projects or if the construction technology has not yet been developed, or if experienced workers are not available.
The risks in the market emerge if the technology does not yet exist in the market (in other words, it has not yet been industrialized), or if only imported products are available, or if the product choice is limited by lack of types of products. The risk factors might also be a reason to increase the costs.
The lack of awareness can cause the technology to be rejected by consumers and the system might not operate properly because of untrained users. The occupants may also find the technology inconvenient and their complaints can cause financial and image losses for the construction companies.
The risks related to policy can occur if the regulations cause losses of industries and consumers as the technology is applied.

2.1.2 Target technologies of low energy house

A review of the literature [5] found that the core technologies that affect the energy performance of low or zero energy houses included design-related elements such as building orientation, surface area ratio, and window area ratio; technologies to reduce load so that energy will not be used, such as thermal insulation of walls and windows, air tightness, ventilation volume, and heat recovery performance; highly efficient cooling and heating, lighting, ventilation, hot water systems, and control systems that efficiently supply required energy; and finally, renewable energy technologies such as solar heat, photovoltaic power, geothermal heat, wind power, and biomass to supply minimized energy use while reducing carbon emissions.
Since this research focused on operating energy only, building design elements and embodied energy materials are excluded from the target technologies. Table 1 shows the technologies finally selected for this research. Load reduction technologies were selected, including technologies for window thermal performance improvement, wall thermal performance improvement, air tightness and ventilation system performance improvement. Renewable energy technologies include geothermal, solar thermal and photovoltaic systems

Table 1 Target low energy technologies

Load reduction technologies	Renewable energy technologies
Window thermal performance	Geothermal system
Wall thermal performance	Solar thermal system
Air tightness	Photovoltaics
Ventilation rate and recovery	

2.1.3 Outline of the survey

Level of Low energy technologies		Type of Risks	1 (Not at all)	2 (Not much)	3 (Average)	4 (Somewhat important)	5 (Critical)	Cannot assess
level 1	U-value 1.4 W/m²K (16mm+22mm) Double Glazing Double Window system (low-e coating)	technology			✓			
		market			✓			
		occupancy			✓			
		policy		✓				
level 2	U-value 1.2 W/m²K 52mm Triple Glazing (low-e coating)	technology			✓			
		market				✓		
		occupancy						
		policy			✓			
level 3	U-value 0.6 W/m²K Vacuum Double Glazing System	technology					✓	
		market				✓		
		occupancy				✓		
		policy				✓		

Fig. 1 An example of expert survey about risks of technologies

Risk Assessment Survey was conducted for risk analysis. An expert survey for risk analysis of low energy technologies targeting apartments was performed by distributing a questionnaire to professionals involved in design, construction, and research or consulting. A total of 40 sheets were distributed and 30 answers were collected.
The first part of the questionnaire consists of general questions about respondents' job and career. The second part is about the barriers to low energy technologies and the practical energy performance standards of current apartments. The last two parts are the evaluation of risks of technology: the third part is about load reduction technologies and the fourth part is about renewable energy technologies. The risks are evaluated by 5 grades according to the level of technology and the risk categories.
Fig.1 shows the extracted response sheet regarding the window insulation performance. All of the questionnaire sheets are provided in the appendix.
The respondents consisted of 40% of design persons including architectural, mechanical and landscape experts, 47% research and consulting persons, and 13% construction persons. Their average work experience was 7 years.

2.1.4 Survey results about risk levels of technologies

Table 2 shows the results of average risk levels based on the technology and risk categories chosen by the respondents. The high levels of load reduction technologies like windows, walls, and air tightness were marked as high risk levels. Low levels technologies like renewable energy technologies were viewed as higher risk than load reduction technologies.

Table 2 The risk levels of each technology

		Technology	Market	Occupant	Policy	**Average**
Windows	U-value 1.4W/ m² K	2.17	2.40	2.13	2.28	**2.24**
	U-value 1.2W/ m² K	2.40	3.40	3.07	2.97	**3.08**
	U-value 0.6W/ m² K	4.14	4.32	3.54	3.55	**3.89**
Walls	U-value 0.3 W/ m² K	2.47	2.80	2.47	2.67	**2.60**
	U-value 0.2W/ m² K	3.41	3.53	3.17	3.50	**3.40**
	U-value 0.08W/ m² K	4.24	4.50	3.86	4.29	**4.22**
Airtightness	Infiltration 0.2ACH	2.47	2.67	2.47	2.57	**2.54**
	Infiltration 0.1ACH	3.45	3.48	3.00	3.14	**3.27**
	Infiltration 0.05ACH	4.34	4.39	3.75	4.21	**4.17**
Ventilation system	Min. ventilation rate 0.5ACH	2.03	2.23	2.40	2.50	**2.29**
	Heat recovery 60%	2.67	2.70	2.80	2.50	**2.67**
	Heat recovery 70%	3.27	3.40	3.40	3.27	**3.33**
	Heat recovery 80%	4.00	3.96	3.93	3.75	**3.91**
Geo thermal	Geothermal 0.5RT	2.59	3.14	3.21	3.07	**3.00**
	Geothermal 1.0RT	2.79	3.46	3.38	3.28	**3.23**
	Geothermal 1.5RT	3.24	3.79	3.76	3.76	**3.64**
	Geothermal 3.0RT	3.71	4.00	4.00	3.89	**3.90**
Solar thermal	Solar thermal 3 m²	2.62	3.07	3.21	3.00	**2.97**
	Solar thermal 6m²	3.29	3.75	3.85	3.64	**3.63**
Photovoltaics	Photovoltaics 1kW	2.76	2.82	2.96	3.00	**2.89**
	Photovoltaics 2kW	3.17	3.39	3.50	3.61	**3.42**
	Photovoltaics 3kW	3.41	3.64	3.77	4.00	**3.70**
	Photovoltaics 5kW	3.87	4.00	4.09	4.29	**4.06**

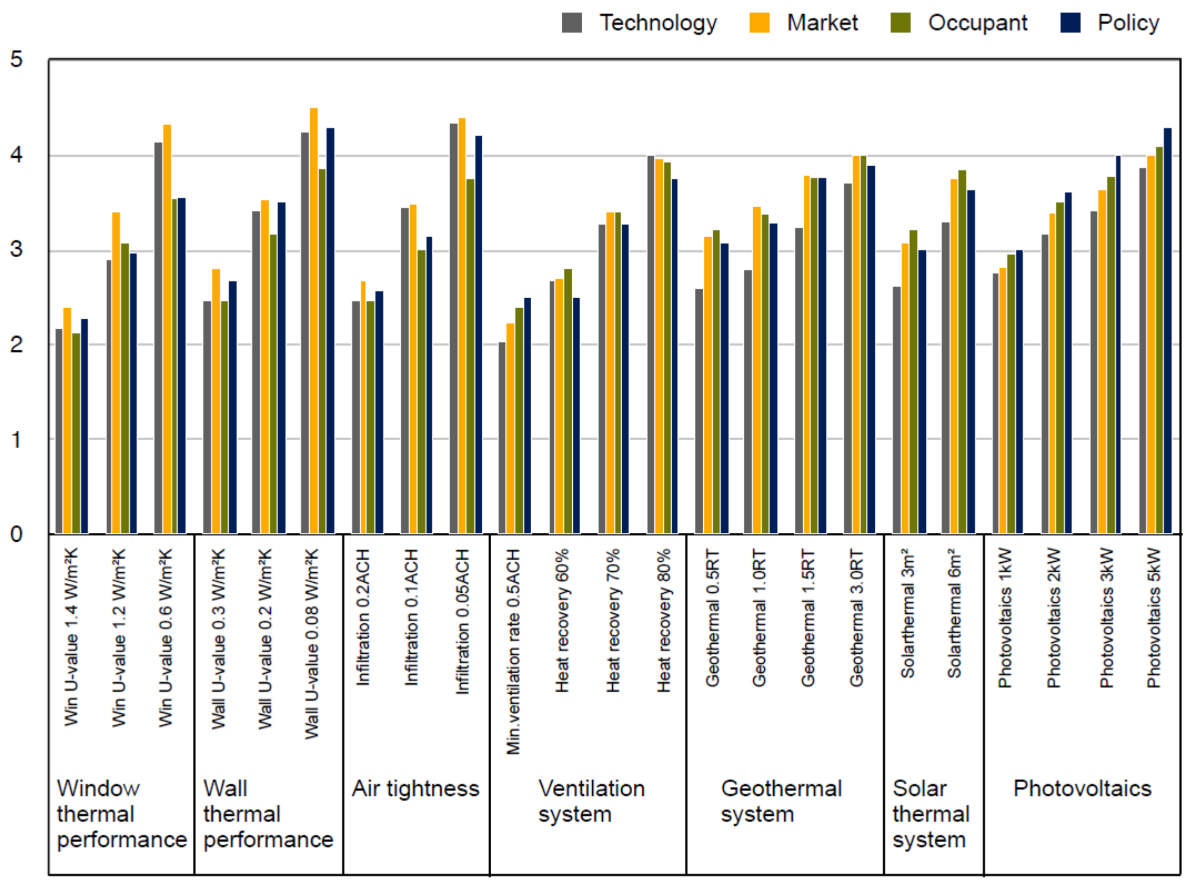

Fig. 2 The risk levels of each technology

2.1.5 Risk groups of low energy technologies

The technologies were divided by risk levels by integrating the literature reviews and survey results. Group 1 consisted of technologies that have average risk levels under 3.0 (average) without political and occupancy problems. Group 3 was defined as the technology that has low energy technologies with few problems over 4.0 and that are not possible in high-rise apartment blocks with current efficiency. Group 2 consisted of low energy technologies that did not belong to Group 1 or Group 3. The categorized technologies are shown in table 3 and the risk factors were set as the risk levels.

Table 3 Technology group

Group	Technologies	Risk level	Problems from literature review
Group 1 (Risk factor 1)	Win U-value 1.4 W/ m² K	2.24	
	Infiltration 0.2ACH	2.54	
	Wall U-value 0.3 W/ m² K	2.60	
	Photovoltaics 1kW	2.89	
	Solar thermal 3 m²	2.97	
Group 2 (Risk factor 2)	Min. ventilation rate 0.5ACH	2.29	Needs to change building code
	Heat recovery 60%	2.67	Lack of user awareness
	Geothermal 0.5RT	3.02	
	Win U-value 1.2 W/ m² K	3.08	
	Geothermal 1RT	3.23	
	Infiltration 0.1ACH	3.27	
	Heat recovery 70%	3.33	
	Wall U-value 0.2 W/ m² K	3.40	
	Photovoltaics 2kW	3.42	
	Solar thermal 6 m²	3.63	
	Geothermal 1.5RT	3.64	
	Win U-value 0.6 W/ m² K	3.89	
	Geothermal 3RT	3.90	
	Heat recovery 80%	3.91	
Group 3 (Risk factor 3)	Photovoltaics 3kW	3.70	Not available in high dense apartment block
	Photovoltaics 5kW	4.06	
	Infilatration 0.05ACH	4.17	
	Wall U-value 0.08 W/ m² K	4.22	

2.2 Economic Analysis of low energy technologies

2.2.1 Outline of the analysis

Energy reduction of each technology application was calculated for economic analysis. Base model for energy simulation was constructed based on paper review [6] [7] and statistical data [8]. Since heating energy accounts for most of the energy use in residential building in Korea, only the heating energy reduction was considered in this study.
The economics of each low energy technology was evaluated by calculating the Savings to Investment Ratio using energy reduction rates and additional cost increase rates. A technology with a high SIR value was cost efficient.

2.2.2 Base model for energy analysis

The target apartment unit plan was designed to have 120 m² area and 3 surfaces facing outdoors and to have 4 rooms on the front side, which is a current trend in type. This type of unit is illustrated in Fig.3. The central region was selected as a study area because of a sufficiently high possibility of new construction, re-construction, and retrofitting of apartments.

Fig. 3 Base model unit plan

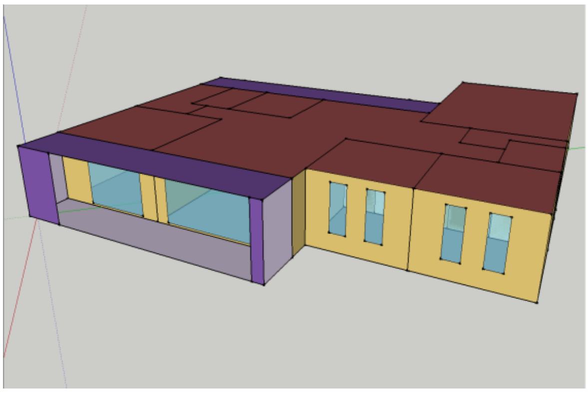

Fig. 4 Building geometry model

EnergyPlus was chosen as a dynamic energy simulation tool in the present research. After modelling of building geometry, the materials are installed based on the performance standard for the central region described in 2008 building code. The completed building geometry model is illustrated in Fig.4.
To construct the model, surveys of energy consumption and consumption patterns in real apartment buildings are conducted and statistical data are used as input data for internal heat gain and system operation schedules for the simulation model. The floor radiant heating system and a packaged air conditioner were installed as in typical apartments. A mechanical ventilation system was also continuously operated at 0.7ACH.
Estimated data were calculated as 9,962 kWh through computer simulation, which is almost the same as 9,939 kWh, the surveyed data of the extracted unit [9]. The simulation error was 2.3%. Therefore, the computer simulation model appeared to be appropriate for use as base model for energy reduction analysis of technologies.

2.2.3 Savings to investment ratio

Based on base model constructed in 2.2.2, the energy reduction of each technology application was calculated. Then, The SIR (Savings to Investment Ratio) was selected as an economic analysis method because the value allows easy recognition of the differences between technologies and the relationship between energy reduction and additional cost. It is a relative comparison between technologies that simplifies the Performance to Cost Ratio (kWh/₩) as used in the Zhu's research [10]. Table 4 shows the SIR value of low energy technologies.

Table 4 Savings to investment ratio of low energy technologies

Technologies		Energy reduction kWh	%	Additional cost ₩	%	**SIR Wh/₩**
Windows	1.4W/ m² K	10.2	6.2	3,300	0.3	**7.59**
	1.2W/ m² K	10.9	6.6	6,600	0.5	**4.93**
	0.6W/ m² K	17.8	10.8	10,000	0.8	**3.52**
Walls	0.3 W/ m² K	8.7	5.3	4,545	0.4	**2.25**
	0.2W/ m² K	10.9	6.6	10,418	0.8	**1.05**
	0.08W/ m² K	14.1	8.5	45,455	3.5	**0.39**
Airtightness	0.2ACH	25.1	15.2	4,545	0.4	**1.92**
	0.1ACH	32.5	19.7	9,090	0.7	**1.20**
	0.05ACH	35.2	21.3	15,778	1.2	**0.89**
Ventilation system	0.5ACH	8.8	5.3	0	0.0	
	HR 60%	17.7	10.7	12,670	1.0	**1.39**
	HR 70%	21.3	12.9	21,355	1.7	**1.00**
	HR 80%	21.8	13.2	29,804	2.3	**0.73**
Geo thermal	0.5RT	36.2	21.9	22,424	1.7	**1.61**
	1.0RT	53.7	32.5	42,667	3.3	**1.26**
	1.5RT	70.0	42.3	106,667	8.3	**0.66**
	3.0RT	87.0	52.6	167,394	13.0	**0.52**
Solar thermal	3 m²	11.2	6.8	68,870	5.4	**0.16**
	6m²	22.5	13.6	137,740	10.7	**0.16**
Photovoltaics	1kW	11.0	6.6	65,758	5.1	**0.17**
	2kW	21.9	13.2	131,818	10.2	**0.17**
	3kW	32.9	19.9	197,778	15.4	**0.17**
	5kW	54.8	33.1	462,333	35.9	**0.12**

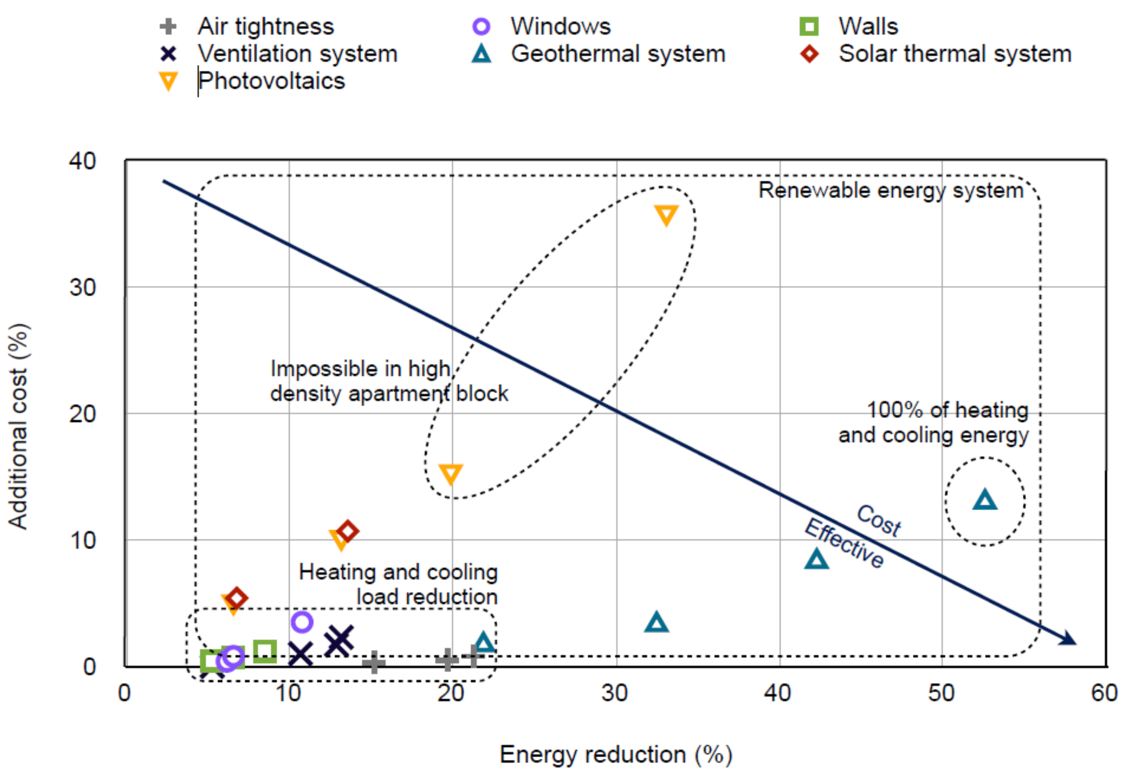

Fig. 5 Energy reduction and additional cost increase of low energy technologies

2.3 Applicability of Low Energy Technologies

Table 5 shows the priority of low energy technology applications based on risk analysis and economic analysis. The technology with the lowest risk factor and highest SIR value is the one with the highest applicability.

Table 5 Priority of low energy technology application

Technologies	Risk Factor	SIR value
Infiltration 0.2ACH	1	7.59
Win 1.4W/ m² K	1	2.25
Wall 0.3 W/ m² K	1	1.92
Photovoltaics 1kW	1	0.17
Solar thermal 3 m²	1	0.16
Min. ventilation rate 0.5ACH	2	
Infiltration 0.1ACH	2	4.93
Geo thermal 0.5RT	2	1.61
Heat Recovery 60%	2	1.39
Geo thermal 1.0RT	2	1.26
Wall 0.2W/ m² K	2	1.20
Win 1.2W/ m² K	2	1.05
Heat Recovery 70%	2	1.00
Heat Recovery 80%	2	0.73
Geo thermal 1.5RT	2	0.66
Geo thermal 3.0RT	2	0.52
Win 0.6W/ m² K	2	0.39
Photovoltaics 2kW	2	0.17
Solar thermal 6m²	2	0.16
Infiltration 0.05ACH	3	3.52
Wall 0.08W/ m² K	3	0.89
Photovoltaics 3kW	3	0.17
Photovoltaics 5kW	3	0.12

3. Development of Low Energy Apartment Models

3.1 Integrated models for low energy apartments

Two types of integrated models are suggested based on the evaluation results.

The one is defined as a low risk model, which can be realized practically and is accompanied by few risks. The technologies of risk group 1, which has low risk levels, are integrated into this model.

The other is defined as the economic zero energy model. It is designed to maximize energy performance while minimizing additional initial costs. Cost efficient load reduction technologies are fully used and renewable energy system technologies are installed to accomplish 100% energy reduction, namely zero energy.

Table 6 Technologies of low risk model and economic zero energy model

Low risk model	Economic zero energy model
Base model + Water savings taps + Power cutting switch + Infiltration 0.2ACH + Win U-value 1.4 + Wall U-value 0.3 + Solar thermal 3 m² + Photovoltaics 1kW	Base model + Water savings taps + Power cutting switch + Min. ventilation 0.5ACH + Infiltration 0.05ACH + Win U-value 0.6 + Wall U-value 0.08 + Heat recovery 80% + Geothermal 1RT + Solar thermal 6 m² + Photovoltaics 4.5kW

3.2 Performance Estimation through Computer Simulation

Total energy reduction according to technology application is calculated from energy simulations in which each technology is added one by one to the base model used for economic analysis.

Fig.6 shows total energy demand and applied renewable energy quantity per unit area of low risk model and economic zero energy model. Energy reduction by load reduction technologies are 27.3% and 53.2% in the low risk model and economic zero energy model, respectively. In addition to the 27.3% reduction, an 18.4% reduction in energy demand is supplied with renewable energy in the low risk model. As a result, a 40.7% energy reduction is achieved by the low risk model compared to the base model.

In the economic zero energy model, a geothermal system covers the minimized heating and cooling load and a solar thermal system covers 70% of the energy needed for hot water. The remaining energy demand of 50kWh/ m² is planned to be supplied by 4.5 kW photovoltaic panels, but this is difficult to realize in high density apartment blocks with current solar panel efficiency because of the quantity of panels needed to install.

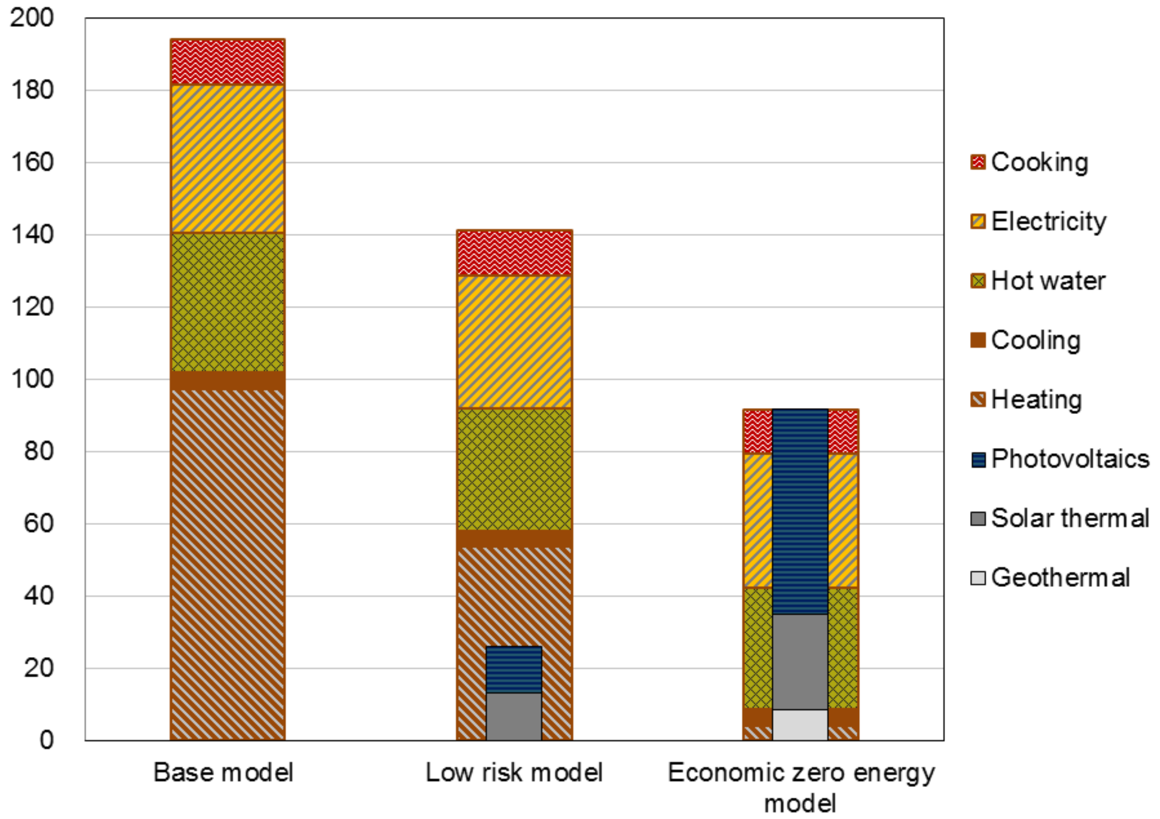

Fig. 6 Energy consumption and renewable energy of integrated models

4. Conclusions

The criteria for low energy technology selection and integration method are suggested through two kinds of analysis in the present study.
The technology applicability evaluation showed that the 40% energy saving model with 11% cost increase was the most appropriate at the present moment. To implement zero energy with the most economical method requires an additional cost of 53% at the present moment, ignoring all risks. In order to achieve zero energy by improving the energy performance of the realistic model, it is critical that the risks of the highly economic load reduction technology first be removed. As it is difficult for the load reduction technologies to achieve energy savings greater than 50%, achieving energy savings greater than this will require that we improve the economic efficiency of renewable energy and that we set up a power supply plan for renewable energy that can be applied to highly dense apartment houses.

The evaluation of technology applicability through risk analysis and economic analysis in this study will be useful for judging the realistic alternative solutions that can be selected in the house construction market at the present moment. Moreover, it will provide directions to develop a zero energy apartment model.

5. Acknowledgements

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Assessing the environmental impacts of log houses with a novel easy-to-use calculation tool, case Karhukunnas

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Summary

This paper presents the life-cycle greenhouse gas (GHG) emissions over a 50-year life-cycle for a log house, and for two alternative designs. The results are shown in terms of embodied and operational carbon.
The embodied carbon related to building material production and material replacements during the lifetime is assessed with a novel easy-to-use calculation tool. The tool is able to calculate the total mass of structures, use of renewable and non-renewable material resources, use of renewable and non-renewable energy, energy content of structures, carbon storage and embodied carbon. However, only embodied carbon is discussed in this paper.
The results are supplemented with calculations on emissions from material transportation, construction site activities and building deconstruction work. The combined results show the total embodied carbon during the life-cycle of the building.
The operational carbon (GHG-emissions related to operational energy use), is also assessed, for two alternative heating methods.
The results show that the lifetime GHG-emissions of log houses are 3% to 13% lower than those of the standard house, depending on the analysed scenario. The embodied carbon, including material production, transportations and site activities accounts for 12% to 33% of the total life-cycle greenhouse gas emissions.

Keywords: log house, life-cycle calculation, GHG-emissions

1. Introduction

The district of Karhukunnas is located in the city of Pudasjärvi, in Northern Finland. The district showcases Finnish log building, and once completely built, comprises of 20 to 30 dwellings. The district development project also included research and development goals, concerning the environmental impacts of log houses. [1]

In order to assess the environmental impacts of district's dwellings, a calculation tool was developed. The tool incorporates a database of existing and up-to-date environmental data of Finnish building materials and an easy-to-use user interface. It enables the designers to calculate the cradle to gate environmental impacts from the material production of detached or attached log houses, and wood framed houses. The tool requires no prior experience in the field of environmental assessments from the user.

2. Presentation of the tool

The tool "Hirsitalolaskuri 2011", translating to "Log House Calculator 2011", enables the user to calculate the environmental impacts of detached or attached log houses, and wood framed houses. The results are calculated in terms of total mass of materials, use of renewable and non-renewable material resources, use of renewable and non-renewable energy, energy content of structures, carbon storage, and embodied carbon of material production.

The calculations are based on typical structure types of detached and attached houses, and on user inputs. The user defines the building one structure at a time, by defining the thicknesses and materials of each structural layer for all the structure types. The material densities are retrieved automatically from the database, but alternative values can also be entered. Also, material specific waste percentage describing construction-time material losses may be assigned. In order to cover the lifetime renovations, the number of replacements over the building's life-time can also be set

Figure 1 shows an example input window of the tool. The specific window is for a ground supported base-floor. The top-left corner of the window shows drop-down menus, which contain the material selections for each of the structural layers of the base floor. To the right from the drop-down menus, there are input boxes for layer thickness, material density, wastage percentage and number of lifetime renewals, in that order. For this specific example, the first three rows contain inputs for floor surface materials. There is an additional input box for these rows, as the last input box allows the user to specify the relative share of different floor surfaces.
Figure 1 also shows some additional inputs for the insulation layers. Insulation below the base-floor is typically thicker at the perimeter of a building, and the input boxes at the bottom-left-side of the window are related to these selections.

Once finished, a structure can be saved, and assigned a total surface area. The total quantities of materials in the specific structure, and the corresponding environmental impacts, are then calculated.

All the structures of a building are entered in a similar way. The list of available user inputs is presented in Table 1. The tool allows a user to input two different foundation types, one continuous foundation type and one pillared

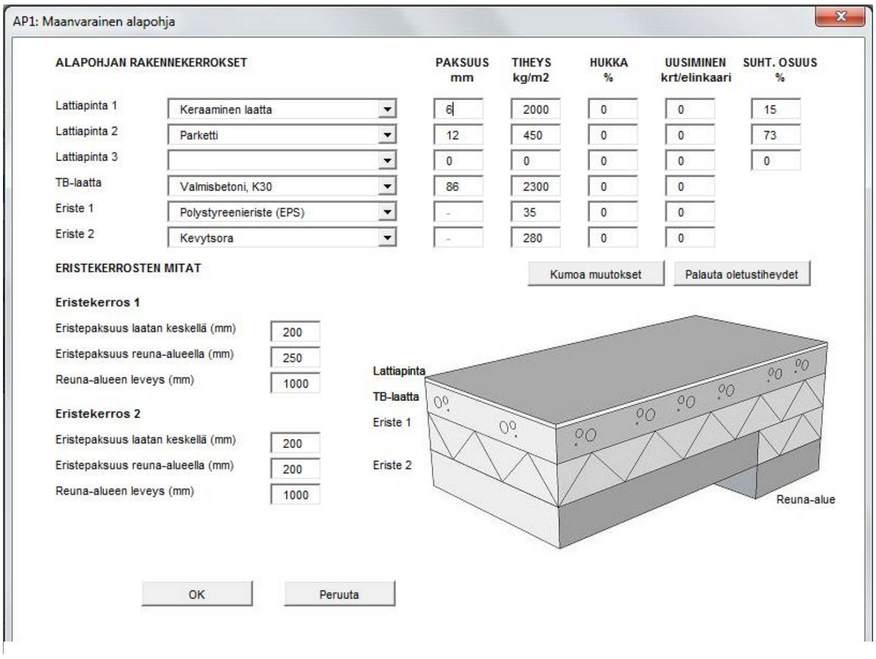

Fig. 1 Example of an input window, ground supported base-floor

Table 1 List of available user inputs in the tool

Structure	Available user inputs
Foundations	One continuous foundation type One pillared foundation type
Base floor and intermediate floors	One ground supported base floor type One ventilated base floor type One intermediate floor type
External walls	Three different external wall types
Internal walls	Three different internal wall types
Roof	One roof type with wooden trusses One roof type with wooden beams
Complementing structures	Windows, doors, fireplaces, staircases, terrace
Other material inputs	Seven user materials, to be selected from a list of 40 materials

foundation. The tool also enables the user to input one ground supported base floor, one ventilated base floor, and one intermediate floor type. Both, the internal and external walls, can consist of three separate wall types. The tool allows the user to define two different roof types, one with wooden trusses and one with wooden beams. The complementing structures can be defined in terms of windows, doors, fireplaces, staircases and terraces.

If there is a need to do corrections to the structures, or to include some additional materials, the user may also enter other material inputs. These can be selected from a list of 40 materials, and up to seven different materials can be defined.

After all the structures are defined, the user may print out the results. The results represent the cradle-to-gate environmental impacts from material production of the building. Depending on the scope of calculations and user inputs, the results may, or may not, include the emissions caused by material wastage and lifetime renewals.

3. Description of the case building and two alternative scenarios

3.1 General information

The studied case building is an attached log house with two separate dwelling units. The total floor area of the building is 140 m^2 and the total volume is 480 m^3.

The following figure 2 shows the layout of the case-building. The building is divided into two separate dwellings by a dividing wall in the middle of the building. Both of the dwellings comprise of a hall, a kitchen-living room, sanitary spaces and sauna, and a single bedroom. The dwellings also have terraces, and unheated storage spaces outside the main entrances. [2]

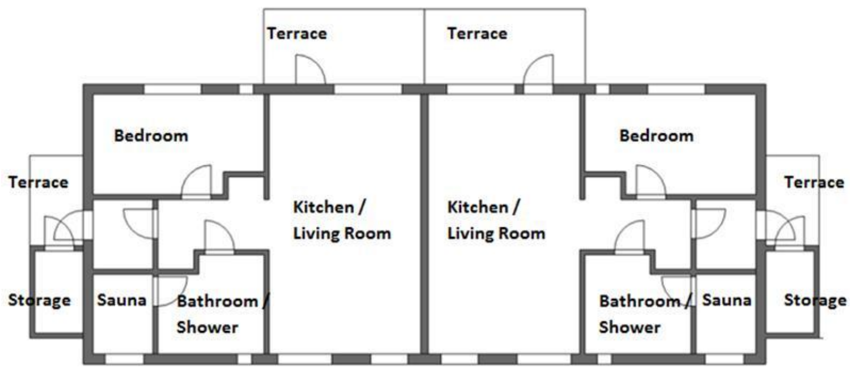

Fig. 2 Layout of the case-building

Two alternative scenarios were also created, namely “the standard house” and “the most ecological house”. The first scenario represents a typical Finnish wood framed building and the second one a building where log and other wood products’ use is maximized. The following subchapters describe the structures of all the calculation scenarios in more detail.

3.2 Foundations

The foundations of case-building are mainly of continuous type concrete foundations, and to a lesser extent, pillared concrete foundations. The continuous foundation extends some 70 metres around the building and under the dividing wall, whereas the pillared foundations (5pcs) are used under the terrace structures. All the scenarios have similar foundations.

3.3 Base floor and intermediate floors

The base floor slab of the case-building and the standard house is a 80mm thick, cast-in-place concrete slab with 200mm thick EPS-insulation under the floor slab. The most ecological case is based on a ventilated, wooden floor structure. The area of the floor slab is 140 m^2 for all the cases.

3.4 External walls

The external wall of the case-building is 243mm thick, and in the most ecological scenario, 270mm thick log wall. The log wall is partly insulated. The standard house has 250mm thick, wood-framed wall with mineral wool insulation. The total area of the external walls is 110m^2.

3.5 Internal walls

The dividing wall between the dwellings is a double-framed wooden wall in both the case-building and the standard house. In the most ecological scenario, has the dividing double wall is made of 135mm thick log.

All the partition walls in the case-building are wood-framed walls, and, in the most ecological scenario, log walls. The walls of the standard house are also wood-framed walls, except for the sanitary spaces, which use lightweight concrete blocks as their wall material.

The internal walls are mainly clad with gypsum board in the standard house scenario, and with wooden cladding in the other scenarios. The total area of internal walls is 125 m^2.

3.6 Roof

The roof of all the cases is supported by wooden trusses. The insulation material for both the case-building and the most ecological scenario is wood fibre, and for the standard house, mineral wool. The ceilings in the first two cases are made with timber cladding and with gypsum board in the standard house. The total roof area of the building is 120m^2.

3.7 Complementing structures

In addition to the abovementioned structures, the building has 21m^2 of windows, six external doors, eight internal doors, and a wooden terrace with a 24m^2 floor area.

3.8 Other material inputs

Some additional inputs were also used for the calculations. A structural plywood layer, used in roof structures, was added using material inputs. The wall structures of unheated storage spaces were input as lump sums of respective materials.

4. Calculation process

4.1 Emissions from building materials

The tool Hirsitalolaskuri 2011 was used for assessing the cradle to gate GHG-emissions of the three scenarios. The structures, as described in chapter 3, were used as calculation inputs.

The material wastage was estimated based on contractor’s typical waste percentages. The internal and external surfaces were expected to be replaced once over the buildings lifetime, but other structures were expected to last for the whole 50-year lifetime

4.2 Emissions from the transportation

The calculation tool does not cover the material transportations to, or waste transportations from the building site, so these need to be calculated separately. A bill of quantities from the tool was used as the basis for the assessment of emissions from transportation.

The transportation distances were based on actual delivery distances, logged by the contractor, and the emission data for emissions of road freight was extracted from VTT’s LIPASTO-database. [3] Based on this information, the emissions from transportations were calculated.

4.3 Emissions from the construction and end of life-phases

All the energy consumption and fuel use during the construction phase was monitored and logged by the contractor. The heating energy use and electricity use were assigned average Finnish emission values, as in 2010.[4] The emissions for fuel powered machines and tools were calculated, based on actual use-hours and emission data by LIPASTO-database.

Due to a lack of data on the end of life-phase, the deconstruction phase was estimated to have the same emission values as the construction phase. All the three calculation scenarios were assumed to have similar construction and end-of-life emissions.

4.4 Emissions from the operational energy use

The calculations on operational energy use were based on energy calculations (energy certificates) of the cases. The operational energy use includes the space heating, water heating, and household electricity use over the building's lifetime.

The emissions from energy production were expected to develop from 2010 to 2030, according to the Finnish Ministry of Employments and Economy's climate strategy. [4] The emissions were assumed to stay at the 2030 level for the remainder of the calculation period.

5. Calculation results for greenhouse gases

The results of total greenhouse gas (GHG) emissions were calculated for each of the three scenarios, by adding together:

- the cradle to gate emissions, including initial material use, wastage during construction and renovations over the lifetime of the building (results from the tool)
- the emissions from transportation (bill of quantities from the tool + manual calculations)
- the emissions from construction and end of life-phases and (manual calculations)
- the emissions from operational energy use over a 50-year lifetime (manual calculations).

The calculations were made for two alternative heating methods: district heating and ground heating. The GHG calculation results are summed up in the following subchapters.

5.1 GHG calculation results for the case-building

The GHG calculation results over the 50-year life-cycle of the case-building showed total lifetime emissions of 231 tonnes for the district heating, and 115 tonnes for the ground heating scenario. Table 2 shows the lifetime GHG emission sources item by item. Embodied carbon, caused by material production, transportation and site activities results in some 35 tonnes of GHG-emissions over the 50-year lifetime of the building. The table also shows that operational phase is the dominant emission source, resulting in either 196, or 80 tonnes of GHG-emissions over the lifetime.

Table 2 Lifetime GHG emissions, case-building, tonnes of CO2-equ.

GHG emission source	District Heat, GHG tonnes	Ground Heat, GHG tonnes
Building material production	28	28
Transportation of materials and waste	1	1
Construction and demolition	6	6
Operation	196	80
Total	231	115

The following figure 3 shows the relative importance of different items on the GHG-emissions of the case-building. The operational energy use is the largest contributor with some 85% share of the total GHG-emission in the case of district heating. However, the lower purchased energy need, and resulting lower emissions of ground heating cause the role of operational energy to decrease to some 70% of the total. Similarly, the significance of embodied carbon doubles, from 15% to 30% of total.

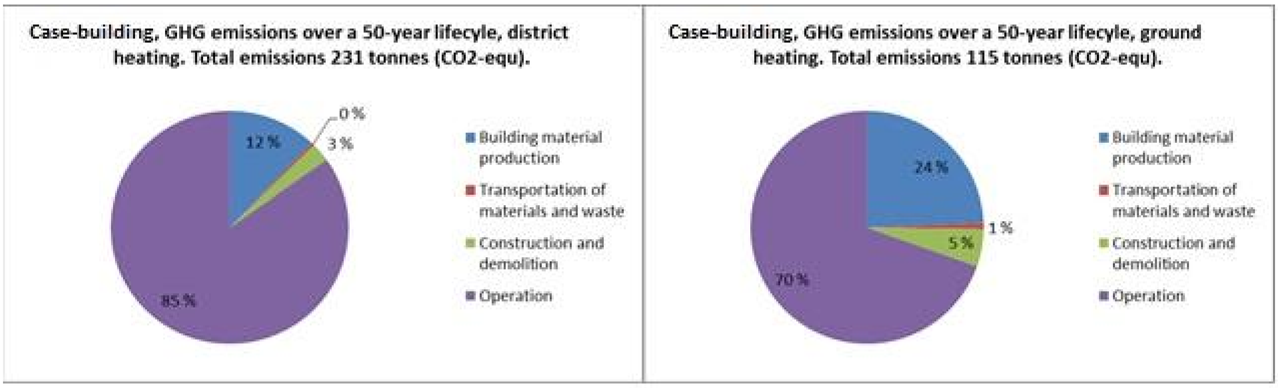

Fig. 3 Distribution of GHG-emissions of case-building

5.2 GHG calculation results for the standard house

The GHG calculation results over the 50-year life-cycle of the standard house showed total lifetime emissions of 237 tonnes for the district heating, and 121 tonnes for the ground heating scenario. Table 3 shows the lifetime GHG emission sources item by item. Embodied carbon, caused by material production, transportation and site activities results in some 39 tonnes of GHG-emissions over the 50-year lifetime of the building. The table also shows that operational phase is the dominant emission source, resulting in either 196, or 80 tonnes of GHG-emissions over the lifetime.

Table 3 Lifetime GHG emissions, standard house, tonnes of CO2-equ

GHG emission source	District Heat, GHG tonnes	Ground Heat, GHG tonnes
Building material production	32	32
Transportation of materials and waste	1	1
Construction and demolition	6	6
Operation	196	80
Total	237	121

The following Figure 4 shows the relative importance of different items on the GHG-emissions of the standard house. The operational energy use is the largest contributor with some 83% share of the total GHG-emission in the case of district heating. However, the lower purchased energy need, and resulting lower emissions of ground heating cause the role of operational energy to decrease to some 67% of the total. Similarly, the significance of embodied carbon almost doubles, from 17% to 33% of total.

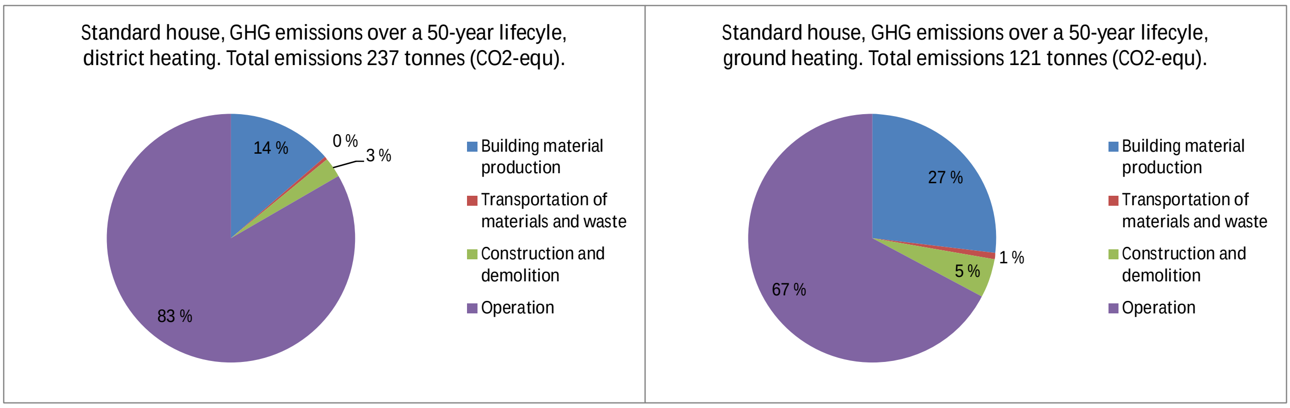

Fig. 4 Distribution of GHG-emissions of standard house

5.3 GHG calculation results for the most ecological case

The GHG calculation results over the 50-year life-cycle of the most ecological case showed total lifetime emissions of 222 tonnes for the district heating, and 106 tonnes for the ground heating scenario. Table 3 shows the lifetime GHG emission sources item by item. Embodied carbon, caused by material production, transportation and site activities results in some 26 tonnes of GHG-emissions over the 50-year lifetime of the building. The table also shows that operational phase is the dominant emission source, resulting in either 196, or 80 tonnes of GHG-emissions over the lifetime.

Table 4 Lifetime GHG emission emissions, the most ecological case, tonnes of CO2-equ

GHG emission source	District Heat, GHG tonnes	Ground Heat, GHG tonnes
Building material production	20	20
Transportation of materials and waste	0	0
Construction and demolition	6	6
Operation	196	80
Total	222	106

The following Figure 5 shows the relative importance of different items on the GHG-emissions of the most ecological scenario. The operational energy use is the largest contributor with some 88% share of the total GHG-emission in the case of district heating. However, the lower purchased energy need, and resulting lower emissions of ground heating cause the role of operational energy to decrease to some 75% of the total. At the same time, the significance of embodied carbon more than doubles, from 12% to 25% of total.

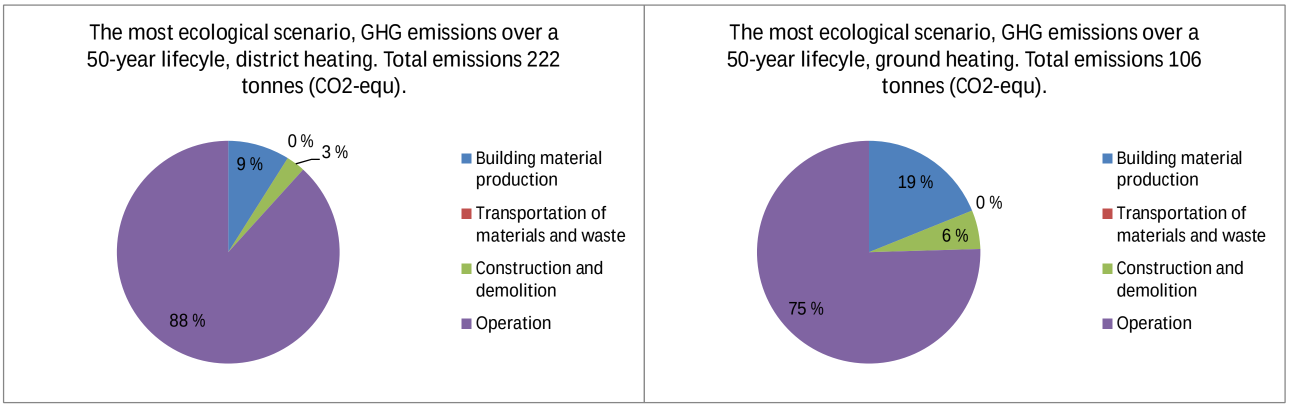

Fig. 5 Distribution of GHG-emissions of most ecological scenario

5.4 Summary of the GHG calculation results

The calculation results showed that over the 50-year lifetime of a building, the case-building and the most ecological scenario had lower total GHG emissions than the standard house. The differences was at the level of 3…13%, depending on the scenario.

The biggest contributing factor to the life-cycle environmental impacts was the operational energy use, contributing to 67… 88% of the total lifetime emissions. The relative share of embodied energy was at the level of 12…33% of the total emissions. The calculation results

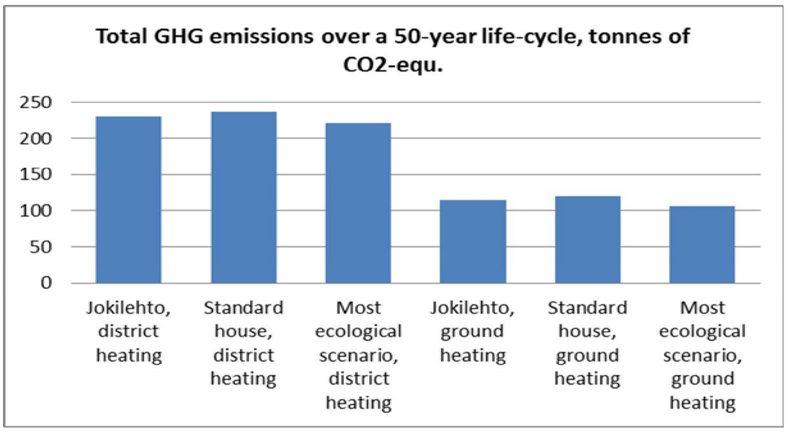

Fig. 6 Calculation results for different scenarios

are summarized in Figure 5.

6. Conclusions

The calculation tool, Hirsitalolaskuri 2011 provides a valuable tool for assessing the greenhouse gas emissions from the material production of a building. The calculation results show that role of material emissions is significant, and it cannot be left out of life-cycle considerations.

However, the calculation results of the tool need to be complemented with additional calculations to cover the whole life-cycle of a building. This study also assessed the emissions from transportation, construction site activities, and operational energy use.

The results showed that the lifetime GHG-emissions of log houses were 3% to 13% lower than those of the standard house, depending on the analysed scenario.

The embodied carbon, including material production, transportations and site activities accounted for 12% to 33% of the total life-cycle greenhouse gas emissions.

The selected heating method has a significant effect on the results. The lower operational energy use and related emissions of ground heat caused the relative importance of building materials to rise. For the case-building, for example, the share of embodied carbon shifted from 15% to 30%, from ground heating to district heating.

It can be concluded that material selections do have a noticeable impact on life-cycle greenhouse gas emissions, and the embodied carbon needs to be taken into account in life-cycle analyses. The embodied carbon accounted for up to 33% of the total life-cycle greenhouse gas emissions of this analysis. The results show on their part that when buildings become more energy efficient, the relative share of embodied carbon will rise. Due to this, the selection of the building materials will hold a greater role in greenhouse gas reductions in the future

7. Acknowledgements

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Carbon footprint assessment of buildings – Developing a comprehensive service and understanding the market demand

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Summary

The purpose of the study is to develop a comprehensive service for stakeholders in the real estate sector in order to guide environmentally aware building design by assessing the future greenhouse gas emissions generated by the buildings and their operations. In addition, the service development draws upon the approach of *service productization* in order to readily meet the market needs and demands, which have been examined in this study by a customer survey as well as a set of customer interviews.

1. Introduction

As buildings are responsible for a significant part of global greenhouse gas emission, there remains great potential to reduce the GHG emissions within the sector. Buildings generate emissions throughout their life cycle [1]. Approximately 80% of all emissions are generated at the operation phase through energy consumption [2]. Whereas, manufacturing of the materials, transportations, maintenance and renewals are responsible for 10-20% of all emissions [2]. However, the importance of building materials increases when buildings become more energy-efficient. A great attention has been focused on the building sector which has forced it to re-evaluate the patterns to design, construct, manage and operate buildings.

To assess the environmental performance of buildings European Standard has determined the comprehensive calculation method EN 15978 which creates a uniform scope for assessment and concretizes the environmental performance into numbers. The calculation takes into account the building's whole life cycle from cradle to grave starting from extracting the raw materials, the manufacturing of the construction materials, constructing, operation and maintenance of the building, to the final demolition and disposal. The calculation utilizes the material information from EN 15804 [3]. Through environmental assessments the upcoming emissions generated by the construction and operation of the building can be affected in design phase. However, the assessment of building's environmental performance according to standard becomes often very complex and laborious and requires expertise from many fields which can be a big challenge for designers and architects. To manage the emissions in every day decision making, processes for cutting down the emissions need simple and usable tools to evaluate emissions.

Moreover, this study examines the prerequisites for developing a comprehensive service aligned with the market needs and demands. Herein, the service development approach leans heavily upon *service productization* practices, which in the academic literature is understood as concretizing the service and adding “product-like” features to the service offering. These practices include two constituting ideas: First, specifying and concretizing the service in order to create more exchangeable services in the eyes of customers. Second, systematizing and standardizing internal tasks in order to gain efficient and controllable service production processes [4]. Especially in professional services and knowledge-intensive business services (KIBS), which are characterized by somewhat abstract and intangible outcomes, service productization might offer valuable and useful practices in order to create more marketable and clearer objects of exchange as well as enhancing the service provider's internal productivity [4]. Thus, from the vantage point of the service provider, the productization process aims at elaborating and transforming customer information into customer understanding in the form of a productized service [5].

2. Methods

2.1 Productization of the assessment service

Carbon footprint assessment of buildings is currently quite rare in ordinary planning projects. A toilsome calculation and comparison of results are often a too heavy process when the schedule and the budget of the design work are tight. In order to take into account emissions in the design and every day decision making, the service aims to accelerate the assessment of environmental performance of building by improving the work phases of the calculations and concretizing the results into comparable numbers.

The aim of the study was to develop a service to evaluate the environmental performance of building at the design phase and to yield information about low-emission solutions to the design of new buildings. The indicator to describe the environmental performance of the building was chosen to be CO2 equivalent. Emissions included in the calculation are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) which are summed up by using Direct Global Warming Potentials.

The service has focused on emissions generated by building materials as well as the emissions from energy consumption at the use stage. In the productization the laborious work phases of assessing the carbon footprint such as colleting the quantity and the environmental data of the products needed to be improved. To assess the carbon footprint of construction materials more efficiently, handy calculation software was developed in cooperation with VTT Technical Research Center of Finland. The software utilizes a database into which emission data of materials and construction products was gathered. The quantity data from the design is collected by using a Building Information Model (BIM) analyzer tool. The carbon footprint of building materials is then calculated by integrating the emission data and the quantity data collected from the design.

