EBC

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Communities Programme

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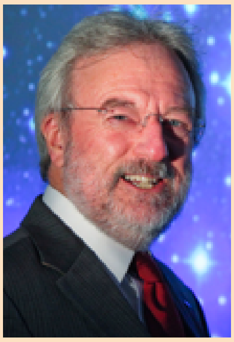
Energy Efficiency Advances

Dear Reader,

Comprising senior experts from IEA member governments, the Committee on Energy Research and Technology (CERT) considers effective energy technology and policies to improve energy security, encourage environmental protection and maintain economic growth. CERT oversees the technology forecasting, analyses and the research, development, demonstration and deployment strategies of the IEA.

The IEA *Energy Efficiency First* message is front and centre in the international collaborative R&D activities of EBC, one of the IEA's Technology Collaboration Programmes. EBC's participating countries are accelerating the transformation of the built environment towards much more energy efficient and sustainable buildings and communities. Our research supports more effective policies, and makes available robust and durable guidance, decision-making tools and integrated systems technologies. The achievements of researchers and industry in Norway in developing new insulation materials and construction systems, upgrading skills and educating the next generation of professionals, and demonstrating the feasibility of zero emission buildings underline the value of participation in EBC research, and lay the basis for the development of Norway's zero emission society.

An example featured in these pages is the recently completed project on probability-based assessment of the performance and life cycle costs of energy retrofitting to give industry guidelines for sound investment decision-making. Other research mentioned is working closely with the financial and public sectors to strengthen risk reducing due diligence processes for deep energy retrofit projects. A current project also described is tackling the software challenges inherent in the design and operation of zero energy buildings and communities, and capable of automating workflows for design, analysis, and optimization, while allowing full integration with simulation tools. Finally, a new project is making a case for building energy epidemiology, using insights from population-based, empirically derived evidence to inform the type, timing and targeting of policies and to assist the development of technologies to manage energy demand.



Prof J Owen Lewis
EBC Executive Committee and former CERT Member for Ireland

Cover picture: Interior view of the ZEB Living Laboratory at NTNU/SINTEF, Trondheim, Norway. The architect is Luca Finocchiaro, NTNU, Norway.
Source: Anne Jørgensen Bruland, NTNU

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EBC Executive Committee Support Services Unit (ESSU), c/o AECOM Ltd
Colmore Plaza
Colmore Circus Queensway
Birmingham B4 6AT
United Kingdom
+44 (0)121 262 1920
newsletter@iea-ebc.org

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Norway Demonstrates Zero Emission Buildings

Arild Gustavsen, Terje Jacobsen and Inger Andresen

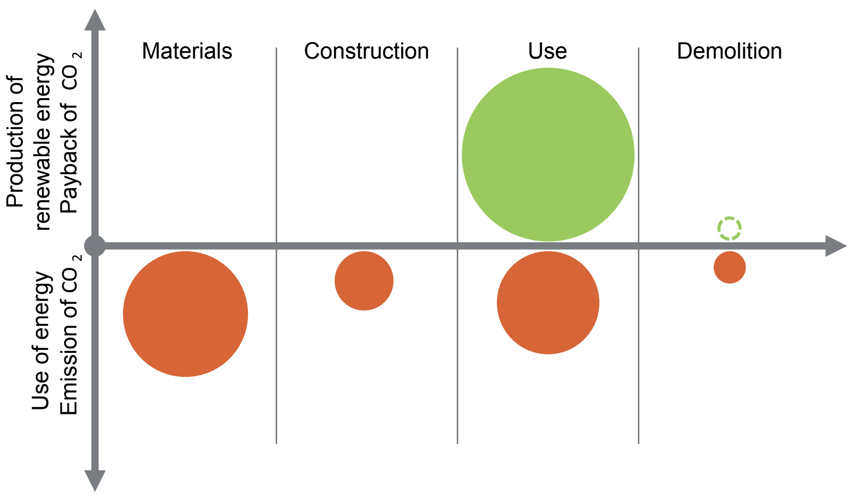
Policy makers in Norway have set their sights on nearly zero energy targets for new buildings from 2020. By building on recent EBC research, Norwegian research teams and their industry partners are being even more ambitious to establish standards for 2025.

Introduction

In 2010, the Member States of European Union signalled their intention to require nearly zero energy new buildings from 2020 in a recast of the earlier Energy Performance of Buildings Directive. By 2012, the Government of Norway had responded with a similar aim explained in two White Papers, 'Good buildings for a better society - building policy for the future', and 'Norwegian Climate Policy'. In 2015, policy makers in Norway introduced strengthened energy requirements at almost Passivhaus levels. Indeed, it is expected that from 2020 Norwegian requirements will also be based on nearly zero energy new buildings. In anticipation of the standards that Norway could adopt for 2025 onwards, these developments have prompted us to consider if buildings with zero emissions of greenhouse gases (GHGs) are technically and economically feasible.

With this in mind, the latest outcomes of our research project, 'The Research Centre on Zero Emission Buildings (ZEB Centre)' are significant. Over eight years, the ZEB Centre work programme has allowed us to explore possibilities for realizing zero GHG emission buildings (ZEBs) in the Norwegian climate. By this, we mean buildings that do not contribute to GHG emissions when evaluated over their whole lifetimes. Moreover, we have incorporated several of our ZEB Centre activities within collaborative EBC international research projects. Our participation in the EBC

Illustration of the zero greenhouse gas emission building concept



Whole life greenhouse gas emissions are constituted by manufacturing of construction materials and building services, the construction process, building operation, and finally demolition, including reuse or recycling of materials. Source: ZEB Centre, NTNU, Norway projects, 'Annex 57: Evaluation of embodied energy and CO_2 equivalent emissions for building construction', and 'Annex 52 / SHC Task 40: Towards net zero energy solar buildings (NZEBs)', has proven to be valuable for our own research.

