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Large Scale Retrofitting of Buildings in Spain

Case Studies & Guidelines for Energy Efficient Communities

Net Zero Energy Housing Case Studies

High Temperature Cooling & Low Temperature Heating in Buildings

Large Scale Retrofitting of Buildings in Spain

How to Revitalise the Economy, Society and the Environment

José María Campos *, Ander Romero Amorrortu and Amaia Uriarte Arrien

*** ECBCS Executive Commitee Member for Spain**

Introduction

In Spain, as in other industrialised countries, new buildings have until recently been responsible for the largest proportion of gross domestic product (GDP) generated by one of the pillars of its economy, the construction sector. Moreover, they have received greater attention by policy makers than existing buildings in terms of energy use and other environmental impacts.

But, after many years of strong economic growth, Spain is now struggling with one of the deepest and longest-lasting recessions in its recent history, affecting the construction sector. This crisis is limiting the financial capabilities of the country's public institutions, which have generally reduced to a minimum any incentives or financial support for renewable energies or sustainable development. A significant exception to this is a continuing level of public investment for applying energy saving measures to existing buildings.

Figure 1 shows the age of the building stock in Spain. Over 40% of the Spanish residential stock was built before 1960. These buildings consequently do not meet more recent demanding energy efficiency standards, suggesting good prospects for large scale energy retrofitting. The combination of this and

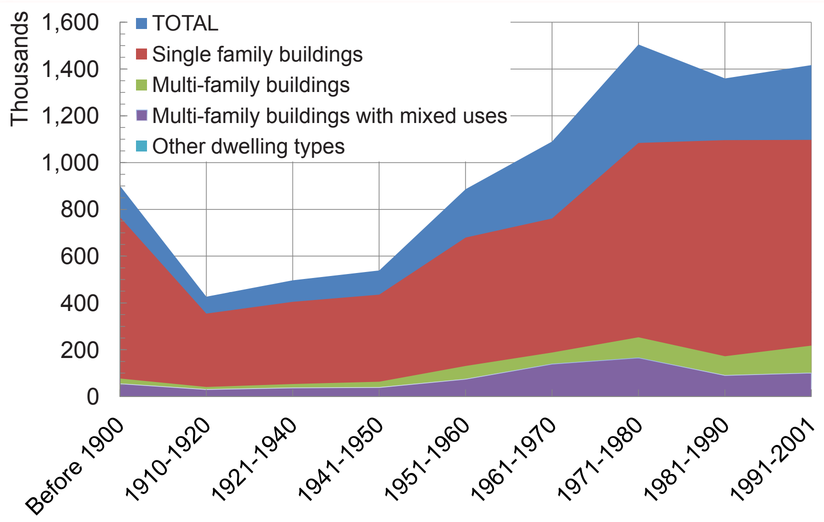

Figure 1. Age of the residential building stock in Spain.

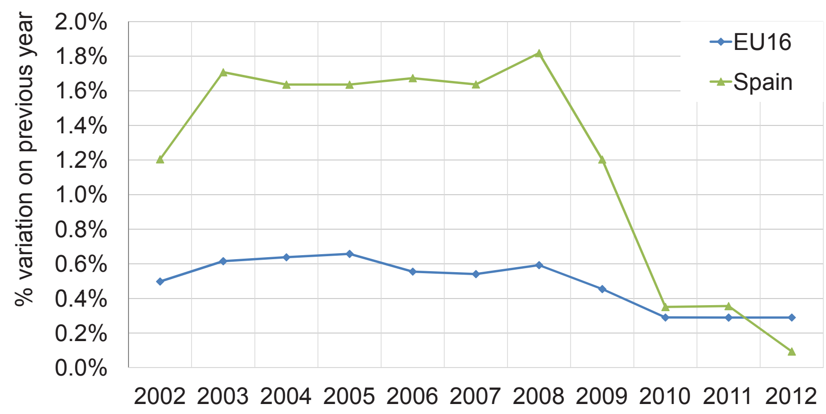

Figure 2. Population growth in Spain and the EU16.

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ECBCS Executive Committee Support Services Unit (ESSU), c/o AECOM Ltd, Colmore Plaza, Colmore Circus Queensway, Birmingham B4 6AT, United Kingdom, Tel: +44 (0)121 262 1920, Email: *newsletter@ecbcs.org*

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a weakened construction economy therefore presents a major opportunity to simultaneously revitalise the economy, society and the environment. In fact, there are multiple benefits associated with such stock improvements, including:

- economic and societal advantages by requiring increased skills and employment, generating additional revenue for the construction sector, and improving comfort and health by careful planning for better indoor environments during retrofits;
- economic and environmental improvements by reducing operational energy use and associated greenhouse gas emissions arising from buildings.

The national context

With a GDP around $1500 billion (US), Spain is the fourth largest economy in Europe, and twelfth globally. Situated in the south of the continent, it is the fifth most populated country in Europe with a total population of 46.2 million, having experienced rapid growth in this area between 2001 and 2008 (see Figure 2), essentially due to a very high immigration rate. Over the same period, the average economic growth rate was 3.4%, almost twice the European average. (The EU16 average growth of GDP from 2001 to 2007 was 2.0%).

Figure 3 shows that Spain's current economic situation differs strikingly from the period from 2001 to 2007. In 2008 with the onset of the worldwide economic crisis, the Spanish property bubble exploded. While Spain's economic growth was +0.7% in 2011, forecasts for 2012 and 2013 are negative (-1.8% and -0.3% respectively), highlighting Spain as the only European country with negative projected GDP growth for 2013.

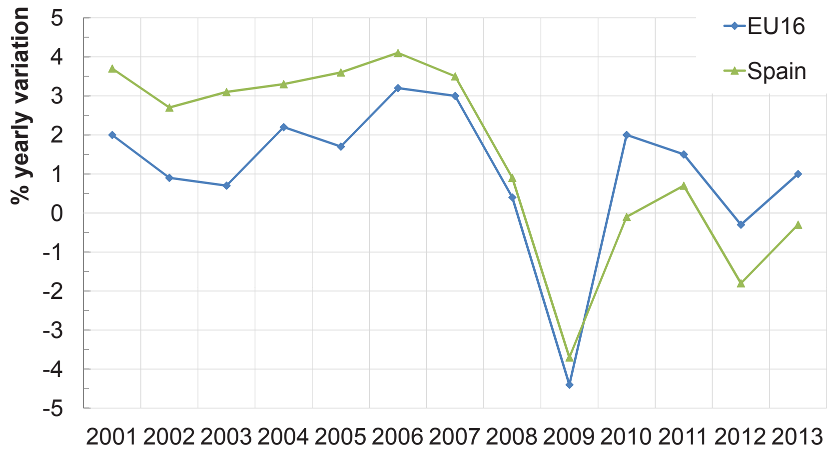

Figure 3. GDP variation in Spain and the EU16.

In 2005 the construction of 635 thousand new dwellings was initiated in Spain. Six years later, the number of new dwellings started was only 63 thousand. Moreover, the sector has shrunk from 20% of total contribution to national GDP to less than 15%. These two statistics clearly reveal the severe crisis that has affected the construction sector from 2005 until the present day. In the same interval, unemployment rates rose from below 6% to 20%.