The assessment of the emissions from the operation stage of the building is conducted with comprehensive energy simulations. Simulation takes into account buildings design, structural characteristics and all technical performance data of HVAC and electricity systems such as heating, ventilation and lighting.

2.2 Mapping out market perceptions – Results from a customer survey and focused customer interviews

A customer survey was conducted in order to map out quantitative market perceptions concerning carbon footprint issues within the real estate and construction (REC) industry. Additionally, qualitative customer interviews were conducted in order to furthermore gain insights from the customer point of view.

The customer survey was conducted as a web-based questionnaire between late August and mid-October 2012. The questionnaire was conducted alongside a broader market study – *Green Market Study 2012* – conducted by Pöyry Finland Oy in order to map out sustainability trends in the REC industry [6]. The customer survey results used in this study include responses from 88 individuals representing different stakeholders in the REC industry in Finland. The survey respondents have been grouped into the following stakeholder groups: *Users* (N=10), *Real estate managers* (N=11), *Owners* (N=18), *Developers and Contractors* (N=21), *Public sector* (N=21) and *Others* (N=7).

Whereas, the customer interviews (4 in total), were conducted with key individuals from Finnish organizations representing potential customers of the carbon footprint assessment service. The interviewees included two environmental managers from privately held construction companies, a construction manager from a pension insurance company, and a development manager from a public sector organization dealing with housing production. The interviews were conducted using a semi-structured approach, where the focus was on carbon footprint issues concerning the built environment and aspects concerning a carbon footprint assessment service. The interviews served the purpose of furthermore verifying and interpreting the results of the customer survey.

3. Results

3.1 Content and implementation of the assessment service

As mentioned earlier the assessment service considers greenhouse gas emissions caused by the building materials and energy consumption. With co-operation of VTT Technical Research Center of Finland we developed a tool that would ease the assessment of emissions of building materials and meet the needs of different level environmental assessment. To improve and intensify the assessment work a database of GHG emissions of the most typical building materials were collected by VTT Technical Research Center of Finland. Currently the database contains almost 100 different types of construction material and the information is updated regularly to meet the latest information. Emission data consists of emissions generated from material production from cradle to gate and the typical transportations. In addition, material wastes generated at construction sites were evaluated. Emissions caused by materials used in HVAC systems were left out of the assessment tool due to the complexity of collecting the material quantity data. Material usage in these systems was also found to have minor effect to the total environmental performance of building. However, to conduct a comprehensive life cycle assessment materials of technical systems can be evaluated separately.

In the actual calculation process the user fills out a web-based calculation form by selecting materials from the material database. One form is filled for each building element. User also sets thickness and service life for each material. In order to carry out assessment quantity data of building materials such as square areas of walls and floors should also be known. The bill of quantities can be collected by using Building Information Model (BIM) from which quantities can be transferred to Excel. Excel-format bill of quantities is downloaded to calculation software which integrates the material information filled to the forms and the quantity data. The GHG emissions of all building materials are calculated by combining the emission data of the chosen materials to the quantity data. Depending of the elaborateness of the design and the accuracy of the quantity data the calculation process takes from a day to a few days. Assessment of one building material or one building element takes only a few minutes. First assessments can be made with very minor input data at the early stage of the design and can be specified during the design process.

The energy consumption caused by heating, hot water supply, ventilation, air conditioning and electricity use is evaluated with dynamic energy simulation. Simulation model is created to meet the features of the design building. Location, operational profile, technical systems such as ventilation, space and water heating, lighting must be taken into account in order to obtain accurate result. GHG emissions are then calculated using the CO2 conversion factors.

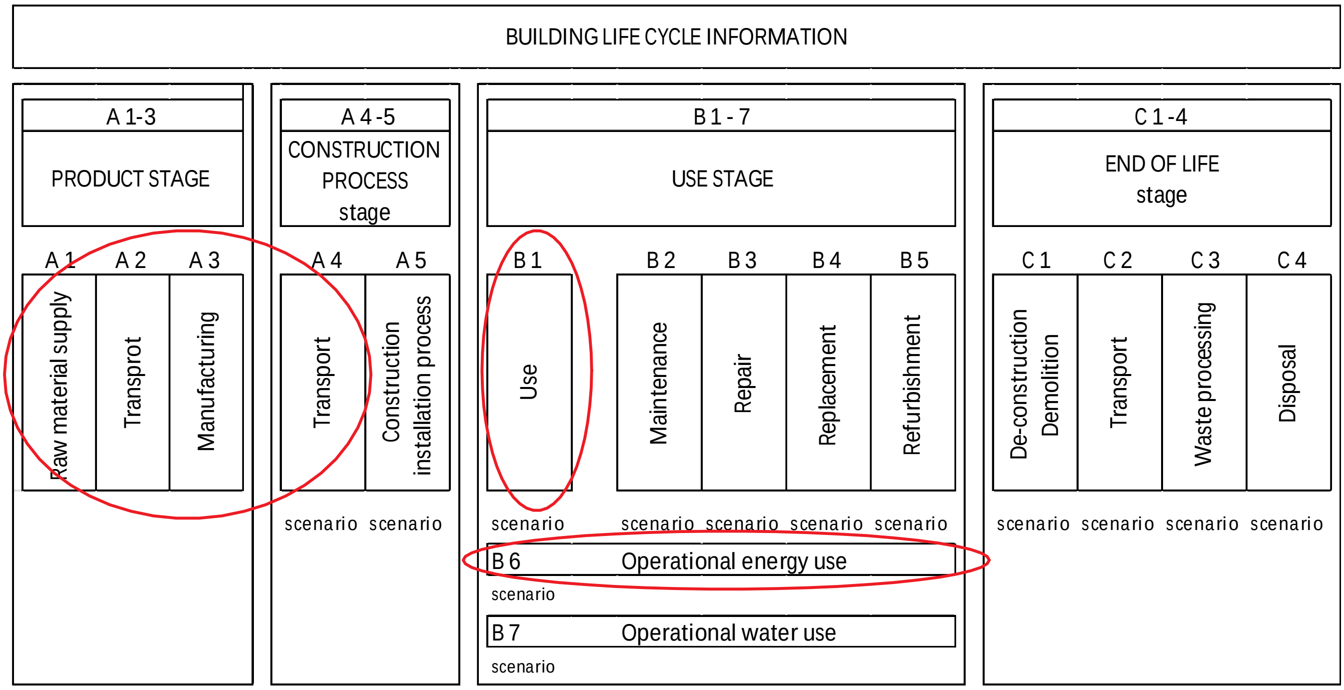


Figure 1: The developed carbon footprint assessment service takes into account the emissions related to the building materials as well as the emission generated during the use stage of the building. In terms of EN 15978 standard the developed assessment service covers whole product stage (A 1-A3), transportation from construction process stage (A4), energy use (B1) and estimated renewal frequency of the building materials (B4). service

Collecting initial data

- Quantity data from the BIM
- Information of used materials
- Technical data about the structures and HVAC/eletrical systems

Carbon footprint of materials

- Creating structure types according to the plans
- Uploading the quantity data
- Software intergates gather information and calculates the carbon footprint for every structure type and for the whole building

Carbon footprint of use stage

- Energy simulation according the design
- Emissions generated from the energy consumption is calculated by using emission factors of energy production

Figure 2: The work phases in the assessment service

3.2 Results and findings from the customer survey and interviews

In general, the customer survey as well as the interviews revealed that carbon footprint issues are still an emerging topic concerning the built environment. Nevertheless, as the survey results in *Fig. 3* indicate, carbon or other greenhouse gas (GHG) emissions are relatively well-established in the environmental management practices of companies and organizations, with more than half of the respondents stating that carbon or other GHG emissions are included in their organization's environmental management scheme. Notably, especially among the public sector respondents, the results indicate a very high level of awareness concerning carbon or other GHG emissions. [7]

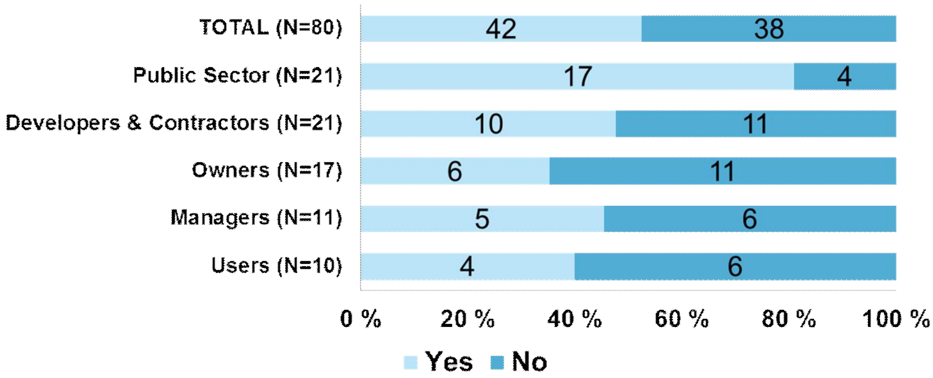
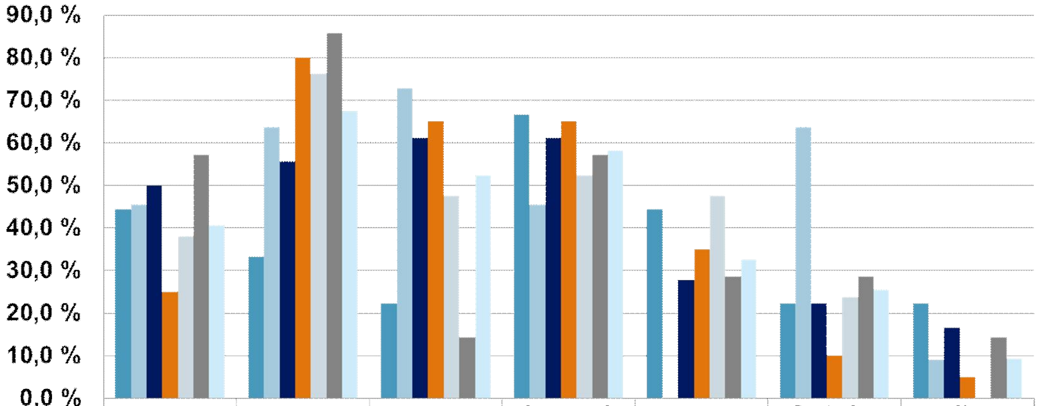


Fig. 3: Customer survey results: Carbon or other GHG emissions included in the organization's environmental management scheme

Whereas, the customer survey and interviews indicate that as a sustainability tool, building carbon footprint assessment practices are still emerging. Also, common practices are still lacking within the industry. Hence, the perceived benefits and value of reducing the carbon footprint of a building or premises still remains somewhat abstract in the eyes of the stakeholders operating in the industry. The respondents were asked to select the top three beneficial factors associated with carbon reduction in buildings or premises, and as *Fig. 4* indicates, there still remains a relatively high discrepancy of the perceptions. Nevertheless, enhanced brand/image value was one of the factors that stood out among the rest which may also be linked to an organization's corporate social responsibility (CSR) efforts. Only a few number of respondents responded negatively; seeing no direct benefits in carbon emission reduction. Moreover, the interviews revealed a strong need for common metrics concerning building carbon footprint assessment, this would in turn allow an enhanced perception of the benefits as well as make the implications more sensible. [7]



	Exemplary CSR	Enhanced brand/image value	Increased property value	Increased quality of the building /premises	Responding to regulations	Capturing current trends in sustainability	No associated direct benefits
Users (N=9)	44,4 %	33,3 %	22,2 %	66,7 %	44,4 %	22,2 %	22,2 %
Managers (N=11)	45,5 %	63,6 %	72,7 %	45,5 %	0,0 %	63,6 %	9,1 %
Owners (N=18)	50,0 %	55,6 %	61,1 %	61,1 %	27,8 %	22,2 %	16,7 %
Developers & Contractors (N=20)	25,0 %	80,0 %	65,0 %	65,0 %	35,0 %	10,0 %	5,0 %
Public sector (N=21)	38,1 %	76,2 %	47,6 %	52,4 %	47,6 %	23,8 %	0,0 %
Others (N=7)	57,1 %	85,7 %	14,3 %	57,1 %	28,6 %	28,6 %	14,3 %
TOTAL (N=86)	40,7 %	67,4 %	52,3 %	58,1 %	32,6 %	25,6 %	9,3 %

Fig. 4: Customer survey results: The perceived benefits and value in reducing the carbon footprint of a building/premises

Moreover, the willingness to invest in carbon footprint assessment service was also asked from the respondents in terms of the nature of the need as well as expressed in monetary value, the results presented in *Fig. 5* and *Fig. 6*. First and foremost, the results show that a service of this kind is strongly understood as an additional service serving secondary needs in respect to broader sustainability needs of the stakeholders, more than half of the respondents indicated that the service would be acquired alongside other sustainability related services serving sustainability needs in a broader perspective. Whereas, the interviews indicated that the need is not immediate, and most likely carbon footprint assessment will be included not until the near-future in upcoming projects. [7]

Second, the respondents were asked to enter approximated values regarding how much they are willing to invest in a carbon footprint assessment service. The results in *Fig. 6:* reveal that the majority of the respondents are willing to invest rather modestly, with a high frequency of responses in the interval of EUR 1 – 12 000. However, there also appears to be a group of respondents that are willing to invest more extensively, showing another yet smaller peak of responses in the interval of EUR 18 001 – 30 000+. [7]

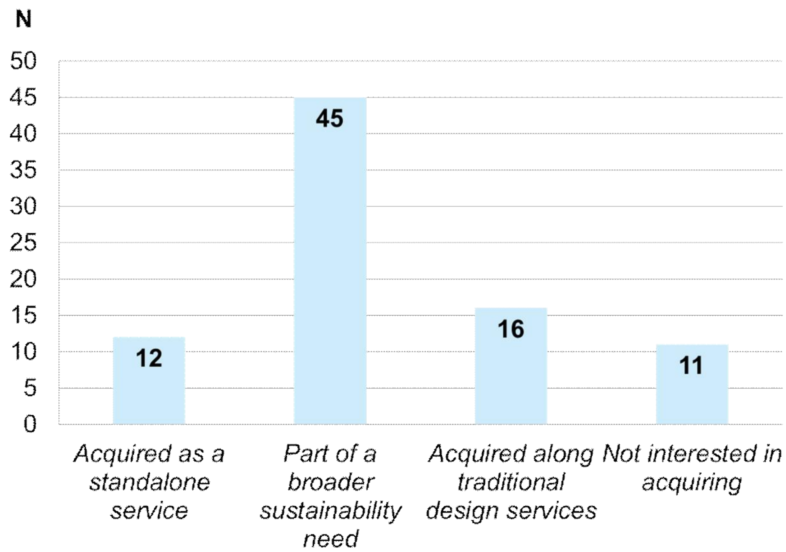
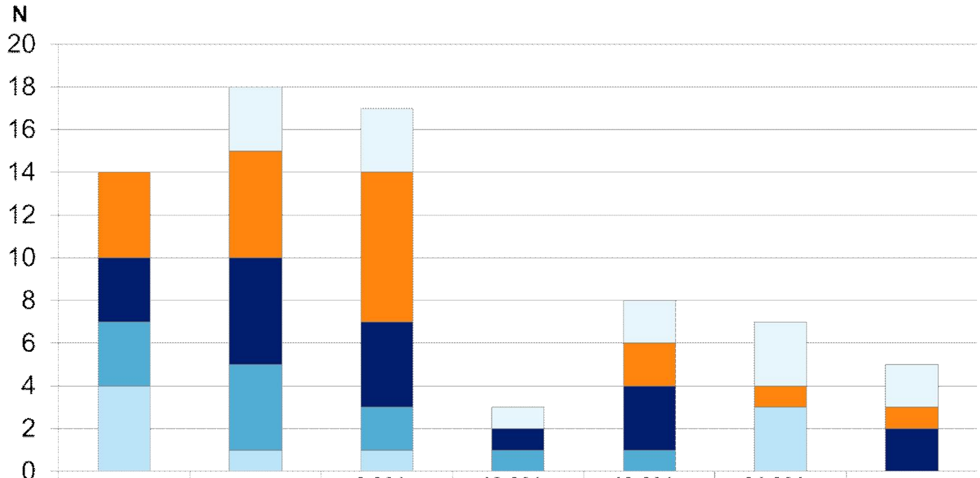


Fig. 5: Customer survey results: Motives in investing in a building CF assessment service



	0	1 - 6 000	6 001 - 12 000	12 001 - 18 000	18 001 - 24 000	24 001 - 30 000	30 000 +
Public Sector, N=20	0	3	3	1	2	3	2
Developers & Contractors, N=20	4	5	7	0	2	1	1
Owners, N=18	3	5	4	1	3	0	2
Managers, N=11	3	4	2	1	1	0	0
Users, N=9	4	1	1	0	0	3	0

Fig. 6: Customer survey results: Willingness to invest in a building CF assessment service expressed in monetary terms

4. Conclusions

The customer survey and interviews indicate that the carbon footprint is still an emerging issue within the REC industry in Finland. Nevertheless, including carbon and other GHG emissions into environmental considerations of the organizations have steadily increased among the various stakeholders operating in the industry. However, at the building and real estate level, common practices are still struggling to gain ground and common metrics are needed. Moreover, establishing univocal and commonly accepted procedures would also furthermore increase the ability to pinpoint the resulting value and benefits of carbon emission reduction in buildings and premises, which at the current state still remain rather abstract among the different stakeholders in the industry.

Whereas, the nature of the need for a carbon footprint assessment service is strongly perceived as serving broader sustainability needs concerning the built environment. Thus, it is clearly the case that a carbon footprint assessment service serves as an additional service alongside other sustainability considerations, such as building environmental certification or energy efficient building design. Moreover, the willingness to invest in a carbon footprint assessment service expressed in monetary value is for the major part at a modest level, indicating that the service serves as a low-cost additional service in the eyes of most potential customers. However, the customer survey results also indicate of a smaller, yet still significant, group of potential customers that are willing to invest more decisively and extensively in the carbon footprint assessment of their buildings/real estate projects. Arguably, this gives indications of a rather two-fold market demand: the modestly interested and willing ones, and on the other hand, the "forerunner" organizations with higher motives and willingness.

Most certainly the pressure to reduce GHG emissions in the real estate industry will not reduce in the future. Thus, it is evident that tools verifying emission reduction are required. The CF assessment brings concrete information and measurable quantities about environmental performance of buildings. However, the standards of the assessment lead often to unnecessary complex and heavy calculations for every day decision making. As the survey results reveal there is demand both for smaller and more extensive CF assessment services. The assessment service developed in this study responds to the smaller scale evaluation need. Through service productization the calculation has improved the elapsed time of the assessment work and the decreased the service costs and made the multiplying of the service easier. The service can be easily extended to cover more stages of the building life cycle in the future. To support sustainable planning and to get the environmental assessment into wider use in the field, lighter versions of calculations are essential. Hence, guidelines and commonly agreed procedures for such assessments are needed to ensure comparability of the results.

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A Study on the analysis economic efficiency and CO_2 emission of super tall apartment houses and general apartment houses of South Korea

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Summary

In this study, the CO_2 emission characteristics and economic efficiency of super tall apartment houses constructed in South Korea were evaluated, and were analyzed comparatively with general apartment houses as a way to establish database on the evaluation of environment-friendliness and CO_2 emission cost of super tall buildings. To that end, standard of buildings to be evaluated were proposed through analysis of the designing guideline for super tall apartment houses and general apartment houses proposed by South Korean government, and CO_2 emission amounts of the subject buildings were evaluated based on the characteristics of materials admitted into each building and the amounts of energy consumed during lifecycle period. In addition, the initial costs in construction stage and annual costs in operation stage were set as analysis parameters, and along with calculation of direct cost by the consumption of construction materials and energy, the costs of CO_2 emission were evaluated and analyzed. As a result, the CO_2 emission amounts and economic efficiencies of super tall apartment houses and general apartment houses by construction stage and operation stage could be analyzed quantitatively.

Keywords: CO_2, Economic Efficiency, Super Tall Apartment House, General Apartment House

1. Introduction

Throughout the world, enhancement of efficiency of land resources and improvement of environment-friendliness etc are emerging as major concern for sustainable city development, and constructions of super tall apartment houses are increasing. In tune with such trend, domestic and overseas governments, industries, and academic circles etc are actively conducting studies on establishment of guidelines and regulations for designing super tall buildings, development of structure system and construction techniques, elevation of space efficiency, improvement of residential performance, optimization of equipment systems and development of energy saving techniques etc[1)]. However, there have been relatively poor progress for studies on the techniques to evaluate the CO_2 emission amounts of super tall buildings and to analyze CO_2 emission costs.
Therefore, in this study, the CO_2 emission characteristics and economic efficiency of super tall apartment houses constructed in South Korea were evaluated quantitatively as a way of study on the establishment of database for environment-friendliness of super tall buildings and economic analysis including CO_2 emission cost, and these data were analyzed in comparison with general apartment houses.
To that end, the standard buildings of super tall apartment houses the subjects of evaluation and general apartment houses were proposed based on South Korean government announcement, and based on preliminary study, the admitted contents of construction materials for each apartment house were deduced. In addition, energy used amounts of apartment houses were deduced and

CO_2 emission amounts per unit area and economic efficiency were analyzed through the energy amounts consumed for each apartment and the total survey report on energy by South Korean Ministry of Knowledge Economy.

2. Proposing standard buildings of super tall apartment house and general apartment house

2.1 Overview

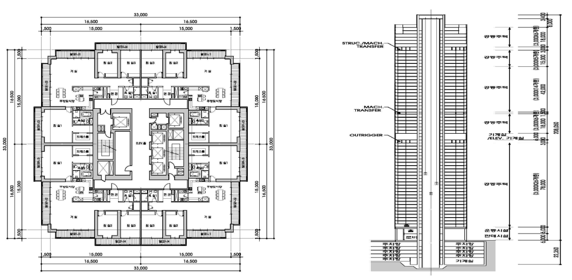
In order to select super tall apartment house the analysis subject of this study and general apartment house objectively, standard buildings were proposed based on the accomplishment data of super tall apartment house that comply with the super tall building designing guidelines of Seoul city[2)] and the evaluation standard house model announced by the South Korean Ministry of Land, Transport and Maritime Affairs.

2.2 Super tall apartment house

In this study, the 60 stories 208m high tower type super tall apartment house of 40,636.36m^2 above ground floors gross area that complies with the super tall designing guideline of Seoul city[2)] and is located in Busan metro city was proposed as standard building. This apartment is composed as 4 plain type buildings of 118m^2, 121m^2, 165.32m^2 and 178m^2 with 280 households in total, and has 3.0m story height. Fig. 1 shows the floor plan for the reference floors and the elevation of the standard buildings of general apartment house proposed in this study.

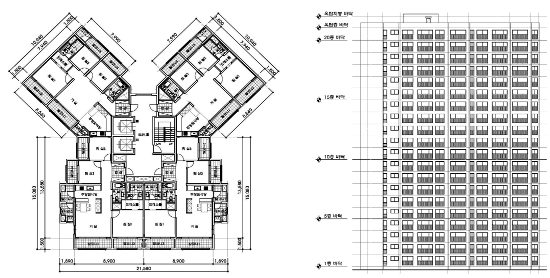
2.3 General apartment house

As for general apartment house, floor plan of 84m^2 dedicated area which is close to the size(85m^2 dedicated area) of citizens house was selected from among 5 floor plans proposed as South Korean house construction standard, and No.4 combination tower type 20 stories apartment house that uses local heating was proposed as standard building. This apartment has totally 80 households, 2.9m story height and 10,833.57m^2 gross area for above ground floors. Fig. 2 shows the floor plan for the reference floors and the elevation of super tall apartment house proposed in this study.



(a) Floor plan *(b) Elevation*

Fig. 1 Base floor plan and elevation of super tall apartment house



(a) Floor plan *(b) Elevation*

Fig. 2 Base floor plan and elevation of general apartment house

3. Analysis of the CO_2 emission characteristics of super tall apartment house and general apartment house

3.1 Overview

In this study, the amounts of construction materials admitted into the construction stage of super tall apartment house and general apartment house and the energy amounts consumed during operation period were set as evaluation elements, and the characteristics of CO_2 emissions per unit area for the above ground floors of each apartment house were analyzed.

3.2 The CO_2 emission characteristics of construction materials

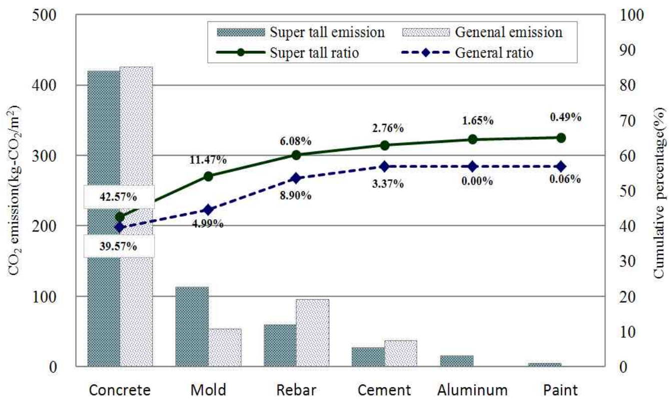


Fig. 3 CO_2 emission ratio in main material aspect of super tall and general apartment houses

For the calculation of CO_2 emission amounts and analysis of characteristics for super tall apartment and general apartment house by construction materials, the admitted amounts of major CO_2 emitting construction materials that occupy 80% or more of CO_2 emission amounts of construction materials were deduced based on preliminary study[3)], and the CO_2 emission amounts of construction materials were calculated as in Table 1 by utilizing the CO_2 emission ratio by Korea LCI database and processes. The total CO_2 emission amounts by construction materials for super tall apartment house and general apartment house were calculated as 986.31kg-CO_2/m^2 and 1,074.60kg-CO_2/m^2 respectively, and super tall apartment house was analyzed as more advantageous in construction materials CO_2 emission amounts over general apartment house. This is analyzed to be because the admitted amount of construction materials in super tall apartment house like concrete and reinforced concrete etc decreased due to the use of high strength concretes with outstanding efficiency of space by the number of floors greater than general apartment house. On the other hand, the CO_2 emission ratios in main material aspect were in the order of concrete 42.57%, mold 11.47% and rebar 6.08%, and in general apartment house, concrete 39.57%, rebar 8.90% and mold 4.99% as in Fig 3.

Table 1 The construction materials admitted amounts and CO_2 emission amounts of super tall and general apartment houses(part)

Item	Material	Unit	Material admission amount (unit)		CO_2 emission amount (kg-CO_2/m^2)	
			Super tall	General	Super tall	General
Concrete	25-500-21	m^3	12,050.00	-	160.73	-
	25-400-21	m^3	17,036.00	-	204.28	-
	25-300-15	m^3	4,571.00	-	48.47	-
	25-240-15	m^3	-	2,494.07	-	83.01
	25-210-15	m^3	-	9,975.46	-	331.28
	25-180-15(plain)	m^3	224.00	89.07	6.44	10.98
Rebar	HD10-HD35	ton	5,209.43	26,15.94	50.80	95.68
	SHD32(500kg)	ton	781.88	-	7.62	-
	D13	ton	108.72	-	1.06	-
	D16	ton	53.71	-	0.52	-
Cement brick	0.5B	sheets	2,500	250,310	0.08	28.42
	1.0B	sheets	75,360	97,050	2.28	11.02
Cement	40kg, CNF	Sacks	29,289,00	10,380.34	27.22	36.18
Sand	-	m^3	1,072.00	802.06	0.09	0.26
Mold	ACS, GANG FORM	m^2	30,973.00	8,603.83	0.20	5.19
	EURO FORM	m^2	2,730.00	69,204.74	0.27	42.16
	Wooden mold	m^2	8,387.00	39,028.98	3.09	6.28
	AL-FORM/inside	m^2	39,080.00	-	24.19	-
	SKY-DECK	m^2	61,088.00	-	84.05	-
	STEEL FORM	m^2	819.00	-	1.36	-
Iso pink	T:10mm, 30mm, 50mm, 70mm	m^2	15,442.00	6,615.38	3.30	1.81
Paint	-	m^2	57,523,00	17,077.23	4.86	0.62
Aluminum	Curtain wall	kg	72,626.32	-	4.27	-
	Window	kg	195,838.88	-	11.52	-
	Grill	kg	8,501.40	-	0.5	-
Total					986.31	1,074.60

3.3 The CO_2 emission characteristics of energy consumption amount in operation stage

For the analysis of amounts of CO_2 emission by the annual energy using amount in operation stage, the actually measured amounts of energy consumed for 1 year at 6 locations of super tall apartment houses and the average annual amount of energy consumed for local heating in general apartment house was surveyed from among the total survey report of energy[4)] by South Korean Ministry of Knowledge and Economy, and the CO_2 emission amounts per unit area were analyzed as shown in Tables 2 and 3. The annual CO_2 emission amounts in operation stage were calculated as 107.85kg-CO_2/m^2-yr, 48.33kg-CO_2/m^2-yr respectively, and in particular, in super tall apartment house that used curtain wall as cover, the annual CO_2 emission amounts per unit area were analyzed as 2.5 times higher compared with general apartment house.

Table 2 Annual energy measurements and CO_2 emission amount of super tall apartment houses(part)

Class		A	B	C	D
Heating method		Centralized heating	Individual heating	Local heating	Local heating
Annual energy used amount	Electric power (kWh/m^2)	183.09	301.88	212.21	150.68
	City gas (m^3/m^2)	11.37	0.07	6.87	6.02
CO_2 emission amount (kg-CO_2/m^2)		106.79	134.43	109.71	80.44

Table 3 Annual energy used amount and CO_2 emission of general apartment houses(local heating)[4)]

Class	Electric power (kWh/m^2)	City gas (m^3/m^2)	Profane (kg/m^2)	Heat energy (Mcal/m^2)	Hot water (Mcal/m^2)
Annual energy consumed amount	37.99	1.38	0.05	94.36	0.75
CO_2 emission amount (kg-CO_2/m^2)	16.91	3.07	0.16	26.52	1.67

4. Analysis of the economic efficiency of super tall apartment houses and general apartment houses

4.1 Overview

With the construction materials used amounts and annual energy consumption amounts of super tall apartment house and general apartment house set as the evaluation elements, the economic efficiencies of each apartment house were analyzed. At this time, the direct costs by construction materials and energy consumption and the CO_2 emission rights(CER: Certified Emission Reduction) costs by CO_2 emission were set as the economic efficiency analysis range, and in operation stage, present price that reflects future time value was calculated with the use of present price coefficient[5)].

4.2 Analysis of the economic efficiency of construction material

In the analysis of the economic efficiency of construction material, costs were analyzed through the admitted amounts of construction materials by apartment house deduced in "3.2. The CO_2 emission characteristics of construction materials" above and standard quantity per unit cost estimation of building construction in South Korea[6)]. At this time, the economic efficiencies of construction materials were classified into direct cost, indirect cost and CO_2 emission cost, and in particular direct costs were evaluated by being ramified into material cost, labor cost and general expenses[7)]. In the evaluation of indirect cost, indirect cost was estimated as 5% direct cost a method of rough calculation, and in CO_2 cost evaluation, it was analyzed by applying 3.8€/T the present market price of CER of Europe[8)]. Total costs by construction stage were calculated as KRW 1,606,901/m^2 and KRW 1,010,004/m^2 in super tall apartment house and general apartment house, and super tall apartment house was analyzed as disadvantageous to some degree in cost aspect compared with general apartment house. That is analyzed to be because high unit price materials are extensively used and labor costs increase due to aerial works during construction of super tall apartment house. On the other hand, CO_2 emission costs were analyzed to be KRW 5,715/m^2 for super tall apartment house and KRW 6,131/m^2 for general apartment house.

Table 4 Analysis of the economic efficiency in the construction stage of super tall apartment houses and general apartment houses

Class	Detailed item		Super tall apartment house (KRW/m²)	General apartment house (KRW/m²)
Initial cost (present price)	Direct cost	Material cost	754,579	537,572
		Labor cost	756,505	402,748
		Expense	13,856	15,748
		Sub total	1,524,939	956,069
	Indirect cost		76,247	47,803
	CO_2 cost		5,715	6,131
	Total for construction stage		1,606,901	1,010,004

4.3 Analysis of the economic efficiency of energy consumption in operation stage

For the analysis of the economic efficiency of energy consumed annually in operation stage, per unit area costs were analyzed based on the actually measured amount of energy consumed in super tall apartment house and the annual average amounts of energy consumed for local heating in general apartment house analyzed in Tables 2 and 3. Unit prices by energy source were analyzed based on the fee tables of Korea Electric Power Corporation, Korea District Heating Corporation and Seoul City Gas respectively, and the future values by the lifecycle of buildings per the characteristics of energy consumption in operation stage were considered through present price coefficient. At this time, as for interests rate, 6.54% the average interests rate of bank from 2000 to 2009 was applied[9)]. In operation stage as for the total costs of super tall apartment house and general apartment house which were KRW 17,557/m^2 and KRW 10,656/m^2 as of 1 year after construction completion, super tall apartment house required 1.65 times more cost than general apartment house, so super tall apartment house was found to be disadvantageous to some degree over general apartment house as in construction material section. As shown in Table 5, in the economic efficiency evaluated assuming that building lifecycle is 60 years, economic efficiencies

Table 5 Analysis of the economic efficiency of operation stage of super tall apartment houses and general apartment houses

Age	Present price coefficient	Super tall apartment house (KRW/m²)		General apartment house (KRW/m²)	
		Energy cost	CO_2 cost	Energy cost	CO_2 cost
0	1.0000	16,942	615	10,381	275
1	1.0654	18,051	655	11,060	293
2	1.1351	19,231	698	11,784	313
3	1.2093	20,489	743	12,554	333
4	1.2884	21,829	792	13,375	355
5	1.3727	23,256	844	14,250	378
⋮	⋮	⋮	⋮	⋮	⋮
21	3.7824	64,083	2,325	39,266	1,042
22	4.0298	68,274	2,477	41,834	1,110
23	4.2933	72,739	2,639	44,570	1,183
24	4.5741	77,496	2,812	47,485	1,260
⋮	⋮	⋮	⋮	⋮	⋮
41	13.4283	227,508	8,255	139,403	3,699
42	14.3065	242,387	8,795	148,520	3,941
43	15.2421	258,239	9,370	158,233	4,199
44	16.2390	275,128	9,983	168,581	4,474
⋮	⋮	⋮	⋮	⋮	⋮
55	32.5985	552,300	20,040	338,415	8,980
56	34.7305	588,420	21,350	360,547	9,568
57	37.0019	626,903	22,747	384,127	10,193
58	39.4218	667,902	24,234	409,249	10,860
59	42.0000	711,583	25,819	436,013	11,570
Sub total		11,316,056	410,594	6,933,769	183,997
Total cost			11,726,650		7,117,765

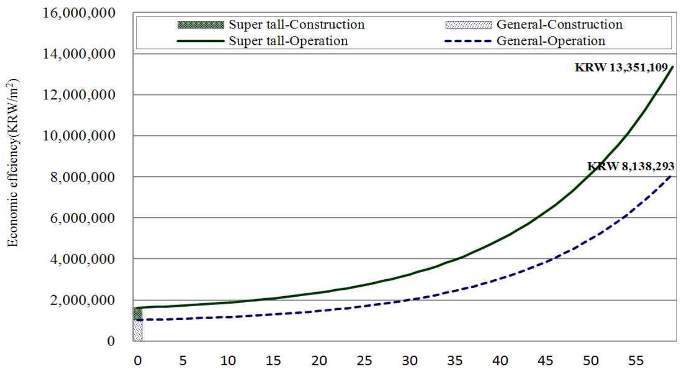


Fig. 4 Analysis of the whole economic efficiency of super tall apartment houses and general apartment houses

were calculated as KRW 11,726,650/m^2 and KRW 7,117,765/m^2 respectively for super tall apartment house and general apartment house, and super tall apartment house was analyzed as requiring more cost by KRW 4,600,000/m^2 per unit area over general apartment house throughout entire operation period. On the other hand, CO_2 emission costs were analyzed to be KRW 410,594/m^2 in super tall apartment house and KRW 183,997/m^2 in general apartment house assuming 60 years of lifecycle.

5. Conclusion

This study was conducted to evaluation the CO_2 emission characteristics and economic efficiency of super tall apartment house and perform comparative analysis with general apartment house as a way of study on the establishment of database for analysis of economic efficiency of super tall building including the evaluation of environment-friendliness and CO_2 emission cost, and the following conclusions were reached:
The CO_2 emission amounts of construction materials were evaluated as 986.31kg-CO_2/m^2 and 1,074.60kg-CO_2/m^2 in super tall apartment house and general apartment house respectively, and the annual CO_2 emission amounts in operation stage were estimated as 107.85kg-CO_2/m^2-yr and 48.33kg-CO_2/m^2-yr respectively. In addition, the total economic efficiencies in construction stage were calculated as KRW 1,606,901/m^2 and KRW 1,010,004/m^2 in super tall apartment house and general apartment house respectively, and also the economic efficiencies in operation stage were evaluated as KRW 17,557/m^2 and KRW 10,656/m^2 respectively, so in economic aspect, super tall apartment house was analyzed as disadvantageous over general apartment house. On the other hand, in the economic analysis evaluated assuming that the lifecycle of building is 60 years, economic efficiencies were calculated as KRW 11,726,650/m^2 and KRW 7,117,765/m^2 in super tall apartment house and general apartment house respectively, and super tall apartment house was analyzed as requiring KRW 4,600,000/m^2 more cost per unit area compared with general apartment house.

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CO_2 emission reduction performance assessment in concrete and building with Smart blast furnace slag

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Summary

Recently, CO_2 emission reduction studies is becoming an issue in the concrete industry with active use of concrete admixtures with low basic unit of CO_2 emission such as blast furnace slag (BFS). Basic unit of CO_2 emission by SBFS was computed in order to assess CO_2 emission by reinforced concrete building with smart blast furnace slag (SBFS). In addition, SBFS concrete was applied to the subject building for assessment of CO_2 emission during material production step among construction steps. Life cycle CO_2 emission assessment on the subject building was classified into 7 cases according to mix ratio of BFS and SBFS. As a result of assessment, $LCCO_2$ emission from case 1 to case 7 was respectively 481.98, 454,88, 427.79, 400.7, 454.79, 427.61 and 400.42[kg-CO_2/m^2]. The reason for slightly lower CO_2 emission by SBFS concrete compared to BFS concrete when SBFS concrete and BFS concrete were applied at the same substitution rate (%) on the subject is because of slightly lower basic unit of CO_2 emission by SBFS in comparison to BFS.

Keywords: Blast furnace slag, Concrete, Building, CO_2 emission, Reduction performance

1. Introduction

Blast furnace slag made into fine particle through quenching of blast furnace slag produced in steel industry has basic unit for CO_2 emission of about 450 CO_2-kg/ton. Considering the fact that basic unit of CO_2 emission by ordinary Portland cement (OPC) is about 800 CO_2-kg/ton, BFS shows about 1/2 of CO_2 emission. Use of BFS as concrete admixture or blast furnace slag cement can greatly reduce CO_2 resulting in cement and concrete industries. The purpose of this study to develop cement excitant, blast furnace slag excitant and early strength additive for securing economic feasibility of smart blast furnace slag powder with early strength expression and early age strength enhancement at low temperature, to develop an original material technology for mass production, and to quantitatively assess CO_2 emission reduction effect when SBFS concrete is applied to construction of reinforced concrete buildings.

2. CO_2 emission assessment in reinforced concrete building with SBFS

2.1 Outline

Using elements and methodologies of previously developed life cycle CO_2 emission assessment, CO_2 emission of concrete mixed with blast furnace slag (BFS) or smart blast furnace slag (SBFS) was assessed. Concrete mix was classified into 7 cases according to mix ratio of BFS and SBFS. Analysis results for basic unit of CO_2 emission by BFS and SBFS on domestic manufacturer were applied. In addition, CO_2 emission of the subject building (apartment house) was assessed for each case of SBFS concrete.

2.2 Selection of assessment subject

For the 24MPa concrete most widely used at construction sites, concrete mix was classified into 7 cases as shown in Table 2.1. Components of SBFS concrete were analyzed in terms of OPC, BFS, SBFS, and aggregates. Case 1 is the basic concrete mixture in which BFS and SBFS are not adde d. Cases 2 through 4 are concrete mixes with 10%, 20% and 30% BFS. Also, Cases 5 through 7 ar e concrete mixes with 10%, 20% and 30% SBFS compared to the basic mix of Case 1. In addition, reinforced concrete wall structure generally used in apartment houses was selected as the subject of assessment. Outline of the subject building is as described in Table 2.2. The subject building is a flat type apartment house in Seoul with primary configuration used in Korea with an area of 33 py eong (supplied area of 111.33m^2), 25 ground floors, and 4-unit combination.

Table 2.1 Classification of Assessment Concrete by SBFS Mix Ratio

Class	Mix Ratio(%)	Amount of Mix [kg/m^3]						
		OPC	BFS	SBFS	G	S	W	AE
Case1	0	350	0	0	895	875	176	2
Case2	10	315	35	0				
Case3	20	280	70	0				
Case4	30	245	105	0				
Case5	10	315	0	35				
Case6	20	280	0	70				
Case7	30	245	0	105				

* OPC: Ordinary Portland cement, BFS: Blast furnace slag, W: Water, AE: Admixture
SBFS: Smart blast furnace slag, G: Aggregate, S: Sand aggregate

Table 2.2 Outline of Subject Building

Outline	
▪Building type: Flat type	▪Unit combination: 4-unit
▪Use of building: Apartment house	▪Structure: Concrete wall
▪Exclusive area: 84.95m^2	▪Floors: 25F on the ground
▪Supplied area: 33 pyeong (111.33m^2)	▪Strength: 24Mpa on all floors
▪Residential area: 26.43m^2	▪Ready mix concrete: 25-24-150

Table 2.3 Classification of Subject Building According to SBFS Mix Ratio

Class	Details
Case 1	Ordinary concrete
Case 2	Concrete with 10% BFS
Case 3	Conc ete with 20% BFS
Case 4	Concrete with 30% BFS
Case 5	Concrete with 10% SBFS
Case 6	Concrete with 20% SBFS
Case 7	Concrete with 30% SBFS

2.3 Assessment method

2.3.1 CO_2 Emission Assessment for SBFS Concrete

1) Material step
CO_2 emission according to concrete production is computed as an accumulation of multiplication between quantity (kg) per 1m^3 of each material included in production of concrete and basic unit, using basic unit of CO_2 emitted during production of each component material. For basic unit of CO_2 emission for each material configuring concrete, the national LCI DB, input-output analysis, individual integration method, and data from Japanese Society of Civil Engineers are utilized. Equation for computing CO_2 emission according to production of material used per 1m^3 of concrete is as shown in Eq. 2.1.

$$CO_{2M} = \sum (M(i) * \text{basic unit } M, CO_2) \qquad \text{Eq. 2.1}$$

(i= 1: Cement, 2: Aggregate, 3: Sand aggregate, 4: Admixture, 5: Water)

Here, CO_{2M} is CO_2 emission in material step according to unit concrete production [kg-CO_2/m^3], M(i) is quantity of each material per 1m^3 of concrete [kg], and basic unit M,CO_2 is basic unit of CO_2 for each material [kg-CO_2/kg].

2) Transportation step

For CO_2 emission assessment in transportation step, total quantity of each material of concrete and number of transportation devices for each material are computed. CO_2 emission for transportation step is assessed with consideration on such computed number of transportation devices, transportation distance, and fuel efficiency. Equation for computing CO_2 emission in transportation step is as shown in Eq. 2.2.

$$CO_{2T}=\sum[(M(i)/L_t)*(d/e)*\text{basic unit T,}CO_2] \quad \text{Eq. 2.2}$$

(i= 1: Cement, 2: Aggregate, 3: Sand aggregate, 4: Admixture)

Here, CO_{2T} is CO_2 emission in transportation step according to unit concrete production [kg-CO_2/m^3], M(i) is quantity of each material per 1m^3 of concrete [ton], L_t is load of each material transportation device (i) [ton], d is transportation distance [km], e is fuel efficiency [km/L], and basic unit T,CO_2 is basic unit of CO_2 emission for energy source of transportation device [kg-CO_2/L].

3) Manufacture step

CO_2 emission for manufacture step can be deduced by computing energy consumption of manufacturing facility for production of 1m^3 of concrete and by converting this energy consumption into CO_2. Manufacture step of concrete can be classified into five steps including unloading of materials supplied by suppliers, storage of each material, transportation to mixer, measurement for mixing, and mixing process. After investigating the type and data of facilities that use power and oil energy during each process, capacity and annual power usage by batcher plant are analyzed to deduce energy consumption during production of 1m^3 of concrete.

$$CO_{2F}=\sum[(E(i)/R)*\text{basic unit F,}CO_2] \quad \text{(Eq. 2.3)}$$

(i= 1: Power usage, 2: Oil usage, 3: Water usage)

Here, CO_{2F} is CO_2 emission in manufacture step for unit concrete production [kg-CO_2/m^3], R is annual production of ready mix concrete [m^3/year], $E_{(i)}$ is annual quantity of each energy source used [unit/year], and basic unit F,CO_2 is basic unit of CO_2 emission for each energy source [kg-CO_2/unit].

2.3.2 CO_2 emission reduction performance assessment on SBFS Concrete building

In this assessment, CO_2 emission was assessed for material production step among construction steps for the building's life cycle. Material production step is related to production of construction materials that compose the building. The scope of analysis ranges from extraction of necessary raw materials to actual production of materials. Emission is computed by multiplying quantity of material with basic unit of CO_2 emission.

First, CO_2 emission basic unit database was constructed after selecting major construction materials that take up over 80% of CO_2 emission in standard building (apartment house) to be assessed. Among major construction materials, basic unit of CO_2 emission for materials such as reinforcement and steel plate other than concrete was identically applied to all cases, utilizing input-output analysis method based on input-output table by the Bank of Korea, national LCI DB, and individual integration method for basic unit of CO_2 emission.

$$CO_{2M}=\sum(M(i)*\text{basic unit M, }CO_2) \quad \text{Eq. 2.4}$$

(i = Major materials of building)

Here, CO_2M is CO_2 emission in material production step of building [kg-CO_2/m^3], M(i) is quantity of major materials composing the building [kg], and basic unit M,CO_2 is basic unit of CO_2 for each material [kg-CO_2/kg]

1) Structure Quantity Computation Technique Using MIDAS

For structural analysis, a wall structure analysis program of Korea called MIDAS ADS was used. Quantity of the subject building (apartment house) to be assessed with structural analysis was computed, applying identical quantity throughout Cases 1 through 7. After reviewing structure of the subject building and deducing appropriate element size, MIDAS was used to compute quantity of concrete, reinforcement and mold.

2) Quantity Computation for Finishing Material Using BIM

In accordance to size of each element deduced through structural analysis and building drawing, the 25F subject building (apartment house) was modeled using BIM and ArchiCAD 10. Using detailed BIM model drawing and quantity of structure computed earlier, finishing area and material quantity for the subject building (apartment house) were deduced. Quantity for 81 materials was computed by applying unit price.

Table 2.4 Components and Basic Unit of CO_2 Emission for Assessment Materials

Material	Type	Basic Unit of CO_2 Emission [kg-CO_2/unit]	Unit	Basis for Basic Unit of CO_2 Emission
OPC	Type 1	0.951	kg	Ministry of Land*
G	Crushed aggregate	0.262	m^3	Ministry of Land*
S	Sea sand	0.004	m^3	Ministry of Land*
BFS	Type 3	0.038	kg	Individual Integration Method**
SBFS	-	0.035	Kg	Individual Integration Method**
W	Waterworks	0.000332	Kg	Ministry of Land*
AE	Standard	0.25	Kg	Japanese Society of Civil Engineers

* Carbon Emission Computation Guideline for Facilities, Ministry of Land, 2011

** Smart blast furnace slag (SBFS) CO_2 Basic Unit Assessment, Ministry of Land, 2012

Table 2.5 Example of Quantity Computation for Major Building Materials for Subject Reinforced Concrete Building

Material Name	Unit	Quantity Per Case (Unit/m^2)
Concrete	m^3	0.84
Deformed bar	kg	37.31
Rectangular lumbar	kg	10.32

Table 2.6 Example of CO_2 Emission Basic Unit for Materials

Item	Unit	Basic Unit of CO_2 Emission [kg-CO_2/Unit]		DB Basis
Concrete	m^3	Case1	376.84	Individual integration method
		Case2	344.58	Individual integration method
		Case3	312.33	Individual integration method
		Case4	280.08	Individual integration method
		Case5	344.48	Individual integration method
		Case6	312.11	Individual integration method
		Case7	279.75	Individual integration method
Deformed bar	kg		0.39	National LCI DB
Rectangular lumbar	kg		0.34	Input-ouput Analysis

3. CO_2 emission reduction performance assessment result in concrete and building with SBFS

Assessment result for life cycle CO_2 emission of SBFS mixed concrete on Cases 1 through 7 was respectively 376.65kg-CO_2/m^3, 344.31kg-CO_2/m^3, 311.97kg-CO_2/m^3, 279.62kg-CO_2/m^3, 344.20kg-CO_2/m^3, 311.75kg-CO_2/m^3, and 279.30kg-CO_2/m^3. When SBFS and BFS were applied with identical substitution rate (%), SBFS concrete was assessed / tested to emit slightly small amount of CO_2. This is because basic unit of CO_2 emission by SBFS(0.035kg - CO_2/kg) is slightly lower than basic unit of CO_2 emission by BFS (0.038kg-CO_2/kg). As a result of step-wise analysis, CO_2 emission in material step for each case was shown to account for about 95% of total emission. CO_2 emission in transportation and manufacture steps accounted for about 1.6% and 3% of total emission. In comparison to Case 1, CO_2 emission was reduced in Case 2, Case 3 and Case 4 mixed with 10%, 20% and 30% BFS by about 8.59%, 17.17% and 25.76%. Case 5, Case 6 and Case 7 mixed with 10%, 20% and 30% SBFS also showed reduction compared to Case 1 by about 8.62%, 17.23% and 25.85%.

Table 3.1 Analysis Result on Life Cycle CO_2 Emission for Each Case of Concrete

Class	CO_2 Emission [kg-CO_2/m^3]				
	Material Step	Transportation Step	Manufacture Step	Total	Reduction Compared to Case 1 (%)
Case 1	360.03	5.51	11.11	376.65	0
Case 2	327.77	5.42	11.11	344.31	8.59
Case 3	295.52	5.34	11.11	311.97	17.17
Case 4	263.27	5.25	11.11	279.62	25.76
Case 5	327.67	5.42	11.11	344.20	8.62
Case 6	295.31	5.34	11.11	311.75	17.23
Case 7	262.94	5.25	11.11	279.30	25.85

For life cycle CO_2 emission assessment on the building, basic unit of CO_2 emission by concrete classified into different cases according to mix ratio of BFS and SBFS was applied to material production step among construction steps. Assessment results shown in Table 3.2 were deduced from life cycle assessment on Case 1, Case 2, Case 3, Case 4, Case 5, Case 6 and Case 7 of the subject building. Life cycle CO_2 emission assessment result on Case 1, Case 2, Case 3, Case 4, Case 5, Case 6 and Case 7 was respectively 481.82kg-CO_2/m^2, 454.65kg-CO_2/m^2, 427.48kg-CO_2/m^2, 400.32kg-CO_2/m^2, 454.56kg-CO_2/m^2, 427.30kg-CO_2/m^2 and 400.04kg-CO_2/m^2. As in Fig. 4.3.1 compared to Case 1, Case 2, Case 3 and Case 4 mixed with BFS concrete that used basic unit of CO_2 emission by BFS concrete showed reduction of about 6%, 11% and 17%. Case 5, Case 6 and Case 7 that applied basic unit of CO_2 emission by SBFS concrete were reduced by about 6%, 11% and 17%. In particular, CO_2 emission by Case 4 and Case 7 was 16.91% and 16.97% reduced in comparison to emission by Case 1. This seems to have resulted from application of BFS and SBFS concrete instead of basic unit of CO_2 emission by ordinary Portland cement.

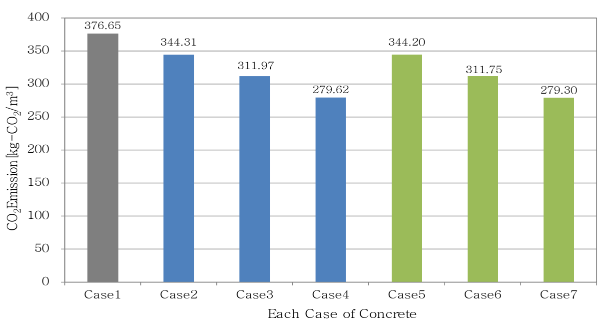

Fig. 3.1 Comparison of Concrete LCCO$_2$ Emission

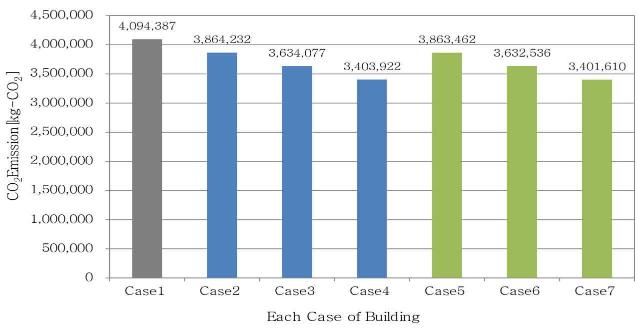

Fig. 3.2 Comparison of RC Building CO_2 Emission

Table 3.2 Analysis Result on CO_2 Emission for Each Case of Subject Reinforced Concrete Building

Class	Total CO_2 Emission [kg-CO_2]	CO_2 Emission Per Unit Area [kg-CO_2/m^2]	Reduction Compared to Case 1 (%)
Case 1	4,094,387	481.98	0
Case 2	3,864,232	454.88	5.63
Case 3	3,634,077	427.79	11.27
Case 4	3,403,922	400.70	16.91
Case 5	3,863,462	454.79	5.65
Case 6	3,632,536	427.61	11.31
Case 7	3,401,610	400.42	16.97

4. Conclusion

In this study, basic unit of CO_2 emission by BFS and SBFS was computed and basic unit of CO_2 emission by concrete mixed with SBFS was developed as a means to assess CO_2 emission of reinforced concrete building that applied concrete mixed with smart blast furnace slag (SBFS).

