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Research highlights in

energy and eco-efficient built environment

VTT

VTT RESEARCH HIGHLIGHTS 1

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ISBN 978-951-38-7819-1 (print)
ISBN 978-951-38-7820-7 (online)

ISSN-L 2242-1173
ISSN 2242-1173 (print)
ISSN 2242-1181 (online)

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Paino Kopijyvä 2012

Research highlights in energy and eco-efficient built environment
Espoo 2012. VTT Research Highlights 1, 200 p.

Technologies in the built environment changing more rapidly than ever

Buildings and the whole built environment are in a key role when societies are mitigating climate change and adapting to its consequences. Despite the temporary economic downturn, construction globally remains one of the most significant areas of human activities globally. Due to the urgency of measures related to climate change and the need to provide a proper environment for living and working, a large number of national and international measures have been agreed to guarantee the future development of sustainable built environment for all. Indirectly, this has led to a need to develop existing and completely new technologies and processes for the built environment with a speed faster than ever and with a more holistic performance metrics than ever.

"Built environment" here refers to buildings and districts as well as the physical networks for water & waste, transport, energy and information. From a technological point of view the built environment is increasingly becoming a holistic "machine" requiring consideration of all the technologies in the system simultaneously. Yet the technologies are only there to serve a purpose. Long-term human needs, like sustainability, are at the end the foundation for all the development.

Sustainability as a dominating driver of technology development can also be seen in the R&D portfolio of VTT Technical Research Centre of Finland. A clear focus of our research for the building sector is sustainable construction, particularly the energy efficiency of the built environment. The annual volume of research related to the issues of sustainability reaches EUR 6–7 million. Some 50 researchers are working primarily on various aspects of sustainability of the built environment and another 30 researchers are contributing part of their time to these R&D questions.

The current focus lies in a solid background of decades of relevant research at VTT. The first energy efficiency projects were carried out in the 1950s, and practically once in a decade special programmes dedicated to energy efficiency have been carried out. Environmental impact assessments (LCA, LCC) have been part of our research agenda for some 20 years. While earlier development of individual construction products or individual buildings has played a central role, recent research has increasingly turned its focus towards district-level solutions. Despite the long research tradition, the changing performance requirements and development of technologies beyond the construction sector keep these research topics as important as ever before.

The role of people as co-producers and users of the built environment is being increasingly recognised, also as a research topic. Future intelligent systems are built to empower people; at their best intelligent systems are invisible enablers of sustainable living. By providing appropriate information, the systems also guide the users towards more sustainable behaviour.

At the current level of technology, the use of the building has a higher impact than construction on CO_2 emissions. However, while energy consumption is approaching zero, the relative significance of materials is increasing. As by far the largest consumer of materials, the need to pay attention to material selection is increasing. Embodied energy in construction products will become a factor in decision-making. A shortage of specific materials is also expected to have an impact on the construction technologies of the future.

Due to the slow change of the building stock, retrofitting buildings is a growing part of the construction business. Without major progress in the energy efficiency of existing buildings the challenging political goals of the EU, for example, will be impossible to meet. Methods of upgrading the existing building stock are highly need, including the development of renovation processes more convenient for users.

This publication presents a compilation of extended abstracts of VTT's recent research on energy and eco-efficient built environment. Most of the research reported has been conducted with partial funding from Tekes (Finnish Funding Agency for Technology and Innovation) or the Commission of the European Communities. Some of the research presented has been performed as assignments by companies or public organisations and with their full funding. Most of the work has been done in collaboration with both domestic and foreign universities, research organisations and enterprises. However, each of the extended abstracts has only one author, i.e. the contact person within VTT. The collaborators have been acknowledged in each paper, but we would still like to acknowledge the significance of our partners: Without a broad network of excellent partners, the quality and impact of our research would not be anything like it is at the moment.

The primary contact people listed on the following page are currently responsible for setting the future research direction and ensuring that the entire organisation delivers what has been promised. We hope this collection of current information provides you with a good overview of VTT's research on eco- and energy efficiency of the built environment and the competences available for serving our customers and for working together with researchers from other organisations.

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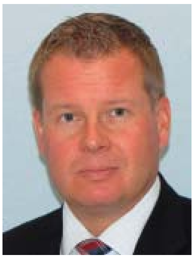

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Hazards to infrastructure in a changing climate

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Methods of the extreme value analysis have been developed and regional climate model simulation data analysed in order to reveal the effects of global climate change on the built environment. The results show that many adaptation measures are required in structural design and land use planning, as well as in upgrading the transport system.

Introduction

Global climate change will affect not only the mean climate but also the return periods of extreme events. Significant climate change is predicted by global climate models to occur within the typical design life-time of infrastructure. Therefore, the first step in the adaptation to climate change must be that engineering practices, recommendations and building codes are re-evaluated based on predictions of the probabilities of extreme events in the future climate.

Methods

A new probabilistic method has been developed to estimate the return periods of natural hazards [1–3]. This was necessary because the commonly used theoretical extreme value distributions are not valid when analysing very rare events, and because theoretical foundations for the "plotting positions" have been missing.

The new statistical methods have been applied to evaluate the effects of climate change on the occurrence of natural hazards [4, 5]. The data are from simulations by the Nordic regional climate model of the Swedish meteorological and hydrological institute. Extreme events were selected from the simulated climate data and analysed, as well as extrapolated to 50-year return values.

Results

Various problems with the commonly used extreme value analysis methods have been revealed and corrected [1–3]. It was also shown that the plotting positions of the extreme value analysis are independent of the parent distribution [3]. An improved method to fit a distribution to the plotted data has also been developed.

The new statistical methods have been applied to the analysis of simulated climate data. Some examples of the results are shown in Figures 1 and 2 for changes from 1961–1990 to 2071–2100.

Qualitatively, the most significant results of these simulations are:

- Short-term precipitation extremes increase in Finland by 25–50%.
- No significant changes in the extreme wind speeds are projected, except on the southern coast. In Denmark and southern Sweden extreme wind speeds may increase as much as 20%.
- In Finland, summer extreme maximum temperatures will rise by about 5°C and winter extreme minimum temperatures by about 10°C.
- The extreme snow load will be reduced by 50% in southern Finland but increase in some parts of the country.

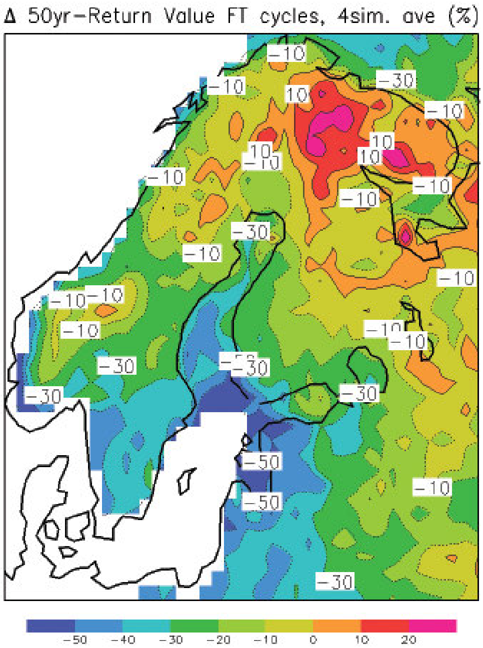

Figure 1. Projected change (in %) in this century in the precipitation amount in five days that is exceeded once in 50 years in the mean.

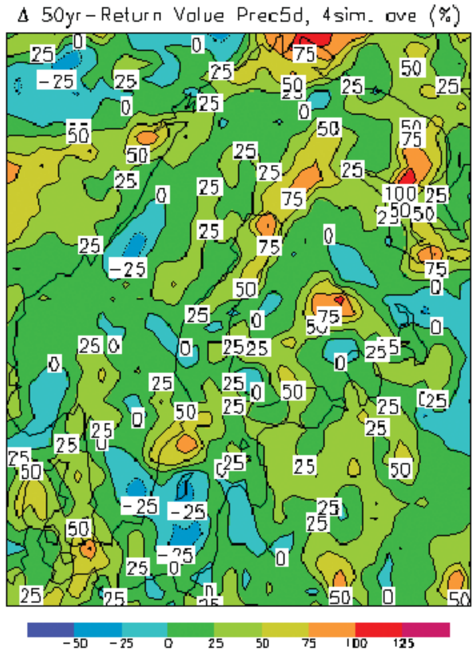

Figure 2. Projected change (in %) in this century in the mean annual driving rain impinging on a vertical surface.

- The intensity of extreme snowfalls will increase in spite of the general reduction in snow.
- The climate will become wetter, so that corrosion of steel and decay of wood will increase.
- The number of freeze/thaw cycles will increase in the cold areas and decrease in the warm areas.
- Driving rain will increase considerably.

Discussion and conclusions

Using conventional methods of extreme value analysis typically result in underestimation of risk. Adoption of the new methods developed at VTT will thus improve the safety of the built environment.

The new climate simulations showed that several adaptation measures to global climate change are necessary. The changes in the extreme temperatures suggest the possibility of reducing the maximum capacity of heating systems and the need to increase the maximum capacity of refrigeration systems.

The simulated increase in extreme winds in Denmark and the southern tip of Sweden indicate a need to increase the reference wind velocity for the building codes in these areas.

The results showed a generally increasing trend in precipitation. These changes are so large that renovation of drainage capacity is required, particularly in urban areas. In addition, management of the water level of water reservoirs should be re-evaluated in view of flooding and dam safety.

The analysis suggests that, despite a widespread decrease in total annual snowfall in a warmer climate, extreme snow precipitation will increase in most parts of the Nordic area, thus requiring increased awareness and resources for securing transport under severe winter conditions.

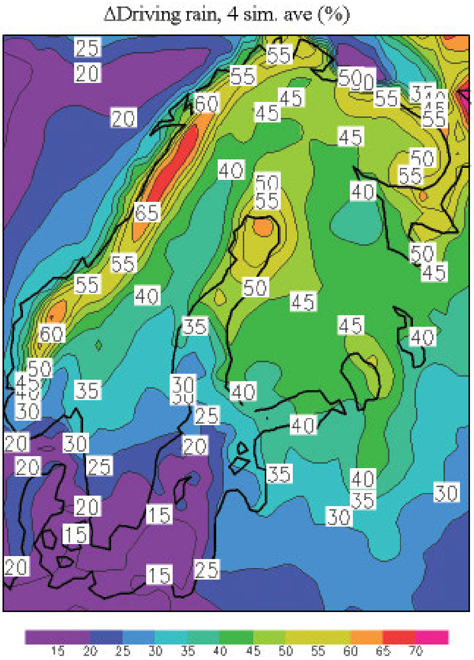

Figure 3. Projected change in the maximum frost depth during an average year in the Nordic countries in areas which are kept clean of snow (roads, airfields, etc.) [6].

The extreme cumulative snow amount will decrease in most of the Nordic area but increase in some parts of it. This suggests that for optimal structural design, the snow load maps of building codes should be updated, carefully taking local differences into account. An example of the estimated consequences of climate change is shown in Figure 3, where the maximum annual frost depth is shown for the present and future climate. This shows that some changes that are very important to road infrastructure, for example, will be substantial.

More attention will have to be paid to the selection of building materials used on exterior walls, because driving rain, freeze/thaw cycles and the conditions resulting in corrosion will change.

Exploitation potential

The results of the theoretical part of the work will be used in re-analysing the probabilities of natural hazards that were previously analysed using conventional statistical methods. This will improve the existing risk analyses that are based only on the present-day climate.

The first step in adapting to climate change in the building sector must be that engineering practices, recommendations and building codes based on historical climate data are re-evaluated. The results of this work regarding the projected climate change in terms of extreme weather have the key role in this adaptation process.

Acknowledgements

The authors wish to thank Markku Rummukainen from SMHI in Sweden, as well as Leena Ruokolainen and Jouni Räisänen from the University of Helsinki. The work has been supported by the Finnish Ministry of Environment.

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Assessing ecological sustainability in urban planning — ecobalance model

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Urban planning solutions and decisions have large-scale significance for ecological sustainability (eco-efficiency) the consumption of energy and other natural resources, the production of greenhouse gas and other emissions and the costs caused by urban form. Climate change brings new and growing challenges for urban planning. The EcoBalance model was developed to assess the sustainability of urban form and has been applied at various planning levels: regional plans, local master plans and detailed plans. The EcoBalance model estimates the total consumption of energy and other natural resources, the production of emissions and wastes and the costs caused directly and indirectly by urban form on a life cycle basis. The results of the case studies provide information about the ecological impacts of various solutions in urban development.

Introduction

An ecologically sustainable area can be described as an area which requires the supply of as little energy and raw materials as possible (especially non-renewable materials), and which produces the minimum of harmful emissions and waste from all building and operating processes on a life cycle basis. A sustainable area should also offer people a good living environment and be economically affordable. The EcoBalance model has been developed and used in several cases in Finland for evaluating the impacts of different solutions in urban planning at various planning levels: residential area (detailed plans), municipality (master plans) and regional (regional plans) levels. The results of the case studies show how ecologically sustainable various areas are, which impacts appear from area to area and from one urban form level to another, the essential choices of urban planning and transportation, and how to act to promote ecological sustainability in land use planning.

Methods

The EcoBalance model estimates the total consumption of energy and other natural resources, the production of emissions and wastes and the costs caused directly and indirectly by urban structures and transportation on a life cycle basis (Figure 1) [1–5]. The EcoBalance model is divided into three sub-models: production, operation and transportation models. The ecological balance sheet has the following dimensions: consumption of energy (primary energy), consumption of natural resources (building materials, fuels, water), emissions, wastes and costs. All effects are measured with their natural dimensions (tonnes, kWh, m3, euros). The EcoBalance model includes all urban structures: buildings, technical infrastructure and green areas. The model covers the whole life cycle of urban structures, starting from the production of building materials and fuels and continuing through maintenance and the use of the structures, as well as transportation in the urban structure, and

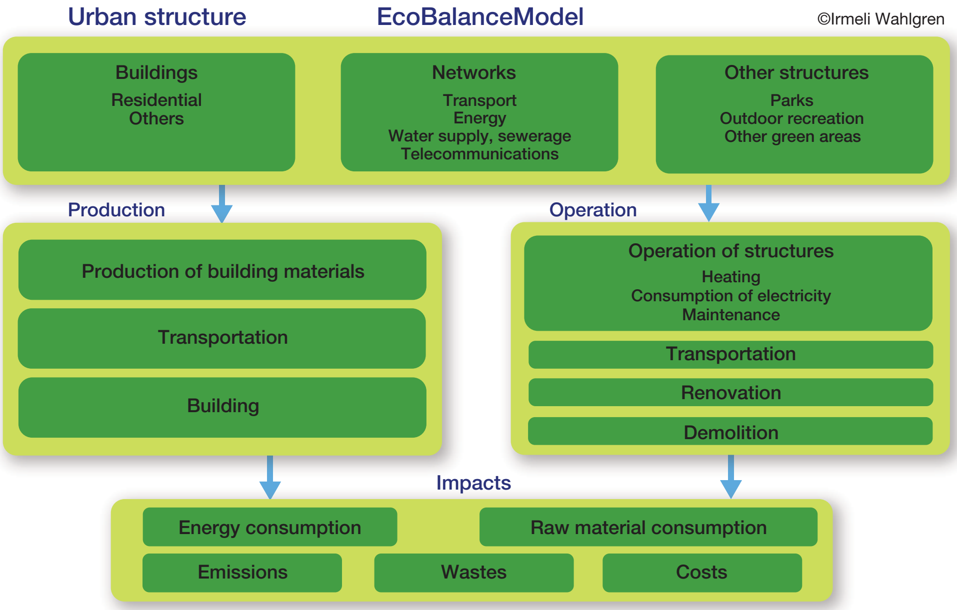

Figure 1. Structure of the EcoBalance model [1 – 5].

finally to the demolition of the structures. The input for the model is the volume data about all the area and transportation structures. The details of the information depend on the planning level.

The EcoBalance model calculates:

1. total energy consumption (primary energy, kWh)
2. consumption of building materials (tonnes of wood, concrete, other stone materials, metals, glass, oil and plastic products)
3. consumption of fuels (tonnes of gasoline, diesel oil, fuel oil, coal, gas, peat, wood, etc.)
4. production of emissions (tonnes of CO_2, CO, SO_2, NO_X, CH and particles; greenhouse gas emissions CO_2 eq. calculated from CO_2, CH_4 and N_2O)
5. water consumption and waste-water production (m^3)
6. production of waste (tonnes for recycling, compost, dump, etc.)
7. total costs of construction, operation as well as transportation (EUR).

All these factors are evaluated during various phases of the life cycle: production, operation and transportation. Continuous impact (operation and transportation) is evaluated using, for instance, a period of 50 years. The output of the EcoBalance model consists of total and relative figures (for instance, CO_2 eq. tonnes per inhabitant) for each ecological dimension.

Results

The results of the case studies offer information about the ecological impact of various solutions in urban development. This paper introduces the results of some of the case studies in which the EcoBalance Model has been used. Examples of results introduced in this paper focus on greenhouse gas emissions. Eco-efficiency of residential areas is introduced by 10 case study areas in various parts of Finland. Study areas have varying solutions with regard to location, structure, building efficiency, housing types and heating systems, etc. Two of the studies concern areas already built, and two concern area

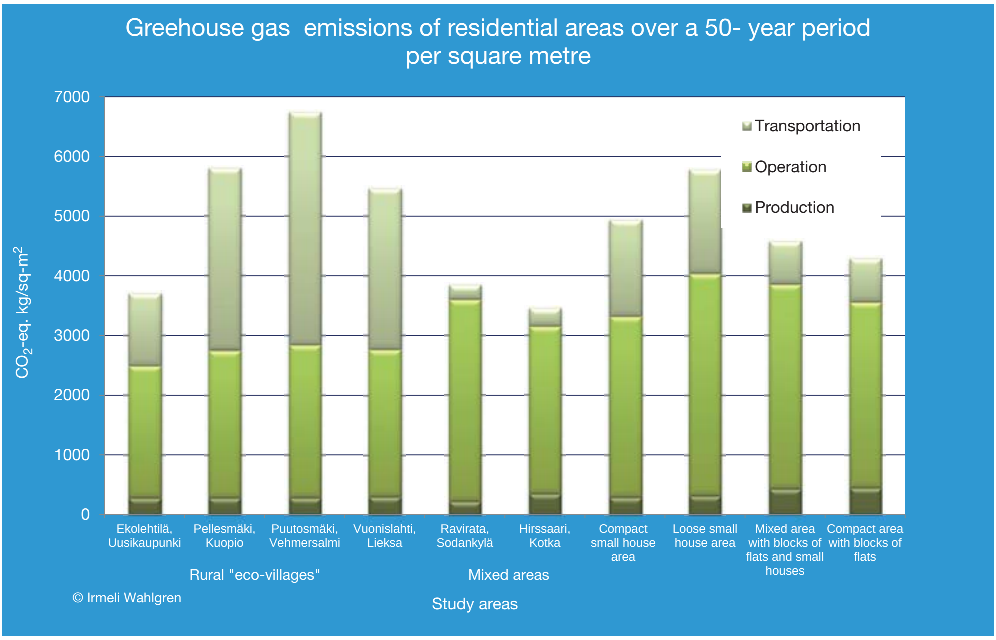

Figure 2. Greenhouse gas emissions of residential areas over a 50-year period. Emissions are produced most in rural areas by transportation [1–5].

plans: studies have been made at the planning phase and assessment has been utilised in planning. The study areas are: 1. four typical Finnish residential areas: a compact small house area, detached small house area, mixed area with blocks of flats and small houses and compact area with blocks of flats, 2. two relatively new areas: Ravirata (former race track) in Sodankylä and Hirssaari in Kotka. They are mixed areas with a majority of small houses, and 3. four "eco-villages" (rural areas that have been planned or are being developed with environmental interests as a priority): Ekolehtilä in Uusikaupunki, Pellesmäki in Kuopio, Puutosmäki in Vehmersalmi (nowadays a part of Kuopio) and Vuonislahti in Lieksa. The first two are relatively new areas with new technical or other solutions intended to lead to environmental conservation. The others are old villages where sustainable solutions for their future development are sought.

Greenhouse gas emissions account for 3.5–6.7 tonnes of CO_2 eq. per square metre in a 50-year period (Figure 2). The production phase is responsible for only about 10% of total energy consumption and greenhouse gas emissions. Most of the total energy consumption and greenhouse gas emissions are due to heating and the use of electricity in buildings. Energy consumption is highest in rural "eco-villages" and small house areas, because of long distances and the widespread use of private cars. Energy consumption is lowest in areas which have district heating and an efficient energy production system, which are located close to the city centre and where walking/bicycling as well as public transport are widely utilised. Greenhouse gas emissions caused in the operation phase are lower in rural "eco-villages" than in other areas, due to the use of wood heating. Greenhouse gas emissions caused by transportation nevertheless eat away at the savings obtained by wood heating. Transportation is the greatest difference between areas.

The results of the case studies show that there are big differences in the ecological impact of different areas. Eco-villages are

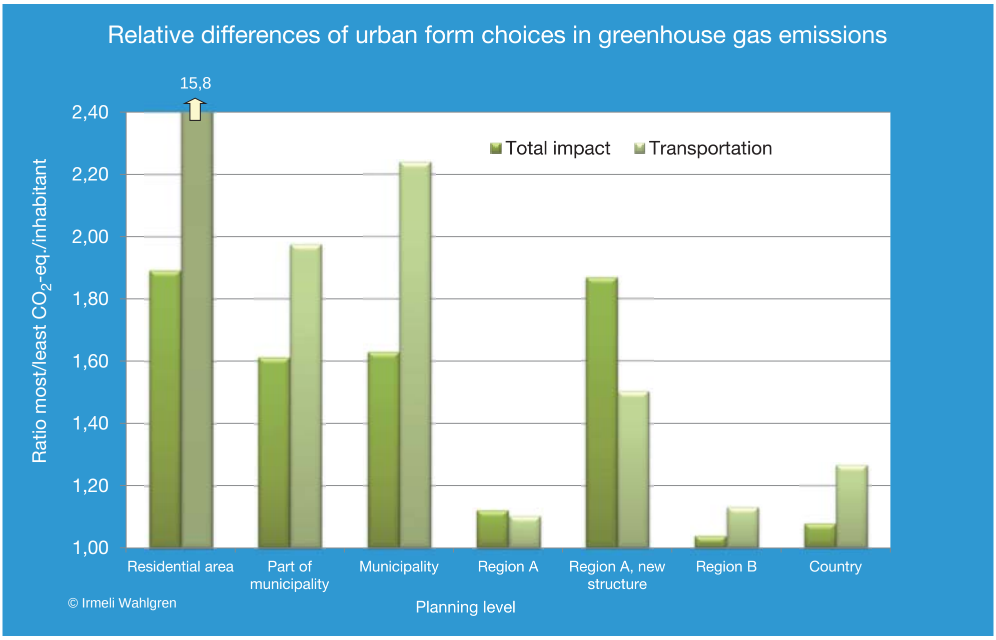

Figure 3. Relative differences of urban form choices in greenhouse gas emissions at different planning levels. Ratio between the best and worst solution at various planning levels.

not necessarily very sound from an ecological point of view. On average, eco-villages require more energy and raw materials, as they produce more emissions and cost more than urban areas. One of the most important explanations for the differences is transportation, especially in the use of private cars. This is strongly affected by the location of the area, the availability of public transport and individual preferences. Another important explanation for the differences lies in the consumption of heating energy, especially electricity. It would be most desirable to minimise electricity consumption.

Discussion and conclusions

Planning solutions may reduce greenhouse gas emissions by 10% at regional level, by 60% at local community level and even by 200% at local dwelling area level. Impact on emissions caused by transportation is even greater: at least double compared to the impact on total emissions (Figure 3). Similarly large impacts can be seen concerning consumption of energy and other natural resources as well as costs. The most important factors in sustainable urban planning are at the residential area level as well as at the municipal and regional level. Crucial factors at the residential level are: location, what forms the transportation basis, structure, building density, house types and space heating systems. Factors at the municipal and regional level are: area density, energy consumption and production systems, location and distances between dwellings, working places and services, transportation systems, possibilities of walking and cycling, the availability of public transport and the necessity for use of private cars. Important choices in urban planning concern the location of areas, distances, share of urban and rural development, complementary building, building density, structure, the total number extent of networks, consumption of heating energy and electricity, heating system, energy production system, building systems and materials, living space, transportation system, possibilities to walk and bicycle, availability of public transport (especially rail traffic) and the need for the use of private cars.

Existing buildings should be utilised for new purposes when necessary. Existing infrastructure should be used for new purposes when necessary, utilising complementary building. New areas should not be implemented before utilising complementary building and infill possibilities. New areas should be located favourably within the urban structure in order to avoid requiring the use of cars. Possibilities for walking, bicycling and the use of public transport – especially rail transport – should be created. Areas should have a good structure and a decent density. To stop urban sprawl and promote sustainable built environment, measures are required in planning, land use and housing policy as well as in transportation and taxation policies. Additionally, more needs to be done in regard to cooperation, interaction and information dissemination.

Exploitation Potential

The EcoBalance model can be used to access eco-efficiency at different levels of urban and regional planning.

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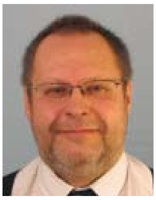
Extreme weather impacts on the European transport system



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As climate change seems to progress and extreme weather phenomena become more common, the need for in-depth analysis of extreme weather's impacts is inevitable. European FP7 project EWENT builds a holistic picture of the impact of extreme weather on the European transport system. The methodological approach explicitly follows a standard risk management process, which makes it transferrable to other sectors where extreme events might play an important role. The critical steps for successful analysis are 1) the identification of risky phenomena, 2) estimation of probabilities and 3) assessment of consequences, including cost impacts. All these steps require a combination of methods and analytical tools.

Introduction

Climate change and extreme weather phenomena are global issues that are on the table of inter-governmental organisations and national governments. The European EWENT (Extreme Weather impacts on European Networks of Transport) project, financed by the European Commission and VTT under 7th Framework Programme is tackling extreme weather phenomena.

EWENT's research strategy is based on a generic risk management framework and the whole project is structured like a risk management process. This process identifies harmful phenomena and their consequences, analyses their probabilities and estimates the cost of resulting damages and losses to European communities, companies and citizens. The final step will include policy and strategy recommendations to European Union, member states and local and regional communities on how to best and most cost-effectively adapt to and mitigate extreme weather impacts today and especially in the future.

The first two significant reports identify the most harmful weather phenomena [1] and estimate the probabilities of these events occurring between today and 2040–2070 [2]. Furthermore, numerous impact mechanisms are described in order to identify the most effective countermeasures and how these could best be implemented.

The recent events in Fukushima and the eruption of Icelandic volcanoes demonstrated concretely how vulnerable our technical systems can be to extreme events. Even smaller-scale weather phenomena, which still can be regarded as "extreme", bring enormous costs to societies in economic, social and human terms. Recent years' snowstorms in the EU and US have occasionally paralysed the transport system and halted the daily functioning of affected communities. Governments and international organisations (WEF, WB, OECD, WMO, etc.) have reported in a variety of ways that extreme weather events account for losses that are several percentage points of nations' GDPs.

Not only is the transport system affected. Identical impacts are obvious for all technical systems: electricity and power supply, energy supply and networks, water, sewage

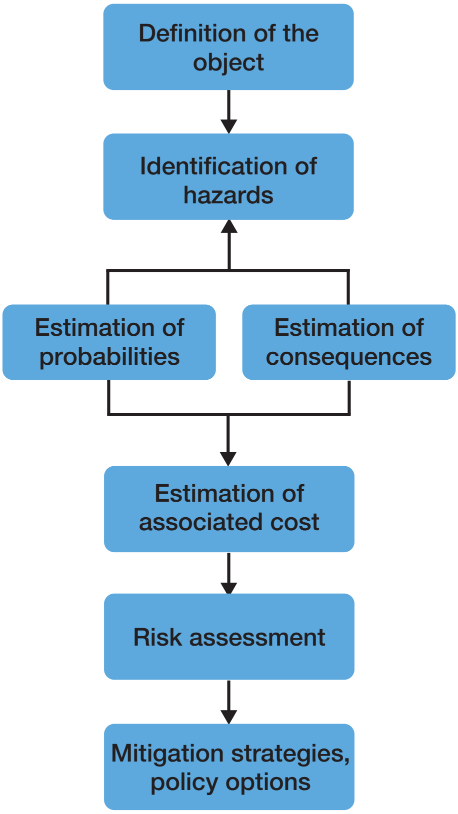

Figure 1. Standard risk management process according to IEC 60300-3-9.

and drainage systems as well as physical constructs like buildings, bridges, dams and other infrastructures of built environment.

Methodological approaches

The standard risk management framework sets the scene for extreme weather phenomena analysis (see Figure 1). Each step in the process requires several methods within.

The identification of extreme phenomena requires first and foremost the definition of "extreme". This concept has chronological (how often?), causal (how severe are the consequences?), economic (how costly?), demographic and geographic (how vulnerable and/or exposed?) dimensions, at least; there may well be more depending on the context. A single-dimension approach seldom works which clearly complicates the analysis and results in higher requirements for the quality and quantity of research effort.

Another problem inevitably encountered is the outlining of impacts and consequences. Impact assessments are needed, first to understand and second to foresee what the harmful phenomena can factually cause and why. Impact assessments are causal analyses on the origins (or inputs) and destinations (or outputs) of the impact mechanisms. There are several ways to carry out impact assessments, depending on the availability of data, empirical material and analytical resources (Table 1) [3].

The third major challenge will be economic and financial assessment of impacts and consequences. A euro or a dollar is not always the same as a euro or a dollar. The pricing techniques can vary significantly and also result in cost/price estimates that are method-dependent (Figure 2) [4]. A valuation using market-based cost information will produce results that are different from values based on a willingness-to-pay analysis. Yet in most cases, for example the valuation of physical infrastructure damages, the social costs of accidents and risk premiums required for project appraisal are all necessary for holistic valuation of extreme weather consequences. This results in a coherence problem for economic and financial analysis. In the EWENT project, all available valuation techniques will be applied and some of the outcomes even summed up, regardless of the theoretical problems that shadow the coherence of the results; for without applying a wide range of techniques, it will be impossible to derive cost and price estimates that cover the relevant segments of stakeholders, infrastructures and services and operations.

Finally, the combination of economic impacts, probabilities, quantitative impacts and consequences can be combined for panorama-like risk assessment which will be done in EWENT.

Model type	*Characteristics*	*Data need examples*
Analytical	Empirically validated, widely accepted model; produces results in "what-if" scenarios	Known input variables
Empirical, validated	Empirically validated, but the model validity is discussed or criticised; not widely accepted; can be used for ex ante scenario work	Suggested input variables
Empirical, unvalidated	Continuation of empirical experience, e.g. trend models; not valid if the underlying dependencies or mechanisms change	Historical data, time series
Logical, descriptive	The dependencies can be illustrated or described but not analytically quantified	No explicit or immediate data needs, some historical data or prior studies may back the argumentation; data serving deduction and induction; interviews and gathering of insights and experiences and other qualitative data usually utilised extensively
Heuristic	The model appeals to perception of the reality and included associations between associated phenomena	

Table 1. Impact assessment model types [3].

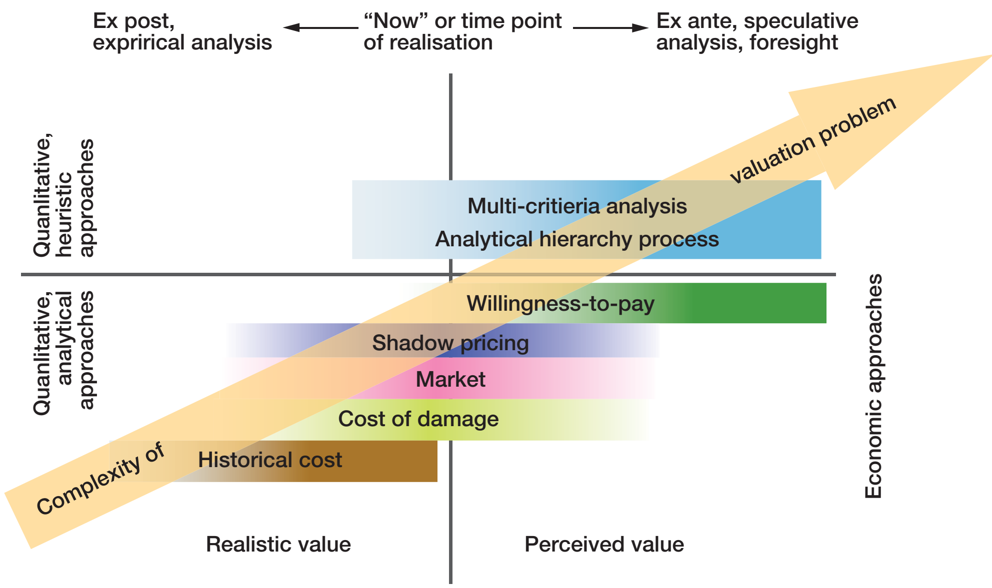

Figure 2. Valuation techniques [4].

Results

EWENT has identified a list of weather phenomena and their threshold parameter values (e.g. wind speeds (m/s) and rain fall intensities (mm/d)) that can be regarded as harmful. Extreme rainfall, i.e. precipitation, is probably the most common and widely appearing adverse weather phenomenon and in some respects it may be even manageable. It affects most modes of transport and most segments of transport systems (infrastructure, operations).

The probabilities of extreme weather phenomena will most likely change in accordance with climate change. The projections of extreme weather changes are based on the selected scenarios of Inter-governmental Panel on Climate Change (IPCC). A number of different change patterns were identified, the most important of which was the warming of the climate. This will have impacts on the Baltic Sea's ice cover, for example [2].

Discussion and conclusions

The EWENT project made an ambitious attempt to assess the consequences and costs of extreme weather phenomena on the European transport system. The first results imply that much of the goal can be achieved. The methodological approach can be modified to fit other contexts quite well, but its application will require a relatively high volume research effort, regardless of the field.

Exploitation potential

EWENT results will be used by European member states in their adaptation and mitigation strategies for extreme weather events. The European Commission can utilise the results for its policy analysis and build-up. Even individual companies, including not only transport operators but also large industrial units, have been involved in EWENT's exploitation.

Acknowledgements

EWENT is funded by the European Commission. The EWENT consortium involves VTT, German Aerospace Center, Finnish Meteorological Institute, Via Donau, Foreca Consulting, Institute of Transport Economics of Norway, Meteorological Service of Cyprus, European Severe Storms Laboratory and World Meteorological Organisation. These partners are acknowledged for their significant contributions. Also the advisory group is acknowledged for their support: Finnish Ministry of Transport and Communications, European Investment Bank, OECD International Transport Forum and Allianz SE.

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Metrics for value creation in a sustainable knowledge society

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This paper highlights the need to create potential value metrics for sustainable neighbourhoods, capable of working simultaneously at a variety of spatial scales for different stakeholders (multi-scalar reciprocity), moving from top-down imposed metrics towards bottom-up formulated ones. Metrics for Value Creation should be constituted using different approaches. One dimension is the built environment, where the present rating schemes focus on the environmental impact of the use of buildings, namely energy use. Another dimension is the corporate aspect, where triple bottom line reporting also emphasises environmental and social issues, but the discursive civic square environment risks domination by economic sustainability of the production and growth-oriented business environment. The third dimension is the city itself with its social networks, concerning indicators for employment and crime, for example. The fourth dimension aims to measure the quality of life of individual citizens, which is not easy to define. At present, all four approaches are used separately without interoperability between the systems [1].
Current environmental rating schemes, such as BREEAM, CASBEE, Green Star, HQE, LEED, PromisE, etc. are able to structure the processes of setting objectives, monitoring the process and assessing the state of buildings by some simple indicators. Mostly they focus on resource use and environmental impacts, but also cover some performance parameters, such as indoor environmental quality or aspects of accessibility. However, they are not contributing to the objectives of value creation in a knowledge society. This paper discusses major limitations of current sustainability indicator sets and rating tools. Finally, it describes a new approach to value metrics for sustainable neighbourhoods, using the LivingLab approach. This is a user-centric multidisciplinary research approach and a user community-driven innovation based on real-life experiments. The benefits of this approach are highlighted together with some main results.

Introduction

In Europe, Knowledge Society has been stated as an objective for achieving sustainable development. Sustainable development indicators have been developed from different points of view. At a city level, Agenda 21-based metrics focus on social aspects, such as employment and crime. Present building rating schemes emphasise environmental aspects, like energy efficiency. Companies that occupy buildings in city neighbourhoods do not really meet city or building-level sustainability metrics in their triple bottom line reporting. In addition, different quality of life indicator systems have been developed at a country and city level with quite different settings.

There is a need to create interoperable metrics that can be used at a neighbourhood level where innovations take place. Such a system should assess sustainability of the city, its buildings and infrastructure, and corporations that operate there; and it should be linked with citizens that live, work and play in there. Various sustainability indicator projects have been carried out globally by the UN and other international organisations. There have been a number of research projects in this domain funded by the EC. In addition, civil society organisations have worked in the field and LivingLab environments have been implemented to study these aspects. One of the challenges is how universal design can be implemented and assessed at a city and at a building level to support sustainability.

EC's Information Society Technology Programme funded research roadmaps leading to sustainable Knowledge Society. One of them, Intelcity, envisaged the concept of eAgora to support the improved management of cities to achieve long-term physical, social and economic sustainability. That brings together previously unconnected information sources and makes them digitally available to planners, developers, policy makers and individual citizens. It is based on the active participation of citizens that encourages collaboration between different stakeholders in policy-making processes. Another roadmap, Neskey, stated that a new economic feedback system should utilise an elegant core set of measures, indexes, and methods commonly used by business, cities and regions, civil society, and governing bodies, where global networks and practice communities collaboratively improve measures and methods. It advised research emphasis on intangible reporting for cities and regions.

This paper outlines potential value metrics for sustainable neighbourhoods based on these visions complemented by recent research in this domain funded by the EC. It discusses major limitations of current systems (see Table 1), highlighting the need to create interoperable metrics that can be used at a neighbourhood level where innovations take place. Such a system should assess sustainability of the city, its buildings and infrastructure, corporate that operate there, and it should be linked with citizens that live, work and play in there. The main research questions posed by the paper are:

1. Do existing (built environment) metrics and indicators constrain creative responses to the delivery of Sustainable Urban Development in the EU?
2. Do existing metrics and indicators inhibit the development of the knowledge economy in the EU?
3. What "knowledge economy" tools can we create to enable balanced sustainable solutions?

Discussion and conclusions

At present, environmental rating schemes (BREEAM, CASBEE, Green Star, HQE, LEED, etc.) are gaining popularity at a building level amongst building owners and users. Such procedures may structure the processes of setting the objectives, monitoring the process and assessing the state of buildings by some simple indicators. They are not, however, fully contributing to the objectives of value creation in a knowledge society.

This paper has highlighted the need to create potential value metrics for sustainable neighbourhoods, capable of working simultaneously at a variety of spatial scales for different stakeholders (multi-scalar reciprocity), moving from top-down imposed metrics towards bottom-up formulated ones.

Metrics for Value Creation should be constituted using different approaches. One dimension is the built environment, where the present rating schemes focus on the environmental impact of the use of buildings, namely energy use. Another dimension is the corporate aspect, where triple bottom line reporting also emphasises environmental and social issues, but the discursive civic square environment risks domination by economic sustainability of the production and growth-oriented business environment. The third dimension is the city itself with its social networks, concerning the indicators

Global	Global Competitiveness Report (World Economy Forum), Transnationality Index (UNCTAD), Globalisation Index (A.T.Kearny), Globalisation Index (World Market Research Centre), Global Warming Potentials (IPCC), etc.
National	ESI (Environmental Sustainability Index), Sustainable national product (SNP), Human development index (HDI), Sustainable economic welfare index (ISEW), (Daly & Cobb), Emergetical return of investment (Odum), Ecological footprint (Rees), Information Society Index (for KS), WEF (Economic Competitiveness), GIS (Innovation), CPI (corruption perception), HANPP (Human Appropriation of Net Primary Production), Happy Planet Index (HPI), MIPS (Material Input per unit of Service), etc.
Regional	WWF Sustainability Checklist, Ecological footprint, etc.
City	Agenda 21, BRE Sustainability Checklist, CASBEE-City, Community Sustainability Assessment, SPARTACUS, SEEDA Sustainability checklist, SCALDS, CITY Green, Quality of Life model, PLACE3S, Citizen Engagement matrix, Democracy indicators, CASBEE for Urban Development, ECOTECT, DOE 2.2, etc.
Community	Agenda 21, UK Audit Comm Qu-o-L; BREEAM Communities, CASBEE Urban Development, LEED for Neighborhood, HQE2R, Safety indicators, etc.
Organisation	GRI, G3, UPBEAT, IAM (Intangible Assets Monitor), WBCSD, etc.
Infrastructure	CEEQUAL
Buildings	SB Tool, CASBEE, LEED, PromisE, SPeAR, EcoCal, BREEAM, HK-BEAM, SBAT, EcoQuantum, HQE, SuBETool, Qualitel, EcoEffect, LiderA, Økoprofil, Legep, Green Star, Sustainable Buildings Climate Index (UNEP); Building Design Advisor, Minnesota Sustainable Design Guide, etc.
Materials	ECOPOINTS/ECOProfile, etc.

Table 1. Overview of indicators, indices and rating systems on a different spatial scale.

for employment and crime, for example. The fourth dimension aims to measure the quality of life of individual citizens which is not easy to define. At present, all four approaches are separately used without interoperability between the systems [1].

This paper has ultimately shown the opportunities to define metrics for value creation using the Living Lab approach. This is a new research paradigm integrating both a user-centric multidisciplinary research approach and user community-driven innovation based on real life experiments. As explained by Core Labs (2006), Living Labs represent regional innovation environments focusing on user communities embedded within "real life". Additionally to the technological aspects, Living Labs allow insight into the human dimension of technology, which is of paramount importance for a successful societal deployment of new technologies. This approach enables re-usable experiments (i.e. dataset, research protocols and methods), contributing to bring science and innovation closer to the citizen.

The next steps will involve the development of a "knowledge economy" tool, using a "value template" as a framework for the self-generation of value-based metrics.

Acknowledgements

This article is edited from a paper presented in the CIB World Congress in Manchester in May 2010. The author wishes to thank the co-authors Patrizia Lombardi from Polito in Italy and Veli-Pekka Niitamo from Nokia in Finland for producing that paper and collaborating in the Intelcities project supported by the EC in FP6.

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Urban eco-efficiency and system dynamics modelling

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Assessment of urban development is generally based on static models of economic, social or environmental impacts. More advanced dynamic models have been used mostly for prediction of population and employment changes as well as for other macro-economic issues. This feasibility study was arranged to test the potential of system dynamic modelling in assessing eco-efficiency changes during urban development.

Introduction

The idea of implementing current evaluation methods into the dynamic environment became relevant after the recent development of tools for assessing urban eco-efficiency for the City of Helsinki [1] and the simultaneous availability of new dynamic modelling software. This possibility was recognised during the IBEN project (Eco-efficient Intelligent Built Environment) and addressed in the presented study where the proposed model combines evaluation of urban eco-efficiency with system dynamics modelling (see Figure 1).

The current model tries to answer the basic question of whether the dynamic modelling approach brings new useful aspects to urban planning and decision-making when considering the contribution of these activities to global issues of sustainability and climate change. The basic structure and elements of the developed dynamic model are quite conventional in the dynamic modelling discipline.

The innovation of the current modelling effort lies in its attempt to integrate a classic assessment procedure for static objects (in this case a specified urban area) to a dynamic environment (like urban development). Within the wide spectrum of assessment disciplines and aspects this work concentrates on the eco-efficiency of the built environment.

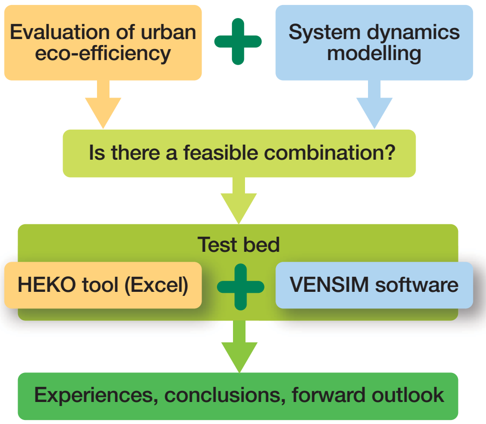

Figure 1. The main idea of the feasibility study and the tools used.

Methods

The core of the model is calculation and simulation of **urban eco-efficiency** *UEE* as the ratio of the quality of life *QL* and environmental load *EL* (Eq. 1), which is a common approach in existing environmental assessment tools [2–4]. In our case, both *QL* and *EL* are relative numbers from 0 to 1 (0 is the lowest possible quality or load at given time and 1 represents the highest possible quality or load) in order to keep the model working in different locations and time periods with the varying standards.

