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Energy Conservation in Buildings & Community Systems

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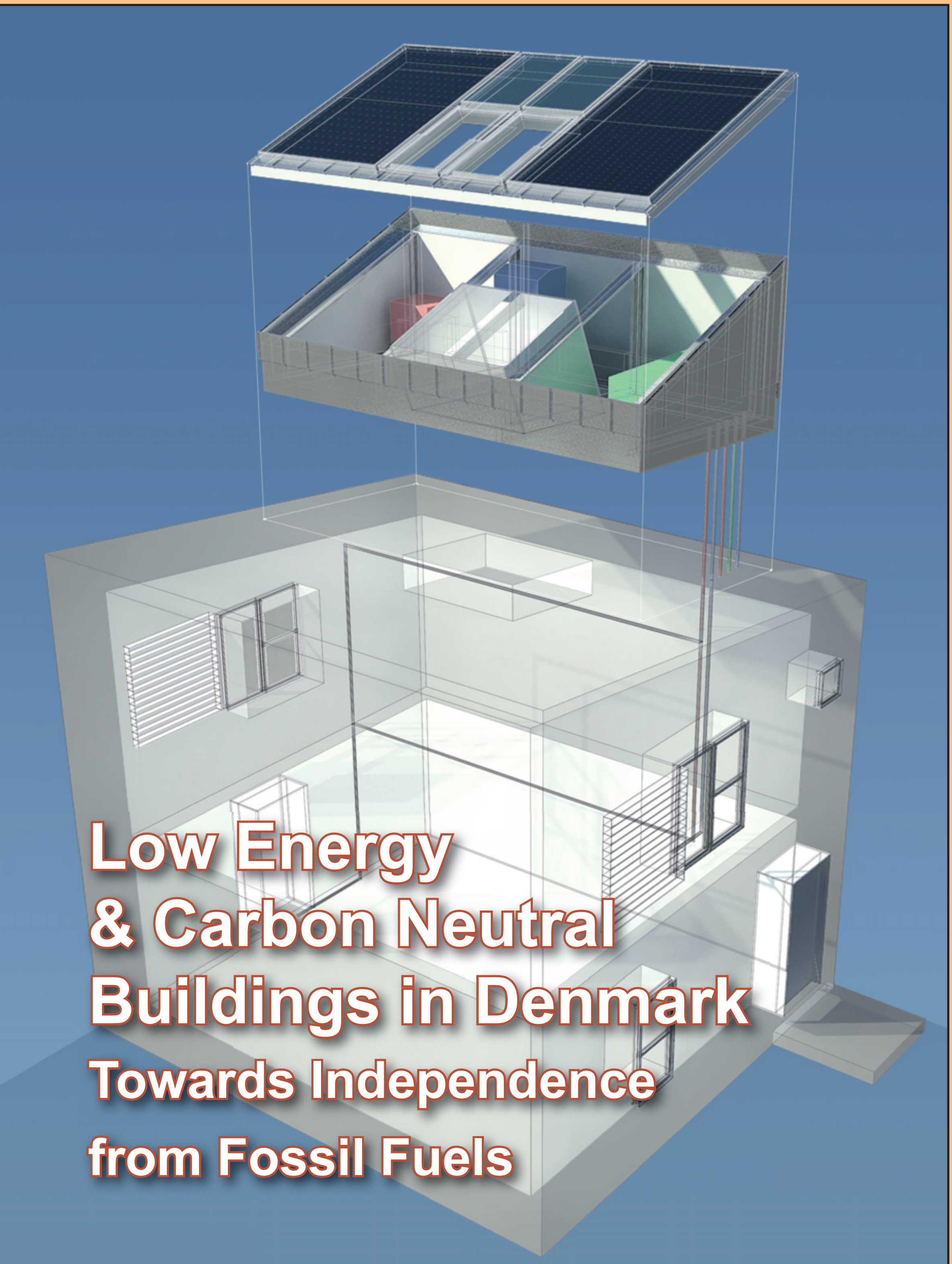
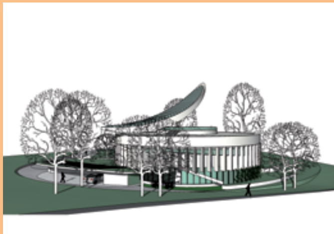


Low Energy & Carbon Neutral Buildings in Denmark

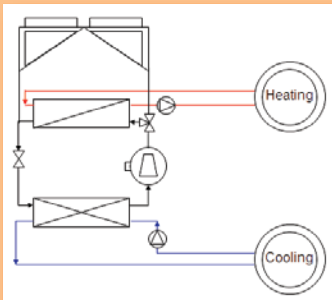
Towards Independence from Fossil Fuels

New Project: Energy & GHG Optimised Renovation



Responsive Building Concepts

Reliability of Retrofitting



Reversible Heat Pumping & A/C

Energy Quality in Community Systems

Low Energy and Carbon Neutral Buildings in Denmark - Towards Independence from Fossil Fuels

Lennart Anderson, ECBCS Executive Committee Member for Denmark

The Government of Denmark has stated in 2007 its position that the country should be a green and sustainable society with visionary climate change and energy policies. The vision is that in the long run Denmark will become independent of fossil fuels. This is a very ambitious objective, given that today the main part of the national energy supply is based on fossil fuels such as oil, gas and coal. This vision calls for far-reaching changes in energy supply, conversion and use. Research into new cost-effective energy technologies is also crucial to becoming fully independent of fossil fuels.

About Denmark

Denmark is a small and flat country situated in northern Europe, Scandinavia, with approximately 5.5 million inhabitants. Since 1973 Denmark has been a member country of the European Union. It has a mixed market capitalist economy and a large welfare state.

During recent decades Denmark has been a net exporter of oil. Back in the early 1970s Denmark was among the OECD countries which were most dependent on oil in its energy supply. More than 90% of all energy supply was imported oil. As a consequence Denmark launched an active energy policy to ensure the security of supply and enable Denmark to reduce its dependency on imported oil.

Danish gross energy consumption in 2009 was at the same level as in 1972 despite an economic growth of more than 100% over the same period.

Interim targets

To achieve this long term objective, a series of interim targets have been defined within Danish energy policy up to the year 2025. In fact, the proportion of renewable energy must be doubled by 2025 and more efficient use of energy must be pursued. Compared to the 2006 level, energy use must be reduced by 2% in 2011 and by 4% in 2020.

Because energy use related to buildings currently accounts for about 40% of the total, it is essential that buildings-related demands are significantly reduced, particularly for heating, ventilation and lighting. The savings potential is therefore great for both public and private sector organisations. Even so, the potential is currently only exploited to a limited extent.