However, while the number of 'Municipal Construction Licenses' for new build developments has fallen steadily throughout the crisis period, the number of Licenses issued for retrofitting activities has remained almost constant (see Figure 4).

Energy supply & demand

Spain is one of the most energy dependent countries in Europe, with over 75% of its primary energy coming from abroad, far exceeding the European average (56%) (see Figure 5). Oil is the main energy resource (45.1% of primary energy), with renewable energies ranking third (11.6% of primary energy and 15% of final energy).

The consumption of primary energy in the country grew continually from 1997 until 2007, when the economic crisis started to affect the national economy. All sectors have been affected by the crisis and the reduction in energy consumption, including the residential sector. The variation of final energy consumption in the latter was -4.2% from 2008 to 2009. The national energy intensity fell by 1.7%

The EU16 - the European Union group of member states that share the Euro currency: Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia and Spain.

The EU25 - the European Union group of member states including the EU16 and Czech Republic, Denmark, Estonia, Latvia, Lithuania, Hungary, Poland, United Kingdom and Sweden.

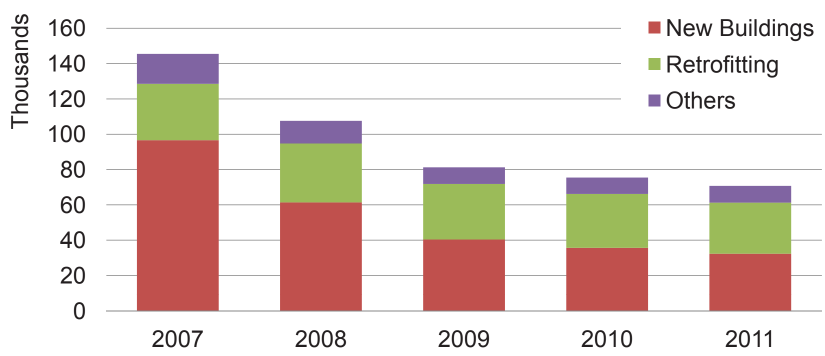

Figure 4. Number of Municipal Construction Licenses issued in Spain.

in 2011 (primary energy consumption fell by 0.6% in 2011, and final energy fell by 4.4%).

The energy sector is thus suffering a serious crisis after a long period of growth, especially in the area of renewables. In particular, subsidies are no longer available for new power plants running on renewable energy sources to prevent an escalation of the billions of Euros of debt now held by utilities.

In 2008, the energy intensity of the residential sector in Spain was about 40% below the European average (0.9 toe/dwelling compared to 1.5 toe/dwelling). This is mainly due to Spain's advantageous climate conditions compared with other European countries, which are reflected in reduced energy needs for space heating of 40% on average in comparison with the European average of 70%.

The Spanish Government recently approved the second National Action Plan for Energy Efficiency, for the period 2011 to 2020, in line with certain European Directives. This new Action Plan aims to improve the final energy intensity by 2% per year between 2011 and 2020, with estimated cumulative savings of 121 Mtoe for the entire period. To attain this cumulative energy saving, the Spanish Government estimates a total cumulative investment of €46.0 billion for the whole period (the estimated cumulative public investment for the whole period will be €5.0 billion).

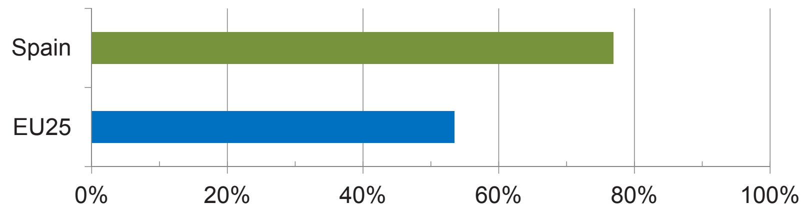

Figure 5. Energy dependency in 2010 in Spain and the EU25.

"The energy sector is thus suffering a serious crisis after a long period of growth, especially in the area of renewables"

For the buildings sector, the estimated energy savings are shown Table 1 assuming new and retrofit buildings meet very demanding energy criteria. The energy savings have been calculated taking the year 2007 as a point of reference. For 2010, the indicated figures are those achieved through the first National Energy Efficiency Action Plan 2007-2010. To meet these targets, the normalised energy intensity in the country must be reduced by 2% over the period 2010 to 2020 (from 0.0114 toe/m^2 to 0.0110 toe/m^2). A range of measures are planned for implementation to achieve these savings, as presented in Table 2.

Table 1. Estimated energy savings in the building sector.

	2010 ktoe/a	2016 ktoe/a	2020 ktoe/a
Residential	752	119	211
Envelope and thermal systems	699	85	161
Lighting	53	34	50
Tertiary	1,570	2,497	2,736
Envelope and thermal systems	1,322	1,858	1,944
Lighting	248	639	792
Systems	207	57	-80
Public Services	29	56	125
Public lighting	11	19	58
Water supply	17	36	67

Growing a green economy

If one is to examine the energy use of buildings and communities in Spain, one cannot ignore the severe crisis affecting the country. The analysis must nonetheless be framed in the context of Europe, of which Spain is an integral part. The Europe Union is aiming to achieve complete decarbonisation of its economy by 2050, with a major impact on the construction sector. New buildings in Europe must be nearly zero-energy buildings by 2020, and comply with the European Energy Policy - Vision for 2050 (a reduction of 40% to 50% of energy used by the construction sector), as well as the European Environmental Policy – Vision for 2050 (a reduction of over 90% of greenhouse emissions). To meet this latter objective, existing buildings will need to be retrofitted at a minimum rate of three times the current level.

Spain, facing the future

Most experts and analysts consider that the new buildings market in Spain will be stagnant for a decade, due to the huge excess of unoccupied new buildings in the country and the lack of new land available for construction. Retrofitting is thus expected to become the lifeblood for the sector.

In order to achieve the energy targets for 2020 and 2050, Europe must significantly increase its retrofitting of buildings, not only in terms of the rate but also the depth

Table 2. Estimated energy savings and investments in the buildings sector.

Energy saving measures	Final energy savings ktoe/a		Investment (public support) million €	Total investment million €
	2016	2020	2011-2020	2011-2020
Energy efficient retrofitting of existing building's envelope	775	775	1,109	5,594
Improvement of thermal systems in existing buildings	908	908	283	7,258
Improvement of interior lighting in existing buildings	674	842	192	8,763
New and retrofitted buildings with very demanding energy criteria	224	247	788	4,868

of retrofitting (in terms of reduction of energy consumption). Some studies at a European level show that the retrofitting rate must grow by 300% to meet the energy and environmental targets agreed by the Member States. A combination of incentives and regulatory measures are expected to be implemented to realise these targets. Research activities in Spain and elsewhere are focusing on how to ensure a high level (in depth and rate) of retrofitting in an affordable manner.

