EBC

Energy in Buildings and Communities Programme

Annual Report 2017

Energy in Buildings and
Communities Programme

International Energy Agency

EBC Annual Report 2017

Energy in Buildings and Communities Programme

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Energy Technology Network

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Participating countries in EBC: Australia, Austria, Belgium, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Italy, Ireland, Japan, R. Korea, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, UK and USA.

Front cover: The natural ventilation system at CML Kindergarten, Portugal, a case study within EBC Annex 62 Ventilative Cooling (p. 42)
Source: Guilherme Carrilho da Graça

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EBC Executive Committee Chair's Statement

The UNFCCC Paris Agreement adopted in 2015 symbolizes the international consensus on the necessity to aggressively reduce greenhouse gas (GHG) emissions. In developed countries, reductions by 2050 of around 80% are being targeted for the buildings sector, and many countries have established their shorter-term goals, such as those working towards emissions reductions by 2030. The goals in the buildings sector are planned to be accomplished mainly by decarbonization of electricity and improvement of energy efficiency of buildings and their technical services systems.

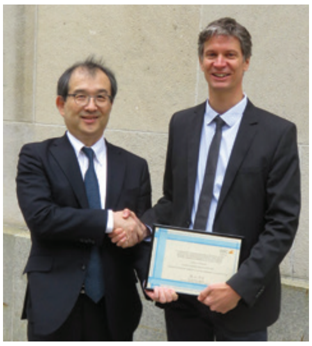
The standard of ethics practiced by technical experts is important, and moreover their practical, realistic, scientific, unbiased and transparent approaches to the accomplishment of the goals are clearly indispensable. Producing technical know-how that is impactful on reduction of energy use in buildings is a key expectation of EBC and other IEA Technology Collaboration Programmes, as well as the delivery of outputs to create and support new societal systems, such as making those for building regulations and other policies more practical and effective.

The value of building technologies cannot be judged only from the view point of energy efficiency, but our societies must also be supplied with convenient and reliable measuring tools for the energy efficiency of buildings and their technical systems. Unfortunately, such tools have probably not yet been developed sufficiently in any part of the world. Buildings have highly varied and complicated functions and are usually designed and constructed individually, unlike other industrial products.

Emerging new technologies in surrounding technological areas, such as artificial intelligence (AI), the 'Internet of Things' and building information modelling (BIM), should also be taken advantage of in buildings-related R&D. At the same time, we should much more clearly recognize the importance of properly dealing with existing ideas and technologies, which can be considered as conventional technologies. Among the latter, there are still many energy technologies without clear definitions and ways formulated to fully utilize them in practice, and as a consequence there is still a large room for improvement in actual energy efficiency. We do not have a great deal of time before 2030 or 2050. Therefore, especially for the improvement of conventional technologies that are already deployed, R&D should be tackled in our EBC Programme to produce more effective and useful knowledge. Through national and internationally aggregated statistics, the year by year success or failure of the experts with responsibility for GHG emissions from the buildings sector is being monitored, including those in the EBC Programme. Let's imagine the buildings sector as a whole, incorporating R&D experts, will find their success within the future statistics of energy use and CO_2 emissions from our sector.

In 2017, I was privileged to be elected as successor to Andreas Eckmanns as EBC Executive Committee Chair and have recently begun my term. His outstanding leadership of the EBC Programme over the past six years is evident from its recent expansion and the continuing delivery of high quality outcomes. Please enjoy reading about our progress in the latest EBC Annual Report.

Dr Eng Takao Sawachi
EBC Executive Committee Chair



Takao Sawachi (left), the incoming EBC Executive Committee Chair, expresses the Committee's appreciation to Andreas Eckmanns (right), the outgoing Chair, for his excellent work.

Affordable Heating and Cooling

A REVIEW OF THE EBC RESEARCH PROJECTS WITH SPECIFIC RELEVANCE TO THE MISSION INNOVATION CHALLENGE 7: AFFORDABLE HEATING AND COOLING

Mission Innovation (www.mission-innovation.net) aims "to accelerate the pace of clean energy innovation to achieve performance breakthroughs and cost reductions to provide widely affordable and reliable clean energy solutions that will revolutionise energy systems throughout the world over the next two decades and beyond." Seven innovation challenge area have been established and Challenge 7 Affordable Heating and Cooling of Buildings has the objective to "make low-carbon heating and cooling affordable for everyone". This objective has much in common with EBC's Strategic Vision, which proposes that: "By 2030, near-zero primary energy use and carbon dioxide emissions solutions have been adopted in new buildings and communities, and a wide range of reliable technical solutions have been made available for the existing building stock.

Mission Innovation (MI) recognises that globally, buildings account for almost a third of final energy use, with space heating and cooling (H/C) and the provision of domestic hot water, accounting for approximately half of this energy use. Space cooling is a fast growing sector. The H/C sector is extremely fragmented along the following lines: 1) local climatic conditions; 2) technologies; 3) age of installed stock; and 4) energy sources exploited. Most of the energy demand for H/C is currently satisfied with fossil fuels (natural gas, fuel oil and coal) with far less use of renewable energy sources. This is due to various obstacles, ranging from technical, financial, legal, social, and cultural. The MI Challenge 7 addresses the six priority areas shown in Table 1.

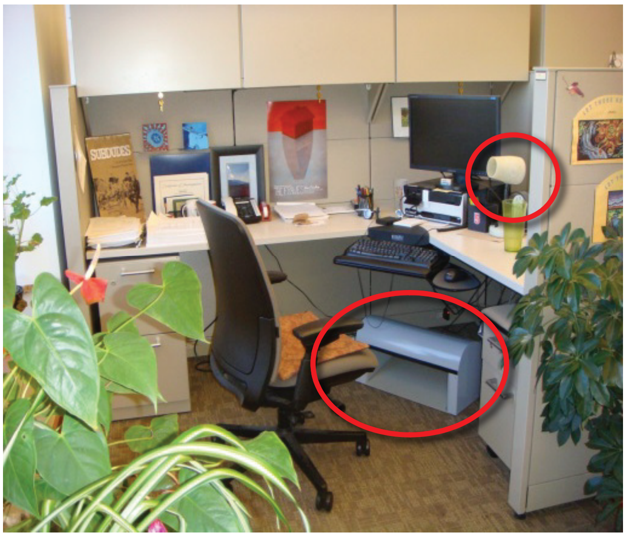
MI Challenge 7 has 21 member countries plus the European Commission (as Table 2 shows, 15 of these countries are members of the EBC Technology Collaboration Programme). To reinvigorate global efforts in clean energy innovation, MI members have declared a common goal to develop and scale breakthrough technologies and substantial cost reductions. MI members have stated an aim to seek to double public clean energy research and development investment over five years.

A number of completed and ongoing EBC Annexes are focused on research that is directly relevant to MI Challenge 7, Affordable Heating and Cooling of Buildings:

EBC ANNEX 52 / SHC Task 40, Towards Net Zero Energy Solar Buildings, a joint project with the Solar Heating and Cooling Technology Collaboration Programme, was completed in 2014 and produced a report detailing solution sets for net zero energy residential and commercial buildings from around the world (http://task40.iea-shc.org). Many of these buildings contain technologies and systems relevant to achieving the goal of MI Challenge 7. Participating countries were: Australia, Austria, Belgium, Brazil, Canada (Operating Agent), Denmark, Finland, France, Germany, Italy,

N°	Priority Area	Relevant for Heating	Relevant for Cooling
1	Thermal energy storage	***	*
2	Heat pumps	***	**
3	Non-atmospheric heat sinks and sources	*	***
4	Predictive maintenance and optimization	***	***
5	Building-level integration	***	***
6	Physiological studies	**	***

Table 1. Mission Innovation Challenge 7 Priority Areas.
Source: Paul Ruyssevelt



In air-conditioned buildings, personal control systems play an important role in thermal adaptation (EBC Annex 69).
Source: Edward Arens, University of California at Berkeley

New Zealand, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, UK and USA.

EBC ANNEX 59, High Temperature Cooling and Low Temperature Heating in Buildings, was completed in 2016. Here the aim was to achieve high temperature cooling and low temperature heating by reducing temperature differences in heat transfer and energy transport process. The technology and systems innovations detailed in the four final reports demonstrate how cooling and heating can be delivered more efficiently in a range of climates. Participating countries were: Belgium, P.R. China (Operating Agent), Denmark, Italy, Japan and Republic of Korea.

EBC ANNEX 61, Business and Technical Concepts for Deep Energy Retrofit of Public Buildings, was completed in 2017. The reports not only detail a range of solutions to achieving deep cuts in the demand for heating and other energy uses in residential and public buildings that can be achieved through building retrofits, they go further to illustrate how these can be made cost effective and delivered with guaranteed performance. Participating countries were: Austria, Belgium, Denmark, Germany (Joint Operating Agent) and USA (Joint Operating Agent).