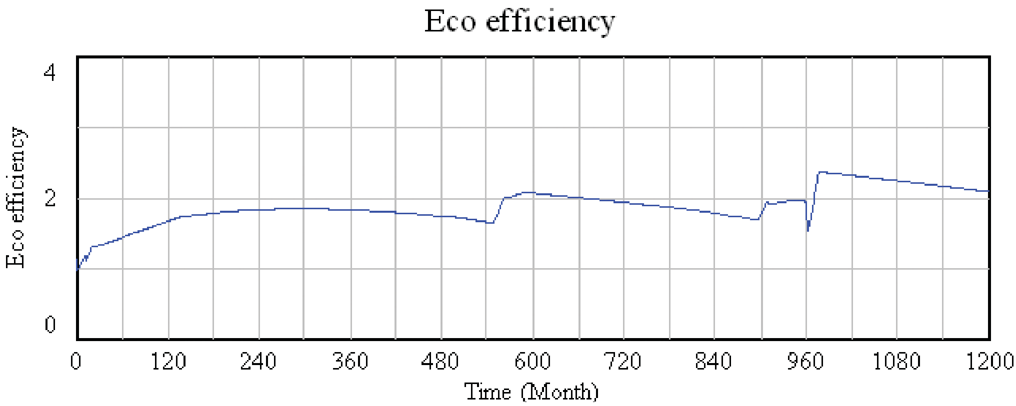

Figure 2. Example of the simulated development of the eco-efficiency in a theoretical test case.

$$UEE = \frac{QL}{EL} \qquad (1)$$

The system dynamics outcome in a speculative case study is graphically represented in Figure 2. In the presented example, two major area upgrade and maintenance actions can be observed (time 550 and 900) as well as rebuilding that temporarily decreases the area quality but has a potential to improve overall urban eco-efficiency (time 960). These changes are automatically triggered when the housing quality drops to a critical level but may also be inserted manually during the simulation.

The problem of such a model arises when the environmental load is very low and a small difference in *EL* creates relatively large differences in eco-efficiency. This can be solved for example by introducing a classification of eco-efficiency with unequal class sizes as in [3].

Each of the basic model variables relies on a set of system dynamic sub-models that are interconnected where appropriate (e.g. a calculated variable from one model can serve as an input for another one). The quality of life is the weighted average of four partial qualities (quality of housing, quality of services, area attractiveness and quality of transport) while the environmental load is based on indicators obtained from the HEKO tool [1].

The dynamicity of the model environment is simulated as a **population change over time**, and therefore all of the urban efficiency sub-models are based on this parameter and provide feedback to the population change gradient. Obviously, the increasing quality of life in the simulated area attracts more people which in turn (sooner or later) decreases the area attractiveness and thus slows down the increase of the quality of life. The population is also affected by mortality, natality and overall migration rates and is divided into three basic groups (families without children, families with children and people requiring a special assistance) that respond differently to the model parameters (see Figure 3).

The model is developed for assessment of smaller urban districts, and therefore migration is also strongly affected by the surrounding quality of life. The size and connectivity of the studied area is important for this type of additional migration, and the parameters have to be adjusted for a specific area.

Results and discussion

Although the study was not carried out to provide particular results of a specified case area, it became obvious that such a model is suitable for various applications. Most of the model variables can provide useful infor-

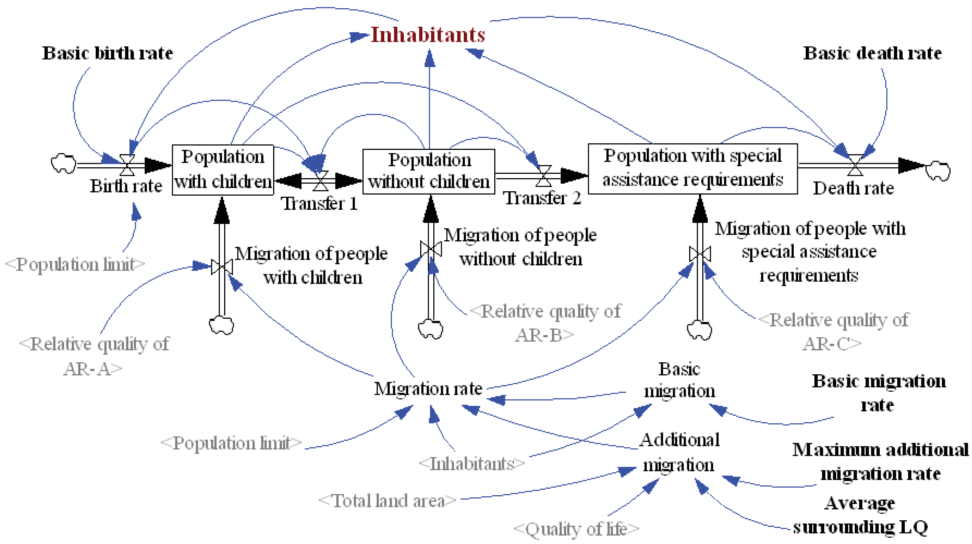

Figure 3. Population dynamics model.

mation since they are changing in time and connected to the overall simulation.

The next development phase could be focused on the following three study lines:

1. in-depth analysis of the most relevant factors and variables of urban dynamics affecting eco-efficiency (requires some basic research, check of data availability, critical synthesis)
2. creating the first generation of the dynamic urban model able to produce relevant new and credible information of the development of urban eco-efficiency
3. the testing of an urban dynamics model in real life cases (in an existing city with a real data set and user feedback).

Exploitation potential

The experiment shows that there is a real potential for further development of dynamic modelling in urban eco-efficiency. This feasibility study covers only some of the wide variety of possible parameters in the fields of both urban dynamics and urban eco-efficiency. Even this rather limited simulation shows that the results could illuminate possible choices in urban development both for urban planners and designers as well as for municipal decision-makers and development companies. The results may reveal considerable potential to improve urban eco-efficiency and contribute to climate change targets set at local, national and global levels.

Most of the model's input variables have to be adjusted and calibrated for a specific application, and there are many additional parameters that were only estimated since there is no exact knowledge about their value. However, this modelling revealed particular topics for a further research and at the current stage is able to provide a list of important parameters together with the output sensitivity to their values.

It is also possible to make similar studies in fields of urban dynamics modelling other than the mathematical modelling referred in this report. The game theoretic approach could be one of these possibilities, as well as different combinations of GIS-based cartographic simulations and organic or fractal growth models. Lastly, the integration of different modelling approaches could open quite new avenues to greater understanding of urban dynamics.

Acknowledgements

The research was supported by VTT's internal IBEN project (Eco-efficient Intelligent Built Environment) leaded by Jouko Törnqvist. The authors also wish to thank Appu Haapio from VTT's life cycle management team for the review of existing urban eco-efficiency tools, Sampsa Ruutu from VTT's System dynamics and optimisation team helping with model development, and Jutta Jantunen from VTT's Transport strategies and services team for the model calibration data. More detailed study results are presented in the project report [5].

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Tool for assessing eco-efficiency in urban planning and design

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The goal of this project was to develop a fast, comprehensive and user-friendly eco-efficiency estimation method for urban development. A preliminary study concluded that urban planners, designers and architects lack a practical and comprehensive tool for the overall assessment of community-level ecological performance. The report on the tool itself concluded findings concerning the needs of urban planners and designers in the City of Helsinki, which were transferred to the structure and contents of the assessment tool. The project continues the development efforts during the next couple of years, integrating 14 partners.

Introduction

During the study, it was found that available commercial tools could not adequately address questions of eco-efficiency relevant for urban planners in the City of Helsinki. The HEKO tool is based on a definition of eco-efficiency applied specially for the built environment and seen from the view point of urban planning and design.

Methods

The assessment approach adapted for HEKO differs from the commercial rating systems (such as LEED for Neighbourhood Development, BREEAM Communities and CASBEE for Urban Development or CASBEE-UD). A brief review of some of the rating systems indicated that the existing tools are relatively comprehensive and can address a large range of environmental issues in urban planning. However, these tools could not sufficiently address some of the questions of eco-efficiency considered relevant to urban planners in everyday practice. Furthermore, these tools do not fit well into Finnish urban development practices because of specific local government, cultural, and climatic conditions in northern Europe as well as the frequently ad hoc nature of needs which do not allow implementation of large and expensive commercial tools. Thus, there was a clear need to develop a new locally relevant assessment tool that reflects parameters set by the Nordic climate and the Finnish urban development culture and available resources.

Results

The core concept was defined as *eco-efficiency of urban development*. The aim of the HEKO tool is to assess the eco-efficiency in urban development. Eco-efficiency is part of a larger concept of sustainability or sustainable development. A typical definition of sustainability includes considerations for social, economic and ecological aspects. If one integrates this "triple bottom line" approach into an assessment method, one immediately faces the challenge of mixing quantitative and qualitative parameters as well as problems of combining very many different types of qualities and measurement units. The mixing of qualitative and quantitative parameters leads to a situation where the aggregated result of a comprehensive analysis is ambiguous, with blurred transparency and where the assessment method can be defended only on highly subjective grounds.

In order to develop a tool that can be used to successfully measure eco-efficiency in the built environment, the concept of sustainability must be further processed. There are many conventional, effective and exact methods for measuring the economic performance of the built environment. Therefore there is no need to include evaluation of economic parameters into the eco-efficiency tool. Sustainability is first reduced to eco-efficiency, where the general definition follows the OECD-based formula referred to in European Science Foundation COST Action C8 Sustainable Urban Infrastructure [4], for instance.

$$\text{Eco-efficiency} = \frac{\text{Quality of life}}{\text{Cost * harm to the environment * resource use}} \tag{1}$$

Eco-efficiency is defined here as a quality of life provided by the use of natural resources, taking into account the subsequent harmful environmental impacts. The general definition of eco-efficiency was further adapted to the built environment [1]

$$\text{Eco-efficiency} = \frac{\text{Services and products provided by built environment}}{\text{Use of natural resources and fossil fuels * emissions * waste}} \tag{2}$$

However, in practice quality of life or value of services and products provided by the built environment cannot be measured exactly by using numerical values. Quality of life is an ambiguous, vague and abstract concept that consists of numerous things sensitive to subjective experience. Services and products provided by the built environment are reduced to one single factor: total floor area, or sum of inhabitants (or dwellings) and jobs (or workplaces). Thus eco-efficiency (for the built environment) is defined as:

$$\text{Eco-efficiency} = \frac{\text{Total floor area or sum of inhabitants and jobs}}{\text{Use of natural resources * harm to the environment}} \tag{3}$$

This reduced definition covers now the “hard core” of eco-efficiency. Total floor area or sum of inhabitants and jobs represent here the products and services provided by the built environment. Use of natural resources consists of the use of materials and energy, with a specific focus on non-renewable fuels and materials. Harm to the environment consists of emissions (especially greenhouse gases), production of waste and ecosystem damage.

The development of the tool was based on a well-known spreadsheet software common to all urban planners and designers. The tool approaches eco-efficiency from six viewpoints or criteria: flows of materials and energy, share of renewable energy sources, flows of emissions and waste, and impact on the ecosystem. Eco-efficiency in the built environment is calculated with 21 “indicators” that are divided into five groups: land use, water usage, energy use, traffic and services, and carbon and material cycles, see Figure 1.

The tool produces one single aggregated average value of 21 independently calculated and weighted indicators.

$$\text{impact of indicator} = 100 \pm \frac{\Sigma\,\text{(category's weight * indicators weight on category)}}{\Sigma\,\text{(total weight of all categories)}} \tag{4}$$

$$\text{total impact of indicators} = \frac{\Sigma\,\text{(indicators value)}}{\text{number of indicators}} \tag{5}$$

The results are presented both in numbers and graphs. The overall average is called “total eco-efficiency”. This result can be used to label the studied area. Labelling resembles familiar European Union energy labels with colours (Figure 2).

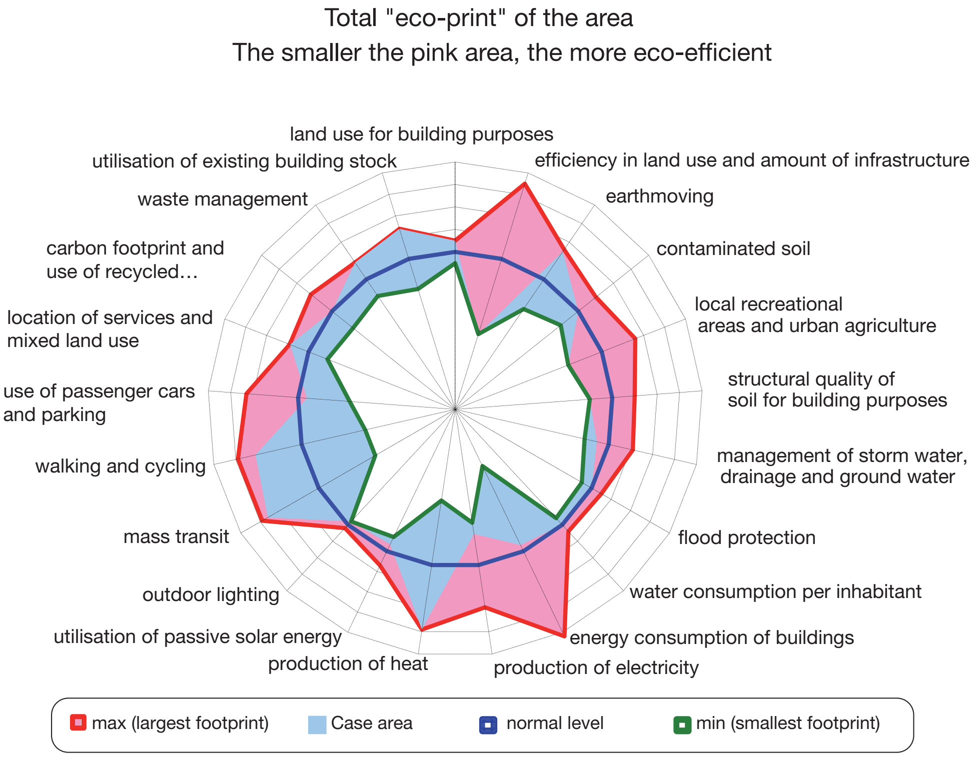

Figure 1. Illustration of indicators.

ECO-EFFICIENCY POINTS (total eco-efficiency)		
points	value category	CLASSIFICATION
110 or more	top value	A+
105...109,9	excellent	A
95...104,9	good	B
86...94,9	normal	C
75...85,9	sufficient	D
below 75	weak	E

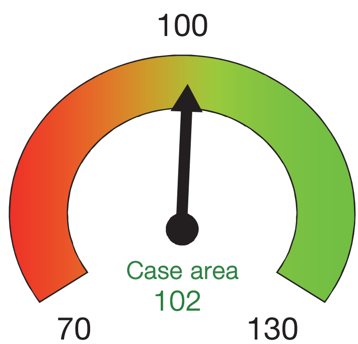

Figure 2. Illustration of eco-efficiency classification.

The tool also delivers a real-time indicator "speedometer" for planners and designers to follow improvement of eco-efficiency during their design process.

Discussion and conclusions

During the development process and subsequent testing in pilot areas, the HEKO tool proved to be user-friendly, comprehensive and suitable for the overall assessment of community level ecological performance. However, the indicators used are still rather unbalanced. Some indicators are well developed while some others are lagging behind in scientific evidence and details. Furthermore, some indicators and more exact calculation modules are missing, especially for carbon footprint and ecosystem services. Mass transit, walking and cycling modules need to be further improved to include the impact of changing modal split and vehicle mileages.

Urban planners and designers participating in the project were quite satisfied with the outcome. Average time spent to use the tool for a quick estimation was only approximately two hours.

After finishing the test phases in Helsinki and Tampere, a larger development project KEKO started. The aim of the research is to fill the gaps in the current assessment knowledge base and evaluate alternative methodological approaches in order to be able to provide urban planners, designers and developers with more comprehensive, reliable and user-friendly tools. The KEKO project is scheduled for 2011–2012 and is funded by 14 partners: Tekes (Finnish Funding Agency for Technology and Innovation), VTT, Aalto University, SYKE (Finnish Environment Institute), seven cities, two building and development companies as well as the Ministry of Environment.

Acknowledgements

The research was funded by the Cities of Helsinki and Tampere as well as VTT.

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Development of a concept for eco-efficient city planning process for St. Petersburg

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VTT developed, together with local partners, a concept for the design of eco-efficient neighbourhoods for the city of St. Petersburg, Russia. A list of criteria was compiled to help to identify the most important aspects that should be taken into account in the sustainable area planning process, including buildings, services, transportation, energy, water and waste management. The EcoGrad concept was tested with three pilot case areas, and life cycle emissions were calculated for different energy scenarios. Also a questionnaire was made for residents in St. Petersburg to understand their opinions about living conditions. One of the major findings was that there was a lack of policies and knowledge regarding certain renewable energy technologies and improving the energy efficiency of buildings.

Introduction

In Russia ecological planning is still in the early stages of development. Energy production based on renewable energy sources is also quite an unknown solution. However, there are already some regulations that support ecological urban planning, for example the regulation that orders a maximum permitted distance from residences to services used daily.

The aim of the EcoGrad research project was to develop a concept for the design of appropriate eco efficient neighbourhoods for the city of St. Petersburg, Russia. The project was executed in 2010.The research report of the EcoGrad project is published in Finnish, English and Russian versions in the publication series VTT RESEARCH NOTES [1]. The partner on the Russian side was the Coordination Center for International Scientific-Technology and Education Programmes.

One of the guiding principles in the planning process was the Globally Optimised, Locally Designed (GOLD) principle. Practically this means that local conditions are taken into consideration, when applying global optimized solutions into the EcoGrad concept.

Methods

The initial approach was to collect basic data and directly create plans according the EcoGrad concept for pilot areas. However, it turned out to be very difficult to get reliable base data, because it is hard to get energy consumption data on a single building level. Therefore the approach was changed. First a basic concept, based on Finnish base data, was developed. It was presented to the local authorities and adjustments were made based on the feedback received. The development process could be called an iterative process. As a result, the minimum emissions saving potential in Russia could be evaluated. However, even larger emissions savings may be achieved in St. Petersburg, since it is probable that the current Russian buildings consume more energy than buildings in Finland.

The project included three pilot residential areas locating in St. Petersburg. A rough city plan was drawn and different energy systems were modelled and calculated. These plans included different building types in the area

Figure 1. Aspects of EcoGrad concept.

(residential, services and offices), floor areas of each building type, number of residents, the energy consumption level of buildings, green areas, suitable transportation solutions, and the structure of the area. Different energy system scenarios of pilot cases were modelled and compared (different energy consumption levels and different energy production technologies). Emissions (CO_2, TOPP and SO_2 equivalents and small particulates) produced during the entire lifecycle of the energy production process were calculated using the Global Emission Model for Integrated Systems (GEMIS). The basic aspects included in EcoGrad concept are presented in Figure 1.

A questionnaire for local residents was made together with Finec, the St. Petersburg state university of Economics and Finance. It showed, among others, a poor willingness to pay for renewable energy and good indoor air. Security issues should be also highlighted.

Based on the findings from the pilot studies and negotiations with the local authorities, a criteria list for an ecological city plan was made, presented, and iterated. It included aspects from the international LEED and BREEAM criteria and national Finnish criteria. The criteria list is divided into following sectors: energy, buildings, transportation, the structure of the area, land usage, landscape, waste and water solutions. There are three categories in the criteria list: general level criteria, details and specifications of the criteria and special notices from Russia. [1]

Results

After completing this project, it can be concluded that ecological city planning principles can be applied in Russia. One of the major findings was that it is important to aim buildings' energy consumption towards passive building levels. A significant energy and emissions saving potential was found. Criteria regarding important aspects of sustainable urban planning in St. Petersburg were identified.

It seems that there is a lack of knowledge and policies regarding renewable energy as well as technologies that improve the energy efficiency of buildings. The development of renewable energy systems is not yet common enough in Russia. Policies need to be clarified, for example the buffer zones for bio energy plants were not known by Russian partners. And as another example, an important part of the passive house concept is the mechanical ventilation with efficient heat recovery. It needs to be emphasised that buildings cannot be built airtight and well insulated unless proper ventilation is ensured. However, this is quite an unknown solution according to the survey of residents, and its implementation may be difficult due to local policies.

Discussion and conclusions

Generally speaking, the issues related to base data issues, ownership and operating conditions in existing buildings have to be resolved. Future efforts should be put on exporting knowledge and best practices on these issues. With better knowledge local norms can be developed in a sustainable way. This knowledge will also support development of the city planning process.

In contrast to similar studies conducted in Finland, the survey results suggested that while renewable energy is not a priority for Russians in new neighbourhood developments, there is an interest in indoor quality and larger living spaces. Challenges revealed include unwillingness to pay for improvements and low safety in neighbourhoods, suggesting underlying economic and social issues that need to be addressed in addition to providing energy and environmental opportunities. It seems that passive solutions that are not very technology dependent are valued more highly in Russia. Technological solutions are not considered ecological. Smart metering systems for electricity consumption raised interest, but were still considered with scepticism.

During the project it was noticed that it is very important to have an active local partner in this type of development project. The local partners need to have their own funding for the project to ensure that the work is being prioritised.

Exploitation potential

One of the most important further development steps is the actual implementation in eco-efficient pilot areas. The next step in the development of new ecological areas is to take the criteria developed in this project into the planning process. In addition, the results of the questionnaire made for residents in St. Petersburg imply that residents should be more involved in the planning process.

The EcoGrad concept can be utilised also in another locations, but differences in climate conditions and cultures as well as in social issues have to be taken into account.

Acknowledgements

The work has been supported by the Ministry of Foreign Affairs of Finland.

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Eco-efficient solutions for China's urbanisation

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China's total energy consumption in 2009, including energy sources ranging from oil and coal to wind and solar power, was equal to 2265 billion tons of oil. China became the largest energy consumer of the world, compared with 2169 billion tons used by the U.S. Building energy uses accounted for 20.7% of China's total consumption in 2004. Chinese academics estimate that the buildings sector will exceed 30% of total energy consumption by 2010 with the existing building area of 40 billion m^2 and new construction annually 2 billion m^2. By 2015, half of the world's new building construction will take place in China; more than one-half of China's urban residential and commercial building stock in 2015 will likely be constructed after 2000.

Introduction

Presently, the share of renewables in the built environment is very modest, and aims at covering only the base load. Both at the national and international levels the targets for energy efficiency and the share of renewable production (e.g. the 20–20–20 target and 2050 vision in the SET Plan but also national programs), imply a steep increase of intermittent renewable energy. For the built environment, it is envisaged that the total yearly energy demand could be covered by thermal and electrical energy, produced from renewable sources, generated within the built environment. To fulfil this ambition, almost 20% of the total current energy demand should be produced at district level, apart from the contribution at building level. The ambition of this project is to enable the utilisation of the full potential of renewable energy (up to covering 100% of the energy demand on district level).

Methods

Based on the objectives of the project, the structure of the project is illustrated in Figure 1. Dissemination activities will take place during the running of the project and in particular in the last phase, when results can be shown to the professional world. While the EESCU can be considered as a system, three levels can be recognized in the project:

1. the level of inventory analysis
2. the level of solutions
3. the level of concept implementation (demonstration).

Results

There are no results yet but the project will answer what kind of buildings should be developed for providing high-level living conditions with minimised environment impact in China. The project will deliver quantitative results using both passive strategies and active measures to ensure the implementation of NetZero energy building concept. The results will include: the concept of NetZero energy building with low energy systems; development of design principles for practical cases implementing the concept of NetZero energy building; low energy systems' technical design and dimensioning of heat/cool generation utilising ground source energy under different climate conditions. In addition, a guideline will

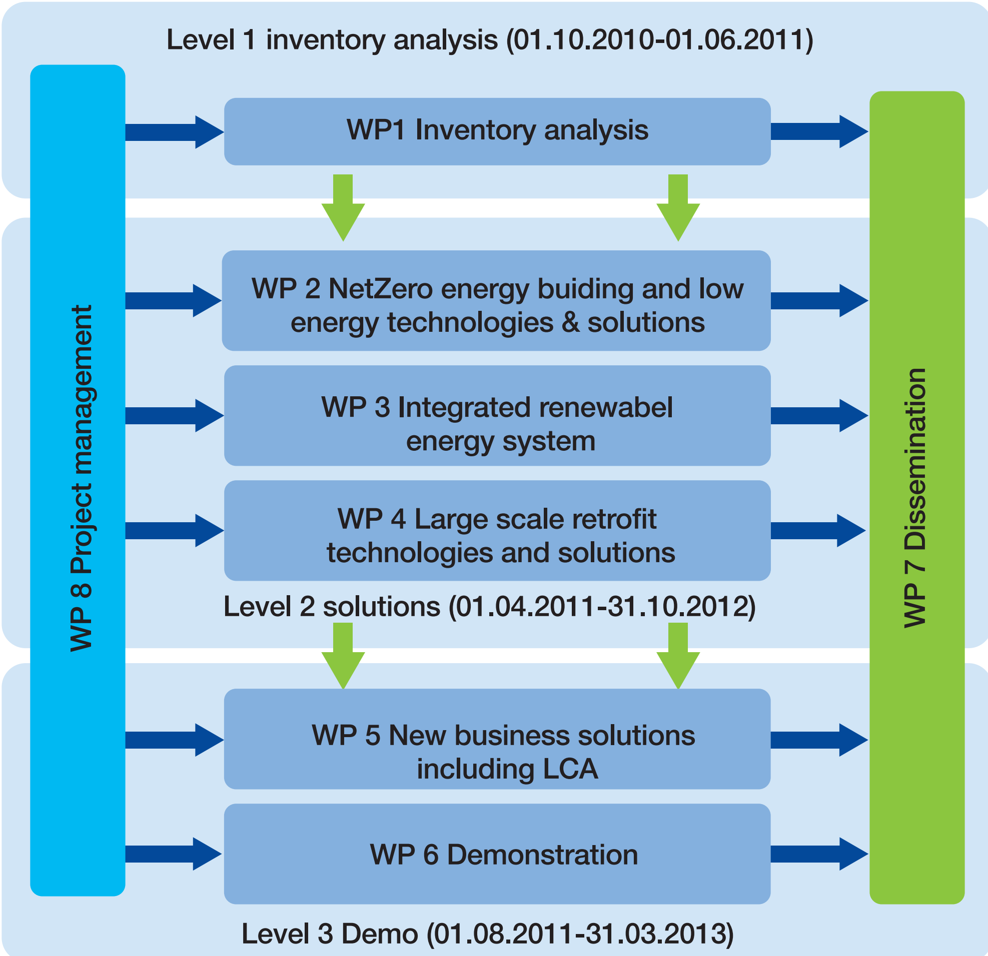

Figure 1. The structure of the project.

be made to apply façade structures with a high level of thermal insulation and concepts of building systems based on innovative building technologies with specific indoor climate target values.

The project will develop an innovative integrated renewable energy system suitable for built districts in China. By this system, the energy may be available as locally generated renewable energy, externally imported renewable energy (e.g. green electricity or biofuel) or industrial waste heat. The locally generated renewable energy may be generated in a distributed way (e.g. from PV modules on a number of residences) or by centralised means. The project will also make a comprehensive analysis of the current situation regarding sustainable renovation, taking a life cycle perspective.

Discussion and conclusions

The EESCU project aims for a significant cut in energy consumption by providing a wide range of eco efficient solutions to the Chinese building sector together with Chinese partners. The pay-back period of those eco efficient solutions is estimated at 5–8 years. However, it is not always easy to understand beforehand the consequences of different solutions in different areas with various economic conditions. New concepts and knowledge of eco strategies in urbanisation will help the community and building owners in realising their dreams of a better building environment and a better life. The current research project aims to integrate client needs in the construction process and add value to the processes and outcomes of the specific sector.

Exploitation potential

This project will bring a wide social and technological network with a large amount of market opportunities to Finnish companies. The wide social and technological network consists of Tongji University, Dalian University of Technology, Shengyang Jianzhu University and Beijing Institute for Real Estate Science and Technology. The market opportunities will be provide by Chinese partners with local governmental and industrial support. Finnish companies will attend those workshops and seminars organised in the project. In the demonstration part, Finnish companies will be involved in implementation of eco-efficient solutions in collaboration with Chinese partners.

Acknowledgements

The research was funded by Finnish Funding Agency for Technology and Innovation and VTT.

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Eco-districts in Jyväskylä

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The new National Building codes of Finland concerning the energy efficiency of buildings took effect in 2010. The required improvement in the efficiency of heating was 30% in new buildings. The required improvement in the following recast of the building code in 2012 is expected to be 20% more. The improved energy efficiency of buildings will, in the future, also reduce the energy demand of districts. The reduced energy demand will eventually lead to a transition from district heating and building specific heating systems to district-level energy systems. Therefore, the district-level energy systems must be taken into account already in the district planning phase. This generates a requirement for a new area of expertise among district planners. Also, tools for the district planners to quickly and easily evaluate the energy efficiency on a district level are needed.

Introduction

Energy efficiency is developing towards an asset in the competition between different district solutions and a factor increasing the attraction of districts. District development projects require the cooperation of several stakeholders and there is following development within the domain:

- the development of the business of the construction sector from product-centred operation towards user-oriented comprehensive solutions
- generalisation of distributed and building-integrated energy systems
- the development of contractual usages regarding the transfer of land.

Six municipalities from the central Finland participated in the Jyväskylä Ekotaajama project. Each municipality provided a case district. The planning of the case districts was at different stages; in some districts the district plan was ready and in others the district plan was at the draft stage. The results obtained during the project were supposed to be implemented in the planning process.

Methods

Six case districts in total were assessed during the project. In the assessments, each district was defined with information received from the participating municipalities. The building types, size of buildings and number of buildings were defined through existing district plan drafts or utilising the information received from the participating municipalities.

The energy consumption of the case districts was evaluated on three different energy efficiency levels: current buildings codes, low-energy buildings and passive buildings. The distribution losses of a possible heat transfer network were also taken into account while calculating the energy consumption of the case districts.

A number of different energy system alternatives were then defined for each case district. These energy system alternatives consisted of centralized and distributed alternatives as well as combinations of them. Each energy system alternative was then evaluated according to the life cycle emissions it would generate, if it would be the energy system of a certain case district. The emissions which were taken into account in the evaluation were: CO2-equivalent emissions, SO2-equivalent emissions, TOPP-equivalent emission and particulate emissions. Life cycle emission calculations were done with Global Emission Model for Integrated Systems (GEMIS).

Another outcome of the project is a district-level energy efficiency rating tool. The main criteria included in the tool are: the energy efficiency of the buildings, land use efficiency, energy production, traffic and services. These criteria are assessed by a number of sub-criteria, for example, the share of renewables in the energy production.

Results

As a result, a comparative study of different energy system alternatives for different case districts was accomplished. The results can be utilised as guidelines while planning the districts further. The comparison results of emissions of different energy system alternatives in the case districts shows that there is great potential to reduce the emissions related to heating energy and electricity consumption by both choosing the correct energy production technologies as well as pursuing higher energy efficiency of buildings.

On the basis of the energy calculations, recommendations will be made for each case district. These recommendations concern the actions that should or should not have been done in the district planning process in order to make the district more eco efficient. The recommendations as well as the development of the district energy rating tool are still being worked on.

Discussion and conclusions

The energy calculations and the comparison of different energy system alternatives through the emissions they generate gives a good overview of the potential emission reduction the district planners can achieve by taking energy questions into account in the planning phase. Creating possibilities for the utilisation of renewable energy within the planning phase, for example planning enough space for a district-level biomass-operated thermal power plant, does not exclude any alternative when the district is built.

Exploitation potential

The tool used to evaluate the energy systems of the case district can be exploited in future district energy efficiency studies. However, as all of the case districts were rather small, the tool must be modified to meet the requirements some larger districts may set. Also, the emissions database created for the tool is for Finnish solutions at presented. Therefore, it needs to be updated for in order to calculate the emissions of case districts in international projects.

Acknowledgements

The research was funded by the municipalities, which received the funding from Sitra and Tekes. The municipalities included in project were: Jyväskylä, Jämsä, Kannonkoski, Petäjävesi, Multia and Toivakka.

Miaofeng Mountain Town EcoCity

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An EcoCity essentially has high ecological quality but at the same time it is technologically sophisticated and most modern. This is a kind of town that has not yet been realised anywhere in the world. Attempts to build an EcoCity so far have been bases on optimisation of different sectors or technologies, and thus they fall between high-level targets and the present level of design. However, there is not just one EcoCity concept but a variety of possibilities that need to be adjusted to fit the local context, local culture and local economic realities. This is the way to achieve a possible solution with regard to the local resources, but at the same time to meet the high goals set for an EcoCity. High-tech solutions are one way to the EcoCity, but they are not the only goal of an EcoCity.

Introduction

The project produced a concept of an EcoCity to be built in Miaofeng Mountain Town in Mentougou District Beijing, and suggestions for implementation of the concept as long-term development. The feasibility study combined Chinese and Finnish expertise and experiences with sustainable communities. The development is based on Finnish experiences with production of environmentally friendly materials, buildings and sustainable communities combined with Chinese technology and local expertise.

The proposed EcoCity area is located in the Miaofeng Mountain Town northwest of Beijing City. The area has natural value and has been declared an ecological area. This restricts the use of natural environments to a minimum. The area consists of 17 separate villages with varying numbers of inhabitants. The feasibility study suggests that new villages be developed to improve the economic structure of the area and proposes technological and functional ways and means to reduce the environmental impact of the whole settlement.

The economic structure of the proposed EcoCity area relies on new services, enhanced local culture, agriculture, and tourism. In the recent years, work possibilities have been reduced because of the closing down of activities that harm the environment. The feasibility study suggests activities that improve the economic performance of the whole area.

Methods

An EcoCity essentially has high ecological quality but at the same time it is technologically sophisticated and very modern. There is not just one EcoCity concept but a variety of possibilities that need to be adjusted to fit the local context, local culture and local economic realities. This is the way to achieve a possible solution with regard to the local resources, but at the same time to meet the high goals set for an EcoCity. High-tech solutions are one way to the EcoCity, but they are not the only goal of an EcoCity. To map the possibilities in the EcoCity area in Mentougou Miaofeng Mountain town area, a framework for decision-making was developed (Figure 1).

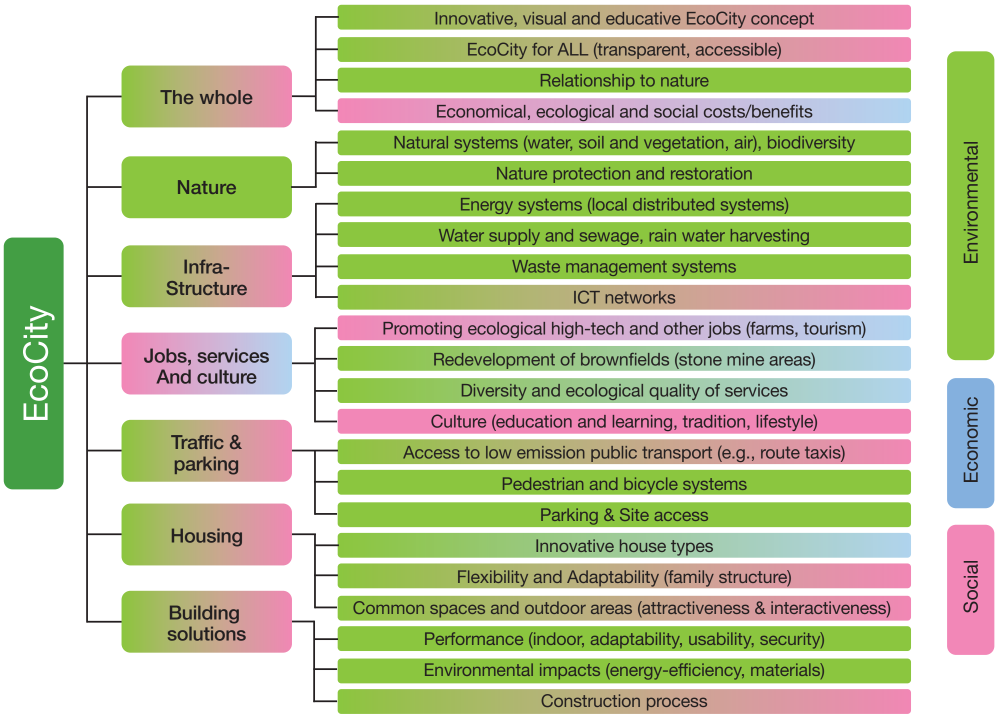

Figure 1. EcoCity framework for the Miaofeng Mountain town. The purpose of the framework was to aid the decision-making process to concentrate on the most important and urgent issues in the EcoCity development.

The Miaofeng Mountain Town EcoCity project produced a concept of an EcoCity to be built in Mentougou District Beijing, and suggestions for implementation of the concept as long-term development. The proposed EcoCity area is located in the Miaofeng Mountain Town northwest of Beijing City. The area has natural value and has been declared an ecological area. This restricts the use of natural environments to a minimum. The area consists of 17 separate villages with varying numbers of inhabitants. The feasibility study suggests that new villages be developed to improve the economic structure of the area and proposes technological and functional ways and means to reduce the environmental impacts of the whole settlement. There are shut-down quarries in the area, and these brownfield areas are used for new settlements (Figure 2).

Results

The economic structure of the proposed EcoCity area relies on new services, enhanced local culture, agriculture and tourism. In recent years, work possibilities have been reduced because of the closing down of activities that harm the environment. The feasibility study suggests activities that improve the economic performance of the whole area.

Life cycle costing (LCC) was used to compare the cost of an EcoCity plan to the plan for a typical area using energy cost as a parameter. The EcoCity relies on wind and solar energy, whereas a typical area uses a coal-fired condensing power plant for electricity production. Over a 20-year calculation period the EcoCity's life cycle costs including buildings, infrastructure and energy production systems is more beneficial to

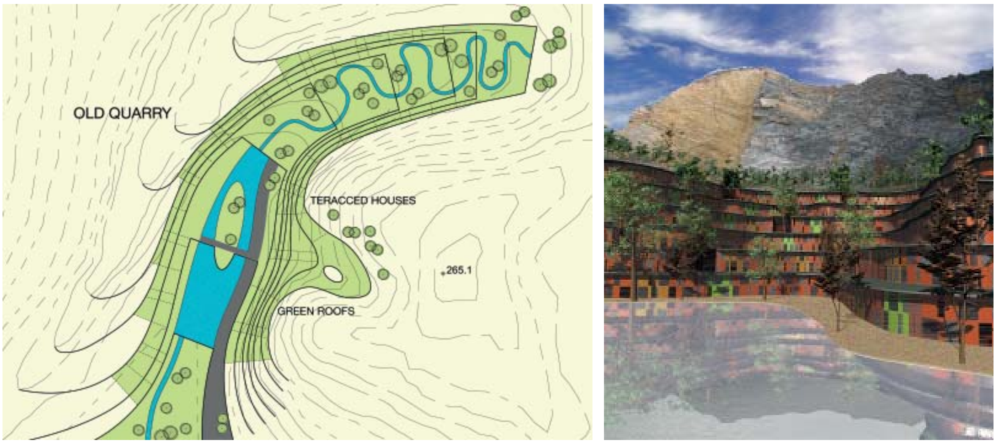

Figure 2. Example of a settlement in shut-down quarry, and an architect's proposal of a possible solution (architect Kimmo Lylykangas).

typical town construction at an energy price of 0.5 RMB/kWh.

A carbon footprint analysis showed that an EcoCity can reduce carbon emissions by more than 90% compared to Mentougou's present emissions. The estimate does not include transport, which in an EcoCity can give a substantial increase in carbon emission reduction.

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Energy-efficient districts

Choosing the optimal energy system for buildings and districts

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One of the major focuses in the development of districts and buildings today is energy efficiency. The base for the energy efficiency of buildings is set by the national building codes of Finland, but even more efficient methods of construction are constantly being developed. The energy efficiency on a district level is defined not only by the energy consumption of the buildings in the district, but also by several other factors. These factors include traffic, efficiency of land use and a numerous of other indicators. One factor which plays a crucially important part in the definition of an energy-efficient building or district is the way the energy to meet the demand is supplied.

Introduction

The European Union has set a target in the RES (Renewable Energy Sources) directive for the share of renewable energy in the final consumption to be increased to 20% by 2020. The target for Finland is, according to the RES directive, that the share of renew-able energy sources should cover 38% by 2020. [1] According to the district heat statistics by Energiateollisuus [2], the share of fossil fuels in the production of district heat exceeded 80% in 2009. Although the district heating network is a usual selection for the energy system of buildings in districts it is available, more alternatives should be given for the energy system selection process, especially alternatives that are focused on renewable energy sources. Providing decision-makers with alternatives for traditional energy systems, such as district heat or electric heating, requires comparison of different alternatives. The results of the comparison of different energy system alternatives depend on the criteria used to compare them and the relative importance given to each criterion in the comparison. Thus, by weighting the criterions used in the comparison according to the preferences of the decision-maker, an optimal energy system alternative can be determined.

The main purpose of this study was to present a method to be used in the selection of an optimal energy system for buildings and districts. The term optimal energy system was defined as the energy system which best suits the preferences of the stakeholder on whose preferences the energy systems are evaluated. As optimality of an energy system depends on whose point of view the systems are compared and which criteria are used to compare them, the study intends to answer the following questions: Who is the most influential stakeholder when decisions concerning energy systems are made and what qualities do they emphasise in the selection? What are the criteria used to compare energy systems? The case studies are also conducted in order to answer the question: Does the size and structure of the district have an effect on the selection of an optimal system?

Methods

The study consists of five parts: key elements influencing the energy demand of buildings and districts, inventory of enabling renewable

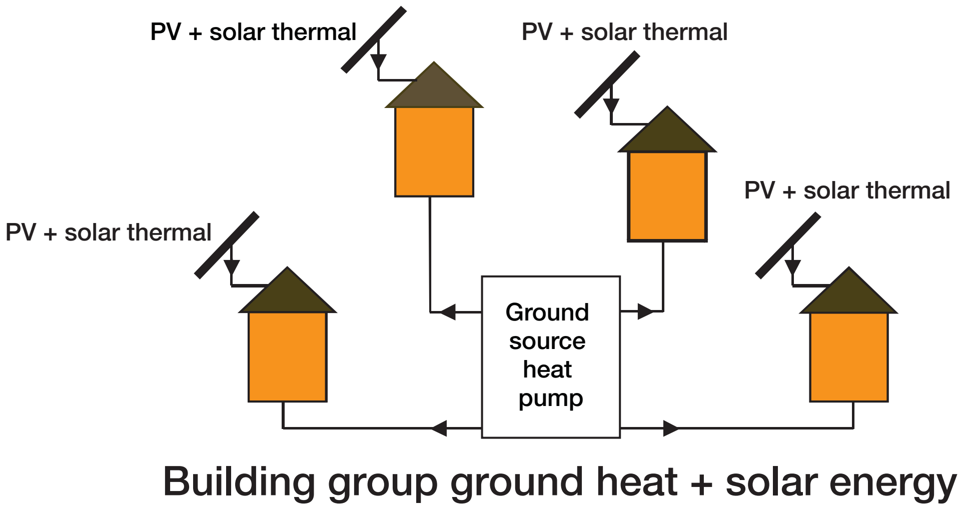

Figure 1. One of the energy system alternatives studied.

energy technologies, theory for decision-making, case studies and discussion. Background analysis is made of factors influencing the energy demand in buildings and districts, and inventory of enabling renewable energy technologies for energy supply. Not all of the presented energy conversion and storage technologies are used in the case studies due to technical feasibility requirements of the compared systems; for example fuel cells might prove to be an important technology in the future of energy conversion and storage. The background analysis part is followed by the theory and definition of the energy system selection method. The key stakeholder in the decision making is introduced along with the criteria used to compare the energy systems. Results of a questionnaire concerning the values affecting the selection of energy system are presented in the definition of the selection method.

The energy system selection method is applied in two case districts. The districts in the case studies were different in their size but also in their structure. The energy consumption of the case districts is calculated and a series of energy system alternatives is selected for the optimisation process in both case studies. The case studies are made in order to apply the energy system selection method defined by the study in practice. The effect of the differences in the size and structure of case districts on the optimality of different energy system alternatives will be examined in the case studies. Therefore, the case districts selected for the case studies are different in terms of both size and structure.

Results

The study presents a method for the selection of an optimal energy system in district development projects. The optimality of energy system alternatives is evaluated according to a series of criteria and the weight given to the criteria by the stakeholder who makes decisions regarding the energy system. The selection method includes the definition of the district, calculating the energy consumption, creating models for energy system alternatives and finally comparing different energy systems from the point of view of the most important stakeholder regarding the selection of the energy system. An example of energy system alternatives is illustrated in Figure 1, in which thermal energy is produced in a mid-centralized way on a building group level but there is also distributed solar energy production in each building.

Discussion and conclusions

The optimality of energy system alternatives is evaluated according to a series of criteria and the weight given to the criteria by the stakeholder who makes decisions regarding the energy system. The selection method includes defining the district, calculating the energy consumption, creating models for energy system alternatives and finally comparing different energy systems from the point of view of the most important stakeholder regarding the selection of the energy system.

In this study, the most influential stakeholder involved in the selection of an energy system is recognized to be the decision-maker who is in charge of district planning. It is assumed that the development of the district can be directed through district plan regulations, recommendations or instructions. The question of how far into the selection process the stakeholder responsible for district planning can influence remains open, however. The criteria which the community level decision-makers appreciate in energy system selection were studied by a questionnaire sent to the steering groups of two district development projects. These districts were used as case districts in this study.

Exploitation potential

The energy system selection method is most applicable in the pre-selection phase of planning a district's energy system. If the weights of the criteria are known, the selection method can be used to point out the optimal energy system. The energy system can then be optimised more precisely to meet the requirements of the building or district. Energy supply systems such as solar thermal collectors could be added to the energy system as well. The new versions of the initially selected energy system could be compared again with the multi-criteria method.

The strength of the selection method and especially the multi-criteria comparison is its transparency as the selection process is converted into a numerical form. This reduces the effects of favouring certain energy systems. Energy system alternatives which might on a first thought appear the best choice, might not receive such a high rank in the results of the comparison.

Acknowledgements

The study was done as a master's thesis within the EU project E-Hub.

The author wishes to thank Ismo Heimonen, a colleague from VTT and the supervisor of the master's thesis, for the dedicated support he provided during the writing of the master's thesis.