Notably, Spain is participating in the current ECBCS project, 'Annex 56: Cost-Effective Energy & CO_2 Emissions Optimization in Building Renovation'. This project has been created to improve the technical basis of standards and regulations by providing solutions and guidance suitable for single and multifamily residential buildings. (See the June 2012 edition of ECBCS News for further information.)

If a 'green economy' is understood to be based on those activities that reduce unnecessary energy consumption and use of raw materials, limit greenhouse gas emissions, minimize waste and pollution, and protect and restore ecosystems, then could the green economy represent a mid- to long-term business opportunity for the construction sector in Spain? Could this be a possible way out of the current economic crisis that the country is facing? It could be concluded that in the short term there is no alternative scenario than a marked paring down of the construction sector. But, a longer-term perspective offers a more positive outlook based on the development of a green construction economy underpinned by a healthy retrofitting industry.

Further Information

For further information, please see:
www.minetur.gob.es
www.fomento.gob.es
www.bpie.eu
www.buildup.eu

Conference Announcement

MICROGEN III

ICROGEN
The 3rd International Conference on
Microgeneration and Related Technologies
Naples, 15-17 April 2013

3rd International Conference on Microgeneration & Related Technologies

15th - 17th April 2013, Naples, Italy

The conference theme is promoting the transition to high efficiency distributed energy systems, focusing on the diffusion of low carbon microgeneration technologies for residential and small commercial applications, with a special attention on building integration and grid interconnection.

The conference is multi-disciplinary and is an opportunity for the different stakeholders (researchers, students, professionals, manufacturers, etc.) working in the field to meet and exchange knowledge at a time of rapid technological developments and changes to energy supply and demand.

Visit the website at **www.microgen3.eu** for more information.

Case Studies & Guidelines for Energy Efficient Communities

ECBCS Project Update: Annex 51

Reinhard Jank, Volkswohnung Karlsruhe, Germany

Background

At present, more than 50% of the world's population lives in urban areas and this figure is increasing. Thus, adaptation and development of cities for the future must prioritise reduction of their environmental impacts and consumption of resources.

On the one hand, sustainable urban development has been demonstrated to be feasible. But, on the other, it is rarely achieved in practice in cities, when measured by the present rate of meeting targets for reducing fossil fuel use and related greenhouse gas (GHG) emissions by at least 50% by 2050. It is generally acknowledged that these targets can in principle be achieved with existing technologies. In fact, there are communities that have successfully reduced their fossil fuel use and GHG emissions, although these are rare exceptions. The prevailing opinion today is that cities are too complex to be able to collectively achieve urban sustainability.

Local policy makers, stakeholders and urban planners are confronted with difficult decision making processes, fragmentation between disciplines and lack of holistic thinking. Due to economic and demographic changes, substantial investments are regularly made in infrastructure and the buildings sector in most communities in both towns and cities. These investments influence long-term urban development and would provide potential stimuli for desirable changes in approach.

"Local policy makers, stakeholders and urban planners are confronted with difficult decision making processes, fragmentation between disciplines and lack of holistic thinking"

However, since an overarching plan for sustainable urban development is missing or is prevented by local frictions or conflicting goals, concerted actions are not being achieved. This is exacerbated by the fragmentation between the disciplines involved in town planning, infrastructure, energy, transportation, facilities management, architecture etc, by which a holistic view of the community as a system is impeded. So, a systematic transfer of existing experiences or technical innovations into widespread urban applications is lacking.

This is the background to the creation of the ECBCS project 'Annex 51: Case studies and Guidelines for Energy Efficient Communities'. Specifically, as major public programmes on energy transformation in communities have been established in recent years, there has been a desire for an exchange of international experiences and learning from current practice in communities. At the project outset, the main technical and societal barriers preventing communities from successfully implementing municipal energy and climate change policies were identified as:

a) knowledge about strategic planning,
b) availability of tools and instruments for decision making, planning and monitoring, and
c) management ability during the implementation process.

The main emphasis of the project has been to focus on overcoming the technical barriers identified in (a) and (b) above. By evaluating the experiences from innovative case study projects, the knowledge has been improved and new tools and instruments created, so contributing to (c). This is documented in the 'Guidebook on Successful Local Energy Planning', as one of the main project deliverables.

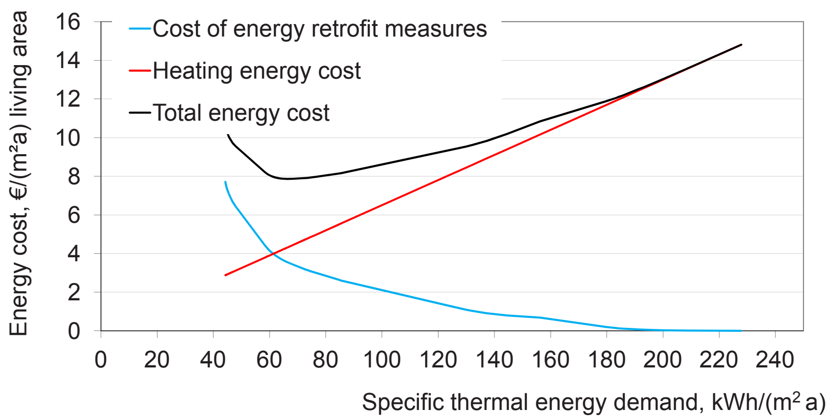

Figure 1. Economic optimization of retrofit costs measures for a multi-family residential building constructed in 1955: The least-cost feasible energy retrofit measures (annual capital costs) and heating energy costs together give total energy costs with a minimum at about 50 kWh/(m² a).

Figure 2. Typical residential building in Rintheim, constructed in 1955 and refurbished in 2010.

Economic limits of energy retrofits for individual buildings

The real challenge of urban energy planning is addressing the existing building stock rather than new developments. Even with current technologies it is possible in principle to achieve drastic improvements of the energy demand for existing buildings, although there are limits in terms of economic viability. In one of the case studies, 'Karlsruhe-Rintheim', the existing building types within the planning area were analyzed to search for the least (total) cost combination of energy conservation measures. The result of this analysis showed that - given current energy prices in Germany and local climatic conditions - the minimum total cost was achieved by a building type specific combination of energy conservation measures yielding a specific heating demand of 40 kWh/(m^2a) to 50 kWh/(m^2a). Figure 1 illustrates this example for a multi-family residential building in Rintheim, as shown in Figure 2.

Similar results have been found for all other building types considered in this case study (employing different combinations of energy conservation measures, dependent on the building type). This is almost two third less than before retrofit, but is still not close to the 'Passivhaus' standard, which recommends a heating demand after

Urban neighbourhoods & districts – the gap in urban energy planning

At the level of neighbourhoods, detailed planning of integrated energy concepts is necessary whether for major individual projects, or for neighbourhoods or districts. Ideally, this is done for several or all city districts, including a consideration of possible interactions of measures in adjacent neighbourhoods, which may benefit overall system optimization. Further, a comprehensive municipal energy master plan should be developed and regularly updated. Although still based on limited data, a higher degree of detail is required for a municipal energy master plan than for a conventional urban energy action plan, since the former will be the basis for concrete and far reaching decisions.