EBC ANNEX 64, LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles, was completed in 2017. This project draws attention to the need to make best use of the low grade heat sources at a community scale as a way of maximising the heating (and cooling) benefit whilst at the same time reducing carbon emissions. Participating countries are: Austria, Denmark, Germany (Operating Agent), Italy, the Netherlands, Sweden and USA.

EBC ANNEX 67, Energy Flexible Buildings, due for completion in 2019, recognises that energy flexibility in buildings will play an important role in facilitating energy systems based entirely on renewable energy sources. This project addresses the lack of comprehensive knowledge about how much energy flexibility different building types and their usage may be able to offer to

ENERPOS, a Net Zero Energy Building in Reunion Island, France, a tropical climate (EBC Annex 52 / SHC Task 40).
Source: François Garde

Counties	EBC member	MI 7 Member
Australia	*	*
Austria	*	
Belgium	*	
Brazil		*
Canada	*	*
P.R. China	*	*
Denmark	*	*
European Commission		***
Finland	*	*
France	*	*
Germany	*	*
India		*
Ireland	*	
Italy	*	*
Japan	*	
Mexico		*
New Zealand	*	
Norway	*	*
Portugal	*	
Republic of Korea	*	*
Saudi Arabia		*
Singapore	*	
Spain	*	
Sweden	*	*
Switzerland	*	
The Netherlands	*	*
United Arab Emirates		***
United Kingdom	*	***
United States of America	*	*

Key		
Full member	*	*
Lead country		***

Table 2. Coincidence of EBC and Mission Innovation Challenge 7 country memberships.
Source: Paul Ruyssevelt

the future energy systems and hence how zero carbon heating and cooling can be delivered from renewable energy sources in the future. Participating countries are: Austria, Belgium, Denmark (Operating Agent), France, Italy, the Netherlands, Norway, Portugal, Spain, Switzerland and UK.

EBC ANNEX 69, Strategy and Practice of Adaptive Thermal Comfort in Low Energy, due for completion in 2019, is focused on creating a scientifically based explanation of the underlying mechanism of adaptive thermal comfort for people in buildings. It is developing the application and evaluation of the thermal adaptation concept to reduce building energy used for heating, cooling and dehumidification through design and control strategies. Participating countries are: Australia (Joint Operating Agent), P. R. China (Joint Operating Agent), Republic of Korea, UK and USA.

EBC ANNEX 73, Towards Net Zero Energy Public Communities, started work in 2017 on summarising the state-of-the-art technologies and concepts for community-wide 'near zero energy' master-planning that consider power, heating and cooling needs. The project is developing the methodology and the decision-making process for achieving near zero energy in public communities like military garrisons, universities, housing areas, and similarly large campus sites. Participating countries are: Austria, Australia, Canada, Denmark, Germany (Joint Operating Agent), Italy, Norway, UK and USA (Joint Operating Agent).

MI Challenge 7 has proposed that workshops will be held to define technical focus areas and relevant targets for each priority area and that through collaboration between member countries, opportunities for new research to meet defined targets will be identified by mid-2018 and further explored. EBC will work through national representatives to ensure that the completed and ongoing work of the EBC Annexes is represented in the workshops and is influential in the future research agenda of this Challenge.

Prof Paul Ruyssevelt
EBC Executive Committee Vice Chair

New Research Projects

DEEP RENOVATION OF HISTORIC BUILDINGS TOWARDS LOWEST POSSIBLE ENERGY DEMAND AND CO_2 EMISSION

(EBC ANNEX 76 / SHC TASK 59)

ASSESSING LIFE CYCLE RELATED ENVIRONMENTAL IMPACTS CAUSED BY BUILDINGS

(EBC ANNEX 77 / SHC TASK 61)

COMMUNITIES AND CITIES
(EBC WORKING GROUP)

Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO_2 Emissions

EBC ANNEX 76 / SHC TASK 59

In many countries, historic buildings represent a significant share of the existing building stock. They are the distinctive features of numerous cities, and will only survive if maintained as living spaces. To preserve this heritage, it is necessary to find conservation-compatible energy retrofit approaches and solutions, which allow the historic and aesthetic values to be maintained while improving comfort, lowering energy costs and minimizing environmental impacts.

Over the last 10 years, a paradigm shift could be observed. For instance, at the time of the introduction of the first European Energy Performance of Buildings Directive, strong opposition from conservators and architects was evident, with comments along these lines of, "Don't touch these buildings." There is now an increasing openness, leading to much more constructive approaches such as, "Let's find the right solutions together." Examples of these changes are the implementation of the International Scientific Committee on Energy and Sustainability within ICOMOS and the development of the 'Guidelines for improving the energy performance of historic buildings' (EN16883) agreed through CEN TC 346 Conservation of Cultural Heritage. It is therefore timely to identify and promote good approaches and solutions.

Completed examples have shown that a reduction of 'Factor 4' (i.e. reduce the energy demand by 75%) may be possible for historic buildings while preserving their heritage value. However, defining minimum performance similarly to 'standard' modern buildings does not make sense in the case of historic buildings. Rather the design team should not 'stop thinking' too early when looking at a specific case. A considerable reduction in demand - together with optimised use of passive solar design - opens up the possibility of proceeding with an effective solar contribution towards a net zero energy building (NZEB). In this context, the opportunities for using solar energy in historic buildings are far more substantial than one might initially expect, especially if solar panels and collectors are compatible in colour and design, are wisely integrated as to not interfere aesthetically with the building, and their installation is reversible.

Objectives

The objectives of the project are to:

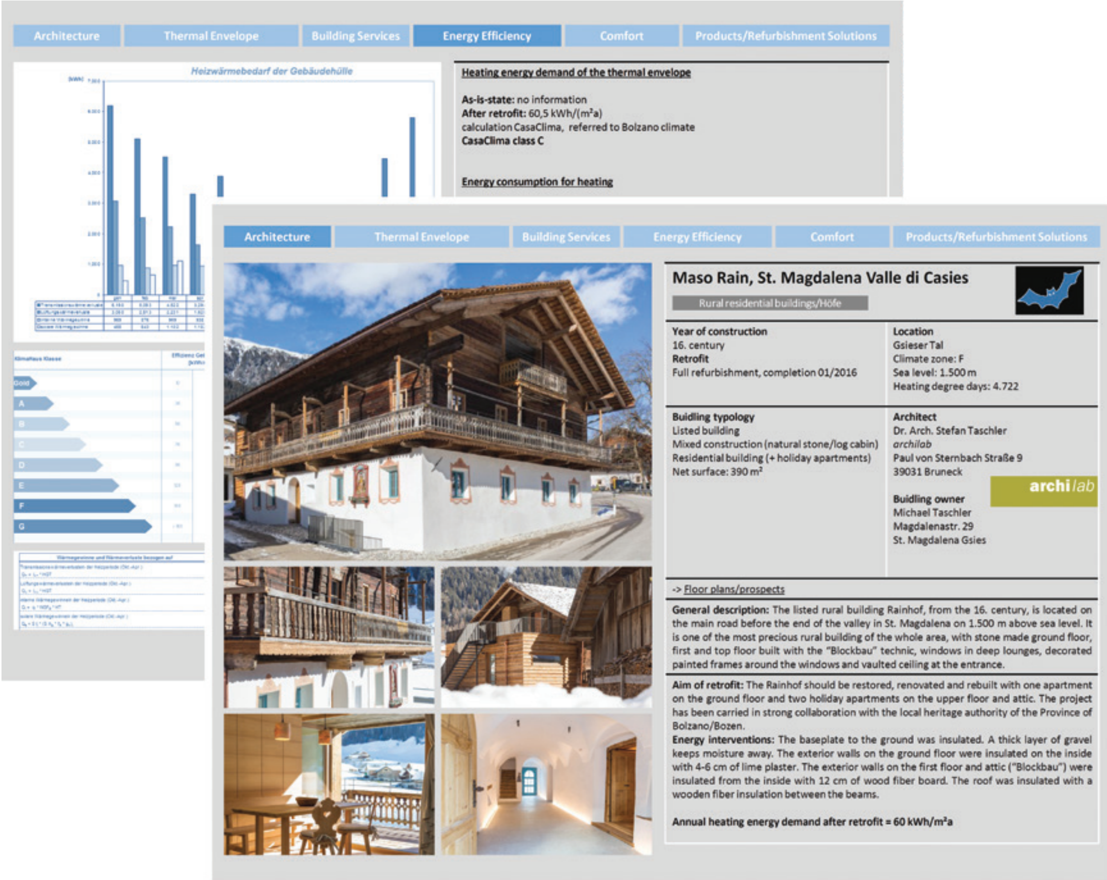
- develop a solid knowledge base on how to save energy in renovation of historic and protected buildings in a cost efficient way;
- identify the energy saving potential for protected and historic buildings according to typologies of building studied (residential, administrative, cultural, …);
- identify and assess replicable procedures on how experts can work together with integrated design to maintain both the heritage value of the building and at the same time make it energy efficient;
- identify and further develop tools which support this procedure and its individual steps;
- identify and assess conservation compatible retrofit solutions with a 'whole building perspective';
- specifically identify the potential for the use of solar energy (passive and active, heating, cooling and electricity) and promote best practice solutions;
- transfer all knowledge gained in the project to relevant stakeholders, including building owners, architects and planners, real estate developers, and policy makers.