The ZEB Centre objectives and consortium partners

The ultimate objective of the ZEB Centre is to develop competitive products and solutions for existing and new buildings. This would be expected to lead to strong market penetration of buildings that have zero GHG emissions related to their production, operation and demolition. Such buildings should not only provide healthy and comfortable indoor environments, but also need to be flexible and adaptable to changing user demands. Further, they should be cost-effective, architecturally attractive and straightforward to construct, occupy, operate and maintain. Finally, they need to be robust with respect to varying climatic exposure and future climate changes.

The ZEB Centre project consortium spans the construction industry value chain: manufacturers of materials and products, contractors, consultants and architects, property managers, public administration and authorities, trade organizations, and university and research institutions. The Research Council of Norway is co-funding the work jointly with the partners.

Definitions of net zero emission buildings

The underlying principle agreed at the start of the ZEB Centre project was that all GHG emissions related to the lifespan of a building should be offset by new energy generated solely from renewable sources. This includes embodied emissions related to production and maintenance of the construction materials and building services, as well as emissions related to the construction, operation, and demolition phases. What separates this definition of zero emissions buildings from many others is that the emissions related to construction materials and building services installations (and their maintenance) are included in the balance. Other definitions focus only on the operational phase.

Results from conceptual studies and real pilot buildings show that materials and the building services usually contribute to more than half of the total GHG emissions during a building's lifespan. Also, knowing that half of all raw materials are used in the construction industry, a holistic approach taking materials into account is needed to reduce the environmental impact of buildings.

To allow for distinct increases in performance for our demonstration buildings, the ZEB Centre has defined several levels of ambition, depending on how many phases of a building's lifespan are to be addressed. The five main definitions are:

- ZEB-O: The building's renewable energy production compensates for GHG emissions from operating the building.
- EB-O-EQ: The building's renewable energy production compensates for GHG emissions from operating the building minus the energy use for equipment (plug loads). This is the definition that would most likely be similar to a zero energy building requirement.
- ZEB-OM: The building's renewable energy production compensates for GHG emissions from operation and from the production of its building materials.
- ZEB-COM: The building's renewable energy production compensates for GHG emissions from construction, operation and production of building materials.
- ZEB-COMPLETE: The building's renewable energy production compensates for GHG emissions from the entire lifespan of the building, including from building materials, the construction process, operation and demolition.

Demonstration with real buildings

Our demonstration projects based on real buildings have been an important arena for research, learning and innovation in the ZEB Centre. We are developing nine projects in Norway, with five of these completed so far:

- The residential building, 'ZEB Living Laboratory', in Trondheim was completed in September 2015, meeting the ZEB-O ambition level. This building also serves as a laboratory, where human interaction studies are carried out. Some of the researchers that were part of the design team benefitted from participation in the EBC research project, 'Annex 58: Reliable building energy performance characterization based on full scale dynamic measurements'.
- An office building for the Norwegian Defence

The Powerhouse Kjørbo zero emission building demonstration project, situated in Sandvika, Norway.
Source : Snøhetta/MIR, Norway

Estates Agency at Haakonsvern in Bergen was completed in 2016. A ZEB-O-EQ ambition level was set for this 2000 m² building. The project placed a high emphasis on cost-effectiveness and focused on using well proven technologies in an optimal combination.

– The ZEB Pilot House in Larvik is a 200 m² residential demonstration building completed in 2014, with an ambition level of ZEB-OM. The project has focused on using locally sourced and renewable materials such as wood and reused materials, as well as combining various heat recovery and renewable energy systems, such as solar thermal systems, photovoltaics and heat pumps.
– Powerhouse Kjørbo, located near Oslo, consists of two office blocks from the 1980s that have been transformed into an up-to-date and modern office facility, with 5000 m² total floor area. This project was completed in 2014, meeting the ZEB-OM ambition level (not including energy use for appliance and plug loads). Innovative measures include the reuse of building materials, a low carbon cladding system, and a hybrid ventilation system with extremely low electricity use. Significantly, occupant surveys have shown high satisfaction with the indoor environment.
– Five dwellings on the Skarpnes housing estate near Arendal were completed in 2014, according to the ZEB-O ambition level. The project employs well insulated and airtight envelopes, efficient equipment, building integrated photovoltaics and a ground source heat pump. Interviews with the occupants have revealed high satisfaction with general quality and comfort. Measurements of energy use and the indoor environment are in progress.

Monitoring and evaluation of performance and occupant satisfaction are important aspects of the evidence base, and activities to assess these are underway for these demonstration projects. We have also evaluated their design and construction processes. These projects have redefined the boundary regarding achievable environmental performance for Norwegian buildings, and show that zero emission buildings using different approaches.

Four of our demonstration projects are still under development. For two of these, construction is planned to start in 2016: These are the Heimdal High School in Trondheim and the Campus Evenstad office and educational building near Elverum, north of Oslo. The Heimdal High School project aims to achieve the ZEB-OM ambition level, while the Campus Evenstad project is targetting the ZEB-COM level. Several novel and innovative technologies are being applied, including

The Pilot House zero emission building demonstration project, located in Larvik, Norway.
Source: Snøhetta/EVE

new low carbon wood construction, hybrid ventilation systems, electrochromic windows and biofuel based micro co-generation.