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Feedback between heat use and electricity generation

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Variable power sources (e.g. wind, photovoltaics) increase the value of flexibility in the power system. A possibly very large source of flexibility is heat use for space heating, warm water, and industrial processes. Research at VTT together with Risø DTU has investigated the benefits of combining electric heat boilers, heat pumps, CHP plants and heat storage in a district heating network when the share of variable power increases considerably. This section is based on paper [1], which in turn is based on results from [2]. An optimisation model for planning system wide investments in heat and power has been used. The model, Balmorel, uses an hourly resolution and enforces temporal continuity in the use of the heat storage. Scenarios with high amounts of wind power were investigated. Results show that district heating systems could offer significant and cost-effective flexibility to facilitate the integration of variable power. Furthermore, the combination of different technologies offers the largest advantage. The results imply that, if the share of variable power becomes large, heat storage should become an important part of district heating networks.

Introduction

Wind power is projected to be a large contributor to fulfil electricity demand in several countries. This could take place due to relatively low cost of wind power electricity or policy mechanisms promoting renewable energy. In any case, power systems with a large fraction of power coming from a variable power source will need to be flexible. Flexibility is used to cope with the increased variation in residual load (electricity demand minus variable power production) and with the increased forecast uncertainty in the residual load. Lack of flexibility will cause larger costs from increased variability and forecast errors. Therefore, it is prudent to investigate cost-optimal configurations for the combined power and heat generation portfolios.

Heat generation could offer significant possibilities to increase the flexibility of the power system. In most countries heat demand is on the same order of magnitude as electricity demand. Currently, part of the inflexibility of the power system comes from CHP plants that are operated to serve the heat load while electricity is a side product. Installation of electric resistance heaters next to the CHP units or elsewhere in the heat network could break this forced connection. During periods of low power prices, which will become more common with a high share of wind power, CHP plants could be shut down and heat would be produced with electricity. The dynamics can be made more economical with the use of heat storage. A further option is to have heat pumps in the DH network, but they will require a large amount of full load hours to be profitable and will compete with CHP plants for operating space.

The study has been restricted to residential and industrial district heating systems. Buildings not connected to district heating systems were not considered, although these also require heat. Cooling demand could also offer similar possibilities, but the problem was not addressed here. Industrial heat demand and water heating do not usually have strong seasonal variation and can therefore be more valuable for the integration of variable power.

Methods

The Balmorel model is a linear optimisation model of a power system including district heating systems. It calculates investments in storage, production and transmission capacity and the operation of the units in the system while satisfying the demand for power and district heating in every time period. Investments and operation will be optimal given input data assumptions covering parameters such as fuel prices, CO2 emission permit prices, electricity and district heating demand, technology costs and technical characteristics. The optimisation period in the model is one year divided into time periods. This work uses 26 selected weeks, each divided into 168 hours. The yearly optimisation period implies that an investment is carried out if it reduces system costs including the annualised investment cost of the unit.

The geographical resolution is countries divided into regions that are in turn subdivided into areas. Each country is divided into several regions to represent its main transmission grid constraints. Each region has a time series of electricity demand and wind power production. The transmission grid within a region is only represented as an average transmission and distribution loss. Areas are used to represent district heating grids, with each area having a time series of heat demand. There is no exchange of heat between areas. In this article, Finland is used as the source for most of the input data.

The hourly heat demand has to be fulfilled with heat generation units, including heat storage facilities. Loading of heat storage adds to the heat demand. Loss during the heat storage process is not considered. The dynamics of heat networks were not taken into account.

Analysis is done for the year 2035. By this time, a large portion of currently existing power plants will have been retired. Three district heating areas were considered. These will have a rather different existing heat generation portfolio by 2035. Considering the projected future profile of heat generation helps to uncover some interesting dynamics in the results section.

In this paper, scenarios without new nuclear power are compared (scenarios “Base NoNuc” and “OnlyHeat NoNuc” in article [2]). This meant that wind power had a very high share of electricity production. Accordingly, there was more demand for flexibility in the system.

Finland has been aggregated into three district heating areas: the “Urban” area presents the heat demand in the capital region (6.2 TWh), the “Rural” area aggregates non-industrial heat demand in other areas (21.0 TWh) and the “Industry” area aggregates the known industrial district heating demand from several different locations (46.8 TWh). “Rural” is probably the most interesting example, as the existing capacity covers only 20% of the heat capacity demand. Therefore, the model has to optimise almost the whole heat generation portfolio. There are wood resources (limited amount of forest residues and more expensive solid wood) available unlike in the “Urban” area.

Results

In the “Urban” heat area heat measures enabled the replacement of CHP coal units with production from heat pumps, and to a smaller extent from electric heat boilers (Figure 1). Also, wood-based heat boilers were replaced. Investment in heat storage was relatively smaller. However, heat storage units were cycled more due to a faster charging rate.

Combined heat measures were used to shut down existing natural gas-based CHP power plants during hours of average or lower electricity prices. During periods of

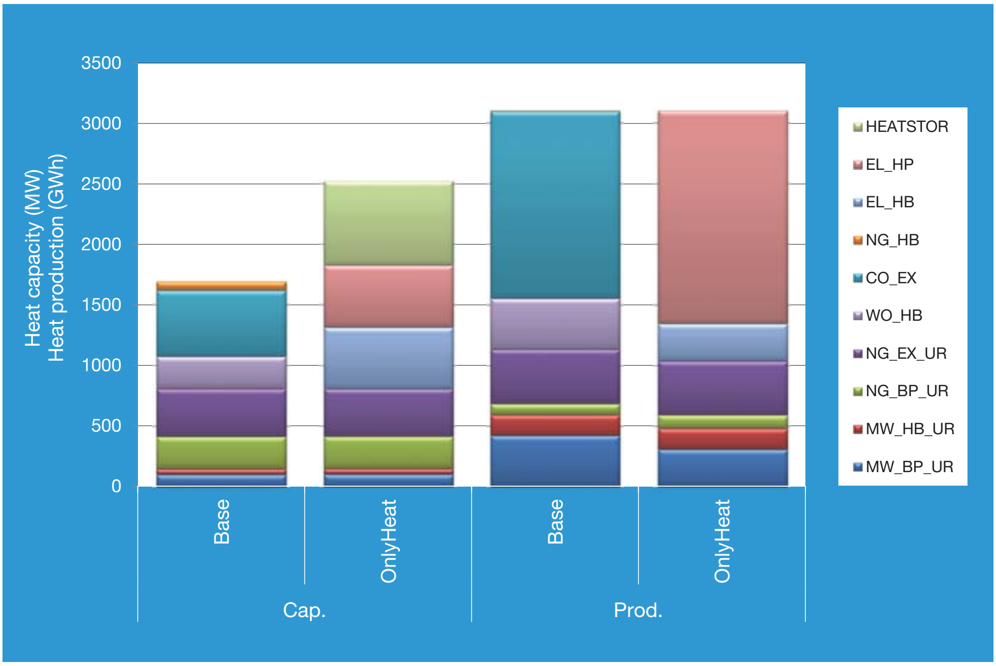

Figure 1. Heat capacity and production in the "Urban" heat area.

low electricity prices, electric heat boilers were used to charge heat storage. Accordingly, during average electricity prices heat was used from heat storage to prevent the use of electric heat boilers. At peak electricity prices, electric heat pumps were also shut down with the help of heat from heat storage.

The most important difference between "Urban" and "Rural" heat areas is the availability of wood residues in the "Rural" heat area (Figure 2). For the most part this resource was able to out-compete heat pumps as a means to produce heat. Heat measures still helped to replace coal CHP. The combination of electric heat boilers and heat storage was again a large source of additional flexibility in the system.

Most of the daily fluctuation in heat demand was smoothed with heat storages and electric heat boilers in all heat areas. If CHP units were operated, they were usually operated at maximum heat output.

The investment cost for heat storage was assumed to be EUR 1840/kWh. With the assumed storage capacity to heat capacity ratio of 12, this translates to EUR 153/kW. In comparison the capacity cost of electric heat boilers was assumed to be EUR 40/kW and EUR 50/kW for natural gas heat boiler. This means that investment into heat storage capacity was not driven by need for new capacity, since heat boilers were cheaper. There had to be operational benefits from the use of heat storage to cover the additional investment costs.

Heat storage creates operational benefits by moving consumption from more expensive sources of heat to less expensive ones by shifting demand in time. In all heating areas, the entire operating range of heat storage facilities was used. During most 168 hour periods heat storage reached both the minimum and maximum storage capacities. In the "Rural" area heat storage was 2.1% of the time either full or empty. With a larger storage capacity this could have been reduced, but it was not worth the investment.

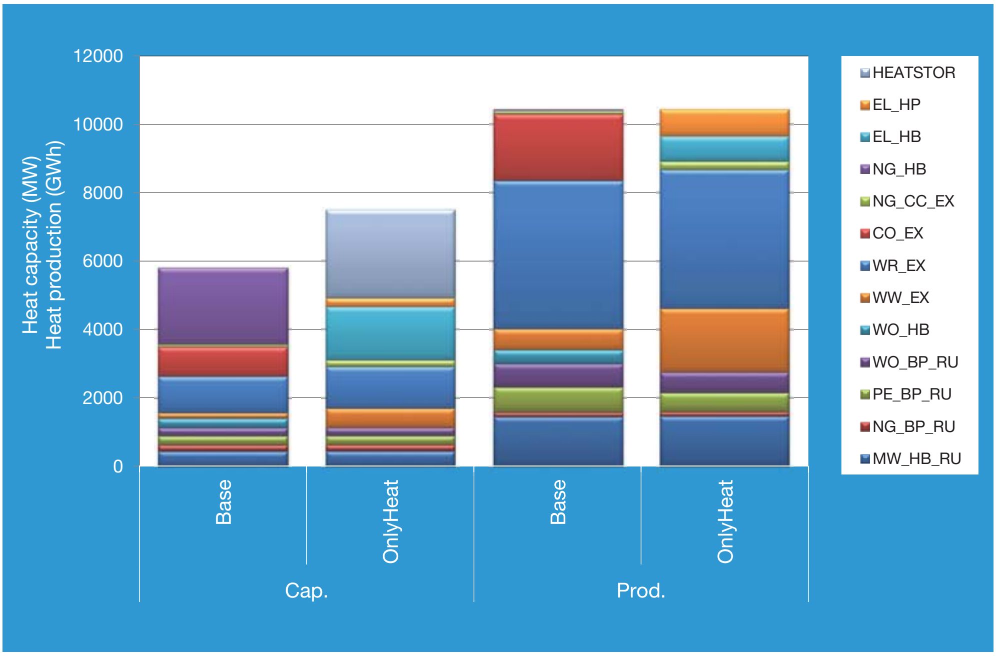

Figure 2. Heat capacity and production in the "Rural" heat area.

Discussion and conclusions

District heating systems offer good possibilities for increasing the flexibility of the power system, if the penetration of variable power like wind power increases greatly in the future. According to the results the best means to increase flexibility are the use of heat storage and electric heat boilers, and the flexible operation of CHP units.

Investment in electric heat boilers in district heating systems is driven mainly by periods of very high wind power production. The resulting cheap electricity is converted to heat and to some extent stored in heat storage for later use. Investments in heat storage in turn are driven by the same mechanisms, but also aim to create flexibility in the electricity production when prices are higher. To enable this, the operation of CHP units and heat pumps is altered with the help of heat storage. Heat pumps mainly compete against CHP as a source of heat. They succeed in replacing coal CHP, but are not very competitive against wood residues. This is naturally due to assumed costs where coal has a considerably penalty due to CO_2 cost. Heat pumps are not very important as a source of flexibility, since they require lot of full load hours due to their investment cost.

While research has been conducted on district heating, similar dynamics could be achieved in household heating not connected to district heating networks. However, the costs are likely to be larger unless there is an existing hot water tank. Flexibility could also be gained from district cooling or air-conditioning units with the addition of cold storage.

Exploitation potential

Understanding the value of flexibility in the energy system can have far-reaching consequences for heat demand and generation in residential and commercial buildings. If the use of fossil fuels will be phased out, renewable energy will be used much more extensively than today. Out of these, variable sources (solar and wind) have by far the largest resource potential and they are rapidly approaching cost competitiveness. As a result, the heating sector could develop into a very flexible resource for variable power generation. This kind of future should be extensively studied to identify future business opportunities. The tools used here are an excellent start to increase the necessary system-wide understanding.

Acknowledgements

The author wishes to thank Peter Meibom from Risø DTU for his contribution. Work has been supported by Cleen Ltd under SGEM program and by VTT.

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District heating solution for very low-energy residential building

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A number of prospective district heating solutions were investigated for the first time in the context of application to buildings needing 75% less energy compared with standard solutions. The analysis conducted suggests that district heating with traditional room radiators and current billing tariff structure may not be cost-effective due to high investment costs. However, other options exist. The most cost-effective district heating solution was based on ventilation-integrated heating. The solution included domestic hot water system equipped with a storage tank connected to the district heating network through a heat exchanger.

Introduction

The Action Plan for Energy Efficiency published by the European Commission and legislative initiatives of European Parliament motivate efforts to reduce energy consumption in the building sector in Member States. Since 2010 a reduction of 25–30% in heating load is required when compared with previous regulations in Finland [1]. In 2012 further cuts will be announced by the Ministry of Environment. For the far future, the government has published a vision in which Finland's greenhouse gas emissions in 2050 should be 80% less than they were in 1990. This implies that the building stock, which is responsible for 40% of nation's energy consumption today, will have to undergo a fundamental refurbishment. Low-energy construction needs to start immediately and become a regular practice as soon as possible. District heating (DH) solutions must be developed in compliance with tightening energy efficiency requirements in order to remain applicable for the new building standards.

Methods

From the traditional point of view, it does not make sense to establish a district heating network in the areas of low energy consumption. In this project a technically feasible and cost-effective combination of district heating with a very low-energy building was attempted for the first time. A holistic approach was used, covering the entire system, from room space, through the distribution piping and district heating substation to the district heating network. Dynamic simulations were used to assure both indoor comfort of inhabitants and efficient technical performance of the systems investigated.

Very low-energy house

For the heating system simulations a very low-energy building was computationally constructed from an existing multi-storey apartment house. The target was to reduce the total district heating energy by 75% compared to the Finnish building code level in 2009 [1]. The typical standard consumption was 130 kWh/m^2, i.e. the target was 33 kWh/m2. The measures that were finally chosen after a series of energy balance calculations are reported in [2].

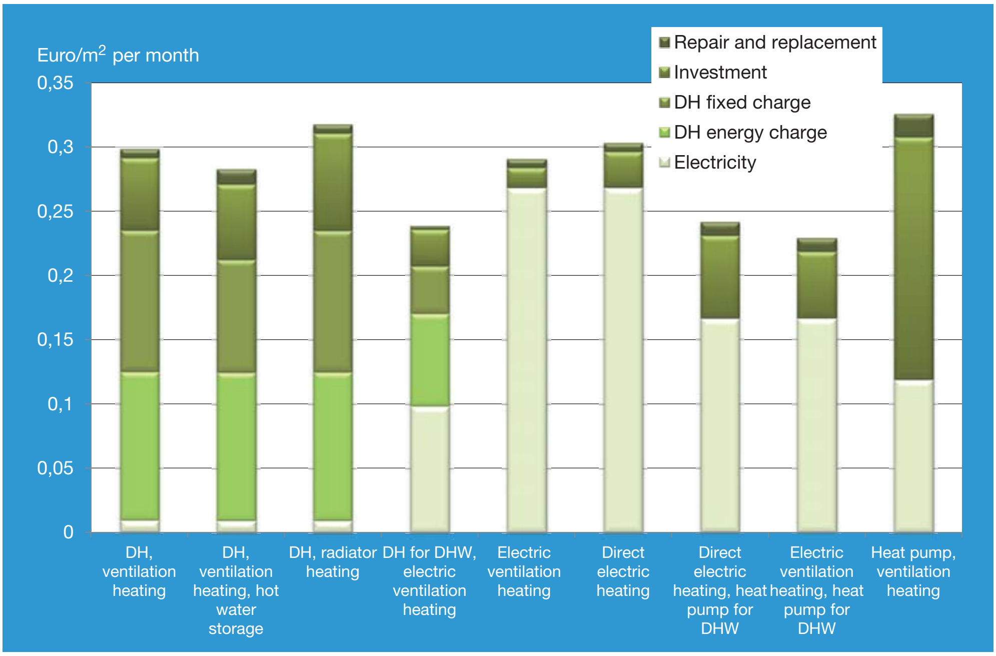

Figure 1. The monthly present value cost for different heating systems (DH = District Heating, DHW = Domestic Hot Water). Real interest rate 2%.

Life cycle analysis

Altogether nine different heating systems, including some non-district heating, were analysed from the life cycle cost point of view. Conducted analysis suggests that district heating with traditional room heaters and current billing tariff structure may not be cost effective due to high investment costs. Present values (of energy and investments) of all investigated solutions projected over 30 years are displayed in Figure 1. The ground heat pump system dimensioned for full load was the most expensive and the ventilation-integrated heating system using electricity with domestic hot water prepared by a ground heat pump was the least expensive.

Discussion

A number of prospective district heating solutions were investigated in the context of buildings needing 75% less energy as compared with standard solutions today. A holistic approach was used, covering the entire system from room space, through the distribution piping, district heating substation to the district heating network. Additionally, the cost-effectiveness of district heating was compared with other heat distribution technologies. The research also covered the performance of the district heating network in areas with very energy-efficient buildings.

The different heat distribution versions studied included traditional radiator system and two types of ventilation integrated heating systems: i) a separate control for each room, and ii) a single common control for the whole dwelling. Each of these solutions can be successfully combined with district heating. However, the most cost-effective solution combined district heating with ventilation-integrated distribution using a single controller for the whole dwelling. This solution also included a storage tank for the preparation of domestic hot water, connected by a heat exchanger to the district heating system. Such a solution has the advantage of low dimensioning load, and thus an inexpensive connection tariff. Conducted simulations indicate that this connection will very effectively decrease the return water temperature of the heating system.

Altogether nine different solutions, including some non-district heating, were analysed from the life cycle cost point of view. Conducted analysis suggests that district heating with traditional room heaters and current billing tariff structure may not be cost effective due to high investment costs. Present values (of energy and investments) of all solutions investigated and projected over a 30-year span remained within the range EUR 0.23–0.33/m2 per month. This apparently narrow cost range band indicates that in addition to costs, other features should also be considered when selecting an energy system. These could be include achievability of a high indoor comfort level, functionality, outlook of heating terminals.

Exploitation potential

Since most of the costs of district heating network are investment costs, the share of investment in the total costs will become high in areas of low energy consumption. Some of the running costs could be reduced by improved insulation and decreased diameter of the network piping, because pumping costs will remain reasonable. What seems to be most important is to design and dimension the network in accordance with demand and avoid over-dimensioning due to a desire to provide a "safety margin" for future growth. Based on the conducted analysis some further investigation is recommended regarding the composition of the billing tariff. At present, the constant part of the bill is high in comparison with the consumption-based part. District heating companies have good justification for that. In the future it might be reasonable to rearrange the tariff, e.g. by decreasing the weight of the constant part. Such a change would also increase the attractiveness of district heating on the market for customers in very energy-effective houses.

Acknowledgements

The work was carried out in the project supported by Finnish Energy Industries, Fortum Power and Heat, Danfoss, VVO Group plc. and VTT.

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Geo-energy utilisation in the energy service of the community

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The aim of the GeoEner project was to promote the utilisation of geoenergy in Finland and to provide Finnish industry and companies with research results and knowledgethat they can easily use in their business activities, and make Finland one the leading countries in the world in the geoenergy sector.

Introduction

Rocks, minerals and groundwater have a huge capacity to transfer and store heat. They have an approximately constant temperature which at shallow depth roughly corresponds to annual average air temperature. A large proportion of geothermal heat capacity is caused by the solar energy absorbed by the earth's surface and groundwater. The Earth's surface can be described as a huge solar energy collector. The energy is thus sustainable, provided we don't remove more than is replenished by solar and geothermal fluxes. At the immediate surface (down to few meters depth), some seasonal fluctuation will occur, with heat from the sun tending to warm the soil in the summer. The large heat capacity of the geological environment means that any seasonal variations are damped so that the soil is generally warmer than the air in winter. Conversely soil is generally cooler than the air in summer.

The GeoEner method, presented below, explains the comprehensive geo-energy utilisation model including building energy simulation, geothermal simulation, LCA, LCC and business model development.

Methods

The GeoEner method, presented below, explains the comprehensive geo-energy utilisation model including building energy simulation, geothermal simulation, LCA, LCC and business model development.

Results

The project had several case studies: the Bergans apartment house area, the Kuopio fire laboratory, the Painiitty single and detached house area and the Ruukki office case utilising energy piles. The Bergans case study [1] concerned an apartment house area, planned to be built in Espoo, which will utilise geothermal heating and cooling (floor heating and ceiling cooling). The heating and cooling energy demands of an exemplary apartment house were dynamically simulated by VTT House Building Simulation Tool with four alternative solutions:

1. passive house structures
2. passive house structures and a cold storage room
3. low-energy house structures
4. low-energy house structures and a cold storage room.

The warm service water heating energy demand was estimated based on measurements of an existing apartment house. The heating and cooling energy use profiles were calculated for each structure/storage alternative. Geoenergy utilisation concepts were designed with different ground heat pump dimensioning grades: 90%, 70%, 50%, 40% or

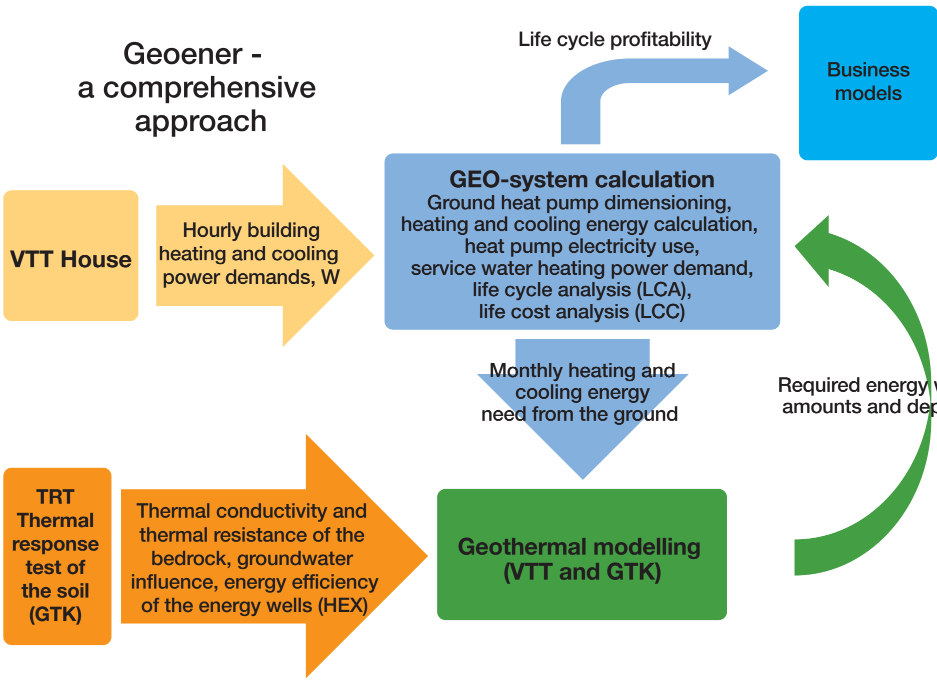

Figure 1. The GeoEner method.

30% of the maximum heating power demand. Geothermal solutions were compared to district heating solutions with compressor cooling by means of life cycle cost calculation (LCC) and life cycle analysis (LCA).

LCC compared two alternatives: 1) geothermal heating and cooling, auxiliary heating with electricity and 2) district heating, compressor cooling. The time span was 20 years and the interest rate was 6%. Two scenarios for energy cost increase were used: a moderate scenario with yearly cost rises of 2% for heating energy and 3% for electricity and a fast scenario with yearly cost rises of 4% for heating energy and 5% for electricity. The initial electricity cost was EUR 95/MWh and the initial district heating cost was EUR 55/MWh.

LCA calculation of the carbon footprint included building structures, heating and cooling systems and energy use. The time span was 50 years and the ground heat pump dimensioning grade was 50%.

Four different electricity emission scenarios were used for LCA:

1. ground heat pump and auxiliary heating using average Finnish produced electricity
2. ground heat pump using average Finnish produced electricity and auxiliary heating using electricity produced in a condensing power plant (separate electricity production by coal)
3. ground heat pump and auxiliary heating using electricity produced in a condensing power plant during winter (December, January and February), otherwise they use average Finnish produced electricity
4. ground heat pump and auxiliary heating electricity produced in a condensing power plant.

LCC calculation showed that geothermal heating was more affordable than district heating in all scenarios. The lowest life cycle costs were attained with a ground heat pump dimensioning grade of 50% from maximum heating power demand. According to LCA calculations geothermal heating had a smaller carbon footprint than district heating in three of the four scenarios.

Discussion and conclusions

The aim of the GeoEner project was to promote the utilisation of geoenergy in Finland and to provide Finnish industry and companies with research results and knowledge that they can easily use in their business activities, making Finland one of the leading countries in the world in the geoenergy sector. The project produced new concepts for energy supply, hybrid renewable energy solutions and business models. Furthermore, the project promoted the roles of GTK and VTT in technology transfer and used the expertise of TuKKK (Turku School of Economics) to develop innovative business models.

Exploitation potential

The GeoEner project created both basic and specialised knowledge about the utilisation, design and implementation of geothermal energy systems for the participating companies and research participants. Information was successfully gained due to the work of company-driven pilot projects.

Acknowledgements

The authors wish to thank colleagues from The Geological Survey of Finland (GTK) and Turku School of Economics (TSE). The work has been supported by the Finnish Funding Agency for Technology and Innovation (TEKES) and the following Finnish companies: Are Oy, Bergans Kiinteistöt Oy, ERAT Arkki-tehdit Oy, Fortum Power and Heat Oy, Rakennusosakeyhtiö Hartela, Kalliokaivo Oy/Poratek, Projectus Team Oy, Rautaruukki Oyj, Senaatti kiinteistöt, St 1 Oy, Suomen Lämpöpumpputekniikka Oy/ Lämpöässät ja Uponor Oyj.

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Impact of high penetration of heat pumps on elecricity use

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Energy-saving policies of the national government and the EU puts pressure on oil and direct electric heating which is shown as rising energy prices and tightening building regulations. There is also governmental pressure to increase the use of renewable energy sources in heating and to encourage heat providers, by the way of subsidies, to change from oil or direct electric heating to heat pumps or bio fuel heating.

Today there are slightly over 390,000 heat pumps in Finland according to the statistics of Finnish heat pump association SULPU. The growth has been nearly five-fold in five years and the vision is that the market will continue to increase. By 2020 the number of heat pumps will be about 1 million, of which nearly 60% will be air/air heat pumps and 25% ground source heat pumps.

The aim of the research was to analyse the passive and dynamic grid impact of the large-scale penetration of different heat pumps and changes in heating solutions, possibilities and disadvantages in the short and long term.

Introduction

The expected increase in heat pump installations will affect the use of electricity, both the level and the load curve form. This study was an attempt to assess the effects. The study included a glance at the European heat pump markets, an overview of Finnish energy use for space heating and domestic hot water heat, a short introduction to heat pump types and characteristics as well as heat pump scenarios for the residential sector, specifically for detached houses, semi-detached houses, apartment buildings and recreational residences. Load curves for air-air and ground source heat pumps were also presented.

Methods

The impact of large-scale penetration of heat pumps on the consumption of electricity and power demand were analysed separately for different building types: detached houses, semi-detached houses, apartment buildings, public buildings and recreational residences. The analysis included scenarios up to 2030 and were based on the current building stock, current heating choices and foreseen changes both in building (volume, heating demand) and heating systems.

The total number of apartment building stock of Finland will increase due to the foreseen increase in population. Statistics Finland has estimated that the population will be 5.6 million in 2020 and 6.1 million in 2050. This population projection means that the need for new apartments is about 15,000 on a yearly basis.

Heating demand of the building stock will decrease because of the tightening building regulations. At the moment the regulations are related to new buildings but will in the future most likely cover also the renovations of old buildings. It is not only the regulations but also the raising energy bills and incentives to energy retrofits that motivate investment in energy saving technology.

The scenario presented in the study assumed that the heating energy need of new buildings will gradually decrease so that after 2020 the energy demand of a new building is at the passive house level at the most. Moreover, it was expected that there will not be remarkable decrease in the heating energy demand of the existing building stock but the investments will focus on the heating system renovations which will decrease heating energy use (but not demand).

In BAU scenarios, the division of heating systems of the total building stocks will stay more or less at the present state in the period under review (20 years). Minor changes were expected because the heating choices of new buildings differ from that of the total stock.

In heat pump scenarios it was assumed that heat pump penetration will increase substantially. Mainly ground source heat pumps will gradually replace oil and electric heating. The biggest change is expected in the oil heating sector. The use of air/air heat pumps as auxiliary heating will increase especially in electric heating sector and as the main heat source in basic heating of recreational residences.

Energy demand and heating power demand analysis consisted of the following steps:

1. Number of buildings by energy source (oil, electricity, ground source heat pump, wood and district heat) was adjusted to match the data of Statistics Finland
2. Heating energy and heating power demand was adjusted to match the energy statistics
3. Penetration of heat pumps was adjusted to match the vision of SULPU of the growth of the heat pump markets
4. Expert predictions were made of the renovation choices for each heater type (oil, electricity, ground source heat pump, wood and district heat)
5. Construction of new buildings was adjusted to match common knowledge
6. Reduction of buildings was adjusted to match common knowledge
7. Number of renovations per year was based on expert estimation.

Results

There are two kinds of impact of large-scale penetration of heat pumps on electricity use. First, the heating electricity consumption of residential houses is estimated to decrease compared to the BAU scenario. Second, the heating electricity power demand will rise compared to the BAU scenario.

The total heating electricity consumption of residential buildings is 9.8 TWh today and is estimated to rise to 10.4 TWh by 2030 in the BAU scenario and in the heat pump scenario the heating electricity will be 9.6 TWh.

The total power demand of residential building heating at present is 7.9 GW and it is expected to rise to 8.8 GW by 2030 in the BAU scenario and in the heat pump scenario the power demand will be 9.3 GW.

The study presents also hourly load curves for the most common types of heat pumps, namely air/air and ground source heat pumps. The load curves are calculated for typical detached houses built in the 1970s and 2000s and for a modern passive house.

Discussion and conclusions

The study covered the impact of large-scale penetration of heat pumps on the electricity use of residential buildings. The impact was evaluated for the coming 20 years. The analysed house types included detached houses, semi-detached houses, apartment buildings and recreational residences.

The heating electricity consumption of residential houses in the heat pump scenario was estimated to decrease compared to the BAU scenario and even compared to present electricity consumption. This can be explained by the fact that despite oil heaters will change over to mainly heat pumps; direct electric heaters are searching for ways to save energy and in this the various heat pump solutions are quite attractive. Moreover various heat pump solutions will be top-rated in the new building sector.

The power demand was expected to rise both in the BAU and the heat pump scenarios. This is explained by the popularity of air source heat pumps that decrease the energy consumption but do not affect the peak power demand of heating.

Using the load curves developed in the study together with estimates of changes in annual heating electricity usages, the net effect of all the assumed changes on the total Finnish peak load seems to be well below the 1.5 GW estimated in previous studies. The preliminary simulations show the net effect to be negligible, as the reductions in direct electric heating counterbalance the introduction of new heat pumps. However, as the used load curves were restricted in number, which meant a lot of simplifications, especially when looking at the peak load. For example, using load curves for detached houses when estimating the heating load of summer cottages is not representative, as the heating operation is quite different and the use of domestic hot water even more so. All in all, the net effect of switching to heat pumps on the system peak load is, at most, only a few three percents by 2030.

Exploitation potential

The results are useful for grid companies that face also other fundamental changes in the infrastructure (distributed generation, electric vehicles, etc.) as well as for authorities that need the information of the expected scenarios of the use of renewable energy. The results are also fundamental for the development of future smart grids.

Acknowledgements

The study is part of the Smart Grid and Energy Market (SGEM) research programme, which in turn is part of the Finnish Energy and Environments Competence Cluster (Cleen).

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Smart grids and energy markets

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The large majority of smart grids stakeholders including the government are now fully aware the a) their overall target of RES-E by 2020 means the grid must be re-engineered and b) intelligent grid-based systems potentially offer a cost-optimal way to re-engineer the grid. It is clear that without smart grids or alternatives to possibly more expensive technologies used to reinforce the grid, it would become less stable and blackouts may occur much more frequently. The nuclear catastrophe in Japan in March 2011 makes clear that smart grids are the key enabler for a low- risk, highly sustainable energy system providing energy with high security of supply suitable for our society at a reasonable cost. Investments in the grid are long-lived. There are long lags between the formulation of an idea for a research topic and the time at which the result of that research can be applied in smart grid infrastructure.

Introduction

Smart grids are customer-driven marketplaces for distributed generation and consumers. Smart grids provide cost-efficient grid and market connection, enable efficient operation of centralised and distributed generation, offer services to promote consumer level energy efficiency and guarantee an uninterrupted and high-quality supply of energy. Traditional distribution grids have a one-directional power flow and weak market integration. Smart grids include centralised and distributed power generation produced substantially by renewable energy sources. They integrate distributed resources (i.e. generation, loads, storages and electricity vehicles) into energy markets and power systems. Smart grids can be characterised by controllable multi-directional power flow. Smart metering has been seen as an essential part of the vision of smart grids. Remote readable energy meter is being developed to be intelligent equipment (i.e. interactive customer gateway) including different kind of new advanced functions based on local intelligence and power electronic applications. This gateway as part of smart grids opens possibilities for network companies, energy traders and service providers to offer new kinds of added-value services to end customers.

Methods

The research programme for smart grids and energy market led by CLEEN Oy has a five-year overall research plan for 2009–2014. The research programme is divided into seven different research themes:

1. Drivers and scenarios
2) Future infrastructure of power systems 1; low and medium voltage networks
3) Future infrastructure of power systems 2; high voltage smart grids
4) Active resources 1; active customer, customer interface and ICT
5) Active resources 2; electric vehicles, energy storages and distributed generation
6) Management and operation of smart grids
7) Development of energy market and business potential.

All industrial partners in the consortium will provide an essential contribution to the R&D in the programme, and the majority of the work will be carried out by the industrial partners. The demonstrations will be performed as a collaboration of different types of industrial partners and research institutes. All relevant research groups in Finland contribute to the research work in the programme.

Results

The main general results of the research programme can be listed as follows:

- create an innovation foundation for new solutions, products and services to enable the implementation of the smart grids vision
- demonstrations of solutions in real environment, not limited to Finnish grids, are an essential part of the research
- the relevance of the research is measured on global basis, i.e. the targeted solutions shall be applicable on the international market
- cultivate the competence accumulation in the research and business environments to secure long-term competitiveness
- international research cooperation is a prerequisite to achieve the objectives.

The following international activities can be measured when assessing the prestige of the research programme:

- number of international publications
- participation of international conferences and other events
- amount of international funding
- research exchange.

Exploitation potential

The research programme collects major industrial companies operating in Finland, essential network companies and all major research institutions of the considered research domain to jointly work for the common vision. All industrial partners in the consortium will provide an essential contribution to R&D in the programme, and the majority of the work will be carried out by the industrial partners. The demonstrations will be performed as a collaboration of different types of industrial partners and research institutes. All relevant research groups in Finland contribute to the research work in the programme.

Traditionally there have been many Finnish companies with a strong position in the global market providing equipment and systems especially at distribution network level. In addition, Finnish distribution companies and distribution networks have many innovative methods and advanced features which create useful preconditions for the research programme of smart grids. Distributed generation is an issue not yet widely utilised in Finnish distribution systems, but there are still active Finnish industrial actors in that field globally.

The SGEM programme generates new scientific knowledge, information and technology for physical products, information systems and services to be applied in the global markets for smart grids. Smart grids provide cost-efficient grid and market connection, enable efficient operation of centralised and distributed generation, offer services to promote consumer level energy efficiency and guarantee an uninterrupted and high-quality supply of energy. The SGEM programme also provides solutions for the energy grid renovation process which are validated by demonstrations. With the dynamically developing domestic power distribution practices, the Finnish companies are well positioned to capture significant pieces of the new global business opportunities driven by smart grids.

One essential aim of the whole research programme is to establish an international cooperation network. The programme will closely follow similar initiatives within the EU and USA. Many consortium members have complementary activities in EU projects within the same domain. The consortium will form a network to collaborate with these projects as well as with relevant standardisation bodies and IEA implementing agreement committees.

The programme will continuously benchmark with similar initiatives to ensure that the focus is on the leading edge technologies.

Acknowledgements

The authors wish to thank their colleagues in the SGEM consortium. The work has been supported by the TEKES – the Finnish Funding Agency for Technology and Innovation and Cleen Ltd.

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Eco and energy efficiency in buildings

Barriers and drivers for sustainable building

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What are the actual barriers and drivers for sustainable building? A literature review, interviews and case studies were presented in this paper [1] to address this question. Sustainable building is not hindered by a lack of technologies and assessment methods, but is instead beset with organisational and procedural difficulties entailed by the adoption of new methods. New technologies are resisted because they require process changes entailing risks and unforeseen costs. These hindrances can be reduced by learning what kind of decision-making phases, new tasks, actors, roles and ways of networking are needed. The barriers are outlined as steering mechanisms, economics, a lack of client understanding, process and underpinning knowledge. The most important actions to promote sustainable building are the development of the awareness of clients about the benefits of sustainable building, the development and adoption of methods for sustainable building requirement management, the mobilisation of sustainable building tools, the development of designers' competence and team working and the development of new concepts and services. The interviews and case studies were carried out in Finland, but the results may be applicable or interesting to other countries as well.

Introduction

The barriers and drivers for sustainable building (SB) [2] were studied using a literature review, interviews, expert workshops and case studies. On the basis of these results, this paper discusses what actions are needed in order to best promote SB. Resistance to new technologies occurs because they require process changes, entailing the perception of possible risks and unforeseen costs. These hindrances can be reduced and overcome with help of new efficient processes and by learning what kind of decision-making phases, new tasks, actors, roles and ways of networking are needed. In addition, the existing knowledge about the benefits of SB has to be disseminated to clients.

The SB process is defined as the overall quality of the process that enables the delivery of SBs. SB technologies include concepts and products with the help of which significant improvements can be achieved in terms of the use of resources, harmful emissions, life-cycle costs and productivity, and building performance. The premise of this work was that technologies and methodologies are available for SB, but full benefits are not achieved because these concepts and methods are not effectively utilised. The original research plan of this study described that there are process-related barriers for SB and these barriers include, for example, rules of competition, functioning of value chains, possibilities to apply integrated design processes, lack of knowledge and lack of demand.

On the other hand, the premise of this work was also that there are issues that promote the adoption of SB concepts. These include, for example, beneficial operation costs of SBs, the improved well-being of building occupants and benefits to the national economy because of reduced emissions.

Methods

Research for this paper was conducted using a variety of methods. Research began by a critical review of the literature, which analysed the barriers and drivers mainly on the basis of academic literature. Viewpoints of Finnish building professionals on the most significant barriers were studied using a web-based survey (158 responses). In addition, certain individuals (20) were interviewed to define the needs for changes. Expert panels and workshops were organised to describe the characteristics, tasks and roles in SB processes. Detailed case studies were analysed to reveal possibilities to improve the SB processes and the impacts and benefits of SB.

Results

The respondents of the web survey represented architects and other designers (40%), contractors and builders (17%), owners (16%), manufacturers and suppliers of products and services (14%), state or municipal authorities (7%) and others (6%). The respondents addressed the lack of awareness of clients, competence of designers and other actors, availability of tools, lack of economic incentives, lack of sustainable renovation concepts and relevant new services for maintenance and energy supply.

In light of the interviews and the web survey responses, the most important measures towards SB would include the development and delivery of SB information for professional clients as well as for home buyers, development and use of tools for assessment, monitoring and comparison of SB solutions, support for designers in order to enable competence improvement, development and use of economic incentives in order to increase the attractiveness of SB investments and the development of sustainable renovation concepts, maintenance services and energy services.

On the basis of the results, unjustified fear of costs is not considered an important barrier. Most interviewees said that clients have a realistic understanding of the actual cost of SB. This is interesting since in the past the higher cost has been seen as one of the main barriers and this claim is still frequently repeated in trade magazines.

Closely related to the SB information-related barriers is the lack of comparable, quantitative and reliable data on which market value estimates could be based. Information should be gathered about risks, uncertainties and benefits as well as about realised profits and losses. Several interviewees considered labelling systems as the best way of influencing this barrier.

Interestingly, all the interviewees emphasised the role of public owners: to act as forerunners, to lead by example and to integrate others into SB processes. To a certain extent this is already the case. The respondents identified the client and his/her commitment to a sustainable building process as the crucial actor for the successful implementation of SB.

Discussion and conclusions

On the basis of the interviews and case studies performed during the SUSPROC project the following issues are important in Finland to promote SB. First, the need to increase the expectations, demands and awareness of end users (both occupants and owners) about the potential of SB. After increasing the awareness the following improvements should take place in the fields of the adoption of methods for SB requirement management, the effective mobilisation of (integrated) SB tools, the development of designers' team working and competence and clarifying/re-defining the role of chief designer. Important is also the development of new concepts and services as well as development and implementation of different kinds of measures needed to enable these issues.

Exploitation potential

The results of this research can be exploited by the industry when developing new business possibilities around sustainable building. Research indicates the weaknesses in the current building processes but also reveals that client behaviour could be strongly influenced by improving the delivered information. For the academic community this paper provides and extensive literature review on sustainable building barriers as well as thorough analysis of 20 interviews and 158 web survey responses as well as case studies.

Acknowledgements

This paper presents part of the overall results of the Finnish national research project Sustainable Building Processes (SUSPROC) [3]. The overall results are published on the project website [3] and in other articles. The study was completed within the European project Sustainability and Performance Assessment and Benchmarking of Buildings (SuPerBuildings) [4]. The work has been supported by members of the Finnish construction industry, the Finnish Funding Agency for Technology and Innovation (Tekes) and FP7.

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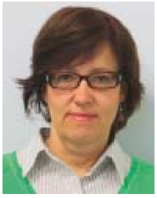
Environmental impact of passive house nursery



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It is often believed that reduction in energy use automatically leads to the total reduction of the carbon footprint and other emissions. To achieve better energy efficiency more raw materials may be needed not only for insulation and better windows but also for heating systems like ground source heat and solar panels. The use of advanced building systems increase the use of electricity and in winter where electricity production is already inadequate the additional stand-by power plants must be taken in use. These are not as effective as CHP plants for heat production. Moreover also the passive house structures can be produced in dozens ways and from many different materials which all have different service life, different need for maintenance and also different effect on the overall carbon footprint. Finally as the nursery is the overall concept, besides the building structures outdoor playgrounds and specific operations requiring day care trips, personnel commuting and waste treatment must be taken into account.

Introduction

A life cycle assessment was conducted on a nursery design intended for Espoo, Finland. The aim of this nursery study was to achieve understanding of the significance of the environmental impact of different sources on an entire building project, the construction and operation phase. One goal for designers was to design the nursery according to passive house Nordic where space heating should be 20–30 kWh/m^2 annually [1].

The research describes the assessed environmental impact of alternative design options, and of different parts of the construction work considering all used building and site materials, HVAC systems and from the use an operation of nursery including the energy consumption, commute and day care trips and daily waste management.

Methods

Life cycle assessment (LCA) evaluation method [2] was used for describing the aspects which need to be considered when the target is the building sustainability and low environmental impacts. Based on the building plans, life cycle inventory for the whole building project was made as completely as it was possible taking into account the dynamic building design. Energy simulation is made for checking the fulfilment of passive house criteria for nursery.

Results

A LCA was conducted for the soil and infrastructures, building production, the use phase (use of heating and electricity, commuting and day care trips, waste management), the production of building services, the heat production system (ground source heat pump or district heating) and building maintenance. For the result greenhouse gases, use of natural raw materials and energy efficiency from the building site, design options and operation were assessed [3].

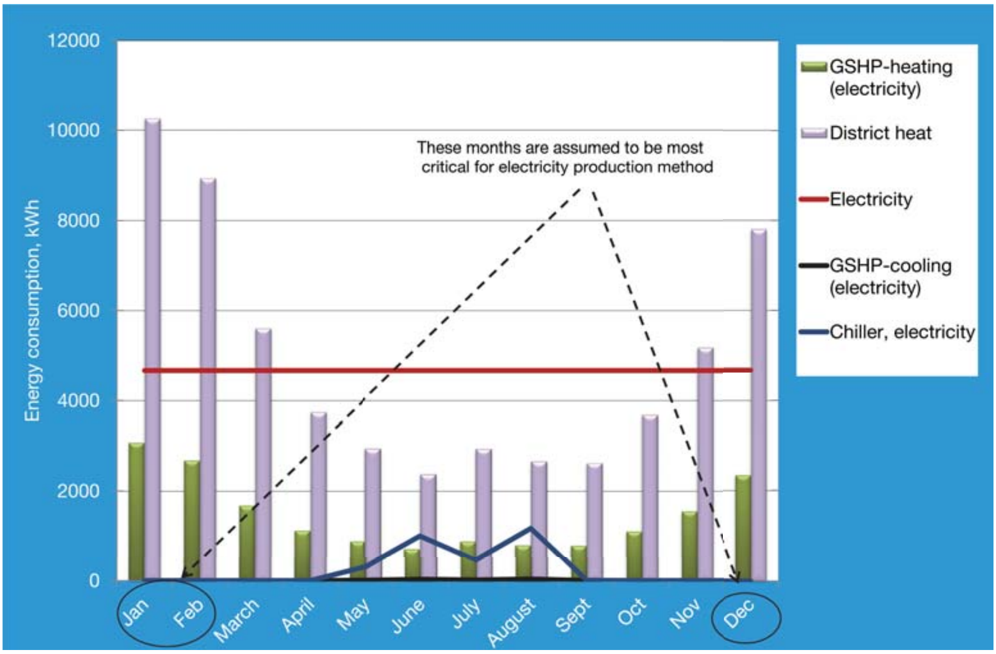

Figure 1. Monthly energy consumption.