To achieve the project objectives, the IEA Solar Heating and Cooling Technology Collaboration Programme (TCP) is working with the IEA EBC TCP at a 'Medium Level Collaboration', and with the IEA Photovoltaic Power Systems TCP at a 'Minimum Level Collaboration', as outlined in SHC's Policy on Collaboration.

Deliverables

The following deliverables are planned:

- a web-based collection and documentation of approximately 50 case studies of best practice from all participating countries;



Draft template for the web-based database of best practice.
Source: Eurac Research

- an assessment report of the best practices including evaluation of the cases' replicability and the transferability of specific favourable framework conditions and incentives;
- an assessment of European Standard EN16883 'Guidelines for improving the energy performance of historic buildings' and proposals for its improvement;
- an assessment of the existing tools, methods and guidelines that are relevant in relation to standard EN16883 and others (e.g. ASHRAE 34P) in the form of a report including 'fact sheets';
- an integrated platform with tools for holistic historic buildings retrofit to support the planning process towards conservation compatible NZEBs;
- a report on conservation compatible energy retrofit technologies, with focus on restoration and thermal enhancement of window systems, documentation and assessment of materials for robust and economically viable internal insulation, and evaluation of energy and cost efficient HVAC-systems and roof integrated solar technologies;
- a report on strategies to achieve high energy and environmental performance, as well as heritage value conservation, considering not only specific building typologies, but also local climate and traditional construction practices;
- online communication and dissemination of objectives and activities of the project, as well as news, audio-visuals and webinars by means of a website and a project flyer;
- face-to-face communication and dissemination of the project results by means of a workshop series, participation in stakeholder events and a touring exhibition to be used by all participating experts in the diverse events in which they are organizing or taking part.

Progress

The project was approved at the 81st EBC Executive Committee Meeting, held in June 2017 in London, UK.

Meetings

The 1st Project Meeting was held in Edinburgh, UK, in September 2017. A workshop with local stakeholders was organized by Historic Environment Scotland following this meeting.

Project duration
2017 – 2021

Operating Agent
Alexandra Troi, Eurac Research, Italy

Participating countries (provisional)
Austria, Belgium, Denmark, Ireland, Italy, Spain, Sweden, UK, USA

Further information
www.iea-ebc.org

Integrated Solutions for Daylighting and Electric Lighting

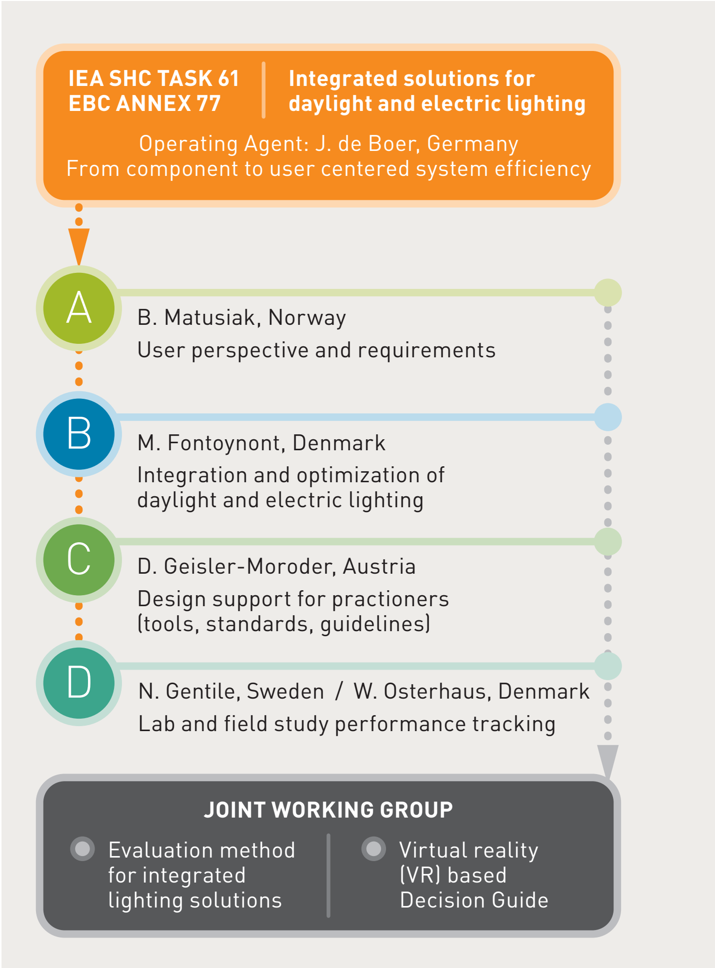
EBC ANNEX 77 / SHC TASK 61

This new project is focusing on R&D to create and develop strategies combining daylighting and appropriate lighting control systems lead both to:

- very highly energy-efficient lighting schemes, and
- solutions offering the best lighting conditions for people.

This project is expected to bring together around 30 to 40 international experts and companies involved in dynamic daylighting, lighting and their controls.

Useful knowledge and results from research is being gathered concerning the perceptions of building occupants on lighting quality, user interfaces and control strategies. The project is creating models for lighting controls that integrate occupant behaviour and expectations. It is identifying best practice approaches for control solutions for lighting and daylighting (movable components of windows), with wireless and wired controls, open loop and closed loop, Internet of Things, etc). It is also conducting onsite and laboratory monitoring of innovative solutions and publish the findings to document their benefits. Part of the work will lead to deliverables to inform standardization proposals, particularly in relation to CEN and ISO.



The project structure of EBC Annex 77 / SHC Task 61. The four subtasks are generating the key results, which are then being integrated by means of a joint working group. According to the individual focuses of stakeholders, the joint working group is providing information tailored to their specific needs.
Source: Adapted from EBC Annex 77

Objectives

The overall objective of the activity is to foster the integration of daylight and electric lighting solutions to the benefits of higher occupant satisfaction and at the same time energy savings. This is subdivided into the following specific objectives:

- Review the relationships between occupant perspectives (needs and acceptance) and energy in the emerging era of 'smart and connected lighting' for a relevant sample of buildings.
- Consolidate findings from use cases and create 'personas' reflecting the behaviours of typical occupants.

- Based on a review of specifications concerning lighting quality, non-visual effects, as well as ease of design, installation and use, provide recommendations for energy regulations and building performance certificates.
- Assess and improve the technical, environmental and financial robustness of integrated daylight and electric lighting approaches.
- Demonstrate and verify, or reject concepts through laboratory studies and real use cases based on performance validation protocols.
- Develop integral photometric, occupant comfort and energy rating models (spectral, hourly) as pre-normative work linked to relevant bodies, including CIE, CEN, ISO, and initiate standardization activities.
- Provide decision making and design guidelines incorporating virtual reality sessions. Integrate approaches into widespread lighting design software.
- Combine competencies: Bring electric lighting and façade component manufacturers together using workshops and specific projects, and thereby promote the added value of integrated solutions in the market.

Deliverables

The following documents and information measures are planned to be published during the course of the project:

- 'Personas for occupant-centered integrated lighting solutions' report
- 'Integration and optimization of daylight and electric lighting' report / source book
- 'Guidelines for the use of simulation in the design process of integrated lighting solutions' report
- 'Integrated solutions for daylighting and electric lighting in practice: results from case studies' report
- Standardization: Initiation of new work items by appropriate standardization bodies and proposals for methods for draft standards (BSDF daylight system characterization, hourly lighting energy demand rating method)
- Virtual Reality Decision Guide
- A Web-based tool providing an hourly lighting energy demand rating method
- Industry workshops during the project duration, in conjunction with every project meeting, which will be organised in the host country of each meeting, and to which representatives from authorities, manufacturers and designers will also be invited.

Progress

The project was approved at the 82nd EBC Executive Committee Meeting, held in November 2017, and will officially start in 2018.