CO_2 emission of concrete mixed with blast furnace slag (BFS) or smart blast furnace slag (SBFS) was assessed. Also, Concrete mix was classified into 7 cases according to mix ratio of BFS and S BFS. In addition, CO_2 emission of the subject building (apartment house) was assessed for each c ase of SBFS concrete. Life cycle CO_2 emission assessment on the subject building for Cases 1 thr ough 7 respectively resulted in 481.82kg-CO_2/m^2, 454.65kg-CO_2/m^2, 427.48kg-CO_2/m^2, 400.32kg-CO_2/m^2, 454.56kg-CO_2/m^2, 427.30kg-CO_2/m^2 and 400.04kg-CO_2/m^2. In comparison to Case 1 and Case 4 that applied basic unit of CO_2 emission by BFS concrete showed reduction by about maxim um 16.91%. Case 7 that applied basic unit of CO_2 emission by SBFS concrete were reduced by m aximum 16.97%, respectively. When SBFS concrete and BFS concrete were applied to the subject building at identical substitution rate (%), SBFS concrete was found to show slightly lower CO_2 em ission than BFS concrete because basic unit of CO_2 emission by SBFS is somewhat lower than ba sic unit of CO_2 emission by BFS.

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Towards user-oriented suburb renovation

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Summary

A broad Finnish national research project, KLIKK - lähiöiden käyttäjä- ja liiketoimintalähtöinen korjauskonsepti (User- and Business-oriented Suburb Renovation Concept), was started in the beginning of 2012. The project will end in June 2014. The perspective of energy efficiency is emphasised in the project, but at the same time it addresses what improving the energy efficiency of suburban residential apartment buildings means from the standpoint of architecturally valuable and conservable buildings that represent different periods. The primary goal of the project is to develop a user-oriented, industrial, overall economic renovation concept for suburban apartment building renovation and extension as well as construction of additional storeys.

Keywords: User-oriented, renovation concept, prefabrication, energy efficiency, town planning

1. Introduction

Construction in the near future will focus on suburb renovation and in-fill construction, which will face a demanding challenge due to the objective of improving energy efficiency. The concrete-frame apartment buildings constructed in Finland in the 1960s and 1970s are approaching the age when they require renovation. These buildings contain significant share of the whole housing stock, making this a renovation job that affects a large share of Finns. [1]

These suburban apartment buildings require exhaustive technical repairs both inside and outside. For example, problems related to the quality of the concrete and the reinforcements of the sandwich elements used and the durability of the trusses and fasteners of the elements, moisture damage and poor thermal economy are the most common reasons behind façade renovations. Not only the outer walls but also the roofs, windows and balconies need repair or renewal. Adding balconies to smaller apartments that often lack a balcony or enlarging the existing balconies with insufficient size would also increase living comfort and pleasantness. [2], [3]

These types of renovation projects are excessively laborious and difficult for building managers, housing associations and residents alike. It is hard to find operators who are capable of or willing to take on suburban apartment building renovations, and it is often necessary to search for and hire several contractors for a project. It is very difficult to integrate their work. In practice, renovations are slow, expensive, dirty and disruptive.

The reputation of suburbs is poorer than the possibilities they offer. [4] Therefore, renovations that promote good practices are very significant as improvers of the profile of suburbs. However, traditional developing and contracting have been dominated by functional decentralisation where various contractors and operators are chosen on the basis of the lowest bid, without regard for life cycle costs or other indirect expenses. For this reason projects that employ traditional bidding methods are very costly for the orderers and do not induce suppliers and interest groups to act in accordance with the orderers' objectives. Deficient management of the numerous parties involved in renovation projects has often led to contradictions and at least partial failures of the projects.

By developing new operating methods that affect the entire delivery chain it is possible to convert suburbs from underrated living areas into attractive environments. Although real estate companies are generally aware of the need for renovation, the problem has become getting renovation decisions passed by the companies' decision-making bodies. Postponement of renovation decisions has partly led to a situation where the condition of ownership-based housing company apartment buildings is poorer than that of rental apartment buildings in the same suburb, as they undergo regular maintenance.

1.1 Social, economic and cultural durability

Reinforcement of social, economic and cultural durability and renovations that support sustainable development are the main cornerstones of suburb development. The principles of sustainable development are naturally connected to environmental challenges, such as slowing down climate change, but also to safeguarding the vitality of each living area. This way, e.g. new and in-fill construction can be used in suburbs to boost areal populations, thereby ensuring that services remain and improving the prerequisites for public transport. [4]

New construction's impact on improving the energy efficiency of the whole building stock is a slow process. [5] Therefore, it is very important to improve the energy efficiency of existing buildings. Suburbs are currently the least energy-efficient segment of Finland's building stock. The residential apartment buildings built in the 1960s and 1970s are most problematic—they are poorly insulated and they are the most numerous. Improving the energy efficiency of precisely these buildings would have the greatest impact on energy consumption of the building stock in Finland. The most effective measures for improving the energy economy of a residential building are adding insulation to the exterior of the ceiling and outer walls and making them more airtight, renewing the windows, balcony doors and exterior doors to meet the requirements of the near future, renewing heat production systems and constructing an intake and exhaust air ventilation system with heat recovery units in each apartment. [4]

Majority of the older people live and want to live in their own home. The need for services and an accessible residential environment are decisive factors associated with older people's coping at home. [6] In the future there will be a growing need for apartments suitable for lone dwellers and well-equipped life-cycle apartments where services that replace institutional care can be arranged. Buildings without lifts are a major problem in Finland's building stock. In the end of 2006 there were 48,700 staircases in at least three storeys high buildings without a lift. More than a half a million people lived in these buildings—100,000 of them were at least 65 years old and needed a lift. [5]

1.2 Wood material in renovation

The market outlook for renovating suburban apartment buildings changed significantly in Finland in April 2011 when a new fire code became effective. The new regulations allow construction of additional lightweight timber-framed storeys atop residential apartment buildings and renovation and additional insulation of the outer walls of buildings using lightweight timber-framed elements. The reasons for the change are the desire to slow down urban sprawl and the need to preserve suburban populations in order to safeguard their services and thereby their attractiveness. [7]

2. Objectives of the project

The objective of this project (1.1.2012-30.6.2014) is to develop a user and business-oriented renovation concept for renovation and extension of suburban apartment buildings.

Residential apartment buildings are renovated in Finland using the same methods as in new construction production; industrial service concepts for renovation have not been developed yet in this sector. It is not possible to face the growing renovation debt of Finland's suburbs or the near-future requirement to improve the energy efficiency of the existing building stock without enhanced construction methods brought about by industrial construction. However, the individual needs of suburban buildings are so varied in terms of technical solutions and architectural and environmental constraints that it is not possible to develop a universally applicable renovation solution for suburban buildings. Indeed, the objective is to develop an industrial renovation concept where solutions can be site-specifically and all-inclusively tailored within the framework of a novel operating model that integrates suppliers and new rules of the game to be developed in the project, and implement those solutions by means of networked business operation.

2.1 All-inclusive

Because no one in the construction field in Finland has the capability to naturally operate all-inclusively—in the same turnkey manner as single-family home deliveries are made—the goal of the project is to build a business-oriented operator network. The objective is to create solution models and develop detailed inter-operator interface solutions for participating companies to ensure the compatibility of their different products and deliveries. Thus, the manner in which the participants work together—defined by the all-inclusive model developed in the project—will create the prerequisites and possibilities for new kinds of products and innovative operating models.

Since the goal is overall development, attention should be paid to both customer satisfaction and the delivery chains of other organisations and their management. With standardised operating methods, methodicalness and manageability will reduce costs, improve quality and decrease dispersion. Thus, the main objective of the project is to create a user-oriented, industrial, overall-economical and efficient renovation concept for suburban apartment building renovation and extension. From the standpoint of the housing company and residents, user-orientedness means speedy, non-disruptive construction work, which is not possible with the renovation methods that are currently employed. The operating model will require companies to adopt new kinds of operating processes; the prerequisites for this will be created in the project by modelling value chains and developing networked business models. The goal of the project is to collaborate with the various operators in formulating novel operating models and processes for working together which are transferable to practical business operations.

Early inclusion of all parties involved in the renovation project and the possibility to influence is the best starting point for getting renovation decisions passed in housing companies' decision-making bodies. Factors of choice and motivation related to buildings and renovation have been studied as they apply to both private and professional owners. Important in professional operation are management of economic processes and long-term owner policy, i.e. technical and economic rationality. Private individuals are motivated in matters centrally related to their own well-being, such as experienced comfort. [8]

Because suburban apartment buildings require exhaustive technical renovation both inside and outside, the motivation and needs of apartment owners are an essential part of the renovation process and the development of a new renovation concept. Residents' choices are limited by their financial capacity, but improvement of their own comfort is most important. Even in energy renovations—which in principle are within the sphere of technical and economic rationality—the primary criterion for making a decision is comfort (e.g. a draught-free apartment is more important than energy or monetary savings). This requires various all-inclusive solutions that are correctly focused also from the end user's (resident's) perspective, where not only are the need for technical repairs resolved and the level of technology updated, but the residents are offered noticeably better comfort which can be seen and experienced as more pleasant apartments and environment. [8]

Important from the standpoint of housing companies is the cost structure of the renovation project, as not many housing companies have reserved funds for renovation purposes. For this reason constructing an additional storey(s) may be a decisive opportunity for funding necessary façade and balcony renovation or building a lift, for example. [9] From the standpoint of housing companies or other real estate owners, alongside of selling permitted building volume it is necessary develop new types of financing instruments in collaboration with the Housing Finance and Development Centre of Finland (ARA) and employee pension companies. These could be, for example, partial ownership of the real estate through supplementary construction and financing of supplementary or in-fill construction through leasing or so-called life-cycle model funding. The goal of the project is to come up with user-oriented ways to finance suburb renovation and in-fill construction and find new business models at the interface between the financing and real estate and construction sectors.

2.2 Suburb in-fill construction

Suburb in-fill construction is justified from the standpoint of integrating and densifying the urban structure. This has a favourable effect on the environmental impact of communities and promotes preservation of suburbs' dwindling services, which is in the interests of area residents. From the perspective of housing companies, supplementary construction may be one way to finance necessary renovations, although this operating model requires revision of current zoning practices to make supplementary and in-fill construction flexible in practice. [9]

Fig. 1 Additional storey(s) and in-fill construction. Present situation on the left.

An objective of the project is to develop a less complex zoning model for suburb renovation and in-fill construction in collaboration with participating cities, and simultaneously develop practices for environmental impact assessment tools to support and justify suburb in-fill and supplementary construction. The project will analyse and test new types of more flexible zoning practices in pilot areas indicated by participating cities in collaboration with urban zoning and building authorities and the areas' residents and real estate. These less complex zoning models could be e.g. an areal exceptional permit process with construction method guidelines or a general area plan with loose specification of permitted building volumes, in which case exact construction methods and building volumes would be specified for each block in the building permit phase. It is also necessary to review parking place requirements from the viewpoint of areal services offered.

2.3 User-orientedness and a model book

In terms of environmental impact assessment, user-orientedness in suburb renovation calls for a participative process and consideration of sustainable development values already in the project planning phase. The objective is to achieve resident-oriented solutions to local needs that are in the interests of the owners. The guideline is a comprehensive vision that includes resident-oriented planning objectives regarding e.g. the housing company's energy consumption, the residents' safety, comprehensive waste handling and indoor environment control (indoor air quality, lighting, heating and temperature conditions).

Guidelines for post-renovation monitoring of use will be compiled during the research project. The monitoring phase consists of observing key performance indicators (KPI) for environmental impact assessment, such as land use, energy and water consumption, indoor environmental quality (e.g. moisture, air quality) and the impact that visualising energy consumption has on residents' behaviour and social interaction. The outcome will consist of guidelines for assessing and possibly certifying the realisation of objectives accordant with sustainable development. The objective is to support value creation for residents by means of marketing, communication, price trends, better sales value and monitoring of energy savings. The project will gather the best practices of assessing the environmental impact of suburb renovation in Finland’s conditions.

Fig. 2 Additional storey realised using box elements on rooftop. Excerpt from the floor plan and south elevation with new balconies and surfacing of the exterior walls.

The objective in this User- and Business-oriented Suburb Renovation Concept research project is to compile a publicly available model book in collaboration with partner companies which will help housing companies start renovation projects by providing them with tools for user-oriented ideating and planning. The purpose of the model book is to present different types of all-inclusive solutions for block in-fill construction and construction of additional storeys atop suburban apartment building using box elements; energy-efficient renovation of the outer shell of buildings—particularly exterior walls—and façade renewal using various materials; construction of balcony systems and installation of lifts. The goal of the all-inclusive concept is to also include the possibility to construct apartment-specific sanitary rooms using box elements as extensions of the building frame and, if necessary, install apartment-specific ventilation systems as part of the new façade. To this can be added tools that serve energy and real estate management as well as apartments’ indoor environments and methods for verifying performance (instrumentation, monitoring). The current state of buildings and the success of renovations should be verified with in-situ measurements.

3. Parties of the project

The parties to the project consist of a wide range of Finnish universities, research institutions and companies in the construction sector. The participants are the University of Oulu’s Department of Architecture and Department of Industrial Engineering and Management, Aalto University’s Department of Architecture, Tampere University of Technology’s Department of Construction Engineering and the Technical Research Centre of Finland. Participating companies in the construction sector include Stora-Enso, Isover Saint Gobain and construction companies. Other partners include several cities like Joensuu, Kouvola, Porvoo and Turku, real estate representatives, the Ministry of the Environment and the Finnish Real Estate Federation.

4. Benefits of the project for the partners

4.1 Residents, housing companies and real estate owners

The project will develop a user-oriented, industrial, overall-economical and efficient renovation concept for suburban apartment building renovation and expansion as well as construction of additional storeys. This will directly benefit residents, housing companies and real estate owners by enabling swifter, neater and cheaper renovations. The concept will also offer housing companies the possibility to upgrade buildings and thereby increase their value and attractiveness.
With this operating model it will be possible to produce overall-economical renovation solutions that are optimal from the life cycle perspective while balancing the needs of different kinds of interest groups. The project will promote suburb supplementary and in-fill construction which will help reinforce the areas’ population base, thereby ensuring that services are preserved, which is in the interests of the residents and the suburbs.

The model will offer various all-inclusive solutions that are correctly focused from the end user's (resident's) perspective, where not only are the need for technical repairs resolved and the level of technology updated, but the residents are offered noticeably better comfort which can be seen and experienced as more pleasant apartments and environment.

Fig. 3 In-fill construction realised using box elements on rooftop.

For building managers and housing companies, user-orientedness in the project means that the project's implementation planning, cost estimation and realisation are reliably available from one source and they are based on a project description compiled and agreed on together in advance. The concept will benefit residents and housing companies by allowing users to participate in renovation ideation and planning from the very beginning of the process.

4.2 Cities

By examining the pilot areas the project will produce ideas, methods and solutions for technical high-quality renovation of suburbs. Development of operating methods in land use planning associated with renovation will widely benefit cities and promote sustainable development in suburbs and cities.

The project will develop—in collaboration with the participating cities—a less complex zoning model for suburb renovation and in-fill construction. At the same time it will develop practices for environmental impact assessment tools. Cities will benefit from the results of the development by getting better methods to densify the urban structure.

4.3 The Ministry of the Environment

The project will produce a national tool or guidelines that the Ministry of the Environment can utilise in less complex suburb zoning in connection with suburb renovations.

4.4 Research partners and partner companies

The know-how of research institutions and international and domestic research results will be developed in the project in collaboration with partner companies to create new know-how, a business model and marketable industrial solutions.

The project will develop model solutions for ensuring the compatibility of different products and deliveries and detailed solutions for the interfaces between them for the participating companies. This will introduce new types of services and product concepts to the market and provide the companies opportunities to broaden their business operation.

4.5 Construction companies and developers

Construction companies will benefit from the novel business concept for suburb renovation, which will be developed together. It will speed up implementation, increase profitability and decrease risks.

The concept will make it possible to change from cost-based operation to a novel service business where renovation solutions can be site-specifically and all-inclusively tailored and implemented by means of networked business operation.

5. Target areas

For the cities' pilot suburbs, the research and guidelines will support buildings' project-specific planning and compilation of lists of tasks. In the planning phase it is necessary to assess the quality of the city image and the immediate surroundings, evaluate the need to improve drainage water treatment, map the landscape of plots and examine the need for landscape and traffic planning. The planning process also includes energy simulation or calculation and a tentative life cycle analysis of materials. Environmental impact assessment requires documentation and verification calculation of quantities for material life cycle analysis (LCC and LCA). The environmental impact of the renovation process should also be monitored during the realisation phase. Attributes that should be documented include use of time, construction site energy consumption and transports. Waste formation should be monitored with the goal of planning material savings; the quantity and quality of waste produced by the building products used during the production process and at the construction site.

The target sites for town plan analysis have been chosen together with the partner cities: two suburbs in Turku, two in Porvoo, two in Kouvola and one in Joensuu. The areas differ greatly in size and nature, so they form an excellent series in which they complement each other. Assessment of the environmental impact of the sites has begun and the zoning work of each area is starting as a Master's thesis under the joint supervision of the cities and universities. Planning of the pilot construction case at Kirkkokatu 18 in Joensuu will begin as soon as the zoning change has been approved.

6. Discussion

The frames of suburban apartment buildings built in the 1960s to 1980s will easily carry the construction of lightweight additional storeys allowed by the new fire code. To minimise disturbance inflicted on the residents, it is sensible to construct them using box elements. However, designing and constructing box elements is challenging because the top ceiling slab usually cannot be loaded, whereupon loading has to be aligned with load-bearing walls below the slab, which may be few in number. On the other hand, to increase floor area it may be desirable to make the top storey larger than those below. Special attention also needs to be paid to existing ducts and ventilation pipes that pass through the roof. [10]

Insufficient or unsatisfactorily functioning ventilation is one reason for moisture problems. Apartment-specific ventilation solutions (wall ventilation and heat recovery) have been tried in new sites and have performed well. Installation has been relatively free of problems. Apartment-specific ventilation may also be partially realised by using existing ductwork or new lightweight ducts. Ventilation solutions and testing of their functionality as part of exterior wall renovation is an important part of the concept.

All-inclusive construction—the objective of this User- and Business-oriented Suburb Renovation Concept—calls for swift construction, so lift shafts also need to be installable as large self-supporting elements, using lift technology which doesn't require a separate machine room.

The renovation concept for suburb renovations must be such that building renovations completed within its framework can be done using various façade facing materials so that the architecture of the building is preserved in the renovation, but also so that alternatively the architecture and appearance of the building can be changed completely, if so desired. [4], [11]

7. Final comments

The challenge with exterior wall elements is the airtightness and load-bearing capacity of the exterior wall, especially in cases where the existing building lacks a load-bearing inner shell or the façades consist of horizontal band elements. The frames of elements also require special strength analysis if the façade facing is very heavy, e.g. brick slabs or planks.

To manage renovation costs, the development work will concentrate especially on wintertime construction, which would allow house factories to use their underutilised autumn and winter capacity. However, this places challenges on job site conditions, especially moisture control, which needs to be addressed in the study.

8. Conclusions

The results of KLIKK project benefit housing corporations in improving energy efficiency by offering new methods of renovation and retrofitting. Same time in-fill construction offers a possibility to finance the renovation and also a possibility to build new common facilities. The residents benefit from less intrusive renovation method which minimizes the disturbances and can be realized without emptying the flats. Construction companies have possibility to create new know-how, a business model and marketable industrial solutions. New retrofitting methods can be applied globally as the industrially produced concrete-frame apartment buildings are common in many countries. Finally, the Enhanced housing quality and declined energy consumption benefits the residents and housing corporations allover in cold climate.

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Improving Satisfaction of Public Engagement for Mega Development Projects through Stakeholder Identification

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Summary

Purpose – Public engagement is becoming increasingly prevalent for mega development projects in Hong Kong. It is encouraged to collect different opinions from the society, integrate the ideas, establish consensus among multiple stakeholders, gain the final support from the society, and enhance the project performance from the public view. However, it is difficult to take into account of all of the needs and wants of multiple stakeholders by balancing the diversified power and interests in the engagement process. For example, environmental groups as an interest group may only concern about the environmental protection by eliminating proposed development; residents may want to accelerate the urban redevelopment simply for upgrading their living environment; the government with the legitimate power concentrates on the regulation and policy, etc.

Stakeholders are individuals or groups affecting or being potentially affected by the public engagement project which claim ownership, rights, or interests on the PE project. Different stakeholders possess diverse power and interests which are key elements for identifying stakeholders. Due to multi-disciplinary stakeholders involved in the public engagement projects, it is a challenging task for the organizer to identify representative stakeholders and determine how to satisfy their expectations. In order to improve the project performance in the society, main characteristics of the stakeholder (power and interest) are adopted to identify multiple representative stakeholders in public engagement projects. The paper thus aims to investigate the complicated relationships between stakeholder identification (power and interest) and final satisfaction of public engagement for construction projects in Hong Kong.

Design/methodology/approach – Based on extensive literature review on stakeholder management and public engagement, a questionnaire survey was designed to investigate the relationships between stakeholder identification (power and interest) and satisfaction on public engagement. Purposive sampling was adopted in which respondents were recruited only if (1) they had direct public engagement experience, such as focus group, workshop or public forum for mega development projects; and (2) they had affected or been affected by the public engagement projects at the time when they filled in the survey. In order to understand the complicated relationships between stakeholder identification and final satisfaction, reliability analysis and Pearson correlation analysis were adopted by using the software SPSS version 19.0. Reliability analysis was adopted to ensure the internal consistency of the identified factors, while Pearson correlation was used to measure the strength and direction of linear relationship among factors.

Findings – This paper has identified five types of stakeholder power (i.e., coercive, reward, legitimate, expert, and referent power), and two types of stakeholder interest (i.e., affected interest and affecting interest). Coercive, reward and legitimate power were classified as formal power, while expert and referent power were considered as informal power. All factors were reliable with the Cronbach's alpha value greater than 0.6. The results of the Pearson correlation indicated that (1) coercive power had a positive significant relation with legitimate power, while reward power, legitimate power, expert power and referent power were significantly interrelated; (2) affected interest significantly related to affecting interest; (3) legitimate power had a significant relationship to affected interest, and expert power related to affecting interest positively; and (4) public engagement satisfaction had a significant and positive relationship with reward and referent power as well as affecting interest, and negatively related to affected interest.

The organizers and project team of public engagement who possess high reward power are critical for the satisfaction by providing necessary support and deliver desirable project. Some stakeholders with high referent power, such as social workers and neighbourhood committee members exert positive impact on PE satisfaction through maintaining good relation with other stakeholders. Stakeholders who are directly influenced by the public engagement projects hold high affected interests. The failure to satisfy the affected interests might hinder the project implementation and decrease the satisfaction. The engagement of stakeholders with affecting interests could drive the public engagement to pay attention on social value and environmental impact. The fulfilment of the affecting interests can make the stakeholders more satisfied about the public engagement project.

Originality/value of paper – To enhance stakeholder satisfaction on public engagement projects, the initiator such as the government is recommended to delegate more decision making authority to the public and balance the power distribution in the public engagement activities. The governmental departments and project team are expected to be engaged directly in the public engagement process, in which reputable stakeholders (such as social workers, district council members, and community representatives) are encouraged to be involved. To achieve high satisfaction level, the organizers of public engagement are suggested to actively respond the needs of the affected stakeholders and gain common interest and goals which could satisfy all internal stakeholders (e.g., local residents, village representatives, local business organizations, etc.). Furthermore, the environmental impact and social responsibility that may affect the decision making are suggested to be emphasized and promoted through public engagement projects. In sum, the results are expected to improve the satisfaction of multiple stakeholders and benefit the public engagement development in construction projects not only in Hong Kong but also for other countries worldwide. As this study focused on public engagement mainly from a stakeholder perspective, further researches (such as large-scale surveys, focus groups and case study) on the public engagement process and behavioural components are strongly recommended to establish a comprehensive PE model.

Keywords: Interest; Mega development projects; Power; Public engagement; Stakeholder identification

1. Introduction

During the different stages of the construction projects, especially mega development projects, a vast number of stakeholders will be affected, both positively and negatively (Olander 2007). To fulfill different stakeholder expectation and needs, public engagement is often used to provide a platform for multi-stakeholders to exchange their views, identify mutual goals and negotiate different interests and power in decision-making and policy-forming activities (Rowe and Frewer 2005). It is becoming common practices to elicit public comments, such as the impact assessment in Finland (Peltonen and Sairinen 2010), the nuclear waste settlement in Sweden and the GM food project in Netherlands (Hagendijk and Irwin 2006).

Multiple stakeholders (including the governmental departments, construction professionals, non-governmental organizations (NGOs), the general public and so forth) are engaged in the public engagement projects (Leung and Olomolaiye 2010). The challenge for the organizer is to identify stakeholders based on different power and interests and determine how to satisfy stakeholder expectations (Rowe and Frewer 2005). However, it is still in its infancy to identify stakeholders in terms of power and interests and subsequently improve satisfaction on the public engagement. This study thus aims to investigate the complicated relationships among stakeholder power, interests, and satisfaction on public engagement projects. Based on the extensive literature review on stakeholder management and public engagement, a questionnaire survey was conducted to the participants of public engagement in mega development projects.

2. Stakeholder identification

Stakeholders are individuals or groups affecting or being potentially affected by the public engagement projects which claim ownership, rights or interests and bear some form of risks on the project (Freeman 1984; Mitchell et al. 1997). Stakeholders possess different power and interests which are used to identify stakeholders (Sirgy 2002). In terms of different stakeholder power and interests, stakeholders can be categorized as internal or external; primary or secondary; voluntarily or involuntarily involvement; and normative or derivative (Phillips 2003; Post et al. 2002).

2.1 Stakeholder power

The stakeholder can exercise power over other stakeholders to affect their vested interests, exert impact on decision making process of public engagement and get the outcomes they desire (Lukes 2005). In terms of its sources, power can be distinguished as formal power and informal power (Brass and Burkhardt 1993). *Formal power,* including reward power, coercive power and legitimate power, is based on structural power sources which stem from the legitimate authority and hierarchical position and exert positive and negative impact including reward and coercion (Peiro and Melia, 2003). The governmental departments and project team possess reward power by providing project funding, and delivering desirable project outputs (Newcome 2003). The government departments and the legislative council also have legitimate power from the administration system and coercive power by issuing regulations and ordinance. Sometimes, local communities and NGOs might impose pressure on the organizers and exert coercive power through criticizing the PE projects.

Informal power which includes expert power and referent power connects to personal competencies, experiences and influence (Olmstead 2000). Social workers and community representatives who are caring and admired persons normally hold referent power. Construction professionals from the project team and external professional institutions have expert power and contribute their specialized knowledge to the public engagement projects.

2.2 Stakeholder interest

Interests, in terms of demands, expectations, reasons, needs, and values, formulate the motivation to engage stakeholders in the public engagement projects actively (Leung 2001; Lukes 2005). The public engagement projects are recognized as an interest-balancing process to achieve consensus on decisions made by multi-stakeholders (Gregory and Keeney 1994).

Stakeholder interest can affect or be affected by the public engagement projects (Joerin et al. 2009). Those interests that are potentially influenced by public engagement projects refer to the *affected interest* on political influence, financial benefits, living environment and so forth (Cragg and Greenbaum 2002). Stakeholder interest can also affect public engagement projects and be categorized as *affecting interest* such as justice, corporate social responsibility, environmental impact and so on (Reichart 2003). In this study, we identify stakeholders involved in public engagement based on their power and interest on mega development projects (see Table 1).

Table 1 Stakeholder Identification Based on Different Stakeholder Power and Interest

Power \ Interest		Affected interest	Affecting interest
Formal power	Coercive power	- Legislation authorities, Political parties, District council members - Local communities, residents	- NGOs and the environmentalists
	Reward power	- PE project team - The government departments	
	Legitimate power	- The government departments, the legislative council and district council members	
Informal power	Expert power	- PE project team	- The professionals (such as architect, engineers, lawyers, etc.)
	Referent power		- Social workers, district council members, NGOs, community representatives

3. Public Engagement satisfaction

Public engagement satisfaction refers to the stakeholder perception on the final outcomes focusing on the physical effectiveness and implementation of the project, including project decision produced by all stakeholders and productive output within the requirements of quantity, quality and timeliness (Rowe et al. 2008). Hence, satisfaction on the public engagement projects can be identified in terms of the project enhancement, the achievement of PE project objectives, and the future impact on other public engagement projects (Leung et al. 2004; McComas 2003).

It is inevitable about the asymmetrical distribution of stakeholder power and the tension between stakeholder interests in the public engagement process (Coff 1999). To achieve satisfaction, public engagement process is required to make the balance among different stakeholders which are identified in terms of stakeholder power and interest (Podsakoff and Schriesheim 1985). Hence, this study investigates the relationships between stakeholder power (i.e. coercive power, reward power, legitimate power, expert power, and referent power) and interest (i.e. affected interest and affecting interest) and satisfaction on the public engagement projects.

4. Research methodology

4.1 Survey design

To investigate the relationships between the stakeholder power and interests and the final satisfaction, a questionnaire was designed consisting of four parts: (1) background information, (2) stakeholder power, (3) stakeholder interest and (4) satisfaction on the public engagement projects. All the factors are summarized in Table 2. Purposive sampling (Adams and Schvaneveldt 1985) was adopted in which respondents were selected only if they had experience on participating in public engagement activities, such as focus groups, workshops or public forums and they had affected or been affected by the public engagement projects before they filled in the survey. All respondents meeting the inclusion criteria were asked to identify their most satisfactory public engagement project and fill in the questionnaire based on this experience. In total, 57 completed surveys were collected, representing a response rate of 14%.

Table 2 Factors of Stakeholder Management in the Public Engagement Process

Stakeholder Power	Stakeholder interest
SP-1 Coercive power	**SI-1 Affected interest**
sp1 Make projects unpleasant	si1 Concern the distribution of political power
sp2 Make PE distasteful	si2 Concern the allocation of power
sp3 Make others fail to achieve their wants	si3 Concern the distribution of influence
SP-2 Reward power	si4 Wealth be influenced
sp4 Make project desirable	si5 Health be influenced
sp5 Increase financial resources	si6 Comfort be influenced
sp6 Important approval for PE	si7 Convenience be influenced
SP-3 Legitimate power	**SI-2 Affecting interest**
sp7 Make demands of others	si8 Interest to gain knowledge
sp8 Expect others to carry my wishes	si9 Interest in the PE news
sp9 Represent the authority	si10 Interest in the PE information
SP-4 Expert power	si11 Consider environmental impact
sp10 Provide technical knowledge	si12 Reflect social value
sp11 Provide useful suggestions	si13 Involve the powerless
sp12 Share experiences	
SP-5 Referent power	
sp13 Be respected	
sp14 Be admired	
sp15 Be acceptable	

In order to investigate the complicated relationships among stakeholder power, stakeholder interest, and satisfaction on public engagement projects, both reliability analysis and Pearson Correlation analysis were adopted with the software SPSS version 19.0. Reliability analysis was used to examine the internal consistency of the identified factors, while Pearson correlation was adopted to measure the strength and direction of linear relationship among factors.

5. Results

To test the internal consistency of factors, reliability analysis was conducted on stakeholder power, interest and PE satisfaction. All factors were reliable with the Cronbach's alpha value greater and 0.6 (Hair et al. 1998). Those reliable factors were summed by arithmetic means together with corresponding coefficient alpha reliabilities, as shown in Table 3.

Table 3 Calculation and Reliability of Factors of Stakeholder Power, Interest and Satisfaction

Major components	PE factors	Measurement items	Alpha (α)
1. Stakeholder power	SP-1 Coercive power	= (sp1+sp2+sp3)/3	0.881
	SP-2 Reward power	= (sp4+sp5+sp6)/3	0.660
	SP-3 Legitimate power	= (sp7+sp8+sp9)/3	0.721
	SP-4 Expert power	= (sp10+sp11+sp12)/3	0.639
	SP-5 Referent power	= (sp13+sp14+sp15)/3	0.637
2. Stakeholder interest	SI-1 Affected interest	= (si1+si2+si3)/3	0.894
	SI-2 Affecting interest	= (si4+si5+si6+si7)/4	0.847
3. Public engagement satisfaction	Sat PE satisfaction	= (sat1+sat2+sat3)/3	0.700

The relationships between various stakeholder power, interest, and satisfaction on public engagement projects were investigated by Pearson Correlation analysis (Table 4). The results of the Pearson correlation analysis indicates that (1) legitimate power (SP-3) positively related to coercive power (SP-1) and reward power (SP-2); (2) reward power (SP-2), legitimate power (SP-3), expert power (SP-4) and reference power (SP-5) were interrelated; (3) affected interest (SI-1) related to legitimate power (SP-3) positively and affecting interest (SI-2) connected to reward power (SP-2) and expert power (SP-4); (4) affected interest (SI-1) related to affecting interest (SI-2) positively; and (5) satisfaction related to reward power (SP-2), referent power (SP-5) and affecting interest (SI-2) positively and connected to affected interest (SI-1) negatively.

Table 4 Correlations among Stakeholder Power, Interest and PE Satisfaction

	Stakeholder							
	SP1	SP2	SP3	SP4	SP5	SI1	SI2	Sat
SP-1 – Coercive power	1							
SP-2 – Reward power	0.178	1						
SP-3 – Legitimate power	**0.353****	**0.473***	1					
SP-4 – Expert power	-0.060	**0.331***	0.182	1				
SP-5 – Referent power	-0.017	**0.413****	**0.357****	**0.321***	1			
SI-1 – Affected interest	0.127	0.066	**0.316***	0.117	-0.214	1		
SI-2 – Affecting interest	-0.205	**0.268***	0.052	**0.335***	0.091	**0.532****	1	
Sat – PE satisfaction	-0.133	**0.306***	-0.062	0.134	**0.380****	**-0.348***	**0.288***	1

Note: * Correlation is significant at the 0.05 level (2-tailed);
** Correlation is significant at the 0.01 level (2-tailed);

6. Discussion

The complicated relationships between stakeholder power, interests and satisfaction on public engagement projects were illustrated based on the results of Pearson Correlation analysis (see Figure 2). The results indicated that reward power and referent power and stakeholder interest relate to final satisfaction directly. Other kinds of stakeholder power and interest might associate with final satisfaction indirectly.

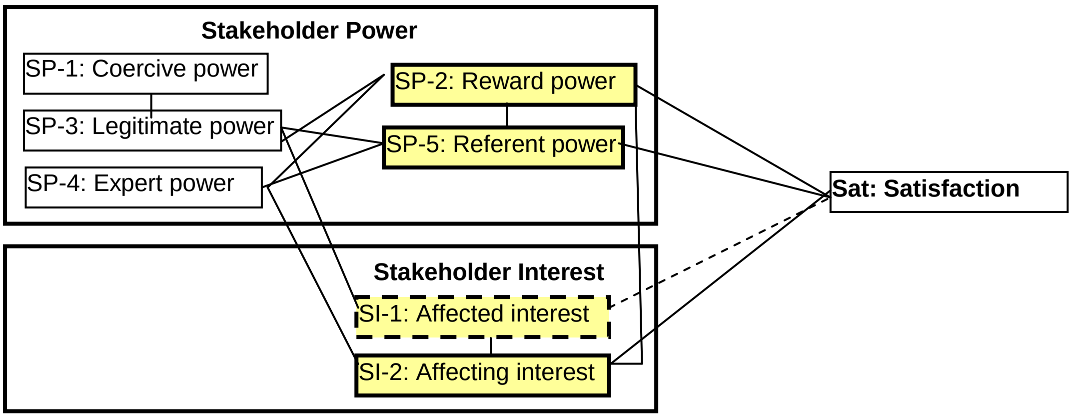

Figure 2 Relationships between Stakeholder Power, Interest, and Satisfaction on Public Engagement
Note: Refer to Tables 3 for the relationships;
——— positive linear significant relationship;
- - - - - negative linear significant relationship;
variables positively significantly relating to satisfaction; and
variables negatively significantly relating to satisfaction.

Among all kinds of formal power, *reward power* relates to satisfaction on pubic engaement directly, and coercive power and legitimate power might influence final satisfaction via the effect of reward power. The initiator and organizers of public engagement (e.g., the government and project team) who possess high reward power tend to provide sufficient support, ensure successful project implementation and deliver the desirable project to other stakeholders (Bourne and Walker 2005). Final satisfaction will be improved with more support and favorable project outcomes (Rawwas et al. 1997).

Referent power as a major type of informal power has direct positive impact on satisfaction, aligning with other studies (Gassenheimer and Calantone 1994). It is easy for stakeholders with referent power (e.g., social workers, professors, committee members, etc.) to build trusting relationship with other stakeholders. Stakeholders who are caring and admired might understand the demands of the general public and improve cooperation with different parties. Their engagement can encourage others to participate actively in public engagement projects and enhance the level of satisfaction on final outcomes (Petts 2008).

Both affected interest and affecting interest relate to satisfaction on public engagement directly. Stakeholders possessing *affected interest* are those who are directly influenced by the public engagement projects, for example, political influences of different parties, the maximization of land compensation for local residents, the reduction of disturbance, less removal or relocation of local business, etc. It is extremely difficult to fulfill all affected interests. When public engagement fails to balance the affected interest and find out the common interest for all stakeholders, they may feel dissatisfied about the final outcomes (Carpini et al. 2004).

Stakeholders with *affecting interest* often pay attention on public engagement information, social value, and environmental impact and so on. NGOs are the typical stakeholders possessing affecting interest. They tend to concern for the interests of the whole society, make trade-offs among competing and conflicting stakeholder expectations and actively engage in the public engagement projects. With their engagement, the projects can be more inclusive and desirable (Jones et al., 2007).

7. Recommendations

Research on the complicated relationships among power, interest, and satisfaction is still rare in the public engagement for construction projects. The findings of this study strengthen that stakeholder identification influences final satisfaction significantly through different stakeholder power and interests. To apply stakeholder identification in the public engagement projects, several suggestions have been brought out. The initiator or organizer of public engagement projects is suggested to *provide an equal and fair platform* to avoid the imbalance distribution of power and interest (Sunshine and Tyler 2003). Stakeholders with high *reward power*, such as the governmental departments and project team members, should *directly engage* in the decision-making process in order to understand the public views and deliver the satisfied products. To use the referent power source and enhance final satisfaction, *social workers, researchers in relevant fields and other reputable stakeholders* are suggested to engage in public engagement projects.

The failure to fulfill affected interests might hinder the project implementation and reduce satisfaction. Hence, it is suggested to actively respond *the needs of the affected stakeholders and gain common interest and goals* which could satisfy all affected stakeholders (e.g., local residents, village representatives, local business organizations, different parties, etc.). To achieve high satisfaction level, *the importance of environmental impact and social responsibility* are suggested to be emphasized and promoted through public engagement projects.

This study researched on public engagement mainly from a stakeholder perspective. However, there are no standard criteria to identify stakeholders and determine the stakeholder sampling. In fact, too many stakeholders can create administrative and resources allocation problems as well as increase difficulty to achieve the common grounds. But too few stakeholders involved might cause some key stakeholders to be ignored, which could lead to the problems in a long run (Pomeroy and Douvere 2008). It is important to establish a systematic method to determine the number of stakeholders involved in the project. Considering of the complexity of the construction projects and diversity of stakeholder attributes, multi-criteria decision making techniques is expected to be used in the stakeholder identification and sampling methods. There are some other factors affecting the stakeholder satisfaction in the PE process (e.g., logical team process, participation, commitment), which were out of the current research scope. To establish a comprehensive model for public engagement projects, further researches (such as large-scale surveys, focus groups, and personal interviews) on the systematic PE process and the behavioral components are strongly suggested.

8. Conclusion

Stakeholder identification determines the success and failure of the public engagement projects. However, public engagement has been blamed for their inappropriate stakeholder identification and failure to balance stakeholder interests and power. In order to identify stakeholder representatives for the public engagement projects, this paper proposed to investigate the complicated relationships among stakeholder power, interests, and final satisfaction on public engagement projects. Based on the literature in the areas of stakeholder management and public engagement, this paper has identified five types of stakeholder power (i.e. coercive, reward, legitimate, expert, and referent power), two types of stakeholder interest (i.e. affected and affecting interest) and final satisfaction.

This study indicates the complicated interrelationship among stakeholder power, interests and satisfaction on public engagement projects. Reward and referent power and stakeholder interests (both affected and affecting interests) relate to final satisfaction directly, while other stakeholder power might connect to the satisfaction indirectly. To enhance stakeholder satisfaction on public engagement projects, it is recommended that the initiator provide equal platform for relevant stakeholders and balance the power distribution. The governmental departments and project team are expected to engage directly in the public engagement process in which reputable stakeholders (such as social workers, district council members, and community representatives) are encouraged to participate. The public engagement projects are suggested emphasizing on environmental impact and social responsibility in order to promote satisfaction level and actively respond the affected interests in order to find common interest of multiple stakeholders. To establish the comprehensive public engagement model, further researches including large-scale survey, focus group and case study are recommended.

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A method for evaluating the suitability of the existing apartment building stock to the needs of the senior dwellers before the renovation

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Summary

Population is aging globally ageing and the number of people having memory disturbances and in need of help is increasing. The majority of seniors wish to live as long as possible in their homes. This sets challenges to housing stock and built environment. The existing housing stock doesn't suit to the needs and wishes of the senior dwellers but accessible and suitable senior housing stock cannot be created only with new construction. Renovation would be needed. There is lack of knowledge of distribution of features that trouble everyday life of seniors. To get the best profits of the renovation projects, the knowledge to which buildings and building parts the renovation measures should be aimed is needed. For that purpose an evaluation method is developed. This article presents the method and the first experiences of using the method.

Keywords: Evaluation, housing planning, habitability, renovation, seniors, functional capacity

1. Introduction

Population is aging globally, with the percentage of those aged 60 and over expected to double between 2009 and 2050. Also, the older population itself is aging. Currently, the eldest group (persons aged 80+ years) constitutes 14% of the population aged 60 or over, and constitutes one of the fastest growing segments of the population. It is expected that by 2050, 20% of the eldest population will be aged 80 or over. [1] [2] As the population is ageing, the number of people having memory disturbances is increasing. The prevalence of dementia, MMSE score lover than 25 [3], is 8.8% among the population over 60 years of age and more than every third of those aged 80 and over suffers from dementia. [4]

The need for help increases with age. Among younger pension-aged or 65–74-year-olds, about 20% are in need of help, but among those aged 85 and over, the corresponding figure is 80%. [5] The increasing need of help is associated with decline of functional capacity with age. [6] The proportion of seniors living alone has doubled and also the children of these seniors are ageing, which weakens opportunity to get help. [2] The majority of seniors wish to live as long as possible in their homes, where they can best carry on their existing lifestyle and master their own lives. [7] This is also the objective of senior policy in many countries. In addition, moves to unfamiliar environments such as nursing homes are associated with negative performance in coping in daily routines [8], along with the considerable costs of institutional care for both society and the patients and their families.

The aging of the population, along with increasing numbers of people with need of help and memory disturbances, sets challenges to housing stock and built environment. The functional performance of an individual is affected by the qualities of the surroundings. [9] Same time it has been proved that the majority of existing housing stock doesn't suit to the need of the senior dwellers. [10] Especially memory disturbances haven't been taken into account in earlier planning instruction. It requires maintenance and alterations to meet the changing needs of the dwellers. Accessible and suitable senior housing stock cannot be created only with new construction, because only 1% of the Finnish housing stock is renewed annually. [11] Therefore, renovation is crucial. But there is lack of knowledge of distribution of features that trouble everyday life of senior dwellers in the existing housing stock. To get the best profits of the renovation projects, the knowledge to which buildings and building parts the renovation measures should be aimed is needed. This knowledge serves also facility management and strategic planning of the housing corporations, since the seniors are growing customer segment.

2. Objectives

The objective is to develop a method which would help in evaluating the suitability and the habitability of the existing housing stock to the needs and the wishes of the senior dwellers. The method should be easy to use and the results should illustrative. The method is developed for my doctoral thesis, which focuses on the suitability of the existing Finnish apartment building stock built between 1950's and 1980's to the senior housing. The apartment buildings are chosen type of housing, as popularity of living in one increase with age of a dweller. [12] The age range of the building is validated as they form the majority of Finnish apartment building stock. [13] This article describes the experiences of using the method. For the present the method is developed for evaluating the Finnish apartment buildings and was tested with these ten representative apartment buildings.

3. Evaluation criteria

The suitability of the apartment buildings for the senior dweller is evaluated from four main points of view: 1) accessibility, 2) safety, 3) decline of vision and hearing, and, 4) the memory disturbances. They encompass the most common aspects of declining functional capacity associated with age. Physical capacity declines and insufficiencies become more general. [6] The frequency of the accidents demanding hospital treatment is increasing and the most of the accidents of the seniors occurs in their homes. [14] Decline of vision and hearing and memory disturbances become more general. [15] [16] [4] Combining all four points of view builds a good overall picture of the suitability to needs of the most senior dwellers. The points of view are partly overlapping since several features play a role in more than just one point of view. For example the handrails on both sides of the stair flight are important for both safety and accessibility. All points of view encompass most common aspects of declining functional capacity associated with age. Since the criteria is planned to cover the needs of the most senior dwellers, the severe disabilities and personal preferences like colors are excluded. The physical and cognitive capacity of a dweller is expected to be suitable for living alone safely. This doesn't exclude aids, home help or nurse visits. The evaluation focuses on such features of buildings and building parts that according to literature review most commonly trouble everyday life of senior dwellers in the existing housing stock.

3.1 Earlier criteria and evaluation methods

The method is based on the review of the literature focusing on aging and senior housing, and on the survey of existing evaluation tools and criteria. The existing evaluation criteria focus mainly on new construction [17] [18] [19] and the ones focusing on the existing building stock [20] [21] are few. There are also criteria focusing on limited features of the living environments like outdoor areas. [22] They are useful tools in planning process of new construction. They produce lots of information and therefore they are laborious to use in the evaluating the suitability and habitability of an existing building before more detailed planning or in comparing several buildings. When the renovation process is on the planning phase they are useful. The existing criteria and method have been great help in developing a new one for the existing building stock.

Table 1 Pros and cons of existing criteria

Method	Key pros	Key cons	To be reclaimed
ARVI [17]	Very detailed Several user profiles	Very laborious.	Plenty of dimensioning data
KUTRI [18]	Clear grading Easy to use	Grading emphasize services (restaurant etc.) and equipment not realistic for housing corporation Too cursory to produce information for actual planning	Sheet structure Some criteria Tripartite scale
WoonKeur [19]	Clear detailed instructions and checklists	Laborious Focus on new construction	Several criteria and dimensioning data
ELDERATHOME [20]	Possibility to take user preferences into account	Open various interpretation Dimension criteria missing Requires expertise	Several criteria
Checkliste für individuelle Wohnungs-anpassungen [21]	Clear sheet structure Combines features to larger entities	Dimension criteria missing Requires expertise Some irrelevant criteria (furniture etc.)	Sheet structure Tripartite scale
SuRaKu [22]	Clear detailed instructions	Focuses on outdoor areas	Criteria for outdoor areas

3.2 Evaluation process and information sources

The evaluation is started by gathering the planning permission drawings of the building. Other materials like documents from construction phase or condition assessment reports, and interviewing someone who knows the building well, like a representative of a housing corporation or a janitor, provide useful information. The most important part of information acquisition is the survey on the site which is done with a pre-structured sheet. For example, there are several measurements to be taken like dimensions of door openings. The quality of lighting is measured by illuminometer and subjectively.

The evaluating is executed by analyzing the gathered information. The evaluation form is divided in four entities: entrance and staircases, common facilities, apartments and resources. The resources are (partly) unused qualities which can be realized to finance future renovations of the housing corporation. All the entities consist of several features like staircase and entrance facilities consist of criteria for inter alia front doorsteps, front door and canopy above the front door. Every feature is valued in tripartite scale. In good level the criterion is met. In moderate level the criterion can be met with reasonable renovation. In poor level the criterion can be met only with significant renovation. The costs of moderate renovation can be considered to be less than 2000 euros. With that sum of money is possible to build a canopy above an entrance or buy new wardrobe in hallway, but the sum doesn't cover expenses of enlarging the bathroom to meet the needs of a wheelchair user. The tripartite scale is chosen to simplify the evaluation. Also the Swiss evaluation tools for existing buildings uses the tripartite scale. [21] If needed, the extra partitions can be added to the method.

3.3 Criteria accessibility

The accessibility is a key point of view, as the physical capacity of the most seniors declines with age. [6] Muscular strength starts to weaken after 50 years of age. [23] Many seniors use different aids for moving like a walker or a stick [24], and therefore they need extra space for moving. [25] Most of the seniors have an acute arthritis causing stiffness and restricting the movements. [26]

Firstly and most of all the seniors need help in heavy housework and carrying out shopping. [27] Declined physical capacity complicates climbing stairs, reaching up and down, and tasks that require muscular strength. A clear defect for a senior dweller is lack of a lift [28], but also opening a front door can be hard for a fragile senior. The built environment suitable for senior dweller must be accessible and the fragility must be taken into account.

Table 2 Examples of the criteria accessibility

Feature to evaluated	Tripartite evaluation scale
Storage room for aids (walker etc.) used moving outdoors located near the entrance	Good level: The criteria are met. Moderate level: There is little storage room, but more can be arranged easily. Poor level: There is no storage room.
…	…
Accessibility of an entrance and a hall of a apartment Free door opening width min. 850 mm and height 1950 mm, threshold height max. 25 mm. Front doors with double door leafs are troublesome for moving aid users. There should be 400 mm free space on the handle side of the door opening towards. Dimensioning of the hall is sufficient for a wheelchair user (diameter of turning over min. 1300 mm.	Good level: The criteria are met. Moderate level: The criteria are met with moderate alterations. Poor level: The criteria can be met only with significant renovation.

3.4 Criteria safety

The frequency and the severity of the accidents demanding hospital treatment are increasing with age. The significant share of the accident occurs at homes. The majority of the accidents of the seniors are falls. [12] Almost very third aged over 65 years falls at least once a year and more than four out of ten aged over 80 years. Behind the falls of aged under 80 years there are most commonly external factors like slippery surfaces thereafter the internal factors become more significant. [29] Features of physical environment that contribute falling are slippery or wet surfaces, difference of levels, objects along the path and insufficient lighting. Also unfamiliar environments raise the risk of falling. [30] Especially preventing falling in stairs is important. Though falls in stairs are not numerous, the consequences of them are serious. [31] Use of aids in moving sets more challenges to the safety of the environment. Also safe use of appliances must be taken into account, like protecting user from sauna stove by railing. Declined functional capacity set risks in situations requiring escaping. Declined functional capacity slower saving oneself and calling for help and sometimes make it impossible. [32]

Preventing burglary and vandalism are included in safe housing. Crimes often take place in densely populated areas like the city centers. Though becoming a victim of a crime is rare and the seniors are statistically most unlike victims, they worry the most. Characteristics of the building affect likelihood of the dwellers or the building itself to become a victim of a crime or vandalism. Characteristics affect also experience of safety and so they may also affect dwellers willingness to move outdoors or use common facilities. [32]

Table 3 Examples of the criteria safety

Feature to evaluated	Tripartite evaluation scale
Safety and easy use of stairs Stair flights are straight or helical stairs wind around large opening and the run is min. 310 mm also in inner side of the stairs. There is level to rest between two floors. The rise of step is max. 160 mm and the run min. 310 mm. There are round shaped handrails, 120-160 mm round, on both sides on the stair flight fixed 900 mm above floor level. The surface material of steps is not slippery. The edges of steps are clearly visible. There aren't free openings between steps or there are laths on rear edge of the steps preventing objects from falling or feet slipping through.	Good level: The criteria are met. Moderate level: The criteria are met with moderate alterations. Poor level: The criteria can be met only with significant renovation.
…	…
Door telephone	Good level: There is a door telephone. Moderate level: There is a combination lock in the front door. NB: not suitable for dwellers with memory disturbances Poor level: There is no door telephone and the front doors are open in the daytime.