	Heating energy kWh/m²/a	Electricity kWh/m²/a	Cooling (electricity) kWh/m²/a	CO_2 eq, kg/year/m² Case 1 / Case 2
GSHP	12	38	0,058	11 / 23
District heat	40	38	2	17 / 24

Table 1. Annual energy consumption and carbon footprint. Carbon footprint for district heat calculated according to the district heat produced in Espoo. Carbon footprint for electricity in case 1 is calculated according to average Finnish electricity mix while case 2 takes into account Finland electricity deficiency in winter time and in three winter months it is assumed to produced according to the coal condensed power plant while all other months according to average mix.

In energy simulation it is assumed that in the case of district heat space cooling performed with chiller in the case of GSHP it is not needed. The energy consumption is shown in the Figure 1 and Table 1.

According to the assessment the finding was that carbon footprint of soil and infrastructure construction was practically of the same magnitudes as that of building structures while the building appliances and HVAC systems, on the other hand, was relatively low (Figure 2). The carbon footprint over the nursery project and operation time 50 year is shown in Figure 3.

Discussion and conclusions

Ecological goals should be set for the building use phase and for the used materials and building solutions which all have influence to the material and energy flows and

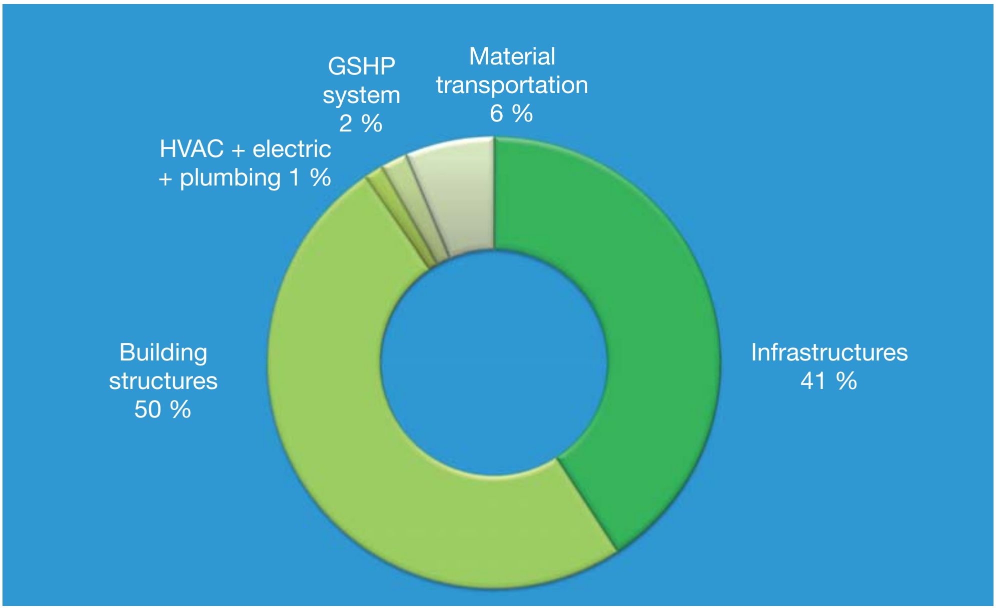

Figure 2. The carbon footprint of the total built area was ~1,370 tons.

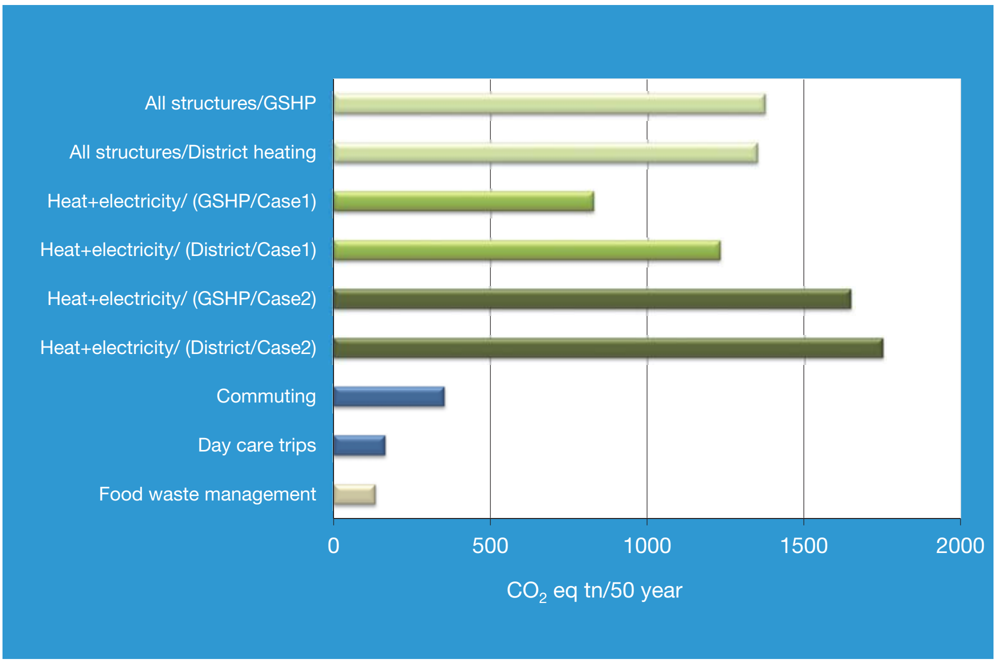

Figure 3. Carbon footprint for passive house nursery.

bring about environmental impact. LCA is the method for environmental assessment. LCA in building design phase are often focusing only energy and building envelope assessment and extensive work and material amount in site and infrastructures is often forgotten but carbon footprint from those could be almost of the same magnitude as that of building structures.

In buildings which designed according to passive house standard a significant reduction is achieved in heating energy and corresponding environmental impact. When the consumption of heating is such a low relatively more environmental impacts accumulate to the used materials. The assessment shows that the chosen materials (all structures) may have a significant meaning in the case of passive structures and nursery causing almost half of the total carbon footprint when the reference period is 50 years.

Impact from operational energy (GSHP and district heat) depends from the energy demand, and also from energy production methods in futrure. Two scenarios presented here showed that despite of GSHP efficiency carbon footprint result depends from electricity production especially in winter time.

Exploitation potential

The case study ended up in conclusion that systematic approach and sustainability indicators help project-specific management of sustainable building and supports continuous improvement. The result could be used for benchmarking and also for designers use.

Acknowledgements

This sustainability assessment of kindergarten was one part of the SUSPROC research project. The research has been funded by Tekes (Finnish Funding Agency for Technology and Innovation), VTT, cities of Joensuu and Espoo, HSE, SATO, Hartela Group , Finnmap Consulting Ltd., KVA Architects Oy, Architect bureau Ulpu Tiuri Ltd., Parviainen Architects Ltd., SIMLAB, ARE Ltd. and Senate Properties.

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Net zero energy buildings

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Two net zero apartment buildings with basically similar architecture have been built in Finland, in Kuopio (latitude 62.9o) and in Järvenpää (latitude 60.5o). The aim was to test the possibilities to build zero energy buildings at high latitudes. The Kuopio case is a student hostel and the Järvenpää case a home for elderly people. The total energy demand in the buildings are 102 MWh for Kuopio and 94.3 for Järvenpää corresponding to 48 and 45 and kWh/gross-m2. The buildings utilise district heat and are connected to the local grid. The renewable energy production bases in the Kuopio case on solar heat and photovoltaics. The Kuopio building have been finished in 2010 and the Järvenpää building in 2011.

Introduction

A net zero energy building refers to a building where the amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building in a year. A net zero energy building bases on a very low-energy building concept to minimise the energy demand. The low energy demand defines the design of the building integrated renewable energy production systems.

The pilot buildings (Figure 1) have been built in Kuopio (latitude 62.9o) and in Järvenpää (latitude 60.5o). The buildings utilise district heat and are connected to the local grid. The renewable energy production bases in the Kuopio case on solar heat and photovoltaics. In Järvenpää building integrated wind power is also an option. The Kuopio

Figure 1. Kuopio Zero energy apartment house. The solar systems of the Järvenpää zero energy apartment house.

Options	Järvenpää		Kuopio	
	Demand, MWh	System size	Demand, MWh	System size
All heating compensated by solar heat	56,6	123 m^2	57,2	142 m^2
All electricity compensated by PV	37,9	255 m^2	44,8	320 m^2
Electricity for systems compensated by PV	9,8	65 m^2	11,7	85 m^2
Household electricity compensated by PV	28,1	190 m^2	33,1	240 m^2
50% of all electricity compensated by wind power	19,0	6,5 kW	-	-
50% of all electricity compensated by PV	19,0	128 m^2	-	-

Table 1. Net zero energy options.

building have been finished in 2010 and the Järvenpää building in 2011. Options to fulfil the net zero energy target in Table 1. It is of importance to note that although Finland is a space heating-dominated country, the space heating is not the dominant energy consumption in a zero energy design Table 2.

Table 2. Net zero energy building, Kuopio.

Energy demand	
Space heating	12 kWh/m^2
Water heating	13 kWh/m^2
Electricity, facility	6 kWh/m^2
Total	31 kWh/m^2
Renewable energy	
PV	7 kWh/m^2
Solar thermal	16 kWh/m^2
Ground heat	12 kWh/m^2
Total	35 kWh/m^2
Excluded	
Reidents electricity	16 kWh/m^2

Results

The environmental impact of a net zero energy building as a carbon footprint was assessed using a life cycle assessment approach. The calculation covers raw material extraction, production and material transportations.

The net zero apartment buildings prove that a zero energy building is possible at high latitudes. The preliminary cost analysis of the Järvenpää case also proves that the extra costs of the net zero energy approach are in the range of 10–15%. As the extra costs of the basic solution for a zero energy building, a very low-energy building, are in the range 2–5% compared to typical apartment houses, the further development of concepts and increasing knowhow will set the extra costs to about 10% and below. New solutions for building integrated renewable energy production will also make the net zero energy construction more attractive in the future. The Energy Performance of Buildings Directive's defined nearly zero energy building is already possible for a wide adoption in new construction.

Discussion and conclusions

Net zero energy building is a rather challenging target in the Finnish climate. Especially in the case of Kuopio net zero energy building, the space demand of solar thermal and PV systems is too high compared to space available, and thus these two measures are not enough to fulfil the demand. The building's location in the city centre is not optimal for the target, but taking into account requirements for the whole urban structure, the location of a new building in a densely built area is better than outside the dense centre. The level of technology is not sufficient to serve for the zero energy target.

Nearly zero energy house IEA5

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Energy Performance of Buildings Directive requires that all the new buildings need to fulfil the principle of a nearly zero energy building as of the beginning of 2021. A nearly zero energy building has a very low energy demand achieved with technologies that are cost-effective in a life-cycle perspective. This project has shown that such a building is possible even in the cold Nordic climate.

Introduction

The Finnish demonstration house IEA5 for International Energy Agency's Solar Heating and Cooling program Task 13 "Advanced Solar Low Energy Buildings" was built in 1994 for the annual housing fair held in Pietarsaari (latitude 62°). The aim of the IEA5 solar house (Figure 1) was to reduce the consumption of purchased energy to as low a level as possible by utilising available best practice technology of 1993. Good indoor climate and comfortable living conditions were set as requirements for the design.

The building performance has been good throughout the years. The results from a three-year monitoring project and yearly follow-up until today has proved that the total consumption of purchased energy is about 30% and the heating energy consumption less than 20% of the consumption of a new single-family house of 2010.

Although the technical systems of the house are performing well, ventilation system with heat recovery and ground source heat pump were replaced two years ago with new more efficient equipments, thus reducing the energy consumption considerably.

Figure 1. The Solar House IEA5, Pietarsaari Finland.

IEA5 solar house

The heated floor area of the IEA5 Solar House is 166 m^2. The building has an extremely well insulated timber framed envelope. The U-values of the structures are well competitive even with the present building code requirements (Table 1). The air tightness of the envelope was measured to be 0.8 1/h (at 50 Pa pressure difference). A small sun space was built on the southwest corner of the house. The sun space serves for user comfort with only minor contribution to the building's heating demand. A short-term measurement was used to estimate the building's heat loss coefficient. The measured heat loss coefficient is approx. 85 W/K, which is 15% lower than the calculated value. A value of approx. 6.5 kWh/K was obtained for the effective heat capacity.

	Pietarsaari 1993	Typical 2011
Component	**U-value [w/m²K]**	
Wall	0,12	0,17
Roof	0,09	0,09
Floor	0,1	0,16
Door	0,4	1,0
Window	0,7	1,0

Table 1. IEA5 Solar House.

Figure 2. Solar energy systems of the IEA5.

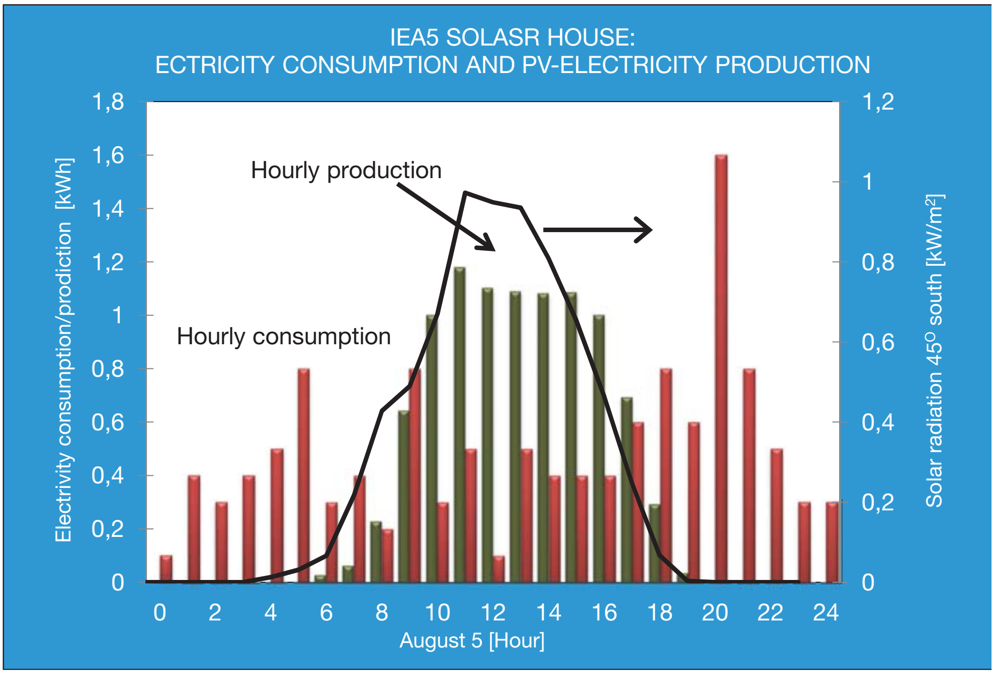

Figure 3. Electricity consumption and production on 5 August 1996.

All necessary technical systems are in the centre of the two-storied house. This makes it possible to utilise the heat loss of the installations in the heating of the house. All the ducting and pipelines are installed into an installation shaft next to the heat storage and suspended ceiling in the first floor.

The 10 m² solar collector system on the south-facing side of the roof consists of four modules connected in parallel. The original heat pump of the house had a capacity of 7 kW, while the new pump's capacity is 5 kW. The change improved the efficiency (COP) from an yearly average of 2.4 up to 4.0. A new ventilation system with heat recovery efficiency of 80% was introduced as well. These changes reduced the electricity consumption to below 40 kWh/m² from the original 48 kWh/m². In order to satisfy the need for heat in winter a ground heat pump with a capacity of about 7 kW is included in the system. A 3 m3 water-filled heat storage unit is the heart of the building's heating system. The heat distribution system is floor heating. The floor heating system can be used with low air to floor temperature difference for cooling as well; however, there has not been demand for cooling so far.

The building's photovoltaic system (Figure 2) on the south-facing side of the roof consists of 45 amorphous silicon solar panels with a capacity of 2 kW, Figures 2 and 3. The produced electricity is fed to local grid. The PV system is as well considered to be replaced with a system of the same area but a capacity of 8 kW. The yearly electricity production of the new system exceeds the electricity consumption in the house, and thus the house will be a net zero energy building in the coming years, see Figure 3.

Conclusions

The Energy Performance of Buildings Directive requires that all the new buildings fulfil the principle of a nearly zero energy building as off the beginning of 2021. A nearly zero energy building has a very low energy demand achieved with technologies that are cost effective in life-cycle perspective. The IEA5 project has shown that such a building is possible even in the cold Nordic climate.

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Embedded systems for energy-efficient buildings

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eDIANA [1] addresses the need of achieving energy efficiency in buildings through innovative solutions based on embedded systems.

Introduction

According to the European Union Directive on the Energy Performance of Buildings [2], buildings are responsible of more than 40% of the energy consumption in Europe.

Moreover, buildings are the largest source of CO_2 emissions (about one-third) in the EU27. The tendency shows that the total energy consumption has been rising since 1990 and will continue if strong actions are not taken. The challenge is to reduce the energy consumption (compared to 2005) and GHG emissions (compared to 1990) by 20% by 2020. In this reduction, buildings shall contribute accordingly.

ICTs and, therefore, embedded systems, as an enabling technology for energy efficiency shall, as stated by the European Commission in its communication addressing the challenge of energy efficiency through ICT, strongly contribute to the challenge. While such systems exist today, their effectiveness is often limited by a lack of interoperability, leading to fragmentation and limited overall impact. The project that is presented in this text is a strongly application-oriented initiative which is focused on the conceptualisation, design, development, demonstration and validation of new devices operating in a uniform platform called eDIANA.

The eDIANA platform is a reference model-based architecture, implemented through an open middleware including specifications, design methods, tools, standards and procedures for platform validation and verification. eDIANA platform will enable the interoperability of heterogeneous devices at the cell and macro-cell levels, corresponding respectively to a living/working unit (one house, one office, etc.) and to a residential or non-residential building (usually composed of several cells) and it will provide the hook to connect the building as a node in the producer/consumer electrical grid.

Thus, eDIANA will provide a reference architecture for a network of composable, interoperable and layered embedded systems that will be instantiated to several physical architectures. The eDIANA platform realisations will then cope with a variable set of location and building-specific constraints, relating to parameters such as climate, cell/macro-cell configuration (one to many, one to one, etc), energy regulations, etc.

eDIANA architecture

The eDIANA reference architecture covers all the present and future elements involved in the energy management of the houses, taking into consideration the different grades or levels of comfort that those elements provide to the user. The eDIANA reference architecture is a hierarchical and open architecture; it does not demand a unique implementation of its elements so it enables the addition of new components, change and update them whilst they are compliant with the architecture.

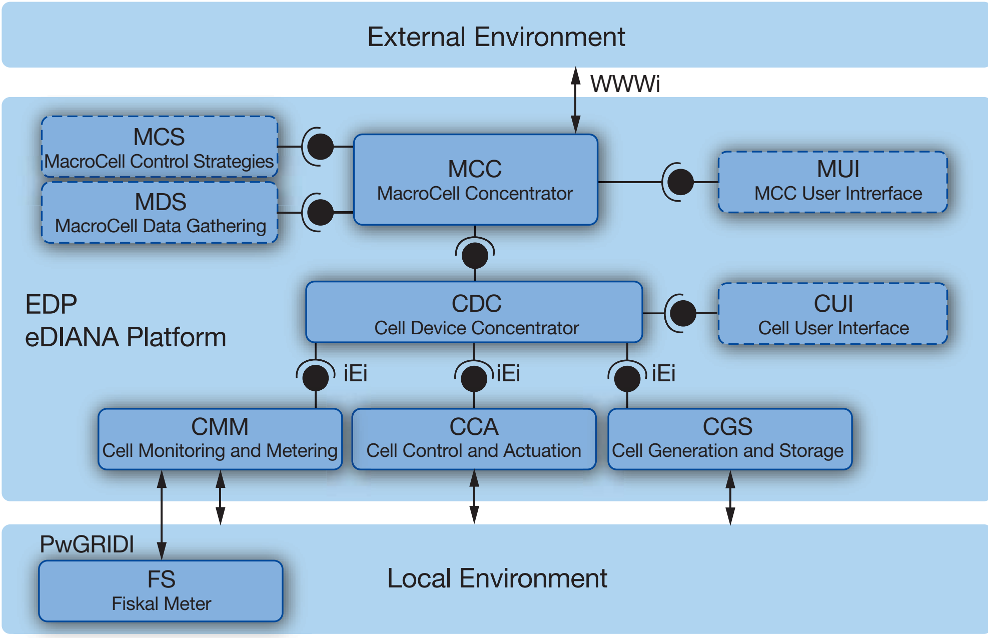

Figure 1. eDIANA Platform and external and local environment.

This is why the eDIANA reference architecture is based on components located in different levels. All the components interact with the rest of the platform components through interfaces. These interfaces allow the communication between components at the same level or different level.

The eDIANA components are logical; their implementation can be translated to a device for each component; however this is not compulsory, several components can be implemented in the same device. The component classification and characterisation plus their interfaces enable to model the architecture so that an implementation of the eDIANA architecture will admit any device that hosts an eDIANA component with its correspondent interface.

Figure 1 shows how the eDIANA platform (EDP) interacts with external environments. The local environment interacts with the lower level of the platform; this environment refers to the elements of the building that eDIANA platform controls to achieve the objectives of energy efficiency and user comfort.

On the other hand, the external environment interacts with the upper level of the platform, this environment refers to the building outside, the power grid, and the platform remote access. As previous sections have described, the eDIANA reference architecture has a hierarchical organisation, there are two levels that make up the eDIANA platform (EDP), the macro-cell level and cell level.

The eDIANA reference architecture defines several components for each layer, attending the functionality each layer should provide. Considering a bottom-up approach and description, cell level integrates all components that interact with the building elements and devices: appliances, lighting, HVAC, etc. The eDIANA reference architecture defines the next component types inside eDIANA cell level (see Figure 1):

- Cell Device Concentrator (CDC)
- Cell User Interface (CUI)
- Cell Monitoring and Metering (CMM)
- Cell Control and Actuation (CCA)
- Cell Generation and Storage (CGS).

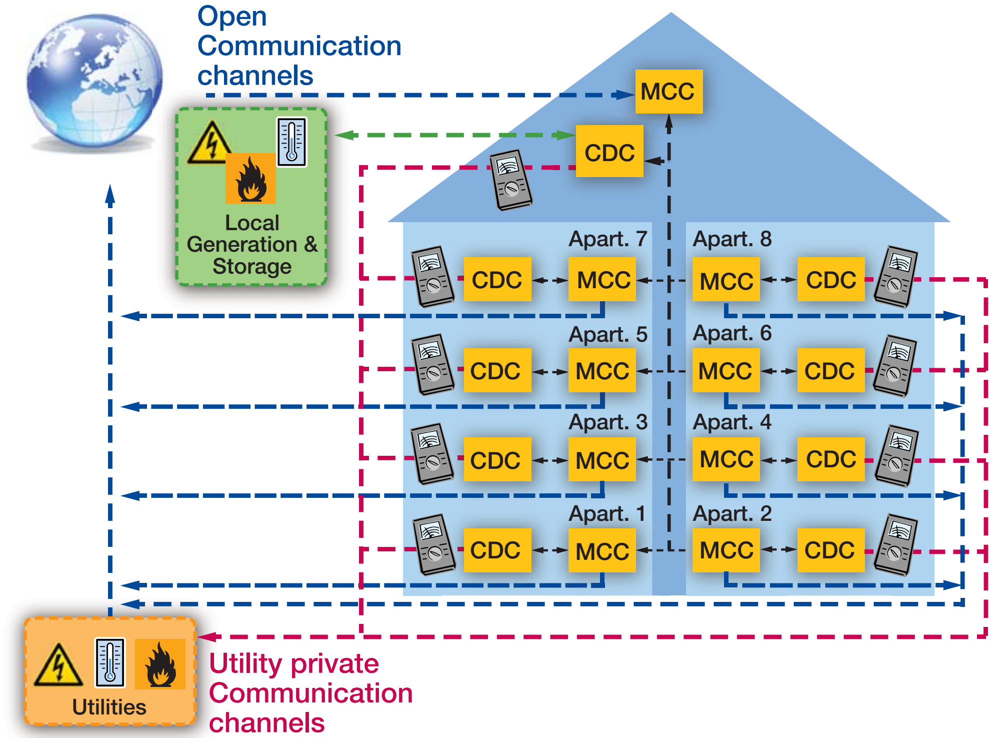

Figure 2. Apartment building with communal energy generation and storage capabilities.

An implementation of the eDIANA reference architecture can separate these components into different devices or integrate some of them into one. More specifically, the last three component types undertake the task of obtaining all the information about the energy consumption of all elements of the building, communicating with the cell device concentrator through the iEi (intelligent embedded interface) and executing the orders that above components and layers define.

The communication between these components is hierarchical too; CMM, CCA and CGS can only communicate with the CDC. The architecture defines a unique interface, the iEi, to accomplish this task. In the definition of this interface, the architecture will describe the functionality required by all the components that use it, although a component may not implement all the services that the complete interface provides, only the ones that concern with the component.

The cell user interface is another component at the cell level. It communicates only with the CDC in order to provide cell level information to the user of the platform.

Keeping on the bottom-up approach, the CDC is in charge of the communications between the cell level and macro-cell level. This communication is made between the CDC and the MCC, through the interface c2MCCi (cell to macro-cell concentrator interface).

The components that the eDIANA reference architecture defines at macro-cell level are:

- MacroCell Concentrator (MCC)
- MacroCell Control Strategies (MCS)
- MacroCell Data Gathering (MDG)
- MCC User Interface (MUI).

Figure 3. Demonstration sites in Espoo and Vantaa.

The components placed in this MacroCell level interact with the external environment in order to obtain information to elaborate the necessary strategies. These strategies will take into account the external environment (data from the Power Grid-PwGRIDi and external resources-WWWi) and the information of the cells that are in charge of that macro-cell when producing the recommendations to the cell device concentrator.

eDIANA scenario example

As it was explained before, the platform is flexible enough to be used in several kinds of buildings. A good example of this could be an apartment building, which the concrete cell/macro-cell configuration is explained in Figure 2.

In an apartment building with communal local energy generation and storage capabilities the next cell/macro-cell configuration is applied (see Figure 2):

- One macrocell that corresponds to the building (with its macro-cell Level concentrator, data gathering component, implemented control strategies and user interface devices). The building macro-cell contains:
  - * A cell with the communal capabilities of the building that contains:
    - A Cell level Concentrator (CDC)
    - Solar panels (Generation & Storage)
    - UI channels (User Interface).
- A macro-cell for each apartment with its macro-cell level concentrator, data gathering component, implemented control strategies and user interface devices) that contains:
  - * A cell that corresponds to each apartment:
    - A cell level concentrator (CDC)
    - Activity and presence sensors (monitoring and metering)
    - Devices that can be controlled by the system (control and actuation devices):
      - ◊ Household appliances such as dishwasher, washing machine, fridge, etc.
      - ◊ Lamps and lights
    - UI channels (user interface).

All the MCCs could interact among them in order to reach common goals, especially the MCC of the building macro-cell and the MCCs of apartments.

eDIANA upcoming results

The eDIANA platform will be demonstrated in one residential (Eindhoven) and three office buildings (Madrid, Vantaa and Espoo), see Figure 3. Demonstration activities have been divided into three functional areas, in order to evaluate eDIANA performance in the same conditions but in different locations:

- Demonstrating energy consumption reduction in HVAC, lighting and other building systems
    * Demonstrating overall energy optimisation including consumption and storage
    * Demonstrating an internet portal service and application called "eDIANA Portal" for overall energy consumption and benchmarking services, with real data from case buildings.

Two office building demonstration sites are located in Finland.

The results of these demonstrations will be available at the beginning of February 2012.

Acknowledgements

Thanks to the eDIANA Consortium, which consists of 21 partners from Spain, Italy, Netherlands, Germany and Finland. eDIANA partners according to the alphabetic order are: ACCIONA Infraestructuras, ATOS Origin, Elsag Datamat, European Software Institute, FAGOR Electrodomésticos, Fidelix, GAIA, IKERLAN, Information & Image Management Systems, Infineon Technologies, LABEIN, Mondragon Goi Eskola Politeknikoa, Philips Electronics Netherlands, Philips Consumer Lifestyle, Philips Research, QUINTOR, ST Microelectronics, University of Bologna, University of Rome La Sapienza, VTT and ZIV Medida.

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Intelligent energy efficiency control in hospitals

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The concern of European society for the well-being of its residents and the sustainability of the environment has led to the consciousness that energy savings need to be at the top of the political agenda. Until recently, the focus of energy reduction has been on schools and offices. Hospitals, however, also use large amounts of energy. Therefore, the project will address specifically the hospital domain. HosPilot will address the two main technology areas Lighting and HVAC (Heating, Ventilation and Air Conditioning), thus covering the largest part of the energy-consuming areas. By adding intelligence, ICT (Information and Communication Technology) will play a vital role to achieve significant energy reduction in the complex environment of a hospital.

Introduction

The main goal of HosPilot is to prove that the proposed energy reduction service leads to reduced energy consumption and improved level of comfort for the end users. This goal will be achieved by identifying requirements of hospitals with respect to the building, its surroundings and its usage; designing a generic methodology addressing the needs, yielding the most energy efficient solution.

The methodology will be interlinked with expert knowledge of the various technologies into one holistic energy-saving service. The project is ongoing through 2011. The project will end in 2012 after a whole year of monitoring in the pilots followed by analysis and conclusions. The target is to achieve energy savings of 40% comparing to the average consumption in the existing hospitals, where the contribution of ICT to this result is 20%.

Methods

First the user must fill in general hospital data such as location, etc. Then he chooses the rooms that they want to refurbish, defining the number and type of rooms and the geometry of the typical rooms. The existing HVAC and lighting system and equipment need to be described in a way which facilitates the energy calculation of the existing situation. According to the hospital needs and its budget, the HosPilot tool will propose appropriate solutions by analysing existing systems. The Hospilot methodology will give applicable solutions for the selected rooms, and the energy demand for them is calculated (Figure 1).

To make these appraisals, the hospital baseline energy demand in the existing situation is calculated and after that the annual savings and the associated investment cost, based on the chosen energy-saving measures.

Finally, the HosPilot engine generates a report, showing which Energy Conservation Options (ECOs) and their combinations are achievable, proposing additional energy saving measures, and giving the effect of each ECO on the annual energy consumption. Moreover, energy savings on building level also appear.

Three pilots will be executed in hospitals during normal operation. HosPilot will provide

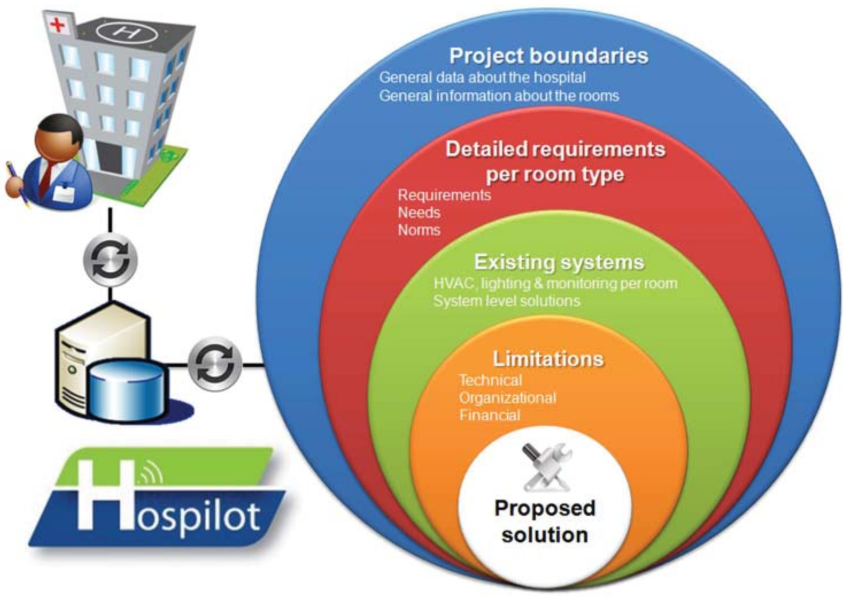

Figure 1. An integrated approach for targeting the best ECOs for a given hospital.

the most advanced ICT technology for future replications at European level. This paper will describe the installations and the present situation of the Finnish pilot at South Ostrobothnian Hospital District (EPSHP).The piloting activities in the three hospitals are ongoing. The aim of the project is to find applications that can be permanently used rather than only on this pilot project. These applications may serve as an example for the rest of the hospital, so that they can be introduced there as well.

The hardware specifications for each pilot have been brought to practical implementation steps. Almost all relevant parameters are now real-time monitored and will be concentrated into a single server where data will be charted and analysed. The main aim of this monitoring phase will be to prove the results predicted by the methodology.

The pilots will provide valuable data on how often typical rooms are used and how presence detection control can be used to reduce energy use in HVAC and lighting. Also occupant behaviour, e.g. opening windows, can be analysed based on the data from the pilots.

The methodology energy calculations for each ECO type will be calibrated based on the results from the pilot sites and also checked against the results of simulations using dynamic calculation tools.

Results

The pilot area in the EPSHP Seinäjoki hospital consists of ward H02 (half of the 0-floor in building H) having a floor area of about 1000 m2. This area is compared to ward H01, which is similar in construction and use and also equal in size. The pilot area includes patient rooms, corridors, personnel rooms, storages and toilets. The main HVAC systems (air handling units, riser ducts, radiator network piping, etc.) were not renovated when the pilot area wards in H02 were renovated. Air terminals in supply and extract and also radiator valves and water faucets were renovated. [2]

The HVAC system pilots will be carried out between selected rooms: some rooms

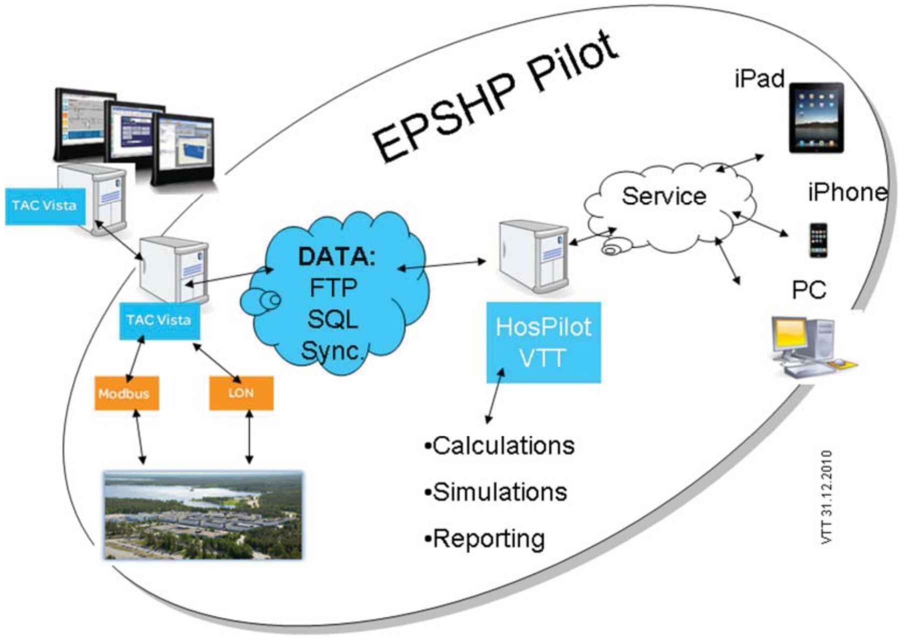

Figure 2. The EPSHP hospital pilot [3].

have state-of-the-art equipment, such as variable air volume ventilation and others have the normal/traditional equipment, such as constant air flow and ordinary thermostatic radiator valves. [1]

The whole electricity distribution in the H02 area was renovated and for lighting systems state-of–the-art equipment, such as LED tubes and advanced controls, such as presence detection were installed. In the state-of-the-art part, the installations include DALI gateway technology. This area will be compared with the other half of the floor (H01) with conventional equipment such ordinary fluorescent lights and manual on-off lighting switches.

All controlling will be implemented with room controllers communicating over a LonWorks field bus connected to the hospital building automation system via an IP network. Lighting and HVAC controllers and user interface devices will share information, such as room occupancy status, over the LonWorks field bus (Figure 2)

The monitoring results are not whole year yet but so far it seems that the monitoring results can easily be used to compare rooms side-by-side to see the effect of intelligent systems, e.g. motorised radiator valve connected to FM system compared to the thermostatic valve.

Also the dynamic simulations used in this case RIUSKA by Olof Granlund has an advantage of using the detailed data from rooms for simulations compared to the estimated ones.

Discussion and conclusions

The HosPilot results are in alignment with the project proposal. The tool for decision-makers seems to be one part only. The actual learning of the project has raised the interest to know more about the real potential based on monitoring as well on simulations to run hospital facilities in sustainable way and especially raising user comfort at the same time.

Acknowledgements

The project is initiated by EU (contract No. 238933) and involves 11 partners (of which three are hospitals in Spain, the Netherlands and in Finland) in five European countries. The coordinating partner is Philips Lighting in the Netherlands.

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Energy-efficient and low CO_2 office building

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Current office buildings are becoming more and more energy efficient. In particular the importance of heating is decreasing, but the share of electricity use is increasing. When the CO_2 equivalent emissions are considered, the emissions from embodied energy make up an important share of the total, indicating that the building materials have a high importance which is often ignored when only the energy efficiency of running the building is considered. This paper studies a new office building in design phase. The results showed that the reduction of energy use reduces both the primary energy use and CO_2 eq. emissions. Especially the reduction of electricity use has a high importance for both primary energy use and CO_2 emissions when fossil fuels are used. The lowest CO_2 eq. emissions were achieved when bio-based, renewable energies or nuclear power was used to supply energy for the office building. Evidently then the share of CO_2 eq. emissions from the embodied energy of building materials and products became the dominant source of CO_2 eq. emissions.

Introduction

The ambition in sustainable development of the built environment is to reduce the harmful impact of the nature of materials and building energy use [1]. Often the building energy use and the minimisation of its CO_2 eq. emissions are considered to be the desired goal. However, as the energy use decreases the importance of CO_2 eq. emissions originating from building materials and products increases. Thus, what kind of materials and building products are used becomes more important [3]. In addition, the minimisation of CO_2 eq. emissions is perhaps not the only desired target, but we need to consider also the minimisation of primary energy use, since it highlights rather well the use of natural resources. The aim of the study is to 1) find out the different available options in the design phase in order to minimise the energy consumption; 2) consider how the CO_2 eq. emissions from the embodied energy from building materials and CO_2 eq. emissions from energy use in the building should be treated; 3) consider how we should weight the primary energy use and the CO_2 eq. emissions of different design options. In this study a real office building was studied.

Methods

The studied building is an office building located in Helsinki developed by Skanska Commercial Development Finland. The building was under design phase and the aim was to study different alternatives in order to choose the most energy and environmental efficient way to erect the building. The gross floor area of the nine storey building is 26,000 m^2. The geometry of the building is quadratic. The studied properties are shown in Table 1.

The buildings were modelled in a dynamic IDA simulation environment [2]. The building model was the architect's real 3D model but the building spaces were simplified to 43 different zone models each representing typical

Feature	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Building envelope excl. windows	Building Code 2010	Building Code 2010	Building Code 2010	Building Code 2010	Building Code 2010	Passive house
Windows (W/m2K)	1.0	1.0	1.0	1.0	0.7	0.7
Ventilation heat recovery	70%	70%	80%	80%	90%	90%
LED lighting	in garage	in garage	in garage	in garage	in all spaces	in all spaces
Systems control level	building	room	room	building	room	room

In the 2010 Building Code the U-values for external walls is 0.17 W/m²K, base floors 0.16 W/m²K, roofs 0.09 W/m²K and doors 1.0 W/m²K. The ventilation heat recovery requirement in the 2010 Building Code is 45%, which was not used in calculations, since that was not an option in the design phase. In the so called passive house level the U-values for external walls is 0.08 W/m²K, base floors 0.15 W/m²K, roofs 0.08 W/m2K and doors 0.7 W/m²K.

Table 1. Studied design alternatives. The control systems include ventilation and lightning.

	Primary Energy Factor	CO_2 equivalent *
District heating average	1.87	0.22
District heating bio	0.4	0.12
Electricity average	1.87	0.38
Electricity from district heating average	1.87	0.38
Peak electricity from nuclear power	2.8	0
Peak electricity from coal	2.0	0.928
District cooling	0.25	0.12
Green electricity	0.2	0

* Unit: kg CO2/kWh.

Table 2. Primary energy factors and CO2 equivalent emissions used.

uses of the space type, such as office rooms, meeting rooms, cafeteria, etc.

Embodied carbon in materials

The embodied CO_2 includes energy consumption of building materials and products, the use of raw materials and greenhouse gases. The most important greenhouse gases are fossil fuel derived CO_2, CH_4 and N_2O. In the calculations the greenhouse gases are transformed to CO_2 eq. by using IPCC's characteristic factors.

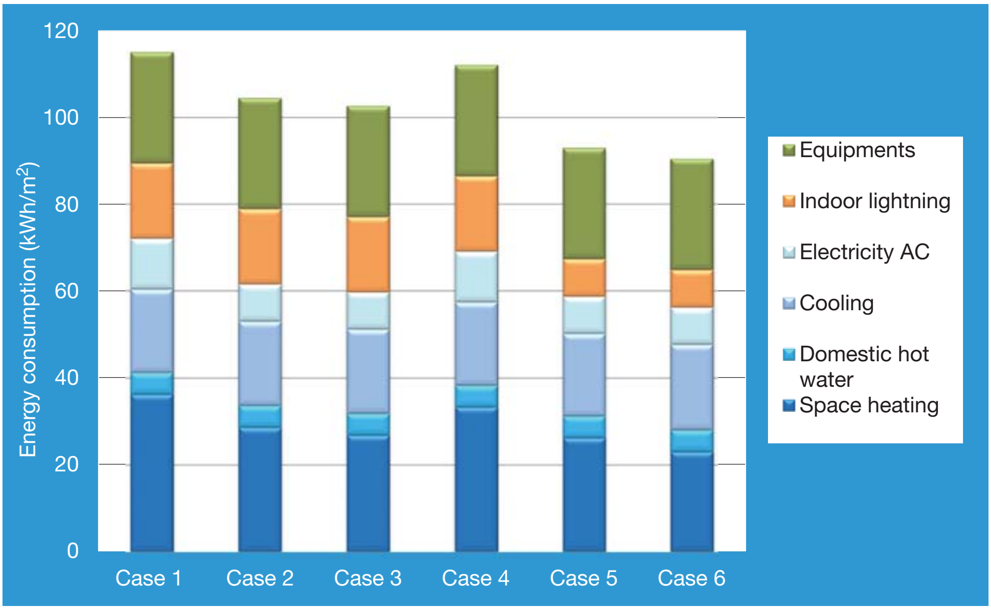

Figure 1. Yearly energy consumption in different cases. Electricity AC represents for electricity for air conditioning systems.

Energy sources and their CO_2 equivalent emissions and primary energy

The studied alternatives for energy and their CO_2 emissions are shown in Table 2.

The service life for building was assumed to be 50 years. The embodied CO_2 emissions from building materials and process were estimated according to design drawings.

Results

The energy consumption was highest in case 1 and lowest in case 6. But the energy consumption in case 4 was also really high, being nearly the same as in case 1 and showing that the building level control is inefficient with respect to energy saving. In particular the heating energy consumption is the highest when the control is at the building level. The energy consumption was 20% lower in case 6 compared to case 1. The only difference between cases 3 and 4 was the temperature control. In case 3 the control was at the room level, while in the case 4 the control was at the building level. That resulted in a 7% difference in total energy consumption and a 20% difference in space heating, in addition the difference in cooling was also 20% between those two cases (Figure 1). Since in office buildings the electricity use has higher importance than heating, case 6 does not have that much difference in consumption, even though the insulation values are much better (equal to passive house). The major difference between cases 3 and 5 was the LED lightning, in case 5 all lightning was done by LEDs, which clearly resulted in lower energy consumption.

The Finnish Building code is very advanced with respect to reducing heat losses from buildings; e.g. the U-values and ventilation heat recovery, as well as air tightness of the building envelope, are required to be rather good. This can be clearly seen from the energy consumptions (Figure 1). The CO_2 eq. emissions of heating are also rather low due to the low energy consumption when average Finnish district heating; cooling and electricity are used as energy sources.