New materials, solutions and tools

The development of new materials, solutions and tools has also been a notable outcome of our work. Some examples include new insulation materials, new construction systems, and a new energy exchanger. In the overall perspective, over the past eight years we have achieved our key objectives as listed below:

– We have demonstrated the feasibility of zero emission buildings.
– We have progressed technology development for future zero emission buildings and have implemented research methodologies and tools in laboratory studies and demonstration buildings to assist this.
– We are educating postgraduate students for employment in the construction industry, as well as upgrading the skills of existing professionals.
– The industry partners in the ZEB Centre are basing their business strategies on the state-of-the-art for zero emission buildings.
– We have set out the next steps required for development of the zero emission society.

Buildings fit for a zero emission society

The ZEB Centre has enabled collaboration between the whole value chain needed to realise the zero emission building concept in practice, so advancing the buildings sector towards a more sustainable future. It has also enabled our participation in fruitful international initiatives such as the EBC research programme.

Next, we will focus our activities to include how the implementation of the zero emission society as a whole can be accelerated, and how buildings can be a catalyst in this context. Thus, our follow up research will focus on the development of 'zero emission neighbourhoods', in which carbon neutrality is sought for a group of buildings. In this way, each building does not necessarily need to achieve a zero emission level. For this to happen, more market players need to become involved, for example the construction industry, the energy sector, ICT companies, municipalities, manufacturers, and governmental organizations. Hence, our next step in the search for the zero emission society is to evolve the role of the zero emission building to function well as part of its local neighbourhood and its wider district. To this end, a new Research Centre on Zero Emission Neighbourhoods in Smart Cities is now under consideration. By continuing to participate in EBC research projects to support this, we expect to greatly enhance our work.

Further information

www.zeb.no and www.iea-ebc.org

Arild Gustavsen and Inger Andresen both work at the Norwegian University of Science and Technology (NTNU) and Terje Jacobsen works at SINTEF.

Computational Tools for Buildings and Communities

Current Project: EBC Annex 60

Michael Wetter and Christoph van Treeck

Building simulation programs face new challenges for the design and operation of zero energy buildings and communities.

The general framework for the design and operation of building and district energy systems is currently undergoing a major transition in many industrialised countries, due to three major drivers: Firstly, building and district energy systems are expected to become 'zero energy'. Secondly, energy delivery is shifting away from fossil fuels to electricity with a larger share supplied from intermittent renewable sources. Thirdly, the building design and delivery process is becoming more integrated, based on planning and design tools such as building information modelling (BIM). Together, these drivers call for buildings and district energy systems to be better integrated. In response, the latest powerful computational tools for BIM, design and operational support of building and district energy systems enable the necessary integration to be put into practice.

State-of-the-art building energy simulation programs are now expected to provide 'modular' services that integrate seamlessly with other tools, sometimes at simulated timescales as short as minutes, or even seconds, and at spatial scales from city districts to buildings, individual rooms and sub-divisions within each building. This situation leads to new functional requirements that are not addressed by existing simulation programs, which are often load-based and assume ideal and non-integrated steady-state control of each individual subsystem. Existing programs are therefore hard to extend from design to operational tools, or from single buildings to districts. The state-of-the-art also requires a radical structural shift away from programs lacking capabilities to automate workflows for design, analysis and optimization, or to properly integrate with other simulation tools.

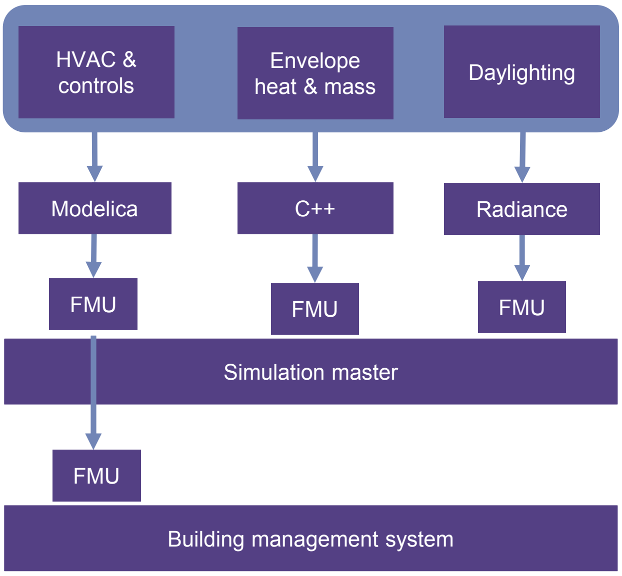
Other engineering sectors have already made large investments and substantial progress in next generation computing tools for the design and operation of complex, dynamic, integrated systems based on the open standards Modelica, a modelling language, and Functional Mockup Interface (FMI), a standard for exchanging models. The EBC international research project, 'Annex 60: New Generation Computational Tools for Building and Community Energy Systems', is transferring and adapting these technologies to the buildings-related industries through the collaborative development of Modelica libraries, FMI-technologies, and BIM translators. Two examples explained below illustrate some outcomes of this project:

- the development of the next generation of EnergyPlus, and
- Modelica and FMI from an HVAC manufacturer's perspective.