3.5 Criteria presbyopia and presbyacusis

The normal worsening of vision with age presbyopia, affects everyone. The most common symptom is worsening of near vision. [15] Also extreme sensitivity to glare, reduced contrast sensitivity and slowed adaptation to changing brightness are age-related. Weakened vision hinders executing daily tasks and increases risks of accidents like falling and taking wrong medication. [34] Color recognition stays also in high age. The red and yellow hues are best recognized. [35] Especially patients suffering from Alzheimer's disease recognize reds and yellow better than blue or green hues. [36]

Presbyacusis is normal decline of hearing associated with age which occurs without contribution of any disease. Approximately two thirds of aged 75 years or older have at least mild hearing impairment. Typical features of presbyacusis are declined capacity to separate high frequencies, recruitment and declined recognition of direction wherefrom the sound comes. Often word recognition is low compared to hearing decline especially in background noise. Weakened hearing can bring on risks if the signals of appliances, like smoke alarms, are inaudible. [16]

Good lighting for senior dwellers is efficient and smooth, but the contrasts are clear especially in risky areas like between steps, different levels, and, doors and wall. Glare and reflections should be avoided. In choosing colors for objects which are meant to be recognized like handrails and signage the red and yellows hues should be preferred. Size of the letters and figures in signs should be large enough. In good acoustic environment the background noise and long reverberation time should avoided. Logical reflection of sounds is also important, as it helps picking up the speaker from the group. High frequencies should not be used in signal sounds.

Table 4 Examples of the criteria presbyopia and presbyacusis

Feature to evaluated	Tripartite evaluation scale
Lighting in the staircase Lighting is efficient, smooth and not glaring. There aren't dark areas in the staircase. On passages the lighting power should 100 lx and in stairs 150 lx. The lighting highlights the vertical and horizontal surfaces of the stairs and differences between levels. In good lighting the signage in readable and peoples' faces are recognizable.	Good level: The criteria are met. Moderate level: The lighting is a bit too dim and unsmooth and glary Poor level: The lighting is dim and efficiency varies a lot. The lighting is insufficient in stairs.
…	…
Acoustics is staircase	Good level: There is no disturbing echoing. Moderate level: There is a bit of echoing hindering word recognition. Poor level: There is a lot of echoing in the staircase.

3.6 Criteria memory disturbances

Normally cognitive functions slower with age and especially episodic memory weakens but these changes don't restrict executing daily task. Ability to learn new things stays in high age. It only takes longer time and distractions play larger role. If the daily tasks can't be executed normally the reason is usually pathologic status or temporary disorder. [37] The prevalence of dementia, MMSE score < 25 [3], is 8.8% among the population over 60 years of age and more than every third of those aged 80 and over suffers from dementia. [4] And even more suffer from milder memory disturbances since the early symptoms of dementia are often not diagnosed. [37] Patients with mild dementia are able to live independently but in moderate phase independent living starts to become impossible. The dementia is the most important reason for institutional care among the elderly. [38]

Typical symptoms for mild dementia is forgetting recent events, losing things, leaving electric appliances turned on, problems in executing complicated tasks and worsening of orientation in place and time. Spatial disorientation is frequently observed with individuals aged 70 and over who show no other sign of mental deterioration. Unfamiliar and monotonic environment are challenging for people with memory disturbances. [39] Changing floor by using a lift has been proved to confuse orientation of people with moderate dementia. [40] Landmarks are particularly useful in orientation for the elderly. Distinctive and natural landmarks can be used in wayfinding still in moderate dementia. In moderate dementia logical thinking, ability to concentrate, perceptive skills and recognition of people and things decline significantly. [39] Strong patterns in floor covering can be recognized as level changes [21] [40] and glossy covering as slippery. [39]

The elderly with memory disturbances can make use of the signs even though ability to comprehend written text starts to decline with moderate dementia, but single words can still be effective in orientation. [39] Therefore signs should be kept simple, because numbers are easily forgotten, color codes or abbreviations don't work and there is little information about intelligibility of pictograms. [39] [40] The positioning of signs has to be planned carefully since Alzheimer patients' have difficulties in distinguishing relevant information from irrelevant and they can make nonsense links between closely situated messages. [40]

Built environment suitable for seniors with memory disorders should include hints and landmarks to support memory, executing complicated tasks and orientation in place and time. Patterns which could cause false perceptions should be avoided. Signs should be kept simple and intelligible and installed on proper height.

Table 5 Examples of the criteria memory disturbances

Feature to evaluated	Tripartite evaluation scale
Appearance of the entrance To help orientation the entrance should stand out from the façade.	Good level: the entrance is highlighted by pilasters, canopy, etc. Moderate level: the front doors separate from doors of storage rooms but the entrance doesn't clearly stand out. Poor level: the entrance merges with the façade. Front doors are alike with doors of storage rooms etc.
…	…
Clarity of the staircase Layout of the staircase is clear and intelligible. It is easy to orientate in ground floor and upper floor(s). There aren't blind spots which would weaken orientation and also increase the risk of vandalism.	Good level: layout is clear and orientation is easy. Moderate level: layout is a bit messy or there might be minor blind spots. Poor level: layout is confusing. There are blind spots and some door are located "behind the corner".

4. Discussion

The first ten apartment buildings are evaluated with the method. According to first experiences the information gathered by collecting documents, interviewing and surveying is adequate to perform the evaluation. The survey of the building didn't turn out to be very laborious if the planning permission drawings are gathered beforehand. They enable studying to building in advantage. In most of the cases the quality and availability of planning permission was good. The interviews gave valuable extra pieces of information for example from user experience which is not usually documented. Only source of information which turned out to be less productive were the condition assessment reports. The information they provided wasn't very usable in suitability or habitability evaluation. Their focus varied a lot. Some of them were more general and some focusing only technical condition of specific building parts like sandwich elements of exterior walls.

The evaluation itself was more laborious. There are many details effecting suitability and studying the layouts and dimensions properly takes time. Also judging between steps of tripartite scale was sometimes difficult. Adding more partitions to method wouldn't make the task any easier. One weakness of the evaluation method is the subjectivity of the evaluation. Some of the evaluated features cannot be evaluated totally objectively or at least criteria cannot be written watertight. Good example of this dilemma is evaluating the appearance of the entrance (see table 5). Otherwise the evaluation work was executed straightforward. The expertise in architecture, construction and in seniors' needs helps a lot in evaluation work. Without expertise the criteria should be more detailed and thereby more laborious. The same applies to most of the studied evaluation methods. [18] [19] Some of them require even more expertise. [20] [21]

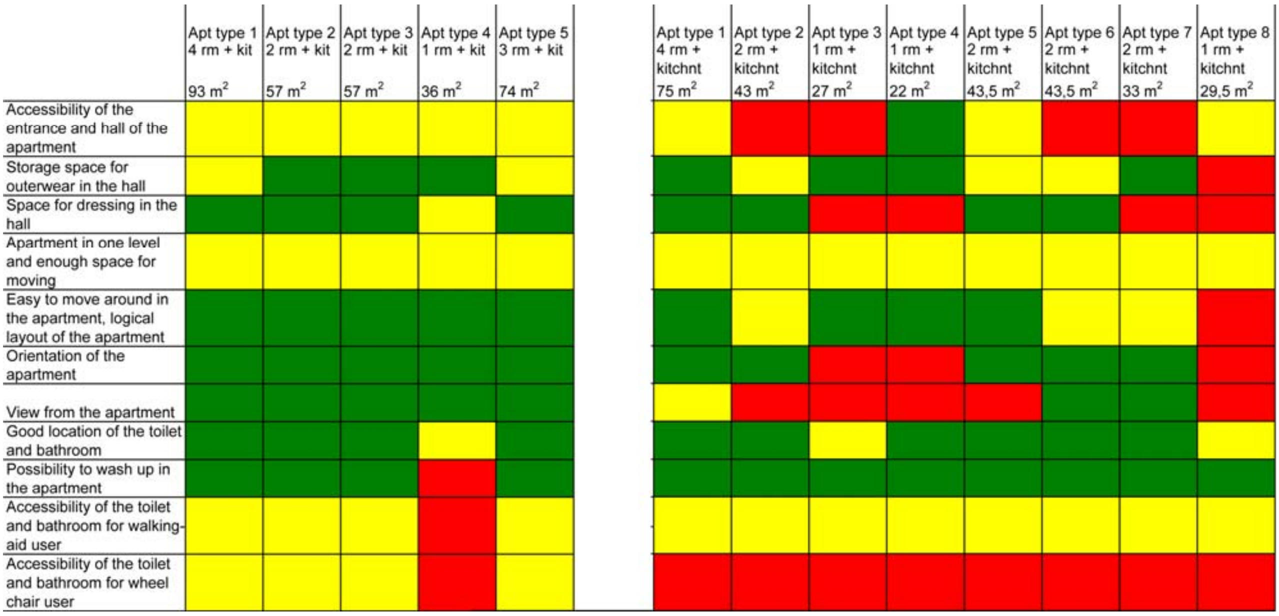

Fig. 1 Excerpt of evaluation of apartments of two separate apartment buildings (colors: green - good, yellow - moderate, red - poor)

The results of the evaluation are illustrative (see fig 1) as the objective was. Simple comparison between several buildings can be done with a glance. The information produced by the method can be used in early phase of the renovation planning and also as a checklist during the further planning. In detail planning there are more useful methods like ARVI or WoonKeur which are aimed for new construction and contain plenty of detail information. [17]

The method is flexible. The evaluation can be done from one or more points of view or the evaluation can focus specific parts of the building like the common facilities. The evaluation of whole building illustrates overall picture of the suitability and habitability for senior dwellers.

5. Final comments

The method was proved to be useful in evaluating existing apartment building stock. The basic structure of the method is practical. Naturally there are some features which must be refined and developed further. Adding more partitions can be done if needed. It could be sensible to study possibility to add importance factors to certain features which are considered the most important in specific case. The method could be widened to apply also detached houses and row houses.

6. Conclusions

The evaluation serves as the first phase of project planning. It provides information where the renovation work should be aimed to improve the suitability and habitability. The information produced by the evaluation method benefits also senior dwellers when they are purchasing a new apartment or planning the future of their current apartment. The information benefits housing corporations in planning their strategy. Especially corporation owing several buildings can target most suitable buildings to senior housing and the others to other dweller groups. The information is also useful for home help and service providers who can tune their products according to specific setting. The information about suitability and habitability benefits all the dwellers as the accessible, safe and intelligible apartment building is convenient for most of the dwellers.

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Residential energy consumption patterns in Finnish households

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Summary

Promoting higher energy efficiency is one of the focus areas of current policies intending to advance more sustainable future. Buildings and residential energy consumption, heating, cooling and operation of the residential buildings as well as household electricity use, are in the focus as the share of these is estimated to be 30-40% of the global energy use. Despite extensive research around the issue, there still seems to be a gap in the literature on the overall energy consumption patterns of different types of households living in different types of areas. This is due to three factors. First, when actual consumption data is utilized, it may well appear that the energy consumption deviates significantly from the theoretic efficiencies due to just user behavior. Second, it is not enough to look at the energy consumption on an apartment level as a large share of energy use, especially heating energy in apartment buildings, relate to communal spaces and the majority of the operational and maintenance activities require energy that is communal in nature in apartment buildings. Finally, residential spaces other than the primary residence, such as summer cottages and other second homes, increase the overall energy use. In this study we take a step towards filling this gap. We conduct a comprehensive analysis on the energy consumption patterns in Finnish household taking into account heat and electricity on both communal and household direct consumption levels. We take into account possessed summer cottages and other second homes. We calculate the energy requirements of average households living in different types of areas in Finland using a four category division of Helsinki Metropolitan Area (HMA), (other) cities, semi-urban areas and rural areas. We utilize statistical data of Statistics Finland and Metla including statistics on housing companies and household expenditure data to put together a comprehensive analysis. The results show that when the overall energy requirements of operating apartment buildings is taken into account, the differences in housing energy consumption of households living in different types of areas are small. In fact, whereas the overall energy requirements are slightly lower in apartment building dominated cities on household level, in less urbanized areas less energy (in kilowatt hours) is used on both per capita and per square meter, and the share of renewable fuels in the energy-mix is higher.

Keywords: energy, energy use, energy requirements, household, building, residential, renewable, non-renewable, lifestyle

1. Introduction

Promoting higher energy efficiency is one of the focus areas of current policies intending to advance more sustainable future. Lower energy demand would both decrease the greenhouse gas emissions directly and accommodate the transition towards renewable energy sources. Urban areas and urbanization seem to play a central role, as according to the International Energy Agency, the urban areas are accountable for approximately two thirds of the global energy use [1].

Improvements in energy efficiency can occur on any products or production process. Buildings and residential energy consumption, heating, cooling and operation of the residential buildings as well as household electricity use, are in the focus in urban planning as the share of these is estimated to be 30-40% of the global energy use [2]. Residential energy is also the single largest source of energy demand from the consumer perspective [3-6]. As a consequence, housing energy use has been studied extensively. However, these studies have largely concentrated on the overall energy requirements of different types of households or consumers with comparisons between the energy requirements related to different consumption categories, e.g. [5, 7-9]. On the other hand, an extensive body of literature exists that focuses on just the building related energy requirements. These predominantly compare the energy requirements related to different building characteristics or between building life cycle phases [10-12]. Especially related to urban sprawl research, studies that compare urban core and suburban areas exist, which often look at both the residential energy use and energy related to transportation. The traditional conclusion of these studies has been that a more dense or compact urban form can reduce the energy consumption due to reduced living spaces and multi-story apartment buildings replacing detached houses [13-15].

Nevertheless, there still seems to be a gap in the literature on the overall energy consumption patterns of different types of households living in different types of areas. Firstly, when actual consumption data is utilized, it may well appear that the energy consumption deviates significantly from the theoretic efficiencies due to just user behavior [16, 17]. It may also be that the fiscal incentives lead to significantly different behavior. For example, in an apartment building with central heating and/or cooling the residents often have little incentives to save energy and may even be unable to affect the majority of the energy use [18]. Heating and cooling energy tend to be embedded in housing management and rental payments and thus don’t create fiscal incentives for energy efficient behavior. On the other hand, in detached houses the residents pay for their energy use directly and thus also gain directly from energy saving behavior. Secondly, it is not enough to look at the energy consumption on an apartment level as a large share of energy use, especially heating energy in apartment buildings, relate to communal spaces [18]. Also, the majority of the operational and maintenance activities require energy, which also adds to the communal energy share in apartment buildings. Finally, when the energy requirements of households are concerned, spaces other than the primary residence increase the overall energy use. Living in a less spacious city apartment may be compensated by summer cottages and other second homes and by increased use of public spaces such as restaurants, cafés and hotels [19].

In this study we take a step towards filling the described gap by conducting a comprehensive analysis on the energy consumption patterns in Finnish household taking into account heat and electricity on both communal and household direct consumption levels. We take into account possessed summer cottages and other second homes, but leave out services related space use due to data restrictions. We calculate the energy requirements of average households living in different types of areas in Finland using a four category division of Helsinki Metropolitan Area (HMA), (other) cities, semi-urban areas and rural areas. We utilize statistical data of Statistics Finland and The Finnish Forest Research Institute (Metla) including statistics on housing companies and household expenditure data to put together a comprehensive analysis. The results show that when the overall energy requirements of operating apartment buildings are assessed, the differences in housing energy consumption of households living in different types of areas are small. In fact, whereas the energy requirements are slightly lower in apartment building dominated cities on household level, in less urbanized areas less energy (in kilowatt hours) is used on both per capita and per square meter.

The remainder of the paper is structured as follows. In Section 2 the methods, data and the research process are explained. Section 3 shows the results and Section 4 discusses the findings and their significance as well as evaluates the robustness of the results. Finally, Section 5 presents the key conclusions of the study and sets the path for extensions of the study in the future.

2. Methods, data and research process

The study concentrates on calculating the overall residential space related energy requirements of average households living in different types of areas in Finland. For the area types we utilized the categorization of statistics Finland that separates three different area types in Finland based on the degree of urbanization on municipality level: cities, semi-urban areas and rural areas. To achieve a more informative selection, we further disaggregated Helsinki Metropolitan Area from other cities, thus ending up with four different types of areas. Table 1 shows some main characteristics of the four areas to depict the differences important for the housing energy requirements.

Table 1 The main characteristics of the four area types of the study.

Area / Characteristics	*HMA*	*Cities*	*Semi-urban areas*	*Rural areas*
Definition (stat.fi)	*Four cities: the capital Helsinki and its neighbors Vantaa, Espoo and Kauniainen. Area's total population is about one million and it forms an inseparable entity of workplaces, public transport etc.*	*"municipalities in which at least 90 per cent of the population lives in urban settlements or in which the population of the largest urban settlement is at least 15,000"*	*"municipalities in which at least 60 per cent but less than 90 per cent of the population lives in urban settlements and in which the population of the largest urban settlement is at least 4,000 but less than 15,000"*	*"municipalities in which less than 60 per cent of the population lives in urban settlements and in which the population of the largest urban settlement is less than 15,000; and those in which at least 60 per cent but less than 90 per cent of the population lives in urban settlements and in which the population of the largest settlement is less than 4,000"*
Average family size	*1.93*	*2.05*	*2.27*	*2.33*
Housing types				
- Apartment	*72%*	*60%*	*32%*	*14%*
- Terraced/detached	*27%*	*40%*	*67%*	*86%*
Heating modes				
- Electricity	12%	21%	28%	36%
- District heat	81%	60%	29%	14%
- Oil	5%	14%	22%	20%
- Wood	0%	3%	11%	18%
- Other	2%	9%	10%	12%
Living space per household (m2)	*76*	*82*	*103*	*103*
Area density (households/km2)	688	*40*	*7*	*2*

We comprised three data sets in the study to create a comprehensive picture of the actual energy requirements of the average households living in each of the four types of areas. The primary data is formed by the Household Budget Survey 2006 of Statistics Finland [20], which is the most recent budget survey conducted in Finland. The survey comprises the private consumption of Finnish households according to the international CIOCOP categorization. In the study, the category 4.5 "Electricity, gas and other fuels" was separated from the rest of the data. The data was complemented with an assessment of the energy expenses embedded within rental payments and housing management charges in the Household Budget Survey. The disaggregation of the housing management charges was done according to the data of Statistics Finland on the finances of housing companies in Finland [21]. Table 2 shows the distributions of energy expenses within housing management fees in Finland. Different distributions were used for HMA and the rest of the country to avoid biases from the higher housing costs in HMA.

Table 2 Energy expenses embedded in the housing management fees in Finland.

Shares of energy in the housing management charge	*HMA*	*Rest of the country*
- Electricity	*3%*	*5%*
- Heat	*20%*	*25%*

To add the energy embedded in rental payments into the analysis, we first disaggregated the rents to housing management charges and other, and then further to energy and other costs according to the shares depicted in Table 2. To extract the housing management charges from rental payments we assumed that the average rent in each area comprises a housing management charge similar to the average housing management charge in the area. We also separated the primary apartment related energy expenses from those related to summer cottages and other second homes. Table 3 depicts both the direct energy purchases extracted from the Household Budget Survey and the assessed values for the energy paid within housing management fees and rental payments.

Table 3 Average households' annual energy purchases for primary homes in the different area types in Finland.

Area / Purchase value (€/a)	*HMA*	*Cities*	*Semi-urban areas*	*Rural areas*
Direct energy purchases				
- Home electricity	374	516	740	860
- Heating oil, etc.	74	132	231	212
- Firewood	13	53	172	230
- District heat	129	134	74	69
Total	*591*	*835*	*1,218*	*1,371*
Indirect energy purchases				
Housing management charges	*1 111*	*615*	*326*	*172*
Housing charges paid within rents	*850*	*596*	*369*	*314*
Of which				
- electricity	54	60	34	24
- district heat	375	244	87	39
- oil and other	19	47	89	85
Total	*358*	*274*	*148*	*147*
Overall energy purchases	*1,043*	*1,202*	*1,428*	*1,518*

Next we repeated the same process with summer cottages and second homes. The only difference in the analysis is that we used the Finnish average percentages for energy costs embedded in the housing management charges: electricity 4%, heat 24%. This choice was done since the locations cannot be traced from the utilized data. Table 4 shows summer cottages and second homes related annual energy expenses in possession of the average households of each area.

Table 4 Average households' annual energy purchases for summer cottages and secondary homes in the different area types in Finland.

Area / Purchase value (€/a)	*HMA*	*Cities*	*Semi-urban areas*	*Rural areas*
Direct energy purchases				
- Home electricity	77	45	40	31
- Heating oil	5	1	0	1
- Firewood	5	4	4	5
- District heat	10	9	24	19
Total	*96*	*59*	*68*	*56*
Indirect energy purchases				
Housing management charges	*20*	*15*	*39*	*23*
Housing charges paid within rents	*41*	*32*	*18*	*18*
Of which				

- electricity	3	2	2	2
- district heat	11	8	10	7
- heating oil	4	3	4	3
Total	*18*	*13*	*16*	*12*
Overall energy purchases	*114*	*72*	*84*	*68*

To convert the monetary expenditures into energy consumption, energy prices for the reference year 2006 were retrieved from energy statistics of Statistics Finland for electricity, oil, and district heat [22]. The energy prices for each of the areas were calculated by taking into account the distribution of the building types in each area as depicted in Table 1. Oil prices are the spot market prices for Finland as a whole, but the prices of both district heat and electricity decrease along the size of the annually purchased amount. Electricity price is thus lower for detached houses using electricity for heating and district heat for the largest housing companies. Table 5 comprises the utilized energy prices the different area types, calculated according to the building type distribution in each area.

Table 5 Energy prices for oil, electricity and district heat in the different areas.

Average price (cent/kWh) / Energy type	*HMA*	*Cities*	*Semi-urban areas*	*Rural areas*
- Electricity	11.0	10.4	9.4	8.7
- Heating oil	5.85	5.85	5.85	5.85
- District heat	4.52	4.57	4.67	4.74

At this point we also employed the above mentioned third data set to assess the energy from domestic burning of firewood. There is a lack of data for firewood prices for the reference year 2006, and the method to report wood values in the Household Budget Survey are likely to lead to significant underestimation of wood usage in households with fire places and wood heated saunas. The third data set is provided by Metla, and it comprises the firewood use in detached houses and terraced houses in Finland based on the burned quantity. According to the data, a household living in a detached house in Finland burns an average of 3.2 m3 of firewood per annum [23]. However, in the Southern Finland the annual amount is only less than half of the national average, 2.1 m3 per annum, and thus we utilized this figure for detached type primary homes in HMA. The respective amount in terraced houses is approximately 0.4 m3 per annum. No data were available to distinguish HMA from the rest regarding terraced houses, but the amount is such small that the impact for the energy assessment is insignificant.

According to the same data, approximately 1.8 m3 of firewood is used at a summer cottage per annum, which was used to assess the overall energy use related to summer cottages in possession of the average household in each area type. The figures for the summer cottages in possession were retrieved from the primary data, Household Budget Survey, according to which 25% of the households in HMA possess a summer cottage or such, 22% in other cities, 23% in semi-urban areas and 20% in rural areas.

To calculate the energy content of the burned firewood we used two conversion factors. First, according to Alakangas the heating value of firewood is 1.25 MWh/m3 [. Second, a one m3 stack volume of firewood is equivalent to 0.67 m3 of full firewood.

Finally, according to the purchases, unit prices and the quantity information for firewood, we calculated the overall annual energy use of the average households in the different types of areas (in kWh/a). In addition, we also calculated the figures on per capita basis and on per square meter (m2) basis. The results are presented in the next section.

3. Results

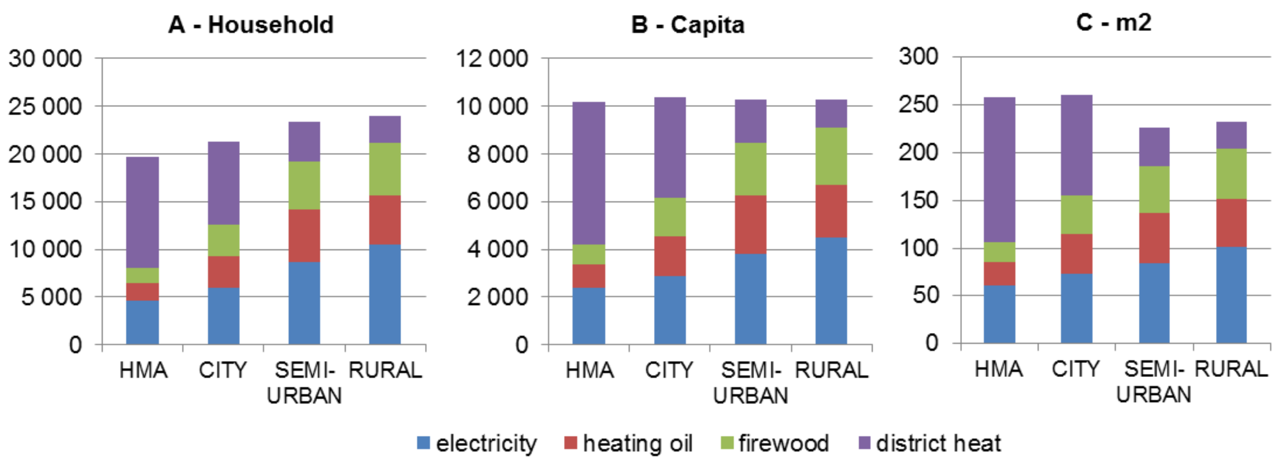
Complying with many previous studies, the households living in the least urbanized areas seem to have on average the highest annual energy consumption according to the study. In rural areas the annual amount of energy use is 24,000 kWh, in semi-urban areas 23,400 kWh, in cities 21,300 kWh and in HMA 19,700 kWh. Approximately 90% of the annual energy use is related to the primary residence in each of the areas, from the lowest 88% in HMA to 93% in rural areas. Summer cottages and other second homes contribute between 1,600 kWh (rural areas and cities) and 2,200 kWh (HMA) annually to the overall energy use of the average households.

As the monetary purchases depicted in Section 2 already indicated, the distribution of used fuels is but equal between the areas. When looking only at the primary residence, electricity use more than doubles from the average of 3,900 kWh/a in HMA to 10,200 kWh/a in rural areas. Cities are closer to HMA with 5,500 kWh/a, and semi-urban areas to rural areas with 8,300 kWh/a. Reversely, 11,100 kWh/a of district heat is used in HMA, but only less than 2,300 kWh/a in rural areas. Again, cities are closer to HMA, and semi-urban areas follow the pattern of rural areas. Oil and firewood are both sources of slightly lower importance, but both are used significantly more in the less urbanized areas. Table 6 depicts the overall energy use of the average households in the different areas divided into the primary residence and summer cottages and other second homes.

Table 6 Annual average energy use per household in the four area types in Finland.

	HMA	*Cities*	*Semi-urban areas*	*Rural areas*
PRIMARY HOME				
home electricity	3,420	4,940	7,900	9,930
communal electricity	490	570	360	280
heating oil	1,680	3,330	5,480	5,060
firewood	770	2,580	4,220	4,880
district heat	11,140	8,280	3,450	2,270
TOTAL	*17,500*	*19,690*	*21,410*	*22,410*
SUMMER COTTAGES AND OTHER SECOND HOMES				
home electricity	700	410	360	280
communal electricity	20	20	30	20
heating oil	150	60	60	60
firewood	840	740	770	670
district heat	470	380	720	560
TOTAL	*2,180*	*1,620*	*1,950*	*1,590*
OVERALL	**19,680**	**21,310**	**23,360**	**24,010**

When the energy use is looked on per capita and per m2 levels the differences even out significantly. However, due to the differences in the household sizes, on per capita level the energy use is almost equal in all the areas at 10,200-10,400 kWh. On the per m2 level the results are actually reverse if only the reported living spaces are taken into account; 230 kWh/m2/a in HMA, 240 in cities, 220 in the two least urbanized areas. Figures 1 A-C depict how the functional unit affects the results.



Figures 1 A-C The annual energy use (kWh/a) in the different area types in Finland measured in different functional units.

One additional interesting perspective is to look at how the utilized fuels are distributed between renewable and non-renewable sources. If first firewood use is erased from the energy use figures, a very similar quantity is used annually in all the areas even on a per household level: 18,100 kWh

in HMA, 18,000 in cities, 18,400 in semi-urban areas and 18,500 in rural areas. Looking these figures in per capita terms shows that in the more urbanized areas, HMA and cities, more kilowatt hours are used when wood is omitted from the figures: 9,400 kWh/a in HMA, 8,800 in cities, 8,100 in semi-urban areas and 7,900 in rural areas. On per m2 level the differences now appear as relatively large, from 240 kWh/a in HMA to 220 in cities and 180 in semi-urban and rural areas.

The analysis on renewables–non-renewables can be taken further by looking at the production fuels at the power plants in Finland. To facilitate the analysis we adopted an assumption that in all four areas the Finnish average energy, both electricity and heat, is used. In electricity production the Finnish average fuel distribution consists of 34% of renewables, 34% fossil fuels (coal, natural gas, oil) and peat, and 32% of nuclear power [25]. District heat is produced largely as combined heat and power production (CHP) where fossil fuels dominate. In heat production the share of coal, natural gas, oil and peat is approximately 75% [25].

Now, if the overall annual energy use of the average households in each area is divided into renewable fuels, nuclear power and other non-renewables, in all the areas a rather equal amount of non-renewable fuels seem to be used. On per capita basis less non-renewable fuels are required for the energy use in the less urbanized areas. Figure 2 shows the distributions.

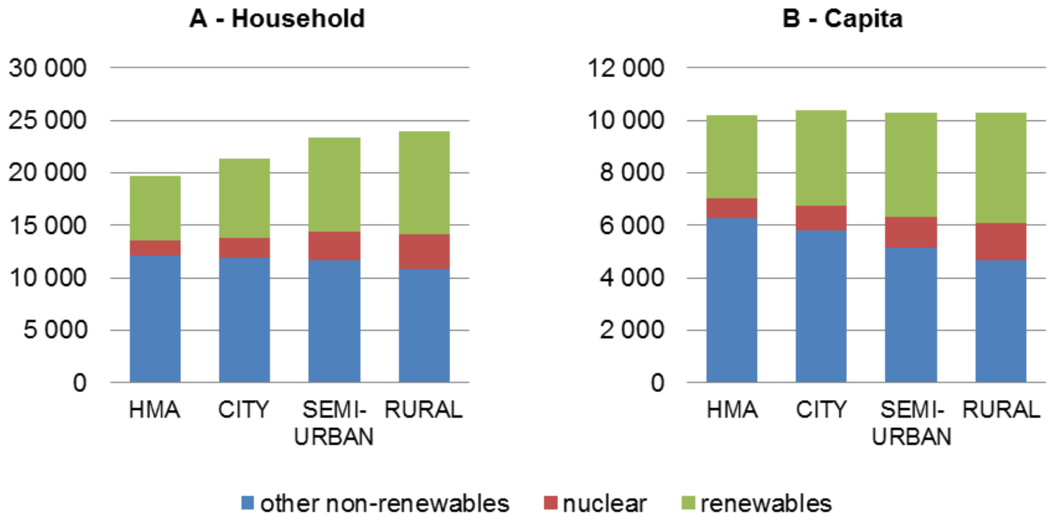


Figure 2 A-B The shares of renewable and non-renewable fuels in the annual average energy use in Finnish households (kWh/a) on per household and per capita basis.

4. Discussion

The study was set to conduct a comprehensive analysis on the energy use patterns of the average households in Finland living in different types of areas. The motivation for the study is that even though the energy requirements of both buildings and households have been studied extensively, not many studies have approached the issue with actual consumption data. There are considerably different incentives for energy efficient behavior related to different types of residences, especially between homeowners living in detached houses and households living in housing company operated apartment buildings (see e.g. [18]). Thus, while it is obvious that in theory more energy is used in the more spacious detached houses, the actual differences may appear much smaller just due to distinct user behavior.

In addition, to get a comprehensive picture of the energy requirements of households living in different types of residences, it is not enough to consider their direct own apartment related energy. This would strongly favor apartment buildings where a significant amount of energy is needed for heating and lighting the communal spaces of a building, operate elevators, heat communal saunas etc. [18]. Even the building maintenance doesn't show in the direct energy use of a certain household in an apartment building, but is embedded in housing management charges or rental payments. Finally, households living in different types of surroundings may have different incentives to possess and use summer cottages and other second homes, which should be taken into account when comparing the energy use of households.

We chose to calculate the energy requirements of average households living in different types of areas in Finland using a four category division of Statistics Finland of Helsinki Metropolitan Area (HMA), (other) cities, semi-urban areas and rural areas that together include the whole Finland. As indicated in Table 1, the characteristics of the average households in these four types of areas deviate significantly from each other providing thus a good basis for an analysis of the study.

The study depicted that in overall terms the household energy requirements are the lowest in the most urbanized areas of HMA and cities with an approximately 20% increase from HMA to rural areas. As Table 1 shows, the household sizes also increase towards the less urbanized areas and thus the difference is reduced to almost zero on per capita level despite the more spacious residences in the less urbanized areas. This would indicate that the above stated assumption of distinct incentives to energy efficient behavior indeed has an impact on the actual energy use.

The share of energy use related to summer cottages and other second homes is only 7-12% of the overall annual use. The differences are not huge, but in absolute terms a household in HMA uses 2,200 kWh/a to operate a summer cottage or second home, approximately 600 kWh more than a household in rural areas and in cities, and slightly more than a household in semi-urban areas. The households in the less urbanized areas also seem to own city apartments since they seem to purchase more district heat for their second homes than the households in the more urbanized areas.

To get a comprehensive comparison of energy use in different types of contexts, we also assessed firewood use that is often neglected in similar assessments. Firewood actually appeared to be in a relatively significant role, especially in the less urbanized areas where detached houses dominate housing modes. The share of over 20% of overall energy use in the less urbanized areas can be interpreted as further evidence of behavior intending to save on energy consumption. The firewood used in detached houses is often own or benefit-in-kind and thus decreases the energy bills. If firewood is omitted from the comparison of energy use, the result is interestingly that the differences on per household level are greatly reduced and on per capita level the less urbanized areas appear as more energy efficient.

When the analysis of the use of renewable and non-renewable fuels was taken further, the result was interesting, as on per household basis the amount of non-renewable fuels required annually is almost equal between the different areas. On per capita basis the absolute amount of non-renewables steadily increases towards the more urbanized areas and the amount of renewables decreases.

The results of the study actually comply with many earlier studies even though the overall findings indicate that living in less dense less urbanized areas in detached houses is not necessarily very energy intensive compared to apartment buildings in the more urbanized areas. On per household basis the average energy use seems to be higher in the less urbanized areas. The difference is even relatively significant if only the energy related to just the living space is taken into account, and the communal energy use in apartment buildings omitted. This is in accordance with e.g. Fuller and Crawford (2011) who hypothesize, concerning Australia, that energy use would increase significantly towards the less urbanized areas, but explain the increase predominantly with rapidly increasing living space [26]. Norman et al. (2006) present very similar results, reporting energy use to increase significantly towards the less dense suburban areas, but also primarily due to a significant increase in the living space [27]. In Finland the differences in the living space per capita are not huge, especially if the communal spaces in the apartment buildings would be divided according to the number of residents. Myors et al. (2005) actually report the highest energy use related to high-rise urban core apartment buildings [28]. According to them the efficiency of an apartment building decreases quickly when the height increases due to high operational energy requirements. One explanatory factor in their study is the decrease in the average household size towards the more urbanized areas, as is the case in Finland as well.

There are uncertainties related to the analysis. We combined three different data sets to create an overall picture of the energy use in Finnish households. It might be that calculating the communal building energy based on the housing management fees and rental payments overestimates or underestimates that share, especially the share embedded in the rental payments. A comparison of the household purchases data and the statistics on the finances of housing companies would indicate a relatively good comparability, but deviations are still possible. Yet a more significant uncertainty relates to the assessment of energy from firewood, which was taken from a totally separate data. Further, the presented renewables–non-renewables analysis is subject to uncertainty as we were forced to use the Finnish average energy production fuel distributions for all the areas. In reality there are significant variations in the fuel mixes between individual power plants which might cause certain area to deviate from the presented patterns. Finally, it can be argued that heat and electricity consumption should not be summed and compared. Primary energy coefficients could be one possible solutions to increase the robustness of the analysis from this perspective. In the future this kind of extension to the study should be conducted, but the fact that approximately 70% of the district heat in Finland is produced as CHP production adds complexity to such an analysis as well.

5. Conclusions

The primary conclusion based on the study is that the actual energy use cannot be estimated solely based on the theoretical characteristics of a residence. Two factors, the different incentives to save on energy and the communal building energy, that doesn't show in the direct energy use of a household, significantly narrow down the differences between households living in different types of contexts. Secondly, the most reliable level in energy use analyses might be the per capita level instead of household and the results also suggest that the traditional per m2 measurement of energy consumption is misleading. In the study we depicted how the different functional units return very different outcomes, the household level leaving the less urbanized areas worse off as the average household sizes tend to increase as the level of urbanization decreases. Finally, in addition to the incentives to save energy in detached houses, a significant share of the annual heat requirements seem to be produced with own firewood burning. The amount of renewable fuels should thus be analyzed when comparing the energy use of the residents of different types of buildings and residential areas.

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Renewable Material and Energy
Zero Carbon Potentials in Urban Context

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Summary

Economies all over the world have mainly been based on mineral and fossil raw materials like oil, uranium and metals. These resources are limited in stock and cause severe environmental problems during their life cycle. In this paper two approaches on different scales are suggested to overcome these problems within urban contexts: **Using renewable resources as building materials and for energy generation as well as decreasing energy demand in the building sector.** This multifold approach towards a complex system decreases CO_2 emissions within processes of urban renewal and is applied on different scales: urban building renovation and urban expansions. This paper shows the potential of such an approach as realized in different research and demonstration projects.

Regarding improvements of single buildings renewable resources have a high potential for decreasing energy demand through **urban building renovation**. The project *RenewBuilding* concentrates on the existing building stock and strategies for its environmentally sound retrofit in Central Europe. A number of insulation materials from renewable resources can be used for retrofitting: straw, reed, hemp, flax and sheep wool, but also regional materials like clay and further recycling products are considered. Renewable raw materials act as CO_2 sinks during their growth period and CO_2 storage after being implemented as a building material. They have a low energy demand during the material fabrication stage and can be easily reintegrated into the natural cycle (e.g. by composting) after their use. More and more products of renewable raw materials are certified, for example straw bales, which can be used to insulate walls, roofs, or top-floor ceilings and thereby save a relevant amount of heating energy varying from typology to typology. The potential of renewable materials is explored not only in small-scale rural renovation projects, but also in urban renovation, for example insulation of the top-floor ceilings with straw bales, interior insulation of buildings under preservation order, or attic conversions, executed in the inner districts of Vienna.

In order to achieve zero carbon solutions in an urban context multidimensional strategies have to be employed. In the **urban expansion** project *Zero Carbon Village*, a demand-matching energy supply system and regional renewable building materials in prefabricated modules form the core concept. Zero Carbon Village in Traismauer (Austria) is planned to consist of residential buildings, a community center, an innovative energy supply system and infrastructure for eco-friendly mobility concepts. For the prefabrication of building elements, wood frames insulated with straw bales, a “virtual factory” concept has been developed – connecting different enterprises to organize planning, production, transport and building more efficiently. CO_2 emissions are not only reduced by this use of renewable materials in a resource-efficient way, but also by innovative processes of energy production, above all by replacing electric energy with thermal energy. The supply system is based on thermal solar energy combined with a biomass backup and adequate storage systems and provides thermal energy that is used for thermal energy services in households like cooking, washing or cooling. *Zero Carbon Village* shows the compatibility and synergies of efficient energy systems and building materials of renewable resources and the potential for expansion regions of

urban peripheries.

The multifold approach of using renewable resources and decreasing energy demand is applicable in cold as well as in hot climates. Transferability has been proved in the Philippines: In the project *Zero Carbon Resorts,* tourist buildings in different cities have been improved by insulation, natural cooling systems and many further interventions on detail levels according to the necessary **climate-sensitive adaptations**.

Keywords: Renewable building materials, renewable energy, urban renovation, urban expansion, climate-sensitive building

1. Introduction

Although cities cover only 2% of earth's surface, they consume 75% of resources and cause 80% of greenhouse gas emissions. [1] The multifold approach of using renewable material and energy efficiently on different scales is a path to less environmental impact, but also poses a number of new questions. Innovative research methods and prototype implementations are indispensable to answer them. The described projects follow assessments of the applied materials and energy performances in order to learn about their environmental impact and to utilize their energy saving potentials.

For urban planning, not only environmental impact and energy saving potentials have been taken into account but also infrastructure, cultural and social demands. Therefore an important first planning step is a sound analysis of local conditions, including parameters for social and environmental targets. In the following projects, urban areas are addressed on different scales: either on small scales as in urban renovation, focusing on improvement of residential buildings and neighborhoods, or on larger scales where settlements are planned and executed in order to serve needs of an urban society.

Considering the whole life cycle of the built environment offers a variety of potentials to decrease CO_2 emissions and to spare resources. Building concepts of the following projects foresee usage of renewable resources that can be recycled, minimize logistic efforts, foster healthy environments and support efficient energy concepts. These relations are considered already in the planning phase. During the building phase energy can be saved substantially, e.g. by efficient prefabrication, but also air pollution, noise emission and soil are decreased, especially at the building site. The design of outdoor areas and surfaces helps to conserve natural balance by using nature-oriented materials and constructions, composting or avoiding soil sealing of larger areas. During the continuous usage energy and water can be saved. [3] At the end of the life cycle specific materials can be recycled.

1.1 Project Aims and Methods

Optimized planning processes and ecologically motivated decisions on material use and energy consumption are addressed:

1. Material: The use of renewable resources and locally available building materials has less impact on the environment and can contribute to save CO_2 emissions due to a lower energy demand for production as well as shorter transport distances. In addition, efficient use of materials in terms of dimensions is promoted as well as consideration of deconstruction from the planning process on: Specific constructions foster recycling, and composting after the use period. By using building techniques appropriate to building materials of renewable resources, structural damages can be avoided. [2]

2. Energy: Energy during the use phase can be saved by improved household appliances and consequently by changed user behaviour as well as by the building design itself; for example natural cooling strategies [4], thermal insulation and passive house components [5] drastically increase efficiency. To reduce the Carbon Footprint a switch from fossil fuel to renewable energy resources which are available at the specific regions is necessary. Emissions and pollution in urban and remote areas can thus be reduced.

1.2 Assessments

Assessments and quality control of buildings can be executed on different levels and foci: Besides building rating programs like LEED (USA) or WBS (Switzerland), the Austrian *klima:aktiv* assessment criteria show a broad approach including architectural quality, site, infrastructure, energy, social quality and economics. [6] A mandatory assessment instrument in Austria is the so-called *Energieausweis*, an indicator computing the energy demand per m^2 and year in accordance with national and European laws. [7;8] Assessment of building materials is a sensitive topic: a big range of different materials is available for building owners and planners. In order to choose the most appropriate, a number of technical and environmental factors have to be considered. Building materials should be non-polluting, have warm surfaces, be humidity balancing, capable of sorption, have pleasant smell, low radioactive radiation, and show high haptic quality. [9] To improve environmental impacts these criteria are complemented by two main strands:

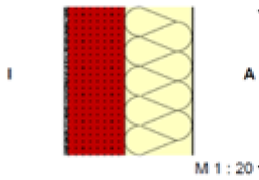
1. Technical parameters (like heat conductivity, heat storage capacity, reaction to fire, vapour diffusion resistance, sound insulation or dimensional stability) are pre-conditions of material decisions for different elements of the building. [10]

2. To minimize negative impact on environment a low PEC (primary energy content of non-renewable resources) in MJ/kg, GWP (Global Warming Potential) in kg CO_2/kg, and AP (Acidification Potential) in kg SO_2/kg, as shown by *Baubook* [11;12] is required.

For comparisons it is important to evaluate the entire construction, not only its components, as shown in figure 1. This figure shows a comparison of a conventional wall element and a wall element constructed with renewable resources, mainly wood and straw bales and their environmental and technical benchmarks. The best performance in that criterion is shown by renewable resources such as straw bales, which can store CO_2 throughout the building's lifetime. [13]

AW brick-EPS

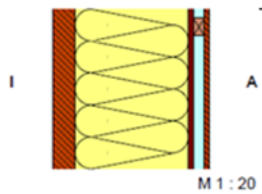
E-I



		d [m]	λ [W/mK]	R [m2K/W]	GWP [kgCO2eq/kg]	PEI n.e. [MJ/kg]	usage period
1	silicate plaster	0,0020	0,8	0,002	0,321	6,260	50
2	Polystirol EPS F	0,3000	0,040	7,500	3,490	102,000	50
3	brick	0,2500	0,415	0,602	0,176	2,390	100
4	cement plaster	0,0150	1,000	0,015	1,560	1,560	100
	heat transfer resistance			0,170			
					GWP	PEI n.e.	
		0,567	RT =	8,289	[kgCO2eq/m²]	[MJ/m²]	75
			U =	**0,12**	97,3216	1093,5	

AW straw-wood

E-I



		d [m]	λ [W/mK]	R [m2K/W]	GWP [kgCO2eq/kg]	PEI n.e. [MJ/kg]	usage period
1	wooden facade	0,0200			-1,690	2,270	60
2	wooden laths	0,0500			-1,600	4,290	60
3	clay plaster	0,0200	0,810	0,025	0,003	0,343	100
4	straw-bales	0,5000	0,045	11,111	-1,250	0,846	50
5	CLT-wood	0,1280	0,130	0,985	-0,080	4,600	100
	heat transfer resistance			0,170			
					GWP	PEI n.e.	
		0,7180	RT =	12,291	[kgCO2eq/m²]	[MJ/m²]	74
			U =	**0,081**	-96,49	390,16	

Fig. 1: Comparison of two different wall constructions. Above: a construction of renewable and local materials from project Zero Carbon Village; below: a conventional wall construction. Own calculation and image

Also, local availability is a core aspect for a low *grey energy* of construction materials, considering the energy demand for transport. Through this, local economies, especially small and medium enterprises, are stimulated by producing and using renewable materials and low carbon technologies for buildings and appliances. [14] Materials and constructions with recycling or composting potentials are preferred.

2. *RenewBuilding*: urban building renovation

The EU LIFE project *RenewBuilding* [18] explores the potential of renewable resources as building materials for renovation. The materials are applied in prototypes of different building elements. Their potential is explored not only in small-scale rural renovation projects, but also in an urban context. Therefore, urban best practice buildings were researched and the realization of a demonstration project in a typical Viennese *Gründerzeithaus* from the period of around 1900 was documented. During the renovation of such houses, besides factors like living comfort, connection to public space, incidence of light, combination of living units or flexibility in function, ecological factors play important roles: reduction of pollutants, energy consumption, protection of resources, recycling of building materials, noise protection and limitation of material variety. [19] Successful renovations with consequent use of building materials of renewable resources in the center of Vienna have been executed in two different best-practice projects that were researched and analyzed within the project *RenewBuilding*: *Erstes Wiener Strohhaus* (First Viennese Straw House) by the architects *allmermacke* [20;18] and an attic conversion of a top floor in Vienna by *pos architekten* [21;18].

Fig. 2: Straw bale insulation of the top floor ceiling at demonstration project near Karmelitermarkt, Vienna, 2nd district: logistics and finished insulated ceiling. Own image

2.1 Renewable building materials, especially for renovation

During the course of the *RenewBuilding* project a top-floor ceiling was insulated with straw bales. About 900 straw bales have been used to insulate the top-floor ceiling of a typical *Gründerzeithaus* as shown in figure 2: An area of around 240 m^2 was completely covered with straw bales of 35 cm thickness, reducing the U-value of the construction from 1,1 W/m^2K down to 0,10 W/m^2K, almost a factor 10 improvement. In an urban context, the acoustic insulation value of straw bales brings about a certain advantage, as the high density provides the necessary level for building parts like ceilings, especially when the insulation layer is not penetrated by timber elements. Future deconstruction is very simple and construction waste can be composted. Giving an example for the potential of ecological consequences, a thermal retrofit with polystyrene insulation of one typical Viennese building block of the period of *Gründerzeit* containing about 10 buildings with top-floor ceiling areas about 250 m^2 each, floor space would produce about 100 t of CO_2 (based on an insulation layer of 32 cm suitable for passive house standard). A similar U-value can be reached using a 42 cm layer of straw bales, resulting in around 160 t of CO_2 being stored within the insulation. [24] A variety of further building materials of renewable resources can be implemented:

cellulose, hemp, reed or flax for example. They also show an excellent compatibility with traditional building elements [25] and hence are especially fit for renovation of historic buildings.

2.2 Energy saving by insulation

Most European cities contain a huge potential of abandoned buildings. If energy demand for production and transport are considered, renovation of vacant buildings is more efficient than demolition and new construction. Thermal insulation substantially reduces the amount of required heating energy. In Vienna, the majority of top-floor ceilings of houses from the period of *Gründerzeit* is not insulated, although a non insulated upper ceiling or roof is responsible for a major heat loss. [22] Especially natural building materials like heavy wood fibre insulation or straw show a high density as well as a high specific heat capacity. These technical characteristics increase living comfort by compensational qualities and can obviate cooling and decrease heating energy at the same time. [23] All renovations in Austria have to present an *Energieausweis* that shows the energy demand [7]. *allmermacke* architects reached an energy demand for thermal heat of about 45 kWh/m^2 [20].

2.3 Individual implementations and maintenance in an urban context

Urban regeneration takes place in individual and small-scale implementations, thus maintaining the existing building stock which often shows great functionality and is of historic value. The use of renewable materials for constructions and surfaces has positive effects on the indoor climate as well as on the microclimate in urban space, e.g. through heat compensation. The presented projects prove reduction of energy demand can be reached with renewable building materials. Furthermore, by use of local materials socioeconomic values are created for the specific regions.

3. *Zero Carbon Village*: multifold approach in urban expansion

The main goal on larger scale is to optimize a complete system by interdisciplinary planning. On this urban scale, thinking and building in compounds, synergies of material and energy enfold their full potential. Zero carbon in the building industry can be targeted by focusing on energy- and resource-efficient solutions and by utilizing renewable resources both for building materials and energy supply. Buildings and settlements can become CO_2 neutral and independent from fossil energy resources. To reach this goal, different solutions have been developed to be implemented in an urban expansion project in Lower Austria, containing a settlement of residential buildings, a community center, an innovative energy supply system and infrastructure for eco-friendly mobility concepts. [15]

3.1 Utilizing renewable materials: prefabrication and regionality

One of the approaches to reach energy- and resource-efficiency is *modular prefabrication*. In this strategy the industrialized production of ecological passive houses and modules leads to lower consumption of energy and resources as well as to reduction of waste and increase in quality. Beside an efficient connection of building envelope and housing technology in a high quality, the modular building elements have the advantage of being easily assembled, disassembled and upgraded after their useful life or when user demands change (*re-use system*). Also, waste as well as time (and energy) can be saved during the building phase. Not only building elements, but also the construction materials can be re-used, recycled or used for energy production, as shown in figure 3. A disposal of materials should always be the last option (*cascades principle*). [16]

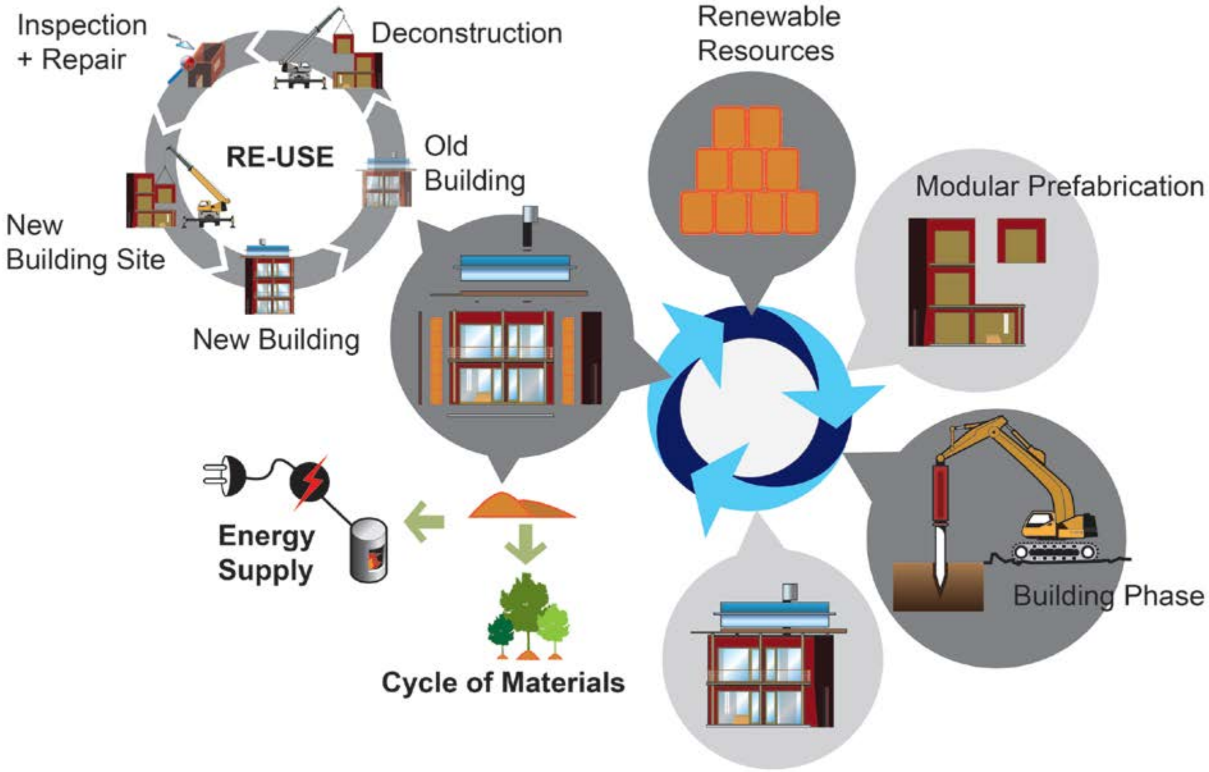


Fig. 3: Life cycle of building materials and components. Own image

A very important step therefore and for decreasing *grey energy* as well as for a good CO_2 balance of a building is the use of *highly energy-efficient and sustainable building materials* based on renewable resources, such as straw bales. Because of the simple production process (the raw material straw only needs to be pressed and tied up) straw bales have a very low primary energy demand. In comparison to conventional insulation materials such as EPS, the production energy is 100 times lower comparing two wall constructions with the same U-value.