Energy Policy & Buildings

In 1960 Denmark was among the first countries in the world to introduce nationwide efficiency standards for energy use of buildings. The standards have been tightened on a regular basis and Denmark now has some of the toughest energy standards for new buildings in Europe.

Tightening of Building Regulations

New building regulations will be implemented in 2010. These will see a 25% reduction in overall energy use. By 2015 requirements will be reduced by further 25%. The intended 2015 level is already introduced in the 2010 regulations as a voluntary, but well defined energy performance target for

Support for Research, Development & Demonstration of New Energy Rechnologies

In 2010 the Government has set aside more than €130M in order to strengthen the innovation chain for new energy technologies, distributed among a number of separate schemes:

- The Strategic Research Council (DSRC), €40M.
- The Energy Technology Development and Demonstration Programme (EUDP), more than €50M, special emphasis on demonstration of new technologies before commercialization.
- The ForskEl and ELFORSK programmes, more than €20M funded from public service obligation charges and focusing on production and consumption of electricity.
- Green Labs programme with more than €8M for testing of green technologies.
- The High Tech Foundation – with more than €13M for projects with high commercial potential.

In addition, there are contributions to the financing of EU programmes.

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new buildings. In 2011, it is expected that the planned 2020 requirements will be also be published. These two voluntary, increasingly ambitious energy performance levels are expected to be helpful. This is because some clients and developers are likely to choose to build one or two levels better than the mandatory requirements, and thus will lead the building industry in meeting tougher obligations in the future.

Energy savings, retrofitting state buildings and scrapping oil boilers

The Government has emphasized that the public sector must take the lead in energy saving initiatives, with all ministries being required to reduce their 2011 energy use by 10% in comparison with 2006. To this end, about €50M of funding has recently been set aside for energy retrofits of state owned buildings and a similar amount for the scrapping of oil boilers. Subsidies are available for conversions to district heating, electric heat pumps and for the solar component of new combined oil / solar heating plants. The scheme is already underway and the preliminary experiences have indicated strong consumer interest.

Labelling of buildings

A number of initiatives have been launched to make energy labelling of buildings more efficient and useful for homeowners and other interested parties. All such energy labels have been made public and can be used actively. To raise the awareness of prospective purchasers about energy standards, new legislation has made it compulsory to display energy labels in sales advertisements for homes.

Green Lighthouse is Denmark's first public carbon neutral house. Source and further information: greenlighthouse.ku.dk/English

Easier to realize savings

There is major potential for viable energy savings in buildings. Measures to achieve these savings have not yet been implemented even though the homeowners have access to financing on reasonable terms through bank loans or mortgages. Therefore, the Government has established a committee with representatives from financial institutions, energy companies, builders, installers and the building industry. This committee has been tasked with producing proposals to make it easier to realize these savings. They are being encouraged to extend the energy service company (ESCO) concept, which has been used to promote energy conservation in major projects such as for municipal buildings. In ESCO projects, the contractor will guarantee the energy savings, while a third party investor will finance the energy-related improvements. The investor and the owner will then share the financial benefits of the energy savings.

Research, Development & Demonstration

In 2008, the Government announced its intention to strengthen research, development and demonstration (RD&D) activities in the field of energy. As a consequence public funding of energy RD&D projects has doubled from €68M in 2007 to €136M in 2010.

More schemes to fund building-related research

Funding of building-related energy technology research is the responsibility of several different organisations and funding schemes in Denmark. Figure 1 shows the national energy schemes as of 2010, in which the sizes of the arrows represent available funding. Each scheme has its own focus, both in relation to the type of technology and to the part of the development chain that it supports. The main funding schemes for building-related projects are:

- The Danish National Advanced Technology Foundation,
- Elforsk,

Cover Picture: Albertslund

Albertslund is a zero-carbon renovated townhouse with a solution combining technologies (solar photovoltaic and thermal collectors, heat pumps, heat recovery ventilation etc.) in order to meet the demands of sustainable housing with comfort requirements of the future.

Location: Albertslund, Denmark
Architect: RUBOW arkitekter A/S
Engineer: Cenergia A/S
Developer: Albertslund Council
Completion: January 2010

Source and further information: www.activehouse.info/cases/solar-prism

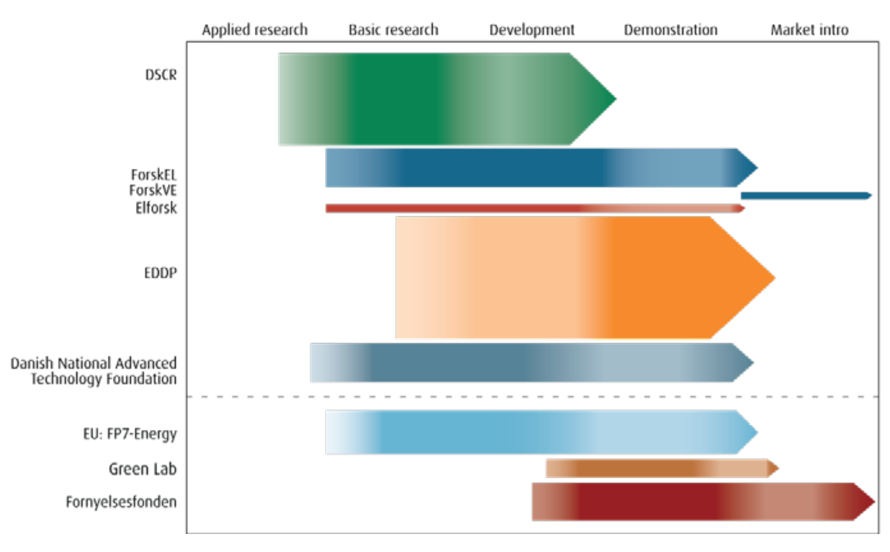


Figure 1. Energy research programmes (2010) in the energy technology development chain.

- The Danish Council for Strategic Research, and
- The Energy Technology Development Demonstration Programme (EUDP).

Priority areas

In view of the massive, unrealised potential for energy savings in buildings, EUDP has chosen to make energy-efficient renovation a high priority. EUDP supports a number of projects aimed at developing and testing new concepts that not only lead to more efficient technology solutions, but also have commercial potential for Denmark.