The next generation of EnergyPlus

Twenty years ago, the U.S. Department of Energy (DOE) started the development of EnergyPlus, an open-source whole building simulation program. This is currently downloaded over 27 000 times at each version update. But, while EnergyPlus' popularity is still growing, its legacy software architecture contains structural shortcomings, which hinder future improvements. The current version of EnergyPlus is rigidly structured around conventional concepts of primary and secondary HVAC (heating, ventilation and air conditioning) loops, complicating the analysis of various low energy systems. EnergyPlus is also not well-suited for design, analysis and testing of control schemes other than rule-based supervisory control sequences, because its load-based models have inputs and outputs that do not match real actuator commands and sensor signals. Crucially, its numerical solution methods cannot handle the fast dynamics, events, and finite state machines that are found in real control systems. In addition, it cannot simulate the complex control systems required for very low energy systems, increased waste heat and renewable integration and electrical grid interaction. It also does not provide a pathway for verification and performance quantification of controls that carries through from design to operation.

To address these shortcomings, DOE is supporting the development of an alternative implementation of HVAC and control modules for EnergyPlus. These are the starting point for the next generation implementation of EnergyPlus. This implementation will share envelope, zone heat and moisture balances, and lighting models with the current version, and will evolve side-by-side with it. The HVAC and controls models for the next generation of EnergyPlus will use the Modelica Buildings library, which in turn has the EBC Annex 60 library as its core. This architecture and the use of FMI allows the next generation architecture to accept and use models of single components, or entire subsystems, such as a model of a smart grid-enabled controller or a district heating substation. Significantly, it will also allow equipment and controls manufacturers to 'plug in' models of their own products.



The software architecture for the next generation of EnergyPlus. Source: Lawrence Berkeley National Laboratory

FMI also provides a standard way to export models for use during operation. For example, the next generation HVAC models can be exported to control systems for real-time monitoring, fault detection and diagnostics. Moreover, Modelica control sequences can be exported in the same way and then used for real-time control within a building automation system, ensuring that the design intent for the controls is realized in operation.

Modelica and FMI from an HVAC manufacturer's perspective

"Designing HVAC components that support a high efficiency building requires the co-design of the HVAC and control sequences as a system together with the typical building use and response," says Per-Johan Saltin of the HVAC manufacturer Swegon. Swegon's FMI-based product-selection tool is currently being re-engineered to use the Modelica standard to allow them to simulate their product models with EBC Annex 60 developed models, to make their models more reusable and to allow customers to use these models within their simulations in IDA Indoor Climate and Energy (IDA ICE) and in the next generation of EnergyPlus. A switch to Modelica also reduces the time needed to simulate new systems and control strategies and to maintain existing models, resulting in more resources that can be spent on research and development that ultimately leads to better products with a shorter time to market. "Using the open Modelica and FMI standards avoids lock-in to one software vendor, and gives us access to a large ecosystem of tools and models, which allows us to combine our own models with those from the Modelica Buildings and EBC Annex 60 libraries", says Saltin.

An additional benefit of Modelica models is that they act like physical components, allowing potential problems to be found earlier in the development phase. For example, if a control valve is connected to a pipe with high flow resistance, it will be inherently difficult to control that valve, whereas a design change of the physical system would avoid this problem. If discovered early in a model-based design process, the change is fast to implement at low cost, whereas if discovered later during physical testing, the necessary change can lead to delays and high costs.

Further information

www.iea-ebc.org

Financing Deep Energy Retrofit Projects

Current Project: EBC Annex 61

Alexander Zhivov and Rüdiger Lohse

Engagement with stakeholders is helping effective delivery of deep energy retrofits projects to encourage private sector investment.

In industrialized countries, three quarters of buildings currently in use were built before energy efficiency policies existed. A major building refurbishment thus offers an opportunity to overcome energy inefficiencies over its remaining life, possibly of 40 years or more. The EBC research project, 'Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings', is providing guidance on how to better exploit such opportunities in practice to exceed minimum regulatory requirements. In this context, a deep energy retrofit (DER) is intended to cut site energy use by at least 50% compared to the energy baseline, consisting of electricity, including plug loads and climate-adjusted heating consumption.

Business Models for Building Refurbishment

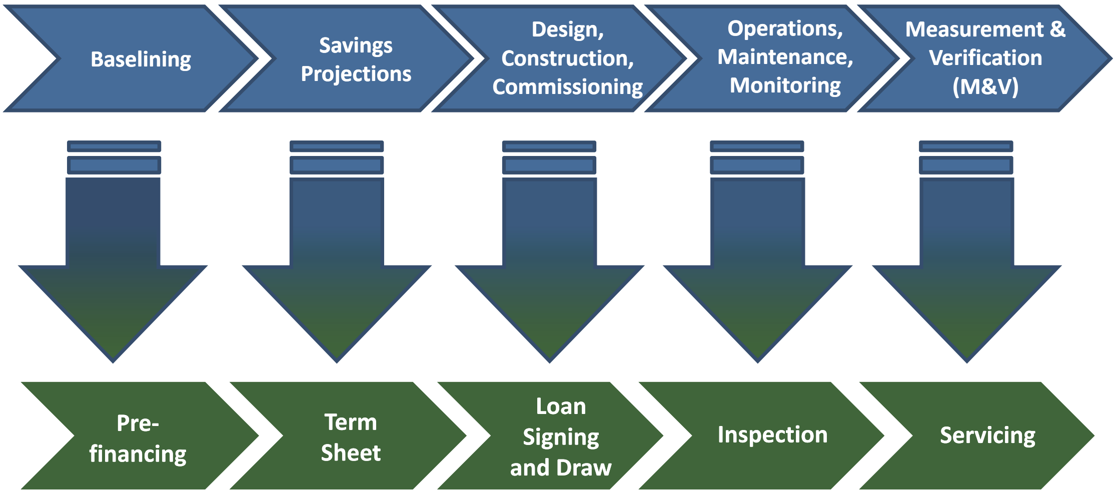
Since public funding is scarce, private investments must play a strong role in financing building energy renovation. However, private investments are rarely used to support DERs, because they are perceived to be high risk, mainly due to a lack of reliable data from completed projects. The major hurdles to implementation of current DER business models for application to public sector include a lack of:

- reliable data from accomplished DER projects,
- DER-specific technical and business knowledge,
- public funding including debt caps, and
- stakeholders willing to engage in DER projects.

The approach taken in EBC Annex 61 has been to assess current business models and to then suggest improvements, by describing the parties involved and the services provided, their revenue and cost structures, and defined values and benefits to each party. Since its inception, major stakeholders have been integrated into the working process to provide market-ready, practical results. Several outreach efforts to stakeholders are summarized below.

Outreach and Engagement Events

To assist public building owners with overseeing DER processes, one of the EBC Annex 61 project deliverables is a Technical Guideline about structuring DER projects, how to cost effectively bundle energy conservation measures for DER, and quality-assurance mechanisms. Technology characteristics have been defined using modelling of different building types located in a wide range of climate conditions, including thermal properties for the major building envelope components. In addition, to inform a market-ready approach, interviews have been conducted with experts from professional associations (including ASHRAE and CIBSE), and invited manufacturers of insulation materials, windows, HVAC equipment, and lighting systems to provide technical information on cost-effective solutions, their applications and limitations, and examples of best practice. In fact, engineers and architects are being supported by EBC Annex 61 with new information on bundles of energy conservation measures in a Technical Guide. Their critical input has helped to improve its quality and acceptance. In this regard, the technical results have been presented at two dedicated ASHRAE conference sessions on DER (2015 in Chicago, IL, and 2016 in Orlando, FL), at the CIBSE Technical Symposium 2016, in Edinburgh, UK, and the REHVA World Congress Clima 2016 in Aalborg, Denmark.



Standardising the deep energy renovation process for the financial sector.
Source: J.Leuchtner

Energy Service Companies (ESCOs) can be effective in helping to bridge the funding gap required to conduct energy improvement projects, while complementing scarce public funds and providing expertise. However, their remit is typically limited to HVAC and lighting systems with controls, from which about 25% energy savings are typically achievable. To enable ESCOs to execute DERs, they should extend their scope of work. So, EBC Annex 61 has provided training to them through participation in national ESCO association meetings in the USA and Germany, and at European ESCO conferences in 2014 and 2015. This has allowed research results to be shared about DER case studies, featuring investment costs, application of cost-effective bundles of energy conservation measures, and advanced business models.

EBC Annex 61 is working closely with the financial and public sectors to strengthen risk reducing due-diligence processes for DER projects. To stimulate this collaboration, EBC Annex 61 has established the 'Investors Day' platform to provide information about research findings, related due-diligence assessments, and best practice. The first Investors' Day was convened together with Building Performance Institute Europe (BPIE) and the Investor Confidence Project Europe (ICP Europe) in November 2014. This European Commission funded event attracted more than 80 investors and 30 representatives from public agencies. The second Investors' Day was organized along with ICP Europe, BPIE, and KEA, and attracted more than 130 participants from the target group. These have provided a 'marketplace' for DER investment projects for buildings. Further Investors' Days are planned for 2017 and 2018.

National government defence bodies are major owners and operators of extensive existing facilities containing numerous buildings. Therefore, EBC Annex 61 participants have incorporated DER guidance into the training curriculum for the 'Net Zero Energy, Water, and Waste Advanced Training Course', supported by the NATO Science for Peace and Security Programme and the US Army. Outcomes from the completed EBC research projects Annexes 46, 50, and 51 were also part of the curriculum, with training delivered by expert representatives. This event took place in Wiesbaden, Germany, in April 2016, and brought together more than 150 decision makers, energy engineers, and managers from 20 countries. Recorded presentations from the course are hosted online by the NATO Energy Security Center of Excellence. Another important outreach activity, 'Deep Energy Retrofit Forum', is planned for 14th - 16th September, 2016, and will be hosted at the National Academy of Science in Washington, DC, USA.