In addition to that, sustainable regional building materials are matching the concept of the *virtual factory*: In this concept SMEs (small and medium enterprises) produce building parts in a decentralized way, while a central umbrella organisation takes care of logistics and marketing to increase efficiency and competitiveness. Because of the labour division, which is part of the virtual factory principle, individual enterprises are still able to work in their domain and region and realize major projects together with the partner companies at the same time. Modular prefabrication combined with the *virtual factory* concept is an efficient method of high quality for building manufacturing.

3.2 Thermal-based energy supply

CO_2 emissions are not only reduced by the use of renewable raw materials in a resource-efficient way, but also by an innovative energy supply system, which is planned to be installed in the *Zero Carbon Village*. Most of the conventional appliances in a household are operated with electricity, although they actually provide thermal energy services, for example washing machines or refrigerators. A substitution of electricity with thermal energy avoids energy losses caused by conversion, thus resulting in a lower primary energy demand. [17] The village's energy supply concept is based on the maximum utilization of thermal energy, gained from solar energy and biomass. All thermal appliances are provided as shown in figure 3. Based on the simulation results for the energy balance (input/output) the most appropriate technologies will be chosen to be implemented in the project. The *Zero CO_2 Cooler*, a refrigerator running on hot water, is also being developed in order to be integrated into this system. Through a consequent consideration of the required form of energy it should be possible to reduce the electricity consumption by up to 80%, based on the average consumption for Austrian households.

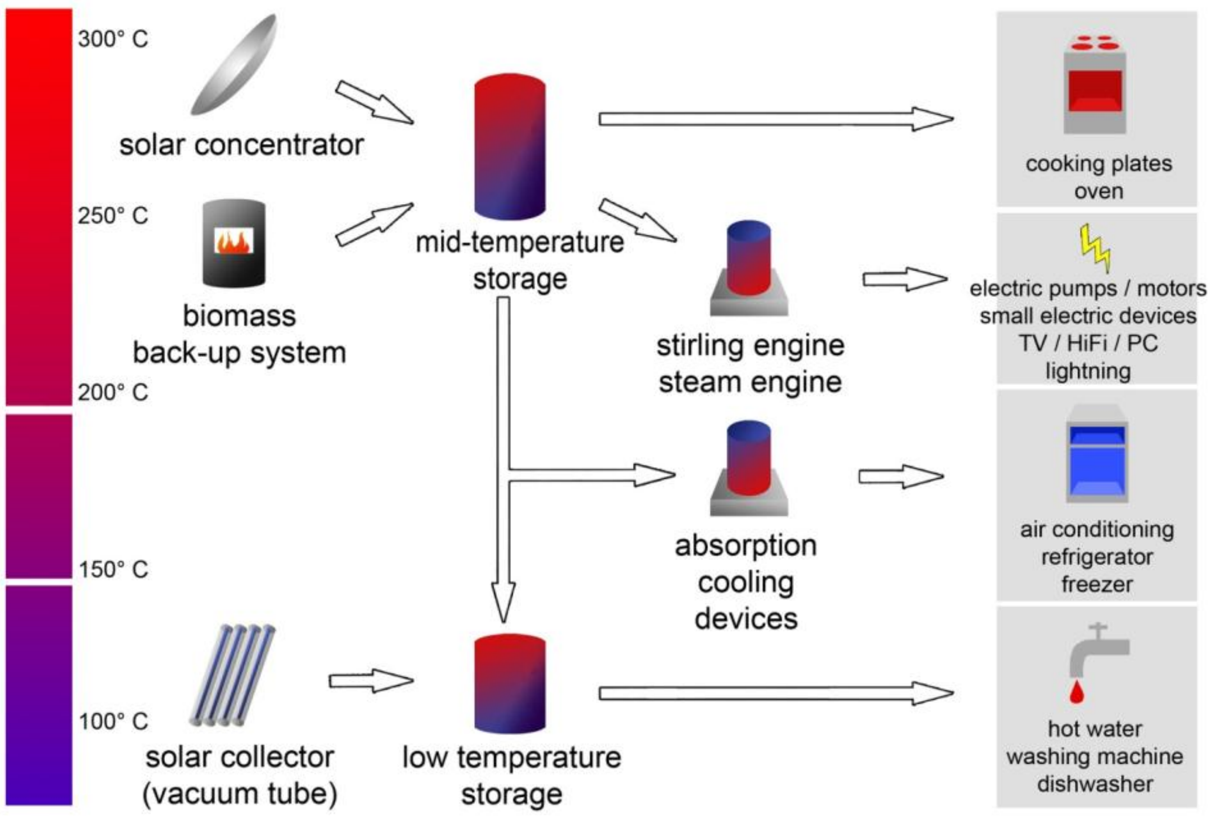


Fig. 3: Energy concept of Zero Carbon Village*. Own image*

3.3 Combination and complementation

The *Zero Carbon Village* shows compatibility and synergies of sustainable energy systems with building materials of renewable resources and the potential for regions of urban peripheries. The goal of energy and resource efficiency is not only fulfilled on a level of individual buildings but also on a larger scale. Building density, number of stories, A/V (surface area/volume) ratio and building orientation are factors that influence the heating energy demand and which are relevant for integration into the urban environment. The emphasis on material and energy decisions is seen in a broader scope of different requirements: The dense typologies are complemented by services like collective waste management or mobility concepts to target an efficient overall concept.

4. *Zero Carbon Resorts*: climate-sensitive adaptation

The described approach towards buildings can also be adapted for different climates [26] – based on research results regarding the potentials of the specific region: The project *Zero Carbon Resorts, Building Energy Autonomous Resorts Creating Appropriate Technology* addresses the increasing energy consumption of the tourism industry in the Philippines by three steps (*3R method*): 1. *Reduce* energy consumption, 2. *Replace* inefficient technologies, 3. *Redesign* buildings and systems. Local production and use of available renewable resources are stimulated, and the capabilities of local engineers, managers, architects, consultants and technicians are improved through a series of training courses, demonstration projects are executed. [27]

4.1 Material and construction

In terms of material the main goals of the *Redesign* part of Zero Carbon Resorts is to minimize consumption of resources, to use regionally available renewable resources and to include a life cycle perspective, resulting in easy separation of building materials during deconstruction and plans for recycling and reuse. To recognize environmental effects of a building, the entire life cycle construction and use of the building until deconstruction and recycling is considered. All goals are strongly interconnected and have effects on each other: According to thermal comfort parameters [30], the cooler the wall temperature through constructive measures, the bigger is the tolerance to higher air temperatures during the use phase. The typical situation in many hotels, but also in residential buildings in the Philippines, is that due to insufficiently insulated walls and ceilings surface temperatures reach high levels and in return ask for a lower air temperature that can only be achieved by excessive air-conditioning. Building design improvements help saving running costs every month by a combination of effects of chosen material and constructions. The main principles are: shading, reflection, insulation, radiation, ventilation, evaporation and heat sinks by thermal mass. Small implications such as shade from vines grown on trellis [31], strengthened by the evaporation effect of plants and further natural ventilation methods, can help saving a lot of energy. Also, green roofs show excellent cooling effects. The choice of building materials strongly influences the environmental impact. Therefore, building materials made of renewable resources and regionally available materials form the substantial basis, especially materials like grasses, bamboo etc. have a far better environmental profile than fossil or mineral resources. [29]

4.2 Energy

In the Philippines the demand for comfort, especially for air-conditioned tourist and urban accommodation, is rising and causing a drastic increase in electricity consumption. The Philippines are heavily dependent on fossil fuel for over 67% of the power generated in the country. Due to the structural and geographical characteristics of the country a centralized power supply grid is very unrealistic; therefore the objective of energy autonomy is aspired in the project *Zero Carbon Resorts*. Most islands run diesel aggregates for electricity supply. The *3R method* has been developed according to environmental aspects such as reducing CO_2 emissions. *Reduce* starts with simple measures that are easy to implement, whereas *Replace* implements solutions in substituting outdated technologies with more efficient and greener ones. These aspects form the main strategies for improving energy supply and consumption. One key approach to determining and understanding energy consumption, energy behaviour and usage as well as appliance efficiency and finally to reducing energy consumption is energy monitoring. Different techniques are implemented, from the most basic analog meter provided by the energy service company to a very comprehensive energy monitoring, reporting and management system. [28] Another key approach is to avoid energy consumption and thus provide comfortable room temperatures, not by turning on the heating or the air condition device but by specific building design: What thermal insulation, amongst other strategies, can affect in European climate, passive cooling principles can do in (sub)tropical climates. These implications strongly refer to the question of applied materials as well as construction techniques (chapter 4.1). [29] The aspect of substitution (replacing electric energy by thermal energy for thermal services) is considered in a bigger context to reach the level of a holistic supply-demand matching as shown in figure 5.

Fig. 5: Supply demand matching in a typical hotel scenario over the day. Own image

4.3 Combination and complementation

Basic principles shall reach high functionality and quality. Sustainable planning ensures environmental solutions for a healthy room climate. Therefore 10 "steps" are carried out: 1. In a tropical country direct sun rays have to be blocked to reduce the heat inside the building. 2. Allowing natural daylight to enter the building reduces reliance on artificial or electrical lights. 3. Using windows or building form to catch the breeze reduces the interior heat. 4. Heat insulation of sun-exposed roofs reduces the entering heat. 5. A lot of household devices can be supplied by rainwater. 6. Different methods of recycling waste water are implemented, for example engineered reed bed. 7. In addition to appropriate user behaviour efficient lighting such as CFL (compact fluorescent lamp) and LED lights can be used. 8. If necessary, efficient air conditioners and ceiling fans can be used in order to reach thermal comfort. 9. Materials that can be re-used, recycled or biodegraded should be prioritized. 10. The structure should be prepared to utilize alternative energy, such as photovoltaic, solar water heater, wind and hydro. [29]

5. Discussion and conclusion

This paper showed three projects opening up the enormous potential of renewable material and energy. The three introduced projects share a similar approach based on the locally available resources: using renewable resources as building materials and for energy generation as well as decreasing energy demand in the building sector. Methods had to be adapted to each local context, for each function and each scale. Planning in urban scale is complex and always different, each approach is thus project and solution oriented, a individual reaction to the local potential, but the developed approach allows a transferability to a certain degree.

All the projects demonstrate excellent potentials to reduce CO_2 emissions in order to create and help to sustain healthy environments and to fulfill the demands of a changing society with different user behaviors. Especially in dense urban situations these factors should not be treated per se, but in combination to reach best performances. Challenges regarding energy AND material are always strongly intertwined, one influences the other. This fact has been experienced in all the introduced projects. One difference concerning system boundaries is that planning in compound as shown in *Zero Carbon Village* rather allows for use of renewable energy in a decentralized way, whereas in individual single interventions in urban renovation projects (such as shown in *Renew Building*) decentralized energy supply is more difficult to realize.

Further differences of the projects stem from the specific environments, especially climate, resources and energy politics, which they were planned for, and which offer different potentials the specific sites offer. Considering renewable material and energy at the same time has huge positive environmental impact and at the same time it poses new questions to scientists about solving details, bringing forth innovative research methods and prototype implementations. To realize the full inherent potential of this multifold approach in urban regions, interventions have to be placed in many directions and areas. Various local contexts are opening new challenges world-wide. Furthermore, in combination they influence their direct and indirect environment on social, economic and political levels.

Common findings during planning and/or realization of the projects are the following:

1. Details are still to be developed – especially for the combination of prefabrication, use of renewable materials and HVAC.
2. Cooperation with local producers and firms shows the need for training in usage of renewable materials and energy.
3. Dissemination and demonstration projects are necessary to create an atmosphere of trust in new as well as forgotten technologies and local resources.
4. New certifications are necessary on national and international levels.

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Study on the indicator of energy reduction using natural ventilation in a city planning

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Summary

According to urbanizing in Asia, Asia needs cooling to solve the mechanism of environmental impact. In Japan, the structure of energy consumption in non-residential buildings has a ratio of the air conditioning for about 40% and a ratio of the lighting and the electrical outlets for about 30%. And, cooling reduction is compared to determine whether natural ventilation can be used or not in each building-blocks. Therefore, we use Urban Climate Simulation System (UCSS, Ashie Y. *et al.*) which can be calculated a temperature and a velocity in part of building-blocks using canopy models. Installing calculated results, we consider the possibility of cooling reduction in a case of urban spatial planning types.

Keywords: energy reduction, natural ventilation, city planning

1. Introduction

Japan has the technological potential to reduce its CO_2 emissions by 70% compared with the 1990 level (NIES, 2008 [1]), which satisfies expected demand for energy services in 2050. We must now demonstrate possible ways of putting these government targets into practice through technical and political measures. Professor Arnulf Grubler (International Institute for Applied Systems Analyses / Yale University [2]) had described the hierarchy of urban energy and CO_2 reduction, as follows,

1. Spatial division of labor (trade, industry structure)
2. Urban form (functional mix, public transport, car ownership…)
3. Efficiency of energy end use (buildings, appliances, processes)
4. Energy systems integration (co-generation, heat-cascading)
5. Fuel substitution (renewables, nuclear)

In Japan, the structure of energy consumption in non-residential buildings has a ratio of the air conditioning for about 40% and a ratio of the lighting and the electrical outlets for about 30% [3]. Asia needs cooling to solve the mechanism of environmental impact.
Therefore, we have studied city types with a view to realizing measures for effectively reducing the energy consumption in the building sector. And, cooling reduction is compared to determine whether natural ventilation can be used or not in each building-blocks.

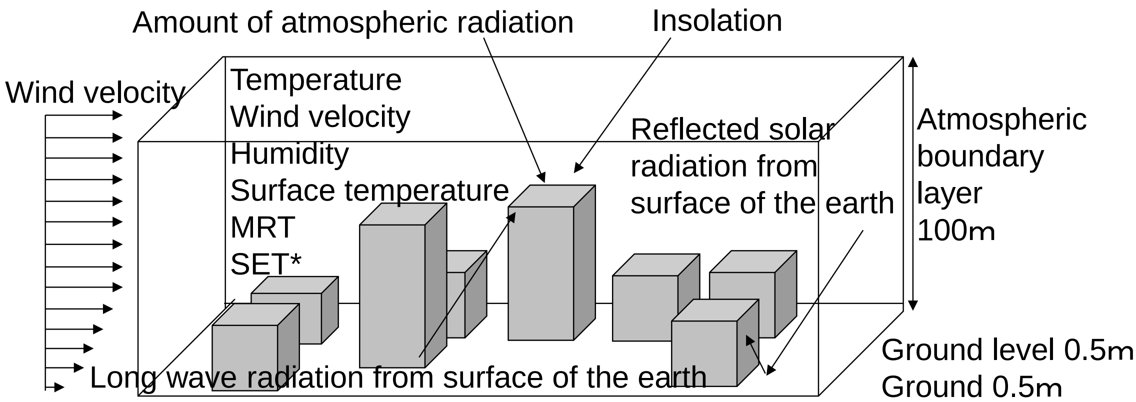
2. Methods

2.1 About Urban Climate Simulation System (UCSS)

Using UCSS (Urban Climate Simulation System by Ashie et al., 2003, Fig1, [4]), we try to develop an indicator for building-blocks evaluation. Getting results of many cases help us to evaluate comfortable level of natural ventilation. Appropriate energy saving information should be provided for the city planning, using such data as Automated Meteorological Data Acquisition System (AMeDAS) measurements delivered by the Japan Meteorological Agency adjustment.

Calculation of form coefficient in a sky view

→Direct solar radiation energy to minute side element
→Diffuse irradiance energy to minute side element
→Long wave radiation to minute side element
→Calculation of a temperature surface outside ground level and building
→ Calculation of MRT

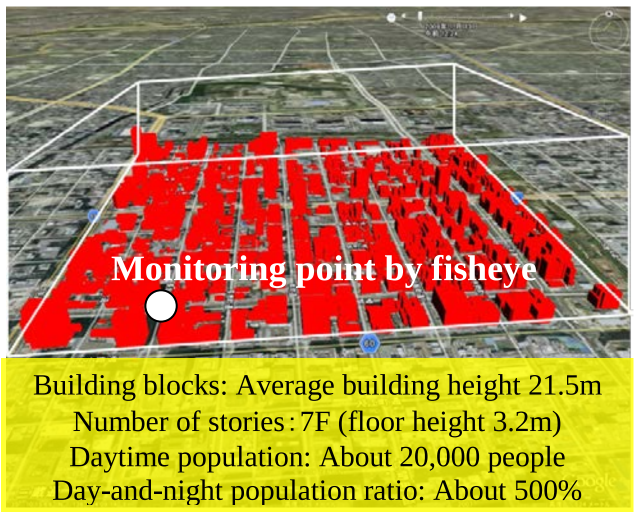


UCSS (Urban Climate Simulation System)
Canopy model by heat revenue and expenditure of building wall and ground level
+Level 2.5 atmospheric turbulent flow model based on K-ε model

Fig1: About UCSS (Urban Climate Simulation System)

2.2 Case study of city planning

Firstly, we used laser-point data to make the 3D-model provided by Kokusai Kogyo corp.(Fig2), which used building-blocks [6, 7, 8] with 7F-buildings (floor height 3.2m). The average building height was 21.5m. Inside the building-blocks, we measured a sky view factor (SVF) of 20% using CanopOn2 tool [5], and the width of the roads equal 8m (Fig3). When we generate canopy-models, we have a base model (Fig4) which consists of D20m×D20m×H20m in 1km^2. A comparison of land use (Table1) is very suited between real site and canopy model.



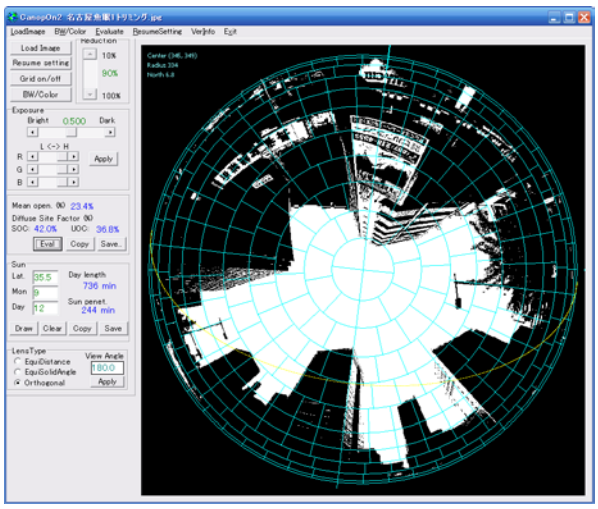


Fig2 (Left): Research site in Nagoya on Google earth

Fig3 (Right): Sky view factor from photo with fisheye (Nikon CoolPix-P5100 +FC-E8)

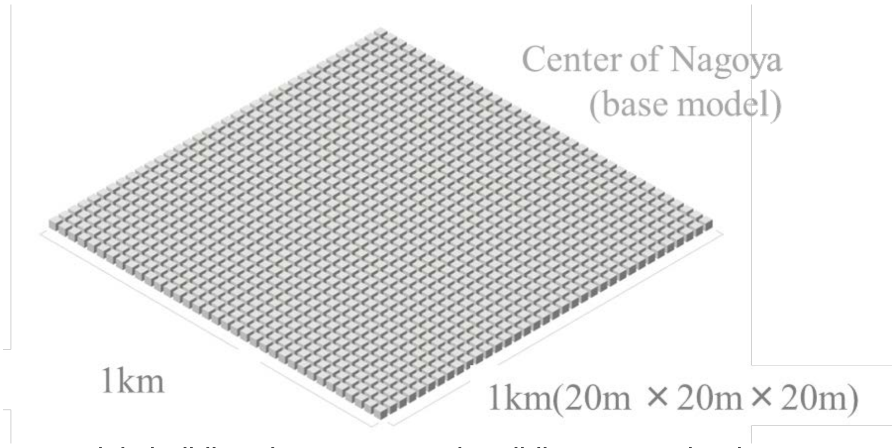
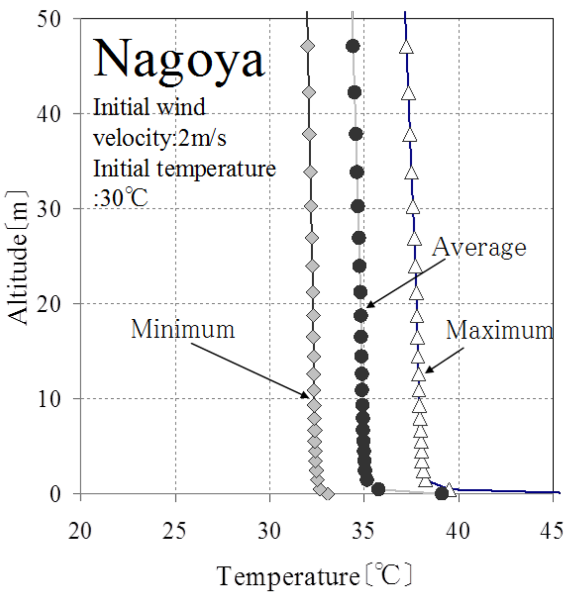


Fig4(Left): Canopy model ･buildings(Current states):Building covered ratio 50%+Green ratio 0%

Table1: Comparison of land use

Comparison of land use	Building coverd ratio	Road coverd ratio	Tree coverd ratio	Bare land ratio
Land use on the map	55	30	1	14
Canopy model	51	49	-	-

We calculated UCSS in a base model (gross building coverage ratio 51% and road cover ratio 49%). Fig5 shows the average temperature of building-blocks by end of the AMeDAS monitoring point, when it is the initial wind velocity 2m/s and initial temperature 30℃. There is difference between grand level and the AMeDAS monitoring point. Fig6 shows the AMeDAS monitoring point and average temperature in building blocks when it is same temperature. Using UCSS, we consider altitude 0m is higher than altitude 0.5m~20m, there is correlation equation between AMeDAS monitoring point and average temperature in building blocks. We calculate 10m (the middle height of 20m) above of the road for natural ventilation use.



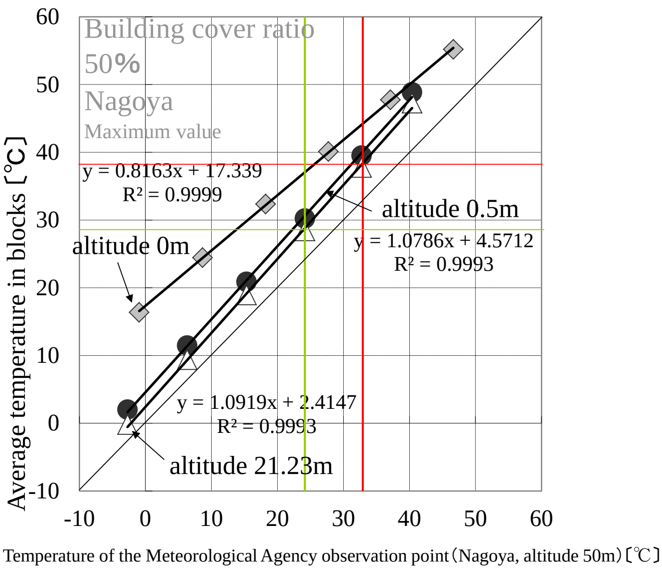


Fig5 (Left): Vertical average temperature (UCSS in building blocks) of Current state

Fig6 (Right): Horizontal average temperature (UCSS in building blocks) of Current state

3. Results

Getting results of many cases, it helps us to evaluate comfort level for natural ventilation use. When we change the land use for gross building covered ratio 50% with green(or water) covered ratio 25% and road coverage ratio 25%, or arranged the building height higher around center (or random) in a base model. Results of UCSS show temperature differences between AMeDAS monitoring point and average temperature in building blocks of altitude 10.91m at Fig8 (average) and Fig9 (maximum).

The average temperature of base model is about 0.3℃ warmer than changing building width 20m and height 20m with green and water in a point of 30℃. In this case, canopy model with water is coolest above 20℃of monitoring point.

Maximum temperature of base model (Fig9) shows warmer than changing with water and green. In case of water, we could save the outdoor temperature rise than any other cases.

Substantial energy reduction requires efficient operational improvement of heat plant after indoor air conditioning system has been improved.

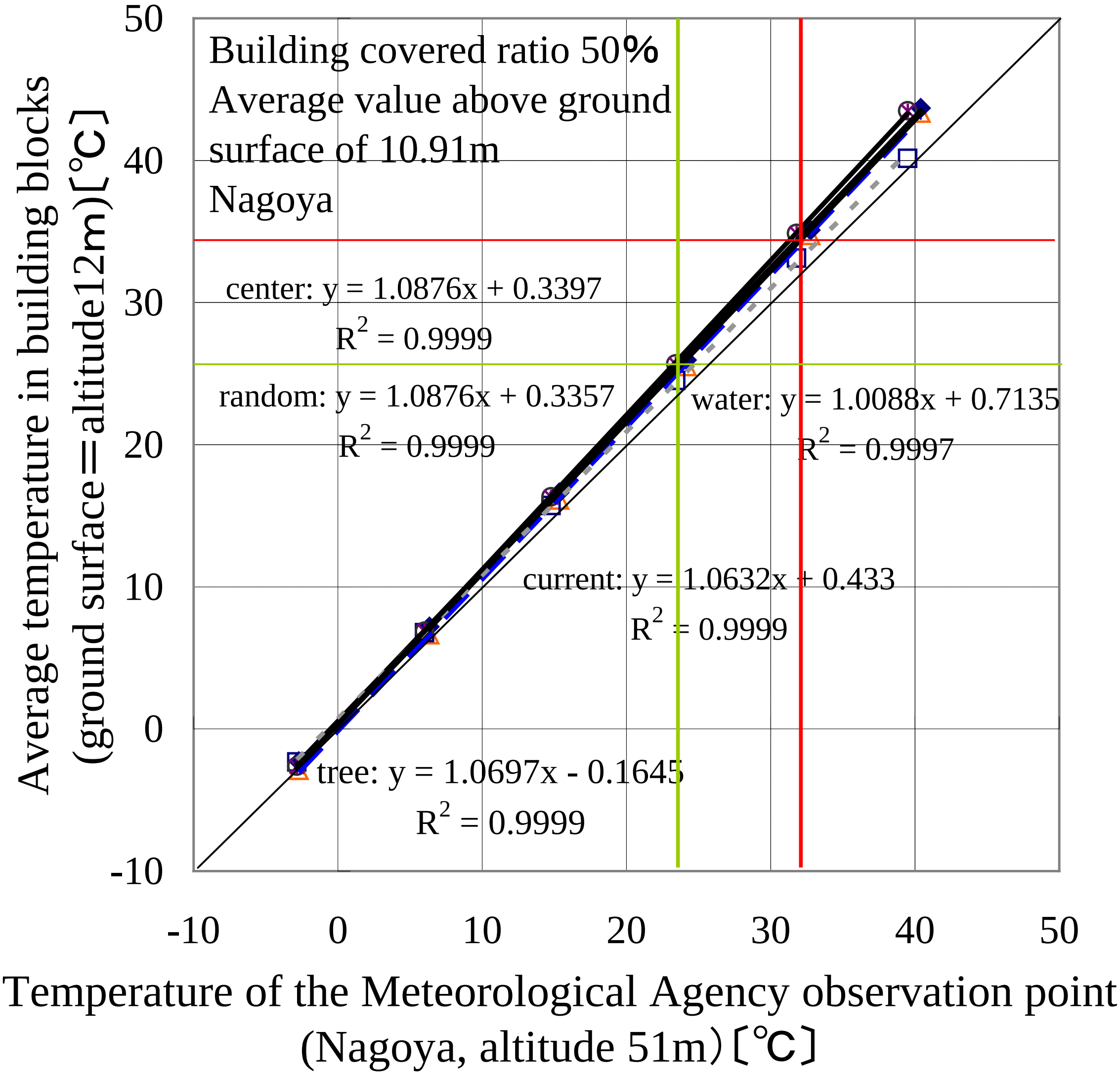


Fig8: Forecast urban climate (Horizontal average temperature of building blocks)

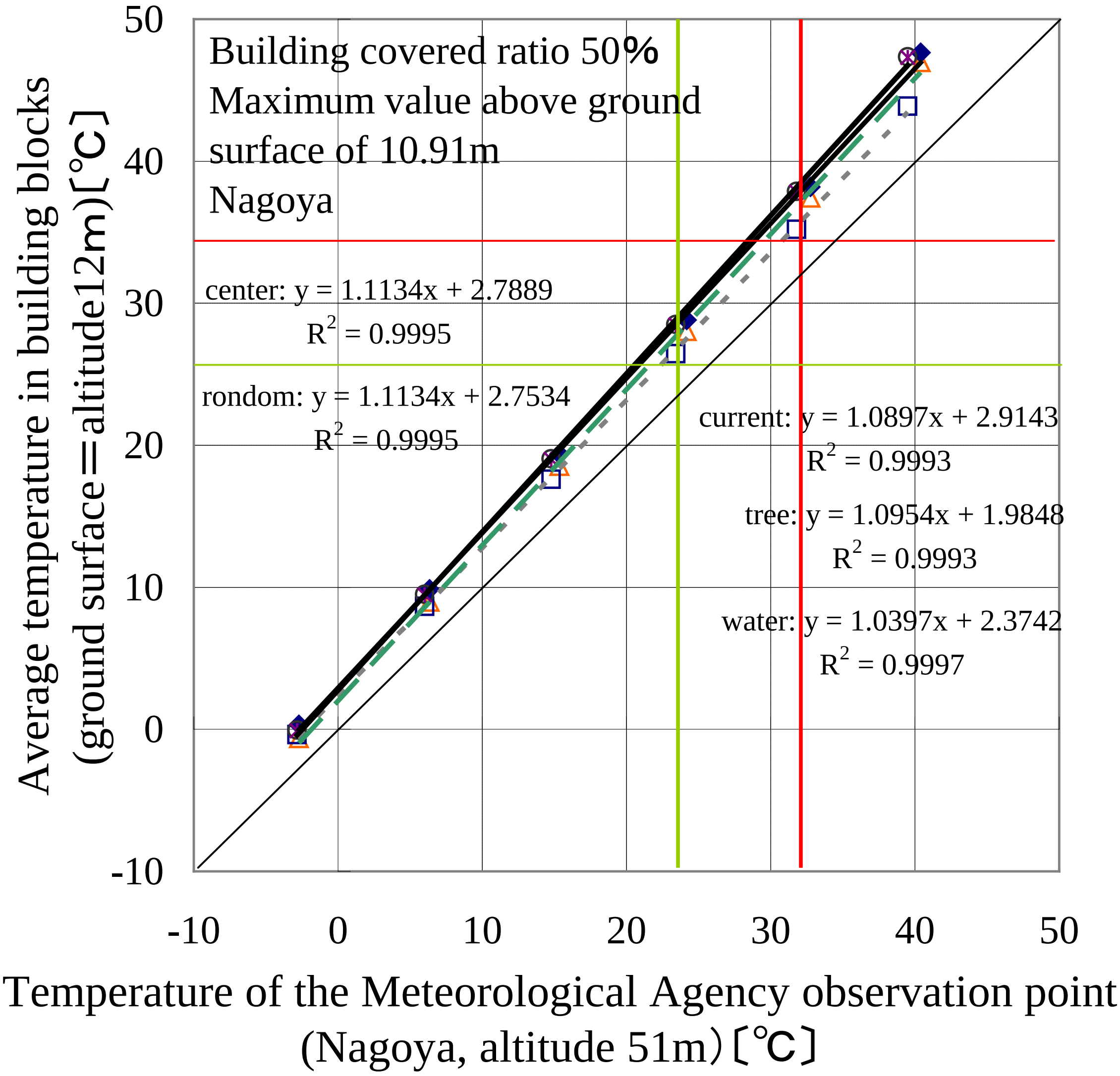


Fig9：Forecast urban climate (Horizontal maximum temperature of building blocks)

4. Discussion

Actually, Asia has urbanized rapidly. We tried to make a vision for 2050 which needs cultural exchange with behaviour (human beings, air, trees, water, etc…) for the nature.

Architectural methods that take into account global environmental conservation generally concentrate on mitigating the heat load of buildings. Then, we evaluated the reduction of energy consumption that can be achieved by improving heating, ventilating, and air conditioning (HVAC) technologies using natural ventilation. And, we should make the outdoor environment sure to use natural ventilation.

5. Conclusion

Fig10 shows hybrid air-conditioning (machine and natural ventilation) judgment flow. Natural ventilation possible range is in ASHRAE comfortable range. Therefore, outdoor environment should be comfort for human beings. HVAC improvement for energy reduction is according to outdoor and indoor temperature.

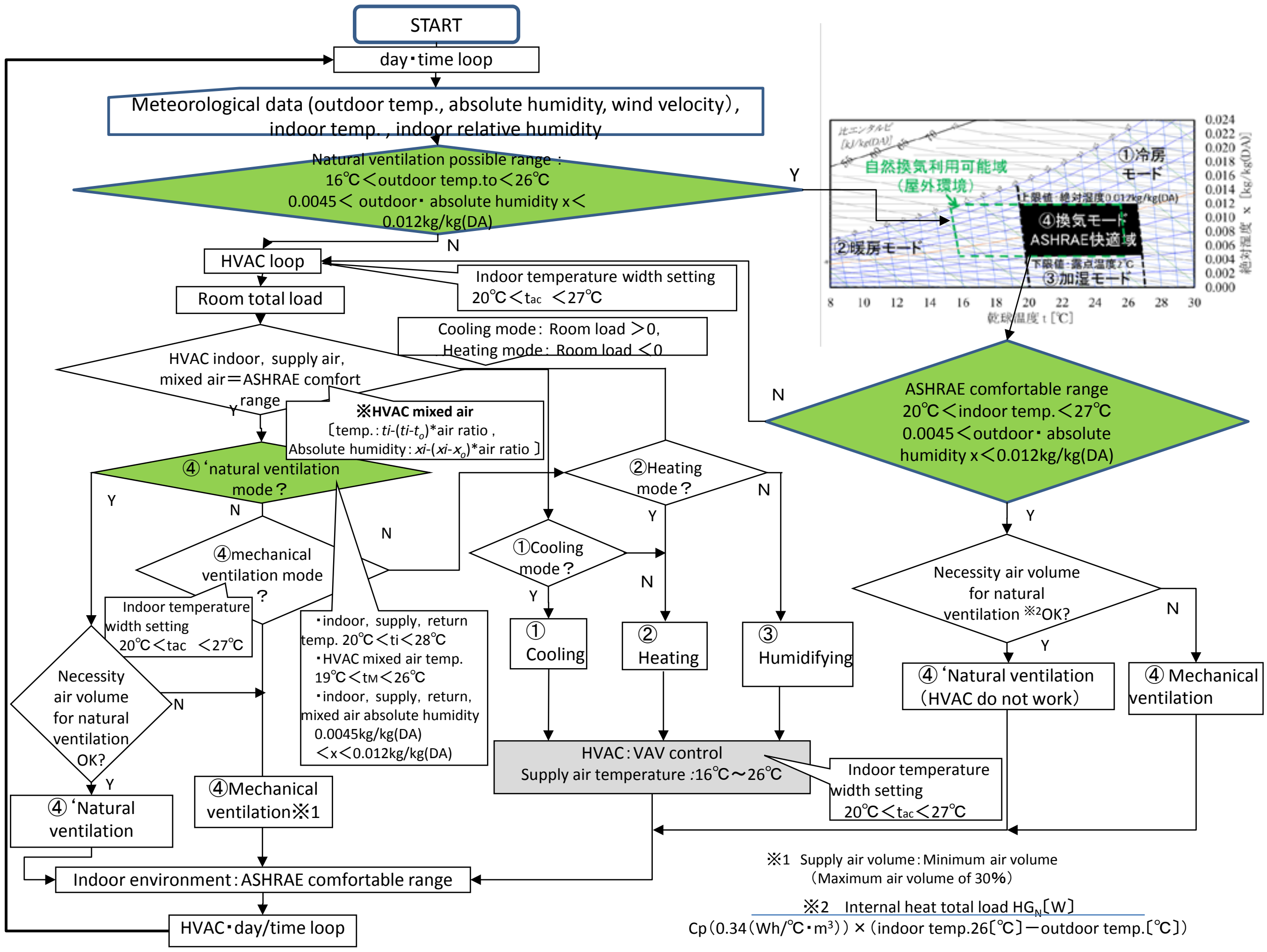


Fig10: Hybrid air-conditioning (machine and natural ventilation) judgment flow

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Energy efficiency and saving potential of population centers of a different size

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Summary

ENEFIR-project was realized in the years 2010 – 2011. One topic was how to develop new metering and instrumentation concepts as well as analyzing tools to improve comprehensive energy performance of buildings. There were three pilot areas in Eastern Finland in the project: One bigger city (in Finnish circumstances), population 100 000, the energy performance of public buildings in relatively well managed, one medium-size small city (population 20 000) and one small community. The energy saving potential of public buildings medium and small size communities were analyzed based on the reference material compared with MOTIVA-material (results of energy audits of Motiva Ltd) and energy efficiency calculation tools. Motiva operates as an affiliated government agency and it is an expert company promoting efficient and sustainable use of energy and materials. In all pilot areas some demonstration buildings were chosen, in which the air tightness was measured using the building´s own ventilation system. The performance of building envelope was determined by thermal scanning. In some buildings the distribution of electricity consumption was measured. In the biggest city walk-through energy audit procedure was tested in two buildings. In the same city, three pairs of similar type of buildings were selected, the other with low heating energy consumption and the other of high heating energy consumption. The goal was to analyses which factors caused the differences in energy consumption. The conclusions, methods and measures vary depending on the type, size and resources of a community; the most important thing is to create a short- and long-term holistic program to improve the energy efficiency. One crucial topic is the use and development of existing building automation systems. In this paper the most important results and conclusions of the project will be presented.

Keywords: Energy Efficiency, Building Commissioning, Sustainable Management Methods and Tools, Sustainable Policy and Responsibility

1. Introduction

In energy management of buildings energy efficiency does not mean to minimize the use of energy but rather to optimize the energy use during the life-cycle, in balance with other important variables like environmental and health impacts. Many communities and enterprises in Finland have consummated so called energy efficiency agreements, which provide verifying and illustrating of the set goals. Verification of energy efficiency requirements demands also new or intensified measuring methods (such as thermography and air-tightness measurements), devices and analyzing tools. By monitoring, control and benchmarking of energy use can be reached ground for savings with reasonable short payback times. Energy management requires that the energy consumption of a building or real estate can be verified exactly enough and in short time, the collected data can be compared with other targets of same type and the energy consumption indicators and parameters meet the user´s needs.

The objectives of the project [1], respecting energy efficiency was to develop new measurements- and instrumentation concepts both to analyze tools to improve comprehensive energy efficiency. It was divided with four sublevels:

1. To localize air leaks by thermography, improving the method and productization of the method for end-user
2. Commissioning of the performance of building envelope by thermography and supporting methods, improving the procedure – including walk through energy audit
3. To productize Continuous Commissioning^{RM}-procedure [2] to the appropriate extent for end-users
4. Exploitation of the measurement data of ground heat pumps in optimizing energy efficiency of buildings

The main goal was to create procedures and tools for energy efficiency management for different size of municipalities.

2. Air-tightness measurements and thermography

According to new building codes, air tightness of a building can be measured also using building´s own ventilation system. In this project 7 buildings were measured using their ventilation system, by the same two-stage indoor and outdoor thermography was carried out, in normal operating conditions and then at 50 Pa depressurization. There were 5 buildings in the biggest pilot city: 2 schools, 2 day care centers and one art museum. Walk-through audits were carried out in the art museum and in one kindergarten. In the medium-size municipality part of a health center/hospital was tested (there was also electricity submetering experiment in that building). In the smallest community one apartment house was measured. The results showed that within certain limitations the own ventilation system of the building can be used at least as an indicative tool in evaluating the air tightness and thermal performance. Thermography must be added in order to locate air leak patterns and thermal bridges both possible defects in the wall structures.

3. Energy audits

3.1 The type of audits

IN ENEFIR-project there was an aim to test the use of so called lightened energy audit (walk-through audit) in decreasing the energy consumption of buildings and in charting possible energy saving potential. In energy audit the recent energy use will be defined and profitable energy saving potential will be introduced. In Finland the energy saving agency Motiva has made instructions for energy audit models for various types of targets, e.g. buildings. Energy audit is a basis for improving energy efficiency.

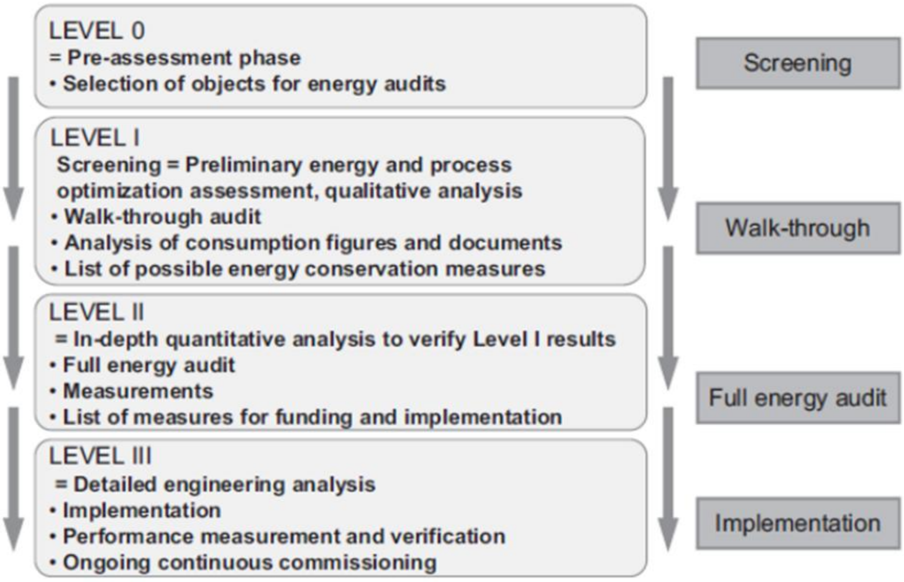

Figure 1. Classification of Energy Audits

Energy audits have been divided into three different levels (figure 1) in USA (ASHRAE) [2], depending on the extent of audit. Level I (walk through-audit) and Level II and Level III – the existing Finnish Energy Audit model approximates to the combination of US-audits Level II and Level III.

3.2 Walk-through audit

In walk-through audit energy consumption and energy efficiency of a building can be evaluated by clarifying

- energy consumption data at least from the period of three preceding years (if possible)
- energy consumption data compared with the consumption of similar buildings
- the performance of the building by one-day checking of the structures, HVAC-systems and building services

In walk-through audit one should find out:

- those energy saving measures with short payback time or
- which does not need big investments
- the most essential and significant energy consumers/spenders
- those topics which need more detailed detection

Also measurements can be done in walk-through audits but mainly it is based on the inspection in the target building and on the review of the data and information found out from the target building. Reporting is done based on particular checklists.

3.3 Limitations and prerequisites of walk-through audit

Before the walk-through audit the following topics must be trawled through:
To untangle and contact the persons responsible for the use and facility management of the building

- Consumption figures (heat, electricity, water from previous 3 years)
- Monthly weather data from the corresponding period (heating need values)
- To input consumption data and preparation of specific consumption and consumption trend charts
- To find out the documents dealing with the building and HVAC-systems in advance (heating system, ventilation system, service areas etc.)

Walk-through energy audit includes the following parts:

- Data collection and screening
- Analysis of consumption data, benchmarking
- A quick go-through of the target building and possible measurements during the inspection (could be done only limited)
- Detection of instrumentation level; also suggestion of increase of meters (if necessary) for the report
- An interview of personnel, operating staff and people in response of energy management (can be prepared beforehand
- Settling of crucial factors affecting energy consumption, listing of obvious big heat losses or energy consumer
- Evaluation of the use and condition of HVAC-technology, equipment and systems
- Utilization of building automation system (if saved long-term data can be collected)
- Definition of those objects where more detailed consideration is needed...
- If reliable consumption figures are not available, must be leaned on average consumption data of similar type of buildings and on the experience of auditor

The duration of walk-through audit including preliminary works, visiting target and analyze of results and reporting is 2-5 person days. The reliability and the scope of the audit depend largely on the experience and expertise of the auditors (as in any audit) and will be particularly emphasized if the question is about a building consisting relatively lot of technology and engineering. The proper audit will follow the lightened audit if there is a reason for that based on the walk-through audit results.

3.4 Results and conclusions

Two walk-through audits were made in the biggest city of the project. The targets were day care center and art museum. Art museum was a specific target building. Two-stage thermography and air-tightness measurements using the own ventilation system of the building were made beforehand in these buildings.

Walk-through audit based on checklists suits very well for energy efficiency evaluation in the case of day care center. In special buildings, like art museum, one can pay attention to such objects which needs closer detection – as determined in many sources. It would be good, anyway, that the auditor would have a “field measurement package” in the use. There are some factors which should be measured in walk-through audit: Indoor temperatures, pressure conditions and the efficiency of heat recovery, especially the waste air temperature.

Nowadays there are small portable data loggers with USB-connector available, which can be programmed in advance and could be left in the building for 2-5 days and red remotely. The extended measurements belong to II- and III-level audits. In the future the building automation system (BAS) should generate measurement data to facility management system, which could process and analyze ready trend analysis, specific consumptions, and conduction losses for instance. Continuous commission-type procedure will decrease the need of auditing but of course does not eliminate it completely.

It is pertinent in taking walk-through audit extensively into use, that

- The building documents are updated and available (also volume and area data)
- Consumption figures and statistics from previous years are available (also weather data and heating need values)
- Comparison data from similar buildings (specific consumptions) is available
- The staff in response of the use is present during the audit

- Building automation system/facility management system and operation and maintenance manual(if exists) can be fully used
- Users can be interviewed
- Calculation software for energy efficiency is in use
- Auditors have adequate expertise and experience
- Cost information (e.g. change of windows etc.) is already collected

The use of building automation system includes also risk factors, in case that building automation system does not operate by proper way – sometimes it is very difficult to detect deficiencies or malfunctions of automation system. The commissioning of the performance of building automation system belongs to larger audits, but it´s defective functioning can significantly effect on energy efficiency.

The biggest and even as more laboriously treatable energy saving potential is in existing building stock. Walk-through audit could be improved and it could complete other audit procedures after the change of energy efficiency requirements.

4. The use of electricity

4.1 Background

The distribution of electricity consumption is necessary to study when is needed to know where the electricity is consumed, what is the daily consumption distribution and when there is just one meter available (as usual). In Finland the local utility provider can measure consumption as hourly power mostly during one week. When the metering is moving to remote readable meters, the situation will change. From the point of view of peak consumption, variation and distribution the hourly average or sampling period of an hour is too coarse; the sampling period should be approximately 1 minute if daily consumption should be analyzed. More accurate measurement of electricity will give also an opportunity for consumption control and for use of optimum tariffs.

In the project was arranged an electricity consumption measurement in a school in the biggest city during autumn vacation (October 2011). The starting point was the basic load, after that the load was increased at intervals of one hour. Consumption was red from the main electricity meter. Results were compared with the results of utility provider. The load was not equally distributed in one hour periods because the manual switching of plug loads and lighting lasted several minutes.

Based on this single test a suggestive impression of distribution of electricity consumption in a dark and relatively cold season was reached. One hour measuring period is too long. The test was relatively easy to carry out because that building – like the other public buildings in the city of Kuopio – was connected to central control room, from where e.g. the ventilation units and part of lighting control could be switched on and off.

The other pilot building was a hospital-health care complex in the medium-size city. In 2011 a submetering system was installed in the building, consisting 35 analyzers. Based on the results the electric power distribution can be monitored in the future.

4.2 Submetering of electricity, results of a school

Submetering is needed for more precise analysis of electricity consumption and for mapping saving targets (e.g. kitchen appliances). According to results, the share of lighting is 30 % of peak consumption, therefore by lighting control, by proper lighting and e.g. by moving to LED-lighting the electricity consumption could be decreased. The other big consumer is ventilation, so that by adjusting of running time there are possibilities to reduce electricity consumption, but not haggling of the indoor air quality on the costs of energy saving. The basic load includes also the stand-by power of the devices.

During the work week the energy consumption by 55kW average power is 6600 kWh and during the weekend ca. 960 kWh in measurement conditions, together 7500 kWh. Electricity consumption varies depending on lighting conditions, it could be roughly estimated that during the seasons, 40 work weeks, savings of 10 % mean consumption decrease of 4000 kWh.

Comparing the electric energy consumption of public buildings (schools, day care centers, health centers) the biggest consumers could be accessed, in which the simple test could be done before the metering has developed. In evaluating of consumption distribution the reasonable saving potential can be estimated.

5. Procedure for improving and analyzing the energy efficiency of municipalities

Based on the results of pilot buildings and communities, a procedure for improving the energy efficiency of municipalities was suggested. The main parts of the procedure are:

1. The basic information of real estates are under control
    - It is primary important from the energy monitoring point of view that the essential basic data of real estates are updated and safe
    - Especially from the viewpoint of energy consumption monitoring important basic data is the extent information as cubic content, heated building volume and corresponding area information

2. The maintenance costs and consumptions of real estates are reliably known
    - From the viewpoint of real estate economy is important to know the level and distribution of maintenance costs
    - In that case one knows also the share of energy costs from total maintenance costs
    - If the monitoring is continuous, real time cost development is known
    - If the follow-up is frequent enough, one can react also quickly to possible deviations

3. The cost and consumption levels of real estates are known compared with other equal type of real estates
    - The real time follow-up of costs and consumptions for one and only real estate does not tell very much about the economical maintenance
    - Reference data gives additional information about economic efficiency

4. The real estate has an energy certificate
    - Energy certificate is required for all new buildings
    - For existing buildings energy certificate can draw up based on realized consumption
    - by means of energy certificates the energy efficiencies of buildings can be compared

5. Calculation of the goal consumption for real estates
    - Energy consumption of realties is affected by many factors
    - According to good building management realty must have goal consumption level for heat, electricity and water
    - Goal consumption are calculated according to building code
    - There are also software available for energy efficiency calculations
    - Calculations also increase the knowledge about costs build-up and factors causing variations in consumption

6. Energy efficiency agreements
    - Energy efficiency agreements (Motiva, the Finnish Energy Savings Agency) are one method toward energy saving building management

7. Specification and comparison of energy saving measures
   - In the situation where the realized consumption exceeds the goal consumption, the reasons for deviations should be found out
   - Calculation software can be utilized, by means of calculation procedures effects of various factors and energy saving potential can be evaluated

8. Profitability and implementation of energy saving measures
   - When energy saving potential is cleared, the needed investments and their profitability must examined
   - Some energy saving measures can be clearly operational, use related and these measures should be realized immediately
   - Realization of measures which demands investments should be reconsidered case-specific
   - Investment calculation method should be applied for profitability considerations (e.g. payback time)

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9. The full exploitation of building automation system
   - By efficient utilization of building automation system one can contribute on energy consumption and indoor air quality of the building
   - By on-demand control of equipment which consume lot of energy (ventilation, cooling, lighting) remarkable sums can be saved in annual level
   - Many building automation systems include also high-level monitoring and reporting features

10. The development of the technical management of buildings
    - For realties must be compiled service- and maintenance plans, in compliance with plans must be operated
    - There are tools and software of different levels and prices for planning, realization and monitoring of service and maintenance

6. The instrumentation and reporting model for building automation

Building automation system is a tool, with which one can effect on indoor air conditions, lighting and widely applied, also on building safety. Technical devices are controlled by building automation, energy consumption, wear of equipment, noise and other operation related damages are tended to minimize. Building automation system can be compared with brain, which controls, regulates and monitors all functions. Various sensors and detectors are detecting elements, which alarms. This is valid only if control, regulation and monitoring are serving properly and sensing devices are measuring right things by the right way and transmit results so, that signal does not garble.

The EU's energy efficiency directive for buildings has come into force, which has caused changes in building codes [3]. The significance of building automation as an effective factor for energy efficiency is increasing because of many reason; the energy consumption of buildings is >40 % of the total energy consumption and 30 % of greenhouse emissions. One can lighten that load by building automation, by the same when standards and norms will open new possibilities for it. A very important development step is European standards, such as SFS-EN15232 and other standards. International investors and also building companies have begun to use even more than before international environmental classifications in new buildings, US-based LEED-certification and BREEAM (UK) for example. Building automation system and its performance level will increase the rating.

In the municipalities which have participated ENEFIR-projects the use and applications of building automation were of a different level. In the biggest city the public building stock is connected with to the district level control center (figure 2). In the middle size city the data of public buildings has been collected in a facility management system. This database was updated during the project.