Figure 2 shows the primary energy consumption as a function of the relation between

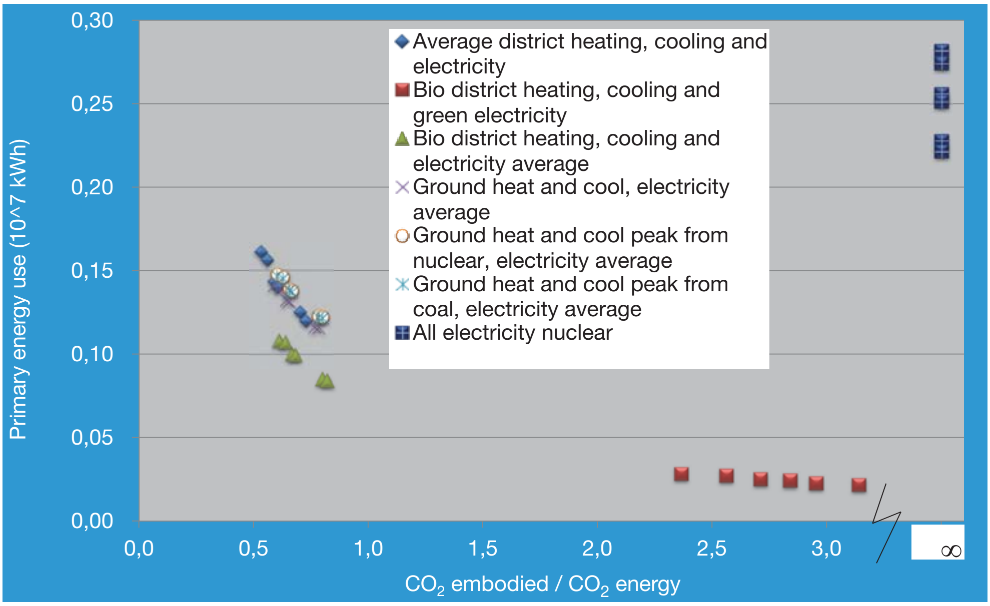

Figure 2. Primary energy consumption as a function of the relation between embodied and energy derivated CO_2 equivalent emissions.

embodied and energy-derived CO_2 eq. emissions. The CO_2 eq. embodied corresponds to the CO_2 eq. emissions from materials during their lifetime and CO_2 eq. energy corresponds the CO_2 eq. emissions from energy use in the building (heating, cooling and electricity). When all different options for heating, cooling and electricity sources were compared it can be clearly seen that the nuclear-based energy alternatives all ended up with rather high primary energy consumption and since the building energy use is carbon neutral, the embodied CO_2 emissions become dominant (Figure 2).

If low primary energy is the target, then bio-based district heating systems seems to be effective as well as the use of electricity from renewable energy sources. Ground heat or the average local heating performed rather similarly in respect to primary energy use. This is because the ground heating systems use electricity but they can utilise the "free" thermal energy obtained from the ground. It can be seen that the local variations do have an effect on both primary energy use and CO_2 eq. emission; in some parts the average Finnish values do have a good correlation to local energy production, but in some places the local production is closer to biomass-based production and in other locations closer to peak conditions. The lowest primary energy use is in alternatives based on bio local heating, cooling and green electricity. The lowest relation between CO_2 eq. embodied and CO_2 eq. energy in addition to low primary energy use was with the cases based on bio local heating, cooling and average electricity. When average electricity or nuclear energy based electricity was used, there was a clear trend in that energy saving gave the highest primary energy use savings.

Discussion and conclusions

The reduction of energy use reduces both the primary energy use and CO_2 emissions. The reduction of electricity use has a high importance for both primary energy use and CO_2 emissions when fossil fuels are used. Often energy originated from fossil fuels is also used as a complimentary source of energy, thus the importance of reducing energy use and especially electricity originated from fossil sources has a high priority.

The lowest CO_2 eq. equivalent emissions were achieved when bio-based, renewable energies or nuclear power was used to supply energy for the office building. Evidently then the share of CO_2 eq. emissions from embodied energy from building materials and products became the dominant source for CO_2. The lowest primary energy was achieved when bio-based local heating or renewable energies were used in addition to local cooling. Obviously the highest primary energy was when nuclear power was used. When the primary energy use and CO_2 eq. are minimised the CO_2 eq. originated from materials become rather dominant. In this study the CO_2 eq. emissions originated from building materials and products is between 2.4 to 3.1 higher compared to CO_2 eq. emissions originated from building energy use during running time.

Acknowledgements

The author wishes to thank Pellervo Matilainen, Ville-Veikko Saltala and Jari Koivu from Skanska. The research has been funded by Skanska.

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Promotion of the very low-energy house concept to the northern European building market

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IEE NorthPass project aims at overcoming barriers on the very low-energy house markets in cold climate, such as the lack of well-defined concepts adapted to the severe climate conditions, awareness of very low-energy houses, lack of products on the market and customer attitudes.

Introduction

Very low energy houses use less than 50% of the energy used in typical buildings and such energy efficient buildings can be achieved in cold climate by carefully designing buildings as a whole. However, the acceptability of very low energy houses in this challenging environment (e.g. northern European countries) depends largely on the economic sustainability of these constructions and to this extent, it requires methods and concepts that differ from the international passive house definition used in central Europe.

Methods

"Management" coordinates the project. "Definitions and concept buildings" creates a solution model for the very low-energy house definitions and concept buildings. "Impact and saving potential of northern European very low-energy houses in northern Europe" analyses the impact and saving potential of the northern European very low-energy house. "Overcoming barriers" identifies and overcomes technological and non-technological barriers to implementation of very low-energy houses in the northern European market. "Market penetration" utilises the data produced in definitions and concept buildings, impact and saving potential of northern European very low-energy houses in northern Europe and overcoming barriers and connects this data to the information of the market demand. In addition communication and dissemination are included in the project.

Results

Definitions and concept buildings has collected and compared local criteria for very low energy houses in the participating countries in "Report on the application of the local criteria/standards and their differences for very low-energy and low energy houses in the participating countries". "Principles of low-energy houses applicable in the participating countries and their applicability throughout the EU" collected and compiled the main principles for very low energy building design to meet the specific demands given by the lower temperature and less sun radiation in the winter time in the northern Europe. In "Energy-demand levels and corresponding residential concept houses and the specific challenges of very low-energy houses in colder climates" the comparison of the existing building regulations and very low energy criteria was performed quantitatively.

Impact and saving potential of northern European very low-energy houses in northern Europe report "A general description of the calculation tools for Cost Benefit Analysis and Life Cycle Assessment of very low-energy houses" introduced the methodology of Life Cycle Cost Analysis (LCC), Life Cycle Assessment (LCA) and Cost-Benefit Analysis (CBA). "Identification of tools for cost-benefit and LCC analysis and success factors for very low-energy housing" performed economic and environmental assessments as comparison between conventional and very low-energy single-family house and a multi-family house buildings in all participating countries. "Report on LCC and LCA analysis and environmental impact assessment of the very low-energy house projects on local level and on national level" demonstrated that although variations in building techniques, materials used, energy supply and heating system, very low-energy buildings in general have a lower environmental impact compared to conventional buildings. For a high energy price trend the very low-energy buildings also have a lower life cycle cost.

"Barriers to implementation of very low energy residential buildings and how to overcome them" of overcoming barriers determined the technological and non-technological barriers and gave suggestions for overcoming the perceived or actual potential internal weaknesses and external threats of low energy dwellings, recommendations for promoting low energy residential buildings and also listed aspects which have to be fulfilled to ensure that a low energy house is accepted by the occupant. "Results from studies concerning availability of components suitable for very low-energy houses in the participating countries and needs for further development of components for Very low-energy houses" showed that most components needed for very low energy residential buildings are available on the markets in the participating countries. Within overcoming barriers a database with major components needed for very low-energy houses will be developed.

Market penetration has carried out market surveys compiled from questionnaires for low-energy house builders to find out their willingness to build low-energy houses and for experts to create an image of the real situation and problems in market. The results will be presented in "Report on low-energy building market situation, trends and influencing factors".

Communication and dissemination has delivered "Suggestions for the reachable minimum performance requirement to be utilised in the update process of the EPBDA".

Discussion and conclusions

NorthPass project has promoted the very low-energy house concept to the northern European building market by defining very-low energy house criteria and concept adapted to the northern European countries, finding solutions to remove market barriers for wide market acceptance of those concepts and products, removing the gap between the demonstration of very low-energy house concept and their broad market penetration and supporting the implementation of the EU Commission's strategy and recommendations regarding very low-energy buildings.

Exploitation potential

NorthPass project increases the awareness and market acceptance of very low-energy house in the North European construction market, accelerates the identification of suitable solutions adapted to the cold climate environment and supports the implementation of the EU Commission's recommendations regarding very low-energy buildings.

Acknowledgements

The authors wish to thank colleagues from Tampere University of Technology, IVL Swedish Environmental Research Institute and Lund University from Sweden, Passivhus.dk ApS, CENERGIA and Aalborg University from Denmark, SINTEF Building and Infrastructure from Norway, National Energy Conservation Agency from Poland, University of Tartu from Estonia, Vilnius Gediminas Technical University from Lithuania and Riga Technical University from Latvia. The work has been supported by the European Agency for Competitiveness and Innovation (EACI).

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Future home for the eldery

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The project demonstrates that both high energy-efficiency and utilization of renewable energy sources in energy management of nearly zero energy buildings can be cost-efficient on life-cycle perspective. The project also demonstrates the performance and sustainable value creation in terms of maximum quality of life and minimised operational energy use, reduction in CO2 emissions, and furthermore the cost efficiency of the very-low energy buildings in terms of rate of return on energy-efficiency and carbon reduction investment.

Introduction

The demonstration building is a housing and service facility for the elderly. Nursing homes, health care buildings and nurseries are typically high energy consumption buildings. The demand for such facilities will increase, as the European population is ageing. The number of over-65s is expected to rise from the present 12% to over 25% during 2030-2050. Simultaneously the climate change mitigation requires not only dramatic reduction in energy use but also a need to utilise and harvest green and sustainable energy sources. Nursing homes as best practice examples of very low energy buildings based on innovation and competitiveness can serve as a tool for dissemination of energy-efficient buildings and their design and construction.

Elderly people spend more of their time indoors. They often also demand higher indoor comfort due to reduced activity, metabolism and dementia. New design features such as use of human thermal modelling for indoor comfort assessment and virtual model for performance in terms of perceived indoor environment are used in concept design. Information and communication technologies (ICT) are utilised for management of safer

Figure 1. Architect's views for the Lahti nursing home (source Arkkitehtityö Oy).

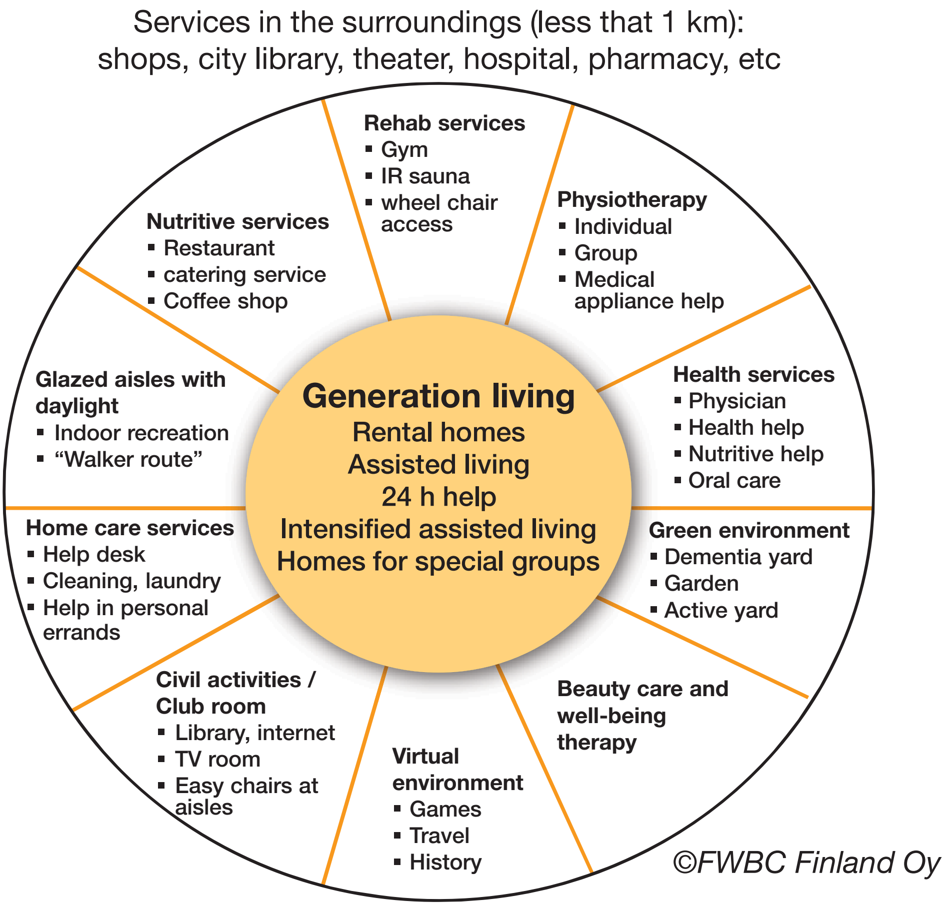

Figure 2. Design guidelines for nursing homes by the Finnish Well-Being Centre. Multiple-valued design can create a feeling of communal living and serve the well-being of the elderly. Integrating serviced living and energy-efficiency and in a nursing home requires as well integration of services. The building technology enables energy-efficiency, but the real outcome depends on how well the building and its spaces corresponds to services production and use of services.

indoor environment, care and services helping the elderly in everyday life as well as monitoring the performance of the building.

Requirements for nursing homes

There are specific design guidelines for nursing homes (Figure 1). The basic design aim is the performance of the building for the well-being of the occupants. Energy efficiency is subordinate managed target, however, many of the energy efficiency targets such as indoor climate; warm surfaces etc. are among the important features of a nursing home.

Procurement

The nearly zero energy home for the elderly is under design in Lahti, Finland. The process included a series of meetings with all the stakeholders including candidate contractors. The meetings focused on procurement processes concerning the building and its activities and performance (Figure 2) A design build contract was chosen for the project. The selection of principal contractor and designers bases on competitive bidding for invited contractors where price, final project plan, organisation and experience of the team, development and innovation, and technical and energy solutions are weighted according to given protocol.

Construction

The new nearly zero energy building for the elderly will replace the existing three apartment buildings built in the 1970s, which will be demolished. The new building has a floor area of 16,500 m2 whereas the existing buildings have a total area of 8500 m2. These buildings are being demolished due to their poor condition and high refurbishment costs compared to estimated costs of the new building. The nearly zero energy concept has an extra cost of about 10% compared to new nursing homes in general. At the same time the building is right in the centre of Lahti thus serving to encourage activity amongst the elderly in good physical condition.

Discussion and conclusions

The project experiences so far show the energy efficiency in such a specific building is not a high-cost target. Also, the briefing process in the very early phase of the process has helped the bidders to understand the specific features of the building and the requirements coming from the high energy efficiency. The process helped the builder, the Lahti Foundation of Housing and Services for the Elderly to focus and accommodate high targets for the building.

Energy use in day care centres and schools

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Commonly energy, space and cost efficiency are calculated in the design phase and greatly affect decision-making during the overall building process. How these decisions influence the use of the building and user satisfaction as well as maintenance is still not that well understood. This study analyses different schools and day care centres in respect of their energy use. The results showed that when the studied buildings were compared to relevant building stock in the same city, heating energy consumption was found to be smaller in the studied buildings where special attention was paid to energy efficiency in the design phase. However, for the electricity consumption such a correlation could not be found. One of the reasons could be that different buildings have different service levels (more equipment). As many earlier studies have indicated users have a high influence on energy consumption. In the future, when feedback is compiled from the users it will be interesting to analyse the results and compare what kind of influence they had on the overall energy consumption of the buildings studied.

Introduction

The energy consumption of schools and day care centres is often rather high and has a clear impact on the energy consumption of communities and hence on the energy bill [1–6]. For example, in the USA the annual energy bill to operate America's primary and secondary schools totals nearly $8 billion which is more than is spent on textbooks and computers combined. Typically as much as 30 percent of a school's total energy is used inefficiently or unnecessarily. According to Butala [7] in Slovenia the schools which had the highest energy consumption also had poor indoor air quality, as expressed by 60% of the pupils surveyed.

Typical annual heating consumptions reported for some European school buildings are 96 kWh/m^2 for Ireland [8], 192 kWh/m^2 for Slovenia [7] and 157 kWh/m^2 for the UK [9]. According to the literature [10], the average annual thermal energy consumption of school buildings in Greece is estimated to be close to 31 kWh/m^2 for the entire Greek region and 46 kWh/m^2 for the coldest climatic zone of Greece, where the examined building sample is located. An older monitoring campaign in the entire Greek region [10,11] found the average annual thermal consumption to be 68 kWh/m^2 for non-air-conditioned buildings. Studies on the energy performance of Greek school buildings [12] concluded that there is a considerable potential for energy conservation in heating loads ranging from 36% to 72% compared to the present state.

Methods

The studied buildings were located in southern Finland. All buildings were rather new ones completed after the year 2000. The studied buildings were mainly schools, but two day care centres were also included. Energy use in all buildings was monitored at least on a monthly basis. The monitored energy con-

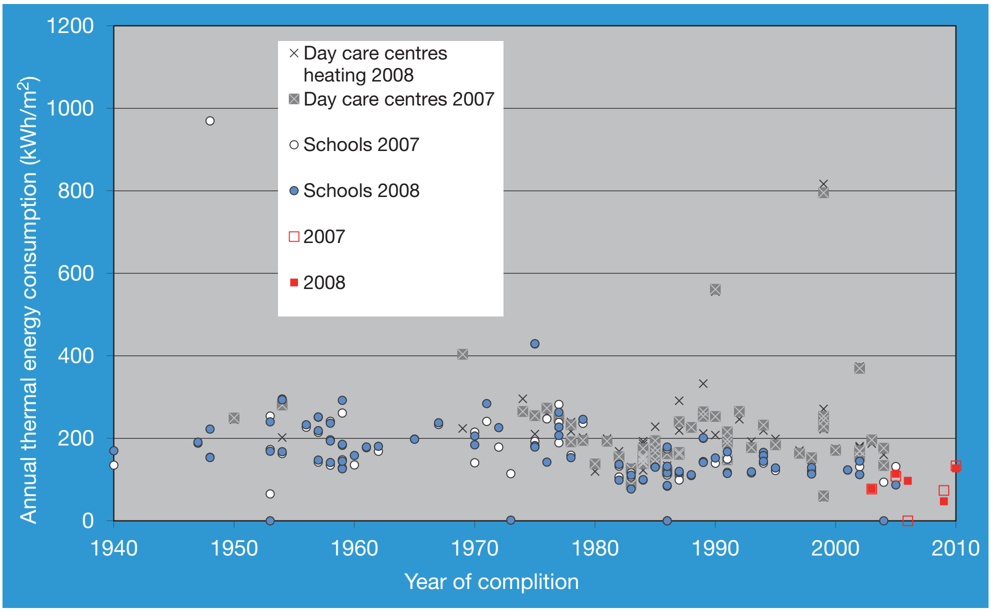

Figure 1. Annual thermal energy consumption in studied buildings and reference building stock in the city of Espoo. Thermal energy consumption includes both space heating and domestic hot water.

sumptions were thermal energy (space heating and domestic hot water) and electricity. The thermal energy could not be separated for space heating and domestic hot water since only the total thermal energy was measured. In addition water consumption was monitored. Three of the buildings were still in the design or construction phase, thus no measurements of energy consumption were available.

Results

Since building size and architecture are one of the key factors in efficient energy and space use, first the building floor area and its increase or decrease trends were studied. It seems that the gross floor area has remained relatively the same over the last 100 years, whereas the gross volume has deviated more and tended to increase in the last century. However, a clear trend could not be seen. The studied buildings are similar to the main building stock in their gross floor area. In addition the proportion between gross floor area and building volume are rather similar in the studied buildings compared to existing building stock, which means that the architecture has in that sense remained rather similar. For example the share of lobbies or corridors with low floor area but high volume has not increased or decreased during these years. Thus, the geometry of the new buildings is not different compared to existing stock. This is slightly surprising since the building geometry has a rather big impact on energy consumption.

The measured thermal energy consumption includes both space heating and domestic hot water heating. The majority of the buildings are connected to a district heating network. As shown in Figure 1, when thermal energy is studied a slight decreasing trend in consumption can be seen, that is, newer buildings consuming slightly less thermal energy. However, this was not true with all buildings. In measured thermal energy consumptions clearly lower thermal energy consumption can be seen in the studied buildings in which energy efficiency had a higher priority in design. In addition the building code

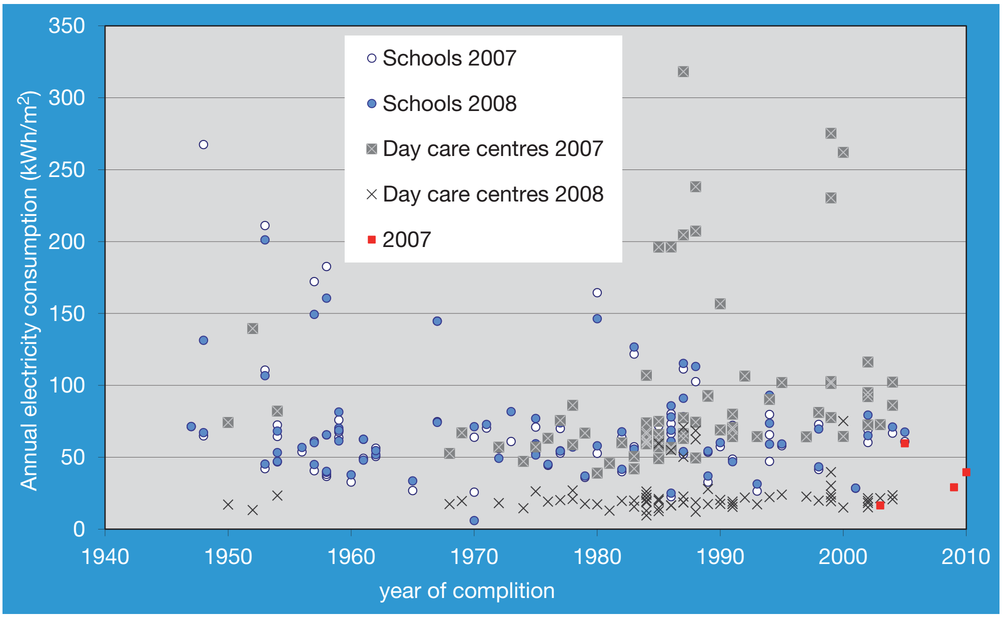

Figure 2. Annual electricity consumption in studied buildings (data from 2007) and reference building stock (data from 2007 and 2008).

changed over the years resulting in lower reference U-values (better insulation) and higher ventilation heat recovery values.

Even though the building use profiles are clearly different in schools and day care centres, no big difference between these two building types could be identified in the measured thermal energy. The day care centres did have slightly higher thermal energy consumption in rather modern buildings (built after 1985). Also there were no clear differences between day care centres and schools, even though generally the hot water consumption and opening hours are slightly higher in day care centres. It seems that the improvements in energy efficiency during the years has also improved the quality of air (higher ventilation rates) which led to higher energy consumption and therefore the trend between 1970 and 2000 shows only a slight decrease in thermal energy consumption. However, a stronger trend towards lower thermal energy consumption can be seen between the years 2000 and 2010. The normalised thermal energy consumptions were rather similar in the studied buildings over many years (not shown in Figure 1), indicating that consumption is rather stable and there were no big changes or complaints from the users.

Electricity consumption does not have any trends, and the consumption values are scattered. As shown in Figure 2, the studied buildings also did not perform better in electricity use compared to relevant building stock in the same city. Both in schools and in day care centres the electricity consumption was mainly higher in the year 2007 compared to 2008. However, there were some problems in electricity measurement readings and the values from 2008 might not be reliable. In addition in some of the day care centres renovations were done, which can be seen in higher electricity use. Especially in the day care centres the differences between these two years were substantial. There was not clear evidence why this had happened but part of the reason could be that the city performed some energy audits during those years and some of the components were changed. The studied buildings did not perform better compared to the reference buildings in terms of electricity consumption.

Discussion and conclusions

The studied buildings were all completed after 2000, and thus are rather new buildings. Also all buildings had some target values in respect to energy or eco-efficiency. In addition they had good indoor climate targets. When the studied buildings were compared to relevant building stock in the same city it was found out that thermal energy consumption was smaller in the studied buildings where special attention was paid to energy efficiency in the design phase. However, for electricity consumption such a correlation could not be found. One of the reasons could be also different service level of buildings (more equipment). Also other quality values could not be compared since such data were not available from the existing building stock. However, it seems that the new buildings do not have significantly lower energy consumption. In some other previous studies a clear correlation between new buildings and low energy consumption could be found. This clearly shows how complicated the relationships between energy consumption and the factors affecting it are. In this study some of the buildings in the existing building stock reached the same level in primary energy use. This shows the importance of the building use and users' impact on primary energy use.

Acknowledgements

The author wishes to thank Tiina Sekki and Arja Lukin from the City of Espoo for fruitful discussions during this ongoing process. This study was funded by the City of Espoo.

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Optimisation of thermal inertia and ventilation strategies

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Buildings consume 30–40% of the total energy in Europe. The majority of the energy used in buildings is consumed as heating or cooling energy, thus it is essential to develop energy efficient building concepts. Heat can be stored in the building structures in order to reduce the indoor temperature or to reduce the cooling load peaks and shift the time when the maximum load occurs. However, the phenomenon of thermal capacity is a complex problem, since there are many parameters affecting the behaviour of a building. Therefore further studies are needed in order to understand the problem more precisely. This study takes one step in order to better understand the complexity.

Introduction

It is increasingly recognised that the use of thermal mass in office buildings might offer significant energy efficiency and thermal comfort advantages, and this has led to more interest from architects and engineers when designing low energy, sustainable office buildings. However, a lack of guidance about the detailed mechanisms that affect thermal mass and how it can be used in modern office buildings has led to a tendency to equate high levels of physical mass with good passive thermal performance. There are many factors that need to be considered and increasing physical mass above certain thresholds does not necessarily improve thermal performance. Many commercial buildings today are structurally heavy but thermally lightweight due to the use of finishes such as false floors, drop ceilings, etc.

Evidently thermal inertia has a positive impact on the internal temperature, but prestudies show that only a layer of 10 to 15 cm is used for 24-hr cycles. Modifications of the surface and the thermal conductivity (e.g. steel composite decks) improve the benefit of a given mass. An essential requirement for beneficial use of thermal inertia is to realise a sufficient air change, therefore the openings in the façade or the ventilating system must be considered (and adapted, if needed).

The aim of this task was to simulate different thermal inertias and ventilation strategies and hence to give guidelines for most efficient way to use the thermal inertia. In addition the aim was to simulate where the thermal inertia should be located and possibly the future PCM (phase change material) applications.

Methods

An office building completed in 2005 in Hämeenlinna, southern Finland was chosen for the night ventilation simulations. The external walls are thermally light, consisting of 13 mm gypsum boards inside, 200 mm mineral wool steel frame wall elements and 9 mm gypsum boards outside. The internal walls have 13 mm gypsum boards on both sides of the 70 mm mineral wool steel frame wall. Floors are made of 265 mm hollow core slabs and are therefore thermally heavy. Above the floor slab there is a 50 mm layer of second state concrete and a 5 mm thick floor cover-

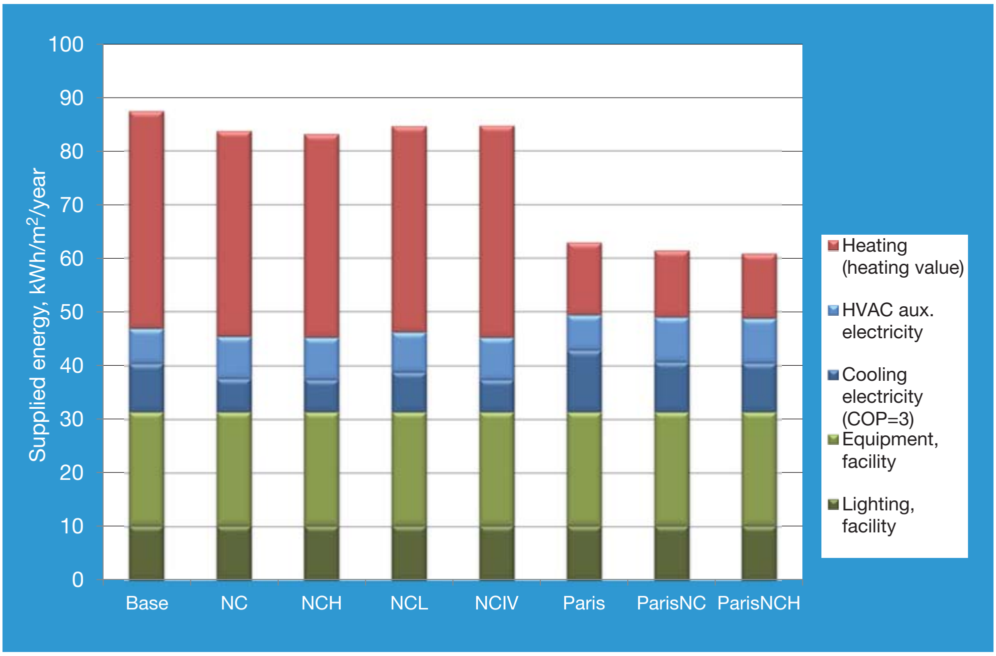

Figure 1. Annual energy use in different cases. Red stands for heating energy; the other colours stand for electric energy.

ing. The U-value of the external wall and the roof is 0.24 W/m²K.

The building was modelled in a dynamic IDA simulation environment, where a RC-network (resistance-capacitance network) model of a building was used. In addition Comsol Multiphysics commercial software (version 3.5a) was used to make CFD simulations of the air flow pattern and heat transfer in an office room.

Studied cases

Thermal simulations were used to study the effect of thermal mass and ventilation parameters on the performance of night-time ventilation cooling. The performance is quantified as reduction of the electrical energy needed for ventilation and cooling. In total eight cases were analysed, the first five in a Helsinki climate (ASHRAE database) and the remaining three in a Paris climate (ASHRAE database):

1. base case without night cooling (noted as Base in the results)
2. night cooling with unchanged air flow rate 1.5 l/s/m² (NC)
3. same as 2 but with thermally heavy construction (NCH)
4. same as 2 but with thermally light construction (NCL)
5. night cooling with increased air flow rate 4.5 l/s/m² (NCIV)
6. base case without night cooling in Paris (Paris)
7. night cooling with unchanged air flow rate 1.5 l/s/m² in Paris (ParisNC)
8. same as 7 but with thermally heavy construction (ParisNCH).

Results

Annual use of supplied electric and heating energy in different cases is shown in Figure 1. The electric energy needed for cooling is only a small fraction of total electricity consumption. It is in the same range as electricity for

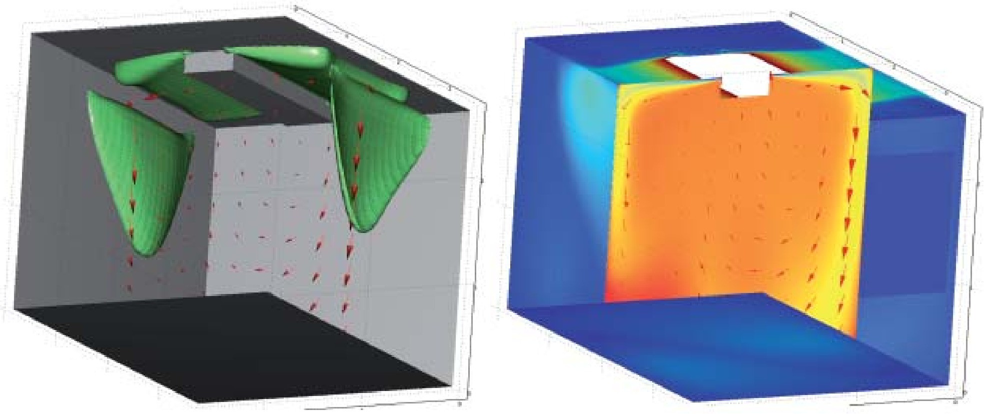

Figure 2. Left: in the CFD simulation the air is supplied from the cooling beam and flows along the ceiling. The velocity vector in the middle of the room is shown as well the velocity isosurface of 0.2 m/s. Right: the heat transfer from the room surfaces in night cooling (red colour more than 25 W/m^2, blue less than 10 W/m^2) and room temperature in a slice in the middle of the room.

fans and pumps (HVAC aux. electricity). Lighting and equipment make up the majority of electricity consumption. It should be noted that the real cooling energy delivered by the room cooling units and the cooling coil in the air handling unit is threefold compared with the supplied energy in Figure 4 because the refrigeration unit is assumed to produce 3 kW of cooling power per 1 kW of electric power (COP = 3).

The total electric energy for the whole HVAC system (incl. refrigeration, fans and pumps) reduce by 11% at best with night cooling, not shown in Figure 1. Higher thermal mass (case NCH) and increased night ventilation flow rate (NCIV) are slightly better than the base case with night cooling. In a Paris climate the benefit of night cooling is much smaller than in a Finnish climate: the increased fan energy almost nullifies the cooling energy benefit. Indeed, night cooling may become more attractive in combination with natural or hybrid ventilation where the fan energy is much smaller.

To get more insight on local heat transfer on room surfaces Computational Fluid Dynamic (CFD) simulations were performed. The air is supplied to the room from a cooling beam that is located in the ceiling. The supply air flushes the ceiling and therefore effectively cools the ceiling, see Figure 2.

The air flow rate is about 6 air changes per hour. The supply air velocity is 1.5 m/s and temperature 16°C. The room surfaces are set at 24.5°C except the windows which are set at 22°C.

The cooling heat flux is highest on the ceiling where the air velocity is high and the air temperature is low. The side walls are also flushed by the air flow and the heat flux is higher than elsewhere in the room. The ceiling receives 40% of the total cooling power. This shows that if the air is supplied from the ceiling it is important to keep the ceiling exposed to heat transfer. A suspended ceiling or acoustic panels may render an important part of the thermal mass in the room useless.

Discussion and conclusions

The cooling energy needed in the simulated office building is only about 20% of total electricity. Therefore the potential for energy saving by night cooling is not very big. In any case the electrical energy for HVAC (refrigeration cooling, fans and pumps) can be reduced about 10% by exposing the massive floor and massive ceiling to cold night air. The increase of thermal mass by making the external walls out of concrete has only a minor effect. On the other hand, the suspended ceiling has a clearly negative impact by making the room thermally light. The increase of air flow rates during night reduces the cooling energy but care must be taken that the increased fan energy does not outweigh the cooling energy benefit. This can be ensured by sizing the air flow ductwork for increased air flow rate. Other possibilities are to use natural or hybrid ventilation which needs much less electric energy.

The energy saving by night cooling may be higher by fine-tuning the present control system. For example the minimum room temperature might be lower than in the present study (22°C). In northern and central Europe the investment on mechanical cooling can even be totally avoided by night cooling. This possibility and the influence of different parameters on achievable indoor temperatures have been studied by [1]. Also a study from [2] showed that in a Belgian climate it is possible to gain good thermal comfort (no overheating) without cooling systems if the internal gains are not too excessive, shading devices outside are applied and if the building is constructed and designed such in a way that thermal mass can be used together with night ventilation.

In [1] it has been shown that the surface heat transfer is a critical factor in effective storage of thermal energy in thermal mass. This suggests that a larger surface area for the thermal mass elements may be more helpful than increasing the absolute amount of mass. Thus, thin thermal mass elements spread around the space on the floors, ceilings and walls are more likely to be useful and more suitably placed for both radiation as well as receiving direct solar gain. Current research into improving heat transfer includes blowing air through cores within the floor slab, or using water in embedded pipes to warm and cool the slab [3].

Night cooling also lowers the operative temperature because the room surfaces are colder in the daytime. This makes it possible to use slightly higher room air temperatures (about half a degree) to achieve the same thermal comfort. The accurate simulation of night cooling is not an easy task. Dynamic building thermal simulations can be done but to be accurate, the room flow and temperature pattern should be taken into account. This was demonstrated in the present study by making CFD simulations for an office room. The convection heat transfer depends considerably on the air supply principle and design.

Acknowledgements

The authors would like to thank the colleges from the ETHICS project and especially the project coordinator Bernd Döring from RTWH Aachen. This project was carried out with a financial grant from the Research Programme of the Research Fund for Coal and Steel, which is greatly appreciated. This study was part of a larger project named Energy and Thermal Improvements for Construction in Steel, ETHICS.

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Indoor performance and sustainability

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Perfection (Performance Indicators for Health, Comfort and Safety of the Indoor Environment, 2009–2011) is a European Coordination Action under the EC's 7th Framework Programme. It aims to help enable the application of new building design and technologies that improve the impact of the indoor built environment on health and comfort, the feeling of safety and positive stimulation integrated within a sustainably built environment.

The Perfection project consists of the following components:

- **the inventory of current standards, regulations, technologies and ongoing and recent research activities and policies related to the optimal indoor environment**
- **an analysis of current indicators for health and comfort, safety and accessibility, positive stimulation, adaptability and usability positioned within a generic framework to assess their impacts on sustainability**
- **experiences from pilot cases exploiting the key indoor performance indicators in different building types.**

This paper presents the findings from applicable design technologies and potential key indoor performance indicators (KIPIs) representing health and comfort, accessibility safety and positive stimulation, usability and adaptability in relation to their impacts on sustainable buildings.

Introduction

The aim of the Perfection Coordination Action is to help enable the application of new building design and technologies that improve the impact of the indoor built environment on health, comfort, the feeling of safety and positive stimulation within the following framework (Figure 1).

Perfection will deliver

- a repository of good indoor performance indicators for health, comfort and safety
- a repository of state-of-the-art environmental technologies that appear to have the potential for an important impact on the indoor performance and sustainability of the built domain
- an interoperable framework for performance indicators qualifying the indoor environment, allowing the successful life cycle management of sustainable buildings and stimulating the exploitation of appropriate technologies
- a decision support tool for different user groups applicable to different building types
- findings from selected pilot cases for the use of the indicators framework and the relevant indoor performance indicators
- recommendations on policies and the future research agenda: a roadmap including incentives and barriers for the application of building design and technologies to improve the quality of indoor environments

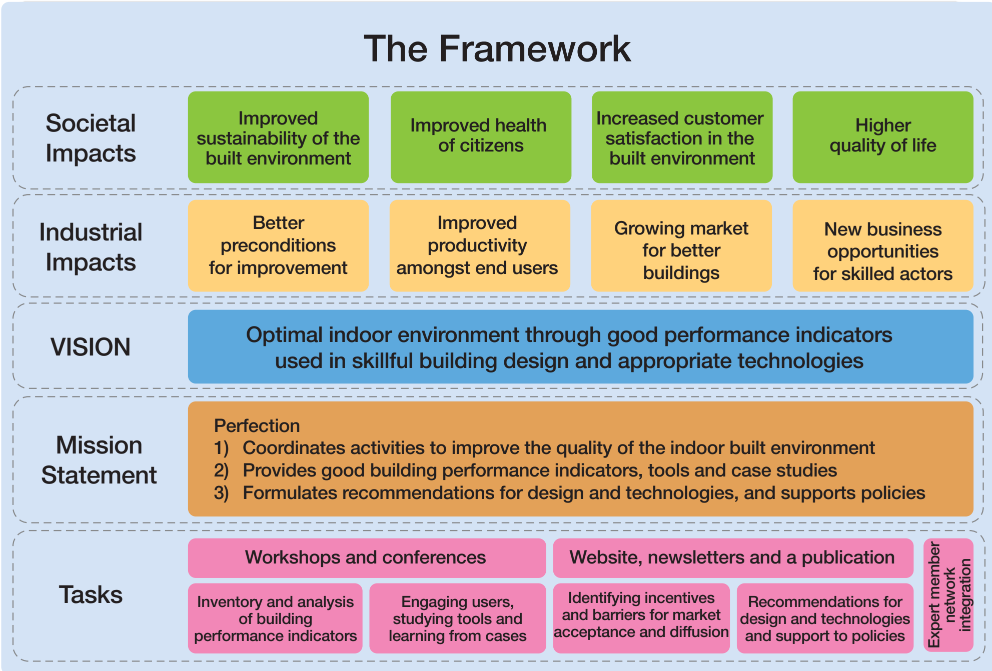

Figure 1. The Perfection vision and expected impacts.

- knowledge and good practices on performance indicators for health, comfort and safety in the indoor environment.
- a wide dissemination of findings through an extensive expert network and the organisation of a series of events.

This paper presents its first results on sustainable building technologies, health and comfort indicators, accessibility, safety and positive stimulation indicators, usability, adaptability and sustainability impacts.

Review of sustainable building technologies

Technological development in recent years has brought a number of tools and knowledge enhancing the sustainability of the built environment.

The most discussed today are clean energy sources and energy saving measures such as combined heat and power generating units, low energy and passive cooling systems, heat recovery, multifunction ventilation systems, high-tech insulations, etc. Parallel to this sustainability "mainstream" there are a lot of other remarkable related technologies improving the comfort and efficiency of the buildings.

New technologies enable advanced monitoring and controllability of a healthy indoor environment.

Compact sets of wireless sensor networks can be used to collect data and provide more efficient real-time building operation management. The information flows can be used to increase the safety of the building. Monitoring camera systems equipped with face recognition can provide security (on the other hand the feeling of safety and privacy could suffer).

One of the Perfection goals is to provide a roadmap including incentives and barriers for the application of building design and technologies to improve the quality of indoor environments.

Review of health and comfort indicators

Performance indicators for health and comfort, which have been documented in standards, regulations, guidelines, research activities and policies used in the design and construction of the built environment have been reviewed. It is the objective of the project to provide an overview and a complete list of performance indicators for health and comfort, which can be applicable in a performance indicator framework for the assessment of building performance. Focusing on the development of such a framework, the performance indicators have been grouped into five core indicators: acoustic comfort, visual comfort, indoor air quality, quality of drinking water and thermal comfort. Each core indicator is described by several performance indicators. Within the project, a performance indicator is defined as a property of a product, building component or building, which closely reflects or characterises its performance (state or progress towards an objective) in relation to the performance requirement that has been set [1]. The indicator should be a quantitative, qualitative or descriptive parameter that can be readily assessed.

Implementation in a performance indicator framework

The study showed that the level of detail at which the information for the assessment of a building is available is the main issue that influences the complexity of the indicator framework. Often, a specific indicator can be assessed at a global level, based on a qualitative and more subjective evaluation of the performance indicators, or a more detailed level, based on a quantitative and objective evaluation. While questionnaires and checklists have shown to be suitable assessment methods for the first approach, detailed measurement of the performance indicators and corresponding parameters are recommended for a second more thorough approach. Focusing on the development of an indicator framework it is recommended to apply such a distinction (global vs. detailed) within the Perfection project. Moreover, the framework could be applied in different phases of the life cycle of a building, such as the design process, the construction and the in-use phase. In each phase, different assessment methods can be applied for the evaluation of the (core) performance indicators.

Review of accessibility, safety and positive stimulation indicators

Accessibility, safety and positive stimulation have an impact on the sustainability of a building, strongly influencing the social aspect of the built environment. Accessible buildings provide the opportunity for every user to use it with the same low-level effort. However, accessibility is not the only aspect to be considered when designing sustainable buildings. In order to encourage the user to participate in social life or to improve his general positive feeling of the built environment (user experience), it is important to consider positive stimulation. This concept prompts the users to do or to feel something. For example, if a designer creates a large public space with mailboxes in a residential building, it will invite people to meet each other in this semi-public space. Positive stimulation is an abstract concept which enhances the user experience. Safety aspects must be considered in the approach of the sustainable design because they are a basic requirement for human life in the indoor environment.

Exploitation potential

The Perfection project will also outline additional indoor performance indicators relating to adaptability and usability, for example. The impact of Perfection key indoor indicators (KIPIs) on sustainability, covering social, environmental and economic dimensions, will be mapped (Figure 2).

This Perfection framework will serve as a basis for the development of a web-based

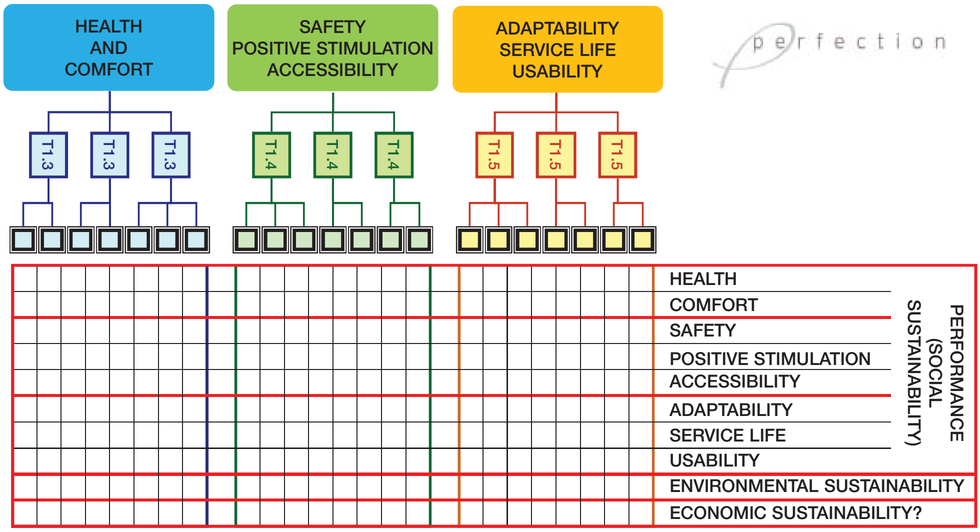

Figure 2. A schematic view on the draft generic framework.

tool to be used in case studies to manage the indoor performance of buildings.

Discussion and conclusions

The Perfection project (2009–2011) will deliver a generic framework for performance indicators qualifying the indoor environment, allowing the successful life cycle management of sustainable, healthy, comfortable, safe and accessible buildings and stimulating the exploitation of appropriate technologies. The framework will be integrated in a web-based tool and used in a series of case studies. The tool will be available for producers, designers and users to evaluate products, technologies and buildings with regard to the indoor environment. By creating a database of showcased products, technologies and buildings the project will stimulate good indoor environmental practices around Europe.