Project duration
2018–2021

Operating Agent
Jan de Boer, Fraunhofer Institut for Building Physics, Germany

Participating countries (provisional)
Australia, Austria, Belgium, P.R. China, Denmark, Germany, Italy, Japan, the Netherlands, Norway, Slovakia, Sweden, Singapore, Switzerland, USA
Observers: Brazil

Further information
www.iea-ebc.org

Working Group on Cities and Communities

EBC WORKING GROUP

Cities face extensive challenges when it comes to transformation of their energy and transport systems, such as the creation of suitable decarbonisation strategies. The selection of the best-fit solutions to meet their specific and individual prerequisites requires comprehensive skills, knowledge and resources, which are often lacking in smaller communities. In addition, these decision making and planning processes often take place in a highly dynamic environment with a large number of further requirements that generally take higher priority. This complexity often leads to uncoordinated decision-making not only within cities, but also within different stakeholder groups. While solutions are often provided at a strategic level, decisions at the urban scale can have substantial impacts on individual approaches and technologies. The 'Working Group on Cities and Communities' (WGCC) intends to improve this situation by integrating these 'urban issues' into R&D being carried out by the IEA Technology Collaboration Programmes (TCPs).

The WGCC is an EBC-hosted (single-leadership) delegating structure that is intended to share (provide and gain) information between multiple IEA TCPs and cities with a bi-directional approach. It is linked to existing IEA Working and Coordination Groups, either directly through the EBC Executive Committee, or through nominated experts, and is planned to feed into IEA publications and workshops. As an open working group, the WGCC is inviting expert participation through the various TCPs to work together on different tasks, as well as the participation of external experts not affiliated with the IEA.

Objectives

The goal of the WGCC is to contribute to an essential step in IEA TCP research towards a full consideration of cities' non-technical needs that extends well beyond technical energy solutions.

Mapping of challenges in context with urban scale at the Conceptual Workshop, held in Paris, France, in June 2017.
Source: SIR

The project aims to:

- assess and identify the needs of cities, their actors and associated stakeholders;
- generate appropriate non-technical 'on demand' input and service ideas for cities;
- identify and discuss bottlenecks and barriers for the transformation of cities' energy and transport systems;
- discuss and provide results and (policy) recommendations on energy and transport systems;
- close the gap between cities and research;
- connect technical researchers from IEA TCPs with non-technical experts and city representatives.

The project is primarily targeting the following audiences:

- urban decision makers (administration, planning staff, etc),
- intermediaries (local / national), and
- IEA in-house staff and the IEA research community.

Deliverables

The WGCC is anticipated to be organized primarily through:

- workshops and other exchange activities;
- capacity building and training activities;
- documenting: cross-TCP activities, joint TCP publications, and policy recommendations;
- short-term projects and research;
- additional activities targeted directly to the specific needs of a project, research, or city requirements.

Through these activities, the WGCC plans to identify the crucial needs of cities, which will be translated into research questions for short term projects and research within the Working Group.

Progress

The WGCC was approved at the 82nd EBC Executive Committee Meeting, held in November 2017, and officially starts in 2018.

Meetings

Planning and discussion sessions to develop the concept for the WGCC were convened at the following IEA meetings:

- Buildings Coordination Group in February 2017
- End Use Working Party Meetings in March and September 2017
- WGCC Conceptual Workshop in June 2017, involving the IEA Secretariat, six TCPs and three city experts
- EBC TCP Executive Committee Meeting in November 2017
- District Heating and Cooling TCP Executive Committee Meeting in November 2017
- Hybrid and Electric Vehicles TCP Executive Committee Meeting in November 2017
- Heat Pumping Technologies TCP Executive Committee Meeting in November 2017
- Solar Heating and Cooling TCP Executive Committee Meeting in November 2017

Project duration
2018–2020

Operating Agent
Helmut Strasser, Salzburg Institute for Regional Planning and Housing (SIR), Austria

Participating countries (provisional)
Austria, Canada, Denmark, Finland, France, Germany, Italy, Ireland, Japan, P.R. China, the Netherlands, Norway, Sweden, Switzerland, UK, USA

Further information
www.iea-ebc.org

Ongoing Research Projects

HVAC ENERGY CALCULATION METHODOLOGIES
FOR NON-RESIDENTIAL BUILDINGS
(EBC WORKING GROUP)

COST-EFFECTIVE BUILDING RENOVATION AT DISTRICT LEVEL
COMBINING ENERGY EFFICIENCY AND RENEWABLES
(EBC ANNEX 75)

COMPETITION AND LIVING LAB PLATFORM
(EBC ANNEX 74)

TOWARDS NET ZERO ENERGY RESILIENT PUBLIC COMMUNITIES
(EBC ANNEX 73)

ASSESSING LIFE CYCLE RELATED ENVIRONMENTAL IMPACTS
CAUSED BY BUILDINGS
(EBC ANNEX 72)

BUILDING ENERGY PERFORMANCE ASSESSMENT
BASED ON IN SITU MEASUREMENTS
(EBC ANNEX 71)

BUILDING ENERGY EPIDEMIOLOGY:
ANALYSIS OF REAL BUILDING ENERGY USE AT SCALE
(EBC ANNEX 70)

STRATEGY AND PRACTICE OF ADAPTIVE THERMAL COMFORT
IN LOW ENERGY BUILDINGS
(EBC ANNEX 69)

INDOOR AIR QUALITY DESIGN AND CONTROL
IN LOW ENERGY RESIDENTIAL BUILDINGS
(EBC ANNEX 68)

ENERGY FLEXIBLE BUILDINGS
(EBC ANNEX 67)

DEFINITION AND SIMULATION OF OCCUPANT BEHAVIOR IN BUILDINGS
(EBC ANNEX 66)

LONG-TERM PERFORMANCE OF SUPER-INSULATING MATERIALS
IN BUILDING COMPONENTS AND SYSTEMS
(EBC ANNEX 65)

LOWEX COMMUNITIES – OPTIMISED PERFORMANCE OF
ENERGY SUPPLY SYSTEMS WITH EXERGY PRINCIPLES
(EBC ANNEX 64)

IMPLEMENTATION OF ENERGY STRATEGIES IN COMMUNITIES
(EBC ANNEX 63)

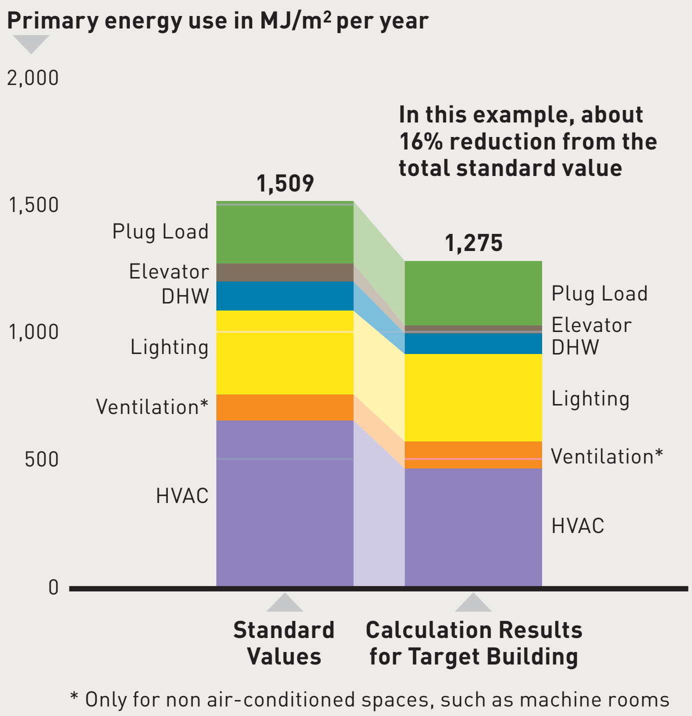
VENTILATIVE COOLING
(EBC ANNEX 62)

AIR INFILTRATION AND VENTILATION CENTRE - AIVC
(EBC ANNEX 5)

HVAC Energy Calculation Methodologies for Non-residential Buildings

EBC WORKING GROUP

As emphasised in the IEA and UNDP publication, 'Modernising Building Energy Codes (2013)', building energy codes are the 'cornerstone' policy instruments to tackle energy use in buildings. And when countries improve their building energy codes and key indices, energy calculation methodologies need to be focused upon as the principal method for performance evaluation. As the first step to dealing with building energy codes in EBC, HVAC energy calculation methodologies for non-residential buildings are being studied as one of the most challenging parts of building energy calculations. Certain national calculation methodologies of the participating countries have been collated and are being analysed in the project by referring to existing documents describing the energy calculation logic to be followed for HVAC systems. In parallel, relevant international standards prescribing parts of the calculation steps and the ways in which countries operate their building energy codes are also being analysed.