Contrary to municipal energy inventories, available planning knowledge and planning tools for integrated neighbourhood energy concepts is still rather limited. Moreover, urban planners responsible for the municipal plan, architects, or energy engineers responsible for the design of energy systems of individual buildings, are usually not formally educated in producing detailed neighbourhood energy plans. These are therefore currently significant barriers to successful urban energy policy. Even more importantly, there is a lack of understanding that implementing a municipal energy action plan as described above is primarily a management task, involving planners, decision makers, local organisations and local policy makers alike. Achieving energy policy targets means - in the case of medium-sized cities of several 100 thousands of inhabitants - investments in infrastructure and the building stock in the range of billions of Euros over several decades. Without proper planning and process management the outcome will be far from optimal resulting in poor value for money or missed policy targets.

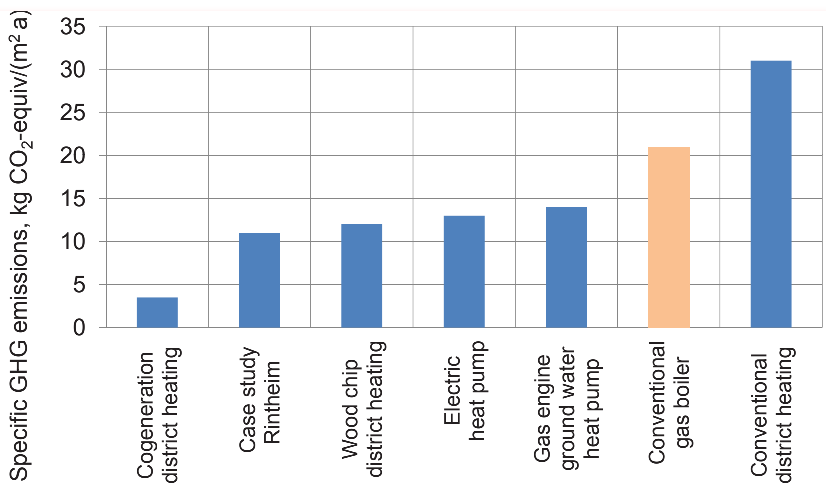

Figure 3. Comparison of optimized building retrofit measures combined with centralised or individual energy supply systems, in terms of GHG emissions (kg CO_2-equiv/(m^2 a)).

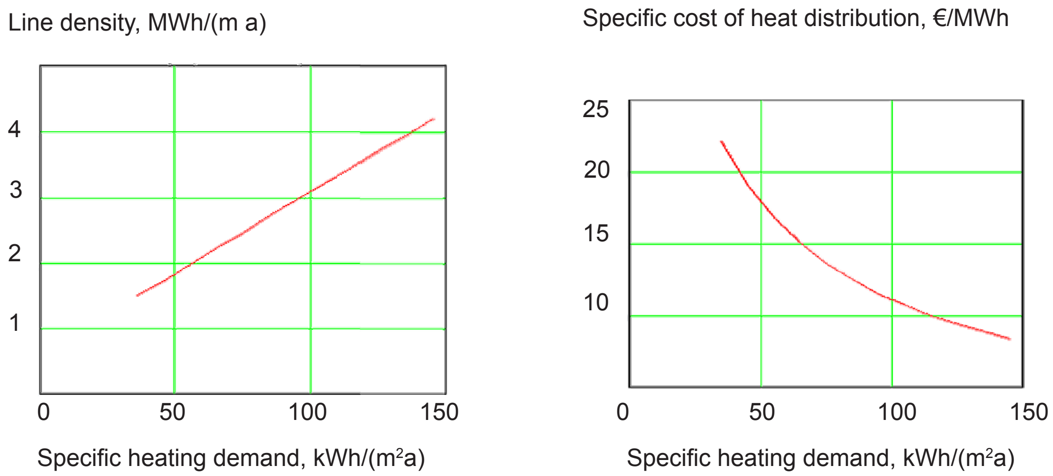

Figure 4. Line density as a function of energy retrofit standard (left) and the resulting specific costs of heat distribution (€/MWh, right). Line density is defined as the amount of thermal energy transported through the neighbourhood distribution grid in MWh/(m a).

retrofit of 15 kWh/(m^2 a). However, as Figure 1 illustrates, more demanding energy retrofits mean steep increases in cost.

Optimization by an integrated neighbourhood planning approach

By considering a conceptual transition from 'individual buildings' to 'many buildings' (neighbourhoods, quarters) further optimization potentials become evident. Due to economies of scale, a number of technologies, such as cogeneration or combined heat and power, waste heat recovery, biomass, geothermal energy, solar heating (and cooling) are more efficient – in technical and economic terms – when used in large installations instead of small ones. Taking advantage of these technologies where locally available will enable the primary energy consumption achieved by a demand and supply optimized system to possibly fall to best practice standards for new buildings, such as the Passivhaus standard. Due to system optimization, this will result in lower costs and with the additional advantage of being feasible at large scales. An approach based on settlements or communities thus offers more economic options, should the energy demand density be sufficient.

Figure 5. Aerial view of the neighbourhood covered by the Karlsruhe-Rintheim Case Study. The neighbourhood is indicated by the irregular pentagon lines. It consists of 36 buildings containing 1300 flats of 5 to 17 storeys and of 44 to 61 years in age. Source: Volkswohnung.

The energy efficiency and resulting GHG emissions of the supply technologies mentioned above can be derived in detail. Appropriate calculation methods are presented in the Guidebook for several worked examples. For the Rintheim case study, assuming optimized building energy retrofit measures consistent with Figure 1, a comparison of the resulting specific GHG emissions of the whole neighbourhood for different supply technologies gives the outcome depicted in Figure 3.

The column 'Case Study Rintheim' in Figure 3 denotes a thermal energy supply over a new neighbourhood scale distribution grid that is fed with thermal energy from the city scale district heating system, which was found to be the best solution in terms of economics. The source of thermal energy in the case of Rintheim is waste heat from industry and a combined heat and power plant fuelled with natural gas. Note that results for supply options that employ cogeneration systems (see leftmost column in Figure 3) will depend strongly on the specific national context for electricity supply.

As Figure 3 demonstrates, sizeable improvements in terms of GHG emissions (and fossil primary energy use) are possible by employing technologies that are more efficient than a simple gas boiler. For the Rintheim case study, the GHG emissions of about 60 kg/(m² a) before implementation of the project (with total costs of about €65 million over 6 years) was reduced by 80%, achieving an emission level similar to new Passivhaus buildings. The residents of the retrofitted buildings pay higher rents after the refurbishment, but these increased costs are almost fully compensated for by reduced thermal energy supply costs. In addition, they now enjoy the comfort of a fully renovated building.

The experience from Rintheim has further showed there is an economic limit of energy retrofit from the viewpoint of energy distribution costs: If the energy density of the supplied neighbourhood is below a certain level, the costs of thermal energy distribution increase beyond a certain threshold, above which the costs become uneconomic and so there are no viable solutions. This is demonstrated in Figure 4, showing that in this case, in a similar way to retrofit optimization, there is an economic limit of retrofit measures of about 50 kWh/(m² a). Below that level, this option would result in higher costs than the conventional gas supply.