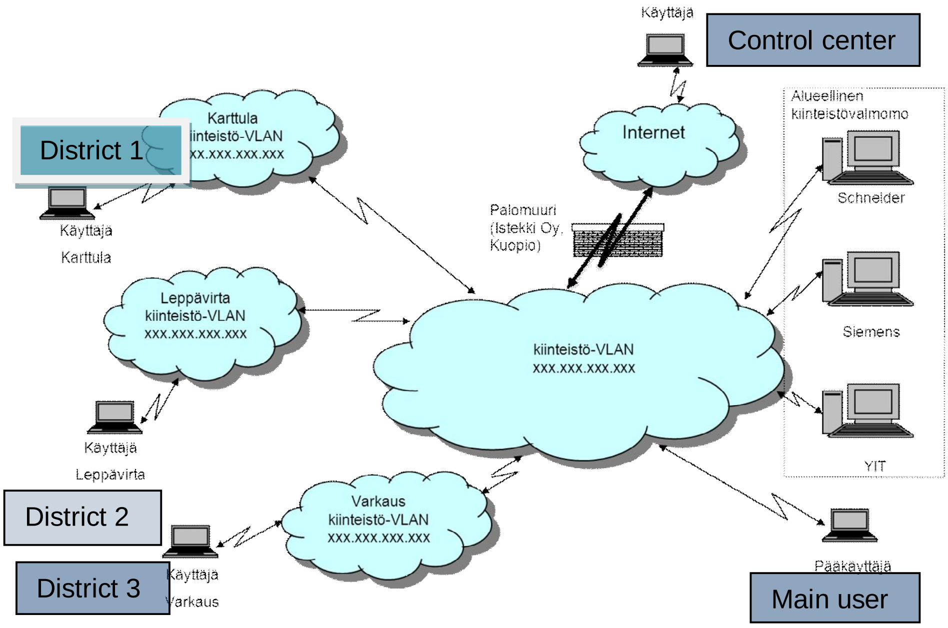

Figure 2. District level monitoring center (Kuopio)

Key performance indicators (KPIs) are these key figures, which effect, describe or have meaning in determining energy efficiency of buildings. What kind of significance will be set for energy efficiency depends on owner´s goals. In the hotels, for example, cleaning costs are the biggest expense. The owner must therefore define the goals and objectives related to energy efficiency, and one must verify the realization of the target values by data collection and reporting. There are many energy- and facility management software and reporting systems available in the market.

Key Performance Indicators (KPIs) must be defined. The energy consumption of a building is determined mainly already in the predesign/design phase, which means that the sensors design of building automation, metering and reporting planning and development of structural details and building services effecting on energy efficiency must be realized early enough. In the renovation cases the reason for repair is very seldom energy savings or improving energy efficiency, but renovation is caused by the change of use or by structural damages. Connected with these measures also energy efficiency can be improved.

KPI meters can be divided by performance meters (directly measurable factors, like energy consumption/costs/floor area) and usability factors (the space use/floor area for example). Customer/user satisfaction should also be measurable. Often it is measured by questionings. Customer/user satisfaction depends, in addition of technical parameters (which is the sum of various elements), on many non-technical factors. In many cases to investigate insufficient performance of building and its systems demands separate measurements. In the ideal situation the existing instrumentation, building automation system and facility management system can report to facility/energy manager the prevailing condition of the building and also the comparison with statistics and history files. Indoor conditions have a strong effect on productivity. The problem is, anyhow, how to measure productivity reliable enough. If we decimate indoor environment by energy saving measures, can achieved savings leave smaller than the costs caused by decreased productivity.

To attain the essential performance targets provide Building Commissioning-process (Cx), in which during construction or renovation process will be verified that the goals will be achieved (figure 3).

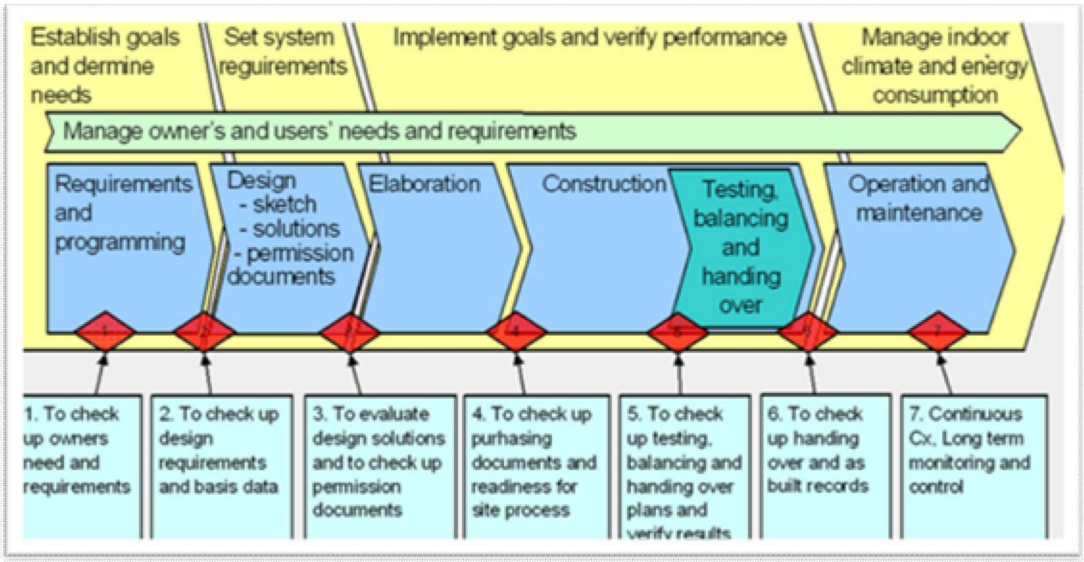

Figure 3. The schematic presentation of building commissioning procedure [2]

7. Development of energy efficiency – pilot areas

7.1 Small size community (population 2000)

The goals were:
1. Evaluation of energy saving potential of the public building stock
2. Thermal performance of building envelope in a selected target (apartment house) before and after the window reparation
3. Energy efficiency calculations for selected buildings
4. Comparison and study of building automation system to a reference city

The heating energy consumption data of 21 buildings was available from 2005-2009. The realized specific heat, electricity and water consumptions were compared with reference files of Motiva (Finnish Energy Saving Agency). The building stock has saving potential. If the 9% saving goal will be set to the period ending 2016, the consumption statistics and files of the municipality should brought up to date in a level, that consumptions could be compared reliably with each other, with previous years and with other statistical files available. The planned development and combining the building automation system will give good chance for that. The basic starting point of the municipality's energy saving goals was that, that the consumptions of building stock have been measured as reliable as possible, and the consumption data is analyzed by that way that energy and facility managers have real time consumption figures in their use by buildings and building types.
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Table 1 represents the saving potential of the building stock. Based on the calculations there is an annual saving potential of 32 000 € in public buildings. Achieving the goals depends on what kind of investment is needed and how much money can be used. By ten years payback time and 5 % interest the sum equals 0, 5 M€ investment. From building group one can direct clearly the biggest consumers with quantitatively biggest savings. This does not exclude the fact that relatively bigger savings can be found in less consuming buildings. It is worth to focus the primary measures to the biggest consumers, while the financial savings are the highest in those buildings.

Building type	Heat (MWh/a)	Heat (€/a)	Electricity (MWh/a)	Electricity (€/a)	Water (m3/a)	Water(€/a)	Total(€/a)
Apartment buildings	173	8 840	65	4 890	1 135	3 180	16 910
Educational buildings	28	1 410	20	1 490			2 900
Healthcare buildings	112	5 720	5	360	520	1 450	7 530
Office buildings	n/a						
Assembly buildings	17	870	45	3 500			4 370
Other type of buildings			5	400			400
TOTAL	**330**	**16 840**	**140**	**10 640**	**1 655**	**4 630**	**32 110**

Table1. Summary of the saving potential (small-size municipality)

7.2 Medium size community (population 20 000)

The goals were:
1. To upgrade the facility management software and files in use in the city and user training
2. Development and experiments of submetering of electricity
3. Thermal performance of building envelope in a selected target (apartment house) before and after the window reparation
4. Recommended further actions based on the results

The building stock owned by the city contains 140 real estates; the share of public buildings is 75 % of the building stock. Schools, day care centers, health care buildings, offices and different types of assembly buildings belong to public buildings. Main part of the buildings (88 %) is connected to district heating.

The city has started to improve energy efficiency in its own buildings, e.g. the city has concluded energy saving agreement. The aim is to save 9 % of the total energy consumption to 2016 by different measures. The heating energy consumption of whole building stock (the volume is 457 000 m^3) in 2010 was 21 028 MWh, equal to specific consumption of 44 kWh/m^3 as weather corrected. The electricity consumption of the building stock in 2010 was 8 380 MWh, equal to specific consumption 18, 3 kWh/m^3. If we use price of district heating 51 €/MWh and electricity price 75 €/MWh, the saving goal of 9 % means 153 000 € annual saving.

One of these energy saving measures is to develop facility management procedure. The city uses commercial FM/EM software, which is updated and customized according to the needs of the city. For the biggest energy consumers (44 buildings) has been drafted updated service plans and collected information about HAVC-systems and their technical conditions. Updated operation and maintenance manual has taken into the use and personnel have been trained to use it. It is possible to achieve 9 % savings up to 2016, The basic starting point is that the consumptions has been measured reliably and the consumption data is analyzed by that way that energy and facility managers have real time consumption figures in their use divided by buildings and building types. the electricity submetering installations started in the hospital and health center must be extended, if possible, relating to other buildings which have significant consumption of electricity.

Table 2 represents the saving potential of the building stock compared with Motiva's statistics as reference file.

Building type	Heat (MWh/a)	Heat (€/a)	Heat (MWh/a)	Heat (€/a)	Water (m3/a)	Water (€/a)	Total (€/a)
Apartment buildings	790	40 000	90	6 500	1 500	4 000	50 500
Educational buildings	920	47 000	450	34 000	2 900	8 000	89 000
Healthcare buildings	150	7 700	4	300	300	850	8 850
Office buildings	-	-	290	22 000	400	1 100	23 100
Assembly buildings	250	13 000	-	-	100	280	13 280
TOTAL	**2 110**	**107 700**	**834**	**62 800**	**5 200**	**14 230**	**184 730**

Table 2. Summary of the saving potential (medium-size municipality

8. Conclusions and lessons learned

Thermography and air-tightness measurements should be connected better than today with a part of performance evaluation, condition survey and energy audits. The most important thing is a systematic approach. Air tightness measurements using building's own ventilation system is possible within certain limitations. The use of thermography can be improved significantly from the existing level. Walk-trough audit can be a good addition for existing relatively heavy audit procedures. The problem in especially small municipalities is lack of resources. The consumptions and costs building stock should be covered by building automation systems and FM/EM tool. "What cannot be measured cannot be managed". Short- and long-time maintenance programs are necessary for good building maintenance. The developing data building automation and data collection technologies will give a good basis for advanced facility and energy management. Submetering and proper instrumentation, data collection and especially proper analyze and reporting is one cornerstone in development.

The communities needed some practical tools in their own use to carry out in-situ measurements and verification procedures for performance evaluation. The basic thing is, anyway, to have "a big picture" about the building stock, its energy consumption and indoor conditions and also to have a sufficient monitoring and reporting tool for maintenance programs and decision making.

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Sustainability indicators for building modernization and urban regeneration

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Summary

The European Union has committed itself to a low-carbon economy, a resource efficient future, a smart, sustainable and inclusive growth. Are these targets contradictory or do they support a sustainable urban regeneration? What are the key indicators to address in this context?

In Nordic countries we are currently facing large scale needs for renovation of our existing building stock as well as a demand for new housing stock in existing urban areas. Regarding urban structures the European challenges are diverse: we have a social need for improved quality of life in urban suburbs, we are struggling with urban decade on one hand and a continuous urbanization on the other. Concurrently, densification is a defined aim for the development of European built environments, as to tackle the impacts of urban sprawl.

Targets for sustainable building and resource efficiency reflect current developments in the field of sustainability, where a holistic approach in accordance with global challenges is applied to projects and processes. One approach to promote a clear set of sustainability measures for a wider stock of residential buildings is to assess individual projects and create a localised database of guidelines and best practice, which may be applied to other similar buildings and entire urban areas. Research and demonstration projects represent case studies for the scalability and replication potential of sustainable retrofit strategies, pinpoint drivers for change. Key sustainability indicators with regard to single building modernization and urban regeneration rely firmly on the three aspects of environmental, economic and social sustainability.

The paper is based on a State of Art study of sustainability indicators for single building modernization and urban regeneration, with a future target of defining indicators applicable to urban renewal processes in Finland.

Keywords: Finland, building modernization, prefabrication, urban regeneration, retrofitting, sustainability indicators

1. Introduction

"Four out of five European citizens live in urban areas and their quality of life is directly influenced by the state of the urban environment." [1]

One example is the view of Finnish residents on their own living environments. The Finnish Environment Institute published in 2011 a survey of Finnish residents´ opinions in 2010. The poll has been realized every 6th year since 1998 and sent out to 2250 respondents. In 2010, 1272 people replied to the questionnaire. [2] The results show weaknesses in Finnish suburbs dominated by multistorey apartment buildings. These include, among others and according to the residents: social disturbances, unrest, insecurity, uncleanliness, a lack of natural environments, noise from the traffic, bad cycling environments, bad image and size of buildings, unsatisfactory yards, low overall rating of the living environment. [3] Most of these can be defined as indicators for the quality of life, the quality and state of the urban environment. There is a social need for urban renewal. Concurrently, the European Union (EU) has committed itself to a low-carbon economy, a resource efficient future, a smart, sustainable and inclusive growth. Are these needs and targets contradictory or do they support each other? What are the key indicators to address in this context?

2. Sustainability indicators for building modernization and urban regeneration

2.1 European urban regeneration: current challenges

In the Nordic countries we are facing large scale needs for renovation of our existing building stock as well as a demand for new housing stock in existing urban areas. The regional perspective in Finland, as in other northern European countries is climatic, based on long heating periods; urban, based on the volume of urban areas built between the 1960's and 1980's in need of renewal, maintenance and repair, continuous urbanization; and industrial, in the development of sustainable, energy-efficient retrofit solutions.

Finland alone has 2 836 000 dwellings [4], 570 000 of which are situated in concrete apartment buildings built in the late 1960´s or early 1970´s [5]. These have now reached the age of major renovations including the renewal of building envelopes, water, heating and electricity supply systems. Energy efficiency is a growing concern: 84% of energy used in Finnish dwellings in 2008-2011 was used for heating and 16% for household appliances. 29% of the heating energy was used in apartment buildings and by estimation, 18% was used for producing hot water. [6]

The scale and amount of future renovations calls for industrialized retrofit solutions. Research and development work has been boosted by European calls for projects with the emphasis on industrialized solutions for improving the energy efficiency of our building stock and real life demonstration building sites. One such project is TES Energy Façade, Timber based element systems for improving the energy efficiency of the building envelope [7]. Retrofit projects demonstrating, among others, the method developed within the project are currently being realized throughout Europe as part of the work within the EU Fp7 project E2ReBuild, Industrialized energy efficient retrofitting of resident buildings in cold climates [8].

On the level of urban structures the European challenges are diverse: we have a social need for improved quality of life, in parts of Europe we are struggling with urban decade and in others with continuous urbanization. In 2006 75% of the Europeans lived in urban areas and it has been estimated that by 2020 the average will be 80%, and in seven countries up to or even above 90%. [9] In Nordic countries, urbanisation, characterized by Rasmussen as "/…/ the process through which society is transformed from one with predominantly rural characteristics in terms of economy, culture and lifestyle, to one which can be characterised as urban (.)" is a current megatrend. [10]

Concurrently, densification is a defined aim for the development of European built environments, as to tackle the environmental, economic and social impacts of urban sprawl defined by the European Environment Agency as "/…/ unplanned incremental urban development, characterized by a low density mix of land uses on the urban fringe." [11] Environmental impacts include increased consumption of energy, land and soil, increased greenhouse gas emissions, air and noise pollution [12]. Social impacts can include risk for social polarization [13].

The Finnish capital Helsinki provides a good example. Helsinki has grown at a speed comparable to south European cities like e.g. Porto, Portugal and Milan, Italy. When comparing low density areas Helsinki is in a top position with close to 100% low density areas. [14] The emphasis of growth impacts are on natural areas. [15] The Helsinki metropolitan area is a representative of the fragmented Finnish urban structure and a good candidate for the application of current targets set by the Finnish Ministry of Environment: the compacting of Finnish cities, with the aim of integrated urban structures causing less greenhouse gas emissions, improving possibilities for efficient public transport, increased services, and resulting in savings in natural resources and energy. [16]

In report 10/2006 by the European Environment Agency on “The ignored challenge of urban sprawl”, one European town is noted as an example of an urban structure characterized as a desirable compact built environment: Munich in Germany. Even if the population has grown with 49% from 1955 to 1990, the town is defined as compact based on two indicators: built-up areas have grown more slowly than the population, and the share of continuous, dense residential areas add up to 2/3 of all residential areas whereas only 1/3 are defined as discontinuous. [17]

2.2 Strategies for sustainable development

On European level strategic measures have been taken as to address current challenges of our buildings, built environments and urban structures with the aim of an environmentally, economically and socially sustainable future.

In 2002 the European Parliament and Council adopted the 6th Environment Action Programme which acted as a roadmap for the development of the environmental policy-making in the EU during 2002-2012. The paper identifies four priority areas: climate change, nature and biodiversity, environment and health, natural resources and waste [18]. Among other actions the Programme includes a call for a Thematic Strategy on the Urban Environment with the objective of contributing to a better quality of life and with the emphasis on developing integrated urban areas and healthy living environments, a sustainable urban development. The strategy was adopted in 2006. [19]

The development was followed up in 2011 through the publication of the “Roadmap to a Resource Efficient Europe”, also a flagship initiative under the Europe 2020 Strategy. [20] It includes two milestones with direct relation to a sustainable development of our urban environments. Firstly: By 2020, EU policies take into account their direct and indirect impact on land use in the EU and globally, and the rate of land take is on track with an aim to achieve no net land take by 2050; soil erosion is reduced and the soil organic matter increased, with remedial work on contaminated sites well underway. [21] Secondly: By 2020 the renovation and construction of buildings and infrastructure will be made to high resource efficiency levels. The Life-cycle approach will be widely applied; all new buildings will be nearly zero-energy and highly material efficient and policies for renovating the existing building stock will be in place so that it is cost-efficiently refurbished at a rate of 2% per year. 70% of non-hazardous construction and demolition waste will be recycled. It is seen that policies promoting energy efficiency and the use of renewable energy in buildings only tackle a part of the challenge and that they need to be complemented through the development of policies for resource efficiency. [22]

Seen through the three pronged approach of sustainability it seems that environmental and economic issues have been tackled in these strategies through emphasizing the development of a green economy, energy and resource efficiency. The next step is in the direction of social sustainability with the proposed new Environment Action Programme entitled “Living well, within the limits of our planet”. [23]

In this context, Finland is a global actor and bearer of responsibility. Finland, along with the European Community and the EU member states ratified the Kyoto Protocol in 2002. A national climate and Energy Strategy was compiled in November 2008 and in 2009 the Finnish Government adopted the Foresight Report on Long-term Climate and Energy Policy, including the target of reducing greenhouse gas emissions by at least 80% by 2050, as compared to 1990 levels. [24]

On single building level, cost efficient improvements of the energy performance of new and existing buildings within the EU are promoted through the recast Directive 2010/31/EU on the energy performance of buildings [25] and the supplementary commission delegated regulation (EU) no 244/2012 [26]. In addition to the 2020 - target of near to zero energy new buildings (NZEB), the Directive lays down a request for national regulations on minimum requirements on the energy performance of existing buildings undergoing major renovations [27].

In Finland, building regulations applicable to new buildings with the emphasis on overall energy performance of a building, rather than numerical requirements for thermal insulation levels for single building structures, came into force in June 2012 [28]. The new and first Finnish statutory regulation on the improvement of energy efficiency of buildings during renovation and alteration works of existing buildings was published in February 2013 and is applied to all building renovation works requiring a building permit starting 01.09.2013 [29]. The aim of the suggested regulations is a decrease of total energy consumption of existing buildings in Finland with approximately 25 % and carbon dioxide emissions with 45% by 2050. Suggested means include, in addition to a revised building code, the promotion of systematic real estate upkeep. [30]

2.3 Sustainability principles for the built environment and urban planning

Current aims for sustainable building, building refurbishment and resource efficiency reflect on going developments in the field of sustainability, where a holistic approach in accordance with global challenges is applied to projects and processes. In the forefront of applied sustainability practice in Finland there is a choice of both international and localized assessment, rating and certification systems for sustainability. Assessment methods set benchmarks and definitions which recognize the efforts within construction projects to go beyond current building regulations.

At the center of urban regeneration is sustainable land-use and sustainable land-management. Good site selection is critical for overall sustainability. The challenge is to identify the potential for sustainability. New building is marginal in the long run, and hence the focus remains on reworking and developing existing urban environments. The existing city is to be added to, not substituted or taken away but added to [31].

Land use becomes critical fast in regions like the Alpines where areas available for permanent settlement are limited. Concurrently the area suffers from urban sprawl. The study on “Land resources in the Alps and instruments supporting their sustainable management as a matter of regional environmental governance” published by Marzelli in 2011 pinpoints the difficulty of assessing the sustainability of land use. In his study he identified 110 different regional instruments designed to stimulate and steer regional development. However, he concludes that “/…/ there is a bottleneck at the point of implementation.” [32]

In response to urban sprawl, there have been efforts to redefine urban models driven by transport planners. Highway road networks expand the linear access model of the city. According to Transit-oriented development (TOD) models, the city is decentralized with alternative modes of mobility yet recomposed by walkable neighborhoods. [33] The aim is to create dense, compact urban structures. [34] Transportation needs to couple with decentralized water and sanitation systems and reduced car use, and promote a human scaled environment. Compact, well-located, walkable and transit-served neighborhoods are critical to a sustainable future. In combination, TOD and green urbanism can deliver a powerful punch of energy self-sufficiency, zero-waste living, and sustainable mobility. [35] One successful example of TOD is Copenhagen´s linear town Ørestad, Denmark. Copenhagen has developed in accordance with TOD since 1947. Knowles published in 2012 an assessment of this development with focus on the progress of Ørestad since the late 1990s. [36] Knowles concludes that Ørestad “…is an important and successful contemporary example of planned sustainable TOD. It builds on the principles of Copenhagen’s renowned 1947 Finger Plan in creating transit-oriented development of jobs, housing and retail, education and leisure facilities.” [37] The study shows that car commuting has been exchanged for public transport with 42% commuting with public transport in winter 2010. [38]

The SmartCity concept aims to reduce greenhouse gases and promote energy efficient built environments by promoting the use of renewable energy sources delivered by smart grids, and by the integration of digital control systems enabled with information technology: real time energy management, transport systems and traffic management, water supplies, street lighting, high-tech manufacturing and data gathering. The target is for a scaling up of innovation, in particular heat and energy reuse, retrofitting to “smart” houses, such as smart homes for the elderly. [39] The development within EU is promoted by the European Initiative on Smart Cities including funding options for ambitious cities [40].

On community level, however, the technological driven approach to sustainability should be balanced by a social approach to change. Social change has to be facilitated to reduce the environmental impact of the use of buildings, and ultimately change social behaviour. End user is the critical link in the value chain. The Finnish context provides a good example.

In Finland, there is a significant volume of urban areas built between the 1960’s and 1980’s which are in need of regeneration, maintenance and repair [41]. There is no possibility to demolish and start from new, even though a large part of the building stock has reached the end of its design life. Fulfilling the requirements for energy efficiency, refurbishment will require additional material effort with higher embodied impacts to deliver performance. Overall, the effort to reach new energy standards will be higher than the gains of urban mining, and there cost of financing the challenge cannot be carried by the residents alone. Due to the speed and scale at which these areas were built, the demographics of the areas are fairly homogenous, and social needs are consistent. In particular the needs of an ageing population define the targets for urban regeneration. Typical in Finland is the need to improve safety and accessibility with lift additions to residential buildings, and rework and reprogram dilapidated shopping centers which no longer meet current retail needs. Out of the economic framework is how local municipalities can reduce growing health care and frail care costs, by subsidizing the investment cost for home renovations. The delivery channels of public services and social priorities have changed since the 1960’s, yet the physical environment is built on the conceptual plans of 50 year old planning ideologies. If the location of the area has potential for infill and demand for expansion, then the investments can be better distributed so long as the land ownership, property legalities and the public planning process can be resolved. Social sustainability is an economic challenge.

2.4 Case studies in urban regeneration

Demonstration projects and studies in urban regeneration represent case studies for the scalability and replication potential of sustainable retrofit strategies. Industrialized methods are developed based on the integration of smart digital work flows with robust and simple construction methods. Industrialized processes aim to remove the manufacturing process from the site, in order to reduce the disturbances to residents. However, they still confront the residents at some point, and the modernization process is inevitably involved with social transformation.

A large built area example is provided by the social housing demonstration in Roosendaal, the Netherlands, partly realized in 2011. The project includes in total the renovation of 246 homes in row houses, 70 of which were renovated to passive house standard in 2010-2011 within the framework of the E2Rebuild - project, and the addition of 100 new homes. [42] The renovation works comprised prefabricated timber facades and roofs, triple glaze windows, ventilation with heat recovery, a condensing gas boiler and solar thermal collectors. The target for overall heating energy demand is a reduction by 80%, and hot water with 50% resulting in 70% decrease in overall building related energy demand. The assembly work was realized on site during one working day and with all building works done within a period of two weeks for each apartment [43]. The retrofit and alteration work was efficient, but a demanding part of the process was the social part, facing habitants representing vast cultural diversity and backgrounds.

Further demonstration works focus on reducing the environmental impacts of urban regeneration, through the evolution of life cycle based products, such as TES Energy Façade. While this anticipates future requirements for environmental product declarations, there are no mechanisms in place to receive compensation for reducing greenhouse gases associated with the material flows of retrofits. The economic benefits of energy efficiency are not reflected in short term investments, and property values do not reflect their life cycle costs.

One example of the application of such methods is case Innova Passivehouse renovation in Riihimäki, Finland, realized in 2011-2012. The building was a typical apartment house for a Finnish suburb, built in the early 1970´s with a load bearing frame in concrete and facades of concrete sandwich elements. The refurbishment included a new building envelope realized through partial replacement of the façade with prefabricated, large scale timber based façade elements, new windows and doors, new balconies and upgraded building services including a new centralized ventilation system with efficient heat recovery. By implementing the TES - method the residents were able to live in the building during renovation works as building works inside the apartment were minimized. The target for energy efficiency was passive house level according to the VTT suggestion for national passive house standard in Finland. [44] The direct replication potential in the Finnish context comprises over half a million apartments in similar multistorey buildings built in the late 1960´s and early 1970´s. [45]

The implementation of urban regeneration on a case by case basis has in fact shown that social regeneration is the key driver. Where the demographics of a residential area have become skewed, or a target market for residential building requires radical changes, the owner is more prepared to invest in redefining the profile of the end users. One example of a target market driven retrofit process is the E2ReBuild demonstration site in Oulu, Finland. "The pilot building in Oulu, Finland, is one of five student apartment buildings and one building with communal facilities in a housing corporation. The building was completed in 1985 according to a Finnish industrialized building system developed in the 1970's using prefabricated concrete units for residential buildings, called the ´BES system´". The aim is a comprehensive refurbishment of both indoor spaces and the building envelope implementing the TES Energy Façade method. The target is for energy efficiency at passive house level and modernized flats that will attract today´s students with families. [46] The main driver for the retrofit was the change in markets: modern students no longer enjoy living in single apartments. Instead, apartments are changed into modern, energy efficient and smart student family homes.

In some cases of social housing, the resident population has no alternative but to remain in the area that is being upgraded, and have to cope with the disturbances. The owners need to convince the residents that the disturbance is tolerable, and sell the residents the benefits of energy efficiency and sustainability, in order to trade off the increased rental costs with the perceived benefits. A careful cost effective energy renovation may be limited to the reuse of heating and installation of "smart" building automation, which has a realistic payback period, and is attractive to institutional owners. This is typical of an engineering approach to energy cost optimization, but requires tradeoffs with the residents, for example kitchen and bathroom renovations, for the disturbances to be accepted by tenants.

3. Discussion, Conclusion and Acknowledgements

3.1 Discussion and conclusion

The EU commitments to a low-carbon economy, a resource efficient future, a smart, sustainable and inclusive growth with regard to urban regeneration are promoted by European and national strategies, research and implementations at least on the scale of demonstration sites. A low carbon society with regard to our built environments is promoted on single building level through increasing and demanding requirements for energy performance of both new buildings and buildings undergoing major renovations [47]. On the scale of built areas, a striving for urban densification, renewal and social well-being can be identified.

Sustainability assessment methods set benchmarks which recognize the efforts within construction projects to go beyond current building regulations. One approach to promote a clear set of sustainability measures for a wider stock of residential buildings is to assess individual projects and create a localised database of guidelines and best practice based on assessment results, which may be applied to other similar buildings and entire urban areas. Regarding built areas, the community plays a significant role. Single building pilots and demonstrations of urban renewal show, that social regeneration and changed demographics might even be key drivers and indicators for change. The technological driven approach to sustainability should be balanced by a social approach. However, the social aspect of sustainability is difficult to verify. Key sustainability indicators with regard to building modernization and urban regeneration rely firmly on all the three aspects of environmental, economic and social sustainability.

3.2 Acknowledgements

The paper is based on a State of Art study of sustainability indicators for single building modernizations and urban regeneration. The aim is to define indicators applicable to urban renewal processes in Finland and the results will be reported in the national, TEKES funded project KLIKK Lähiöiden Käyttäjä- ja Liiketoimintalähtöinen Korjauskonsepti [48]. The project is coordinated by Jouni Koiso-Kanttila, Oulu University. Demonstration object examples were provided by the international ERA-Net Woodwisdom - Net projects TES Energy Façade and SmartTES [49,50], coordinated by Frank Lattke, TU München, and the EU Fp7 funded project E2ReBuild [51], coordinated by Christina Claeason-Jonsson, NCC SE.

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Assessment Tools in Landscape Environment

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Summary

The application of Image Analysis procedures to territory is not something new. Nevertheless, utilizing these techniques to detect the degree of visual intrusion of a photovoltaic plant, or any type of structure, in a landscape is certainly innovative and has yet to be applied in Italy. Under Italian legislation, the assessment of the environmental impact is usually carried out through qualitative investigations that lead to overly subjective judgments. The lack of a single standard has resulted in disputes between various authorities and developers. The methodology presented below helps to define environmental impact in an objective and quantifiable manner with the aim of providing a useful tool for decision-makers.

Keywords: landscape assessment, GIS, perceptual impact assessment

1. Introduction

The analysis and methodology which determine how any type of project is carried out generally use defined parameters, as well as standard indexes and units of measurement, which allow for an objective evaluation. For example, the analyses of the environmental components involved in completing a project take into account the maximum NOx and SOx levels permitted and the level of electromagnetic or acoustic pollution, all of which are defined by specific parameters clearly outlined by law, resulting in a defined range of sustainability. In other types of studies, such as urban, the level of urbanization is determined zone by zone and expressed in cubic meters/square meters so, like an economic feasibility study, the costs are clearly identified by a number and by a unit of measurement.

The clear unequivocal standards mentioned above, however, are largely lacking in assessments carried out to understand the impact that the construction of a new infrastructure, location or building would have on a landscape. It is extremely difficult to objectively evaluate the landscape because of the perceptual aspects which are tied to the subjective judgment of the technician as well as the complexity of the object of the technician's evaluation, the landscape itself. The landscape is a complex idea which is derived from various interrelated factors including: the morphology of the territory, type of human settlement, biodiversity, historical and cultural heritage, type of vegetation as well as other aspects which define and give value to the landscape.

Therefore, the objective of this study is to reduce the level of subjectivity in these assessments and to provide an analytic instrument supported by more appropriate indexes, including the use of numeric data, to guarantee more homogeneous guidelines which, in turn, will result in more homogeneous assessments by all the technicians involved in the evaluating and planning of prospective structures to be built in various landscapes.

2. Current assessment tools

In Italy, the evaluation of a project, and its compatibility with the landscape in which it is to be inserted, is currently based on two main standards. The first criteria involves urban and landscape instruments and requires that the structure conform with urban planning and building regulations in force at the time. The second criteria relates to architectural compatibility and is generally assessed by using viewshed analysis, photo insertion and rendering for simulation. The architects, and other technicians involved, seek to produce models which are as reliable as possible using these tools.

It has become common practice to create viewshed analysis which allow for the reproduction of an object, or structure, in a given area. These viewshed analysis enable us to calculate numeric values related to the geometry of the territory, and they give us an index of the degree of visibility of a certain object from various distances, taking into account visual barriers. Nevertheless, they don't give us any qualitative information regarding the type of landscape being evaluated, including all the factors which contribute to its value, nor do they give us any indication of the quality of the structure to be inserted in the landscape. Furthermore, the biggest drawback of these maps is that they often provide indexes of visibility which are overestimated.

In fact, the computer "sees" an object, or a portion of it, by exclusively following geometrical directions; it recognizes the xyz coordinates of the observation point and the volume of space occupied. For a person, however, the ability to see an object not only depends on the object's dimensions and any visual barriers between the object and the observer but also on the contrast in luminosity - color between the object and its immediate surroundings (relationship shape-background).

For the reasons stated above, it can be affirmed that this type of model is not completely reliable and hence, doesn't allow us to achieve the objective of assessing the visual impact of structures to be inserted in a particular landscape with the highest degree of accuracy possible.

Similarly, the model based on a photo-simulation isn't complete because it doesn't allow us to systematically assess, in numeric terms, the various components that constitute a landscape, such as orographic aspects, soil use, settlements, and cultural heritage. It does have an advantage in that it allows for the collection of qualitative information relating to the chromatic relationship between the object and surrounding area. Nevertheless, it is not a comprehensive model and hence, is not reliable for a complete assessment of all the variables which define a landscape nor can it accurately predict the impact which will result from the insertion of a new structure in this landscape. Furthermore, the results of this model are highly subject to the individual discretion of the technician interpreting the photo-simulation. They depend on the technician's abilities, education, and training and thus, can easily be contested and are not scientifically reliable.

3. Proposal of a method for analysis and evaluation

A multi-disciplinary approach, executed by a competent team of technicians, is fundamental for an optimized and comprehensive study. These technicians, each working in his or her research field, will have to be able to gather the data (indexes), both main and secondary, in the given territory to then share their findings with the other team members to establish relationships and interplay between the various indexes of the landscape being assessed.

For every index analyzed, a model will be produced that is able to reproduce attributes, which can be represented in the report and/or maps. A discussion forum will enable the technicians to decide what weight (importance) to attribute to each index in order to establish a hierarchy of the factors which characterize the territory. At this point, it is possible to create more complex models that can simulate the visibility of a building inserted in a certain location within a territory (Visual Area) and maps which show the sensibility and visual impact of the building.

The map which displays the visual impact is the final result of the first part of the study, in which all of the areas from which the proposed structure can be seen are represented. The areas represented on the map are characterized by various color tones which indicate how the degree of perceptual impact varies from one area to another; the degrees of impact are based on the analysis of the indexes of the various areas. This technique currently represents one standard of analysis used to assess the visual impact of projects being evaluated.

After numerous professional experiences, the majority of which utilized viewshed analysis, we found that the structure, once completed, did not have the same visual impact in the context of the area in which it was built as had been predicted by the simulation. In fact, the synthesis maps always showed a higher impact with respect to the reality, resulting in an overestimation of the visual impact. The problem was rooted in the modeling of the visibility maps.

As mentioned earlier, computers generate visibility maps by utilizing a model which reproduces the surface area of a territory, both natural and anthropic. It is sufficient to represent a structure with a volume and any GIS software with 3D extension will be able to produce a map with all the points from which it will be possible to see the target structure. The only customization that can be introduced into the calculation is a modification of the percentage of the entire volume which can be seen from different observation points.

Based exclusively on geometric rules, the algorithm used by the GIS software does not produce a reliable model of visibility. Theoretically, two points at an infinite distance without any obstacles placed between them (without any interruption in the imaginary line that unites them) are visible for a computer. This example, while perhaps extreme, is very useful in understanding how serious of an error can be made when utilizing visual simulations based on the algorithms standardly in use.

It is an established fact that our eyes have well-defined limitations, both geometric and in terms of luminosity. For a person, the ability to see an object mainly depends on three factors:

* Geometric visibility
* Target dimensions and/or distance of observation point from target
* Contrast in luminosity between the target and its surroundings

The geometric volume of an object and its shape is perceived only if there is a contrast in color either on the surface of the object or compared to the surrounding objects. Therefore, it is fundamental to study the contrast in luminosity between the background and the target object and relate these two factors to the distance at which the object is observed.

4. Case study

We want to demonstrate that a viewshed analysis created by only utilizing the GIS software algorithm can be correct and accurate when combined with the inter-disciplinary approach described above to reproduce a model which much more closely represents the reality of the situation.

A real study was analyzed that was widely-debated in the field of landscape evaluation. It involves a minor intervention but with a large visual impact. The area in which the structure was inserted is a town located in central Italy, which is very important both in terms of nature and landscape as well as cultural/monumental heritage. The zone is protected as a cultural heritage site at both the local and regional levels.

The project calls for the installation of a small photovoltaic plant on the roof of an agricultural building located directly behind the ancient walls which surround the town (fig.1).

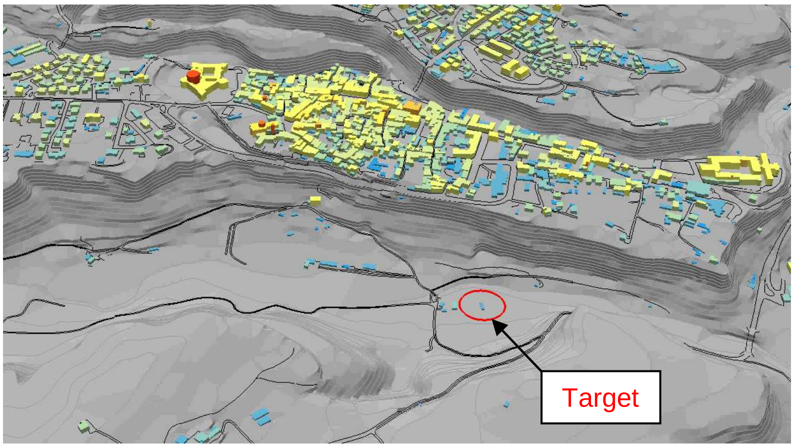

Fig.1 3D model of the territory (a) - agricultural building (b)

On the basis of the 3D model and what is known about the geometry of the building on which the photovoltaic panels would be installed, a standard viewshed analysis was created that shows (using various tones of red) the percentage of the photovoltaic roof which is visible from every observation point (fig.2)

Fig.2 standard inter-visibility map (red visibility 100% - white visibility 10%)

Since the area of the study was very small (57 Ha), it was possible to actually verify the validity of the map produced by doing an on-site audit to visually verify the model of visibility produced from 40 check points. The visual illustration showed that the visibility from the internal areas of the furthest observation points from the target was not confirmed; variations between the current and proposed state of those areas were not able to be detected.

At this point, a very detailed model of the surroundings of the agricultural building was produced to be able to define the characteristics of its luminosity and chromatic contrast, for both the current and proposed state (fig.3)

Fig.3a- 3D current and proposed state (the lines represent the chromatic sections studied)

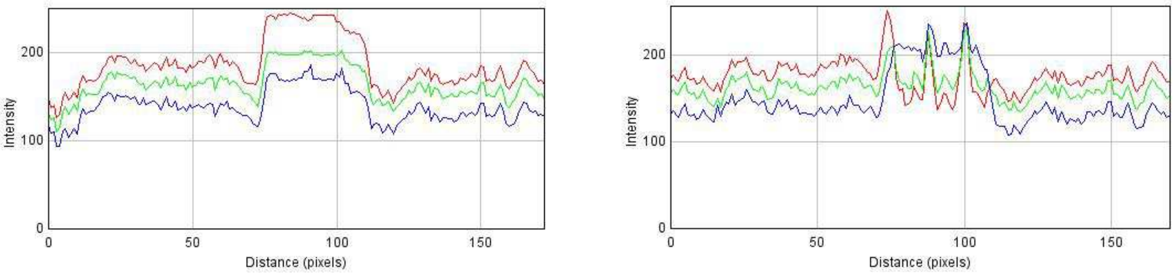

Fig.3b- values of the intensity of the RGB canals along the sections studied

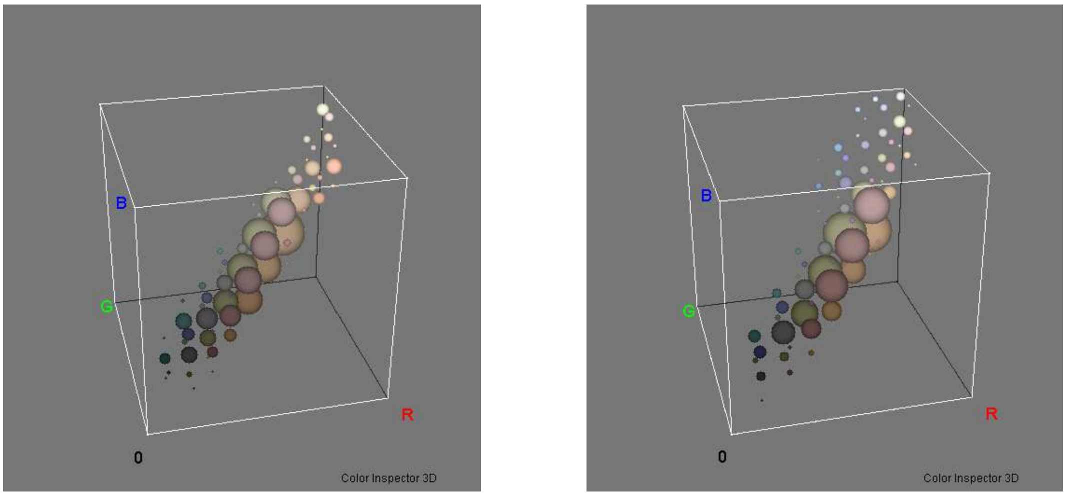

Fig.3c- study of the total variation in the RGB values

Studying the contrast in luminosity and chromaticity between the target and its surroundings allows us to ascertain the visual thresholds of the human eye and hence, to define appropriate limits of distance between observer and target. In fact, the contrast in luminosity is the key parameter that enables us to state whether an object is visible or not.

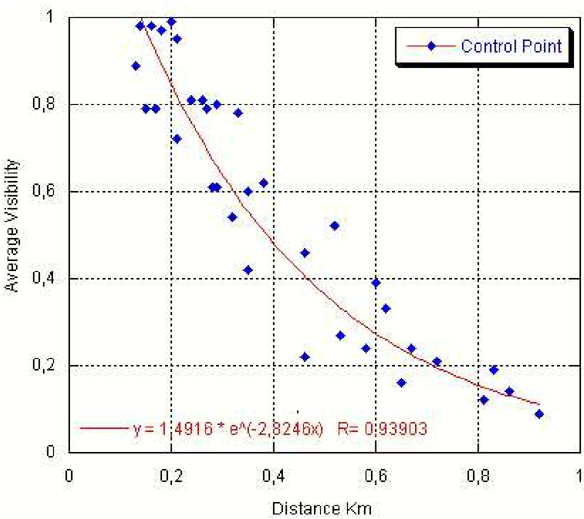

Fig.4- variation of the visibility as a function of distance

As a result of the 40 factors studied, it was possible to create a graph with a defined exponential function that reproduces the variation in visibility as a function of distance for the photovoltaic roof positioned on the building. The error with regard to the fitting was due to the different luminosity conditions in the various areas and/or to the different orientations in the visual line (fig.4)

As can be seen in fig.4, the visibility of the photovoltaic plant becomes practically zero at a distance of approximately 0.9 Km. At this point, we have to revisit the map created and shown in fig.2, inserting an exponential function (like the one shown in fig.4) in the calculation; the result obtained constitutes evidence, even if this is a brief and synthetic text, that the standard algorithms used in the most common GIS software programs overestimate the surface areas from which it is possible to see an object.

In fig. 5, the real limit of visibility of the photovoltaic plant is indicated with a blue circle.

5. Conclusions

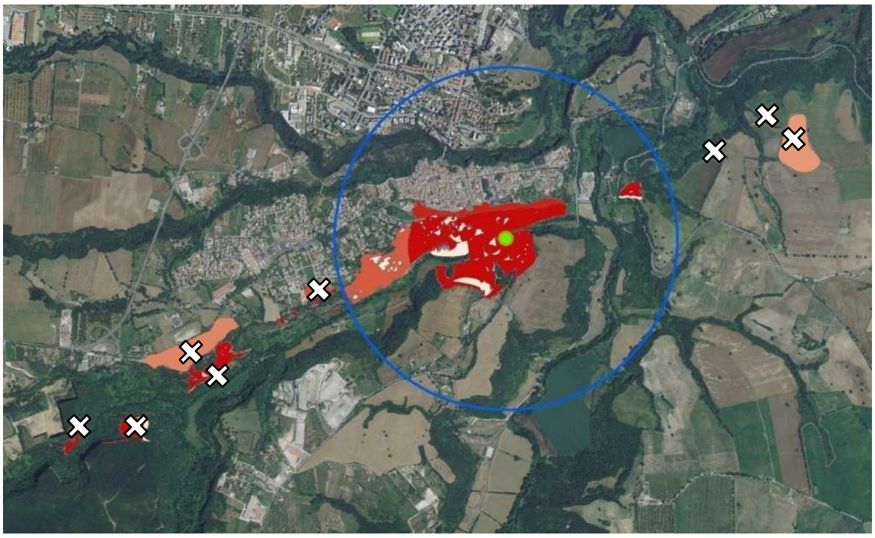

Fig.5- actual limits of visibility of the photovoltaic plant

We do not claim that this study is sufficient for the methodology proposed to become the new guidelines for these analyses. Rather, we intend this study to be a springboard from which other more in-depth and complex studies will arise with the objective of continually improving the models used.

The methodology discussed above gives us an in-depth understanding of the Visual Area at the time when the project is originally proposed as well as a clear picture of the results, in perceptual terms, after a project has been completed.

The type of analysis conducted in the case study allows for accurate planning of any interventions which might be needed to mitigate the visual impact of the structure being inserted into a landscape, hence optimizing the costs of such interventions.

Finally, it is useful to highlight that at the foundation of this study, besides the utilization of well-established methods such as GIS Spatial Analysis and Image Analysis in general, is a multi-disciplinary approach which requires specialized techniques which enable us to grasp historical, cultural and natural complexities to more accurately assess the feasibility of projects proposed in a wide range of challenging landscapes.

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Development and application of a methodology to analyze and evaluate cycling traffic conditions in Joinville, a city located in southern Brazil

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Summary

This paper presents a methodology developed to analyze and evaluate the cycling traffic conditions within the urban perimeter of Joinville, a city located in southern Brazil. With this methodology, we performed a survey of the current situation and recommendations for increasing cycling participation in urban mobility. The goal was to raise the habits and behavior of cyclists in traffic and understand the "solutions" that they find to travel safely and quickly. The existing cycling infrastructure in the city was evaluated to assess its effectiveness and suitability to the cyclist's needs, as well as normal traffic routes, shared with cyclists, in order to understand their level of dangerousness. The number of cyclists and their percentage against other means of transportation was obtained, and also the number of bicycle users in companies and schools, compared with the total number of users in each one. Meanwhile, a survey of unmet demands was conducted through interviews with cyclists on public roads, pedestrians and users of private and public transportation. Interviews with public officials and representatives of civil society organizations were carried out to understand their views on the current reality and the demands for the sector of urban cycling mobility. Finally, a study was done about transit education and related campaigns to verify their efficiency to safely include the cyclists in urban traffic. The knowledge gathered in this whole process is being systematized as a set of recommendations about the best routes and urban infrastructure to be available to cyclists in order to increase the use of bicycles as an effective means of transportation in the city of Joinville. So, we tried to evaluate different aspects of the use of the city cycling network: traffic flow of motorized vehicles and bicycles, cyclist's habits and behavior, urban cycling infrastructure, safety and accidents involving cyclists, educational campaigns for transit, pent-up demand for cycling mobility and opinion of public managers and community leaders. The feasibility of the suggestions characterizes a subsequent step to the research, however it can be stated that clarification generates positive concepts in finding solutions, making it an appropriate educational program to inform the public about the benefits of cycling.

Keywords: bicycle, cyclists, urban mobility, cycle-structure.

1. Introduction

The city of Joinville, in the state of Santa Catarina, according to the IBGE, has 487,000 inhabitants in 1130.87 km^2, a high Human Development Index of 0.857, and an economy based on industry, commerce, services and technology. Joinville is historically known as the city of bikes and has approximately 101 km of bike paths and bike lanes, where it is understood that bike paths are their own lane intended for bicycle traffic, separated physically from ordinary traffic, and bike lanes are part of the roadway solely intended for circulation of bicycles, with appropriate signaling. The cycling density, which is the relationship between the length of the pathways for the bicycle and the area in square kilometers, in Joinville is 0.08. Thus, Joinville's cycling density is more than some large cities such as São Paulo (0.03) and Santos (0.07) [1]

The recent Law No. 12.587/2012 [2] aims to improve the accessibility and mobility of people and freight in cities and integrate the different transport modes. The legislation establishing the guidelines of National Policy on Urban Mobility was sanctioned in January 2012 and gives priority to non-motorized transport and the public transit system and the integration between modes and urban transport services. Therefore we can say that this law can contribute to the improvement of transportation in Brazilian cities. But for its effective implementation, it is crucial to know the reality of each urban municipality, making this adaptation process easier. Thus, this research provides support for urban mobility in the city of Joinville, which may contribute to the development of public policies for urban planning.

So, we tried to evaluate different aspects of the use of the city cycling network: traffic flow of motorized vehicles and bicycles, cyclist's habits and behavior, urban cycling infrastructure, safety and accidents involving cyclists, educational campaigns for transit, pent-up demand for cycling mobility and opinion of public managers and community leaders.

This article is divided into the following sections: Section 2 is the justification of the project, Section 3 contains the methodology, Section 4 presents and discusses some results, and in Section 5 there are the conclusions and final remarks.

2. Justification

Due to the importance of cycling in some Brazilian cities, some factors were chosen to be used in a survey conducted by the State University of Santa Catarina (UDESC) – "Bike transportation in cities in Santa Catarina: methodology for the survey of the current situation and recommendations for increasing participation in urban mobility and raising the awareness of individuals about cycling". They are: personal safety, physical exertion, social acceptability, thermal comfort, bicycle specific infrastructure, cost of travel, distance of travel, comfortable mode of transportation, safe for cyclists, cycling speed, importance of health, personal preference and secure parking bicycle.

Aiming to evaluate the bike in the context of urban mobility, extensive research was conducted in 2010 and 2011 [3] [4] [5] [6], including the development of a methodology that could be applied in other municipalities. The survey focused on making a major survey on the habits and behavior of cyclists, existing cycling infrastructure, in addition to counting the cyclists on routes previously chosen. Furthermore, it was important to raise the opinion of public officials and representatives of community organizations on the bicycle as transportation. This way, it would be possible to better understand the various views on the current situation and urban cycling mobility. Finally, a survey of campaigns for traffic education was also considered vital. The purpose was to check its efficiency, as campaigning for the inclusion of safe cycling in urban traffic. In the end, it was intended to systematize the knowledge collected in the form of a set of recommendations to be distributed between public entities and municipalities.

The survey conducted by this research allows us to generate, in addition to new knowledge, new questions, opening up possibilities for new work. These work can complement those already underway, and help in studies to develop new policies that include bicycles more in the urban mobility system.

3. Methodology

As was stated in the previous section, one of the objectives was the development of a methodology developed to evaluate the use of bicycles in urban areas. Thus, initially all of the procedures were geared toward the city of Joinville. The proposed methodology consists of surveys contemplating the specific purposes. Below there are some details of the methodology.

3.1 Traffic flow of motor vehicles and bicycles

3.1.1 Count the means of transportation in the main streets in many parts of the city, according to the number of inhabitants;

3.1.2 Cyclists evaluation by age and sex, in order to select the respondents;

3.2 Number of bicycle users in companies and schools

3.2.1 Dispatch a questionnaire to schools requesting information about the total number of students and the number of students that use bicycles as a means of transportation;

3.2.2 Dispatch a questionnaire to the companies requesting information on the total number of employees and the number of employees that use bicycles as a means of transportation;

3.3 Survey and evaluation of habits and behavior of cyclists and of the cycling mobility pent-up demand

3.3.1 Application of questionnaire for cyclists in traffic or in places where they are stationary on the same streets where traffic flow survey was done;

3.3.2 Interviews with users of public transport, pedestrians and users of private cars;

3.3.3 Observe the proportionality of sex, age and income bracket of the population of the city;

3.3.4 The questions cover topics such as: route extension, route and schedule choice, traffic care, personal safety equipment, integration with other modes of transport, major difficulties, the reason for the choice of the means of transportation, vehicle conservation and maintenance;

3.3.5 The pent-up demand interviews focus also on the reason for the vehicle used, evaluation of the use of bicycles for transportation, reason for not using the bicycle as a means of transportation and willingness to do it in case of cycling infrastructure improvements.

3.4 Evaluation of bicycle structures in the city

3.4.1 Map and measure the whole structure for cyclist-only circulation such as bicycle paths and lanes;

3.4.2 Evaluate their quality: pavement conditions, signs, width, intersections, conservation, connectivity and security;

3.4.3 Evaluation of the city public bicycle parking;

3.4.4 Survey and evaluation of bicycle racks at public and private companies and schools in the surveyed streets;

3.4.5 Overall assessment of the street layout in the city;

3.4.6 Survey and detailed measurement of the surveyed streets in width, pavement, signs, intersections, maximum permitted speed.

3.5 Evaluation of the safety of cyclists on city streets and survey of accidents involving cyclists

3.5.1 Survey of accidents involving cyclists in transit departments, city hospitals and related organizations to investigate deaths and injuries over the past 3 years.