In order to communicate with the user community, the Perfection consortium is creating a forum for interaction, a web-based evaluation and promotional module and a specific project website (http://www.ca-perfection.eu). A couple of events are also organised in order to provide information about the progress of the project and to discuss some of the results and research work.

Acknowledgements

This paper presents the work and findings of the PERFECTION consortium, which consists of BBRI, VTT, Apintech, CTU, Armines, Oliver Kornadt und Partners, ICTAF, SiTI, TUe, ASM Ltd. and BRE.

This article was edited from a paper presented at the SB10 Conference in Algarve in March 2010. The author wishes to thank co-authors Antonín Lupíšek from TUP in the Czech Republic, Pierre-Henri Lefebvre from BBRI in Belgium and Paul Steskens from TUE in the Netherlands for producing that paper and collaborating as part of the Perfection project supported by the EC in FP7.

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Building energy efficiency and its effect on the frost insulation

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The energy efficiency of new buildings has improved significantly and is still improving. As the thermal insulation of the building envelope increases other properties and "thumb" values might also change. Especially when the thermal transmittance (U-value) of the slab on the ground decreases, the frost insulation should also be reconsidered. The aim of this study is to find out how the frost insulation changes when the base floor and foundation insulation change.

Introduction

In cold climates, such as in Finland, 42% of national energy use is spent on housing, corresponding to 38% of CO_2 greenhouse gas emissions [1]. Indications of emerging climate change increase the pressure to reduce energy demand, leading to low energy and passive houses. As the thermal insulation of the building envelope increases other properties and "thumb" values might also change. Especially when the U-value of the slab on the ground decreases, the frost insulation should also be calculated carefully. The aim of this study is to find out how the frost insulation changes when the base floor and foundation insulation levels change.

Methods

The studied structures are shown in Figure 1. The insulation material used in the base floor was expanded polystyrene (EPS 100 for base floor) and the thickness varied between 200–500 mm. The foundation wall was mainly

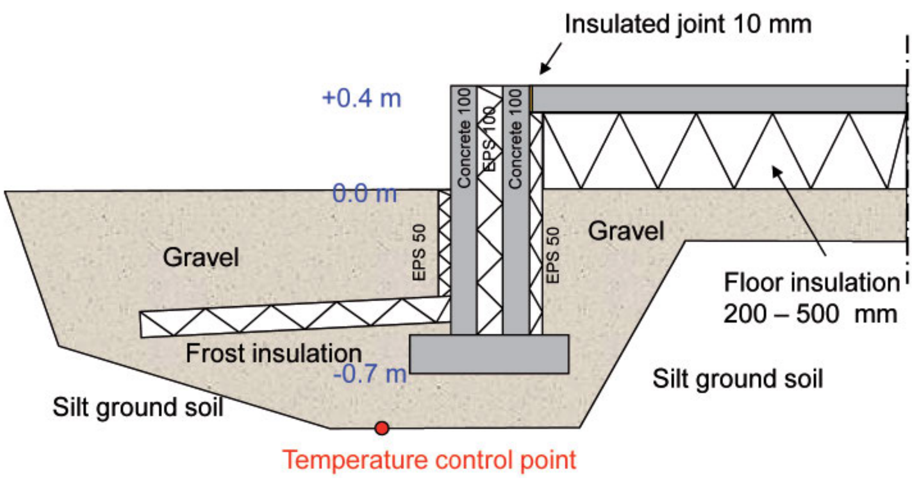


Figure 1. Studied building foundation. The critical point in respect of frost is in the load area below the basement in the frost susceptible soil (marked as a red dot).

	k_u (W/mK)	k_{fr} (W/mK)	c_u (J/kgK)	c_{fr} (J/kgK)	ρ (kg/m³)	l (J/kg)
Silt	1.7	2.2	1440	1022	2000	66,960
Gravel	2.0	2.3	977	841	2033	21,903
Concrete	2.0			1000	2400	
EPS floor, horizontal	0.036			1300	20	
EPS floor, vertical	0.038			1300	20	
EPS frost, horizontal	0.041			1300	22	
EPS frost, vertical	0.039			1300	22	

Table 1. Material properties used in the simulations

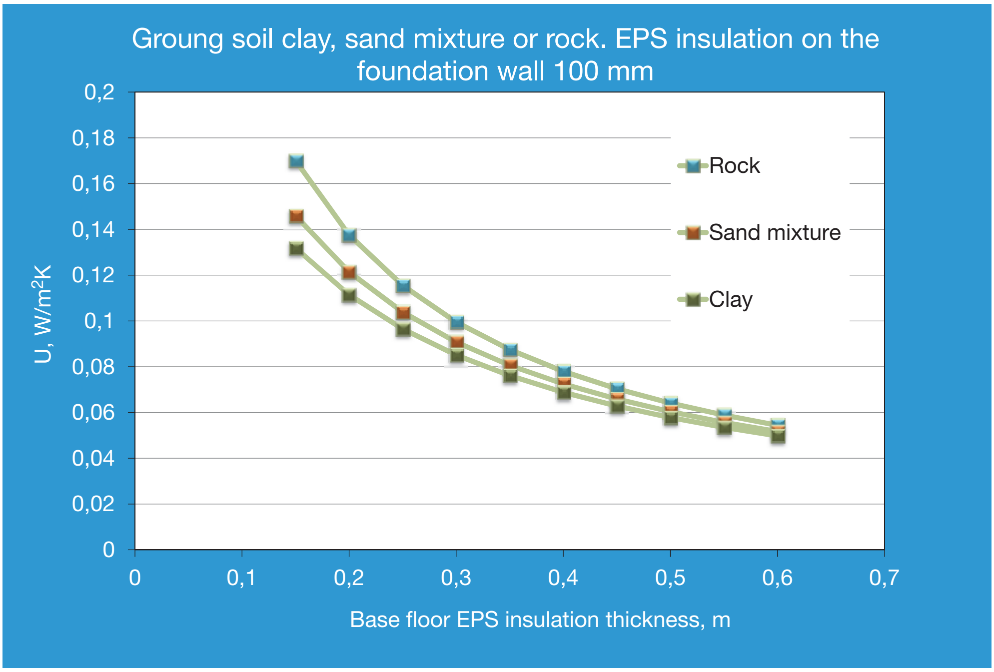


Figure 2. Thermal transmittance (U-value) as a function of base floor insulation and ground soil properties.

made of concrete with EPS insulation layers, but in some cases was also calculated with lightweight blocks. Both foundations had insulations. The concrete foundation above ground level was not externally insulated because this is usually the case even though it would be better to insulate it up to the top of the foundation. [2]

The dynamic simulations were done with Comsol Multiphysics software. Since the phenomena in the massive ground floor are really slow, the first eight normal winters were calculated in order to get stabilised conditions and after that the coldest winter in 50 years (F50) was calculated to see the risk of frost penetration. The calculations were done using

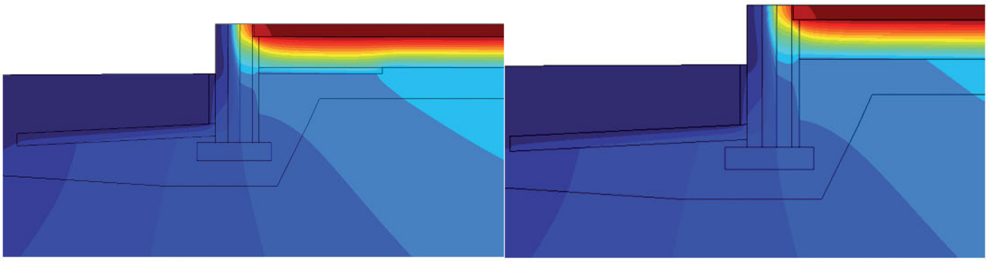


Figure 3. Additional horizontal edge insulation (left) and increased whole floor insulation (right) which produce the same thermal performance. Isotherms are shown at one degree intervals.

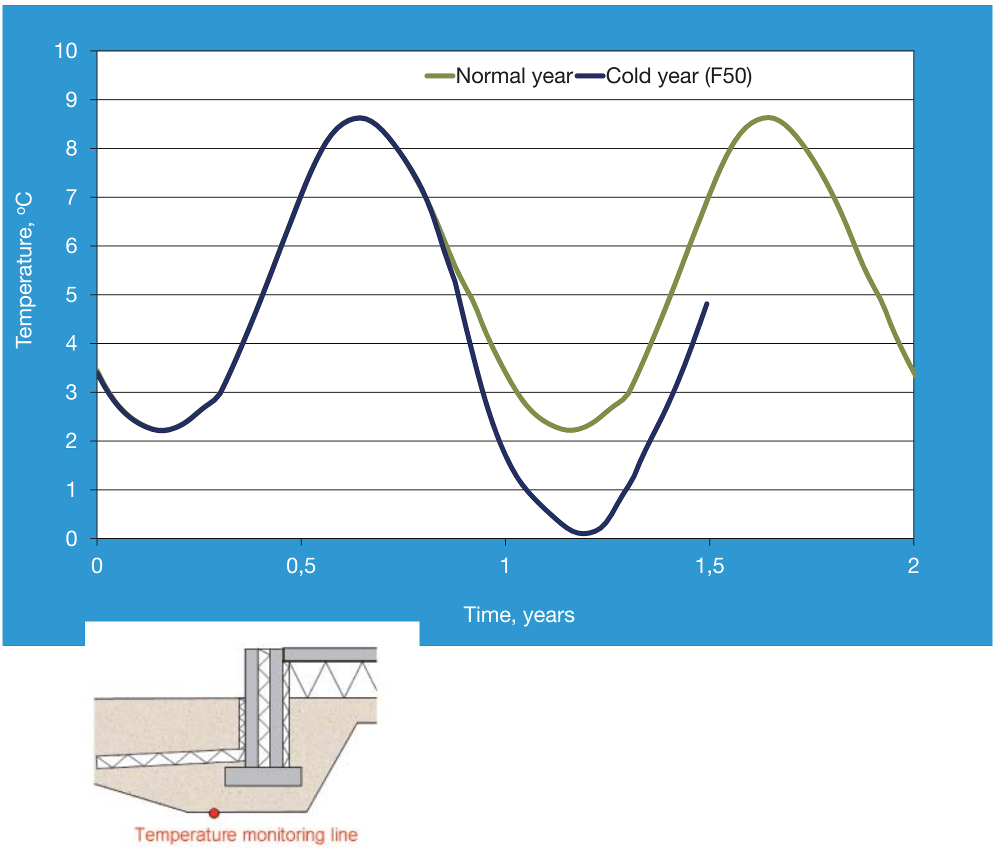
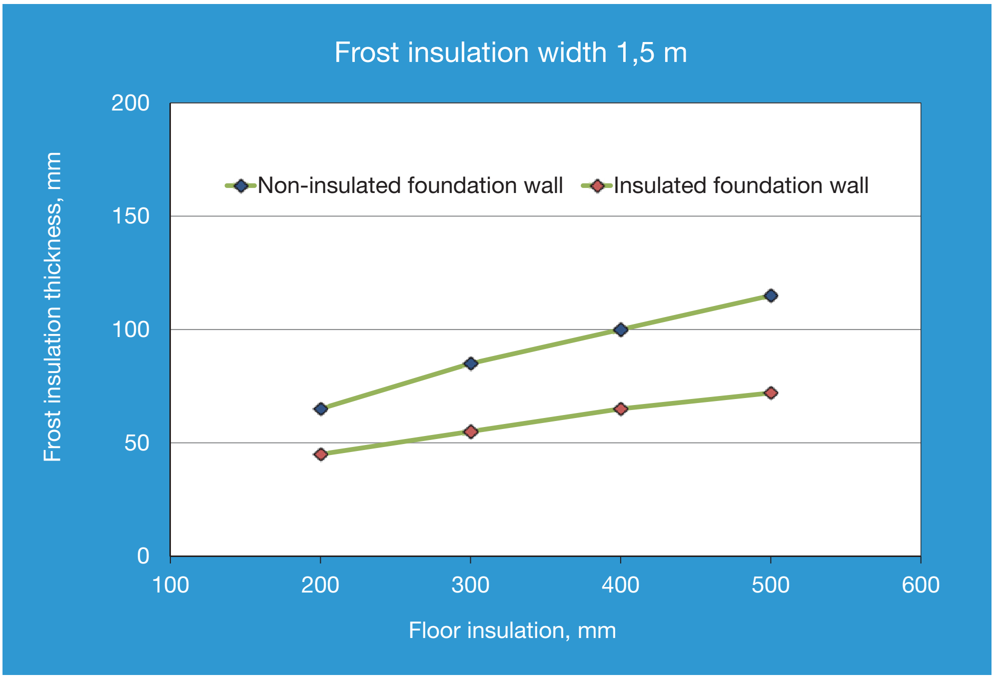


Figure 4. Temperature in the critical location under the basement for one normal winter and one cold winter. Frost insulation plate is 1.5 m wide and 100 mm thick. Floor insulation thickness is 400 mm.



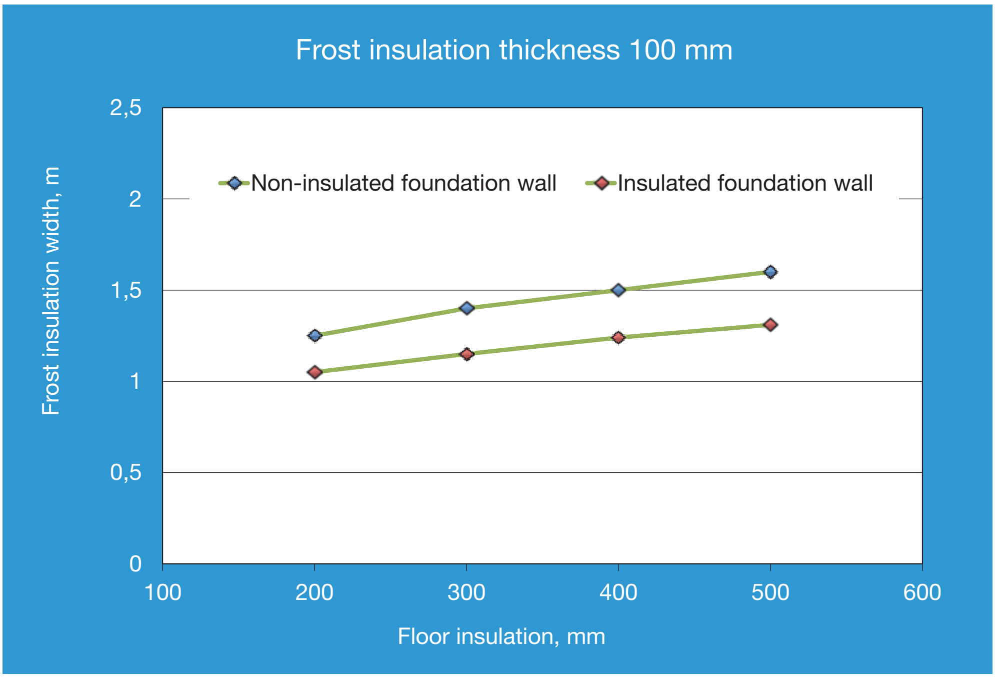


Figure 5. Effect of floor insulation thickness on frost insulation dimensions. The upper curve corresponds to the foundation wall in Figure 1. The lower curve is for a foundation wall which has external 50 mm insulation above ground level as well.

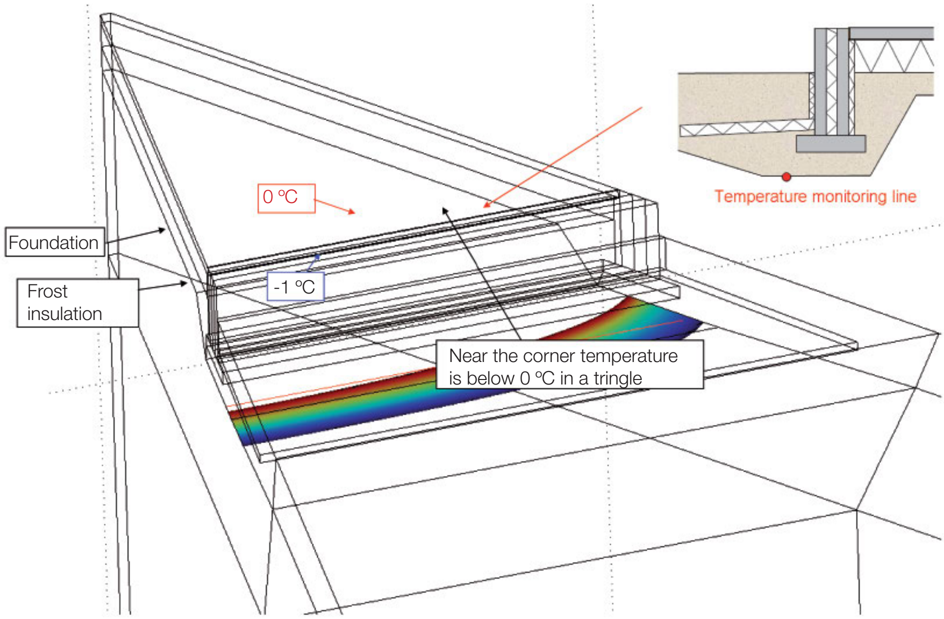


Figure 6. Frost penetration on 28 March 200 mm below the foundation near the building corner.

Jyväskylä, Helsinki and Sodankylä weather data. The weather data used is the new Finnish test year data modified from 2001. The material properties are show in Table 1.

Results

Ground floor U-value and optimal place for extra insulation

It has been common practice in Finland to calculate the thermal transmittance (U-value) of the ground floor without the ground soil heat resistance. However, as Figure 2 shows, soil properties do have an impact on the U-value of the whole construction, but the effect decreases dramatically when the base floor U-value increases.

The ground floor may also have additional edge insulation, usually an insulation plate an extra one metre wide, placed horizontally along the perimeter of the floor. The calculations showed that it is usually more economical, in terms of insulation material volume, to increase the whole floor insulation thickness. Figure 3 shows these two options with the same thermal performance. Increasing the whole floor insulation thickness from 20 mm to 261 mm has the same effect as additional horizontal 50-mm-thick edge insulation.

Frost penetration

An example of frost penetration calculations is shown in Figure 4. The temperature at the critical point (see Figure 1) was of interest. As Figure 4 shows, the frost insulation in this case is just enough to keep the temperature above zero even in an extremely cold F50 winter.

A number of simulations were performed to understand the influence of floor insulation thickness on the required frost insulation dimensions. The case shown previously in Figure 4 is one dot in Figure 5. It can be seen in Figure 5 that the floor insulation thickness has a big influence on the required frost insulation and therefore the new well insulated foundations need more frost protection than older less insulated foundations.

Figure 5 also shows the influence of external insulation in the foundation wall on the frost insulation dimensions. The external wall insulation reduces the need for frost insulation because the concrete foundation wall constitutes a thermal bridge from outdoor air to the building footing. The thermal bridge effect is much less if a lightweight concrete block foundation is used, which has smaller thermal conductivity than concrete.

An example of frost penetration near the building corner can be seen in Figure 6. These three-dimensional simulations showed that corners need more frost insulation than present guidelines suggest.

Discussion and conclusions

The results show that in respect of material use it is more beneficial to place extra insulation under the whole floor than in the foundation wall or horizontally along the perimeter. The frost simulations clearly showed that concrete foundation walls without external insulation need more frost protection than externally insulated foundations or lightweight concrete block foundations. The floor insulation thickness has also a big influence on the required frost insulation. The preliminary frost simulations near the corner showed that corners need more frost insulation than present guidelines suggest. Earlier studies have shown that a well insulated floor contributes to good thermal comfort and also decreases the moisture flow from the ground to the floor structure since the soil is colder and hence has lower water vapour pressure.

Acknowledgements

This study was funded by the EPS insulation industry.

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Existing building stock and renovation

Foreseeing energy efficiency potential in the building stock

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The building sector is a major consumer of energy with about 38% of the world's final energy being consumed in residential and commercial buildings. Relatively high savings potentials, if not the highest, have been identified in buildings compared to other sectors of the economy. Investments in energy efficient buildings are a cost-effective way to save energy. By 2020 a sampling of measures studied would in theory allow potential energy savings of 10–25% compared to no changes in buildings. By 2050 theoretical potential savings of about 40–50% are projected. In reality, however, saving potentials are often significantly lower.

Introduction

The role of buildings in both world energy consumption and energy efficiency potential is central. Residential and commercial buildings consumed 38% of the world's final energy and caused 33% of its CO_2 emissions in 2005, according to the IEA [2]. If energy consumption is high in the buildings sector, so is the potential for savings. The IPCC [3] and the European Commission [1] are among the latest to uncover the greatest energy saving potentials in buildings compared to other sectors of the economy, as is demonstrated by Figure 1. This is especially true in terms of primary energy, as buildings are at the very end of the energy chain and, thus, all effects of efficiency improvements are multiplied in each conversion upstream.

The Finnish residential building stock is 270 million m² of which 55% are single-family houses, 33% apartment buildings and 12% terrace houses. Commercial and public buildings comprise 82 million m² of developed areas.

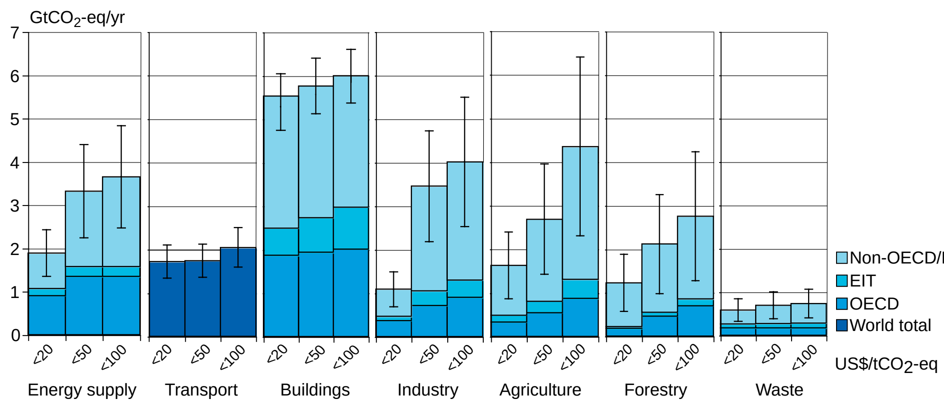

Figure 1. Estimated CO_2 emission mitigation potential for individual sectors as a function of the carbon price reported by the IPCC [3].

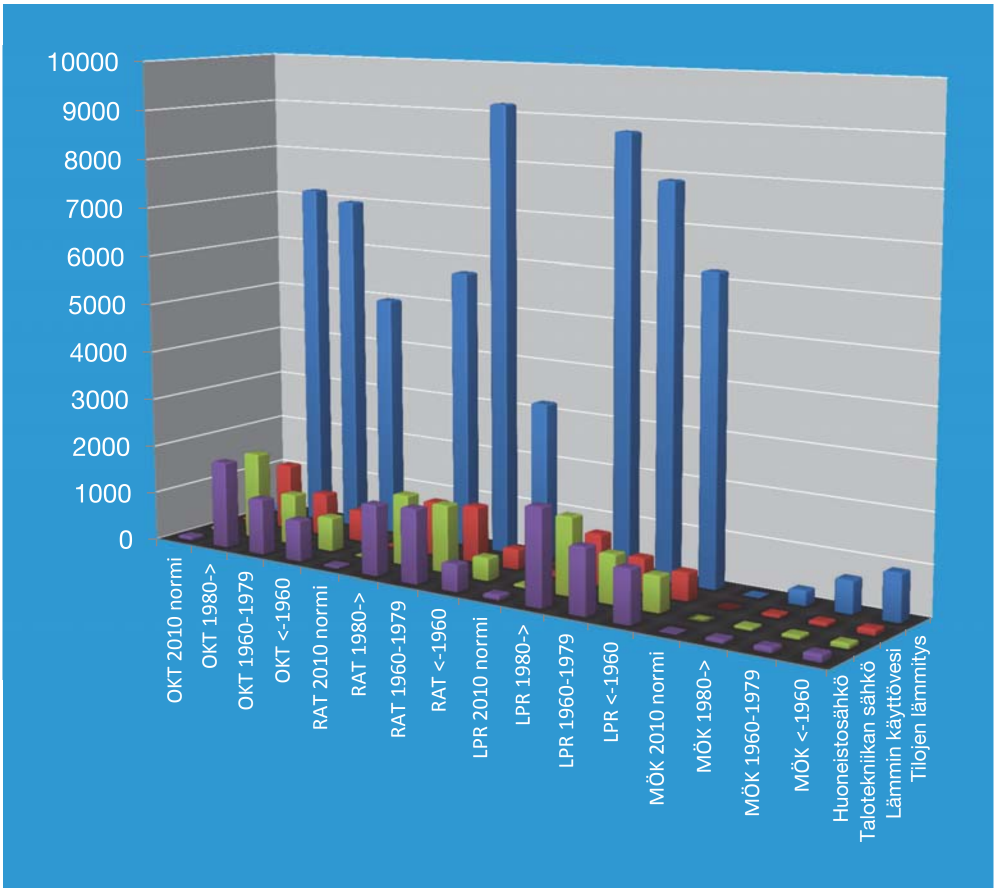

Figure 2. An example of output: a bar graph showing energy consumption in GWh per annum. From the far end towards the front, blue bars represent space heating, red hot water, yellow building services electricity consumption and cyan other electricity consumption in buildings. On the long horizontal axis are different age groups categorized by construction years and building types marked by the following codes: OKT for single family homes, RAT for apartment buildings, LPR for commercial and public buildings and MÖK for recreational dwellings.

District heating is the most commonplace heating source in Finland with a share of 43% of all heated areas. Oil and electric heating share second place with 22% each. Solid fuels such as wood and peat are used in 8% of buildings and the remaining 5% use other heating sources such as ground heat pumps [4].

Improving energy efficiency in buildings is one possible way to limit the consumption of energy and mitigate negative environmental effects. For the measures taken to limit consumption and protect the environment to achieve their maximal potential effect, it is imperative to first implement the measures that have the greatest effect with the smallest cost. To this end, economic analysis of the means at our disposal is called for.

Methods

To assess the effects of energy efficiency improvements in the building stock, a model of the building stock, called REMA, has been

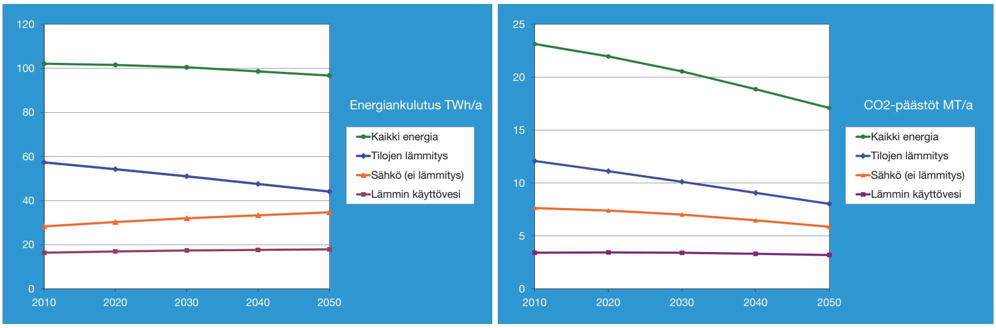

Figure 3. Energy consumption (left, in TWh/a) and CO_2 emissions (right, in MT/a) in a baseline scenario demonstrating the effects of continuing the construction of presently common building designs to perpetuity.

constructed. Previously researchers have usually evaluated individual energy efficiency measures with ad hoc methods, not taking into account possible interactions or cumulative effects and not necessarily using the same building stock data as a basis. REMA offers a built-in constant baseline of building stock that is based on national statistics and previous VTT forecasts of its future development. This means that various scenarios modelled with REMA are comparable in terms of basic data. An example of REMA results is shown in Figure 2.

The aim of REMA is to offer a big picture view of future development. The whole of Finnish building stock is included, excluding industrial buildings as these are commonly studied as energy consumers in combination with the relevant industrial process. For the user this means that input data is given for a few selected building types thought to be representative of different ages and uses. The default characteristics of these building types have been calibrated with data from national energy statistics.

A relatively limited number of inputs and a Microsoft Excel platform were chosen in part to guarantee user-friendliness. The calculation of a number of key indicators and the generation of graphs is instantaneous as the user inputs values in the forms, avoiding laborious and time-consuming cycles of modelling, assessment and remodelling. This offers the unique possibility to do quick what if estimations and relatively easy sensitivity analyses. REMA also uses a simplified model of the energy sector, which allows the calculation of primary energy and greenhouse gas effects for the scenarios.

Results

The use of REMA has been piloted in various ongoing projects. Preliminary results show that investments in energy efficient buildings are a cost-effective way to save energy. By 2020 the measures studied in this optimistic scenario would allow energy savings of 10–25% compared to no changes in buildings. By 2050 savings of about 40–50% are projected. Figure 3 shows a baseline scenario of the effects of the present building code on energy consumption in future.

Discussion and conclusions

REMA is an innovative tool that offers researchers the possibility to do projections of future energy use. It offers a modelling environment where interactions of various energy efficiency measures and the accumulation of their effects are automatically taken into account. User-friendliness and manageable dataset sizes have been key aims in the development of the model. Outputs of the model include projected energy end use for the whole building stock, primary energy consumption and CO_2 emissions.

Exploitation potential

Energy efficiency of buildings has become a central theme in the energy policies of both European countries and the European Union. It is clear that as decisions are implemented and new decisions are contemplated, the need for evaluating their effects will expand significantly. REMA will improve VTT's capability to evaluate the effects of energy efficiency improvements in its projects. The list of possible beneficiaries includes the various ministries and other authorities, government agencies, the EU, municipalities, institutional owners of buildings and the building industry.

Acknowledgements

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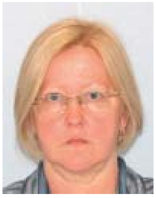
Upgrading building stock by boosting the renovation business



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The existing building stock has been typically renovated more because of functional and visual rather than technological obsolescence. Today this kind of renovation is not enough; upgrading is needed to fulfil energy efficiency requirements. The existing old companies have conveniently left room for new companies to develop to fill this niche in the market. The risk is that building renovation could remain a perpetual opportunity and that the building stock will eventually be replaced. This is also one among solutions – if supply doesn't meet demand, then the demand must reorganise to meet supply. Another option is that building renovation will produce a new industry with its own identity, production and process models.

Introduction

In order to achieve significant reductions in greenhouse gas emissions of building stock in the short term, improving energy efficiency cannot be limited to new buildings alone, but must also be extended to the existing building stock. Improving the energy efficiency of the existing building stock will create some level of discontinuity in the construction markets. The need to renovate in Europe will be driven by [1].

This paper focuses the renovation business within the construction industry [2]. Building renovation is a more demanding market when compared with new construction where only the technology of today can be used. The targets of the renovation are sites and areas developed at various moments in time. The customers are often different than in new construction and they pay more attention to the production process than to the final product.

Today the most skillful construction companies concentrate on new buildings. The renovation business is left to small local companies. The main question is, can the construction business be cultivated into energy renovation business or do we need an entirely new industry [3]?

Methods

This is a review studying how industries have responded to structural change and increasing demand. The material has been gathered by The Summon discovery service. The search words were "structural change", "technology change", "building stock", "refurbishment" and "industry evolution". Besides the construction market change, changes in other industries have also been reviewed. Based on reviewed theories, three possible paths have been formulated.

Structural change

With the development of new technologies, a number of different theories have emerged about structural change. The old sectors can split into new ones or the technology development can give birth to an entirely new sector. Various sector emergence mechanisms have their advantages and drawbacks. When an old sector is reinvented, the resources of the old sector can be harnessed for new activity.

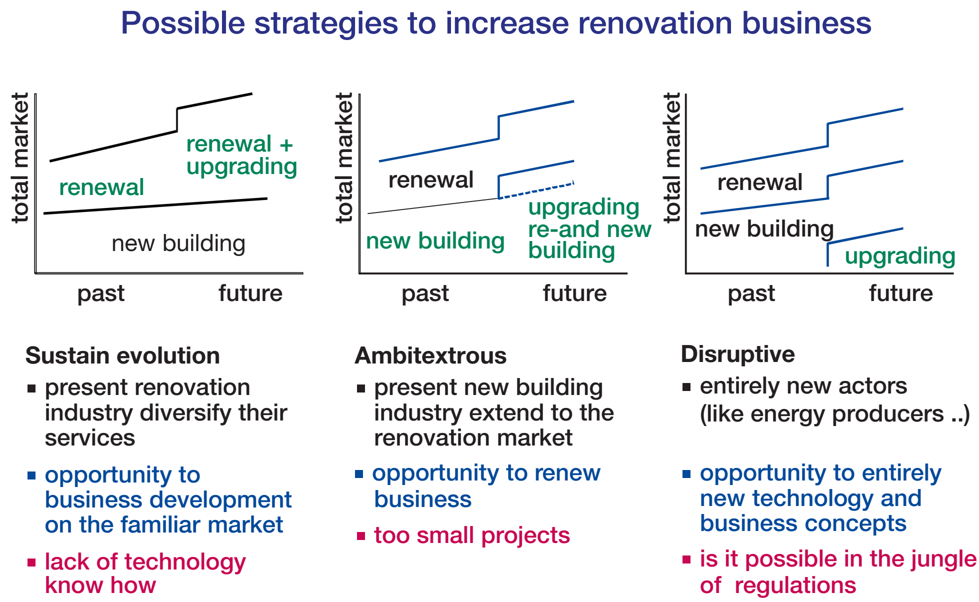

Figure 1. Possible strategies to increase renovation business.

When a sector is conceived from nothing it does not have an old sector's burdens, such as the need to "unlearn" practices or to unlock potential.

Three possible paths

Improving the energy efficiency of our existing building stock is an international political objective. The bodies responsible for formulating this objective do not make the decisions on repairs; that is the task of the owners of the buildings. However, decision-making can be accelerated by information dissemination, guidance, financial support and taxation. The public sector could provide a good example by improving the energy efficiency of public buildings.

In politics, owners and the authorities are considered to be the key operators. This is understandable, since the owners make the decisions and the authorities have a more comprehensive view, stretching further into the future, compared to individual companies and organisations. The required changes are not implemented by the authorities or owners, however. Consequently, nothing will happen if there is no one to implement the changes.

Sectors have been successfully renewed in a number of ways. Traditional sectors have been challenged by the emergence of new technologies that allow the same product or service to be produced more cheaply. Old sectors with a strong identity have also been able to reinvent themselves by questioning the status quo and changing their approach. The radical change in the attitude of customers is easier to achieve if there is new kind of supply. Based on the foregoing empiric and theory, three different paths are formulated (Figure 1).

Sustain evolution

The historical evidence favours the approach that construction companies create new markets rather than orientate themselves toward renovation. Companies wish to operate in a market environment they are familiar with and to manufacture the products they make best. This is one of the reasons why companies in the construction industry have been reluctant with regard to renovation and modernisation.

This kind of behaviour is necessary. Long-term growth needs both productivity growth in pre-existing sectors and the development of new sectors.

Building renovation already has a significant share of the total construction market in developed countries. The renovation market is the main business of many small companies. Energy efficiency renovations would be an option for developing their business. A big problem is that small companies do not invest in research and development.

Ambidextrous

Renovation can be seen as a substitute market that appears during a recession of the new construction market. Efforts to reduce greenhouse gas emissions are creating a huge, expanding market and also increasing the size of renovation projects. In the future especially those kinds of renovation projects will be reminiscent of new construction.

In general it is more sensible to renovate existing buildings when basing decisions on sustainable construction criteria. But in the aftermath of new construction in both developing as well as developed countries, the resulting building stock may exceed their financial capability and economy size. Demolishing old buildings and building new ones is a solution that some parties can justify financially.

Energy-efficient construction will need a new kind of know-how and solutions. Those could be useable not only in new buildings but in developing the building stock as a whole. This would create “ambidextrous” construction service producers.

Disruptive

In many other industries it is quite common to connect after-sales services to product. In building construction this never happens, in civil engineering rarely. Already prior to this energy efficiency agenda the existing companies conveniently left room for new companies to develop to fill the traditional renovation market.

Over time, different parts of construction have diverged into their own separate sectors. This trend may continue. New companies will eventually develop in response to emerging markets, while the traditional companies will attempt to mould the sector’s solutions to suit themselves.

At present and in future, there is order to new solutions. In the energy efficiency buildings roadmap the goal is that buildings will produce energy instead of using it. This vision definitely calls new kind of actors to construction market.

Discussion and conclusion

The significance of the built environment—and especially of buildings—increased when their potential for reducing energy consumption and cutting greenhouse gases was realised. Building renovation is a way to enhance the energy efficiency of the built environment and reduce the formation of greenhouse gases. Energy efficiency renovating will change the renovation market and will be a technological change.

Evolutionary economic theory about the splitting of old sectors and the formation of entirely new ones offers one path to future renovation business. The productivity development of old sectors (new building construction) and creation of new sectors (energy efficiency by renovation) is advisable from view point of economy.

Traditional sectors can be renewed by reinventing by questioning the status quo and changing their approach. This in possible way to the construction sector, which has own strong sector identity. It has moved away from simply meeting demand for new construction to producing a range of services. Reproduction is an advisable path from viewpoint of industry.

The objectives set for the energy efficiency of building stock and for reducing greenhouse gases will create both qualitative and quantitative challenges. Instead of small steps, a developmental leap is needed. This may require entirely new actors in the renovation market. Disrupting technologies are advisable options because they should improve productivity and create new business.

Reinventing the construction business is merely the first wave in which existing resources are harnessed to improve energy efficiency. The next wave will see the generation of a completely new industry. In time, buildings are envisioned to evolve from energy consumers into energy producers. Currently, the construction industry does not possess the skills to fulfil this vision – the companies of the emerging industry will fill this void.

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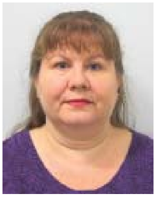
Succesful sustainable renovation business for single-family houses



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In the renovation of single-family houses there is a huge business potential on one hand, and also a remarkable potential for energy savings and indoor comfort improvement on the other hand. Successful business models are needed for sustainable renovation to promote the energy efficiency improvement of single-family houses in the Nordic countries and to facilitate the process for single-family homeowners. In the Nordic project, SuccessFamilies, new business models are suggested based on thorough analyses of the related factors.

Introduction

Energy renovation of existing buildings has a large potential for cost-effective energy savings. Residential buildings are responsible for 70% of the energy use in buildings in the Nordic countries. Single-family houses contribute to more than 50% of this. There is a substantial lack of business concepts for renovation services for single-family houses. [1]

The solution to the lack of business concepts for renovation services for single-family houses is first that renovation service packages should be developed to include standard technical solutions for energy efficiency improvements regarding different building systems and ages. Second, all other necessary services should be included, providing overall renovation solutions for people living in single-family houses (Figure 1). The new services must be supported by new features, like better visualisation, guaranteed prices and funding services. [1]

In order to create such new services, a Nordic cooperation project was started in 2009. The main objective of the Success-Families project (Successful Sustainable Renovation Business for Single-Family Houses)

Figure 1. The logo of the project seeks to express the connection between better energy efficiency, better indoor environment quality and lower costs of energy, and the direction in which the project is headed.

is to change the business environment in order to speed up the implementation of sustainable renovation of single-family houses. The resulting new service concepts will combine both the technical solutions, financing services as well as other promoting issues to overcome the behavioural, organisational, legal and social barriers that exist in sustainable renovation. [1]

Methods

Work towards the objective requires analysis of the existing sustainable renovation concepts, development of new concepts based on the analysis, development of marketing strategies for sustainable renovation by finding out the barriers and opportunities for sustainable renovation concepts and finally description of the new successful service models, based on the information from the analyses and marketing strategies. The project will run for three years, 2009–2011. [1]

Results

The term "sustainable" includes many environmental, social and economic indicators. In this project, sustainable renovation is defined with emphasis on primary energy use, but without disregarding the other indicators [2]: "A sustainable renovation concept is a concept that results in cost-effective renovation of a house with substantially better energy performance, coupled with a mainly renewable energy supply system and improved indoor environment. The level of total primary energy use should be preferably equal to a new house built according to standard building code requirements or better."

The first findings of the project showed that detached single-family houses account for a large share of the total number of dwellings in all Nordic countries. The typical single-family houses identified to have large primary energy saving potential almost descend from the same time period in each Nordic country. The calculations showed that energy efficiency measures in connection with the renovation of single-family houses have the potential for very large energy savings. Typical single-family houses can be renovated to the level of energy performance required for new houses today or in some cases to low-energy level. [2]

The studies also revealed that good technical solutions exist for sustainable renovation. The current renovation market, however, is dominated by a craftsman-based approach with individual solutions, traditional warehouses, "do-it-yourself-shops" and some actors marketing single products. Full-service renovation concepts in the Nordic countries have only recently entered the market. [2]

Through analysis of the existing full service concepts, some possibilities for improvements were found and a new full service concept was suggested by Tommerup et al. in 2011 [3] (Figure 2).

The SWOT analysis of the exemplary full service concept revealed that the most important strength seems to be the fact that establishing partnerships can create synergies in the "production process" and make the way to energy efficient renovation smoother. The most important weakness therefore is that no actors alone possess an overall competence to supply a holistic solution. Trustworthiness of the actors and total package versus neutral counselling also represents a challenge. The overall threat is the fact that a simple cost focus leads to limited renovation and reduced interest in the market.

Financial barriers to implement energy efficiency measures in Nordic single-family houses include the high investment cost of energy efficiency measures, even though such measures are cost-effective in a life-cycle perspective and lack of awareness about the possible energy efficiency measures, including their benefits. Also the financiers perceive energy efficiency projects as risky investments maybe because of their small size, the difficulty of predicting future energy prices and the level of energy savings.

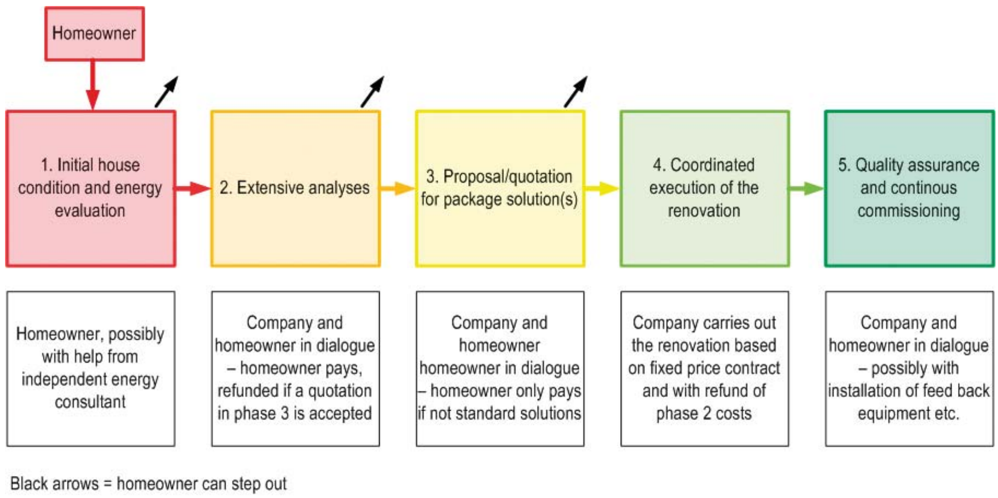

Figure 2. Full-service or one-stop-shop concept [3].

Among the several options to finance energy efficiency renovations in Nordic countries, the best option seems to be that one-stop-shop service providers collaborate with commercial banks to offer mortgage refinancing.

The first step to develop a new and innovative business model is to understand the customers' real needs. Regarding renovation, the home owner might not know his own needs, as he has no knowledge about what can be done to the house in order to make it more energy efficient. The decision-making process in this situation is therefore a "learning process". To "teach" and guide him through this, credibility and trustworthiness is a prerequisite. [4]

The work will continue with development of marketing strategies and description of pilot concepts.

Exploitation potential

The main target groups for the project results include single-family homeowners, insulation material firms, banks, heat pump providers, lighting manufacturers, pipework & ductwork providers, hardware dealers, ESCOs, energy suppliers, etc. When homeowners have easy access to the energy efficiency improvement measures, they will choose these options more often, which in turn will increase the sustainability of society. [1]

Acknowledgements

The project is a part of a Joint Nordic Call of Sustainable Renovation and receives funding from NICe and the Nordic funding organisations (Tekes, Formas and EBST). The partners of the project, who also contribute to the funding themselves are VTT Technical Research Centre of Finland, Danish Technical University (DTU) (Denmark), Segel AS (Norway) and Mid Sweden University.

The author wishes to thank Trond Haavik, Synnøve Aabrekk, Leif Gustavsson, Krushna Mahapatra, Henrik Tommerup and Svend Svendsen for producing the paper and collaborating during the project.

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Eco-efficient renewal of old neighbourhoods

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Apartment buildings built in the 1960s and 1970s represent the most energy inefficient building stock in Finland. Construction in that era was rapid, and more than 570,000 apartments were built. Now a high number of those apartment buildings require renovation of façades, ventilation, balconies and technical systems. Today these buildings and districts often need renovation both for aesthetic and energy efficient reasons.

Introduction

Peltosaari in the town of Riihimäki is an example of the unfortunate development of a neighbourhood (Figure 1). Although the neighbourhood has excellent public transport connections to the capital area and cities of Hämeenlinna, Tampere and Lahti, it has lost its position as an appealing and attractive place to live. Socioeconomic problems have increased, and the value of property has decreased at the same time. The unemployment rate in Peltosaari is very high compared to any other neighbourhood in Finland. The socioeconomic situation requires radical actions to prevent further social exclusion and segregation.