Further information

www.iea-ebc.org

Reliability of Energy Efficient Building Retrofitting

Completed Project: EBC Annex 55

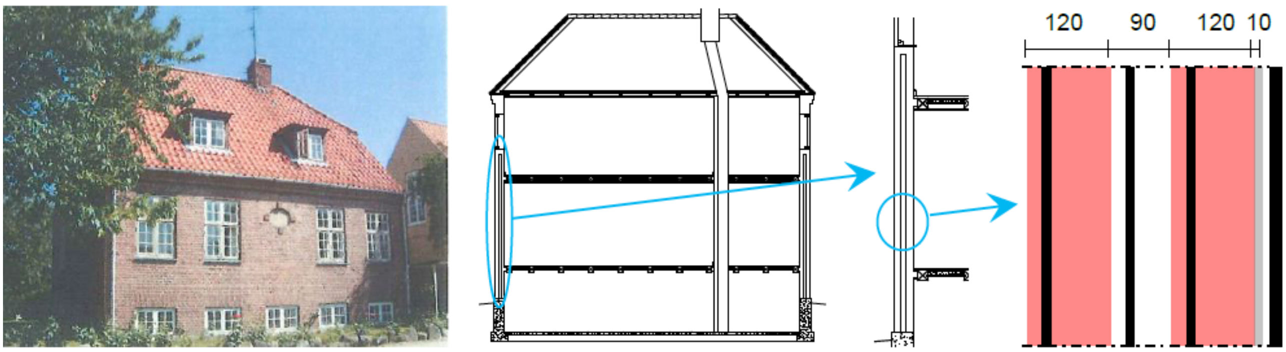
Carl-Eric Hagentoft

Energy efficient building retrofitting is a key element in reaching long-term energy demand reduction goals, with a positive economic impact. Probability based assessment of its performance and costs can assist industry in maintaining customer confidence.

In the participating countries of the recently completed EBC research project, 'Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost', most existing buildings were constructed between 1960 and 1980, with a significant proportion before 1930. Assuming that the estimated average lifespan of residential buildings is around 60 years and energy standards are becoming ever more stringent, many of these buildings will have to be replaced or retrofitted in the near future. But, many building owners are only interested in the initial capital cost of building retrofits. Looking at the risks associated with the actual performance of retrofitting measures and the costs incurred highlights the need for life cycle thinking. So, applicable calculation methods are required in this area. For this purpose, probability assessment in life cycle costing of solutions supports sound decision making relating to investments. For industry, customer relationships are based on future expectations and confidence. These relationships need to be supported by proper assessments to quantify the probability of achieving desired performance in practice.

Stochastic Data and Probabilistic Tools

The project has developed and validated probabilistic methods and tools for prediction of energy use, lifecycle cost and functional performance based on



Schematic overview of the configuration for one of the project common exercises, in which a factor identification and flow chart formation analysis of different post-insulation options for a brick cavity wall were carried out. This assessed both benefits from decreased energy consumption and costs due to potential hygrothermal damage.
Source: Probabilistic Tools report, EBC Annex 55

assessment of energy retrofitting measures. Furthermore, it has delivered decision support data and has developed tools for evaluating energy retrofitting measures, focussing on residential building envelopes. These tools have been based on probabilistic methodologies according to the assessment purpose:

1. qualitative exploration: to identify all relevant parameters, and the relations between them,
2. uncertainty propagation: to quantify the probabilistic character of the assessment's outcome,
3. sensitivity analysis: to distinguish between the dominant and non-dominant input parameters,
4. metamodelling method: to formulate a simple surrogate model, to replace the original model,
5. economic optimisation: financial criteria and optimisation schemes to attain the best solution.

The main results of such probabilistic risk assessments are probabilities or likelihoods, i.e. quantities that show how many out of all the possible cases do, or do not meet, the desired performance.

Probabilistic Assessment of Case Studies

The project has applied and demonstrated probabilistic methodologies on real life case studies to enhance energy savings, secure performance and apply cost analyses. A complete probabilistic assessment is an iterative process, usually beginning with the application of qualitative methods and progressing to quantitative methods, if necessary and appropriate. If a quantitative analysis of building envelope performance is to be carried out, a numerical model of the building envelope must initially be established. With the numerical model created and the supporting data assembled, calculations can be made to estimate the spread in performance and to identify any critical conditions or events. Ultimately, the results of the numerical analyses should be compared with the retrofit targets (also known as performance criteria) allowing the identification of optimal retrofitting techniques.
To inspire the application of probabilistic assessment by others, the following examples of retrofit cases have been investigated in the project:

– performance of a timber framed wall with additional insulation placed on the inside of the wall,
– thermal comfort in an office after window retrofit,
– performance of a massive brick wall with additional insulation placed on the inside of the wall,
– performance of concrete walls with additional insulation placed on the inside of the wall, and
– hygrothermal conditions in cold attic spaces.

Guidelines for Practice

Energy retrofit of existing buildings is a key measure to sustainably decrease the use of fossil fuels and to reduce dependence on expensive imported energy. However, they require considerable investments, but which could in the long term lead to significant cumulative savings. The project has demonstrated the benefits of the renewal of the existing building stock and how to create reliable solutions. For this purpose, it has provided guidelines for decision makers, designers and practitioners.

Further information

www.iea-ebc.org

IEA-EBC Annex 55 Publications

The official deliverables from the project are reports on:

– Stochastic Data,
– Probabilistic Tools,
– Framework for Probabilistic Assessment of Performance of Retrofitted Building Envelopes,
– Practice and Guidelines, and
– Guidelines for How to Use the Developed Framework for Practitioners.

Making a Case for Building Energy Epidemiology

New Project: EBC Annex 70

Ian Hamilton and Paul Ruyssevelt

By merging data from large scale studies and adopting data management and analytical techniques similar to those applied for public health, a deeper understanding of energy and building stocks can be gained.

A profusion of technology and policy interventions and comprehensive empirical evaluations are needed to meet national and global commitments to decarbonize and improve the energy performance of building stocks. However, the data and models to support the design, implementation and evaluation of such interventions are often absent. Consequently, many policies and technologies do not deliver the anticipated impact on energy demand. The collection of, and access to, reliable building and energy use data have historically been limited due to the cost of collection and institutional or governmental structures. In addition, the importance of access to high quality data has been underestimated with an over-reliance on normative models.