Objectives

Prior to this project, a lack of relevant international research in this area became apparent. The project objectives are therefore to:

- collect world-wide examples of technical documentation on calculation methodologies for energy use for HVAC systems in non-residential buildings and on their scientific basis including research work on their validation;
- analyse the collected documentation and pick up characteristics of methodologies, which are appropriate as good examples for broader utilization;
- identify any lack of scientific basis or problems in HVAC energy calculation methodologies to inform future R&D themes.

Deliverables

The results of the analysis will be published as the final project report. The following project deliverables are planned:

- a report including the results of the analysis on national energy calculation methodologies for HVAC systems for non-residential buildings,
- a report containing descriptions and quoted information, and
- a summary report on the project findings.

Progress

HVAC systems in non-residential buildings are often considerably complex, and simplifications are usually inevitable when modelling their behaviour in energy calculation methodologies.

An example of calculated primary energy use for an office building (10,000 m² floor area, located in a mild climate) compared with standard values.
Source: Adapted from EBC Working Group on HVAC Energy Calculation Methodologies for Non-residential Buildings

Ways to approach to actual energy efficiency of subsystems: In some calculation methodologies, seasonal average efficiencies of heat generators are treated independently from both the calculated energy needs (thermal loads) and the capacity of the heat generators to be installed; they are applied directly to calculate energy use from the energy needs. However, such a considerably simplified calculation limits accuracy when estimating actual energy efficiencies under partial load conditions. Although in some situations energy use for fans can be comparable to that for heat generators, fans are often grouped into auxiliary equipment and their energy use is calculated using simple coefficients, which are selected according to the typology of the fan control, which still contains problems.

Importance of defining building use: From the viewpoint of energy use, the impact of outdoor climatic conditions in non-residential buildings is not so large as in residential, because of larger fractions of non-perimeter floor space and a wider variety of building uses, such as working hours (time of the day and year) and internal heat emissions. In some national methodologies, more than 200 categories of room or activity are defined and used for calculating heat needs for HVAC and DHW.

Component characteristics and test standards: Test standards and construction product characteristics based on them are commonly used in building energy calculations. However, those standards were originally developed within each industry to agree the basis for comparing product characteristics. For this reason, some of the characteristics should not be used directly in building energy calculations intended to estimate real energy use. But, if the intention is only to provide relative estimates to select between different products to be installed, such characteristics could work well.

Design standards and energy use: Refinement of energy calculation methodologies needs to include further development of design standards for energy-saving techniques, such as natural ventilation systems for heat removal, variable air volume and variable water volume controls to reduce fan and pump energy use, and control of multiple heat generators.

Checking input data accuracy: When a requirement for checking input data accuracy by an impartial inspector is incorporated into the implementation of the building energy code, this needs additional human effort. Although there may be various ways to maintain accuracy, it seems that technical procedures for checking need to make reference to design documentation and drawings.

Accreditation and utilization of other calculation methods: This issue is related to those mentioned above, and it seems that the same requirements as for national calculation methodologies should be applied to other calculation methods that are used voluntarily. The protocol for accreditation of other methods may form another important theme of the analysis in this project.

Validation by comparison with actual energy uses: It has become evident that insufficient comparisons between calculated and real energy use have yet been made for HVAC systems in non-residential buildings. Trials to obtain better correlation between calculated and actual energy use not only for HVAC systems, but also for other purposes are being carried out internationally. In addition, it is still not straightforward even to maintain correspondence between averages of calculated and real energy use.

Meetings

The 1st project meeting was held in June 2017, in London, UK.

Project duration
2016–2019

Operating Agent
Takao Sawachi, Building Research Institute, Japan

Participating countries
Australia, Canada, P.R. China, Italy, Japan, the Netherlands, Switzerland, UK, USA

Further information
www.iea-ebc.org

Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables

EBC ANNEX 75

Buildings are a major source of greenhouse gas emissions. Reducing their energy use and associated greenhouse gas emissions is particularly challenging for the existing building stock. In contrast to the construction of new buildings, there are often architectural and technical hurdles for achieving low emissions and low energy use in existing ones. Also, the cost-effectiveness of reaching a high energy performance in existing buildings is often lower than in the construction of new buildings.

The transformation of existing buildings to achieve low-emissions and low-energy use is a particular challenge in cities, where many buildings continue to rely to a large extent on heat supplied by fossil fuels. At the same time, there are specific opportunities for district-level solutions in cities that should be explored. In this context, the project aims at clarifying the cost-effectiveness of various approaches combining both energy efficiency measures and renewable energy measures at district level.

At district level, finding the balance between renewable energy measures and energy efficiency measures for the existing building stock is a complex task and many research questions still need to be answered. The questions include:

- What are the cost-effective combinations between renewable energy measures and energy efficiency measures to achieve far-reaching reductions in greenhouse gas emissions and primary energy use in urban districts?
- What are the cost-effective strategies to combine district-level heating or cooling based on available environmental heat, solar energy, waste heat or natural heat sinks, with energy efficiency measures applied to building envelopes?
- How do related strategies compare in terms of cost-effectiveness and impacts with strategies that combine decentralized switching of energy carriers to renewable energy sources with energy efficiency measures applied to building envelopes?
- Under which circumstances is it more appropriate to use available renewable energy potentials in cities at a district level, and under which circumstances are decentralized renewable energy solutions more advantageous, in combination with energy efficiency measures applied to building envelopes?

Objectives

The project has general objectives that are to:

- investigate cost-effective strategies for reducing greenhouse gas emissions and energy use in buildings at district level in cities, combining both energy efficiency measures and renewable energy measures;
- provide guidance to policy makers, industry working in the field of the energy transition, as well as building owners, on how to cost-effectively transforming existing urban districts into low-energy and low-emissions districts.

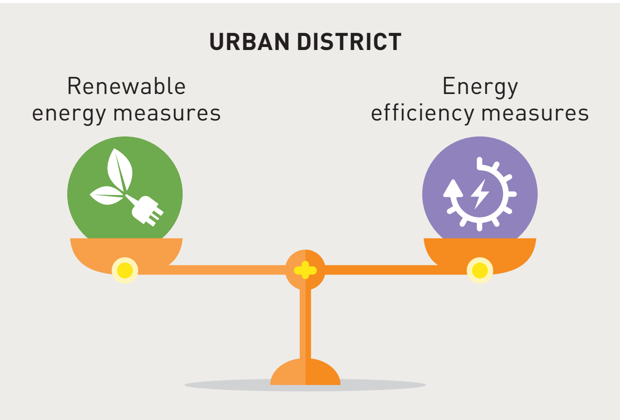
It is focusing on a number of specific objectives, which are to:

- give an overview about various existing and emerging technology options and how challenges occurring in an urban context can be overcome;
- develop a methodology to identify cost-effective strategies for renovating urban districts, supporting decision makers in the evaluation of the efficiency, impacts, cost-effectiveness and acceptance of various solutions;
- illustrate such strategies in selected case studies and gather best-practice examples;
- give recommendations to policy makers and energy-related industry on how they can influence the uptake of cost-effective combinations of energy efficiency measures and renewable energy measures in building renovation at district level.

Deliverables

The following project deliverables are planned:

- a technology overview report on identifying energy efficiency measures and renewable energy measures at district level in an urban context;
- a methodology report on cost-effective building renovation at district level;
- supporting tools for decision makers with identification and adaptation of tools to support the application of the methodology in generic and case-specific assessments;
- a report on the application of the methodology in generic districts;
- a report on the strategy development;
- a report on parametric assessments for case studies;
- a report on good practice examples showing strategies for transforming existing urban districts into low-energy and low-emissions districts;
- a report on enabling factors and obstacles to replicate successful case studies;
- good practice guidance for transforming existing districts into low-energy and low-emissions districts;
- a report on policy instruments, including recommendations for subsidy programmes and for encouraging market take-up;
- a report on business models and models for stakeholder dialogue;
- guidebooks containing guidelines for policy makers and energy-related industry on how to encourage the market uptake of cost-effective strategies combining energy efficiency measures and renewable energy measures and guidelines for building owners and investors about cost-effective renovation strategies, including district-based solutions.



A key question investigated in this project is to find the balance point between renewable energy measures and energy efficiency measures for cost-effective building renovation strategies at district level.
Source: Adapted from EBC Annex 75

Progress

The project was approved for its Working Phase at the November 2017 EBC Executive Committee Meeting and it is still at an early stage of development. During 2017, the project concept, its objectives, scope, work methodology and reports to be produced have been consolidated and agreed. The project organization has also been settled with each participant's responsibilities defined. A detailed work plan and a schedule have also been prepared.

Meetings

During 2017, two meetings were organized:

- The 1st Preparation Phase Internet Meeting was held in July 2017.
- The 2nd Preparation Phase Meeting was held in Guimarães, Portugal, in October 2017.