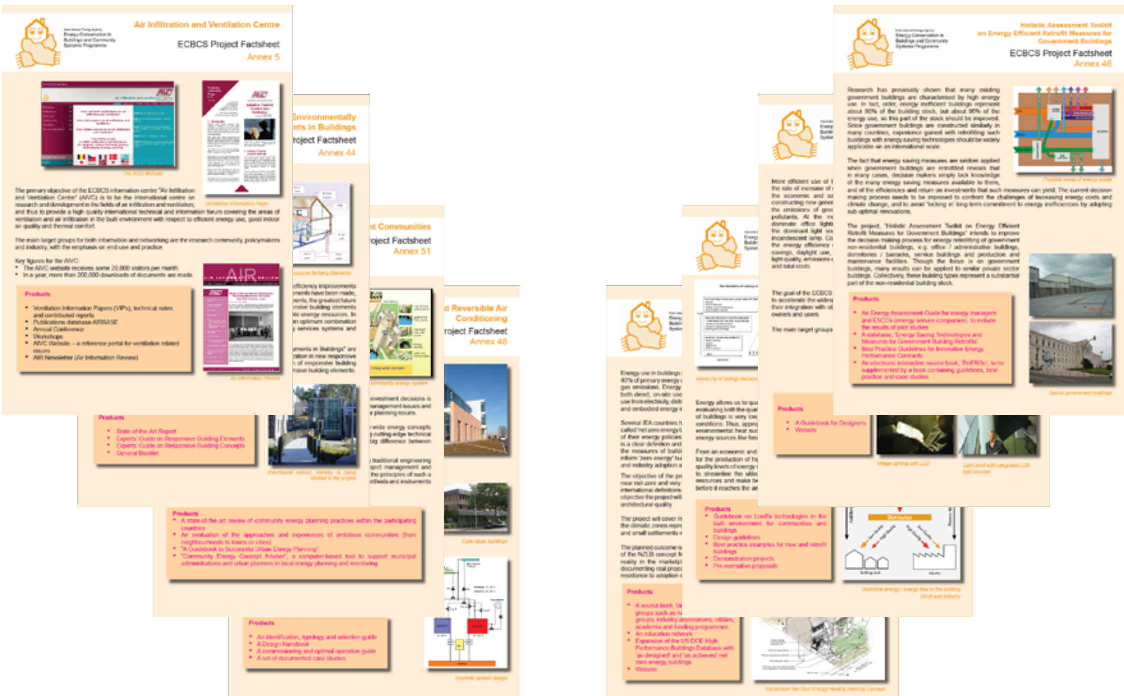
Although the greatest potential for improving energy efficiency lies in energy renovation, energy use in new buildings can be reduced still further. Therefore, schemes like Elforsk and the Danish National Advanced Technology Foundation have granted funding for research in intelligent building materials such as phase-change materials. Other important target areas for the funding schemes are the development of ventilation concepts and intelligent LED-lighting.

International co-operation

It is important and of great benefit to Denmark to work together with other countries in pursuit of more efficient energy technologies. Being a member of the European Union (EU), Denmark participates in a number of EU-programmes. Moreover, for more than 30 years Denmark has been and is still, a committed member of the ECBCS research programme. Currently they participate in about half of the ongoing international ECBCS projects and see this as a cost-effective way to accelerate research and development of new energy technologies for buildings.

Further Information

For further information, please see: www.ens.dk/en-US/policy/Energy_technology/Sider/Forside.aspx



Energy & Greenhouse Gas Optimised Renovation

New ECBCS Project to Set Foundations for Future Standards

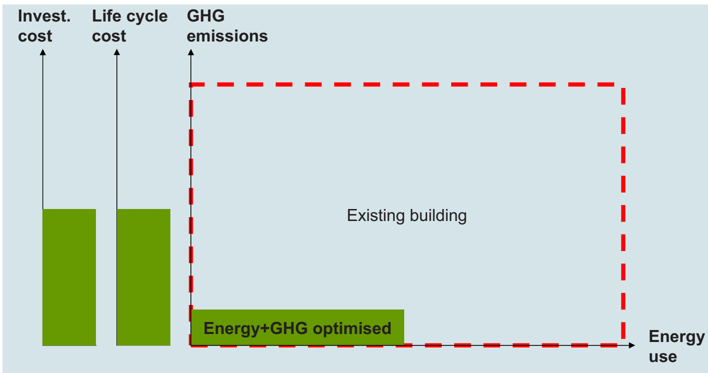
Manuela Almeida, University of Minho, Portugal

Various standards regarding energy use have been set in the last decade, to help to mitigate climate change. As an example, the 'nearly-zero' emissions buildings concept has emerged. Although it does not yet have a universal definition, it is likely to settle on a hierarchical approach that will value energy conservation and efficiency. This implies major investment in the envelope and in building services systems, as well as in the use of on-site renewables and 'offsite' low carbon energy supplies.

However, these standards, and all public discussions about them, are mainly focused on new buildings, ignoring for the most part existing buildings facing similar improvement challenges in the near future. Current standards do not respond effectively to the numerous constraints imposed by existing buildings. In many cases, the requirements result in very expensive measures and complex procedures, seldom accepted by occupants, owners or developers.

It is, therefore, urgent to agree new standards to respond to these constraints and to develop good practice guides that integrate appropriate, applicable and cost effective technologies, whether existing or emergent. With this intent, a new ECBCS project has been approved, 'Annex 56: Energy and Greenhouse Gas Optimized Building Renovation'.

Performance before renovation.



Performance after energy and GHG optimised renovation.

Expected Outputs

The project is expected to achieve the following outputs:

- Flexible decision making tools and guidelines from the perspective of users, owners and developers, designers and policy makers;
- Documented successful case studies highlighting the added-value of each rehabilitation process;
- A rehabilitation guide, based on cost effective solutions and on an optimal value concept.

Objectives

The aim is to develop rules and procedures as the basis for future standards, enabling cost effective refurbishment of existing buildings within the international commitments to reduce greenhouse gas emissions (GHG) and climate change mitigation. This implies rehabilitation towards nearly-zero emission buildings. The main objectives are to:

- Provide tools, guidelines, recommendations, best practice examples and background information for policy makers, designers, users, owners and developers that help to reduce GHG emissions in the existing buildings sector;
- Link the IEA buildings-related research programmes to end users through accessible language and tools that enables them to understand the problems and risks associated with energy efficiency and their role as users, decision makers, developers or stakeholders;
- Clarify the limits of the emerging concepts and their associated points of view to validate their effective impact on achieving present goals;
- Include the notion of 'added value' as a key parameter for the existing building retrofit process.