"A successful urban climate change policy will only be available if economically and technically viable solutions for comprehensively optimized systems can be found and put into practice"

Figure 5 shows an aerial view of the Rintheim neighbourhood. In Figure 5, in addition to the case study area, other types of neighbourhoods can be recognized representing different settlement types. Such archetypes can be used for characterization of different neighbourhoods in terms of energy density, energy distribution costs, etc, which allows the development of optimization strategies for different neighbourhood archetypes. This method can be used for an initial preliminary analysis of different approaches for retrofit and supply with limited information availability for the neighbourhood under consideration. This method has been developed and is in use in several of the project participating countries.

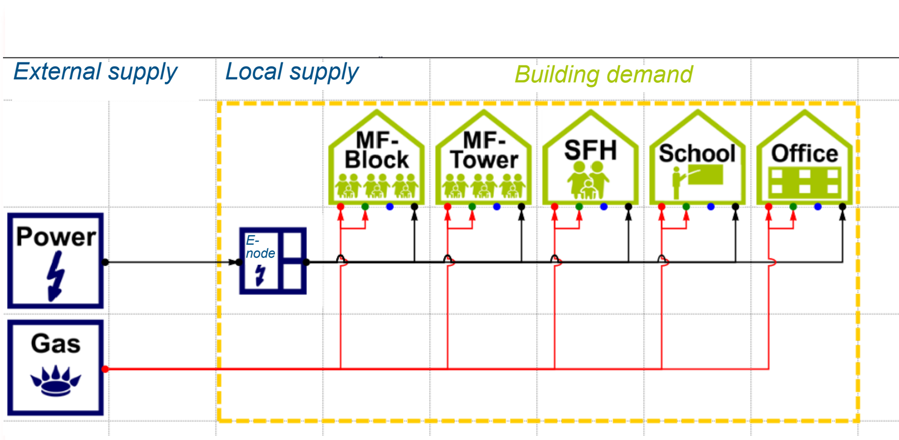

Figure 6. A group of different buildings depicted by the District Energy Concept Adviser, with a possible energy supply system to be evaluated in terms of usable energy, primary energy and GHG emissions.

There are no standard solutions in neighbourhood energy planning. An optimized design and implementation strategy must be found in every new case. It was the subject of our project to demonstrate this by evaluating a number of quite different Case Studies provided by the 11 participating countries.

Project outcomes

Due to the huge overall costs of urban energy transition, a successful urban climate change policy will only be available if economically and technically viable solutions for comprehensively optimized systems can be found and put into practice Communities have an essential role to play to ensure this happens. The aim of the 'Guidebook on Successful Local Energy Planning' is to provide stakeholders and planners in communities with the necessary information to support them in this endeavour. This is a pre-condition to achieving local climate policy goals more successfully than in the past, when ambitious climate change policy targets have often been set by local policy, but never met and in most cases, not even monitored.

The Guidebook includes an overview of the present situation of computer based tools for urban energy planning, a field with increasing importance. This is due to the improving capabilities in energy simulation and graphical information system (GIS) tools that can be used for planning tasks at neighbourhood and city scales. The new 'Energy Concept Adviser' (ECA) tool has been developed based on the experiences of the participating countries to support energy planners in analysing different options at the early planning phase, when detailed planning data are not yet available. This tool provides a means to quickly generate an energy balance for a given neighbourhood and to then analyse the effects of different energy conservation and / or supply measures in terms of delivered energy and primary energy balances. Figure 6 shows a typical ECA screen depicting a group of pre-defined buildings connected to a centralized energy supply system for which this tool provides - among other features - the total primary energy balance of the neighbourhood.

Both the Guidebook and the ECA tool are freely available to the international planning community.

Further Information

For further information, please see:
www.ecbcs.org/annexes/annex51.htm

Net Zero Energy Residential Building Case Studies

ECBCS - SHC Joint Project Update: Annex 52 - Task 40

Laura Aelenei, National Energy and Geology Laboratory, Portugal

Josef Ayoub, CanmetENERGY, Canada

Daniel Aelenei, Nova University Lisbon, Portugal

Introduction

A number of International Energy Agency (IEA) member countries have adopted a vision of so-called 'net zero energy buildings' (NZEBs) as long-term goals of their energy policies. However, what has been missing is a clear definition and international agreement on the measures of building performance that could inform 'zero energy' building policies, programmes and industry adoption worldwide. Although there is no standard approach for designing and realizing an NZEB, there are many different possible combinations of building envelope, services equipment and on-site energy production equipment capable of collectively achieving net-zero energy performance. Therefore, one of the objectives of the joint ECBCS - SHC project 'Annex 52 - Task 40: Towards Net Zero Energy Solar Buildings' has been to collect and document examples of real building projects in various countries to analyse and report the design strategies used.

There is some consensus that zero energy building design should start from the approach of passive sustainable design. Such an approach plays a crucial role in addressing NZEB design by reducing the necessary active heating, cooling, ventilation and lighting loads put on the buildings mechanical and electrical systems, and indirectly, the requirement for renewable energy generation. Relative to the specific NZEB definition, this level of performance can be achieved through the combination of two fundamental steps:

- reduce building energy demand (achieved through passive sustainable design), and
- generate sufficient electricity or other energy from renewable sources to attain the desired energy balance.

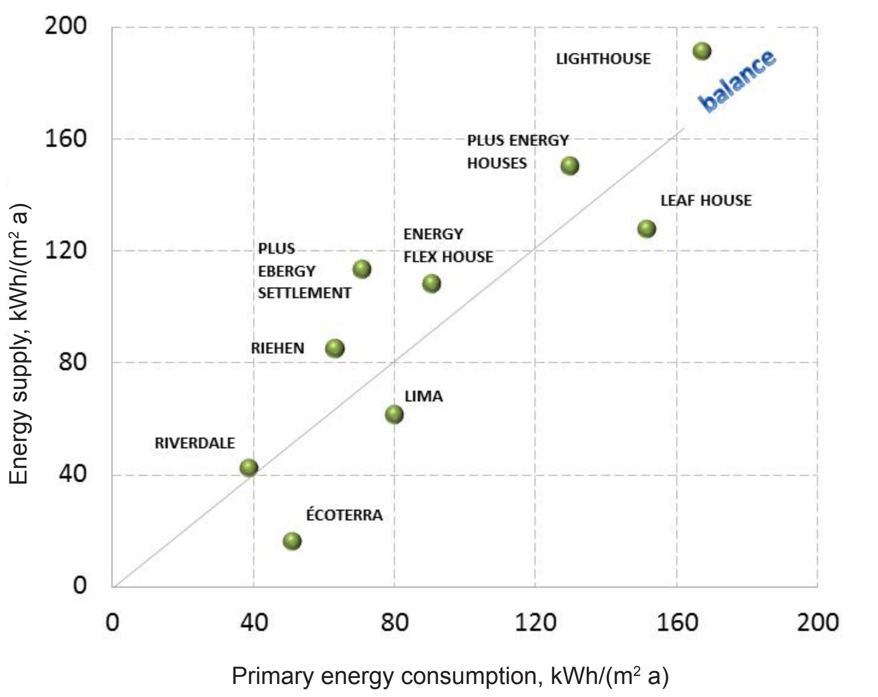

Figure 1. Primary energy consumption and energy supply for the case studies.