Project duration
2017–2021

Operating Agent
Manuela Almeida, University of Minho, Portugal

Participating countries
Austria, Belgium, P.R. China, Czech Republic, Denmark, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland

Further information
www.iea-ebc.org

Competition and Living Lab Platform

EBC ANNEX 74

The project can be considered in part as a 'think tank' with a focus on the education of the next generation of architects and engineers through the use of university-based competitions and 'living labs'. Living labs are experimental buildings characterized by an occupant-centred testing, research and innovation approach.

Underlying the project background is the success story of the Solar Decathlon, which is a series of international student competitions started in 2000 based on an initiative of the U.S. Department of Energy (DOE). In these competition, universities from all over the world are challenged to design, build and operate solar powered houses. It is the only series of global student competitions addressing the realization and performance assessment of buildings and not only the design. During each competition's final phase, every interdisciplinary team assembles its house in a common Solar Village. The final phase includes a public exhibition, monitoring and 10 contests, hence the name 'Decathlon'. Thirteen competitions have been conducted up to the end of 2017, with eight having taken place in the USA, three in Europe, one in China and one in Columbia. Two countries in hot climates will also hold competitions with the addition of the United Arab Emirates and Morocco in the near future. Many of the experimental houses are subsequently used as living labs when transferred back to their home universities. This format intensively stimulates research and education by supplying valuable experience, monitoring data and occupant feedback. The interdisciplinary student projects support and stimulate an integrated educational approach crossing disciplines and faculties.

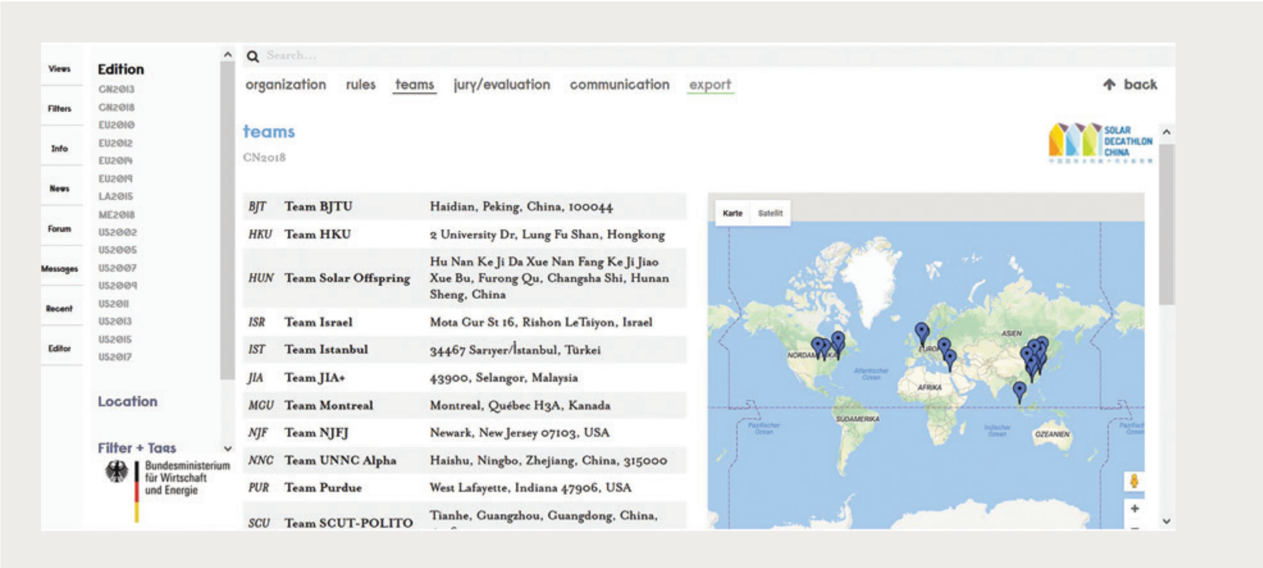
Starting with the 'Proclamation of Madrid' in 2010, a group comprised of organizers and participants of the Solar Decathlon Europe began to discuss the future evolution of the competition format with regard to content and form. This process underlined that an authoritative international platform was missing, linking the activities and experiences worldwide as starting point for this evolution. In contrast to the competitions in the USA, which are centrally managed by DOE, the events in other places in the world have seen new organizations created for each competition. In many ways, in form, content and financially, the evolution of the existing competition formats, as well as new competitions, would benefit from knowledge exchange and a platform to ensure continuity of know-how.

Objectives

The project plans to produce a Web-based knowledge platform to map and link competition and living lab experiences worldwide. It is working towards improving existing competition formats, as well as developing new ones. It is intended to stimulate the technological knowledge, the scientific level and the architectural quality within future competitions and living labs based on the development of a systematic knowledge platform, as well as linking to knowledge from previous and current IEA activities. Competitions and living labs introduce new resources to the existing range of dissemination activities in the IEA Technology Collaboration Programmes (TCPs), including EBC.

To acquire a more solid connection with research, the project aims to develop a framework to collaborate with existing and future IEA TCP projects and integrate these research endeavours into future competition concepts. Given that there is a trend towards monitoring the houses for a more extended period of time, there are a variety of tests, monitoring protocols and sequences that may be implemented.

As a think tank for the creation of innovative and useful competitions, as well as living lab experiences, the project is assisting the evolution of existing competition formats, such as the Solar Decathlon, and the creation, development and incorporation of new competitions. One key goal of the project is to learn from previous



An initial concept for the Competition Knowledge Platform.
Source: University Wuppertal, Germany

competitions and existing living labs to take advantage of this knowledge. This learning will be used to improve and influence the direction and content of new competition formats and living labs initiatives around the world, although not to administer or organize future competitions.

Communication and dissemination are of major importance for the success of the competitions. Past experiences underline that it is not sufficient to simply act during the event period, but however to regularly and consistently engage with the public, energy policy makers, as well as the scientific community.

Deliverables

The following project deliverables are planned:

- a Web-based competition knowledge platform,
- a technology and innovation evaluation report,
- a post-competition and living lab scenarios report,
- monitoring and documentation templates,
- guides for competition rules, criteria and organization, and
- educational material.

Progress

The project was approved for its working phase at the November 2017 EBC Executive Committee Meeting, after a one year preparation phase. All participating experts bring a high level of expertise to the work they manage, for example from former participation in the Solar Decathlon or other competitions, and who undertake substantial research and development in their specific fields. In addition, the European Commission funded activity, 'Solar Decathlon Europe Competitions - Analysis of the Results', is running in parallel with this project and is sharing knowledge.

Meetings

- The 1st Preparation Phase Expert Meeting was held in Berlin, Germany in March 2017.
- The 2nd Preparation Phase Expert Meeting was held in Denver, Colorado, USA in October 2017.

Project duration
2017–2020

Operating Agents
Karsten Voss, University Wuppertal, Germany, and
Sergio Vega, Technical University of Madrid, Spain

Participating countries
Belgium, Germany, the Netherlands, Spain, USA
Observers: Hungary, United Arab Emirates

Further information
www.iea-ebc.org

Towards Net Zero Energy Resilient Public Communities

EBC ANNEX 73

Until recently, most planners of public communities (military bases, universities, and so on) addressed energy systems for new facilities on an individual facility basis without consideration of community-wide goals relevant to energy sources, renewables, storage, or future energy generation needs. In today's resource-constrained environment, public communities (including those encompassing military bases, universities, hospital campuses and residential neighbourhoods) are looking for creative ways to drive additional efficiencies in energy use and reduce associated costs. Large scale coordinated efforts are needed to gain synergies between different energy initiatives and future planned projects to maximize energy use, resilience and cost reduction.

Building-centric planning also falls short of delivering community-level resilience. For example, many building code requirements focus on hardening to specific threats, but in a multi-building community only a few of these buildings may be ‚mission-critical'. Furthermore, hardening is only one aspect of resilience. Recovery and adaptation should be addressed as effective energy resilience solutions. Over the past two decades, the frequency and duration of regional power outages from weather, man-made events, and aging infrastructure have increased. Major disruptions of electric and thermal energy supplies have degraded critical mission capabilities and caused significant economic impacts at military installations, for example. There is a need to develop a highly resilient ‚backbone' of energy systems to maintain critical mission and service operations effectively during such extended power outages over a range of emerging scenarios.

Significant additional energy savings and increased energy security can be realized by considering holistic solutions for the heating, cooling and power needs of communities, comprising of collections of buildings. The status quo in planning and execution of energy-related projects does not support attainment of current energy goals, or the minimization of costs for providing energy security. Therefore, the project is summarizing the state-of-the-art technologies and concepts for community-wide energy master planning considering both power and heating / cooling needs. Furthermore, the project intends to advance the integration of various new energy master planning tools and strategies by standardizing data models and developing new software services for meeting current and future energy efficiency (site and source) and energy security goals. It is researching and integrating innovative energy supply and energy distribution strategies (including information on their performance and costs), which will culminate in a complete community energy modelling tool. Finally, this project is enhancing modelling tools to address resiliency of energy supply solutions, integrate a capability for computation of thermal and electrical network characteristics (capacity, losses, and cost), and provide sufficient visualization of different scenarios to support straightforward decision making about resilience.