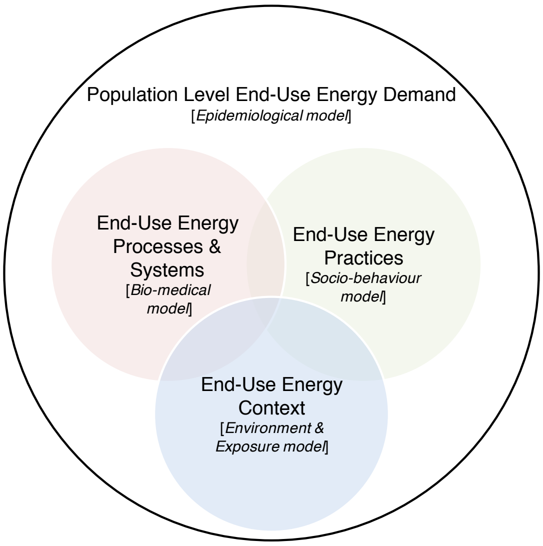
Compared with conventional methods, a much better systems approach is needed to understand how energy demand is changing over time and the factors operating to influence these changes. This energy systems perspective can be obtained by bringing together energy data from large scale population, or building, based studies and adopting data management and analytical techniques similar to those applied to public health (health epidemiology). Insights from population-based, empirically derived evidence can be used to inform the type, timing, and targeting of policies, as well as to provide insights to assist development of technologies designed to manage energy demand and carbon emissions. For example, by linking together large databases of energy, buildings, and energy retrofits data, the efficacy of delivered technology in reducing measured energy use has been determined in the UK. Yet such information is a small fragment of what can and should be achieved with future data sources when these are combined with those from more detailed field studies. This field is becoming known as 'energy epidemiology', the study of energy use within a population.

Energy Epidemiology

There are challenges associated with collecting, describing and using high quality data on energy use in buildings for the purpose of informing national development and low carbon pathways. To respond to these, the EBC research project, 'Annex 70: Building Energy Epidemiology: Analysis of Real Building Energy Use at Scale' is focusing on:

- stakeholder engagement in needs for and uses of energy and buildings data;
- availability, collection methods and structure of building stock data;
- comparisons of actual and predicted energy performance in buildings;
- methods of empirical data analysis of populations of energy and buildings;
- data structures for national building stock modelling.

National building, energy and environment, building control and construction agencies need better quality data on buildings and their energy performance and energy demands for both forward planning and evaluation of past practices. The developers of energy efficient products need better market information and processes for describing real world impacts of



Research concept for research in end-use energy demand epidemiology.
Source: EBC Annex 70, as adapted from Hamilton IG, Summerfield AJ, Lowe R, Ruyssevelt P, Elwell CA, Oreszczyn T. Energy epidemiology: A new approach to end-use energy demand research. Build Res Inf 2013;41:482–97. doi:10.1080/09613218.2013.798142.

their products on energy demand and performance. Also, building energy labels need to better represent performance in use. Focusing on data, their collection methods, analysis and use in national modelling exercises, this project is identifying data gaps and is providing stakeholders with resources. These include a registry of data and methods, from which to draw for national comparisons, modelling and engagement. The project differs from many others because it focuses on empirical data and analysis methods, rather than on technologies and tools. The aim of the project is to support the participating countries in the task of developing realistic transition pathways to substantial and long-term reductions in energy use and related carbon dioxide emissions associated with their buildings by:

- evaluating the scope for applying real building energy use data at scale to inform policy making and to support industry in the development of low energy and low carbon solutions;
- establishing best practice in the methods used to collect and analyze data related to real building energy use, including building and occupant data;
- comparing between national approaches to developing building stock data sets, building stock models, and to address the perceived energy performance gap in order to identify lessons that can be learned and shared.

The project comprises of the following activities:

- engaging with government, industry and technology manufacturers to identify user requirements for data and information upon which future strategy and policy can be based;
- researching aspects associated with empirical building and energy use data for both the residential and non-residential building stock;
- developing best practice guidance for undertaking surveys and for analysing and reporting building and energy use data;
- developing metrics and performing international comparisons of building stocks and their energy use.

The main outcomes of the project will include:

- a registry on national building stock surveys and models (with actual data if available), and
- a series of best practice and information reports on international data, models and methods.

The results will facilitate the use of empirical data in undertaking international energy performance comparisons, policy review exercises, national stock modelling and technology and product market assessments and impact analyses. The deliverables will promote the importance and best practices for collecting and reporting energy and building stock data.