Further Information

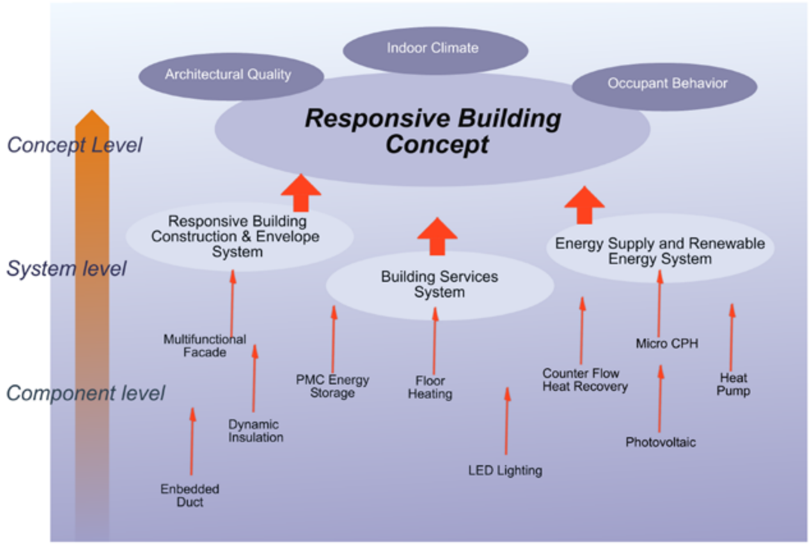
Further information is available from: www.ecbcs.org/annexes/annex56.htm

Integrating Environmentally Responsive Elements in Buildings

ECBCS Project Gives Guidance for Design Teams

Per Heiselberg, Aalborg University, Denmark

The building sector has been established as providing the largest potential for energy-related carbon dioxide (CO_2) reductions by 2020. So, many countries across the world have set very ambitious targets for energy efficiency improvements in buildings. To successfully achieve these targets, it is necessary to identify and then develop innovative building energy technologies and solutions for the medium and long term. These will help substantial energy savings and integration of renewable energy supplies in buildings. The rapid development in materials science, information and sensor technology offers considerable opportunities for development of new intelligent building components and systems.



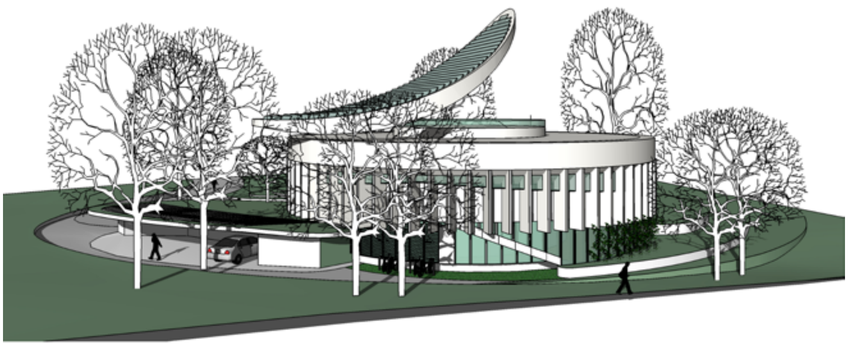
Principle of integration of responsive building elements with building services and renewable energy-systems in a responsive building concept.

Responsive building concepts are design solutions that maintain an appropriate balance between optimum interior conditions and environmental performance. They achieve this by reacting in a controlled and holistic manner to changes in external or internal conditions and to occupant intervention. Such concepts originate from an integrated multidisciplinary design process, which optimizes energy efficiency and includes integration of human factors and architectural considerations. In this respect, responsive building elements are essential technologies for the exploitation of environmental and renewable energy resources and in the development of integrated building concepts. The ECBCS research project, 'Annex 44: Integrating Environmentally Responsive Elements in Buildings' has recently defined these concepts. The challenge was how to achieve an optimum combination of responsive building elements, and how to integrate these with the building services and renewable energy systems to reach an optimal environmental performance.

Environmental design and control of buildings can be divided into two very different approaches. In the usual approach, energy efficient building concepts are created by excluding the indoor environment from the outdoor environment through a very well insulated and airtight building construction. Acceptable indoor environmental conditions are established by automatic control of efficient mechanical systems. There is growing interest in developing buildings that co-operate with nature and make use of the available environmental conditions. In this 'selective' approach, energy efficient building concepts are created by using the building form and envelope as an intermediate between the outdoor and indoor environments. Acceptable indoor environmental conditions are established by user control of the building envelope and of the mechanical systems. It is important that the building is responsive to fluctuations in the outdoor environment and the changing needs of the occupants, which means that the building should have the capability to dynamically adjust its physical properties and energy performance. This capability could pertain to energy capture (as in glazing systems), energy transport (as in air movement in cavities), and energy storage (as in building materials with high thermal storage capacity).

> *"Energy gains can be stored, tempered, admitted or redirected, depending on the desired indoor conditions"*

In a responsive building, an optimum must be found between the sometimes contradictory requirements arising from energy use, health and comfort. From the viewpoint of human coexistence with nature, the approach is to make buildings generally 'open' to the environment and to avoid barriers between indoors and outdoors, while from the position of energy savings this approach actually excludes buildings from the outdoor environment for certain periods. In this way, the area between indoors and outdoors becomes a more or less 'hybrid zone', in which energy gains are not simply rejected, but can be stored, tempered, admitted or redirected, depending on the desired indoor conditions. In this respect responsive building elements (RBE) are essential technologies for the exploitation of the environmental and renewable energy resources and in the development of responsive building concepts (RBC).



The Dutch embassy in Canberra, Australia is used as an example of responsive building design in the report 'Designing with Responsive Building Components'.

Project Outcome

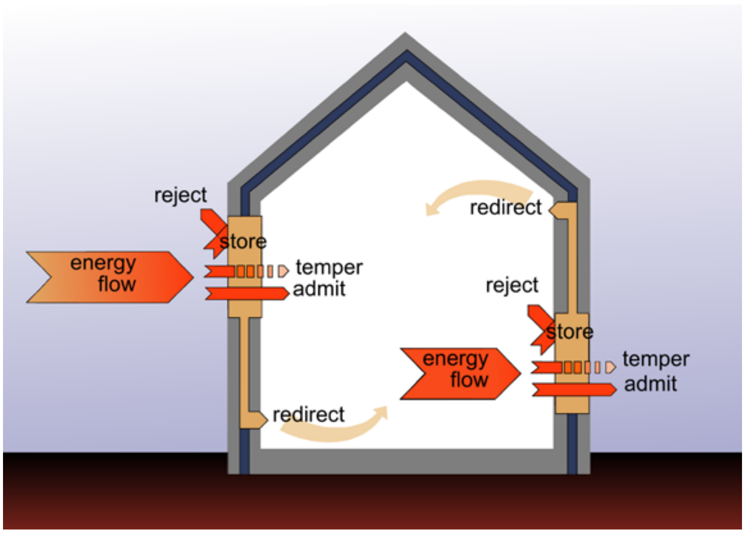
The following publications are available from the completed project:

- Designing with Responsive Building Components – An Expert Guide for Rethinking New Buildings.
- Responsive Building Concepts – Expert Guide Part 1
- Responsive Building Elements – Expert Guide Part 2

Nowadays, we are able to measure and control the performance of buildings, building services and energy systems with an advanced building management system (BMS). This opens a new world of opportunities. A building no longer act as a ridged object that needs a large heating installation in winter and substantial cooling equipment during summer to 'correct' the indoor climate. It becomes an additional 'living skin' around the occupants, keeping them in contact with nature, but at the same time protecting them when necessary.