Objectives

The project scope includes the decision-making process and computer-based modelling tools for achieving net zero energy resilient public-owned communities (military bases, universities, and so on). The main project goal is to develop guidelines and tools that support the planning of net zero energy resilient public communities and that are easy to understand and execute. The specific objectives are to:

- assess existing case studies with regard to technical solutions, costs, and performance data;
- develop a database of energy utilization indexes for public, education, and military building types and communities;
- develop energy targets;
- summarize, develop, and catalogue representative building models by building use type, including mixed-use buildings, that are applicable to building stocks of national public communities and military bases;

A low energy quarter with a low temperature micro-grid in Wüstenrot, Germany.
Source: Prof. Ursula Eicker, ZAFH.NET, Stuttgart, Germany

- summarize, develop, and catalogue representative energy supply and energy efficiency scenarios;
- develop guidance for energy master planning;
- develop a functional modelling tool to facilitate the 'net zero energy master planning process', which will enhance currently used building modelling tools to address resiliency of combined energy supply and energy efficiency solutions, integrate a capability for computation of thermal and electrical network characteristics (capacity, losses, availability and cost), and offer sufficient visualization of different scenarios to support resilience decisions without significant post processing;
- collect and describe business and financial aspects, legal requirements and constraints relevant to the implementation process of net zero energy concepts for public communities in participating countries;
- disseminate this information and train end users in participating countries, mainly decision makers, community planners, energy managers, and other market partners.

The energy master planning guidelines and enhancements of modelling tools, best practices and case studies will support different user groups and facilitate communication among them. The target audiences for the project outcomes include participants in the decision-making process, specifically, decision makers, planners, building owners, architects, engineers and energy managers of publicly-owned and operated communities.

Deliverables

The project will produce the following deliverables:

- a guide for net zero energy planning in public and military building communities,
- an energy master planning tool module,
- a book of case studies with examples of energy master plans, and
- results of several realized or partially realized schemes.

Progress

At the November 2017 EBC Executive Committee Meeting held in Ottawa, Canada, it was approved to start the project working phase in February 2018.

Meetings

- The 1st Preparation Phase Expert Meeting was held in Copenhagen, Denmark in April 2017.
- The 2nd Preparation Phase Expert Meeting was held in Washington DC, USA in December 2017.

Project duration
2017 – 2022

Operating Agents
Alexander Zhivov, US Army Engineer Research and Development, USA, and
Rüdiger Lohse, KEA - Climate protection and energy agency of Baden - Württemberg GmbH, Germany

Participating countries
Australia, Austria, Canada, Denmark, Finland, Germany, Norway, UK, USA

Further information
www.iea-ebc.org

Assessing Life Cycle Related Environmental Impacts Caused by Buildings

EBC ANNEX 72

The project goal is to support planning processes and decision making related to new buildings and retrofit of existing buildings to reduce the primary energy demand, greenhouse gas emissions and environmental impacts along the entire life cycle of buildings and thus to lead to more resource efficient buildings in the future. It is discussing research and harmonization issues arising using life cycle assessment (LCA) approaches for buildings and functions as a platform to exchange experience and knowledge. It also intends to foster the use of environmental information in the building design process in countries with limited experience.

A significant project outcome is expected to be the establishment of a harmonised methodology on how to assess the primary energy demand, greenhouse gas emissions and environmental impacts along the entire life cycle of buildings (production, construction, use and end of life). The creation of guidance on the implementation of such information into sophisticated and advanced building information and planning tools, such as building information modelling (BIM), is anticipated as another major achievement.

Objectives

The project work is organised towards achieving the following specific objectives:

- establish a harmonised methodology guideline to assess the life cycle based primary energy demand, greenhouse gas emissions and environmental impacts caused by buildings;
- establish methods for the development of specific environmental benchmarks for different types of buildings to help to design buildings with a minimum life cycle based primary energy demand, greenhouse gas emissions and environmental impacts;
- derive guidelines and tools (building design and planning tools such as BIM and others) for design decision makers;
- establish a number of case studies, focused to allow some of the research issues to be answered and for deriving empirical benchmarks;
- develop national / regional databases with regionally differentiated life cycle assessment data tailored to the construction sector, covering materials production, building technology manufacture, energy supply, transport services and waste management services; share experiences with the setup and update of such databases.

CRADLE — GATE SITE — HAND OVER — END OF USE — GRAVE

	Preconstruction Stage	Construction Process Stage	Use Stage	End of Life Stage (scenarios)
EMBODIED IMPACTS	Production	Construction	Maintenance, repair and replacement	End of life
OPERATIONAL IMPACTS			Operational energy and water use	

Building life cycle stages and environmental impacts. Embodied impacts occur all along the life cycle, whereas operational impacts occur only during the use stage.
Source: AGNHB/TU Graz, Austria

Deliverables

The main products of the project will include a series of reports related to life cycle based environmental impacts of buildings:

- harmonised guidelines on the environmental life cycle assessment of buildings;
- establishing environmental benchmarks for buildings, including case study examples;
- national LCA databases used in the construction sector, including a standardised characterisation of LCA databases relevant to the construction sector;
- guidelines for design decision makers on optimization using building assessment workflows and tools, including case study examples;
- building case studies (using a standardised template), including guidelines with good examples on the application of LCA in different stages of the design process;
- how to establish national / regional LCA databases targeted to the construction sector, including recommendations for data exchange; and
- publicly available national data set(s) of LCA based environmental indicator results of construction materials.

Progress

During the project preparation phase over the past year, the research questions and the work programme has been further developed and organisational progress has been made. All participants have specified their roles and intended contributions to the project, a timeline aligning all activities has been developed. The project working phase was approved by the EBC Executive Committee during its meeting in Ottawa, Canada in November 2017.

Meetings

- The 1st Experts Meeting was held in Copenhagen, Denmark in May 2017.
- The 2nd Experts Meeting was held in Graz, Austria in November 2017.

Project duration
2016–2021

Operating Agent
Rolf Frischknecht, treeze Ltd., Switzerland

Participating countries
Australia, Austria, Belgium, Canada, Czech Republic, P.R. China, Denmark, Germany, Spain, Italy, France, R. Korea, the Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland, UK, USA
Observers: Hungary, India

Further information
www.iea-ebc.org

Building Energy Performance Assessment Based on In-situ Measurements

EBC ANNEX 71

Over recent decades, policy makers in many developed countries have imposed ever more stringent requirements with regard to the energy performance of new and renovated buildings. The installation of thick insulation layers and more efficient heating systems and appliances has become common practice. Thus far though, building energy performance assessments have mainly been performed during the design phase. Only more recently, however, has awareness grown that more attention should be paid to the actual energy performance of buildings in use.

The project aims to develop replicable methodologies embedded in a statistically and building physics based framework to characterize and assess the actual energy performance of buildings. It is focusing on residential buildings, both at the level of individual dwellings, as well as at the level of building communities. At both levels, the development of methods for characterisation and quality assurance are being explored. Characterisation methods aim to translate the (dynamic) behaviour of a building into a simplified model that can be used to model predictive control, fault detection, optimisation of district energy systems, and so on. Quality assurance methods are intended to pinpoint some of the most relevant aspects of actual building performance, such as the overall heat loss coefficient of a building, the energy efficiency of the heating (or cooling) system, air tightness, or solar absorption.

Objectives

The project objectives are as listed below:

- the development of methodologies to characterize and assess the actual as-built energy performance of buildings;
- collect some well-documented data sets that can be used for evaluation and validation;
- investigate how on-site assessment methods can be applied for quality assurance.

Deliverables

The main deliverables of the project are as follows:

- overview of availability and reliability of input data for on-site building performance assessment;
- dynamic data analysis methods to characterize and assess building energy performance;
- guidelines to apply the methods in quality assessment procedures;
- a detailed and well-controlled experiment that can be used both for development and assessment of statistical methods, as well as for the validation of common building energy simulation models.

Progress

To increase knowledge and stimulate collaboration between participants, the project places a strong emphasis on working with 'common exercises'. The first common exercise was launched in 2017, with contributions from 12 organisations covering six countries, and importantly resulting in the analysis of more than 15 different methodologies. The goal of this common exercise was to explore the reliability of any identification technique with which participants were already familiar, making use of different combinations of measurements for a given case study. The data for the case study were made available by the University of Lincoln, and covered a three-year monitoring campaign in an end-terrace dwelling, one of four social houses in Gainsborough, UK. These buildings are constructed to be highly energy efficient, meeting 'Level 5' of the UK Code for Sustainable Homes.