Case studies

Table 1 presents a summary of nine residential selected case studies from the project database. This selection has been based on criteria such as access to technical documentation regarding physical characteristics, monitored and / or simulated energy performance data, as well as lessons learned about design and operation and from post occupancy evaluation. Regarding climatic challenges, the range of case studies analysed encompasses two climates that lead specifically either to heating dominated or to heating and cooling dominated buildings.

Figure 1 shows the building energy performance for the nine case studies. Six projects represent 'plus energy' buildings and three are nearly zero energy buildings. The Leaf House building was initially designed to meet net zero carbon performance, whereas Lima and Écoterra were designed to be energy efficient to minimise negative environmental impacts. Lighthouse, which is a demonstration building, was also designed as net zero carbon house, and was the UK's first building that also meets Level 6 (the highest level) of the UK Code for Sustainable Homes.

Net zero energy building design features

Although the main principles applied in passive sustainable design are reasonably well known, the fundamental issue is to assess whether this approach can also be extended and applied for NZEB design. To find out the answer, the analysis of the nine case study buildings was performed according to the approach shown in Figure 2.

The first principle in NZEB design focuses on reducing the amount of energy needed through passive design approaches (PA), represented in the inner circle in Figure 2. Given the inherent needs for artificial lighting and possible heating and / or cooling, the second principle aims at implementing energy efficient systems (EES), the second circle in Figure 2. Finally, renewable energy systems (RES) are needed to offset the energy demand required for lighting, heating and cooling. However, rather than performing a detailed analysis of each of the projects, a cross comparison was performed instead. This procedure allows for the identification of the set of relevant NZEB design issues. This set includes the combinations of passive approaches, energy efficient systems, and renewable energy systems that are more likely to succeed in reaching the desired energy performance.

Passive sustainable design approaches

Passive sustainable design approaches play a fundamental role in NZEB design as they directly affect a building's mechanical and electrical system loads, and indirectly, the requirement for renewable energy generation. Therefore, it is understandable why a zero energy building design should start with passive sustainable design for which guidance is already available for example in the Passivhaus standards. All selected buildings have been designed to deal with heating challenges, so it follows that the passive strategies aim to maximise passive solar heating and prevent heat losses. Even though the buildings were designed to meet different nationally agreed energy performance levels, the initial characterization focused on envelope heat transfer characteristics and compactness.

Table 1. Overview of the case studies.

	Name, Location	Annual primary energy balance kWh/m²a	Climate challenge	External wall U-value W/m^2K	Compact-ness A/V m^2/m^3
	Écoterra, Québec Canada	-34.5	Heating	0.16	0.46
	Energy FlexHouse, Denmark	18.0	Heating	0.08	0.41
	Leaf House, Italy	-23.2	Heating & Cooling	0.15	0.52
	Lima, Spain	-18.2	Heating & Cooling	0.19	1.07
	Riehen, Switzerland	22.2	Heating	0.52	0.59
	Riverdale, Canada	3.9	Heating	0.10	0.74
	Lighthouse, UK	24.6	Heating	0.11	0.87
	Plus Energy Houses, Austria	20.9	Heating	0.09	0.47
	Plus Energy, Germany	43.3	Heating	0.12	0.56

In most of the analysed cases, not only do the U-values (thermal transmittance) for external walls shown in Table 1 meet the requirements of the Passivhaus standard, but also the roof and ground floor thermal transmittance. The important trend shown in Figure 1 is that all buildings dealing with heating and cooling challenges are characterised by U-values greater than the one indicated by the Passivhaus standard. The window U-value varies between 0.70 $W/(m^2K)$ and 1.35 $W/(m^2K)$ for all of the case study buildings. The lower values in this range meet the U-value required by the Passivhaus standard. The interesting feature regarding window U-values is that the projects with the best net zero energy performance (i.e. Plus Energy Settlement, Plus Energy Houses, Riehen and Lighthouse) are characterised by lower window U-values compared with the remainder. With the exception of Lima and EnergyFlexHouse, all buildings are characterised by g-values higher than 50%, as required by the Passivhaus standard.

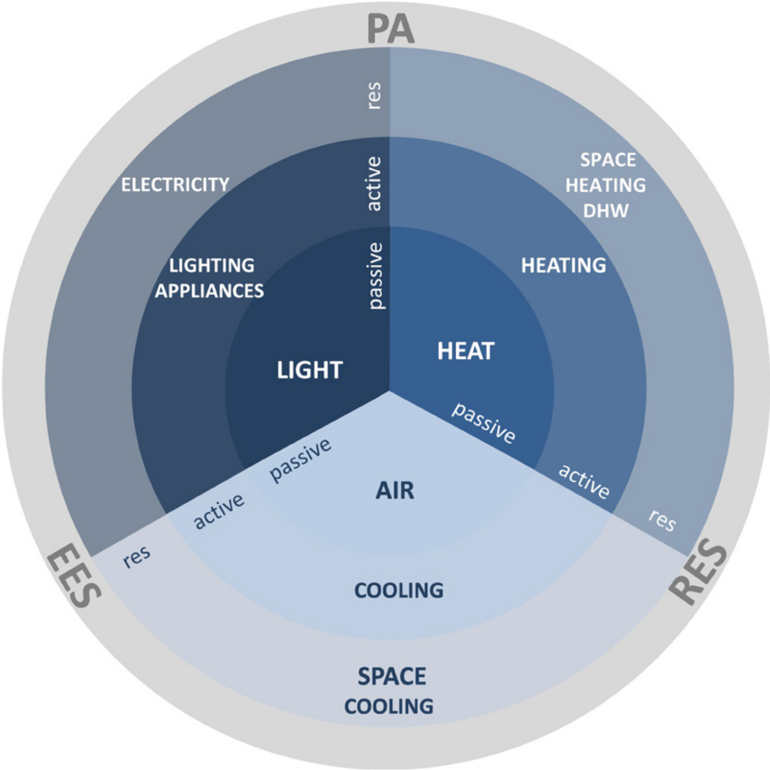

Figure 2. Net Zero Energy Building design approach.

An important role in building heat transfer is played by its envelope heat loss surface area to heated volume ratio i.e. its compactness. Typically, a high compactness is recommended for heating dominated climates because a low exposed surface area limits heat losses, whereas medium-high compactness is more suitable for heating and cooling dominated climates as the cooling demand will be reduced. High compactness can sometimes be sacrificed in favour of a higher surface area oriented to the South. Table 1 indicates that the compactness varies between 0.41 m^2/m^3 and 1.07 m^2/m^3, i.e. high to medium-high compactness.