Good integration of responsive building elements with building services and energy systems in responsive building concepts has a number of important advantages:

- Integration of responsive building elements with energy systems will lead to substantial improvement in environmental and operating cost performance.
- It enhances the use and exploits the quality of energy sources (exergy) and stimulates the use of renewable and low valued energy sources (like waste heat, ambient heat, residual heat etc.).
- It enables and enhances the possibilities of passive and active storage of energy (buffering).
- It integrates architectural principles into energy efficient building concepts.
- Responsive building elements lead to a better tuning of available technologies in relation to the building users and their behaviour.
- It enhances the development of new technologies and elements in which multiple functions are combined in the same building element.
- It leads to a better understanding of integrated design principles among architects and engineers.



Principles of the responsive actions of the building envelope in a responsive building.

However, a number of barriers appear when the borderline between architecture and engineering is crossed; the design process may contain many challenges to those who participate in the process. This ECBCS project helps to overcome the main barriers to realising an integrated design process, by providing:

- increased knowledge,
- information and guidelines,
- successful examples, and
- expertise.

With the integration of responsive building elements, building services and renewable energy systems, building design completely changes from design of individual systems to integrated design of responsive building concepts. This should allow for optimal use of natural energy strategies (daylight, natural ventilation, passive cooling, etc.) as well as integration of renewable energy devices. Design teams including both architects and engineers are formed from the outset. The building design is then developed in an iterative process from the conceptual design ideas through to the final detailed design.

Further Information

Further information is available from:
www.ecbcs.org/annexes/annex44.htm

Heat Pumping & Reversible Air Conditioning

Innovative Approach Established by ECBCS Project

Philippe Andre, University of Liège, Belgium

Introduction

In many climates, office buildings are most often equipped with a heat pump which has the function of providing cooling or air-conditioning of the spaces. The existence of this heat pump offers attractive, but rarely implemented, opportunities to improve the energy performance of the building and to reduce energy-related carbon dioxide (CO_2) emissions.

The ECBCS project 'Annex 48: Heat Pumping and Reversible Air Conditioning' has investigated two options based on the use of heat pumps, not only to provide cooling, but also to meet heating demand, at least partially, by:

- heat recovery at the heat pump condenser, and
- reversibility of the heat pump.

The project has addressed both new building projects and retrofit of existing cases. Indeed, the retrofit of an existing building and even more, the design of a new one, should take all possibilities of heat pumping into consideration as soon as possible. Based upon a number of case studies, the research work conducted has identified a number of constraints and obstacles on the route of the application of this strategy, but has also provided solutions to how these may be overcome.

(Un-)Balance of Heating & Cooling Demands Gives the Starting Point

The success of one of the two options (reversibility or heat recovery) is first a question of the time evolution of the heating and cooling demands. From the outset, reversibility should be promoted in cases in which heating and cooling demands are clearly dissociated and do not occur at the same time. Heat recovery should be encouraged for cases where heating and cooling demands are frequently simultaneous. Dynamic simulation has proved to be a valuable tool to calculate these demands and to quantify a 'performance index' that represents the potential of either strategy. This performance index is simply defined as the part of the heating demand which can be met by the heat pump and can be calculated for both strategies. For a single day, it corresponds to the dashed areas of Figures 1(a) and 1(b).

Various Practical Realisations are Possible

Although the basic principles of reversibility and recovery are fairly simple, the practical realisation in a project can lead to a lot of different solutions. The project has identified and classified in a comprehensive way the multiple possible ways of using a heat pump to satisfy alternately or simultaneously the heating and cooling demands of an office building. On the basis of this work, three general categories can be defined:

- Reversible systems without heat recovery: alternate heating and cooling production;
- Non-reversible systems with heat recovery: conceived mainly for cooling production, they can recover heat at the condenser side while producing cooling at the evaporator side;
- Reversible systems with heat recovery: alternate or simultaneous heating and cooling production.

An example of a reversible system is shown in Figure 2. Other system configurations are possible such as the variable refrigerant volume (VRF) system and the French 'thermofrigopompe'.

A Specific Design Procedure is Required

Selection of heat pumping solutions makes design work more complex. A back up boiler is often needed and its connection to the heat pump must be carefully considered; heating temperature levels need to be lowered so as not to penalize too much the thermodynamic cycle of the heat pump. Hydraulics and control issues make the final performance of the system very sensitive and the selection of the operating point is crucial. This project has developed a specific design procedure that includes special attention to environmental performance criteria and a detailed

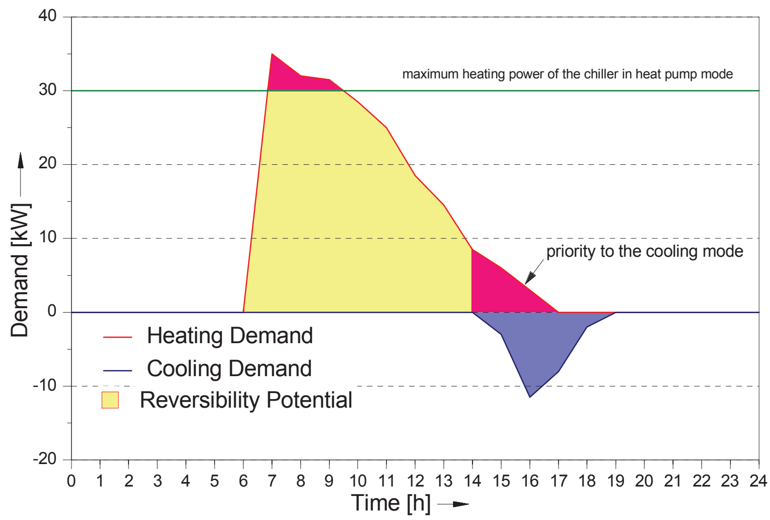


Figure 1(a). Reversibility potential.

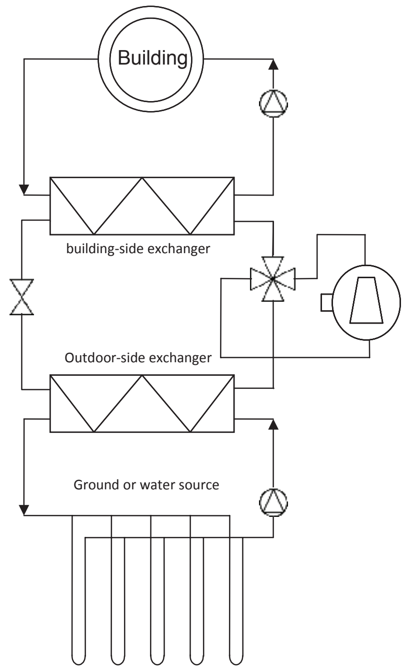


Figure 2. Reversible geothermal heat pump.