Further information

www.iea-ebc.org

EBC International Projects

Current Projects

Annex 5 Air Infiltration and Ventilation Centre
The AIVC carries out integrated, high impact dissemination activities with an in depth review process, such as delivering webinars, workshops and technical papers.
Contact: Dr Peter Wouters
aivc@bbri.be

Annex 56 Cost-Effective Energy and CO_2 Emissions Optimization in Building Renovation
The project is delivering accurate, understandable information and tools targeted to non-expert decision makers and real estate professionals.
Contact: Dr Manuela Almeida
malmeida@civil.uminho.pt

Annex 57 Evaluation of Embodied Energy and CO_2 Equivalent Emissions for Building Construction
The project is developing guidelines to improve understanding of evaluation methods, find better design and construction solutions with reduced embodied energy and related CO_2 and other GHG emissions.
Contact: Prof Tatsuo Oka
okatatsuo@e-mail.jp

Annex 58 Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements
The project is developing knowledge, tools and networks to achieve reliable in-situ dynamic testing and data analysis methods to characterise the actual energy performance of components and whole buildings.
Contact: Prof Staf Roels
staf.roels@bwk.kuleuven.be

Annex 59 High Temperature Cooling and Low Temperature Heating in Buildings
The project is improving HVAC systems, by examining how to achieve high temperature cooling and low temperature heating by reducing temperature differences in heat transfer and energy transport processes.
Contact: Prof Yi Jiang
jiangyi@tsinghua.edu.cn

Annex 60 New Generation Computational Tools for Building and Community Energy Systems
The project is developing and demonstrating new generation computational tools for building and community energy systems using the Modelica modelling language and Functional Mockup Interface standards.
Contact: Michael Wetter, Christoph van Treeck
mwetter@lbl.gov, treeck@e3d.rwth-aachen.de

Annex 61 Business and Technical Concepts for Deep Energy Retrofit of Public Buildings
The project aims to develop and demonstrate innovative bundles of measures for deep retrofit of typical public buildings to achieve energy savings of at least 50%.
Contact: Dr Alexander M. Zhivov, Rüdiger Lohse
alexander.m.zhivov@erdc.usace.army.mil, ruediger.lohse@kea-bw.de

Annex 62 Ventilative Cooling
This project is addressing the challenges and making recommendations through development of design methods and tools related to cooling demand and risk of overheating in buildings and through the development of new energy efficient ventilative cooling solutions.
Contact: Prof Per Heiselberg
ph@civil.aau.dk

Annex 63 Implementation of Energy Strategies in Communities
This project is focusing on development of methods for implementation of optimized energy strategies at the scale of communities.
Contact: Helmut Strasser
helmut.strasser@salzburg.gv.at

Annex 64 LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles
This project is covering the improvement of energy conversion chains on a community scale, using an exergy basis as the primary indicator.
Contact: Dietrich Schmidt
dietrich.schmidt@ibp.fraunhofer.de

Annex 65 Long-Term Performance of Super-Insulating Materials in Building Components and Systems
This project is investigating potential long term benefits and risks of newly developed super insulation materials and systems and to provide guidelines for their optimal design and use.
Contact: Daniel Quenard
daniel.quenard@cstb.fr

Annex 66 Definition and Simulation of Occupant Behavior in Buildings
The impact of occupant behaviour on building performance is being investigated to create quantitative descriptions and classifications, develop effective calculation methodologies, implement these within building energy modelling tools, and demonstrate them with case studies.
Contact: Dr Da Yan, Dr Tianzhen Hong
yanda@tsinghua.edu.cn, thong@lbl.gov

Annex 67 Energy Flexible Buildings
The aim of this project is to demonstrate how energy flexibility in buildings can provide generating capacity for energy grids, and to identify critical aspects and possible solutions to manage such flexibility.
Contact: Søren Østergaard Jensen
sdj@teknologisk.dk

Annex 68: Design and Operational Strategies for High Indoor Air Quality in Low Energy Buildings
This project focuses on design options and operational strategies suitable for enhancing the energy performance of buildings, such as demand controlled ventilation, improvement of the building envelope by tightening and insulating products characterised by low pollutant emissions.
Contact: Prof Carsten Rode
car@byg.dtu.dk

Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings
The project provides a scientifically based explanation of the underlying mechanism of adaptive thermal comfort, and is applying and evaluating the thermal adaptation concept to reduce building energy consumption through design and control strategies.
Contact: Prof Yingxin Zhu, Prof Richard de Dear
zhuyx@tsinghua.edu.cn, richard.dedear@sydney.edu.au

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EBC

Energy in Buildings and Communities Programme

EBC Executive Committee Members

CHAIR
Andreas Eckmanns (Switzerland)

VICE CHAIR
Dr Takao Sawachi (Japan)

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

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

BELGIUM
Dr Peter Wouters
peter.wouters@bbri.be

CANADA
Dr Gilles Jean
gilles.jean@canada.ca

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

CZECH REPUBLIC
To be confirmed

DENMARK
Rikke Marie Hald
rmh@ens.dk

FRANCE
Pierre Hérant
pierre.herant@ademe.fr

GERMANY
Katja Rieß
k.riess@fz-juelich.de

IRELAND
Prof J. Owen Lewis
j.owen.lewis@gmail.com

ITALY
Michele Zinzi
michele.zinzi@enea.it

JAPAN
Dr Takao Sawachi (Vice Chair)
sawachi-t92ta@nilim.go.jp

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

NETHERLANDS
Daniël van Rijn
daniel.vanrijn@rvo.nl

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

NORWAY
Eline Skard
eska@rcn.no

PORTUGAL
João Mariz Graça
joao.graca@dgeg.pt

SPAIN
José María Campos
josem.campos@tecnalia.com

SWEDEN
Conny Rolén
conny.rolen@formas.se

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

UK
Prof Paul Ruyssevelt
p.ruyssevelt@ucl.ac.uk

USA
David Nemtzow
david.nemtzow@ee.doe.gov

IEA Secretariat
Brian Dean
brian.dean@iea.org

EBC Secretariat
Malcolm Orme
essu@iea-ebc.org