Renewal of Peltosaari

The City of Riihimäki has recognised the need to renew the whole neighbourhood of Peltosaari. The process is the city's strategy for future development. Tools available for the city administration are master plan development, site release and rental agreements, other agreements between the city and site owners, organisation of ideas and other competitions, cooperation initiatives with various stakeholders and implementation of innovative development projects.

Riihimäki has taken several steps to tackle the problem:

- Investment in research to find out the main socioeconomic and technical problems as well as problems concerning the urban structure of Peltosaari and its connection to its surroundings. Mutual understanding in Riihimäki concerning the importance of the renewal process of Peltosaari
- Dialogue between architects, planners, builders, inhabitants and Riihimäki
- Emphasis on people in renewal process: housing clinic, network, development of services
- Knowledge sharing

Figure 1. Peltosaari in the winter of 2009.

Figure 2. The winning entry 'Spinning Wheel' (left) and Peltosaari now (right).

- Several partners, social capital and networking values.

The research carried out produced ways and means to overcome the various problems and development of solutions on how to renew the neighbourhood.

The residents of Peltosaari are well connected to the process. People have access to various working groups involved in the renewal process. Information on the process is available through different channels, e.g. a specific meeting place for the residents.

The city of Riihimäki organised an ideas competition on the renewal. The competition resulted in nearly 80 entries. The aim of the competition was to map different possible solutions. The competition entries serve for decision-making and planning of new Peltosaari. The basis of the competition was open for free ideas on the future development.

Technical possibilities of renewal are tackled by demonstration buildings. As a result of a national competition on the passive house renovation of an old apartment house, the winning entry is being renovated in Peltosaari (Figure 2). The aim is to show the technical possibilities of improving the energy-efficiency and overall performance as well as the architecture of a concrete building.

The whole building typology of Peltosaari and architectural and usability shortcomings were also analysed. From the roughly 65 apartment buildings, seven model buildings covering the building stock were created and renovation measures were suggested. Various suggestions to improve the neighbourhood image and attractiveness were suggested as well (Figure 3).

Benefits of the renewal

Eco-efficient renewal of Peltosaari can restore the value of the neighbourhood. The assessment proved that the value loss of approximately EUR 70 million compared to near housing areas can be recovered and even exceeded by a value increase of EUR 100 million. This requires both thorough refurbishment of the building stock, demolition and re-building of the buildings in poor shape, and development of services, urban comfort and connections to the city centre of Riihimäki. The whole renewal process costs roughly EUR 80–90 million but at the same time it incurs costs savings in energy costs at an average of EUR 2 million a year. The level of present technology allows for a reduction of at least 70% in heating demand, and at the same time utilisation of renewable energy sources in the area. The development of the master plan allows for extensions to buildings and infill construction, thus enabling financing for the renewal. The location close to rail transport can be utilised in developing new jobs and services in the area.

Figure 3. Refurbishment can substantially improve the appearance and attractiveness of an old building

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Sustainability challenges of the urban building stock in eastern Europe

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Concrete residential buildings present the largest retrofitting challenge in eastern European countries and one of the best opportunities to substantially improve the energy efficiency of residential buildings on the large scale in the EU. Renovation of this building stock is unavoidable and an environmental necessity, but to make the renovation sustainable means more than improving energy efficiency. In this paper we highlight some of the challenges revealed while reviewing the building stock and the economic environment in Romania. We think these challenges are partly representative of other eastern European countries as well. The study is currently being extended to Poland and the Czech Republic to test this claim.

Introduction

A large proportion of the population of eastern Europe lives in prefabricated apartments built before the 1990s. Figures vary from country to country, but in urban areas in Romania, for example, out of 4.2 million apartments totalling a living area of 159,234,576 m^2, 3 million are made of prefabricated concrete panels covering a living area of 105,245,605 m^2. Thus, 71% of existing housing in urban areas are made of prefabricated concrete panels totalling 66% of the existing living space [1]. Most of these residential buildings were built during the years 1960–1989 [1].

The large number of units being designed and built using the same codes and construction practices opens up the possibility of having systematic deficiencies with a large number of buildings. We found that while these buildings are mainly structurally sound they have major problems with aesthetic aspects, division of internal space, conformance and energy efficiency. The deficiencies related to internal space distribution and inadequacies at district level present the strongest challenge to the sustainability of these neighbourhoods.

Our goal is to look for the adaptability of renovation experience in prefabricated concrete residential buildings in Finland for eastern European countries, with a special focus on technological (e.g. architecture, building physics & structure, safety), economic (e.g. business models), institutional and policy settings.

Methods

We tackle this complex problem from two perspectives. On the one hand a review of the building stock was carried out from a statistical point of view which also focused on the technical details. We also reviewed the historical design codes in order to identify sources of systematic errors generated by their use. On the other hand, the focus has been on the understanding of the commercial, institutional and regulatory environment, in order to find the right mechanisms for stimulating renovation activities. In the next phase we plan to compile information on the technological shortcomings, the available technical solutions and the market drivers in order to suggest strategies for sustainable renovation of the building stock. Our strategies are aimed at private companies.

Results of the technological review

For the sake of the analysis we divided the 1960-1990 intervals into three major periods. In these periods different types of projects were used depending on the state regulation applied. We identified three types of projects with large repeatability:

- 1962–1975: Characterised by a densification of about 70 units/hectare, with a distance between units of about 60 m. Housing units had related facilities (schools, shopping centres, green areas) and residential apartments were small.
- 1975–1982: Built-up with increased densification of 300 units/hectare and a distance between units of about 15 m. There were fewer facilities for housing units, with commercial space provided at ground floors facing main streets. Residential apartments still had a relatively small area.
- 1982–1989: Characterised by a densification of about 80 units/hectare and a distance between units of about 40 m. Housing units had related facilities (schools, nurseries, shopping centres, green areas) and residential apartments were large.

Based on the review of the major building typologies built in these periods, the following systematic shortcomings were found related to the comfort of living in residential neighbourhoods:

- location of neighbourhoods relative to town centres, accessibility, traffic and parking, lack of supporting facilities (e.g. shops, schools, nurseries, etc.) for the housing units;
- disadvantageous distribution of the existing interior space of apartments and inadequacy of auxiliary spaces (basements, shared annexes, etc.);

Figure 1. Allocation of green spaces as parking; the original design did not foresee sufficient parking spaces

- lack of accessibility for persons with disabilities and the elderly;
- poor thermal comfort and energy efficiency;
- non-unified refurbishment interventions on the housing units.

The residential areas were designed with green spaces and adequate parking according to the time of build. However, the transport system was not sufficiently developed, and the number of families owning cars has increased. In crowded districts green spaces were quickly assigned as parking areas (Figure 1), and removing the cars from the streets should be a starting point for district planning. Buildings have been developed with a very rigid system regarding spatial organisation (prefabricated panels) and most partitions could not follow the changing requirements of the homeowners over the years. The spaces became rigidly inconvenient, with many areas undersized compared to current requirements (e.g. living space, terraces) and some spaces becoming redundant in terms of functionality. Thus, balconies are used as storage areas (Figure 2), hallways and toilets are restrictively small for the expected comfort of today. If these building typologies are to survive, solutions are needed for reconfiguring these spaces.

Noise and thermal insulation made with lowered targets compared to current standards also retard efficient use of the buildings.

Figure 2. Improper use of balcony space as storage areas

Classic thermal insulation used, for example, was 8 cm polystyrene. Most buildings are over 30 years old, and the materials used for thermal insulation are outdated. In addition most external façades have not been properly maintained over the past years. Using extended rehabilitation (i.e. engineering services, new thermal insulation and advanced technologies like solar panels and heat pumps, shading and ventilation systems) energy efficient may increase by 85% [2].

Unfortunately, in most cases the renovations in the recent past have been uncoordinated, without a building level plan, which can degrade comfort. A good example is the ventilation system, which was designed to function based on the openings in the façades, coupled with ventilation achieved by a stack effect. During the maintenance of kitchens and bathrooms these ventilation tubes may have been interrupted, and when windows were replaced with double-glazed PVC the reduction in the ventilation capacity was seldom taken into account. This resulted in insufficient air exchange in bathrooms and kitchens, causing excessive humidity to accumulate and indoor air quality to deteriorate. Lately, with additional a/c systems (Figure 2), the ventilation of the buildings has been radically changed with no design to support the change. We observed that these types of individual interventions are driven by the structure of ownership, which is not facilitating cooperation between owners [4].

Discussion and conclusions

The main conclusions of our study point to very serious challenges facing the sustainability of neighbourhoods with prefabricated panel buildings. The difficult challenges relate to the rigidity of the space distribution, at least on equal footing with the energy inefficiency of the buildings. Readily available technological solutions exist for energy upgrading [3], while the need to reconfigure the internal spaces has no feasible solutions. Unless a broader view is adopted energy interventions may be wasted on socially and economically unsustainable neighbourhoods/buildings.

Exploitation potential

With the project, we improve the understanding of the potential of retrofitting measures in the eastern European setting and evaluate the opportunities of using Finnish expertise to achieve cost-effective, ambitious energy renovations. The context is also very important; only by strengthening local knowledge related to technology and construction practices, the institutional setting and the market environment can companies be put in a position to compete in this market.

Acknowledgements

The research has been funded by Tekes, RUUKKI and VTT in the ERACOBUILD framework. The substantial contribution to this work of Viorel Ungureanu, Alexandru Botici and Iulia Tuca from the Politehnica University of Timisoara is gratefully acknowledged.

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Managing the indoor environment and energy efficiency in historical buildings

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In Italy there are a lot of historical buildings that are relevant in cultural, architectural and artistic terms. Such heritage needs a constant process of renovation to keep the buildings secure, safe and efficient and to make them suitabled for host offices, museums, events and art exhibitions. Unfortunately, most of these renovation activities consider only either the security issues or outward appearance or the indoor conditions or the installations; all actions are independently designed and implemented, and an integrated approach is missing. Italian public bodies strongly need support and guidelines to write optimal tenders for building refurbishments.

In this paper, we present a methodology for assessing the state of building and defining tender requirements. The methodology is based on the definition of performance indicators, related to security against human threats, thermal and hygrometric quality, living indoor conditions, air quality, lighting conditions, resilience and management of emergencies in case of natural disasters, accessibility, etc. A very important aspect that the methodology considers is compliance with regulations. Also some economical aspects will be considered.

The methodology is implemented in a decision-support software tool that presents the different indicators in relation to each other, evaluating performance indices. These indices could be used to simulate different solutions and help choose the best one. Particular attention is paid to how the results are shown to end users.

Introduction

In Europe and in Italy in particular, there are a lot of historical buildings with great importance to the culture of the people from an artistic and architectural point of view. They are complex buildings with numerous rooms and spaces that could host different activities with different performance requirements regarding the indoor performance which pose some challenges from a conservation point of view.

This paper describes a methodology for assessing the actual status of the building and to define proper tender requirements for renovation works in order to keep the building efficient and able to support demanding needs (climate, comfort, accessibility, ICT connectivity, etc.), based on the methodology of the FP7 Perfection project.

Historical buildings

Historical buildings are typically employed for cultural activities (museums, art galleries), but they could also represent a good investment in the real estate market. Insurance companies, banks and foundations use them as their headquarters and they often host offices of public bodies as well.

All these activities have different requirements in terms of indoor environment performance. Outward appearance, security issues, indoor conditions, ICT connectivity and equipment installation are only some examples of elements that must be considered for proper conservation of a building. To maximise the results and the building's overall performance an integrated approach is necessary in order to analyse the building structure as a whole. Owners and managers need help for:

- assessing the current status of the building
- defining proper management plans, including preventive conservation
- designing restoration works to improve indoor performance
- establishing guidelines for writing tenders.

The modernisation works must comply with national and international regulations aimed at preserving historical building aspects, such as the artistic and cultural value and be as little invasive as possible.

Performance assessment methodology

The methodology aims to assess the current overall performance of the whole building, analysing the possible relevant aspects in an integrated approach that can be summarised as:

- Indoor environment quality: analysis of all the parameters that play an important role in guaranteeing that the building provides optimal conditions with regard to the appropriate use classifications.
  * Comfort: evaluation of factors important for determining the well-being of people working or visiting the building, e.g. temperature, relative humidity, presence of gases, etc.
  * Security: assessment of the risks against malicious human actions, identification of the proper devices to install, definition of procedures for managing emergencies due to natural disasters.
  * Accessibility: presence of structures that facilitate the access of people to the building.
- Compliance with regulations: guarantee that all the refurbishment actions comply with national and international law and regulations.
- Cost management: assessment of the costs of day-to-day operations to keep the building in working order at all times, with the evaluation from the installation of a system to the disposal at the end of its life cycle.

Performance indicators

The performance indicators of the indoor environment could be classified by taking into account the following perspectives:

- Owner perspective: indicators related to building structure in order to ensure the security and safety of people and objects inside the building.
- User perspective: parameters relevant to the comfort of people inside the building, mainly considering the environment and the services that can be found.
- Artwork perspective: indicators related to a proper conservation of artwork inside the building, taking into account national regulations and compatibility between different objects and the comfort of people.

Decision support tool

The described methodology should be implemented as tools to encourage their use in projects. This chapter provides short overviews on two decision support tools. The first one, EcoProP software, is a commercial product, while the other, Perfection portal, is currently under development and therefore a short introduction to its functionality is presented.

EcoProP software

EcoProP is an application that is based on a performance approach, where emphasis is put on product performance instead of technical specifications and requirement management which helps identify the customer's true needs. Its third generation version draws from numerous international projects and its contribution in Finland on indicator assessment. EcoProP's strength is its systematic requirement management process; user needs are first collected, then defined as requirements and finally verified by the end result. This systematic process is provided to the user through a hierarchical structure, where requirements are described in a database that enables users to build new sets from previously developed sets. The main functionality is that custom reports can be produced individually for project stakeholders. These reports may include exports from one design alternative or two alternatives may be compared.

EcoProP has been used in schools, nurseries, residential housing, shopping centres and office buildings. Simplified cost and environmental calculations help to understand the trade-off between higher construction costs and lower life-cycle costs. Altogether, EcoProP has proven to be a valuable aid in implementing the performance approach in Finland.

Perfection portal for indoor performance

The second decision support tool, Perfection portal, is focused on indoor performance. The development work for the portal is currently ongoing at http://indoorperformance.net. The baseline is that it is used to distribute knowledge on key indoor performance indicators (KIPIs) described in the Perfection project, an EC-funded FP7 coordination action for performance indicators for the health, comfort and safety of indoor environments. The strength of the tool is its innovative and user-friendly approach which has large potential to attract wide consumer interest.

Perfection portal has an ambitious goal of increasing awareness of indoor performance. The portal is a web application that eases networking and has been built with open source content management tools. Second, it also has a stronger business focus. In addition to managing indicators it also links to a product perspective enabling builder practices and related provider offers to be shown to users. A new promotional strategy is used to engage material suppliers and manufacturers more significantly in indicator assessment. Perfection portal is used for indicator assessment, and results are visible to the public in a building showcase.

Future works

The application of the performance indicators set to Villa Reale di Monza can help to validate the project choices. This site is a very suitable case as it is undergoing a huge renovation work that will involve the whole building complex with a very high number of rooms and spaces. Owners needs help to define tender requirements and the presented methodology is fully suitable for this scope.

Moreover, these experiences could aid in further developing the indoor performance indicator system in the Perfection project, helping to identify the most relevant optimisation of the framework. Furthermore, the software tool could be further developed to better meet the requirements and to be used for the systematic management of the indoor performance of historical buildings.

Conclusion

There is a huge potential in improving effective use of Europe's cultural heritage by managing the indoor performance of its historical buildings. This paper presents an approach using indoor performance indicators based on the framework defined in the EC-funded Perfection project, with customisation due to the peculiar characteristics and needs of historical buildings. The methodology has been implemented in software tools to enable objectives to be set and actual indoor performance to be assessed.

This integrated approach aids owners and managers in defining systematic management plans for historical buildings.

Acknowledgements

This article was edited from a paper presented at the SB10 Conference in Prague in June 2010. The author wishes to thank the co-authors Sergio Olivero and Federico Stirano from SiTI in Italy for producing that paper and collaborating in the Perfection project that is supported by the EC in FP7.

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A Nordic guideline on sustainable building refurbishment

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The two main focus areas in developing the sustainable refurbishment guideline have been contents and structure. The contents are carefully considered and put into context to give the user of the guideline the best insight into what to focus on in order to achieve sustainable building refurbishment. The structure of the guideline has also shown to be of high importance. The guideline is divided into six phases: "Finance and procurement strategy", "Requirement setting", "Selecting the team", "Managing the supply", "Operation and maintenance" and "Monitoring, enforcement and evaluation". The first phase (strategy) is most important as a tool for changing the client and is divided into seven steps. The second phase gives guidelines for setting requirements. The methodology is based on approximately 60 sustainability indicators and a PDCA-model (Plan, Do, Check, Act) which are also of high relevance for phases 3–6 of the guideline. Further work on customising country specific or even client-based guidelines and analysing experiences from implementation in multiple case studies is still to be done.

Introduction

In the building sector, reducing energy demand and changing energy sources from fossil fuels to renewable energy have been the main actions to reduce environmental impact. This huge focus on energy reduction is important, but there are also a lot of other sustainable indicators that have to be taken into account when aiming for sustainable building refurbishment. This paper describes a Nordic Guideline on sustainable building refurbishment developed in the Nordic SURE research project (2009–2011) by building researchers from Denmark, Finland, Norway and Iceland. The guideline for early phase planning was created based on findings and conclusions in 10 different case studies, internal and client-specific discussions/workshops combined with the researcher`s theoretical and practical experiences in and knowledge of building refurbishment. The guideline contents and structure is created through internal discussions and brainstorming in workshops in the SURE research project

Methods

Figure 1 shows an outline of the methodology used in this study. Ten different case studies in Denmark, Finland, Norway and Iceland were investigated in order to find sustainable solutions for refurbishment. Further, thorough discussions with the clients regarding ambitions, strategy, energy reduction, future use and numerous other parameters were conducted. For several of the case studies, a condition survey was carried out to get an overview of the performance of the building(s). Thereafter, discussions on recommended measures, overall client strategies, procurement strategies, client as a change agent and the use of guidelines in the specific refurbishment project are summarised in a case study report. The guideline on early phase planning

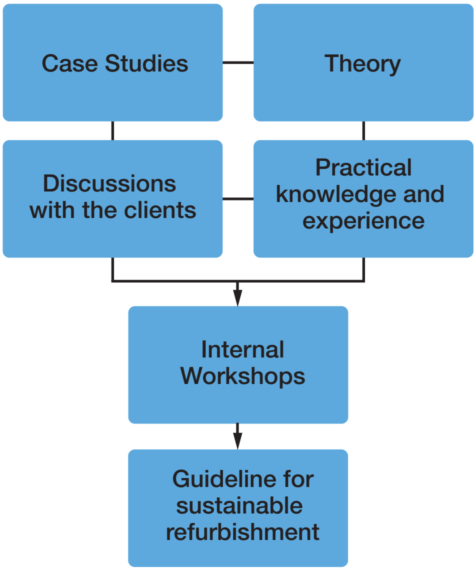

Figure 1. Outline of the methodology.

described here was created based on findings and conclusions from the case studies, internal and client-specific discussions/workshops combined with the researcher`s theoretical and practical former experience in and knowledge of building refurbishment. The guideline contents and structure were created through internal discussions and brainstorming in workshops in the SURE research project.

The guideline

The guideline is divided into six phases: "Finance and procurement strategy", "Requirement settings", "Selecting the team", "Managing the supply" "Operation and maintenance" and "Monitoring, enforcement and evaluation". The first phase is definitely the most important phase - the strategic phase. This phase is divided into seven main steps. First, the client (building owner) has to create a strategy for the refurbishment project. If the client already has an overall strategy, it should be reviewed and specified to suit the specific project. Second, the finances for the project must be set. Which finance models should be used, and which are the finance boundaries? These are the most important questions, as ambitious refurbishment projects are often put on hold because funding is not clarified in advance. Third, when the finance strategy is set, the client has to define sustainability and answer the question, what is sustainable for this specific refurbishment project? The analysis of sustainability will be based on numerous different indicators. At this point the overriding criteria for sustainability is defined, and the client is now (fourth step) encouraged to choose the level of ambition for the project based on different parameters like energy quality, technical standard, adaptability, etc. Fifth, a condition survey of the building is highly recommended to create a performance profile of the building. When the condition survey is finalised, the client should review the level of ambition set in step four and finalise a revised ambition level based on the condition survey and the strategic analysis (sixth step). Finally, a list of priorities should be conducted for the specific building (seventh step).

When the strategic phase is finalised, the client is ready to set the requirements for the refurbishment project. Here, the client has to set quantitative values or choose between different alternatives for approximately 60 sustainable refurbishment indicators, e.g. delivered energy (kWh/m^{2}y) and indoor climate (CO2-ppm). In the SURE guideline, the indicators and requirements are chosen to be mostly quantitative. This will help the client to set measurable values for the project. To try to give a helpful tool for planning, setting requirements, measuring and forming procurement documents, the SURE guideline uses the PDCA principle: Plan, Do, Check, Act. PDCA is an iterative four-step management process typically used in business. The concept of PDCA is based on the scientific method, as developed from the work of Francis Bacon.

Discussion and conclusions

The main reason for creating such a guideline is to give building owners (clients) a helpful tool for making the right choices when aiming for sustainable refurbishment. Very often, the clients have high ambitions, but less finances. In addition to finances, both the quality standard of the building and the possibilities and restrictions have to be highlighted before finalising the ambition level. By going through the guideline, a performance profile of the building(s) will be set. This profile should improve the awareness of sustainability with the help of indicators. The guideline can also be used as a checklist. One of the biggest challenges in developing a common Nordic guideline has been the differences in defining sustainability and the national requirements, building codes, climates, building practice, etc. in different countries. Reducing the energy consumption in buildings is of high priority in most of the countries, but because of the use of geothermal energy, this is not as important in Iceland. It has shown, though, through investigations of the different case studies in Denmark, Finland, Iceland and Norway that the most challenging part is the need for client changes. Therefore, the SURE guideline focuses on the client as a change agent in a six-phase process, starting with the two most important phases "Procurement and finance strategies" and "Requirement settings". Furthermore, the guideline focuses on sustainable indicators to help the client be aware of important parameters to achieve sustainable building refurbishment. The methodology is based on a well-established PDCA model (Plan, Do, Check, Act).

Exploitation potential

This is the first version of the SURE Guideline. Further work on customising country-specific or even client-based guidelines and analysing experiences from implementation in multiple case studies is still to be done.

Acknowledgements

This paper was written within the framework of the ongoing Nordic research project SURE – Sustainable Refurbishment (2009–2011) and as a part of the ongoing SINTEF research & development programme "ROBUST – Robust Envelope Construction Details for Buildings of the 21st Century" (2008–2011). The authors gratefully acknowledge the assistance given by NICe (Nordic Innovation Centre), all construction industry ROBUST partners, the Research Council of Norway and RANNIS – Icelandic Centre for Research. The authors would also like to thank all clients for valuable discussions and input and for making specific case buildings available for investigation.

Acknowledgements

This article was edited from a paper presented at the SB11 World Conference in Helsinki in October 2011. The author wishes to thank the co-authors Anders-Johan Almås and Svein Bjørberg from Multiconsult in Norway, Peter Vogelius and Kim Haugbølle from SBi in Denmark and Jyri Nieminen from VTT in Finland for producing that paper and collaborating in the SURE Joint Nordic Call project where the Finnish part is supported by Tekes.

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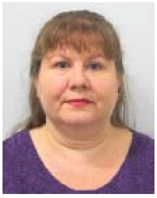
Users’ influence on energy efficiency and thermal comfort

Intelligent use of buildings' energy information



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The IntUBE project will increase the possibility of reaching the European Commission's energy efficiency goals by facilitating more efficient use of the existing building stock. IntUBE stands for Intelligent Use of Buildings' Energy Information. The results of the IntUBE-project are expected not only to enhance the comfort levels of building users, but also to reduce overall energy costs through better energy efficiency. The IntUBE project was a European cooperation between twelve partners from nine European countries and received funding from the European Commission. The project was implemented between May 2009 and April 2011. The IntUBE consortium spans key research partners from northern to southern Europe including SMEs committed to exploiting the results of the project. The project was coordinated by VTT.

Introduction

Buildings are one of the major contributors to energy use and CO_2 emissions in Europe. Considerable improvement of the energy efficiency of the building stock is therefore one major goal for the European Parliament and the European Commission. The twelve partners in the European FP7 project IntUBE – Intelligent Use of Buildings' Energy Information – were committed to working towards this aim: "IntUBE will lead to increased lifecycle energy efficiency of the buildings without compromising the comfort or performance of the buildings by integrating the latest developments in the ICT field into intelligent building and neighbourhood management systems and by presenting new ICT-enabled business models for the provision of energy information-related services." [1]

Methods

The work focused on the development of the Energy Information Integration Platform (EIIP) but also concentrated on analysing, evaluating and developing concepts, methods and tools for the intelligent use of buildings' energy information, after which the most promising strategies were demonstrated. In addition the focus was on producing information about the kind of development needed on the software or hardware in order to enable the implementation of the new business models. After research and development the separate technologies were integrated and validated, and a selection of the systems was demonstrated. The dissemination also aimed to provide feedback on the research. The individual developments from the different parts of the project together constitute the IntUBE system. They were interconnected in many ways and their positioning in the context of the IntUBE project is illustrated in Figure 1. [2]

Results

IntUBE developed tools for measuring and analysing building energy profiles based on user comfort needs. These will offer efficient solutions for improving the use and management of energy within buildings throughout their lifecycle. Intelligent building manage-

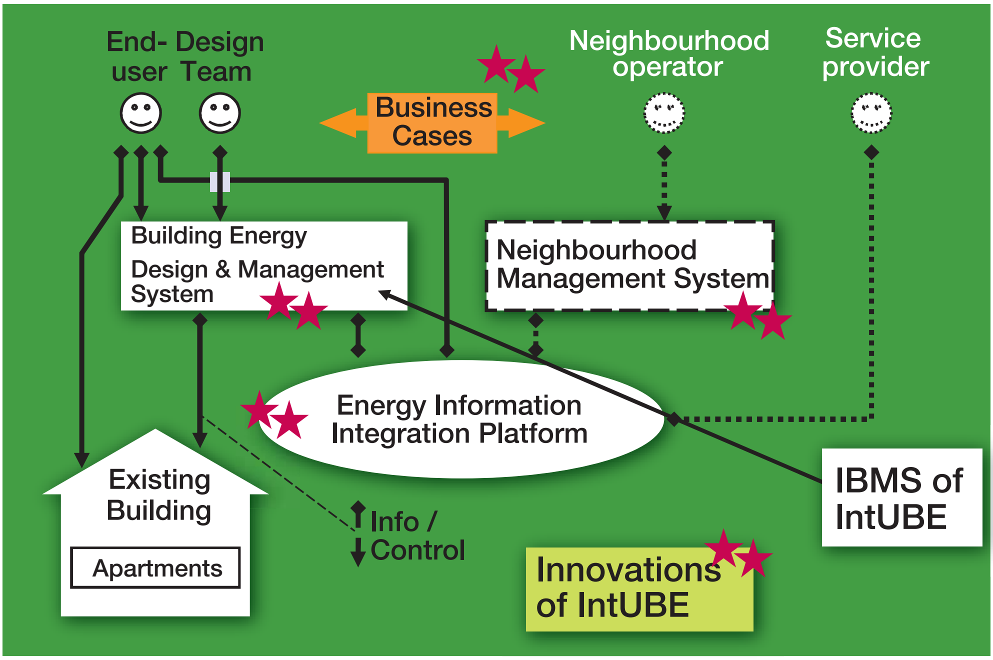

Figure 1. The context of the IntUBE project [2].

ment systems were developed to enable the real-time monitoring of energy use and optimisation of energy performance. They will, through interactive visualisation of energy use, offer solutions for user comfort maximisation and energy use optimisation. A tool for neighbourhood management was developed to support efficient energy distribution across groups of buildings [3]. This will support timely and optimal energy transfers from building to building based on user needs and requirements. New business models to make best use of the developed management systems were drafted. [2]

An essential part of the work is the development of an energy information integration platform (EIIP) enabling the handling of information coming from different sources and needed by different stakeholders and systems. In order to bring about energy-efficient behaviour and decisions among users of different applications, an easily understandable user-interface is a necessity and has been realised within the IntUBE project. [2]

The logical interdependence of the energy information integration platform services/business model/user behaviour/improved energy performance was verified in three demonstration scenarios, demonstrating that the use of the building's energy information through the energy information integration platform (EIIP) developed in the project brings about new services along with business models which improve the energy efficiency of buildings. [4]

Discussion and conclusions

The new business models and ICT tools developed during the IntUBE project constitute the IntUBE system and will enable the multi-phase, multi-role management of buildings' energy information. The IntUBE System will support improved building performance and efficient local grids using natural energy resources in an optimal way. Environmental impacts and life-cycle costs for energy will be reduced. Every stakeholder (e.g. architects, building owners, users, energy service providers or maintenance service providers) will substantially benefit from the IntUBE system. [2]

Exploitation potential

The IntUBE energy information integration platform (EIIP) is based on the combination of energy data coming from different sources of the whole building life cycle and its associated integration approach as a main outcome of IntUBE. The EIIP itself will be an open-source solution and be provided to external stakeholders after validation. [2]

The individual exploitation plan prepared during the project describes the knowledge, products and services which are based on IntUBE results and will be used for exploitation by individual project partners. In all, 24 exploitable results (exploitable knowledge, products and services, including consultancy) were recognised by the different partners, and these were analysed. For each exploitable object the partner interested in exploiting it, the target group and sector, planned IPR protections, the IPR owner, other partners involved in developing the exploitable object and the time until commercialisation were listed. Also a distinction between commercial and scientific exploitation has been made. Also analyses of how the IntUBE results will contribute to business improvement and extension were conducted. [2]

In early stages of the project participants realised that due to the wide scope of the project and the strong role of research organisations in the team, many of the findings are related to the future development needs in this field. This was further confirmed in the review meetings of the IntUBE project: the reviewers stressed that this project would open new research fields and show directions to be investigated more than develop specific equipment for isolated problems. [2]

Acknowledgements

The research was funded by the European Commission (FP7 ICT programme, Grant agreement no. 224286) and the participants, which are: VTT (FI, coordinator), CSTB (FR), Universitat Ramon Llull Fundació Privada (ES), Merloni Termosanitari s.p.a. (IT), Pöyry Finland Oy (FI), SINTEF (NO), TNO (NL), University College Cork (IE), Università Politecnica delle Marche (IT), University of Teesside (UK), Vabi Software b.v. (NL), University of Stuttgart (DE).

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Occupant aspects of improving the energy efficiency of buildings

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Environmental issues are putting more and more pressure on improving the energy efficiency of the built environment. From a technological point of view, there is a huge energy saving potential in both existing and new buildings. In practice this means better insulated building envelope solutions, improved ventilation heat recovery, and the reduced energy consumption of different house appliances. These expected changes will require updating both building service system concepts as well as design and dimensioning criteria of these concepts. To ensure occupant satisfaction, it is recommended to include not only energy balance, but also human thermal sensation aspects when updating concepts and dimensioning criteria of building service systems for energy efficient buildings.

Introduction

It seems that energy efficiency is becoming a key driver for the whole building and construction industry in the near future. Therefore, new construction and building service concepts are obviously needed. Most likely better thermal insulation levels and at least partly new heating and cooling solutions will be adopted. To avoid unpleasant indoor environment outcomes in future buildings, a more holistic approach focusing on occupant aspects is recommended. Since it seems that thermal issues will also be the dominant cause of indoor environment complaints in the future, it is very important to really understand the true nature of both physical and physiological phenomena influencing human thermal sensation and comfort.

Thermal comfort can be estimated with several methods. The widely used international standards ISO 7730 [1] and ASHRAE 55 [2] use Fanger's PMV (Predicted Mean Vote) method for calculating thermal comfort [3]. Fanger's PMV method was developed based on laboratory and climate chamber studies estimating human thermal comfort in buildings [3]. Fanger's method is a good starting point for estimating thermal comfort and has been widely used to calculate indoor environment conditions. However, the PMV method is only applicable to steady-state, uniform thermal environments. It cannot take into account time-dependant phenomena or the local examination of different body parts. To estimate thermal comfort in transient conditions accurately, an adaptive thermal comfort approach should therefore be used. Examples of adaptive methods are human thermal models which take into account the effect of human thermoregulation on thermal sensation and comfort. This paper describes the basic features of a new advanced human thermal model (HTM) developed at VTT, which is integrated with a building simulation tool.

Methods

The Human Thermal Model (HTM) is a module of a non-commercial VTT house building simulation tool, both of which are developed at VTT. The VTT house building simulation environment is used for modelling thermal interactions between the human body and the

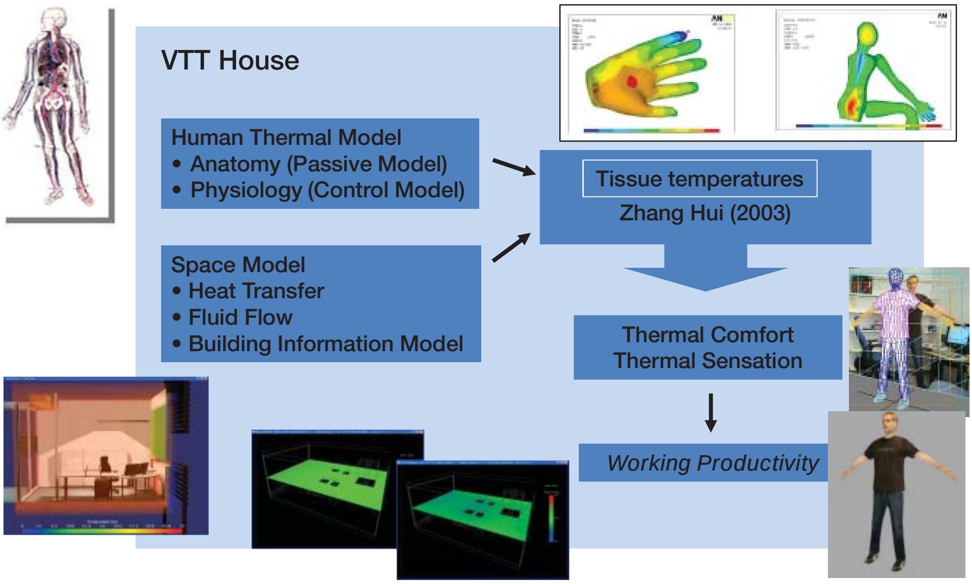

Figure 1. Physical interactions between an occupant and her/his environment, corresponding physiological behaviour, resulting tissue temperatures and predicted thermal comfort and thermal sensation index calculations.

surrounding space including convective, radiation and evaporative heat transfer [4]. Both the human body and the surrounding space are described by a thermal nodal network, which consists of node capacitances and inter-nodal conductance or heat sources/sinks (e.g. net radiative heat gain components). The transient node temperatures are solved using the finite-difference heat balance method.

HTM is based on the true anatomy and physiology of the human body and estimates human body tissue and skin temperature levels. HTM divides the human body into sixteen different parts: head, neck, upper arms, lower arms, hands, chest and back, pelvis, thighs, lower legs and feet. The body parts are further sub-divided typically into four realistic tissue layers (bone, muscle, fat and skin) by concentric cylinders. The functional tissue layers are also connected to adjacent body parts by a blood circulation system, which is used for physiological thermoregulation of the whole body. The passive and control system of HTM and the validation of the HTM tissue temperature calculation is presented by Holopainen and Tuomaala [5].

The thermal sensation and thermal comfort estimation methodology by Zhang Hui [6] is integrated in HTM, allowing much more detailed thermal sensation and thermal comfort index estimations than Fanger's traditional methodology. This integrated method enables the quantitative analysis of the significance of

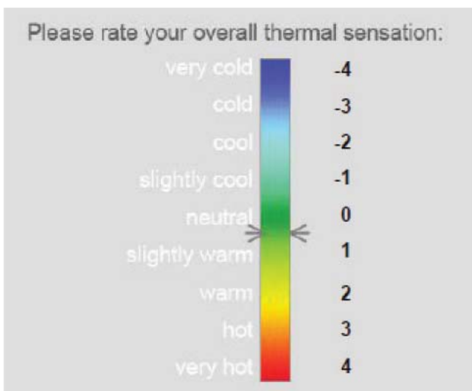

Figure 2. Thermal sensation scale [6].

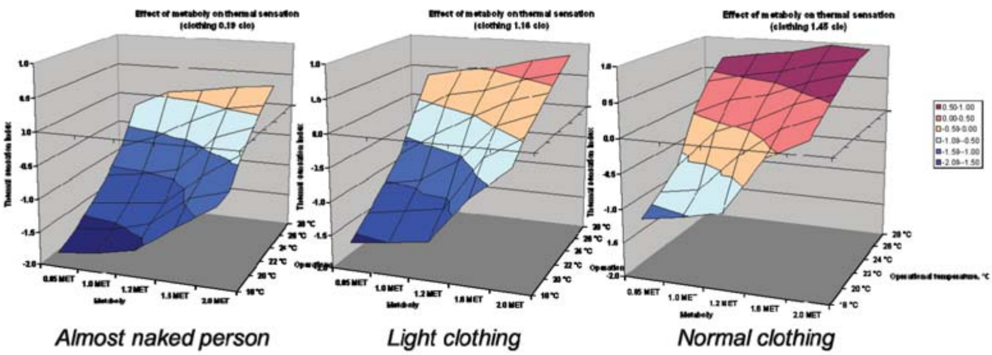

Figure 3. Effects of clothing (three parallel pictures describing different clothing levels), metabolic rate (first horizontal axes) and operative temperature (the second horizontal axes) on the overall human thermal sensation index (the vertical axes; negative values: cool/cold; zero value: thermal neutrality; positive values: warm/hot).

both external (air and surface temperatures, air velocity and humidity) and internal (clothing, metabolism) boundary conditions on thermal sensation and comfort (Figure 1).

Zhang Hui [6] has developed a new thermal sensation model to predict local and overall thermal sensation in non-uniform transient thermal environments. The overall thermal sensation is calculated as a function of the local skin temperatures and the core temperature, and their change over time.

The sensation scale by Zhang is presented in Figure 2. When the local skin temperature differs from the local skin temperature set point, the sensation reaches the sensation scale limits between +4 (very hot) and -4 (very cold). Positive index values indicate various degrees of “hot” sensation and negative values indicate “cold” sensation. The index value equal to zero indicates thermal neutrality. The index values between -3 and +3 are comparable to the ASHRAE thermal sensation scale [7].

Results

Figure 3 presents the thermal sensation index prediction results of a test case, in which clothing levels, metabolic rate and operative temperatures were varied. The three different clothing levels were almost naked (0.19 clo), light clothing (1.16 clo) and normal clothing (1.45 clo). The metabolic rate varied between 0.85 MET (corresponding to a resting person) and 2.0 MET (standing person, medium activity), and operative temperature varied between 18ºC and 28ºC.

Discussion and conclusions

With the help of this new HTM methodology, the effects of both internal and external boundary conditions on human thermal sensation can be estimated. This is due to thorough integration of the building simulation and HTM calculation tools, allowing true physical interaction between an occupant and her/his environment. This is an exceptional foundation for estimating individual thermal sensation based on even individual anatomy, clothing, location and orientation in different spaces with flexible boundary conditions.

Exploitation potential

This prediction and estimation environment of individual thermal comfort can become extremely beneficial for all companies involved with designing, constructing and maintaining both new and existing buildings. True impacts of different boundary conditions on human thermal sensation can be estimated, and in the future this analysis can even be extended to predict the health and productivity of the occupants.

The business potential of these methods and tools is exceptionally large as they can be used for risk management, optimisation strategic and tactical planning of energy efficient and user-friendly buildings and spaces for demanding consumers.

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A human thermal model for improved thermal sensation and comfort

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The PhD thesis (in pre-checking phase) of Riikka Holopainen [1] describes the basic features of a new advanced human thermal model (HTM), which is integrated with a building simulation tool. The thermal sensation and comfort calculation of the model has been validated using dynamical temperature step change test results. The VTT house building simulation tool models thermal interactions between the human body and the surrounding space by means of a finite difference heat balance method, including convective, radiation and evaporative heat transfer. As a module of the VTT house building simulation tool, HTM can be used for estimating more accurately than before the thermal sensation and comfort of building occupants in transient and non-uniform conditions.

Introduction

It seems that energy efficiency is becoming a key driver for the whole building and construction industry in the near future. Better thermal insulation levels and new heating and cooling solutions at least in part will be adopted. Energy saving actions in building and construction sector are likely to have direct effects on both building structure and building service system solutions and an indirect impact on the indoor environment.

Energy-efficient very low-energy houses, passive houses and nearly zero-energy houses have a significantly lower heating power demand than traditional buildings. Therefore, the typical design and dimensioning criteria of conventional structural and building service system concepts need to be verified to avoid problems in the thermal indoor environment.

Fanger's predicted mean vote (PMV) method is traditionally used for estimating thermal sensation and comfort. The PMV method is based on a heat balance model, also referred to as a "static" or "constancy" model. Assuming that the effects of the surrounding environment are explained only by the physics of heat and mass exchanges between the body and the environment, heat balance models do not take into account the human thermoregulatory system but view the human being as a passive recipient of thermal stimuli. According to previous research results, the PMV method progressively overestimates the mean perceived warmth of warmer environments and the coolness of cooler environments. It is therefore valid for the everyday prediction of thermal comfort only under severely restricted conditions.

To estimate thermal comfort in transient conditions accurately, an adaptive thermal comfort approach should be used. Adaptive thermal sensation methods take into account the natural tendency of people to adapt to changing conditions in their environment by increasing or decreasing the skin blood flow rate, for example. Tools for adaptive methods are human thermal models, which can be utilised in connecting the effect of human thermoregulation on thermal sensation and comfort.

Methods

The PhD thesis presents a new adaptive method, where a human thermal model (HTM) is implemented in a building simulation environment. The HTM is used for predicting the thermal behaviour of the human body under both steady-state and transient indoor environment boundary conditions. It is based on the true anatomy and physiology of the human body.

The HTM is a module of the VTT house building simulation environment. Thermal interaction between the human body and the surrounding space has been modelled by including convective, radiation and evaporative heat transfer. Utilising the validated heat transfer methods of the VTT house building simulation environment, reliable estimations of thermal interaction between building structures, building service systems and occupants can be obtained – which is extremely important when evaluating thermal comfort aspects under different boundary conditions.

Zhang [2] has developed a thermal sensation model to predict local and overall sensations and local and overall comfort in non-uniform transient thermal environments. The local thermal sensation is represented by a logistic function of local skin temperature. The overall thermal sensation and comfort are calculated as a function of the local skin temperatures and the core temperature and their change over time. This thermal sensation and thermal comfort estimation methodology is integrated in the HTM.

Results

The HTM simulation results have been successfully validated under various steady-state and transient indoor environment boundary conditions. The results show that the tissue temperatures and thermal sensation simulated by the HTM are sufficiently accurate when compared with measurements made using real human beings. The simulated thermal sensations with the HTM method showed a better resemblance with measured values than Fanger's PMV method.

The significance of the effects of different internal and external boundary conditions on thermal sensation was evaluated with HTM methodology. The operative temperature, metabolic rate and clothing were found to be the most dominant boundary conditions. The operative temperature was clearly dominant compared to air humidity values. An increase of operative temperature by 1°C increased the thermal sensation index by approximately 0.1–0.2 units. According to the results, the operative temperature sets clear boundaries for combinations of clothing and metabolic rate when aiming for thermal neutrality for a human. Combinations of metabolic rate and operative temperature dictate the level of thermal sensation. An increase of metabolic rate by 1 Met increased the thermal sensation index by approximately 1 unit. The effect was stronger with an increased clothing insulation level. The effects of relative humidity and air velocity on thermal sensation were small according to the results.

The effect of increasing wall insulation levels and replacing old windows with new more energy-efficient windows on thermal comfort and annual energy use was simulated for a typical 1970-level built apartment with alternative renovation solutions. The operative temperature, mean skin temperature, thermal comfort index and predicted percentage of dissatisfied were calculated during a cold weather period. Results show that improving the thermal resistance of the building structure increases thermal comfort during the heating season. The higher inner surface temperatures of retrofitted walls and new windows increased the operative indoor temperature and mean skin temperatures resulting in a lower variation of the temperature levels inside a living space and a higher thermal comfort index. The effect of retrofitted windows was higher than the effect of retrofitted walls. The combined effect of retrofitted windows and walls was only slightly higher than the effect of just retrofitted windows. Besides improving indoor conditions, energy renovation also decreases the annual heating energy use by diminishing heat loss through structures. As the increased indoor surface temperature levels of retrofitted envelope components decrease the draught experienced by the radiation of cold surfaces, the indoor set point temperature demand can be lower than with original structures. This will cause further saving in energy costs. The predicted percentages of dissatisfied (PPD) calculated with Fanger's PMV method were clearly higher than the PPD values with the HTM. The results support the findings of Humphreys and Nicol (2002) that Fanger's PMV method progressively overestimates the mean perceived coolness of cool environment.

The effect of different heating distribution systems on thermal sensation and comfort and the impact of varying different boundary conditions were examined with HTM. The overall conclusions of the test case are that the clothing level has the greatest influence on thermal sensation and comfort. Very low-energy structures increased the thermal comfort only slightly when compared to 2010 level structures. There were relatively small differences between different heating distribution systems. The highest thermal comfort was achieved with the floor heating system due the large heating area. The second highest thermal comfort was with window heating due to the diminished cold radiation through window. Radiator heating was in the third place because of the smaller heating area and the lowest thermal comfort was by ventilation heating because it has no heating area.