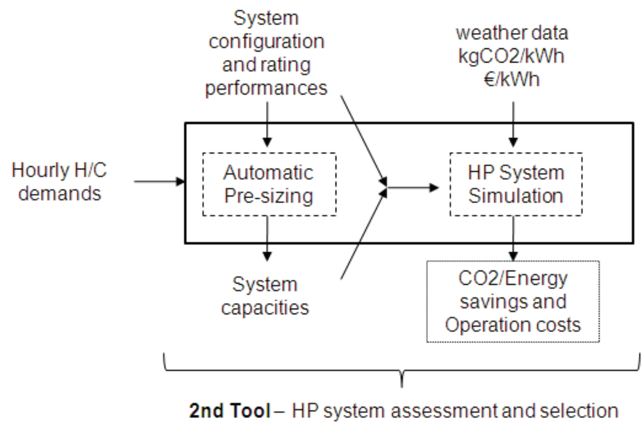


Figure 3. Scheme of the HPSAT software.

analysis of the global behaviour of the system. Therefore, dynamic simulation offers interesting possibilities.

Dynamic Simulation Highly Recommended

For such situations, even more than for classical solutions, dynamic simulation has proved to be a valuable tool to provide a good estimation of the performance of the solution and to allow reasonable optimization of the components sizing, connections and control. Therefore, a series of tools were developed to provide specific design assistance. The HPSAT package (Figure 3) allows an objective comparison at the primary system level of different heat pumping schemes compared with a reference solution (boiler + chiller working independently). For more detailed analysis, TRNSYS applications including the simulation of the secondary system were developed.

Hydraulics Deserve Special Attention

Heat pumping solutions lead to more complex hydraulic schemes, with many valves and pumps to connect the heat pump and the back-up boiler, and / or to make the distribution system reversible. Various case studies have shown that too poor attention was given to these basic considerations, which led to a substantial decrease of the expected performance. One conclusion of the project is therefore to promote a highly improved commissioning procedure in order to make the final performance not too far from expectations.

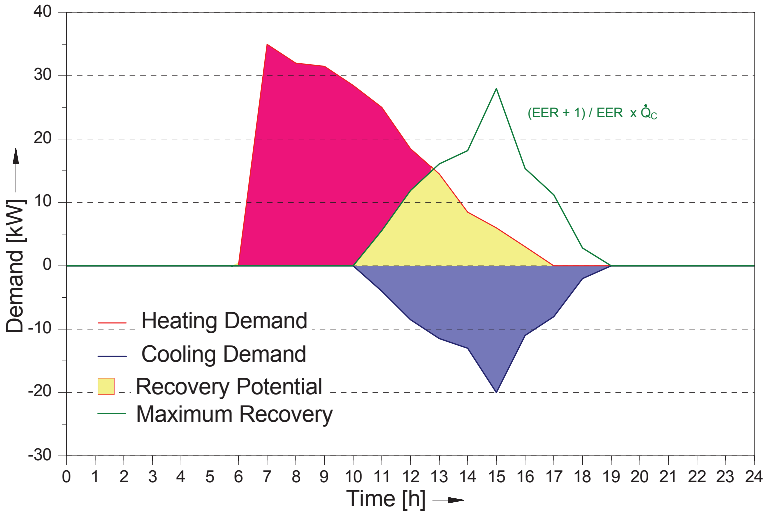


Figure 1(b). Heat recovery potential.

Project Outcomes

- Analysis of building heating and cooling demand in the purpose of assessing the reversibility and heat recovery potentials (report)
- Review of heat recovery and heat pumping solutions (report)
- Simulation tools reference book (plus a set of simulation programs)
- Design Handbook for Reversible Heat Pump Systems with and without Heat Recovery
- Overview of case studies and demonstrations of heat pump systems for tertiary buildings (with 11 case studies) (report)

Conclusions

This research project has examined in detail the problems raised when moving to a more systematic use of heat pumps for providing both heating and cooling to office buildings. While not all the problems were solved, the project has delivered a set of tools, a design methodology and practical illustrations that will help designers, commissioning agents and building operators to pay more attention to these new options and in that way to reduce the environmental impact of buildings.

Further Information

Further information is available from: www.ecbcs.org/annexes/annex48.htm

Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost

ECBCS Project Improving Understanding of True Outcomes

Carl-Eric Hagentoft, Chalmers University, Sweden

A large potential for energy savings is presently available in the existing building stock in industrialised countries. Efforts to make energy efficiency improvements to buildings are already being made by various stakeholders in many countries or will soon be initiated. Therefore, predictions of the outcome of retrofitting measures are of major importance to invest in the most appropriate technologies and to use resources effectively.

The mission of the new ECBCS project 'Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost' is to give guidance on how to design and realize robust retrofitting to give low energy demands and life cycle costs, while controlling risk levels for performance failure. The project will develop and provide decision support data and tools for energy retrofitting measures leading to substantial upgrading of performance. The tools will be based on probabilistic methodologies for prediction of energy use, life cycle cost and technical performance such as transmission heat losses, airtightness and leakage heat losses, durability and moisture safety.

Background

Measurements of energy use (and similarly of hygrothermal properties) show generally random variations between results for different buildings. This may seem straightforward since not every building has the same overall thermal insulation, heating system, occupancy, and so forth. But even when the same building technologies are used a significant spread is still observed in measured energy use. Multiple concurrent causes for this are possible, such as variations in ventilation rates, airtightness, thermal properties of materials, workmanship, existence of gaps and cracks in building components, micro-climate, internal heat gains, maintenance and repair, or occupant behaviour.

For existing buildings, the uncertainties are usually much greater than for new buildings, since the latter present better possibilities for good practice design, construction and commissioning and for efficient operation. So, the effect on energy use (or hygrothermal performance) of retrofitting existing buildings using the same technology will vary from case to case depending on the starting point.

The total life cycle cost for the operation and maintenance of a population of buildings will also vary randomly due to factors such as actual energy use, hygrothermal performance and performance failures. Two examples of performance failures are:

- lack of overall thermal comfort which will lead to compensation by higher average interior temperatures and hence higher energy use,
- moisture damaged wall insulation systems which require renewed retrofitting faster than expected.

Probability Based Life Cycle Cost as a Decision Tool

A reliable decision tool needs to account of the random variation in life cycle cost. In this way, the most suitable retrofitting technology and investments can be made. For a company, the frequency of successful or unsuccessful outcomes of their retrofitting projects is of major importance, hence 'goodwill' and 'ill will' factors should also be included within the life cycle cost.