Solar control strategies, critical for passively heated buildings, are based in most cases on fixed or movable overhangs and / or external screens. Natural (cross) ventilation is a common strategy used to reduce the internal cooling loads in passive design. It is particularly effective when employed at night-time when outdoor temperatures are lower than indoors. In some cases the ventilation system is coupled to earth tubes, so reducing the incoming air temperature with the ground used as a cold source.

Energy efficient systems

In the residential sector in most industrialised countries, major energy consumption is due to systems used for heating and cooling and domestic hot water (DHW). Lighting, together with other occupancy-related electricity use may also account for a significant proportion of total energy use. With respect to the energy efficient systems for ambient heating and cooling, the investigated projects make use of low exergy systems in the form of radiant heating (EnergyFlexHouse, Leafhouse and Lima) and cooling (Lima), as well as efficient mechanical ventilation using air heat recovery. Further, low power electric lighting, energy efficient electrical equipment and load management systems are used as strategies for lowering the energy demand for all of the buildings.

Renewable energy systems

Given the specific energy needs for residential buildings, renewable energy systems should provide either heating and cooling directly or the fuel necessary to run space heating and cooling systems, together with electric lighting and other occupancy-related uses. In this respect, the most common strategies make use of photovoltaic (PV) systems for electricity generation and solar thermal (ST) collectors for DHW production (only Écoterra, Plus Energy Settlement and Plus Energy Houses are not equipped with ST collectors). For space heating and cooling with DHW production, geothermal (Écoterra, EnergyFlexHouse, Leafhouse and Riehen) and biomass (Lighthouse) energy sources may also be used depending on the feasibility and the development cost involved. Energy efficient air source heat pumps used to transfer ambient heat to a useful temperature are also possible (Lima, Riverdale and Plus Energy Houses). Further, a wide range of hybrid strategies can also be employed, for instance:

- geothermal and ST may be combined with low exergy systems (radiant heating) for space heating (Leafhouse and Riehen);
- buildings equipped with heat transfer stations (hot water storage tanks) can be connected to a district heating grid fed by a combined heat and power plant fired by wood chips and natural gas (Plus Energy Settlement).

Conclusions

To reduce building energy demand using passive design approaches and energy efficient systems, the most frequent strategies rely on high thermal insulation and passive solar gains combined with radiant heating and air heat recovery in the case of heating dominated climates, and on a solar control strategy and natural cross ventilation combined with radiant cooling and displacement ventilation in the case of cooling dominated climates. The analysis of nine case studies shows it is possible to achieve zero energy performance using combinations of existing well known strategies. This supports the concept that the design of zero energy buildings should be a progression of passive sustainable design.

Further Information

For further information, please see:
www.ecbcs.org/annexes/annex52.htm

High Temperature Cooling & Low Temperature Heating in Buildings

New ECBCS Project: Annex 59

Xiaohua Liu, Tsinghua University, P.R.China

Conventional building heating, ventilation and air conditioning (HVAC) systems include various sub-systems designed to condition outdoor air to a temperature and humidity within an acceptable range for human thermal comfort. But, such systems have not always been developed with energy efficiency as a priority. In fact, they can include inefficient processes that use more energy than necessary to produce the desired comfort outcome.

The aim of the new ECBCS project 'Annex 59: High Temperature Cooling and Low Temperature Heating in Buildings' is therefore to improve current HVAC systems. The general objective is to examine how to achieve high temperature cooling and low temperature heating by reducing temperature differences in heat transfer and energy transport process. Specifically, it is considering how to avoid unnecessary offset of cooling and heating, dehumidification and humidification, mixing losses of cold and hot fluids, or unnecessary or inappropriate transfer losses due to heat exchange.

"By evaluating HVAC systems from a new angle, it is intended to provide a new perspective and concept for analysis of HVAC systems in buildings"

By evaluating HVAC systems from a new angle, it is intended to provide a new perspective and concept for analysis of HVAC systems in buildings. These will principally be for the benefit of building owners, building designers and equipment manufacturers. The scope includes major commercial building types, such as offices, buildings containing large enclosures, and so on. Two of the case study buildings to be studied are shown in Figure 3.

Figure 1. Case study buildings (left: building with a large enclosure; right: office building).

The main objectives of the project can be summarized as three aspects:

- Establish a methodology for analysis of HVAC systems through reducing mixing and transfer losses
- Proposed novel designs for indoor terminals and outdoor air handling equipment
- Develop high temperature cooling and low temperature heating system in buildings with fully utilized heat / cold sources, high efficiency energy transport and well designed indoor terminals

The intended outcomes of the project are:

- A guidebook on the new analysis method for HVAC system design
- Proposed novel designs for indoor terminals for use in high temperature cooling and low temperature heating systems
- Novel designs for outdoor air handling equipment and their application in high temperature cooling and low temperature heating systems
- A design guide for high temperature cooling and low temperature heating systems
- A report on applications and real-time tests of high temperature cooling and low temperature heating system in typical building types under different climate conditions.

Further Information

For further information, please see:
www.ecbcs.org/annexes/annex59.htm

ECBCS International Projects

5 Air Infiltration & Ventilation Centre

www.aivc.org

The AIVC carries out integrated, high impact activities with an in depth review process, such as delivering webinars, workshops and technical papers. The main target groups for the Centre are the research community and industry including practitioners from design through to construction and maintenance, as well as policy and other decision makers.
Contact: Dr Peter Wouters
E: aivc@bbri.be
Status: ongoing

48 Heat Pumping & Reversible Air Conditioning

www.ecbcs.org/annexes/annex48.htm

When installed, high cost air conditioning systems should be exploited as fully as possible, by allowing them to operate reversibly as required, either in heat pumping or in air cooling modes. Exhaust air heat recovery can also be applied during heat pumping. The knowledge and guidance generated by the project is targetted at designers and is also of relevance to building operators and owners.
Contact: Philippe Andre
E: p.andre@ulg.ac.be
Status: completed

49 Low Exergy Systems for High-Performance Buildings & Communities

www.ecbcs.org/annexes/annex49.htm

This project has developed concepts for reducing the exergy demand (a measure of energy quality) in buildings and community energy systems. The guidance produced is of particular benefit for designers and presents an approach that evaluates how exergy is lost in energy generation, transmission and end use. This permits low exergy sources to be selected to meet heating and cooling demands.
Contact: Dr Dietrich Schmidt
E: dietrich.schmidt@ibp.fraunhofer.de
Status: completed

50 Prefabricated Systems for Low Energy Renovation of Residential Buildings

www.ecbcs.org/annexes/annex50.htm

An advanced design, manufacturing and construction approach has been created to allow existing buildings to be retrofitted using prefabricated external facade units, which are designed to upgrade the building fabric energy performance and accomodate new heating, ventilation and air conditioning systems. Crucially, the building occupants can remain in place during the renovation works. The project has focused on the needs of designers, the building industry and apartment building owners.
Contact: Mark Zimmermann
E: mark.zimmermann@empa.ch
Status: completed