3.6 Evaluation of educational campaigns for transit

3.6.1 Survey of campaigns, educational materials and educational programs in the Municipal Traffic and Education Departments in the last three years;

3.6.2 Evaluation of the approach offered to cyclists on their traffic priority and the recommendations for safe use of bicycles in traffic.

3.7 Opinion survey with public officials and community leaders

3.7.1 Interviews with managers of urban planning and city transit-involved departments on issues such as: priority given in the municipal budget, investments in the development of the city, the main difficulties for the inclusion of cycling in the urban mobility system, opinion about the effectiveness and advantages of different modes of transportation in the city;

3.7.2 Interviews with community leaders (members of Community Councils and Residents Association) involving issues such as: major difficulties for the inclusion of cycling in the urban mobility system, opinion about the effectiveness and advantages of different modes of transportation in the city, demand for the use of bicycles in traffic.

As an experimental survey, the methodology was applied in the city of Joinville.

4. Results and Analysis

4.1 Factors

The survey was carried out on fourteen streets in the city of Joinville during the period from the 14th to the 21st of March 2011, including like riders, motorcycle riders, car drivers, and public transportation users. 401 questionnaires were filled out, 386 were during the day (from 7:55 a.m. to 6 p.m.) and the remaining surveys were filled out at night (from 6:10 p.m. to 10 p.m.). The sampling error was 4.9% with a confidence rating of 95%. In some cases the chi-squared test was performed to check if there were any differences among the answers furnished by the interviewed participants. The adopted significance deviation rating was 5%.

Among the 401 interviewed, 96.5% are residents of Joinville and most are male, except for the public transportation users, where 78.0% of the responders are women. The predominant characteristics among all the groups are self-employed and commercial people and who have concluded high school. Although the monthly gross income varies among the interviewed, the higher monthly incomes were attributed to car drivers. These data and results have been detailed in [6].

Regarding the purpose of the trip, work at (49.6%) is the most predominant, private matters at (29.2%) and shopping at (8.7%). The majority of motorcycle riders (67.0%) and bicycle riders (41.0%) are going to and coming from work, whereas the car drivers and public transportation users, in most cases use these means of transportation for personal matters (31.7% and 36% respectively).

Those interviewed also were asked the question about “The reason for selecting any given means of transportation” and they could give more than just one answer. The bicycle riders said it was faster (64.0%), less expensive (58.0%) and healthy. The motorcycle riders said it was faster (87.0%), less expensive (85.0%) and more convenient (54.0%), when asked to state the reasons for their choice of means of transportation. Speed and convenience were also reasons mentioned by the car drivers (70.3% and 42.6%, respectively), besides the comfort, considered by 46.5% of the responders in this group as the reason for choosing that means of transportation. On the otherhand, the majority of the public transportation riders selected this means as it was their only option (79.0%).

Concerning the reason for selecting the means of transportation, the most common were for work

(49.6%), private matters (29.2%) and shopping (8.7%). The majority of the motorcycle riders (67.0%) and bicycle riders (41.0%) said they were either going to or coming from work, whereas for car drivers and public transportation users, most of them selected their means of transportation for personal matters (31.7% and 36% respectively).

4.2 Bicycle parking racks

The bicycle parking racks in Joinville have also been analyzed, as their locations are of fundamental importance to bicycle riders, who need a safe place for storing their bikes. However, 32% of the bicycle riders do not use the bicycle parking racks and 55% consider them to be of insufficient quantity. This means among the bicycle riders interviewed, only 68% use the bicycle parking racks and these responders were questioned on the capacity, safety, covering, and upkeep of the bicycle parking racks. Another relevant factor derived from the survey is related to safety and 54% of the bicycle riders do not feel safe while pedaling in Joinville, especially due to dangerous traffic. However, in spite of the response which expresses the dangerous traffic, only 9% of the bicycle riders wore individual safety equipment at the time they were interviewed, such as closed footwear, helmet, or gloves and only 12% used safety gear on their bicycles (reflectors, horns, lights, or mirrors).

4.3 Traffic flow

In the traffic flow counting, 14 points were selected on the main streets of the urban area, at which were recorded, initially, total bicycles and cars at times of highest traffic. During the survey, it was determined that there was a need to include motorcycles. With the goal of describing the traffic, and making explicit the importance of each place, a characterization was made of all of the routes where counting was done.

In the streets and avenues, where counting of bicycle flow was performed, two stood out with the greatest flow, with approximately 420 bicycles in two hours. For the counting period the type of vehicle showed a greater flow in the morning for bikes, and in the afternoon for cars. The overall mean flow of all types (bicycles and cars) during the count was 3,279 units. In all the streets and avenues, cars represented the largest percentage of traffic flow. On the average, bicycles accounted for 9.9% of the flow. The average number of each type per period of the count was 325 bicycles and 2953 cars [5].

4.4 Number of bicycle users in companies and schools

In the schools, student cyclists were evaluated. Questionnaires were sent to 80 public schools, asking for the number of students per period and the number of students that use bicycles as a means of transportation. Of the questionnaires sent out, just 26 were returned. That means that the total number of students surveyed, including morning and evening periods, was 18,615. This number is about 30% of the students in the public school system - in May 2009, the total was 62,748 students enrolled at 144 public schools. In the morning, about 7.4% of the students use bicycles as a means of transportation. The school with the highest percentage of student cyclists (44.4%) is located in the Jardim Sofia neighborhood, near the Joinville airport. The neighborhood has 1.99 people/ km². The school with the lowest percentage (0.3%) is in the Saguaçu neighborhood, near the center of the city. This neighborhood has 2,642 people/ km². In the evening, the average of student cyclists is 6.1%. In this period, the school with the highest percentage of student cyclists (49.1%) is the same one that has the highest percentage in the morning - located in the Jardim Sofia neighborhood. The lowest percentages (0.3%) of the evening period belong to two schools that are near each other, one in the João Costa neighborhood and the other in the Adhemar Garcia neighborhood. Compared to the neighborhoods mentioned earlier, these two neighborhoods have higher demographic density (3,715 and 4,781 respectively). Putting the two periods together, there is a large variation of percentages - from 0.44% to 46.88% [5].

We sought to understand the needs of businesses and the roads leading to their locations, evaluating the percentage of cyclists compared to the total number of workers, through a field study of 13 companies. It was discovered that the proportion of workers that use bicycles as a means of transportation is 16.36%, with a percentage variation from 1 to 34%. The two businesses with the lowest percentage were in areas far from the city center having low population density (1565 people/km² and 134 people/km²), while the business with the highest percentage was found in a residential area with a population density of 3122 people/km² [5].

4.5 Evaluation of city cycling infrastructure

The routes used by cyclists have been mapped and are classified as bicycle paths or bicycle lanes, and their length, width and location are detailed. The total length of bicycle paths and bicycle lanes in the city of Joinville is 101,44 meters, which corresponds to less than 0.02% of the total area of the city [4]. The existing bicycle parking in urban bus terminals was evaluated regarding use and safety.

4.6 Survey on accidents involving cyclists

The research on accidents involving cyclists covers fatal and nonfatal accident data involving cyclists provided by the following institutions: Companhia de Urbanização de Joinville (CONURB), Police for Traffic Accident, Instituto de Medicina Legal (IML), São Jose Municipal Hospital and Municipal Department for Health in Joinville. The survey was also done at the hospitals in the city, but they have no records on the subject [8].

In the analysis of the accidents between cyclists and other vehicles, the car is the vehicle with the highest incidence of involvement in accidents involving cyclists. The collision is the main type of accident. Most accidents occur during the day. The percentage of fatal accidents where the victim was the cyclist was 0.2% in 2009 and 0.9% in 2010. Considering that accidents involving cyclists fell in 2010, this figure shows that the severity of accidents has increased. Over 50% of accidents involving cyclists occur in only two neighborhoods. These neighborhoods deserve more attention from the City of Joinville to create bike paths / lanes and improve traffic signs. Most cyclists involved in accidents are male and age from 21 to 50 years.

As a contribution to the development of the proposed methodology, the collected data contributed to the diagnosis of difficulties and achievements for the organization of the institutions, in the surveyed period, 2008 to 2010. The survey results are not conclusive, because there may exist missing or duplicated records. The lack of detailed information on the identification of the victim, characteristics and location of the accident prevented the standardization and validation of data before the statistical analysis thus compromising its quality as a scientific study. The results show a tendency that needs to be confirmed with further research within appropriate parameters.

4.7 Evaluation of educational campaigns for transit

In the evaluation of educational campaigns for traffic, only campaigns involving bike transportation were evaluated. Educational materials of the campaigns with focus on bicycle transit were made by state and municipal public departments, with support and collaboration from private and public institutions in the form of leaflets or campaigns via Internet. There are also some campaigns of civic groups.

4.8 Opinion survey with public officials and community leaders

Structured interviews were conducted with public managers (professional members of public institutions) and community leaders (representatives of local communities, such as presidents of neighborhood associations) [4].

Three public managers were invited to participate, a meaningful sample, but only two accepted the proposal. The missing participant would have represented SEINFRA (Department of Urban Infrastructure of Joinville). The public managers that participated in this research represent IPPUJ (Institute for Urban Research and Planning of Joinville) and CONURB. The first is a civil engineer and the second an architect.

Some of the questions intended for community leaders were also used for the public officials to ensure that different spheres of society were represented and to accomplish an unbiased assessment on urban mobility. Other questions were intended only for the public officials due to the inherent characteristics of public management activities.

According to one of the managers, the intention is to move from the current 11% of trips made by bicycle to 20% by 2020. He quotes the city master plan regarding mobility that has a central paradigm to prioritize non-motorized types over motorized ones, and that the culture of cycling, the growing cycling network, an integrated extensive transport system and special lanes for buses are advantages in urban mobility in the city of Joinville. He comments on the possibility of extending the bicycle routes in the next four years with an investment of 3.5 million reals. He also mentions projects for implementation of monitored bicycle parking in integrated stations and 9 km of bicycle lanes that would feed these stations, 13 km of infrastructure for the Paranaguamirim neighbourhood and 17 km linking a network of parks in the program “Linha Verde”.

For both participants, there are issues that hinder the inclusion of bicycles in the mobility system: making an interconnected cycling network, availability of space to store bikes, integration with other transport modes, the superior speed of motorized transport, lack of traffic education and lack of conscience by society of the importance and benefits of bicycle use. For one of the managers, Joinville has no adverse cultural factors that compromise the use of bicycles. The second member states that the relationship between status and the acquisition of a car is a cultural factor that distances the citizen of Joinville from the use of bicycles. As one of the structural reasons that impair the use of bicycles, one of the managers cited the need to expand the cycling network, and a traffic education with a focus on sustainability. According to the testimony of one of the members, representatives of various districts highlighted, in the 2011 edition of the participatory budget, the need for bike lanes and bike paths.

Ten community leaders (another meaningful sample), nine men and one woman, participated in the survey. All were helpful and showed interest in participating in a survey related to the theme "urban mobility in the city of Joinville." Two respondents are pensioners with only an elementary education. The others have college degrees and varied activities: President of an educational institution, publicist, regional public coordinator, association president, pharmacist, coordinator of industrial maintenance and architect. Regarding the use of bicycles by the participants, 40% never use the bicycle, 50% use it casually for pleasure and only one participant uses the bicycle for all daily activities, including work. The reasons among the 40% that do not use the bicycle vary: long distances, not having learned how to ride, lack of bicycle lanes and not having a bicycle. All respondents that use the bicycle for recreation or work do not feel safe riding on the streets of Joinville. The reasons are: disrespect by car drivers, lack of bicycle lanes and heavy traffic. The participant that contributed with the largest number of suggestions uses a bicycle daily and travels some distance on foot, but also uses the car. He emphasizes the importance of incentive programs and basic education, proposing encouraging advertising campaigns and suggests: "The person that uses the bicycle integrated with the collective system could pay less for the ticket."

Respondents that had fewer suggestions on the expansion of bicycle use in the city believe that the modernization of the transit system depends on works such as overpasses and wide streets that allow driving with higher speeds than those permitted in the city nowadays. Before the inquiry whether to consider or not the bicycle as an alternative solution for transport, one of the interviewees denied saying: "Hinders progress of cities." Another positioning observed was the assertion that in a certain neighborhood of the city residents does not want bicycle lanes because, according to the participant, it would reduce the safety of local residents regarding robbers and homeless. This testimony corroborates the statement of another participant that claims that the use of bicycles in the town is a less decent mean of transportation.

Another member that contributed actively related that bicycles should be sold as a self-sustainable model in the city because rapid changes cannot be expected due to the power of the automotive industry, which pulls the economy and consequently the cities. The above statement agrees with the suggestion of another participant in proposing advertising campaigns for the deconstruction of the cultural factor that assimilates car with social status. The two propositions can generate the following suggestion: advertising campaigns to sell the bicycle as a sustainable model.

5. Conclusion

In a large number of countries, including Brazil, many people ride bicycles as a means of transportation. This means of transportation, besides being inexpensive and healthy, does not pollute the environment, which is an extremely current topic for discussion nowadays. However, it is possible to increase the number of people even more who become bicycle riders, as long as they are aware of the needs of citizens and the reasons which may hinder riding this means as their main transportation vehicle.

Considering this, a study has been performed on urban mobility in the city of Joinville, a flat city in the southern region of Brazil. 14% of the inhabitants ride bicycles, based on [7]. But this statistic could be higher: about 72% of the motorcycle riders, car drivers, and public transportation users would ride more bicycles if the bicycle lane infrastructure were better. However, in the opinion of the interviewed responders, public investments mostly encourage cars and public transportation, or even no means of transportation is encouraged.

The unfavorable opinions regarding urban mobility in the city of Joinville, as well as field research (traffic flow and urban cycling infrastructure) demonstrate the need for a major reformulation of the entire mobility system, aiming at the integration of a variety of means of transportation. The common affirmation that the lack of bicycle racks, lanes and bicycle paths characterize reasons for not using the bicycle as a means of transportation shows that the structure offered by the city relates to the citizen choice of what means of transportation he will choose. In addition to the urgent necessity of building bicycle racks, lanes and paths, it is essential to observe the testimonies asking for continuous routes to connect neighborhoods because, according to individuals in the research, the current one is interrupted. The bicycle lane infrastructure and bicycle parking racks must have good quality in order to attract a larger number of bike riders. It is necessary to furnish anti-theft security equipment in bicycle parking racks, as well as make people aware of respecting bicycle lanes by non-cyclists. In Joinville, the landscape and the climate do not affect the decision to ride a bicycle or not. On the other hand, the bicycle lane infrastructure and safety are the greatest hindrances, so when these issues are solved, based on the measures not considered in this article, then this could attract more people to ride bicycles.

The feasibility of the suggestions is a subsequent stage of the research, however it can be stated that the clarification generates positive concepts in finding solutions, making it an appropriate educational program to inform the population about the benefits of cycling.

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Green space within residential blocks: Building sustainable neighbourhoods on historic precedents

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Summary

The internal reserve space – shared, public-private open space at the centre of a housing block – is a phenomenon often aligned with the early 20th century town planning movement. This paper argues that this disparaged and neglected form has now come of age in an era where local, productive green space is at a premium in high-density city neighbourhoods.

Keywords: green space, density, recreation, safety, open space, urban sustainability

1. Introduction

The internal reserve space – shared, public-private open space at the centre of a housing block – is a phenomenon often aligned with the early 20th century town planning movement. For many key practitioners of that era, the communally used and maintained internal reserve was a 'must have' in the checklist of best practice housing estate design. The popularity of this spatial form has ebbed and flowed; this fact – its inconsistent use through generational change – has, in itself, served to discredit it as a type over time.

While the brief design popularity of the internal reserve space might have been tied to the international emergence of the 20th century town planning movement, the concept of including open space within street blocks of buildings preceded usage within that sphere. Indeed the 19th century provides numerous important precedents for the form, many of which appear to have occurred spontaneously to individual designers and/or social innovators. The same basic typology unifies spaces which are geographically, culturally and morphologically (especially in terms of residential density) quite different. Sunnyside Gardens in Queens, New York was the landmark project which fused the aspirations of housing and planning reformers within the context of a grid city. Not all its interior spaces survive and unfortunately sorry fates have befallen many other such spaces as their primary ideological and functional rationales have been forgotten [1]. The geographer Edward Relph has referred to them as 'slop' (spaces left over after planning) [2]. Yet as cities become denser and new movements promote sustainability, health, localism and place-making, these dollops of green (or grey, or brown) have considerable potential for the future.

2. Low density, high density

These spaces were created in different settings. Firstly, in low density environments, green space was a touchstone of the garden city tradition and the internal reserve originated in the communal allotment gardens provided for residents. The earliest town-planned estates such as Port Sunlight, near Liverpool in England, contained blocks with ‘houses round the perimeter and allotments and a service road in the middle,’ as Josephine Reynolds reported in 1948, more than half a century after the town’s establishment [3]. In the late 19th century, Port Sunlight’s owner-operators – the Lever Brothers soap company – had announced that ‘exercise in the open air strengthens and invigorates the body, while the increasing demand for allotment gardens by men of limited means, amply proves that the pocket is also benefited’ [4].

Allotment garden spaces were primarily for local agriculture – although the understanding was always that such activities could serve as recreation in addition to serving as a community-building exercise for children and adults alike. Food grown would benefit household budgets. Reynolds wrote of the Port Sunlight allotments that ‘where they are enclosed, the care with which the tenants look after them gives an overall appearance and feeling of genuine attachment to the place. The community spirit in Port Sunlight flourishes’ [5]. Following a review of use in the early 1960s, all but one of these allotments have been converted to other open-space functions [6].

Later planned estates, such as Hampstead Garden Suburb, in London, featured small internal parks in blocks both for agriculture – some such spaces appear to have functioned continuously as allotment gardens for close to a century – and passive recreation. As was the case in Port Sunlight, prizes were awarded annually in produce competitions.

A popular manifestation in mass production was the reserve embedded in ‘organic’ low density housing estates. The curved streets of these estates not only demonstrated the surveyor/planner’s skill and the penchant for public ‘street pictures’ but also carried possibilities for creation of more private and enclosed spaces hidden within the interior of residential blocks. In such park-like layouts, where street blocks presented as elliptical shapes and off-kilter rectangles, interior parks were generated in apparently random shapes. In creating opportunities for community interaction, these spaces were voluntarily delivering the open space quantum which would be later mandated by statutory subdivision regulations.

When biologist and social reformer Patrick Geddes added greenfields town planning to his extensive armoury of abilities from the 1910s, he also included open space within blocks in many designs. He saw such spaces as integral to his many plans for Indian cities, both appropriate to Indian culture and as ideal for the promotion of healthy and hygenic low density suburban living. Here Geddes demonstrated his holistic approach with reports described as reading ‘like a philosophical treatise with the narrative weaving an unlikely thread through defecation, sewage, drains, gardens, festivals and universities to propose a holistic vision for making the city habitable’ [7]. His inclusion of central interior open spaces in his ‘fractured grid’ plan for Tel Aviv the following decade went unexplained by their creator, but might be interpreted as following a ‘village green’ style within neighbourhoods.

Interior block spaces were also a feature of more urban, planned higher density environments. The roots here go back at least to new forms of town extension planning intended to deliver amenity, community and public safety. An intriguing progenitor in nineteenth century Finland took shape for the sole purpose of precaution against fire. The city of Turku was rebuilt to a grid plan after the great conflagration of 1827, as was the city of Vaasa where the architect Setterberg instituted a plan in which 15 metre ‘fire streets’ bisected each residential block [8]. A variation on this concept, also intended to reduce risk of spreading fire, was Edelfelt’s 1858 design for Hämeenlinna. Here, Edelfelt produced the ‘novelty’ of ‘dense planted areas in the fire squares in the middle of the blocks’ [9]. Ferdinand Ohman’s 1879 plan for Nurmes aspired to create a town in two parts, one geared to commerce and the other to industry, the two bisected by water. In each the gridded plan featured a variation between the fire block square and Setterberg’s fire streets. There were sixteen fire blocks in all; for reasons unclear, only the western part of Ohman’s plan was constructed [10]. In 1859 Spanish engineer and town planner Ildefons Cerdà envisaged an extension to the city of Barcelona comprising 550 open garden blocks in 20 metre wide streets. Such blocks, which wouldutilise a concept translated into English as ‘interways’ to allow (limited) transit and access (Fig 1), were calculated by Cerdà to facilitate important guards against disease in the prevalent ‘miasma’ theory of the time - the flow of air and access to frequent sunlight. ‘Interways’ and open space would also regulate urban density. Additionally, Cerdà envisaged a combination of private and communal open space within each interway, in which the very old and very young could enjoy 'special gardens' for relaxation undisturbed by the public. Though Cerdà's concept came to be well-known, however, little resulted in built form for some decades after the original publication of his plan; it was formative in the further development of other cities, such as Madrid.

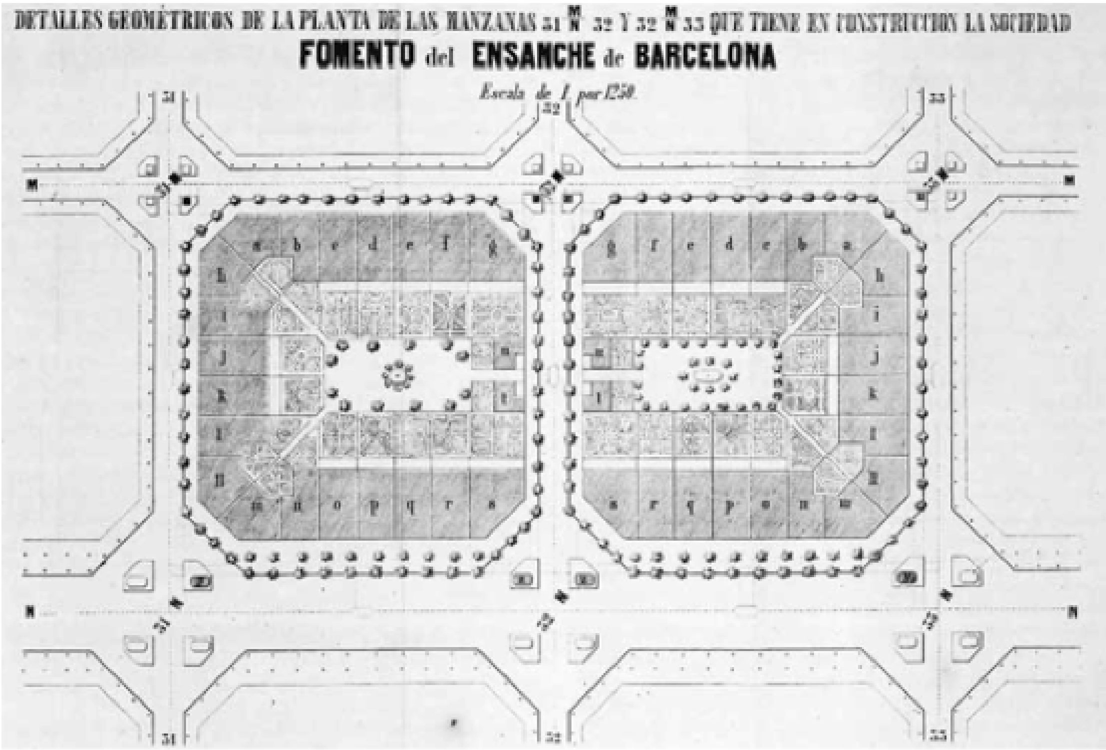

Fig. 1 Cerda's 'interway' block for Barcelona

In 1893, prior to his endorsement of garden city forms, Geddes was similarly conceptualising a reimagining of old city blocks as perimeter housing for active and healthy open space [11]. Intent on revitalising two slum areas of central Edinburgh as part of a larger renewal scheme, Geddes facilitated the demolition of outbuildings and other degraded structures to open up two large spaces for recreation [12]. These were ringed by the previously extant, though somewhat modified, multistorey apartment buildings (Fig 2).

In Ireland in the years just prior to World War I, he initiated a scheme to clean up 2000 derelict sites around Dublin, converting some into playgrounds [13]. His daughter Nora spent the next three years organizing 'gardens for children in corners of [Dublin's] old town' [14]. Geddes made a report to Dublin's 1913 Housing Inquiry in which, Michael Bannon writes, he 'urged the necessity of small open spaces and gardens which he believed were generally more desirable and useful than the larger open areas' [15]. Others in Dublin took up Geddes' mission. Architect Henry Hill, for instance,

Fig. 2 Cerda's 'interway' block for Barcelona advocated limiting street widths in new developments ‘in such a manner that open spaces can be provided for children’s playgrounds near by’ [16]. Responding to Geddes’ and his cohort’s passion for interior space as playgrounds, all competitors to the 1914 contest to find a town plan for Dublin included some form of interior park space in their designs [17].

Hence we find two planning traditions advocating and experimenting with provision of green spaces within and primarily for the residents of housing block, both in earnest from the 1890s. One is associated primarily with housing reform in high density inner cities and follows the narrative of the reformed perimeter housing block [18]. The other is more affiliated with the modern town planning movement and its early preoccupation allied to garden city ideals with decongesting the city through suburban planning [19]. Sharing a common ideological commitment to the power of open space to cleanse, enchant and empower the community, they appear to have been complementary yet largely independent impulses until the 1920s. Their convergence was facilitated by the need to reform the time-honoured urban grid. By the 1930s for many urban designers of a ‘modernist stripe’ the grid could no longer serve as the frame for socially equitable development but rather was “an intractable source of urban misery” [20]. Interstate and state highways and railways linking cities and the ‘seemingly boundless increase in modern city traffic’ [21] were indicative of grid matrixes and perversely led to the demise or partial demise of the central core of these planning systems, with ‘one gridiron leaching the contents of another” [22]. In the 21st century, particularly under the influence of New Urbanism, such assessments seem overblown. As will be seen, the gridiron is in many respects perfect for the form the present authors recommend.

3. Interior space within gridded street blocks

In the 18th and 19th centuries, the preferred schema for western cities was the grid plan, organised as rectilinear blocks fixed within straight streets. Wide, straight, perpendicular, intersecting trajectories most prevalent in grid planning systems make this an efficient form allowing access to natural light, shelter from wind and navigation of streets. Straight streets and uniform blocks also assisted in visibility, defence, passive surveillance and orderly urban development. Such advantages were clearly seen by the Scandinavian and Spanish planners mentioned in striving to ameliorate hygiene and safety issues.

Yet at the time of the increasing popularity of the internal reserve – as engendered by Geddes and peers such as Raymond Unwin – the grid plan was coming to be seen by many in the early modern town planning movement as anathema to appropriate planning practice. Its regularity and predictability – indeed, the very elements that made it appear ideal for most of the 19th century – were rejected. Frederick Law Olmsted Jr’s plan for Forest Hills Gardens, New York was an ostentatious redrawing – to the point of erasure – of a gridded plan, its organic and sinuous design seemingly created to show up a contrast with the grid it might have been, parts of which were already subdivided in adjoining land [23].

Obvious exceptions to the rejection of the grid included practitioners such as Le Corbusier, who envisaged grids and other highly regular planned environments on a grand scale, though with housing in high-rise buildings definitively and precisely at the centre of blocks. However, innovative planners found that the grid need not be inimical to good planning practice. . Enclosed blocks with large open courtyards were built in the 1890s as philanthropic projects in New York by William Field and Sons and later adopted by German reformers such as Bruno Möhring and Rudolf Eberstadt in 1910. Hendrik Petrus Berlage’s 1915 plan for Amsterdam South – Plan Zuid – similarly adopted a ‘syncopated’ grid of long courtyard framing housing blocks [24]. The best-known, and perhaps best, example of this is Henry Wright’s Sunnyside Gardens constructed in New York in the mid-to-late 1920s. This development is pivotal in the rapprochement between the low and high density narratives to reform residential blocks through inclusion of interior communal spaces [25].

4. Sunnyside

Sunnyside was a melange of experiments in housing and town planning. Its designers and developers were innovators in the provision of co-operative apartments, two-room deep houses, generous mortgage arrangements aimed at low-income groups, and, in addition to small backyards, ‘common central gardens in the block interior’ [26] (Fig 3). This all played out within the inherited legacy of a gridiron street pattern.

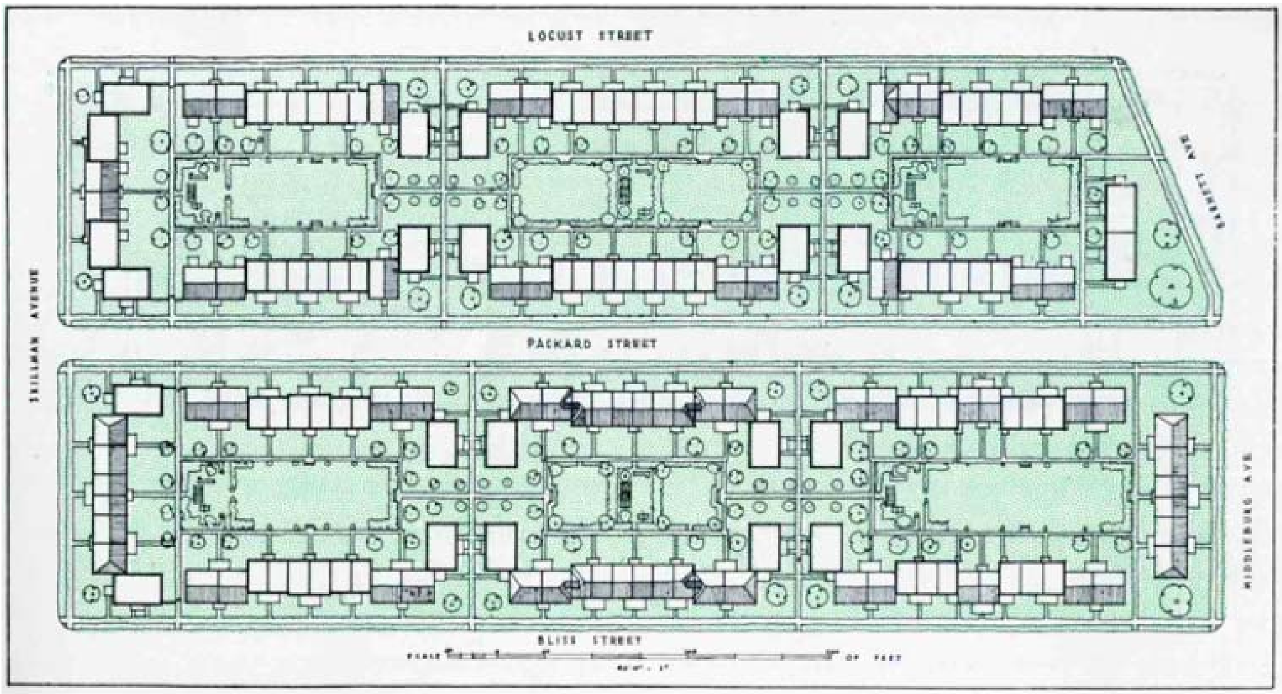

Figure 3 Elongated blocks in Sunnyside, mid-1920s

Pearlstein has recently noted that a crucial contribution of developer Alexander Bing’s City Housing Corporation at Sunnyside was to shift ‘design and development focus from the building to the block’ [27]. Certainly, the interior spaces in each block were a common subject for comment in descriptions and depictions of the Sunnyside project. In his 1928 volume on local parks, L.H. Weir observed the ‘little children’s playground areas’ within Sunnyside blocks and noted approvingly that ‘every block in the entire subdivision has a space similar to this’ [28]. Foreign visitors were similarly impressed. Australian surveyor/planner Saxil Tuxen photographed these spaces in use very early in their existence, during a trip to the USA in 1926 (Fig 4). Shortly after completion, the onset of the Great Depression saw many Sunnyside residents unable to keep up mortgage payments. Once again, the interior spaces were key to depictions of the area: Pearlstein reports that when Sunnyside families marched on the White House seeking assistance, children wore signs pleading with President Roosevelt to ‘Save My Play Yard’ [29].

Though Sunnyside undeniably represented a new direction in affordable housing and amenity provision, one of the most striking aspects of its form was its ‘normal’ street plan. Indeed, the City Housing Corporation had been compelled to use a pre-existing subdivision for its housing blocks. Unlike Olmsted Jr at nearby Forest Hills Gardens, there was no option to redesign the 19th century grid already platted for the precinct. While there is no way to know what form Stein and Wright, given complete control, might have preferred for the suburb, their next major project, at Radburn, New Jersey, gives some clue. Here, a distinctly suburban environment of single-storey houses fronted onto a large interior park with pedestrian and street traffic almost entirely separated. Within the thinking of the period – whereby the streets were seen as presenting both physical and, in many senses, moral danger – Sunnyside was child-friendly, whereby children of the same age (and class) could play with each other in the protective presence of their mothers.

The fate of the original estate is informative in considering the latter day potential of internal reserves as building blocks of a more sustainable urban form. The City Housing Corporation was compelled by the City of New York to jointly vest possession of interior court spaces at Sunnyside with surrounding residents, and could only require them to retain these as open spaces for forty years. In the early-to-mid 1960s, residents progressively (depending on the original establishment of the blocks, which took place between 1924 and 1928) found themselves enabled to peg out sections of interior space as backyard extensions, leaving only a central easement/accessway as public open space. Only some enacted this right, thus giving the central spaces a variety of shapes and sizes (none were erased in total). Generally, those adjoining access paths appear more likely to exercise their rights in this regard, and it may be that perceptions of vulnerability to outside intrusion amongst these landholders was justified. Even in these cases, the surrounding housing features small backyard space with low walls. Residents have placed basic garden elements (benches, stone paths) within the spaces for their own and others' use. Importantly, spaces appear safe due to passive and/or implied surveillance by the number of windows that face onto them. While one might validly regret the compromising of the original generous spaces, what remains within the housing blocks is a range of open areas with distinct character and unique shape, ranging from heavily treed to grassed areas. Most residents clearly value them and the area has long been a desirable neighbourhood. At least one lesson emerges from this scenario: that appropriate co-ownership measures should be put in place at the outset of any communal land-ownership and/or access scheme – a more difficult task in some jurisdictions than others.

Figure 4 Saxil Tuxen's photograph of Sunnyside, 1926

5. Further examples in 20th century town-planned environments

Commonly, then, interior spaces undergo cycles of use and misuse. Documentation of the Australian experience of internal reserves in garden suburb settings indicates mixed fortunes today. While some have survived and have been reinvigorated through strong community action, undoubtedly most remain as rather passive spaces both underutilised and undercapitalised given society's demands for quality green infrastructure. Many of the originally planned reserves – such as the multiple reserve provision in Saxil Tuxen's 1919 plan for Merrilands, in northern Melbourne – have in fact been redeveloped for housing and other institutional purposes. The genealogy of these spaces as products of earlier rounds of idealistic planning and housing reform has inevitably been overlooked [30].

The spaces common to post-war British New Towns also evidence the waxing and waning of fortunes that has done the internal reserve a disservice. Recent research into their usage and the attitudes of surrounding residents illustrate the problems such spaces face over time.
As part of the British government's post-war 'reward' to its citizens, the New Towns program naturally explored and, where possible, utilised what was then seen as best-practice planning. Stevenage, the first of the New Towns, featured among other innovations a series of children's 'play squares' throughout one northeastern section; the 'Archer Road Squares'. In 1970, when AntheaHolme and Peter Massie published their extensive study *Children's Play: A Study of Needs and Opportunities* the carefully planned placement of 'play squares' in Stevenage in particular was notable, and the authors included a photograph of such a square being successfully used by children under five, placing it on a page to contrast with the more limited and inferior options for 'slum' children. Twenty-five years after their creation, Holme and Massie saw the 'comprehensive' design of these spaces with options for varieties of play, their accessibility, and the possibility of passive surveillance from surrounding houses as the foundation of their success [31]. In 2009, when surrounding residents (though, apparently, not local children) were surveyed about the Archer Road Squares, issues revolved around what was seen as inappropriate use:
The most common current uses of the square(s) by respondents were to enjoy plants/trees, speak to neighbours/friends, children's informal play and to walk the dog. Most frequent reasons given for not using the square(s) were that it does not look welcoming, there is nothing to do there, and that people prefer to use their own gardens [32].

Stevenage had undergone not only demographic change but also a change in attitudes towards what were appropriate activities for children. Perhaps their designation as 'play squares' (rather than 'community squares', for instance) has limited the options for possible use; certainly, their concreted and often treeless terrains – the form taken for such spaces in their initial design – show a clear preference for ease of maintenance for council budgets, over widespread use by locals. Contrast this with a suburban area three kilometres north of the Swedish town of Gävle, known as Sätra. This features a range of interior spaces used for recreation by both adults and children. The area was built in stages between 1965 and 1970 with different sections featuring freestanding houses, attached two-storey homes, and higher density apartments but with open spaces a common feature throughout. In one area of two-storey attached homes, all front doors open onto alcoves fronting common play space, and parents or other family members are able to watch children in that space without being seen themselves (Fig 5). That is to say, surveillance of the space is implied and it is difficult for an intruder to watch the central playspace without being certain he or she is not also seen. This element is a counter to a common objection to criticisms (perhaps most famously, from Jane Jacobs) that such spaces are unsafe for lack of 'eyes on the street' [33].
The Alex Wilson Community Garden in a dense residential area of Richmond Street, Toronto is one of thousands of well-known examples of

Figure 5 Interior reserve, Gävle, Sweden

small, local gardens used, policed and protected by the local community. Wilson, who died in 1993, was a horticulturalist and landscape designer ‘interested in ways of becoming reconnected with local ecologies.’ J. William Thompson writes that Wilson and his partner, Stephen Andrews:

> struck a deal with the owner of a weed-grown lot near where they lived. They agreed to pay a dollar a year and the cost of liability insurance for the use of the plot and worked with neighbours to put in meandering paths, a vegetable patch, and a central wild area [34].

The Alex Wilson Community Garden is not an enclosed open space per se, but it shares many attributes with the ideal configuration of such spaces and one key aspect – the revival of waste spaces – is important, particularly in that it serves as an example of a space which draws high-density residents out into the (or to form a) community. In the case of the Alex Wilson Garden, Thompson writes, ‘Residents of the non-profit housing units next door are also some of the users and provide informal surveillance that helps keep the garden intact’ [35]. New Urbanists’ proposals for the provision of open space within newly built urban form – such as Peter Calthorpe’s plan for Stapleton, a new suburb of Denver, Colorado – often follow similar ideals to that of the Wilson Garden, and research published in 2006 suggests the majority of self-identified New Urbanism designers in the key territory of the USA consider communal open space a positive inclusion [36]. Recent work in the field of adaptive urbanism takes such innovations further into new visions of reworking dense living environments to incorporate natural, cultivated and cultured vegetation and agricultural spaces. A recent hypothetical project by Scott and Ben-Joseph seeking to revive Japan’s fifty-year-old Tama New Town suggests the introduction of ‘Internal Reuse’ blocks featuring ‘semi-private spaces’ [37]. The authors propose arrangements of ‘L-shaped houses’ at the corners of square blocks, creating the same square spaces and linear park walkways envisaged by Cerdà a century and a half previously [38]. This is the internal reserve of over a century ago, reinvented. Peter Hall and Colin Ward have called for a more general revival of this urban/suburban form, summoning examples from the early town planning movement to be used in ‘neighbourhoods of new towns or settlements’:

> There are other features that could and should be incorporated in at least some of these developments. The most important is found in many early Garden Cities and Garden Suburbs of the 1905-40 vintage: at Brentham Garden Suburb in Ealing, at Plessy-Robinson outside Paris, and at Romerstadt outside Frankfurt. This is an allotment garden, which ideally would be provided in the communal open space in the middle of a superblock, entirely surrounded by houses and their own small private gardens. It would answer the insistent call for organic food from an increasingly sophisticated and worried public [39].

6. Conclusion: reconfiguration and usage in new city blocks

The examples discussed in this paper represent cases of many varied incorporations of open space into the interior of block spaces over two centuries. As is clear, the issues surrounding such spaces, their use and ongoing upkeep are frequently problematic for owners and users. Even external observers are wary either because they fear others who might use the space, or because, in cases where local government undertakes to maintain such spaces, they are ‘paying’ for upkeep of what they see as ‘private’ space or mere backyard extensions.

The present authors are of the opinion that such space continues to have considerable potential. In cities where conventional block squares are redeveloped in whole or part for residential use, the interior court space is as valid – perhaps more so – than it was in, for instance, Cerdà’s or Ohman’s mid-19th century conceptualisations. The proximity of shared open space is desirable particularly for small children’s recreation and supervised playgrounds, ecosystem services, for potential agricultural/horticultural activities such as community gardens, passive recreation, and a range of small-scale active pursuits like tennis and lawn bowls.

What is particularly important in the 21st century is the proximity of land usable by residents in the high density city both for the encouragement of outdoor activity and the engenderment of community that such space brings. The potential of community comes not merely from the use of such spaces but also in the feeling to be encouraged amongst those who overlook the central space that it, and one's neighbours, 'look out' for one another.

Problems (or at least the potential for same) are, of course, many. As this historical overview has demonstrated, there was overt and perhaps misplaced faith amongst 19th and early 20th century creators of such spaces that the design of a space in itself is the most important element in its successful conduct. But as Jacobs, in her critique of such faith in post-war design practice, wrote: 'parks are not automatically anything' [40]. The playing of ball games within such enclosed spaces is a case in point; in some cases such activity is seen as an essential part of the healthy childhood community, and in others it is assumed to put surrounding homes at risk of breakage or other nuisance. The presence of interior open space can be a source of conflict rather than community spirit, hence a path dependency favouring the status quo.

Ownership and/or stakeholder status are in fact at least as (or more) important than design alone for such spaces. Maintenance, security and usage are aspects to be fostered and reinforced amongst residents if such spaces are to be successful. Recognition of demographic cycles and subsequent changes in use need to be monitored and understood, with no single use edging out others. It is the versatility of the internal reserve form and its status as private-public, or semi-public space that gives it its uniqueness. In line with what Hebbert calls the 'new enclosure' movement of postmodern urbanism, from an historical standpoint, one key aspect to the resilience of this form is the understanding of its intention and capacity, chiefly its versatility and adaptability; its replicability; and its potential for renewable green living [41].

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How to create shared value in built environment?

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Summary

More and more people live in cities than in rural areas and this urbanization trend is expected to continue. Urbanization will provide opportunities for business around the globe but particularly as developing countries transition from agri-centered economies to product and service economies. This is putting pressure on having good living environments and employment for the people moving and living in cities. The recent financial crises have initiated many questions of the current business systems' basic operations. Business as usual has gone through heavy scrutiny due the crises and it is acknowledged that staying competitive and achieving sustainable development are going to be the major challenges the corporations are going to encounter. Porter and Kramer have suggested that the purpose of the corporation needs to be redefined and corporations should pursue shared value creation instead of pursuing monetary value creation only.

Shared value creation can be defined as policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates. Importance of the built environment and the construction industry for triple bottom line of sustainability cannot be ignored. Built environment and construction has high economic importance and evident environmental and social impacts. Every business needs premises to operate and the built environment has significant direct and indirect impacts on social wellbeing and the livelihoods and affluence of local communities and individuals. Therefore built environment has a significant role in sustainable development and significant potential also in shared value creation.

This paper is based on literature and constructive research approach. Some literature has been published on shared value creation, but no model for built environment has been presented. Aim of this paper is in identifying possible business models contributing to sustainable shared value creation and business opportunities. The basic idea in this paper is to identify strategies, which can create value to the companies, contribute to the wealth and well-being of the society, users and residents. Another aim is to understand shared value creation in built environment context and a preliminary framework will be developed and tested in the future studies. It is expected that the findings will enhance understanding of shared value creation value chains and processes in general. Shared value creation can be expected to have boosting effect and applicability in other industries and business in general. A suggestion for preliminary framework will be developed and tested in the further studies. It is expected that the findings will enhance understanding of shared value creation value chains and processes in general and in built environment context. New green and shared value business logics need to be found to build new cities that serve growing urban populations. There fore built environment offers enormous opportunities for sustainable business and mitigation of climate change.

Keywords: Shared value, built environment, green business, business model, sustainability

1. Introduction

Urbanization, climate change and sustainability have been central issues in on-going discussion for a while now. Also for a long time, managing the relationship between business and society has been one of the main topics of academic and business literature [1]. The recent financial crises have initiated many questions of the current business systems' basic operations. Business as usual has gone through heavy scrutiny due the crisis and it is acknowledged that staying competitive and achieving sustainable development are going to be the major challenges the corporations are going to encounter [2]. Managers continually encounter demands from multiple stakeholder groups to devote resources to corporate social responsibility (CSR). These pressures emerge from customers, employees, suppliers, community groups, governments, and some stockholders, especially institutional shareholders [3]. Over the past several decades, CSR has grown from a narrow and often marginalized notion into a complex and multifaceted concept, one which is increasingly central too much of today's corporate decision making. [4]. But is this enough or should there be more proactive measures taken to secure long-term business. Porter and Kramer have suggested that the purpose of the corporation needs to be redefined and corporations should pursue shared value creation instead of pursuing monetary value creation only. Also in the midst of the current financial and economic crisis, some companies have begun to question their role more fundamentally and seem to be awakening to social change issues [2].

More and more people live in cities than in rural areas and this urbanization trend is expected to continue. Urbanization and cities with booming population, but inadequate resources often struggle to provide even the most basic living conditions for citizens [5]. This is putting pressure on having good living environments and employment for the people coming and living in cities. Importance of the built environment and the construction industry for triple bottom line of sustainability cannot be ignored. Built environment and construction has high economic importance and evident environmental and social impacts affecting the livelihoods and affluence of local communities and individuals. People need homes and every business needs premises to operate. For example housing production is a major economic activity in most cities. Building housing not only produces the economic asset of the housing unit itself, but it creates all sorts of secondary economic activities: labourers get employment and then spend their earnings locally, materials purchased in the city support industries and supply businesses, and new housing attracts further investment in the areas where it is built, and tends also to increase nearby land values. [6].

Urban environments across the world both direct and constrain our capacity to respond to issues of resource consumption, carbon emissions, and, more expansively, sustainable human and economic development [7]. Companies do not function in isolation from the society around them. In fact, their ability to compete depends heavily on the circumstances of the locations where they operate. [8]. In the long run, social and economic goals are not inherently conflicting but integrally connected. Competitiveness today depends on the productivity with which companies can use labour, capital, and natural resources to produce high-quality goods and services. Productivity depends on having workers who are safe, healthy, decently housed, and motivated by a sense of opportunity. Improving education, for example, is generally seen as a social issue, but the educational level of the local workforce substantially affects a company's potential competitiveness. The more a social improvement relates to company's business, the more it leads to economic benefits as well. Preserving the environment benefits not only society but companies too, because reducing pollution and waste can lead to more productive use of resources and help produce goods that customers' value. [8].

Yet the municipalities and companies are mitigating climate change by avoiding greenhouse gas emissions but also by finding ways to adapt to the changing climate. They are both buying and selling services, materials and products therefore they have an important role since they are acting both as suppliers and customers. As transparency has been enhanced the expectations have grown concerning companies' and municipalities' responsibility on what and how they are purchasing, producing and offering to customers.

At the moment tracking and measuring company's economic, environmental and in some extent also social aspects is a common practise. Many companies are drawing up sustainability reports for communicating their operations to shareholders and public audience. Corporations can use their charitable efforts to improve their competitive context – the quality of the business environment in the locations or locations where they operate. Using philanthropy to enhance context brings social and economic goals into alignment and improves a company's long-term business prospects [8]. But strategic philanthropy today is almost never truly strategic, and often it isn't even particularly effective as philanthropy. Increasingly, philanthropy is used as a form of public relations or advertising, promoting a company's image or brand through cause related marketing or other high-profile sponsorships [8].

Shared value creation can be defined as policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates. Some literature has been published on shared value creation, but no model for built environment has been presented. This paper will be based on literature review and constructive research method. The aim is to understand current green business models and how these models contribute to shared value creation in built environment context. Another aim is to create a preliminary model, which can be tested and developed in the further studies. It is expected that the findings will suggests a theoretical model for shared value creation in built environment and enhance understanding of shared value creation value chains and processes. Built environments contribution to man-made capital is substantial since a major part of the human created wealth in countries comprises buildings and infrastructures [9]. Based on these issues built environment has an important role in sustainable development and significant potential also in shared value creation.

2. Methodology

The research is based on literature and constructive research method. A constructive method is "a solution-oriented normative method where target-oriented and innovative step-by-step development of a solution are combined, and which empirical testing of the solution is done and utility areas are analysed".

There are seven crucial steps in the constructive research approach:
(1) To find a practically relevant problem, which also has research potential;
(2) to examine the potential for long-term research co-operation with the target organisation;
(3) To obtain a general and comprehensive understanding of the topic;
(4) To innovate and construct a theoretically grounded solution idea;
(5) To implement the solution and test whether it works in practice;
(6) To examine the scope of the solution's applicability; and
(7) To show the theoretical connections and the research contribution of the solution. [10].

This conference paper focuses on steps 1 to 4.

Starting from Step 1 and finding the practically relevant problem with research potential. Aim of this paper is not to focus on recognizing stakeholders, but identifying possible business models contributing to sustainable shared value creation and business opportunities. Yet the CSR approaches to business have been recognized and discussions are on-going, understanding concerning shared value creation as a business model is tangential. The basic idea in this theoretical framework is to identify strategies, which can create value to the companies, contribute to the wealth and well-being of the society, users and residents.

Step 2 is finding research co-operation. As this paper is contributing to RYM-SHOK's built environment innovations programme co-operation will be done with universities and companies taking part to the programme. In future case studies co-operation with companies will play a significant role.

Step 3 included literature review focusing on green business models, shared value creation and sustainability. The study concluded that green business models are recognized and have been investigated, literature concerning shared value creation can be found in some extent and sustainability has been an important and widely studied issue for some time already. Some Case studies and examples of shared value creation had been carried out, but chain in other context than built environment.

Step 4 to create a solution for problem is partly addressed in this paper based on the existing green business models and descriptions of shared value theory and case studies that are combined to a suggestion for shared value creation framework in built environment.

Steps 5-7 will be carried out in future studies.

3. Business Models and Sustainability

The term business model has been used in the literature in various contexts and with different meanings. In management literature, business models have attracted increasing interest since the end of the 1990s in particular in relation to the transition from traditional commercial activities to e-commerce [11]. ‘Business model’ is a term often used to describe the key components of a given business [12]. Osterwalder et al. [13] defined a business model is a “blueprint” for how to run a business. Yet another definition for business model is a conceptualisation how value is created for the customers, company and its stakeholders.

Companies have relationships with many constituent groups and that these stakeholders both affect and are affected by the actions of the firm. Stakeholder theory, which has emerged as the dominant paradigm in CSR, has evolved in several new and interesting ways [3]. Thomas Jones developed a model that integrates economic theory and ethics. He concluded that firms conducting business with stakeholders on the basis of trust and corporation have an incentive to demonstrate a sincere commitment to ethical behaviour. The ethical behaviour of firms will enable them to achieve a competitive advantage, because they will develop lasting, productive relationships with these stakeholders [3].

Despite the growing importance of these new kinds of business models, which are able to combine social and business advantage, literature is lacking. The academic literature is predominantly focused on CSR from a variety of perspective or on the social entrepreneurship topic [1]. Discussion concerning relationship between business and society has been on-going for a while. Porter and Kramer [14] have proposed an interpretation for this considering that the traditional thought on corporate social responsibility (CSR) shares the same weakness: “they focus on the tension between business and society rather than on their interdependence”. Michelini and Fiorentino [1] claim that from a shared value viewpoint, companies must integrate a social perspective into the core frameworks that they use to understand competition and develop business strategy. The shared value principle becomes more influential when companies decide to expand their businesses into developing countries where the link between corporations and society becomes stronger.

3.1 Green business models

UNEP [6] has defined green economy as an economy that results in improved human well-being and reduced inequalities over the long term, while not exposing future generations to significant environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one that is low carbon, resource efficient and socially inclusive. The concept of green business models (GBM) is a way of facing these challenges. GBMs involve the creation of new types of jobs, lower environmental impacts, and they are very promising platforms for innovation. GBMs are business models supporting the development of products and services (systems) with environmental benefits, reduce resource use/ waste and which are economic viable. It is expected that these business models will have a lower environmental impact than traditional business models [15].

GBMs vary in sizes and shapes; however, a common denominator is that the companies applying GBMs can change their core business strategy from selling products to selling service systems which includes their products. Classical green businesses (e.g. cleantech) are usually focused on a green product, which is more energy efficient, produced with less material and energy use etc., while a company making use of GBMs focuses on the management of (or some of) the customer's production and is paid according to the result in the customer's production (i.e. a provider of refrigerators is paid for the service of 3 degrees in the refrigerators instead of being paid for the product, i.e. the refrigerator itself). This gives the producer, who also owns the product, the incentives to design the products to perform optimally in terms of the products life-cycle costs (i.e. energy, maintenance, waste disposal etc.). [15].

Four different business models were selected as basis for examining shared value framework for built environment.

3.1.1 Functional Sales

The phenomenon of functional sales has become more prevalent in current consumer patterns and its emergence is mainly market-driven. In functional sales, a very strong focus is placed on how to fulfil customer needs and create customer value [16]. Functional Sales is a generic model which holds common characteristics of all green business models. In functional sales the provider offers the customer to pay for the functionality or result of the product instead of buying the product itself. One example is the Swedish company Volvo Aero, which produces airplane engines and offers their customers to buy the power of the airplane engines ('power by the hour') instead of buying the engine itself. The structure of the business model gives the provider the incentives to optimize and maintain the product (the engines in the Volvo case) to ensure life-cycle cost effectiveness which will reduce the environmental impact (less fuel consumption). [15].