Traditionally the deviations in cost due to performance variations and performance failures are not accounted for. Rather, single design values for building system components currently govern the decisions. The project will develop a framework and tools to find the probability of deviations from the existing conventionally estimated life cycle cost. Knowing the probability of exceeding a certain life cycle cost is vital to the decision making process. At the moment there is no suitable methodology available that can be used for this purpose. Using the methodology that will be developed within the project, different retrofitting

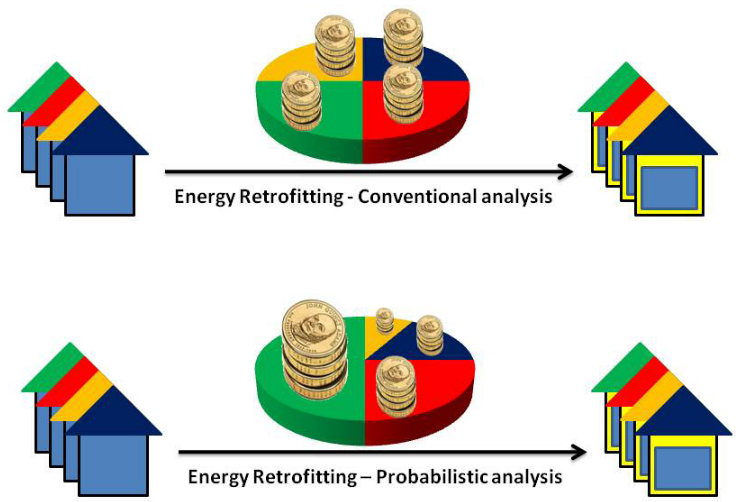


Figure 1. After energy retrofitting measures every single building might have a different life cycle cost.

Figure 2. Left: Social housing in Porto, Portugal, from the 1970s. Right: The Sigtuna case (close to Stockholm, Sweden), a typical multi-family residential building also from the 1970s with great renovation needs.

technologies can be evaluated in terms of expected average life cycle cost and the probability and magnitude of deviations. Figure 1 illustrates a decision tools for the case when a number of similar buildings undergo specific energy retrofitting measures. The pie chart gives the calculated or predicted distribution of life cycle costs. In the example shown, half of all cases gives higher life cycle cost than predicted due to for instance: higher transmission and ventilation heat losses, lacking thermal comfort or insufficient indoor air quality, durability problems and moisture damages leading to replacement of building components and materials and higher maintenance costs.

"The intended outcome is to develop knowledge and tools that support the use of probability based design strategies in energy retrofitting of buildings"

In general, short term investment costs are at present often favoured over long term costs for operation and maintenance, particularly when the funding is supplied by different stakeholders or divisions within organizations. Probability assessment of performance combined with life cycle costing gives a transparent alternative, providing a technique to encourage a change to more sound decision making and cost sharing.

Energy Efficient & Durable Constructions from Retrofit

In reality, only a limited set of technologies is usually available due to architectural, aesthetic, or economic reasons. One example is the use of interior insulation in order to preserve the exterior façade. Thick thermal insulation used to reduce heat loss will result in colder exterior constructions that are more sensitive to moisture, which is hence a risky approach. Obviously, interior insulation is not the safest method to reduce heat transmission, but is still applied in practice and can be relatively successful if applied with care.

A trade-off is normally necessary between different performance demands and cost. It is for instance cheap, at least in terms of initial investment costs, and quick to thermally insulate an attic floor, e.g. by blowing in loose fill insulation. But, how well will it work in the long run and what are the consequences for the durability of the construction on the outer side of the insulation? In this case, this will depend on the random variations of the moisture sources due to air leakage through the attic floor, which in turn depends on the airtightness, air pressure differences and the indoor moisture sources. On top of this, moisture in the external air might also be a threat to the attic, which is now colder than before due to the increased thermal insulation levels.

Figure 2 shows two of the buildings that are intended to be used as case studies in the project. The first one is a typical Swedish multi-family residential building from the 1970's aiming at a 50% energy demand reduction by retrofit. The second case study deals with social housing in Portugal that needs energy retrofitting measures as well as general upgrading. Different retrofitting technologies and the expected performance and life cycle cost will be evaluated.

Anticipated Outcome

Using probability assessment of various design options will give a guide to reliable construction alternatives and the associated spread in life cycle cost and performance. The intended outcome is to develop knowledge and tools that support the use of probability based design strategies in energy retrofitting of buildings to ensure that the anticipated benefits can be realized. These will give reliable information about the true outcome of retrofitting measures in terms of energy use, cost and performance.

Further Information

For further information, please see:
www.ecbcs.org/annexes/annex55.htm

Low Exergy Systems for High Performance Buildings & Communities

ECBCS Project Delivers Guidebook & Assessment Tools

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Much of the energy used in the buildings sector is required to maintain constant room temperatures, usually around 20°C to 25°C. So, in industrialized countries the buildings sector is responsible for about one third of the total energy end use and a major contributor to carbon dioxide (CO_2) emissions. A major fraction of total energy is used for heating and cooling of room spaces, in which the required temperature levels are comparably low and in turn the required energy 'quality' to satisfy these demands is low too. The objective of the ECBCS project 'Annex 49: Low Exergy Systems for High performance Buildings and Communities' has been to show ways of supplying indoor spaces with the required energy, without using high quality sources, such as fossil fuels or electricity. Based on the thermodynamic concept of 'exergy', new solutions for space conditioning have been identified and analysed. Figure 1 shows typical results from the approach followed, illustrating how exergy losses arise in buildings-related energy systems. An example of benchmarking of various system solutions is given in Figure 2 according to exergy losses from both renewable and non-renewable energy sources.

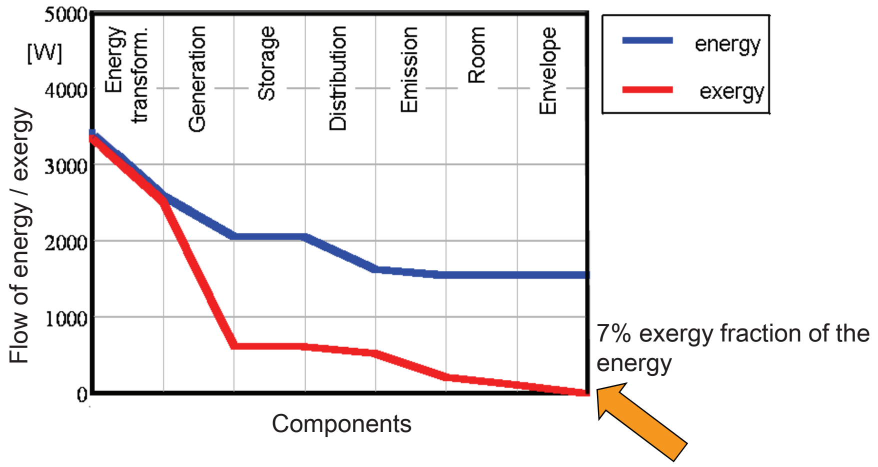

Figure 1. Analysis of low exergy systems.