51 Energy Efficient Communities

www.ecbcs.org/annexes/annex51.htm

Community-wide energy system concepts must be based on optimized solutions in economic terms rather than necessarily introducing cutting-edge technical innovations. The project is specifically targeting local decision makers and stakeholders, who are not experts in energy planning. Guidance, case studies and a decision making tool are being produced to assist in implementing robust based approaches.
Contact: Reinhard Jank
E: reinhard.jank@Volkswohnung.com
Status: ongoing

52 Towards Net Zero Energy Solar Buildings (NZEBs)

www.ecbcs.org/annexes/annex52.htm

There is now a strong interest in net-zero, near net-zero and very low energy buildings. The project is achieving a common understanding of these concepts and are delivering a harmonized international definitions framework, tools, innovative solutions and industry guidelines. The key audiences for the work are government policy makers and research funding programme managers, industry, utilities and the academic community.
Contact: Josef Ayoub
E: jayoub@encs.concordia.ca
Status: ongoing

53 Total Energy Use in Buildings: Analysis & Evaluation Methods

www.ecbcs.org/annexes/annex53.htm

Knowledge of the influence of different factors on energy use in buildings is essential to accurately assess short- and long-term energy saving measures, policies and technologies. This includes an improved treatment of how occupant behaviour can be addressed. The beneficiaries of the work are policy makers, energy services contracting companies, manufacturers and designers.
Contact: Prof Hiroshi Yoshino
E: yoshino@sabine.pln.archi.tohoku.ac.jp
Status: ongoing

54 Integration of Micro-generation & Related Energy Technologies in Buildings

www.ecbcs.org/annexes/annex54.htm

A sound foundation for modelling small scale co-generation systems underpinned by extensive experimental validation has been established to explore how such systems may be optimally applied. The target audiences include system designers and installers and energy services contracting companies, with outputs also of value to local to government policy makers, utilities, social housing providers, technology developers and investors.
Contact: Dr Evgueniy Entchev
E: eentchev@nrcan.gc.ca
Status: ongoing

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

www.ecbcs.org/annexes/annex55.htm

When retrofitting existing buildings, it is vital to ensure anticipated energy benefits are realized in practice. The project is providing decision support data and tools for energy retrofitting measures for software developers, engineers, consultants and construction product developers. These tools are based on probabilistic methods for prediction of energy use, life cycle cost and hygrothermal performance.
Contact: Dr Carl-Eric Hagentoft
E: carl-eric.hagentoft@chalmers.se
Status: ongoing

56 Cost-Effective Energy & CO_2 Emission Optimization in Building Renovation

www.ecbcs.org/annexes/annex56.htm

Current standards for new buildings are generally unsuited to the numerous constraints imposed by existing buildings. 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. To assist this process, the project is delivering accurate, understandable information and tools targeted to non-expert decision makers and real estate professionals.
Contact: Dr Manuela Almeida
E: malmeida@civil.uminho.pt
Status: ongoing

57 Evaluation of Embodied Energy & CO_2 Emissions for Building Construction

www.ecbcs.org/annexes/annex57.htm

The project is investigating methods for evaluating embodied energy and carbon dioxide (CO_2) emissions of buildings. It is developing guidelines to improve understanding of the evaluation methods, with the goal of finding better design and construction solutions with reduced embodied energy and CO_2 emissions. The main receptors for the project outcomes

are practitioners, such as designers and engineers of buildings and their components, as well as decision makers, including policy makers and building owners.
Contact: Prof Tatsuo Oka
E: okatatsuo@e-mail.jp
Status: ongoing

58 Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements

www.ecbcs.org/annexes/annex58.htm
The project is developing the necessary knowledge, tools and networks to achieve reliable in-situ dynamic testing and data analysis methods that can be used to characterise the actual energy performance of building components and whole buildings. The state of the art on full scale testing and dynamic data analysis, including a survey of existing full scale test facilities will be determined for the benefit of the building industry, engineers and consultants.
Contact: Prof Staf Roels
E: staf.roels@bwk.kuleuven.be
Status: ongoing

59 High Temperature Cooling & Low Temperature Heating in Buildings

www.ecbcs.org/annexes/annex59.htm

The project aim is to improve current HVAC systems, by examining how to achieve high temperature cooling and low temperature heating by reducing temperature differences in heat transfer and energy transport process. Specifically, it is considering how to avoid unnecessary offset of cooling and heating, dehumidification and humidification, mixing losses of cold and hot fluids, or unnecessary or inappropriate transfer losses due to heat exchange. The scope includes commercial buildings, such as offices and buildings containing large enclosures. It will principally be for the benefit of building owners, building designers and equipment manufacturers.
Contact: Prof Yi Jiang
E: jiangyi@tsinghua.edu.cn
Status: ongoing

IEA Secretariat
Marc LaFrance
E: Marc.LAFRANCE@iea.org

ECBCS Secretariat
Malcolm Orme
E: essu@ecbcs.org

ECBCS Executive Committee Members

AUSTRALIA
Stefan Preuss
E: Stefan.Preuss@sustainability.vic.gov.au

AUSTRIA
Isabella Zwerger
E: Isabella.Zwerger@bmvit.gv.at

BELGIUM
Dr Peter Wouters
E: peter.wouters@bbri.be

CANADA
Dr Morad R Atif
E: Morad.Atif@nrc-cnrc.gc.ca

P.R. CHINA
Prof Yi Jiang
E: jiangyi@tsinghua.edu.cn

CZECH REPUBLIC
Eva Slovakova
E: slovakova@mpo.cz

DENMARK
Rikke Marie Hald
E: rmh@ens.dk

FINLAND
Dr Markku J. Virtanen
E: markku.virtanen@vtt.fi

FRANCE
Pierre Hérant
E: pierre.herant@ademe.fr

GERMANY
Markus Kratz
E: m.kratz@fz-juelich.de

GREECE
To be arranged.

IRELAND
Owen Lewis
E: Owen.lewis@iol.ie

ITALY
Dr Marco Citterio
E: marco.citterio@enea.it

JAPAN
Dr Takao Sawachi (Vice Chair)
E: tsawachi@kenken.go.jp

REPUBLIC OF KOREA
Dr Seung-eon Lee
E: selee2@kict.re.kr

NETHERLANDS
Piet Heijnen
E: piet.heijnen@agentschapnl.nl

NEW ZEALAND
Michael Donn
E: michael.donn@vuw.ac.nz

NORWAY
Eline Skard
E: eska@rcn.no

POLAND
Dr Eng Beata Majerska-Palubicka
E: beata.majerska-palubicka@polsl.pl

PORTUGAL
Prof Eduardo Maldonado
E: ebm@fe.up.pt

SPAIN
José María Campos
E: josem.campos@tecnalia.com

SWEDEN
Conny Rolén
E: conny.rolen@formas.se

SWITZERLAND
Andreas Eckmanns (Chair)
E: andreas.eckmanns@bfe.admin.ch

UK
Clare Hanmer
E: Clare.Hanmer@carbontrust.co.uk

USA
Richard Karney
E: richard.karney@ee.doe.gov

For full contact details please see: www.ecbcs.org/contacts.htm

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