A key characteristic of functional sales is that the service provider takes over the control of the use phase of the product. By improving the control of the use-phase of the product the producer gets an incentive to improve the output yield and to extend the life-span of the product by making the product more durable, reducing the need for spare parts, making it more energy efficient, improve maintenance of the product etc. Another important aspect of many functional sales models is that they are designed for remanufacturing and reuse of the product. [15].

In Foranet's Green Paper [15] a major potential for functional sales is seen within the construction industry. Presently, construction companies focus on building houses at the lowest possible costs. The largest costs of buildings are related to the use-phase of the building. These costs include costs for energy consumption, refurbishment, cleaning etc. If the provider of the house is also responsible for the house in the use-phase there would be a strong incentive for increasing the material and energy efficiency of the use-phase. Besides for buildings great potential for functional sales can be found within other kinds of infrastructure like roads and in the transportation sector.

3.1.2 Design, Build, Finance and Operate model

DBFO business model is a similar set-up as functional sales where the company that builds the building is also responsible for operation and maintenance. In DBFO the responsibility is assigned through a single contract to design, build and maintain the asset for the contract period. The service provider arranges the financing and the owner repays the investment as part of the service fee starting after commissioning [17].

The model has been emerged in construction industry. In this DBFO long term contracts involving the construction, maintenance and operation phase (typically 20-30 years) of the project (a building) give incentives to improving the quality of the construction project so that the life-cycle costs are lowered. One example is the Finnish Kaivomestari senior school, swimming hall and sports centre realised through a partnership between the project company Arandur Oy and the City of Espoo. [15]. A key advantage of the DBFO model is this division of risk between the client and the provider. For example, if a building turns out to be more expensive than expected, then it is the provider who will carry the extra cost. Similarly, if agreed service and maintenance levels are not fulfilled, there will be deductions in the monthly payment fee from the customer. In short, if the provider does not perform, he will be financially penalized. Due to the total life-cycle approach and risk division, providers are encouraged to come up with innovative technical / design solutions that help reduce operation and maintenance costs in the long-run. [15].

3.1.3 Public - Private Partnership (PPP)

Public - Private Partnership (PPP) can be described as a government service or private business venture which is funded and operated through a partnership of government and one or more private sector companies. Governments are globally searching for more effective ways to produce and maintain economic and social infrastructure facilities and better public services - the important elements of a quality living environment and urban regional competitiveness in a global world. Public-Private Partnerships (PPPs) are introduced as a synergistic way to reach a "win-win-win" situation that benefits all participants - public sector, private sector as well as the general public - in the long term [18]. PPP can help to overcome finance issues and it can also provide needed governance and coordination. For private investment to fully participate in making cities sustainable, investment products, public policies, and civic support need to be created around efforts that combine an interest in sustainability [7].

PPP can be extended to 4P-model where also people (of the area) are included to process. For example in urban development more customer-oriented development processes can be achieved by increasing the citizens' and end-users activity and involvement. Involvement is important because after development and construction delivery, they will use the developed area and its public and private services [18]. It can be predicted that the residents of the area will be more satisfied if they have had a change to contribute to area design.

4. From Green Business Models to Shared Value Creation

Sustainability is an example of what is called a 'wicked problem'. Wicked problems are complex and messy, characterised by several features: no definitive formulation of the problem exists; its solution is not true or false, but rather better or worse; stakeholders have radically different frames of reference concerning the problem; constraints and resources for solution change over time; and, the problem is never solved. [19]. The global climate and environmental challenges are changing the agenda for businesses and policy makers who are shifting their thinking of climate change and resource constraints as environmental problems to seeing them as economic potentials and opportunities [20].These opportunities are aiming for more sustainable products and business. Green business model were introduced in previous chapter, but models as such are not enough. The issue should be addressed from wider perspective. The possible solution for mitigating climate change and urbanization lies in the principle of shared value, which involves creating economic value in a way that also creates value for society by addressing its needs and challenges [21]. The concept of shared value can be defined as policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates. Shared value creation focuses on identifying and expanding the connections between societal and economic progress. [21].

As Porter and Kramer [21] state, companies can create shared value by reconceiving products and markets, redefining productivity in the value chain and by enabling local cluster development. The shared value opportunities at each level will differ by industry, company and geography, depending on how a company's particular business and strategy intersect with social issues. Creating shared value from enabling local cluster development derives from improving the external environment for the company through community investments and strengthening local suppliers, local institutions, and local infrastructure in ways that also enhance business productivity. Shared value creation can create new opportunities for profit and competitive advantage at the same time as it benefits society by unleashing the power of business to help solve fundamental global problems. [22]. However there is no certain defined standard for the concept at the moment.

The purpose of the corporation must be redefined as creating shared value, not just profit per se. This will drive the next wave of innovation and productivity growth in the global economy. It will also reshape capitalism and its relationship to society. [21]. Elkington and Hartigan [23] defined shared value creation as a situation where a company generates value for both the society and its shareholders, while is conducting its own. At the moment value creation is still viewed narrowly, optimizing short-term financial performance in a bubble while missing the most important customer needs and ignoring the broader influences that determine their longer-term success. The success of every company is affected by the supporting companies and infrastructure around it. Productivity and innovation are strongly in\uenced by “clusters,” or geographic concentrations of companiess, related businesses, suppliers, service providers, and logistical infrastructure in a particular field [21].

Shared value creation in built environment should aim for green economy. UNEP’s definition as an economy that results in improved human well-being and reduced inequalities over the long term, while not exposing future generations to significant environmental risks and ecological scarcities. Green economy is seen as low carbon, resource efficient and socially inclusive where people meet their basic human needs including taking part to society’s activities. Companies, policy-makers and users are in key role implementing sustainable life style and improving living standard. One of the key success factors is that products, services and built environment are co-created together with companies, societies and users. GBMs can be seen as part of shared value creation since they contribute to creation of new types of jobs, lower environmental impacts, and function as promising innovation platforms. Successful new concepts offer people a new way of doing things rather than aim to differentiate in price, brand or other traditional marketing factors [24]. Business can be an active partner in delivering solutions that meet the needs of both people and the environment, and in creating true efficiencies that add value and reduce costs. Business collaborates with others to redefine concepts of value and cost to include externalities such as the environment. Business is part of the public dialogue on the social and governmental changes needed to lead society from this point to sustainable global living. Business should also share knowledge, work across boundaries and develop new models for commerce and individual entrepreneurialism. [5].

Businesses do not only do business, they also affect to people's everyday lives. Sustainable business is not to be chosen just because of the sustainability, but because it is delivering better value to different stakeholders. New way of making business, livable society and creating value is to be based on promoting transparency, inclusiveness and sustainability. One way of gaining public trust is utilizing new media and different communication strategies for engaging different stakeholders at new levels. These new levels can for example include new ways for interactive conversations. For example in urban development processes in Finland, communicative and participative planning is used to involve stakeholders in the development processes. Engaging stakeholders will result better business or/and built environment as experiences are gained from users and residents.

When it comes to economic issues, it is important to have a larger vision of the sustainability instead of several small single projects in isolation. A Common goal should be formed for city’s or certain area’s sustainability. Coordinating public, private and civil society actors around a common goal can serve as groundwork for investment from the private sector. For the public institutions, the customers, it is an important driver that projects are completed on time and within budget, that the public infrastructure is properly maintained, and generally that the public gets value for money. Applying PPP and/or DBFO to these kinds of project could bring a better solution and result as shared value is created. Public institutions need to have the right capacity to manage this type of projects, and also to be more aware of the high environmental potential from applying these models, for example by introducing green elements in the public procurement and payment mechanism. Also risks could be managed through shared value creation and partnership model that would bring long term profits and secure economic, social and environmental benefits at the same time. The value achieved in shared value creation process may not only be financial, but it can be social, environmental or aesthetic as we are now related to build environment.

With functional sales several services can be provided to residents and businesses of the area. Sharing cars could bring advantage for example in that way that less parking places are needed and residents have easier access to using car since no large scale capital is needed to invest in a car from single person if it is owned by a service company. In earlier example better quality and sustainability might be achieved by functional sales in construction business.

Demand for a shared value business model is needed for many reasons. Customer demand is one of the driving forces but also politicians and public sector professionals are finding ways to get businesses to be part of the solution. Employees are looking for more meaningful jobs and Porter and Kramer argue that a completely new generation of young people are is demanding that companies to solve problems that they ignored in their previous business activities. [24]. As suggested by Porter and Kramer a renewed balance of financial and social value creation could help corporations to rebuild trust, allow them to stay competitive, and increase their legitimacy. [2]. Efforts in understanding the link between business performance and social value is about to commence. If the link between social and business results is not recognised, also the opportunities for growth and innovation are most likely missed. Unlocking shared value requires understanding the social results from business investments and analysing and improving the business result from social outcomes. [22]. The built environment, defined by the facilities and civil infrastructure systems that people use, is the fundamental foundation upon which a society exists, develops, and survives [25].

5. Conclusions

More people live in cities and this trend is expected to continue. Most significant changes are expected in emerging and developing countries. Urbanisation is and will provide business opportunities and particular opportunities and challenges are encountered in developing countries changing from agricultural economies to product and service economies. As resources are diminishing and environmental and climate change issues need to be tackled actions are needed from governmental, consumer, and business level if the current standard of living is to be retained in future. In the future the leading companies will be those that are helping society to manage climate change and future challenges through their business. As sustainable living environments, products and services will be co-created in greater volume by companies, societies and residents shared value is achieved.

Shared value creation model can be seen as a long-term strategic investment to sustainable living environment and business with overarching common goals for sustainability. Though the shared value creation model competitive advantages, greater market shares and new revenue streams can be achieved with efficiency, sustainable image gains and lower risks. New green and shared value market needs to be created and new business logics need to be found to build new cities that serve growing urban populations. Shared value creation is not only boosting companies but also societies where the companies operate.

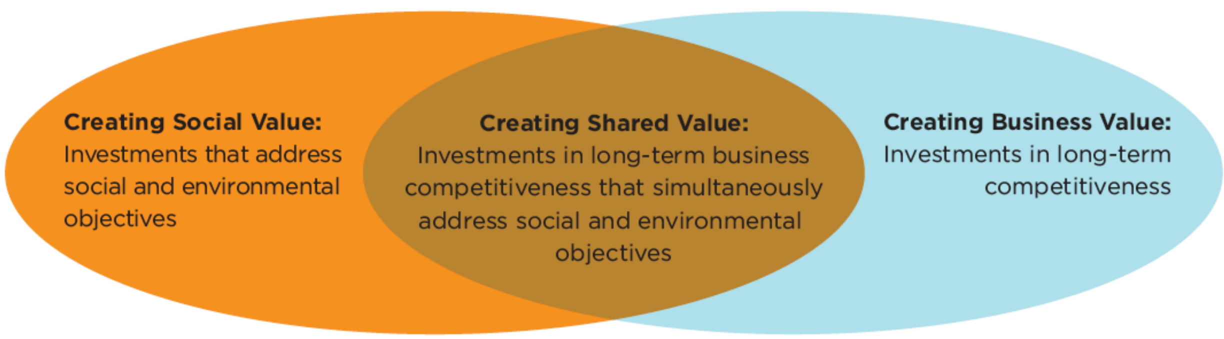

Fig. 1. Linking social value and business value to creating shared value [26].

Shared value creation is more than just one company's view point. It is also more than value co-creation that usually happen between the company and the customer. Shared value creation includes also the surrounding society. It is about interaction, depletion of vital natural resources, viability of key suppliers and surrounding society in which the companies operate. Companies can create shared value by building clusters to improve company productivity while addressing gaps or failures in the framework conditions surrounding the cluster. New business strategies creating shared value and having the potential to reducing environmental impacts can be considered to be a key factor for industrialized societies to lower their environmental impact, enhance social aspects and contribute to economic situation. It expected that new green, innovative and shared value creation business models will enhance and protect society from downturns. Sustainability and shared value creation can be seen as business model innovation in different size companies, community and society. New innovations and business models create more innovations, positive environmental impacts and financial benefit.

Importance of the built environment and the construction industry for triple bottom line of sustainability cannot be ignored. Built environment and construction has high economic importance and evident environmental and social impacts. Built environment also offers enormous opportunities. This paper discussed creating shared value through green business models and a suggestion for business model framework will be created in future studies. The framework will be tested in case studies and developed further based on feedback and obsevations from the case studies.

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Business Models for User Oriented Services in Well-Being Ecosystem

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Summary

Work presented in this paper concentrates on well-being ecosystem in appealing living environment from the viewpoint of service provider. The goal of the work is to develop business logics with underlying smooth service processes for well-being services aside with massive reconstruction building project. New service systems that are based on these processes are piloted in real living environment. The key target is to improve consumer's possibilities to access and receive services. Few possible scenarios were considered and developed by analyzing feedbacks from local social, health care, and business representatives, and service providers. This environment will attract local service providers, retailers, shops, and social and health-care organizations to advertise their business activities, services and products to building inhabitants. Therefore well-being ecosystem allows a multi-service environment. The aim is to develop a business model-based ecosystem concept where enhanced third-party business opportunities are allowed to set up new services through open interfaces in modernized building infrastructures. Furthermore an important target of the project is to discover methods of integrating modern ICT services into existing building engineering infrastructure with the purpose to facilitate new add on services and businesses.

The core of the well-being ecosystem is the (UHE) – a user-centric set of systems, that serve users in domestic environment and expanding its services to public and professional environments. An essential part of the UHE is the Service Gateway, which enables variety of business scenarios. The Service Gateway provides a number of interfaces to ensure an integration of user-oriented services into the infrastructure of households, and a seamless integration with business processes.

Keywords: Business Model, Well-Being Ecosystem, HoviMestari, Ubiquitos, Home Environment, Service

1. Introduction

The population of Finland is one the fastest aging population in Europe. The aging population causes the pressure for change and the needs of a large number of actors in society as housing, services production and urban planning. Current forms of service cannot sustain the growing number of treated elderly citizens. To address such fact, a new service concept has been proposed to be adopted in the existing sheltered housing, home care and residential care alongside.

The proportion of Finland's inhabitants over 65 years of age accounted for 15,0 percent of the total population in 2000. In 2030 it will increase to 26,3 percent. That means that in 2000 there were 777 200 people over 65 years. In 2030, their number rises to 1 389 100, which is 611 900 people more than in 2000 [1]. A need for services is expected to hit the peak during 2025-2040, when the post-war baby boomers generation reaches retirement age. Therefore, important to develop usable business models for user oriented services in a well-being ecosystem – those that will support an independent living.

Business model presents the firm's core logic where usually attached to the fundamental challenges of how the firm gains competitive advantage and profits by creating and capturing value [2] and [3]. Researchers have combined the firm and network view [2], and the business process perspectives and strategy [4] to explain the concept of business model. The basic idea is that the business model is created by organizing the essential elements. A firms' business model can be defined and described by identifying and assessing nine elements. The elements are shown in the Figure 1.

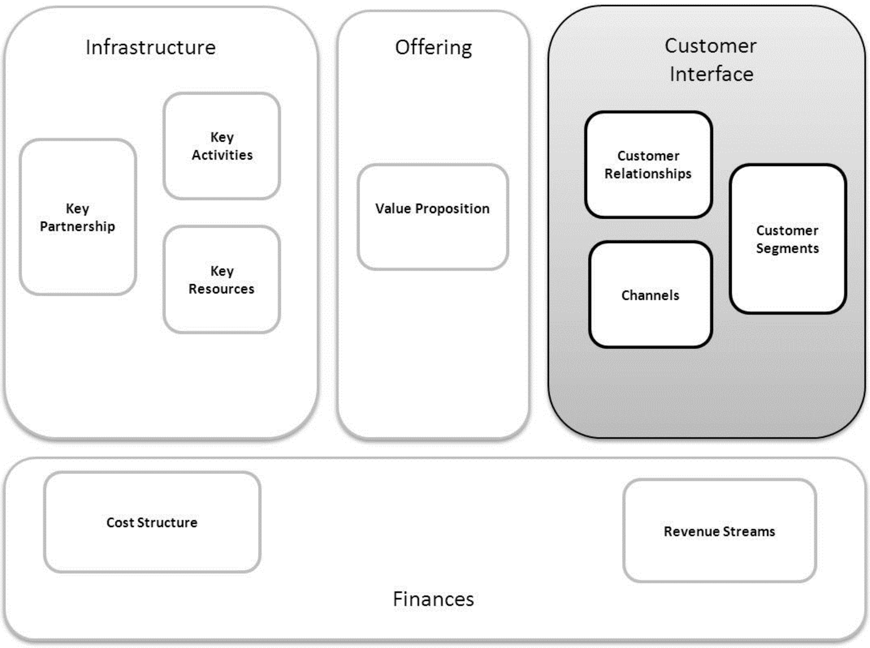

Fig. 1. Business model canvas (modified from [4])

As it is highlighted in Figure 1, Customer Interface is in a scope of this research. The Customer Interface consists of Customer Segments, Channels and Customer Relationships.

2. Well-Being Ecosystem in Ryhti-Project

2.1 Ryhti-Project

One alternative solution to the challenges of independent living has been focused on Ryhti-project. In the work the well-being ecosystem in appealing living environment was considered from the viewpoint of a service provider. New service systems that are based on these processes have been piloted in real living environment. Service providers' and inhabitants' co-operation process model is based on creating value network's business models. Co-operation process defined required information technology infrastructure. Another target of the Ryhti-project is to improve consumer's possibilities to access and receive services.

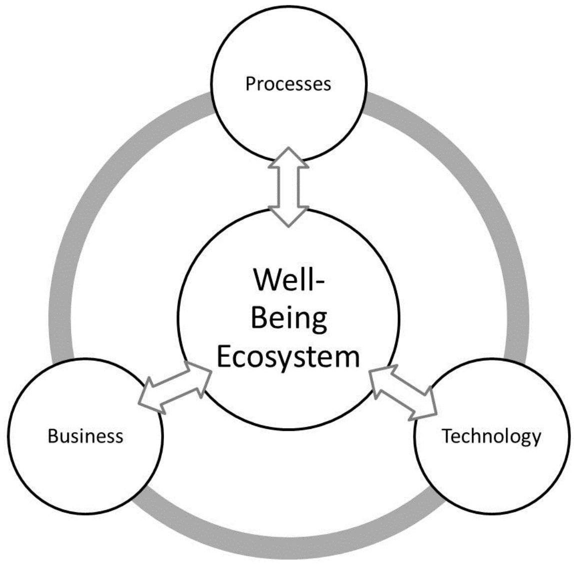

Fig. 2 Basic items of the Ryhti-project

The project consists of four major parts, which are process, business, technology, and the entire well-being ecosystem that is supported with relevant information and communication technologies (Figure 2). The well-being ecosystem consists of infrastructure and service providers, end-users, surrounding environment, and buildings.

Ryhti-project considered and developed few possible scenarios by analysing feedbacks from local social, health care, business representatives, and service providers. This environment will attract local service providers, retailers, shops, and social and health-care organizations to advertise their business activities, services and products to building inhabitants. Therefore a combination of differentiated and possibly distributed set of service providers that are integrated to well-being ecosystem allows multi-service environment.

2.2 Ubiquitous Home Environment

The core of the well-being ecosystem is the Ubiquitous Home Environment (UHE) – a user-centric set of systems that serve users in domestic environment and expanding its services to public and professional environments [5]. ICT Home Services are relevant to activities of such stakeholders as service providers and content suppliers for delivery of value-added services to modern households residing the UHE [6].

To ensure supply and maintenance of the services, the UHE operates over a variety of wired and wireless networks, and its networking infrastructure may include Body Area Networks, Resident Area Network, and Personal Area Network. Modern domestic environment is considered to be the Internet-enabled, covered with Mobile Networks, and penetrated with Digital Broadcast. In addition to that an entertaining content may be brought to the UHE through a variety of generic and proprietary channels, typically TCP/IP-based.

As it has been presented in [7] and [8], the core of the UHE is a serving engine. Serving engine may be implemented in a form of a dedicated in-house server, or built on a base of a modular framework that may be distributed among few computing devices. Typically, the serving engine achieves interoperability with the UHE infrastructure through a variety of generic and dedicated modules. The serving engine should expose a number of GUIs to a selection of end-user or terminal devices. With respect to a domestic environment, such serving engines sometimes referred as home platforms.

Since ICT systems of the service providers and content suppliers are originally not designed to interoperate with the UHE, there is a need of the Service Gateway. The Service Gateway provides a variety of interfaces to ensure an integration of user-oriented services into the infrastructure of households, and a seamless integration with business processes to enable a variety of business scenarios. Service Gateway may be implemented as a part of the UHE, or be a part of the residential area, or real estate owner's information system.

3. Case HoviMestari

3.1 HoviMestari of the UbiHomeServer

For sensing a physical environment, the UbiHomeServer [9] interoperates with several Wireless Sensor Networks (WSN), including those that utilize 6LoWPAN protocol. Wi-Fi coverage of the living environment has been considered essentially. IPTV has been chosen to be an important communication channel. As a core of the engine, an intelligent module that is based yet on a complicated algorithm has been developed. Knowledge technologies, particularly such Semantic Web technologies as RDF, have been considered in design. [6]

The UbiHomeServer provides residents of the domestic environment with front-ends through which it is possible to interact with the UHE as well as consume and manage some of the ICT Home Services [6]. Those front-ends are known as HoviMestari. In order to eliminate a need of the Service Gateway that operates in a classical way – as a dedicated service portal, or a hub of services – the HoviMestari is designed to carry on operations of the Service Gateway.

A grid layout has been selected for the HoviMestari design. Clicking to an active button brings a chosen service interface that is implemented in a similar way as main view, but has a functionality of certain kind and may have its own set of options. One off the options allows removal of currently invoked service to a service basket. Thus the removed service disappears from main screen, but occurs in the service basket. It is also possible to restore a service to the main screen. Entire interface is implemented as low-hierarchical and intuitive. HoviMestari has been designed for elderly people, but can be used by any age group including children of a school age.

The HoviMestari has been targeted to many categories of user terminal devices. Its interactive functionality is provided via mobile devices, or traditional monitors like TV-screen. The user interface can be touch, keyboard or remote control unit based system. The HoviMestari offers a similar user experiences regardless of a category of a device and thus form an identical front-end of the UHE. A main screen of the HoviMestari is shown in the Figure 3.

Fig.3 Main screen of the HoviMestari

3.2 User Tests

The business potential of HoviMestari concept has been studied by several user tests. Preliminary customer identification and consumption analysis served as a general framework for planning the tests. Assumptions of customers and consumption were based on information from national statistics, previous studies and some additional surveys executed during spring 2011.

As part of background analysis, one plausible and quintessential observation has been made. For business modelling purposes customer and user roles may need to be separated, especially when considering senior users – customer making the purchasing decision might not be the end user of the HoviMestari.

Background analysis together with the features of HoviMestari formed the basis of user tests. Methodologically tests followed the typical guidelines of qualitative research and analysis. The main interest in test has naturally been the reception of the innovation among the seniors but the applicability of findings to future seniors has been considered as well.

Testing consisted of three types of tests. Although tests varied according to testing location and the precise questions asked from test users, the main emphasis in all tests had been laid on the usability and desirability of HoviMestari device. Test users represented current seniors, future seniors and benchmark users. The main structure of tests can be divided in different steps. First, the background information of the test user was collected. Then the device was presented and some main features were introduced. Next step in testing situation included some user tests of functions and features and finally the feedback from the device was collected.

First two sets of tests consisted of user tests carried out both in Per Brahe ICT-Center and in local supermarket. Third set of tests was carried out at senior users´ homes and these final tests were also videotaped to analyse the entire testing procedure. The main results of these tests show highly positive response to the HoviMestari in general. Information about special offers in local stores, news feed, emergency call and physician´s reception were among the most valued services. HoviMestari was characterized as handy, desirable and reliable. The use of device was considered relatively easy and manageable. Test users expressed their willingness to pay for the use of device if it was reasonably priced and the services designed according to user´s needs. Bringing tests to users´ everyday living environment helped to deepen the understanding of user needs.

Finally, it should be noted that these user tests not only showed the emerging interest and at least moderate enthusiasm toward developed device they also showed that this kind of user interface helps user to focus on service content instead of the interface. Additionally, developed device motivates users to imagine different use cases and possible service scenarios to be realized with this kind of service gateway system. Thus, it can be said that the preliminary user tests gave encouraging results - HoviMestari seemed usable, beneficial and desirable.

3.3 Business Opportunities

According to background data, some conclusions seemed essential when considering HoviMestari as a new product for senior users. The consumption of the elderly is dominated by consumption on necessary goods and the expected change towards increasing consumption on luxury goods (e.g. leisure time and cultural services) has been rather slow. In addition, it should be noted that dwelling is not only of emotional value for senior citizens but it also forms the firm basis for economic wealth for elderly consumers [10].

Since HoviMestari is strongly linked to household service markets, the clear growth path of major trends in consumption on household services and services in general can be interpreted as an encouraging signal for commercial potential of HoviMestari. Simultaneously with increasing consumption the consumers' awareness of quality issues is increasing. In addition to obvious elements of service quality (e.g. the quality of work, equivalence of desired and received service) it has been studied that quality in household services consists of scheduling, accessibility and functional feedback procedures [11] and [12].

Even though it was possible to recognize and analyze several scenarios for future seniors, uncertainty prevails. The health issues, life expectancy and general economic and social development affect the future markets for seniors' household services and thus demand for the devices like HoviMestari. Improving health, increasing life expectancy, normally increasing economic wealth would make future seniors an interesting potential for HoviMestari. On the other hand, the penetration of high technology in society might restrain the demand for this kind of device since the future seniors are already familiar with using much more complicated devices for different purposes.

Business models canvas was used as a framework in this project for the analysis of service providers' business models that directly or indirectly create and/or contribute to well-being living. As an example of modelling HoviMestari by business model canvas is shown in the Figure 4. In addition, an ecosystem-based approach selected review of the phenomenon from the perspective of the business model and makes it clearer where the future business opportunities lie (as a partner, development of the customer interface).

In the user value part of the business model [4] it is not possible to look at the needs of probable customers. The main purpose is to make it possible for senior citizens to live at home as long as possible. It Is critical that HoviMestari has good usability and reliability.

The revenue streams [4] could be made of fees for the customer. We should pay attention to how much and user pays for reaching services through alternative ways (phone calls, the Internet). The cost of HoviMestari should not be higher than the cost of alternative channels. Service providers can be seen as key resources, they are needed for implementing the whole system. Other important business partners could be housing companies, IT-operators, public authorities, health and social care.

<table>
<tr><td rowspan="2">Key Partners

Service providers (shop, bank, house work service, healthcare, transportation)

network operator

Construction companies

Sheltered homes

Security companies

Public healthcare</td>
<td>Key Activities

Partner management

Sales

Helpdesk/support

Development</td>
<td rowspan="2">Value Proposition

Living at home as long as possible

Security and safety

Keeping in touch

Easier to use than computers

Games, things to do

Status value</td>
<td>Customer relationship

New technology is challenging

Sold as a package

Development

Personal face to face customer support & help desk</td>
<td rowspan="2">Customer segments

End user:
• Senior at home
• Senior at sheltered home</td></tr>
<tr><td>Key resources

Customer knowledge

Technological knowledge

Management of business</td>
<td>Channels

Inspection of capability of living at home for the senior provided by public healthcare

Integrated into homes

Can also be bought at stores (old customers can update their device)</td></tr>
<tr><td colspan="3">Cost structure

Sales & installation fee 140 €/customer
Purchase price of the device estimated 100 €/unit
Overhead costs (support 24/7, management etc.) 59 000 €/month
Provision for the shops that sell the device for the senior</td>
<td colspan="2">Revenue Streams

Inspection of capability of living at home 0 €
One price for installation package 350 eur including the device
Monthly service fee 5 eur
Fees from the service providers that are integrated in to the eButler (packages vary between 100 -1000 eur/year)</td></tr>
</table>

Fig. 4 An example of business model of HoviMestari

Service helpdesk is open 24/7 which requires at least 5 persons working at the service center. Management and sales requires 4 persons. With the selling price of 480 €/device (350 for the installation and 5 eur per month for 2 years contract) we need more than 1800 customers to break even with the overhead costs.

4. Conclusion

User-driven research and development has been proved in practice as a way to create new information and deepen the research results. However well-being ecosystem is so complex and large entity that comprehensive conceptualization and the search for solutions is challenging and requires a long period of time. Nevertheless the end users were willing, able and committed to evaluate the research outcomes in various tests. As a result of these tests it is possible to make clear improvements to the user interface and functionality of the system.

Ryhti-project UHE environment developed Hovimestari user interface. Business models canvas has been observed with a number of different business options. This research points out that a company or entrepreneur is required to business decisions and commercialization plans. As one of the concrete result of the project we claim that our business models for user oriented services in well-being ecosystem allows various business paths. Based on the study it can be concluded that the purchasing customer can be end users, supported housing providers (either public or private), service operators, that can operate as a lead company and invite complementary service partners or in such a way that there is a business network-based system.

Potential end users reacted favourably to the HoviMestari and well-being ecosystem solution. They thought it was part of a real living environment, and that it is a part of home technology. During architectural and construction design, it is important to pay attention to sufficient telecommunications means – both, wired, and wireless. The optical fiber provides satisfying level of bandwidth. The selected building automation and other housing related information systems should facilitate the usage of open interfaces and interoperability with such systems as HoviMestari.

The business research framework applied in this study is an effective tool to highlight the necessary questions to be answered when building the actual business model. The final analysis and decision-making can be seen naturally as part of a commercialisation process.

5. Acknowledgments

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

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Summary

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

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

1. Introduction

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

This study examines the services at a neighbourhood level. The importance of services for a neighbourhood well-being has been proven by several sustainability assessment systems. For example in the ISO 21929 (Sustainability in building construction) standard [4] one of the 14 indicators is availability of services and it is measured as distance to public and personal modes of transportation, green and open areas and to user-relevant basic services. Also the eco-efficiency assessment tool for city planning, HEKO, encompasses five entities, one of which is transportation and services, including the indicator: distance to basic services (day care, primary school, store) and broader services (library, postal office, health centre, secondary school and more diverse commercial services) [5].

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

1.1 Citizen participation and social impacts

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

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

Social impacts of sustainable built environment constitute a main area we are focusing on. For example the Finnish Ministry of Justice [15] defines social and health impacts as factors influencing a human, a group of people, a community or a society. The impacts might influence mental or physical health, well-being or living conditions of people, or the way how well-being is divided between people (for example between different socio-economic groups). According to the ISO 21929 standard [4] buildings and construction sector is an important industry which has remarkable economic and environmental impacts but it also affects social conditions significantly.

Sustainable buildings and infrastructure can be seen as a platform for services and living. According to Tapaninen et al. [16] the environment is related to the sense of community and to well-being as it is the scene for human activities. A good environment is created by social interaction of planning, development and doing. By creating good environments it is possible to ease the belonging to a group and develop sense of community.
Social impacts and well-being is also linked to the concept of social capital which is according to many studies associated with civic engagement [17]. For example a study by Mellor et al. [18] examining personal and neighbourhood well-being indicates a strong relationship between volunteering and personal and neighbourhood well-being. Several efforts have been made in order to increase the well-being and the sense of community of neighbourhoods but the projects cannot take off without engaged people. Therefore socio-cultural inspiration has a strong role in social growth and community development, as it motivates people to commit themselves to different activities [19].

1.2 Research questions

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

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

2. Methodology

An urban suburb from 1970s in the capital region of Finland was chosen as the case study. The aim of the case study was two-fold: The first objective was to identify service-related preferences, demands and thoughts by the residents and different actors of the neighbourhood. Second, a method for incorporating citizens into service planning and designing was tested. Main research methods were a survey and interviews, for identifying the resident perceptions, and a living lab for testing the user engagement method.

2.1 The Case study – the urban suburb of Hakunila

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

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

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

2.2 Interviews and questionnaire

To identify perceptions by the residents and actors of Hakunila, an interview and a questionnaire was carried out. The interview was a semi-structured interview with strict questions, but including also unplanned questions and conversation, depending on the interviewed person. The questions were related to describing the suburb with suitable adjectives, importance of different services in the suburb, good and bad things of the suburb, future scenarios for the suburb and news which would improve the image of the suburb. The questions were multiple choice questions, with the possibility for the respondent to add their own comments and descriptions with free words in many questions. The interviewed persons were people who have an important or active role in Hakunila (e.g. head of the school, CEO of the maintenance service company, members of the city council, head of the library) and have a special understanding about the problems, the current situation and the development of the suburb. Altogether 10 interviews were carried out between spring and autumn of 2012.

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

2.3 Workshops and living lab

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

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

3. Results

This paper presents the preliminary results of the case study. The interviews and the questionnaire presented interesting insight into the Hakunila residents' and actors' thoughts about their surrounding region. Similarities among the respondents could be identified very easily as some issues were highlighted far more than others. According to the interviews and the questionnaire the residents of Hakunila mostly appreciate their neighbourhood because of the existence of nature, cosiness and the high sense of community. The most important services of the suburb are the supermarkets, the library, heath centre and the pharmacy. Residents would like to have more social activities, better commercial services and meeting places and less social problems and disorders in the neighbourhood. The respondents were highly unanimous that the bad image of the suburb is a highly important issue which should be improved. The perception of the future looks considerably good as most of the respondents agreed on the statement that "Hakunila will be a vivid, cosy, multi-cultural suburb, attracting different people with its extensive services and diverse activities". However, differences between the interviewed people and people responding to the questionnaire can be pointed out here as interviewed persons, who are having an active role in the neighbourhood, gave more optimistic responds compared to the people responding to the survey.

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

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

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

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

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

4. Discussion, Conclusions and Acknowledgements

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

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

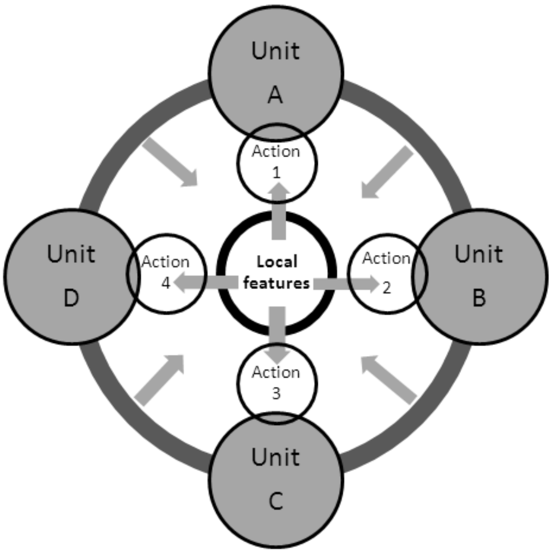

Fig. 1 Collaboration between units of city governance and neighbourhood level actors guided by local features.

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

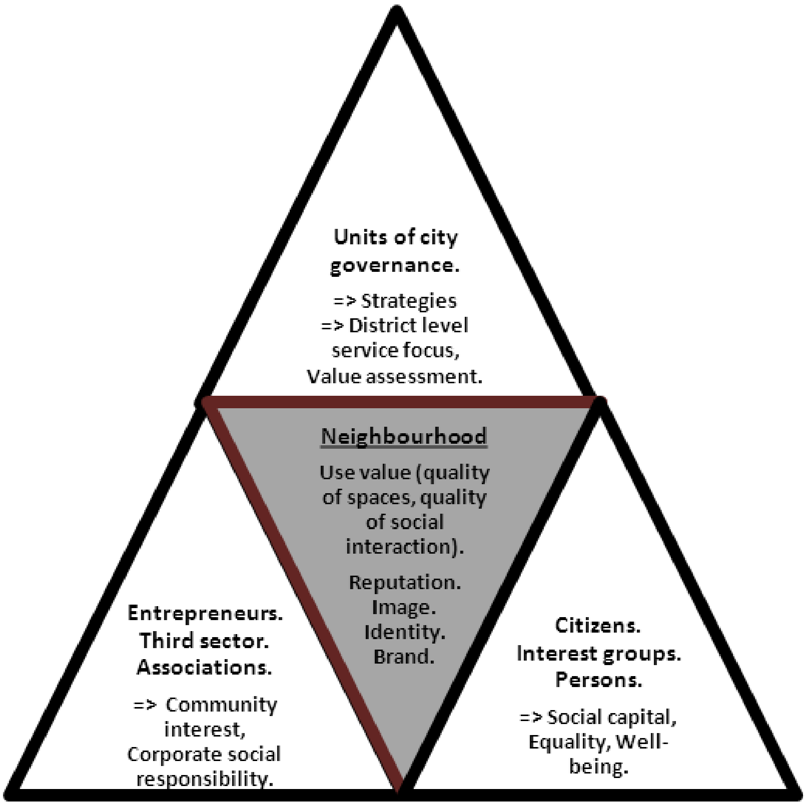

Fig. 2 Actors around the neighbourhood level well-being and use value.

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

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

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

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

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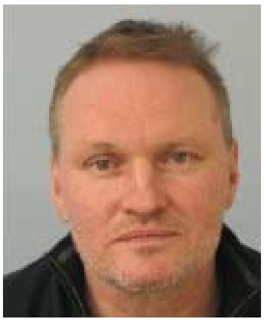
Sustainable built environment – viewpoints, business opportunities and life cycle costs



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Summary

The aim of the project was to increase building process stakeholders' understanding about what a sustainable community is like and how one can be built. Besides ecological also the social and economic dimensions were taken account. Theories were made concrete by new Hiukkavaara residential area in Oulu.
The crucial decisions regarding building a sustainable community are made already before planning starts during goal setting. Zoning, planning and construction for their part have to meet set goals. The aspects of sustainable development are not separate but merge with each other.
The lifecycle cost of building and maintaining Hiukkavaara, residential area for 20 000 inhabitants, is 3,5 billion euros (period under review 50 years, interest rate 3 %). It gives a crucial picture of business opportunities volume. Sustainable development creates new business opportunities at all phases of the building process. In addition to life-cycle projects suitable for large companies with risk-bearing capacity, or building of novel networks, sustainable construction offers opportunities also for small, local companies.
In the design of a one- and two-family house dominated residential area the value chain from general design to finished residential area is long time-wise. Thus, in the early phase it is important to retain the possibility to make changes instead of meeting exact client needs. The value chains of construction must be able to develop solutions for the changing operating environment. Uses must be found for buildings throughout their entire planned life cycle.

Keywords: sustainable community, economic sustainability, ecological sustainability, social sustainability, business opportunities, residential area, life cycle

1. Introduction

1.1 Oulu and climate politics

Population and, thus, also construction activity is concentrated in large urban areas. In northern Finland the locality that draws people is Oulu. Growing urban areas like Oulu have both the need and capacity to build completely new residential areas of significant size [1].
Together with other European countries, Finland has committed to EU climate goals. Oulu has joined a climate network established by the mayors of the six largest cities in Finland [2]. The network intends to promote EU climate goals, improve the energy efficiency of cities, increase the use of renewable energy and advance low-carbon urban development. A sub-goal is to build an energy-efficient, low-carbon residential area in the Hiukkavaara suburb of Oulu (figure 1).
The value chain of sustainable construction project (KERVO), for its part, supports the implementation of the same goals [3]. The project strives to increase understanding of what constitutes an energy-efficient and low-carbon residential area. Building of one requires that future residents approve the solutions and that it can be implemented profitably.

Fig. 1 Hiukkavaara (in colour area) is set near Oulu downtown [4].

In the case of Hiukkavaara, the boundary conditions lead to evaluation of the residential area within the framework of the traditional three pillars of sustainability: social, ecological and economic. Since Hiukkavaara was still under planning during the project, the aspects lending themselves for assessment were the ability of Hiukkavaara to fulfill the housing desires of Oulu residents (social), the eco-efficiency of the plans (ecological), and possible business activities and related development needs (economic).

1.2 Residential area Hiukkavaara - scale and life cycle cost

The aim is to design an urban detached house area for about 20,000 inhabitants and about 9,500 dwellings in Hiukkavaara adhering to the principles of sustainable development. The costs of building and maintaining a neighbourhood of the size of Hiukkavaara, i.e. the life-cycle costs, will amount to 3.4 billion euros over 50 years. Most of the costs will accrue from residential buildings both at the investment phase (85%) and during use (90%). During the investment phase, more money will be spent (10%) on infrastructure construction than on construction of other municipal service spaces (5%). During use the spent shares will be equal (ab. 5%).

Equal amounts will be spent on maintenance and construction of residential buildings over 50 years. Building on an owned plot makes investment costs higher than use costs. On the other hand, building on a rented plot makes use costs higher than construction-phase costs.

In the case of municipal services, use costs are unequivocally higher than construction-phase costs. A decision to invest fixes a significant amount of future costs.

During the period under review (50 years), the infrastructure investment cost is nearly double the use costs. Use costs of buildings are increased by consumables, energy and water, unlike those of infrastructure.

An important question is how much to invest in the energy efficiency of buildings. There is neither clear-cut answer to this question nor a standardised calculation model to provide one. There are several influential factors which have to be forecast. Better insulation and air tightness of the building envelope increase costs while also reducing heating power demand and thereby costs of the heating system.

The increase in construction costs that could be financed by energy conservation was determined on the basis of Hiukkavaara life-cycle calculations. Savings of 25 per cent in heating costs allow investing 1.5 per cent more in energy efficiency in attached houses, 2.5 per cent more in blocks of flats and 3 per cent more in detached houses. Savings of 50 or 75 per cent allow a slightly bigger investment. When construction costs are €1,200…1,300 per m^2 the extra cost is only a few tens of euros per square metre.

2. Residential area in line with sustainable development

Habitation plays a major role in sustainable development. Sustainable habitation meets today's housing needs within the constraints set by nature. Habitation is not merely satisfying a basic need but has also social, cultural and economic aspects [5].
Construction adhering to sustainable thinking creates areas with many activities. Sustainable construction is dense and favours development of brownfield land over use of greenfield land. Residential areas should be accessible by public transport and preferably located near places of work. It is socially beneficial to have affordable dwellings or dwellings of various price levels in the same area in order to avoid segregation [6].

2.1 Socially sustainable society

Socially sustainable development is described by themes. The themes have changed over time. Traditional and quite concrete themes are equity, poverty reduction and securing of livelihood. New themes include identity and social networks. Traditional dimensions of social sustainability are often called 'hard' themes while emerging ones are called 'soft' themes [7].

Table 1. Traditional and new definition of socially sustainable development.

Traditional	Emerging
Basic needs, including housing and environmental health Education and skills Employment Equity Human and gender rights Poverty Social justice	Demographic change (aging, migration and mobility) Social mixing and cohesion Identity, sense of place and culture Empowerment, participation and access Health and safety Social capital Wellbeing, happiness and quality of life

A well-known definition of social development is that by the City of Vancouver from 2005 [8]:
For a community to function and be sustainable, the basic needs of its residents must be met. A socially sustainable community must have the ability to maintain and build on its own resources and have the resiliency to prevent and/or address problems in the future.
Four principles govern social sustainability in Vancouver: equity, inclusion, adaptability and security.
In the planning of Hiukkavaara special attention has been paid to the attractiveness and versatility of the area, a comprehensive and safe network of pedestrian and bicycle routes, safety and accessibility of vehicular traffic, versatile housing production, mixing of population groups and easy access to services and mass transport. A green belt runs through the urban structure parallel to Poikkimaantie Road across a bridge to the centre of the City of Oulu about 6 km away.
According to the Oulu Region resident barometer [9], most house moves there take place within the same municipality of residence. Thus, a significant portion of future Hiukkavaara residents already live in Oulu.
The respondents to the barometer survey indicated that they desire a living environment that is safe and pleasant. They wish to have grocery stores, a health centre, a comprehensive school and mass transport close by. At the planning phase, Hiukkavaara would appear to meet the expectations of many Oulu residents. It remains to be seen whether the centre of Hiukkavaara responds to the hopes that youths and the elderly have about living in a block of flats in a city centre. Another issue is the participation of future residents in the next phase of planning. International experiences suggest that resident participation is an important factor (case of Freiburg) and emphasise the risk related to construction driven solely by market forces (case of Dublin).

2.2 An eco-efficient community

Eco-efficiency is the ratio of the natural resources (materials and energy) required to produce and consume a product or service and the (detrimental) emissions and wastes generated to the received benefit (product or service unit). Eco-efficiency improves as the amount of consumed natural resources and wastes per resident or workplace decreases. The environmental impacts of a built area can be assessed at various points of planning, implementation and use.

Environmental impact assessment methods have been born from national needs, and they reflect both geographical and cultural differences. Transfer of systems from one country to another is complicated by different systems of measurement, conditions, set requirements and standards, etc. Development of a European frame of reference for assessing environmental impacts has only started.

The Finnish HEKO assessment tool [10] determines the impacts of the most typical planning choices (efficiency ratings, location of activities, traffic arrangements, parking, building types, number and locations of green areas, etc.) on eco-efficiency.

The assessment focusses on five themes: land (6 assessed issues), water (3 assessed issues), energy (5 assessed issues), transport and services (4 assessed issues) and carbon and material cycles (3 assessed issues). The aggregate score for an area determines its overall grade.

The model was used to assess the Kivikkokangas section of Hiukkavaara. It has been planned as an urban 1+2 family house-dominated residential area considering the characteristics of its landscape and conservation values.

In HEKO assessment, Kivikkokangas earned 102 points and the overall grade “good”. In terms of eco-efficiency it is in the same class as three other areas in Helsinki evaluated by the same tool: Meri-Rastila (102), Koivusaari (102) and Saukonlaituri (103) [10].

Today’s community development and construction of individual buildings are in line with the wishes of people, but it is eco-efficient only compared to earlier construction. Responding to future challenges requires a leap in construction and utilisation of new technologies. The energy consumption of an area can be reduced by constructing energy-efficient buildings. Emissions can also be curbed by selecting low-emission heating systems. The heating system plays a bigger role in conventional than in low-energy construction.

2.3 Business opportunities

The decision-making and implementation network of community construction is wide and versatile. The network partners – planning authorities, developers, contractors, owners, managers, users and producers of real estate and user services – are closely tied to, and often even dependent on, each other. Choices made at the beginning of the process have an impact on later phases. Understanding entities, identifying the needs of end customers and co-operation between parties are required in developing new solutions and business activities. Examples of new operational modes include planning in partnership, design-build-maintain procurement models and integrated project teams.

The crucial decisions regarding sustainable community construction are made already before planning starts. The task of planning and design is to find a solution that meets set goals, while construction’s task is to implement it. Maintenance, again, ensures the sustainability of the planned solution.

The use phase of the life cycle has a decisive impact on the three dimensions of sustainable development. Energy can either be wasted or generated during the life cycle in a built environment. The basic assumption as regards socially sustainable development is that it is rather a process than an achieved state. If successful, it increases the valuation of an area and property prices which, again, is a factor of economically sustainable development.

2.3.1 Search for a solution that meets expectations

A sustainable community can be pursued and its construction managed through

- maximisation of the properties of the area both as to energy and recreational use
- concentration of services at nodes of mobility/mass transport and by investing in safe and smooth traffic arrangements

- different service promises for areas covered by a town plan and dispersed settlements
- a plan implementation sequence, terms of plot conveyance and pricing of plots
- integrated energy and architectural design aimed at low-energy construction and promotion of renewable energy sources and local energy such as ground-source heat, wind, solar, heat recycling
- prevention of overheating (vegetation)
- appropriate ventilation and lighting and intelligent control
- integration of structures; detail design.

Examples of new planning and consultancy services needed in the construction of a sustainable community:

- fitness of soil for storm water treatment, energy production, safe construction
- selection of optimal municipal engineering systems for an area and building services systems for buildings
- energy-efficiency calculations for new buildings and ones to be renovated.

2.3.2 Ensuring the implementation of goals

Construction aimed at sustainable development also changes the building process, i.e. the implementation of plans:

- preconstruction of plots: geothermal wells, piped waste collection, storm water retention, grey water recycling
- construction according to plan, quality assurance
- lean construction
- team building
- additional management required by self-led projects

New business activities related to implementation of goals:

- do-it-yourself information services for men and impacts of selections
- prefabrication, construction-period protection systems
- franchising of energy-efficient concepts
- measuring, control and information systems.

2.3.3 Ensuring sustainability of solution

The construction process is a short phase in the life cycle of built environment. Success will be measured only during the use of buildings which requires:

- monitoring (humidity, dew point, air quality)
- metering (separately for heating, ventilation, use, cooling)
- systematic maintenance, reviews and a maintenance manual
- incentives for producers of real estate services.

Socially sustainable development is rather a process than a project. The following contribute to a smooth process:

- security, such as a “village policeman”; quick intervention
- sense of community: recreational facilities for all; third sector services
- equality: accessibility (dwellings, mobility, services); rental /owner-occupied housing, social housing.

Realisation of goals must be ensured which requires:

- evaluations
- energy audits and certificates
- quality assurance
- ensuring realisation of goals: air-tightness measurements, thermal scanning, etc.

3. Summary

The value chains of sustainable construction project (KERVO) examined the characteristics and assessment methods of a sustainable built environment. Often the examination of sustainable development is limited to ecologically sustainable development. The KERVO project management team decided to expand the scope of study and include the social and economic dimensions in addition to the ecological one.

The crucial decisions about building a sustainable society are made already before planning starts. Planning, design and construction for their part must meet set goals. The contribution of design to life-cycle costs is small. Yet, investment in it can have a major impact on life-cycle costs of construction and the efficiency of the activity taking place within the spaces.

During the life cycle, the use phase has a decisive impact especially on the social and ecological dimensions of sustainable development. Energy can be wasted or generated during the life cycle in the built environment. The basic assumption as regards socially sustainable development is that it is rather a process than an achieved state. If successful, it increases the valuation of an area and property prices which, again, is a factor of economically sustainable development.

An investment decision ties up a sum equal to the investment for maintenance during use. Although economic analyses have shown low-energy construction to be of minor significance, we should proceed in that direction. In new areas that can be accomplished by regulations and guidance measures. However, that is not enough unless the buildings function as planned. Annual monitoring should be replaced by real-time monitoring and regulation for which technological solutions already exist.

Considering the viewpoint of sustainable development in construction broadens the scope and creates new business opportunities at all phases of the building process. Besides offering opportunities to large companies with risk-bearing capacity to carry out life-cycle projects or build new types of networks, sustainable construction also provides opportunities for small, local companies.

If construction is based just on price competition, it is extremely difficult to produce housing of high quality and consider environmental impacts at the same time. The life-cycle impacts of the project must be made the guiding objectives of construction management. Since they are quite difficult to assess at the start of a project, new types of procurement models (the alliance model, IPD, PPC) where the know-how of the key actors is utilised as early as possible are needed. Co-operation reduces life-cycle costs as well as enables faster delivery and better quality and constructability.

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Sustainable Procurement Models
Analysing conditions and constrains in project management

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During the total life cycle, several types of contracting are used to design, build, maintain and demolish a building. During this process procurement will possibly have a decisive influence on the deliveries from the contracting parties. This paper focusses on the use of project management tools to enhance sustainability in the deliveries. There is a distinction between procurement for newly built constructions and renovation of existing buildings. For both purposes common used procurement models, known from literature, will be presented. These models are described against the background of project management systems, as known from literature. Common known strengths and weaknesses in project management are held against knowledge of procurement models. The literature analysis is used as input for analysis of data from four working conferences in The Netherlands. From these working conferences in 2009 until 2012 it is known that it is far more easy to make criteria for procurement that exclude offers than to formulate criteria to rewards innovative offers. It also appeared that from the side of contractors and distributors in Dutch building industry there is little initiative to explore other procurement and contracting processes than Design-Bid-Build. This changes however, as soon as BIM (Building Information Model) is used to share design data in 3D visualisation.

In several case studies it was shown that integrated contracts can be made, if proper attention is given to the process of collaboration of parties involved. Since all projects are being managed in project management environments, failure of project management systems cause failure of deliveries according to the contract. It also became clear in several cases that knowledge about how to change project management systems in favour of sustainable procurement is very limited. Many persons from all parties involved seem to lean back on old habits, thus reproducing old problems again.

Conditions in the design, procurement and construction process are not optimal for sustainable procurement yet. Better conditions for all these interrelated processes are to be created in the project management environment in which client, contractors, advisors, designers, engineers and external stakeholders are expected to corporate. The main question in this paper is to elaborate when conditions can be improved and by which constrains potential improvements are limited.
Goal of the research is to describe conditions and constrains of project management tools for sustainable procurement. Subgoal is to explore influence of technological innovation (a), improving project organisation (b), improving collaboration of active parties (c) and enhancing communication with stakeholders as well as resilience to external changes (d). These four subgoals are known to represent usual categories of thresholds for innovation. Possible solutions to match procurement models with project management conditions and constraints better, will be analysed and discussed.

Examples of these solutions are use of BIM (Building Information Model), use of past performance information, regular use of working conferences and decision support systems for choosing the right procurement model.

On the other hand, the use of life cycle costing, in combination with BIM, can support changing project management systems and seem to support sustainable procurement considerably.
A discussion elaborates the possible improvement of sustainability in buildings by aligning project management to procurement models. Two working conferences during a extensive research at two universities were used to validate the results against the background of early adaptors and early majority.

The conclusion is that project management can speed up introduction of new procurement systems only if external dynamic can be incorporated in some way and if BIM is used as integral part of the design, construction and maintenance process. but also again the conclusion is that even early adaptors lack knowledge of how to proceed with new project management systems and how to proceed avoiding old habits.

Keywords: Sustainability, Procurement model, Project Delivery System, Project Management.