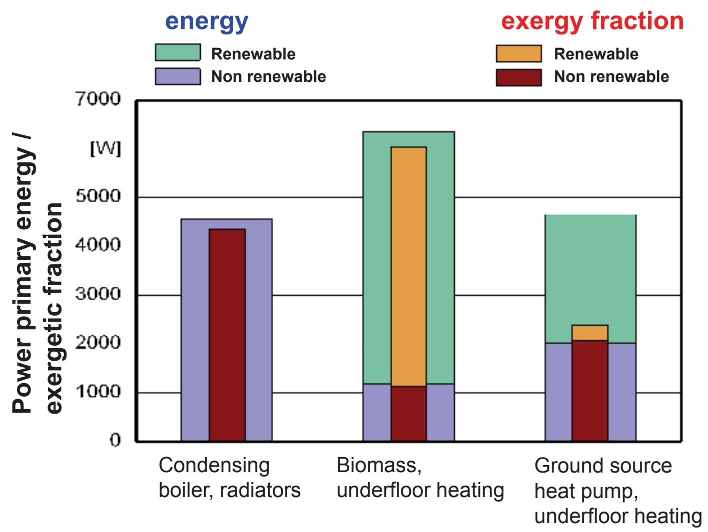

Figure 2. Benchmarking of system solutions.

The outcome from the project is a Guidebook, intended to present the state of the art related to exergy analyses for buildings. It investigates the benefits of applying the exergy concept to the design and optimisation of energy supply systems for buildings and communities. Two versions of the Guidebook are available:

- The full extended version is oriented to scientists and researchers working in the field of energy efficient building systems. The technical background and thermodynamic concepts related to the exergy analysis in building systems are explained thoroughly in a clear and detailed way. In recent years, exergy analyses of building systems have become more prevalent in the scientific literature; however, exergy analysis in buildings (particularly dynamic exergy analysis) is a somewhat controversial issue and is very sensitive to the assumptions made in the analysis. This report is intended to be a reference for further analyses so that comparability can be guaranteed between results of exergy analyses of different building case studies.
- The short summary version is intended to introduce the concepts of and methodology behind exergy analysis to building decision makers and planners. The technical basis behind the exergy concept is explained in a simplified, applicable manner by focusing on the outcomes of exergy analysis and the importance of this concept for building and community systems design.

Tools for Exergy Performance Assessment

One of the core aims of the project was to bring the exergy approach to the attention of building planners, decision makers and architects. For this purpose,

Table 1. Summary of community case studies for exergy analysis.

community	country	LowEx highlights
Alderney Gate	Canada	Sea water cooling coupled with borehole thermal energy storage
Andermatt	Switzerland	geothermal energy systems
Heerlen	Netherlands	low temperature emission systems, low temperature district heat from old coal mines
Letten	Switzerland	geothermal energy systems
Oberzwehren	Germany	utilisation of a low exergy supply source, i.e. waste heat from CHP
Okotoks	Canada	solar thermal heating systems, coupled with seasonal ground thermal energy storage
Parma	Italy	low temperature heating systems coupled with efficient ventilation systems
Twin cities Minnesota	USA	co-generation and district heating
Ullerød	Denmark	low energy district heating, ground source heat pump (GSHP) and air-to-water heat pump (AWHP)

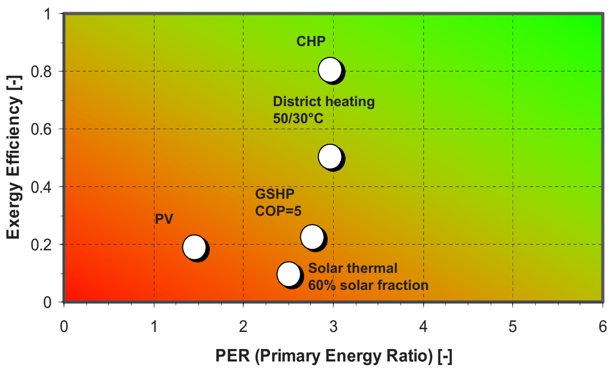

Figure 3(a). Primary energy ratio versus exergy efficiency diagram for the supply options considered for the community of Oberzwerhren, Germany.

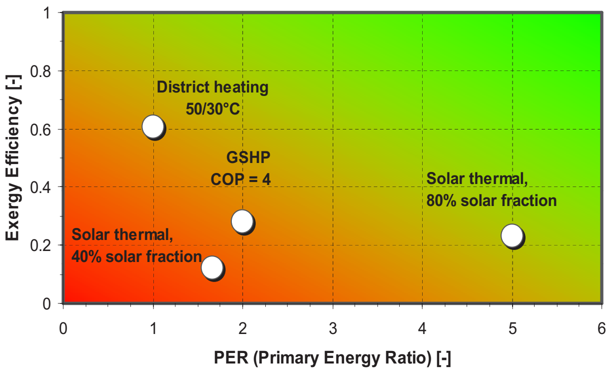

Figure 3(b). Exergy efficiency of the systems versus primary energy ratio for the supply options considered for the city of Parma, Italy.

the development of user-friendly open-platform software for exergy based building design and performance assessment is essential. Within the research activities, six different assessment tools have been developed. These tools are focused on different parts of the energy supply chain, ranging from component analysis, to community systems assessment and to building systems design. Thereby, the whole scope of energy supply in buildings is covered for the benefit of the wider audience relating to energy systems

"The objective has been to show ways of supplying indoor spaces with the required energy, without using high quality sources"

and building design. Significantly, the project has developed a computer based exergy calculation tool, DPV (Design Performance Viewer) implemented within a building information model (BIM) and developed for building designers and architects.

Case Studies

To show the benefits of exergy analysis on buildings, several case studies on building and community energy supply systems have been analyzed. Table 1 gives an overview of the analyzed community level case studies within the project. The main technologies used are shown, along with the countries in which they are located. To compare the exergy performance of the different community case studies with each other qualitatively, diagrams characterizing their energy and exergy performance in a simple and graphical manner have been developed. Figures 3(a) and 3(b) show, as examples, such diagrams for two different community case studies, namely Oberzwehren (Germany) and Parma (Italy). Figure 3(a) for instance shows the good exergy performance of low temperature district heating supply compared to the other options.

Project Outcome

The project has delivered a strong scientific basis for the development of models and tools for the wider implementation of exergy analyses for buildings and communities, supported by a collection of innovative case studies. The Guidebook is a valuable source book for future work within this field. It opens an excellent opportunity for new activities within the development of more efficient energy use and supply structures for buildings and communities.

Further information
For additional information, please see: www.ecbcs.org/annexes/annex49.htm

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