Discussion and conclusions

The typical design and dimensioning criteria of the conventional structural and building service system concepts need to be verified to avoid problems in thermal indoor environment in more energy-efficient future buildings such as very low-energy houses, passive houses and nearly zero-energy houses. Therefore, there is an obvious need to evaluate the future design and dimensioning criteria of structural and building service systems – especially from the occupant's point of view. To avoid unpleasant indoor environment outcomes in future buildings, a more holistic approach focusing on occupant aspects is recommended. Since thermal issues seem to be dominant causes of indoor environment complaints also in the future, it is very important to really understand the true nature of human thermal sensation and comfort.

As a module of the VTT house building simulation tool, HTM can be used for estimating more accurately than before the effects that the alternative building structures as well as building service systems will have on occupants under different conditions. This integrated method enables the quantitative analysis of the significance of both external (structure insulation level, heating/cooling system) and internal (clothing, metabolism) boundary conditions on thermal sensation and comfort. According to the simulation results, the most significant boundary conditions are operative temperature, metabolism and clothing.

Further development needs for HTM will be adding a real-time calculation of convective heat transfer coefficients by means of a CFD (computational fluid dynamics) calculation. The effect of the accumulation of heat and moisture in the clothing layer will be studied to estimate its importance in thermal sensation calculation. Age, gender, weight and the amount of muscle and fat tissues have a clear effect on the experiences of thermal sensation and comfort for a human being. These phenomena will be taken into account by adding a "body builder" to the HTM. The body builder enables the modification of the model according to age, gender, weight and tissue distribution (fat and muscle).

Exploitation potential

During the last hundred years numerous human thermal models have been developed. The utilisation rate of these models has however been low due to the complexity of the models and the difficulty in determining calculation variables. There were few if no human thermal model approaches connected with a building simulation program before the HTM. The new human thermal model integrated in a building simulation environment enables a realistic estimation of the effect of building structures and building service systems on thermal sensation and comfort.

The HTM method allows true physical and physiological estimates of effects that alternative combinations of building structures as well as building service systems and individual human parameters (e.g. metabolic rate and clothing) will have on occupants. This feature is highly beneficial in evaluating new technical concepts for future energy-efficient buildings. With the HTM the realistic thermal comfort of the user can be used as a design parameter for designing better thermal environments in new and renovated buildings. In the thesis the HTM was utilised in two realistic case studies (selection of the energy renovation measure, selection of the heating distribution system) where different building structure and building service system alternatives were compared according to the thermal sensation and comfort of the user.

Acknowledgements

The research was partly funded by VTT.

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Consumers need comprehensible feedback about their energy use

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Numerous studies have shown that feedback on energy consumption can work to effectively reduce household energy consumption. However, little work has been done on the best ways to present information in order to maximise energy savings. In this work, different ways of presenting feedback on electricity consumption were systematically analysed and user interface prototypes were developed based on the analysis. The prototypes were shown to consumers in qualitative interviews to gain information on how well they understood them and what kind of feedback they prefer to receive on their electricity consumption.

Introduction

Although many studies have shown that feedback can work effectively in reducing household energy consumption, consumers typically have very limited possibilities to monitor their consumption. Changes in legislation (particularly the EU Energy Directive) and technological development (especially remote real-time reading of energy meters) will improve our opportunities to monitor consumption. However, care must be taken when choosing the information the consumers are given and with the way in which it is presented. Essentially, it is important that the information provided to consumers is

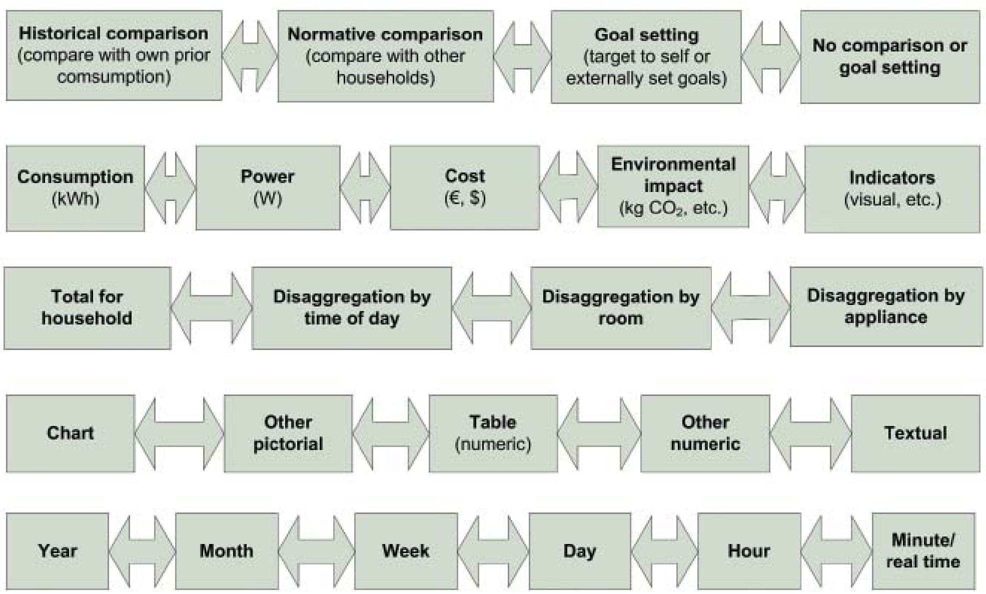

Figure 1. Various options for presenting feedback on household electricity consumption.

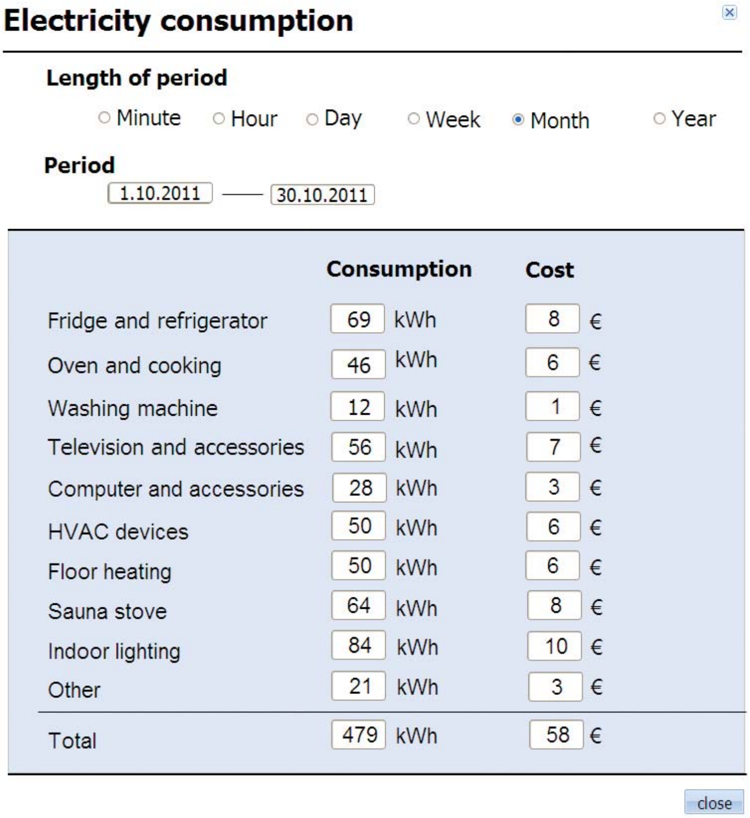

Figure 2. User interface prototype that gives a total overview of consumption and costs with an appliance-specific breakdown.

relevant and enables them to make sustainable decisions about their energy use. The principal purpose of the work was to study what kind electricity consumption feedback consumers understand and prefer. Various ways of presenting feedback are illustrated in Figure 1.

Methods

Interviews were performed to study consumer attitudes to energy monitoring and especially to find out what kind of electricity consumption feedback consumers understand and prefer. As a part of the interviews the participants were showed user interface prototypes to illustrate some possible alternatives for providing electricity consumption feedback. 14 participants were encouraged to think aloud and to comment on eight prototypes while exploring them for the first time.

Results

Most of the prototypes were found to be easy to understand by the participants. The problems with understanding the prototypes mainly involved two issues: (1) many people are not familiar with scientific units and do not understand the difference between W and kWh and (2) many people do not understand how carbon dioxide emissions are related to electricity consumption. In contrast, people are familiar with different kinds of charts and can easily interpret bar charts and pie charts among others.

Clearly the most favoured prototype is the one that gives a total overview of consumption and costs with an appliance-specific breakdown (Figure 2). Other findings include the following. People were not interested in receiving information on carbon dioxide emissions. More attention was paid to historical comparisons (comparisons with own prior consumption) than to normative comparisons (comparisons with other households).

Presentations showing the amount of electricity consumed (kWh) are more useful for consumers than presentations of power (W), since they do not just give instant values but show the consequences of particular behaviour over a period of time. Since consumers do not have a good idea of the proportional consumption of their appliances, an appliance-specific breakdown is helpful for understanding the relevance of individual actions.

Discussion and conclusions

Consumers – even if they are motivated to save energy – are short of the information they need to make sustainable decisions about their energy use. They do not have a good idea about their consumption and they need more information, especially concerning the proportional consumption of appliances, to make the right choices about their use of energy. An appliance-specific breakdown needs special technology (for example, sub-metering or non-intrusive appliance monitoring) but it has the potential to deliver valuable information to aid the understanding of the relevance of individual actions.

Presentations of the amount of electricity consumed (kWh) are more useful for consumers than presentations of power (W), since they do not just give instant values, but also show the consequences of particular behaviour over a period of time.

Regarding the comprehensibility of the electricity consumption feedback, the interviews and paper prototyping revealed the following:

- People can interpret various kinds of charts and tabular presentations if they are well designed.
- Many people have problems understanding scientific units and do not understand the difference between W and kWh.
- Many people do not understand how carbon dioxide emissions are related to electricity consumption and may assume that they are only related to the use of fireplaces.

In summary, the following features of electricity consumption feedback were found to be most valued by consumers:

- presentations of costs (over a period of time)
- appliance-specific breakdown, i.e. information on how much each appliance consumes proportionally
- historical comparison, i.e. comparison with own prior consumption.

Exploitation potential

People need feedback on their energy consumption to make the right choices about their energy use. For this purpose, home energy monitors are currently being developed by a number of companies. This work gives insight in what kind of feedback people understand and what kind of feedback they prefer to receive regarding their electricity consumption in order to maximise the energy savings.

Acknowledgements

This research was supported by the European Commission Artemis project eDIANA (Embedded Systems for Energy Efficient Buildings). The project consortium included 21 partners from five European countries.

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New guidance for thermal comfort: Design primarily for females

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Until now differences between male and female subjects in terms of thermal comfort requirements have been generally considered to be small and insignificant. However, the results of this extensive literature review show that females express considerably more dissatisfaction than males in the same thermal environments. The target should be to create energy-efficient and thermally comfortable conditions for both genders.

Introduction

Individual differences in experiencing indoor thermal environments are well known and no thermal environment can satisfy everybody. Instead, differences between male and female subjects in terms of thermal comfort requirements have previously been considered to be small and insignificant. No comprehensive review on thermal comfort and gender has been published before.

Methods

An extensive literature search was performed to review the scientific literature and give a synopsis of thermal comfort experienced by females and males. When examining the gender differences, the interest was focused on thermal satisfaction instead of neutral temperatures, since occupants are not necessarily thermally satisfied in overall thermal neutrality and often desire a sensation other than neutral.

The target of the literature search was to find all thermal comfort studies that report their results separately for each gender. Conference papers were excluded from this review, firstly because they lack a peer-reviewed status and are often presentations of ongoing work later published in journals.

All the scientific papers were systematically analysed and divided into two groups, one consisting of laboratory studies and another consisting of field studies. In addition, a meta-analysis was performed to find out whether the female gender is a predictor of thermal dissatisfaction.

Results

Clearly more than half of the laboratory and field studies show that females express more dissatisfaction than males under the same indoor environmental conditions. Very few studies show the male gender to be more dissatisfied.

Most gender differences concern cool environments, i.e. the studies agree that females feel more uncomfortable than males especially in cool conditions. Gender differences have been found also in warmer conditions: several studies have found more dissatisfaction with high temperatures among females than males.

A meta-analysis shows that based on the literature females are 1.74 (95% CI: 1.61–1.89; $p < 0.0001$) times more likely than males to express thermal dissatisfaction.

Discussion and conclusions

The results show that females express more dissatisfaction than males in the same thermal environments. However, there are no significant gender differences in terms of neutral temperature. Females are more sensitive to deviations from an optimal thermal environment and less satisfied than males especially in cooler conditions. Because females have lower tolerances to deviations from optimal thermal environments, they have more need for individual temperature control and adaptive actions than males on average.

No clear differences between climates was discovered, i.e. females were found to be more dissatisfied than males in studies performed in different parts of the world. Most field studies concerned office buildings; therefore not many comparisons can be made between types of buildings. The differences in thermal comfort experienced by genders cannot be explained in terms of clothing differences.

Thermal comfort for all can only be achieved when occupants have effective control over their own thermal environment. Because females are more sensitive to a deviation from an optimal thermal environment, they have more need for personal control over temperature than males. Future work should test whether an effective control over the thermal environment results in similar thermal comfort levels between genders.

Exploitation potential

The results have many practical implications. We should no longer neglect the more rigorous requirements that females have for indoor thermal environments. The results suggest that females should primarily be used as subjects when examining indoor thermal comfort requirements, since if females are satisfied it is highly probable that males are also satisfied.

Gender differences indicate that females have a greater need for personal temperature control and adaptive actions than males on average. Personal control systems should be designed primarily for females, e.g. the design of thermostats should be attractive to females.

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Roadmaps, policies and regulations

Energy requirements for new buildings in Finland

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Buildings account for circa 40% of the total energy use in Europe [1] and for about 36% of the EU's total CO_2 emissions [2], including the existing energy conservation in buildings [3]. Key features of the Finnish energy policy are improved energy efficiency and increased use of renewable energy sources. To achieve a sustainable shift in the energy system, a target set by the authorities, both energy savings and increased use of low-pollution energy sources are therefore priority areas. Building low-energy buildings is in accordance with the declared national aim of reducing energy use and thus reducing CO_2 emissions.

The main motivation in renewing building codes for new buildings was to build more energy efficiently, encourage the use the most efficient energy sources and to enhance the use of renewable energy sources. In addition the aim was to give more freedom to find the real optimal solutions for energy efficiency by optimising all aspects including the building architecture and different systems with demand controls. However, in order to ensure the good quality of buildings certain minimum requirements for structure U-values are given.

Introduction

Buildings account for circa 40% of the total energy use in Europe [1] and for about 36% of the EU's total CO_2 emissions [2], including the existing energy conservation in buildings [3]. Even though energy-saving measures at building level have been proposed, the net energy use at city/district level is still increasing. Buildings are important in achieving the EU's energy savings target and in combating climate change while contributing to energy security. As the European strategic energy technology plan (SET-PLAN 2007)[4] states, strategies to improve energy efficiency at each level (energy conversion, supply and end-use) should be better imposed. In addition to the natural environment, the built environment has a large impact on the economy, health and productivity.

Key features of the Finnish energy policy are improved energy efficiency and increased use of renewable energy sources. To achieve a sustainable shift in the energy system, a target set by the authorities, both energy savings and increased use of low-pollution energy sources are therefore priority areas. Building low-energy buildings goes hand in hand with the declared national aim of reducing energy use and thus reducing CO_2 emissions.

Until now the Finnish Building code has mainly controlled the thermal properties (U-values) of building structures. That has decreased the space heating demand, but did not do much to encourage other energy related improvements in buildings. In new building codes the whole building energy consumption is calculated with different weight factors for different energy sources. The energy consumption which is highly dependent on the user is calculated with standard

	Finnish primary energy factors	Weight factor for energy in new building code 2012
Fossil fuels	1.0	1.0
Electricity	2.2	1.7
District heating	0.9	0.7
District cooling		0.4
Renewable fuels	1.0	0.5

Table 1. Primary energy factors in Finland calculated from 2000-2009 and the energy weight factors in new Finnish building code for new buildings.

user profiles. This gives the possibility to compare different buildings, not different users. In addition with this method it is not possible to reduce comfort or indoor air quality level by saving energy.

The main motivation in renewing building codes for new buildings was to build more energy efficiently, encourage the use of the most efficient energy sources and to enhance the use of renewable energy sources. In addition the aim was to give more freedom to find the real optimal solutions for energy efficiency by optimising all aspects including the building architecture and different systems with demand controls. However, in order to ensure the good quality of buildings certain minimum requirements for structure U-values are given.

Weight factors for energy sources

The weight factors for energy sources are based on primary energy use in Finland in 2000–2009. Also the possibility to use CO2 emission-based factors were considered, but the problem was that these kinds of factors do not limit the use of low polluting or renewable energy sources. Low polluting and renewable energy sources are natural resources which we should make use of and therefore the primary energy-based factors were chosen. However, since the aim was to point towards efficient energy use, pure primary energy factors were not used. In Finland 75% of the district heating is produced in co-generation with electricity. The factor of district heating was reduced a little and the relation between electricity and district heating was kept constant. In addition district cooling and the use of renewable energy sources do have a low energy factor, see Table 1.

The new building code also sets maximum values to the energy consumption calculated with weight factors, see Table 2. The maximum values are dependent on building type and for single-family houses also for the area of the building. That was considered important since especially in small single-family houses the investment cost of the heating system is relatively high and also because in countryside not all energy sources are available.

The new building code does not exclude any source for heating. However, the code encourages the use of renewable energy sources and district heating. The aim is to reduce the use of fossil fuels.

It is not possible to compare only the energy factors but the heating system (and its efficiency) also has a high impact on the end result. Table 1 gives an example of different cases.

For the future the Europe-wide electricity markets might pressure Finland to increase the weight factor for electricity as well since it is currently rather high compared to European factors which are typically 2.5.

Estimate of economical impact

The investment costs compared to current building codes are minimal. In actual fact due to relative freedom in optimising building energy consumption it is possible to actually

Type of building	Max value for energy consumption (calculated with weight factors)
Single-family houses	Function of area
Terrace houses	150 kWh/m^2
Apartment buildings	130 kWh/m^2
Offices	170 kWh/m^2
Shopping centres etc.	240 kWh/m^2
Hotels, hostels, etc.	240 kWh/m^2
Schools and day care centres	170 kWh/m^2
Sports halls	170 kWh/m^2
Hospitals	450 kWh/m^2
Other buildings	Energy consumption has to be calculated but no limit values

Table 2. Maximum permitted E-numbers for different building categories.

	Investment cost (EUR/m^2)	Investment cost (%)	Reference investment cost when built according to building code 2010 (EUR/m^2)
Single-family house	-40 … +120	-1.8 … +5.4	2222
Apartment building	-30 … +25	-1.2 … +1.0	2500
Office	-20 … 0	-1.1 … 0	1818

Table 3. Investment costs of new buildings according to new building code 2012 and compared to existing building code 2010.

save on investment costs. Mainly the cost savings can be achieved with efficient architecture, good ventilation heat recovery and optimal structural solutions. Extra investment costs typically come from efficient heating systems or the architecture of the building. The calculated investment costs are shown in Table 3.

Discussion and conclusions

The main motivation in renewing building codes for new buildings was to build more energy efficient, encourage the use of the most efficient energy sources and to enhance the use of renewable energy sources. In addition the aim was to give more freedom to find the real optimal solutions for energy efficiency by optimising all aspects including the building architecture and different systems with demand controls. However, in order to ensure the good quality of buildings certain minimum requirements for structure U-values are given.

Acknowledgements

The author wishes to thank former Minister of Housing JanVapaavuori, Mrs Helena Säteri, Mr Teppo Lehtinen, Mr Pekka Kalliomäki and Mrs Maarit Haakanen from the Ministry of Environment. The research was funded by the Ministry of Environment.

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Improving dwellings by enchancing action on labelling for the EPBD directive

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Improving energy efficiency is regarded by the European Commission as a key element in energy policy. The Energy Performance of Buildings Directive (EPBD) stipulates that residential buildings must have an Energy Performance Certificate (EPC) when they are sold, rented out or constructed. The EPC includes a label rating of the energy efficiency of the dwelling and recommendations of cost-effective energy-saving measures. The project reported here aims to investigate why EPCs seem to hardly motivate dwelling owners to take measures to improve the energy performance of their dwelling and the reason why a large part of dwelling owners apparently do not use the recommendations from the EPC. Electronic questionnaires and in-depth interviews techniques were used. The results of these interviews and questionnaires will be used to provide policy recommendations for further actions in the field of energy savings in the residential sector.

Introduction

Energy certification of buildings, introduced by the EPBD, aims to encourage energy renovations. Its success depends to a large extent on the conditions in the Member States (MS). As a first step, this study defined how much energy consumption for space heating can be avoided if cost-effective energy improvement measures are implemented in the building stock. The challenge is that cost-effectiveness alone is hardly ever a strong enough motivator for owners to carry out energy enhancement measures on their homes in practice. Therefore, both technical and institutional country-specific characteristics were investigated in ten MS, including a number of face-to-face interviews and an extensive electronic questionnaire surveying homeowners.

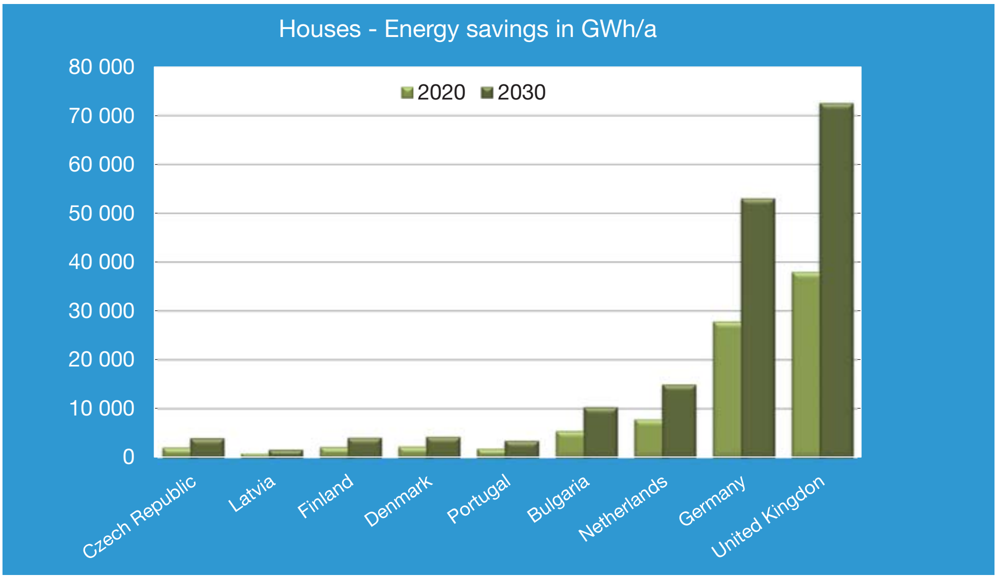
Methods

The project structure:

The *framework on consumer behaviour* will be established with a literature study on consumer behaviour and consumer barriers, while *country-specific factors* provide an inventory of aspects particular to each country. Based on these, *in-depth interviews* and *electronic questionnaires* will provide empirical evidence and monitoring by allowing analysis of the feedback received. *Policy action plans* will establish measures, which will be disseminated. The project includes both countries with prior experience regarding energy labelling (Denmark, Germany, Finland, the Netherlands and the United Kingdom) and less experienced countries (Belgium, Bulgaria, the Czech Republic, Latvia and Portugal).

Energy-saving potential

The savings potential in each country were derived according to the procedure elaborated in [1]. Countries with a large inventory of buildings hold the largest savings potentials in absolute terms. On the other hand, some countries are likely to have large potential for savings at a national level, but their relative contribution to the European total will remain



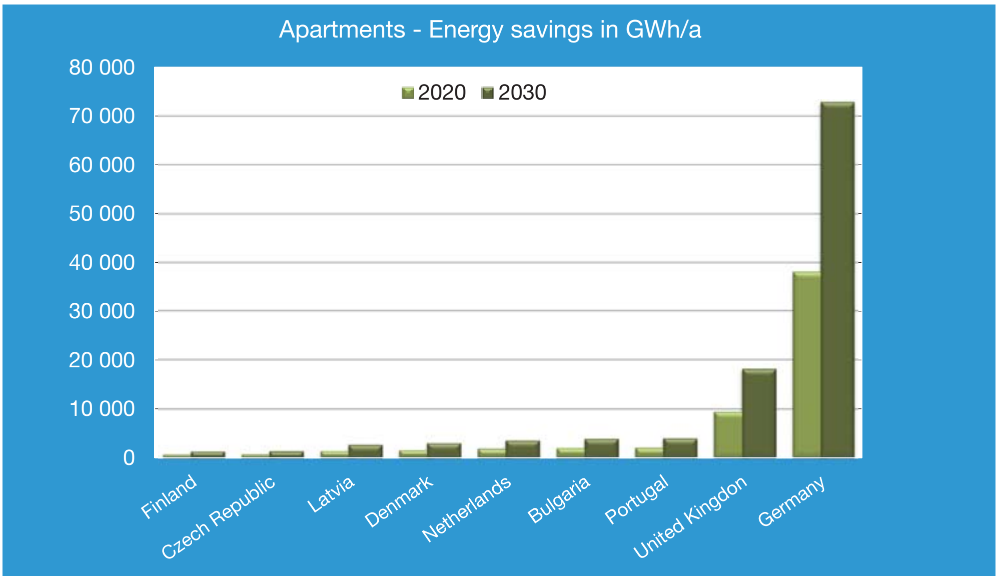


Figure 1. Assessed energy saving potential in the building stock of studied countries.

small. Summing up the results for all studied countries (Figure 1) 88 TWh/a could be saved in single-family houses by the 2020 and 58 TWh/a in apartment buildings, totalling 146 TWh/a. By 2030 the respective figures are 169 TWh/a for houses and 110 TWh/a for apartments, totalling 279 TWh/a for all dwellings. This potential represents approximately 10% by 2020 and 20% by 2030 of present heating energy consumption.

Barriers in Finland

A multitude of barriers hinder improvements in the participating EU countries. Homeowners did not prioritise energy efficiency when they purchased their dwelling and could simply be unaware of or indifferent to the energy consumption of the buildings. Further results of this wider study can be found in [2]. Here, the more detailed information concerning Finland is given as an example of the findings from the various types of interviews, namely six face-to-face interviews with professional (mostly institutional) stakeholders, five face-to-face interviews with common families who recently bought a home, and internet-based questionnaire with 120 responses.

The majority of the interviewees pointed out that the issues of energy repairs practically always exist only in the context of general major refurbishment projects; there are hardly any "energy repairs" as such. On the other hand, there is hardly a major refurbishment project without some energy efficacy improvements included in the project. The expected impact from EPBD seems to be modest because the current requirements already are high. The homeowner interviewees were aware of their potential to save energy and able to name some means for it – e.g. illumination was often mentioned. On the other hand, there was a prevalent notion that they already do some of the achievable and the further saving would lessen their comfort perhaps too much. The overall conclusion is that people feel confident with the information provided by authorities and relevant professionals on energy issues; they hardly feel a need for EPC in solving their refurbishment items.

Exploitation potential

EU-level policy recommendations to increase EPC effectiveness [3]

- Increase the visibility and availability of Energy Performance Certificates (EPCs) across building types and purchasing models (dedicated EPC per homeowner and not only per building).
- Increase the usefulness of EPCs for home buyers by focusing on information they are most interested in (type of heating system installed, potential utility cost, etc.)
- Increase the usefulness of EPCs for homeowners by turning the "energy label" into an "energy pass" and broadening its scope beyond the time of property purchase (EPCs could be made obligatory for all dwellings, not only those for sale, regular updates could be required).
- Increase trust in the EPC by helping homeowners understand the information it provides and increasing trust in the experts issuing EPCs (additional online and offline information; a certification scheme for expert EPC issuers would improve their competences).
- Increase effectiveness of EPC by embedding it into a system of expert information and advice for home buyers and owners (EPC featuring information on where to go for professional assistance, support and advice).

Selected recommendations for Finland [3]

- Strengthen the trust in EPC.
  - * The quality assurance system for every stage of EPC procedure should be developed.
  - * A dedicated register of dwellings with an EPC should be established.
  - * On the government energy agency (Motiva) web page the directories (or links to them) should be available indicating the certified EPC issuers.
- Facilitate an efficient professional support.
  - * A registry and a certification system should be developed to document the qualifications of renovation service providers.
- Improve funding system.
  - * A dedicated and lasting incentive system for different scales of energy efficacy investments in buildings should be developed.
- Social networks.
  - * An active following of the development is advisable and participation recommended to the trials where the social networks and social media will

be utilised in supporting the energy efficiency activities in private dwellings.

Acknowledgements

The work was carried out within the project IDEAL EPBD (Improving Dwellings by Enhancing Actions on Labelling for the EPBD) supported by Intelligent Energy Europe program. The project partners are: coordinator ECN (NL), BRE (UK), BSREC (BG), Ekodoma (LV), ENVIROS (CZ), ISR-UC (PT), Oeko (DE), SBi (DK), UCL (BE) and VTT (FI).

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Strategic research roadmap on ICT-enabled energy efficiency in buildings

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The REEB Project (The European strategic research Roadmap to ICT-enabled Energy-Efficiency in Buildings and construction projects) was a Coordination Action project funded under the European Commission's Seventh Framework Programme. Its main purpose was to provide a strategic research roadmap on information and communications technology (ICT) support for energy efficiency in the built environment and a collection of implementation actions supporting the realisation of the roadmap.

Introduction

Buildings are responsible for at least 40% of energy use in Europe, due to heating and lighting operations. Moreover, buildings are the largest source of CO2 emissions in the EU. According to Smart2020, the worldwide energy consumption for buildings will grow by 45% from 2002 to 2025, where buildings account for about 40% of energy demand with 33% in commercial buildings and even 67% in residential buildings.

Most energy usage throughout a building's life cycle is during the operational stage (approx. 80%). The decisions made in the conception and design stages of new buildings, as well as in renovation stages of existing buildings, influence about 80% of the total life cycle energy consumption. The impact of user behaviour and real-time control is in the range of 20%. ICT has been identified as one possible means to design, optimise, regulate and control energy use within existing and future (smart) buildings.

REEB was launched to identify the current state of research, best practices and provide a vision in the form of a strategic research (roadmap) agenda with supporting implementation recommendations for ICT-supported energy efficiency in construction.

Methods

The main methods used in REEB included:

- Setting up a community dedicated to innovative use of ICT supporting energy efficiency in construction, bringing together key actors from ICT, built environment and energy business sectors.
- Coordinating information exchange between RTD (Research & Technology Development) initiatives and stakeholders.
- Identifying best practices in the use of ICT, standardisation and regulations.
- Establishing an inventory of RTD initiatives and results.
- Developing a vision, a research roadmap and recommendations for implementation actions, including training and education.

Results

The REEB vision for ICT-supported energy efficiency of buildings in the short, medium and long term can be summarised as follows:

- Buildings meet the energy efficiency requirements of regulations and users – short term.
- The energy performance of buildings is optimised with the whole life cycle taken into account – medium term.

- New business models are driven by energy-efficient “prosumer” buildings at district level – long term.
-

It is advocated that full exploitation of the opportunities offered by ICT for energy efficiency requires adjustments of the processes and contractual practices of the construction sector. The core is a transformation of focus from the initial construction cost to whole life performance, i.e. value to owners, especially with regard to energy performance.

The REEB project developed 12 key best practices based on an evaluation of more than 80 case studies. These best practices cover: simulation based energy design, early energy design, integrated modelling solutions based on BIM (building information modelling), smart metering for energy consumption awareness, building management systems, wireless sensor networks for energy performance monitoring, standards-based energy performance assessment software, energy performance audit solutions, websites for collecting and disseminating energy-efficiency “good practices”, smart grids, standards-based solutions for building life-cycle management and standards-based energy data exchange solutions.

During the gap analysis of research and development initiatives, five main priority areas (categories) of research were identified based on a review of more than 270 relevant projects, of which 52 were analysed in detail. The identified priority areas were: integrated design and production management, intelligent and integrated control, user awareness and decision support, energy management & trading and integration technologies.

For each of these five priority areas, detailed roadmaps were developed. These roadmaps covered a (sub-)vision, drivers, barriers, impacts, key business scenarios and short, medium and long term priorities (Figure 1).

To guide towards realisation of the actions identified in the roadmaps, several implementation actions were recommended covering:

- Policies: regulation, taxation, setting up large scale actions/programmes, etc.
- Coordination: roadmaps, think-tanks, working groups, studies, supporting innovation and research programs, facilitation of communication between different initiatives and communities, etc.
- Research and technology development: tolls for energy efficient design and production management, intelligent and integrated control, user awareness and decision support, energy management and trading, and integration technologies.
- Take-up: dissemination, promotion, awareness creation, demonstrations/ pilots.
- Standardisation: interfaces, models, protocols, reference architectures, etc.
- Education and training.

Discussion and conclusions

The REEB project together with its special interest group members and its extensive international REEB community has provided a set of industrial best practices and most importantly a series of roadmaps and supporting implementation actions for ICT-supported energy efficiency in buildings. These have been validated by key stakeholders from both ICT and construction sectors. There is a need however to extend this to a much larger stakeholder forum for proper take-up and implementation. This initiative has now been launched through the ICT4E2B Forum (European stakeholders’ forum crossing value and innovation chains to explore needs, challenges and opportunities in further research and integration of ICT systems for energy efficiency in buildings) project. The main aim of ICT4E2B is to bring together all relevant stakeholders involved in ICT systems and solutions for energy efficiency in buildings, identifying and reviewing the needs in terms of research and systems integration as well as accelerating implementation and take-up.

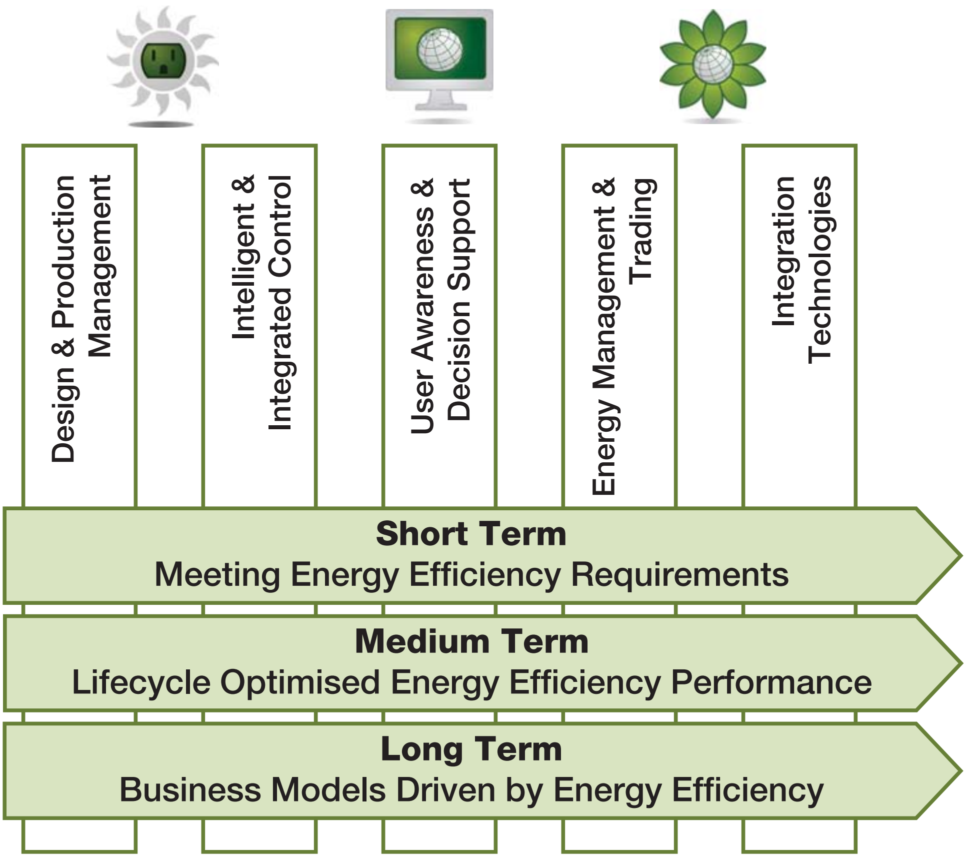

Figure 1. Roadmap dimensions

Exploitation potential

It is envisaged that implementation of the REEB results (in particular the roadmap and implementation action recommendations) will lead to key industrial transformations within the construction sector through the role of ICT for energy efficiency in buildings as follows:

- *Life cycle approach*: integrated design teams, using interoperable model-based tools and communication/collaboration platforms optimise the whole life performance of buildings.
- *Smart buildings*: most buildings will be "smart" and control themselves maintaining the required and optimal performance and responding proactively to external conditions and user behaviour anticipating them, rather than reactively. Holistic operation of subsystems is supported by integrated system architectures, communication platforms, standard protocols for interoperability, sensors and wireless control technologies.
- *Construction as a knowledge based industry*: industrialised solutions are available for configuring flexible new buildings as well as retrofitting existing buildings. Customised solutions are developed by configuring re-usable knowledge from catalogues within organisations and industry-wide.
- *Business models* and regulations are driven by user perceived value. Financing

models provide incentives to stakeholder towards whole life performance of buildings. ICT tools support performance measurement, validation and holistic decision-making.

Acknowledgements

This research was funded by the European Commission and VTT. The project consortium included eight partners from six European countries. The authors would like to acknowledge the contributions of all partners and in particular the coordinator (Dr Alain Zarli, CSTB, France).

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The building stock from perspective of change — renovation roadmap

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By 2050, population, society and economic structures will have changed several times. The long and short-term goals and objectives concerning our built environment are mutually contradictory. Determining objectives or creating scenarios for the future built environment is fruitless. We should approach the development of the built environment from the perspective of change and improve the flexibility and adaptability of the built environment.

For the users, a built environment meeting their basic needs is part of sustainable development. Identified short-range renovation needs include eliminating damp and mould problems, improving energy and eco-efficiency, removing obstacles to mobility and adapting buildings to accommodate the needs of the elderly. Vacated areas and buildings should be recycled and offered a new life supporting a sense of community and service production.

Improved energy efficiency reduces greenhouse gas emissions. Instead of renovating individual buildings, renovation of the entire area is recommended. Sustainability in construction translates into favouring recycling and renewable materials and building-specific energy systems using renewable and/or low-emission resources. It is recommended that renovations to improve energy efficiency are scheduled to coincide with other maintenance/renovations so as to reduce costs.

In renovation construction, the role of service improvement is more important than products. Improved services help to identify a solution that fulfils several customer needs, meets financial limitations and can be implemented efficiently. Companies are advised to view renovation construction as an innovative market segment entitled to its own service portfolio. Truths about new building should be discarded and new services developed based on recent study results and new technologies.

Introduction

By definition, renovation and modernisation is targeted at the existing building stock. In Finland, the construction business took an upward turn in the 1950s and the growing trend continued until the end of the 1990s. Over these decades, new buildings and areas were constructed in increasing numbers. Today, this is visible in the increasing demand for technical renovations. For the construction sector, renovation and modernisation projects has represented a "safe haven" balancing the fluctuating new building markets.

Drivers of renovation are ageing building stock, technological development, structural changes in the economy and the society, individual preferences, climate change and limited supply of non-renewable natural resources.

Method

The roadmap comprised a state-of-the-art literature review on the challenges of the built environment. For renovation roadmap

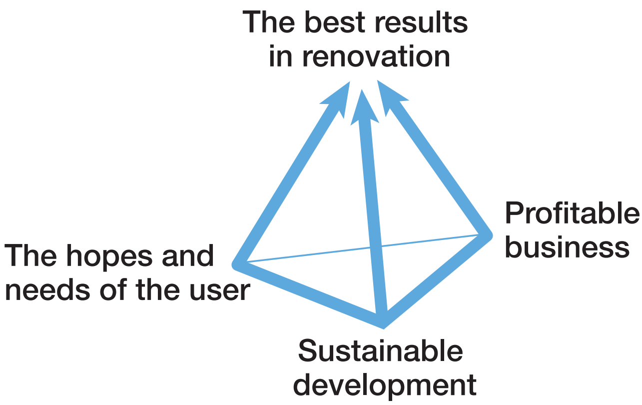

Figure 1. The factors affecting on the results of the renovation.

the political programmes and strategies and future-oriented research projects were scanned to identify challenges. The findings were tested and concretised with young adults in an online laboratory. Solutions to the challenges identified were sought in the traditional seminar featuring the question "To renovate or to demolish?" Based on the above, the roadmap was compiled. The final roadmap is a synthesis of literary reviews and contributions from the workshops and future workshops compiled by the researchers and steering group.

The roadmap

The best results in renovation construction are achieved when it fulfils the needs and hopes of the user, meets the requirements of a built environment set by society, and is successfully implemented as a profitable business (Figure 1).

The hopes and needs of the user

Successful regional and construction decisions support the well-being of the people, the operations of the society and the competitiveness of businesses. Decisions made in the past force current operations to function in a societal structure and in premises which may have become impractical over time. It is not possible to anticipate future requirements on premises or to renovate the existing building stock in advance for future generations. Renovating in advance would deprive future generations of the opportunity to implement the latest technology in their time. The roadmap approach is based on human needs. This will place the developmental emphasis on those skills and technology that can contribute to fulfilling basic needs such as health and safety.

Renovation meeting the objectives of users and society in:

A healthy, accessible and adaptable environment

- Problems with damp and mould eliminated.
- Removing obstacles to accessibility in the built environment.
- Residential buildings adapted for the elderly to enable them to live at home.
- Implemented solutions secure multiple and flexible uses.

An environment that provides a sense of community while securing privacy

- Upgraded neighbourhoods, public facilities and parks and other green areas.
- Recycling of empty premises and buildings (e.g. securing services in residential areas).

Sustainable development

Globally, the construction business accounts for half of the total use of natural resources and 70% of the unimproved land taken into use. A significant proportion of construction materials and products are non-renewable or the refining process is extremely energy-intensive. Environmentally, renovation is a better option than demolishing the old and building something new. Renovation construction is one way of transforming the existing built environment in a sustainable manner. Improving energy management and reducing greenhouse gases can be incorporated into regular maintenance procedures.

Renovation construction contributes to sustainable development by:

Construction of green, integrated communities

- Cooperation between administrations and organisations.
- Areas and town centres developed as one unit.
- Combining renovation and complementary construction.
- Conserving land in its natural state by the recycled use of existing areas and buildings.
- Clustering public and private services around public transport junctions.
- Maximising the collective use of areas and premises.

Energy and material-efficient built environment

- Renewable materials and sources of energy are favoured.
- Technically and economically sound improvements in energy management.
- Value-added recycling of building materials.

Profitable business

Renovations are made in buildings and areas from several different eras. Hence, it is somewhat belittling to refer to renovation construction as merely an emergency solution to stabilise economical fluctuations in the new building markets. Renovation projects require experts and skilled companies – a dedicated business specialising in renovation construction.

Renovation construction – requirements:

Competent and innovative services through:

- Commercialisation of renovation research results.
- Exploiting new technologies in design and production processes.
- Implementing follow-up data in R&D.

Companies providing specialist services

- Business concepts differ from the mainstream.
- Create their markets by, for example, disseminating information about successful projects.

Acknowledgements

The Finland Futures Research Centre of the University of Turku, Aalto University, the Finnish Institute of Occupational Health and VTT Technical Research Centre of Finland have collaborated in the creation of The Roadmap for the Built Environment [1] which was commissioned by Tekes – the Finnish Funding Agency for Technology and Innovation.

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Series title and number
VTT Research Highlights 1

Title	Research highlights in energy and eco-efficient built environment
Author(s)	Miimu Airaksinen (ed.)
Abstract	This publication presents a compilation of extended abstracts of VTT's recent research on energy and eco-efficient built environment. Sustainability as a dominating driver of technology development can also be seen in the R&D portfolio of VTT Technical Research Centre of Finland. A clear focus of our research for the building sector is sustainable construction, particularly the energy efficiency of the built environment. Buildings and the whole built environment are in a key role when societies are mitigating climate change and adapting to its consequences. Despite the temporary economic downturn, construction globally remains one of the most significant areas of human activities globally. Due to the urgency of measures related to climate change and the need to provide a proper environment for living and working, a large number of national and international measures have been agreed to guarantee the future development of sustainable built environment for all. Indirectly, this has lead to a need to develop existing and completely new technologies and processes for the built environment with a speed faster than ever and with a more holistic performance metrics than ever.
ISBN, ISSN	ISBN 978-951-38-7819-1 (print) ISBN 978-951-38-7820-7 (online) ISSN-L 2242-1173 ISSN 2242-1173 (print) ISSN 2242-1181 (online)
Date	June 2012
Language	English
Pages	200 p.
Name of the project	
Commissioned by	
Keywords	energy and eco-efficiency, buildings, energy systems, built environment, sustainable development
Publisher	VTT Technical Research Centre of Finland P.O. Box 1000 FI-02044 VTT, Finland Tel. +358 20 722 111

VTT RESEARCH HIGHLIGHTS 1

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"Built environment" here refers to buildings and districts as well as the physical networks for water & waste, transport, energy and information. From a technological point of view the built environment is increasingly becoming a holistic "machine" requiring consideration of all the technologies in the system simultaneously. Yet the technologies are only there to serve a purpose. Long-term human needs, like sustainability, are at the end the foundation for all the development.

ISBN 978-951-38-7819-1 (soft back ed.)
ISBN 978-951-38-7820-7 (URL: http://www.vtt.fi/publications/index.jsp)
ISSN-L 2242-1173
ISSN 2242-1173 (soft back ed.)
ISSN 2242-1181 (URL: http://www.vtt.fi/publications/index.jsp)

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