This common exercise was very open and flexible for the participants. No methods were prescribed and no limitations were introduced regarding the use of the available data. For example, in order to evaluate the impact on the obtained accuracy, participants were free to reduce the amount of input data, to aggregate data, use a shorter time span, neglect information, and so on.

The case study used for a first exploration of available characterisation and assessment techniques as a common exercise. The available data show, amongst others, indoor temperatures, gas and electricity consumption and climate data for the occupied buildings.
Source: B. Sodagar, University of Lincoln, UK

The outcome of the first common exercise was hence not expected to be the most accurate prediction of the dynamic behaviour of the building, or the most precise estimation of physical parameters. Rather, the outcome was intended to initiate the development of a matrix that links the model accuracy expected for a specific application to a list of required measurements and statistical methods.

Meetings

- The 2nd Expert Meeting was held in Loughborough, United Kingdom in April 2017.
- The 3rd Expert Meeting was organized in Chambéry, France, in October, 2017.

Project duration
2016–2021

Operating Agent
Staf Roels, KU Leuven University of Leuven, Belgium

Participating countries
Austria, Belgium, Denmark, Germany, France, Italy, Norway, Spain, the Netherlands, UK

Further information
www.iea-ebc.org

Building Energy Epidemiology: Analysis of Real Building Energy Use at Scale

EBC ANNEX 70

To help to bring about the transition to a low carbon built environment, this project envisions an empirically grounded and robust evidence base on energy and the building stock, created through data collection, study methods and modelling techniques established to better inform decision-making and policy. Its aim is to develop methods for improving the empirical evidence on energy demand in the building stock.

The project is focused on identifying, reviewing, evaluating and producing leading edge methods for studying and modelling the building stock including: data collection techniques on energy use, building features, occupant characteristics, and building morphology; analysis of smart meter energy data, building systems, and occupant behaviour; modelling energy demand among sub-national and national building stocks. The project is divided into three subtasks as follows, which are being carried out in parallel:

- user engagement (needs and provisions);
- data mechanisms and foundations;
- building stock modelling and analysis.

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

Energy epidemiology provides an over-arching approach for all of the disciplines involved, in which findings from large-scale studies inform energy policy while providing a context for conventional small-scale studies and information input for predictive models. This approach can be used to study and describe the mechanisms of energy demand and determinants of conditions that lead to different levels of demand.

An energy epidemiology approach is well suited to dealing with uncertainty through the use of methodological tools and analysis techniques that include: common definitions and metrics, population selection techniques, study designs for data collection, comparison and analysis, approaches to dealing with bias and confounding factors, guidelines for working towards identifying causal relationships, and systematic approaches to reviewing evidence.

Objectives

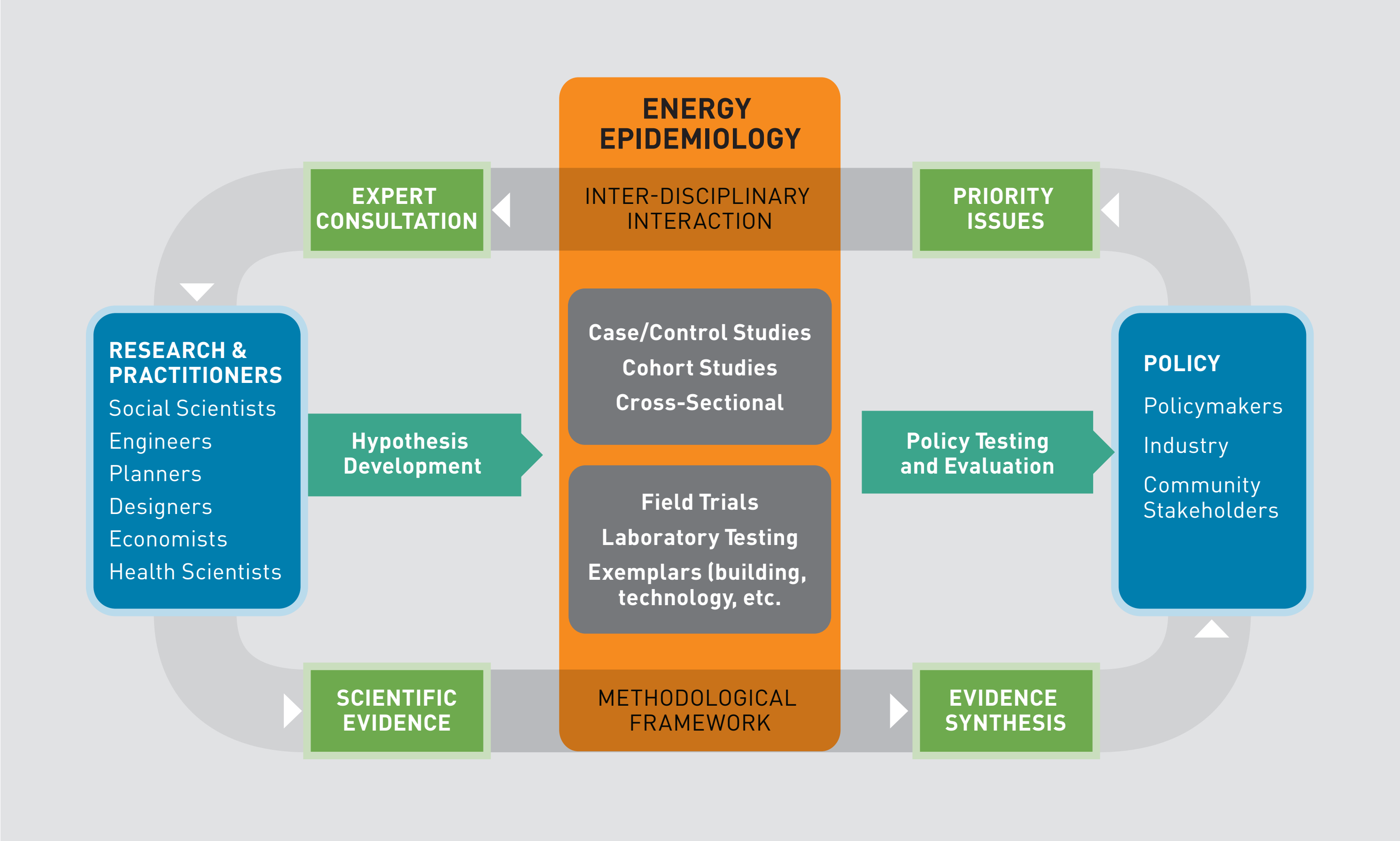
The project objectives are to:

- support countries in developing realistic decarbon-isation transitions and develop pathways through better available empirically derived energy and buildings data;
- inform and support policymakers and industry in the development of low energy and low carbon solutions by evaluating the scope for using empirical stock building and energy use data;
- develop best practice in the methods used to collect and analyse data related to real building energy use, including building and occupant data;
- support the development of robust building stock data sets and building stock models through better analysis and data collection.

Deliverables

The following project deliverables are planned:

- a register of energy and building stock data among participating countries and more widely;
- a register of energy and building stock models;
- a data schema for energy and building stock data for developing and emerging countries;
- guidelines for energy and building stock model reporting and metrics for stock model comparison;
- a series of reports on: stakeholder key issues on needs and uses of data; best practice use cases for energy and buildings data; classification for energy and buildings stock data; classification of energy and buildings stock models; stock model uncertainty and sensitivity tests.



Energy epidemiology in practice and interaction with policy development and evaluation.
Source: Adapted from Hamilton I., Summerfield A., Oreszczyn T., and Ruyssevelt P., "Using epidemiological methods in energy and buildings research to achieve carbon emission targets", Energy and Buildings, Vol 154, pp 188-197 (Creative Commons BY 4.0 license)

Progress

The project has completed the first year of its working phase, with the initial activities nearing completion focused on setting up the user surveys, and developing the data and model classifications. The 'Energy and Buildings Stock Data Users and Needs Survey' has been developed and piloted among the project participants to better understand the available data resources, how they are used and what more is needed. A literature review on issues around data use and need is underway across the participating countries. These activities are intended to inform the development of the energy and building stock data and model registry.

Further, an energy and building stock data classification has been developed that is being used to classify data and models as part of the registry activities. This classification is designed to enable identification of key data attributes in terms of their relevance to energy and building stock analysis and modelling.

The project participants have been engaged in disseminating the concept of energy epidemiology along with the initial outputs of the effort. Participants have held workshops in Mexico, the European Union, and the USA, along with a workshop at the IBPSA international conference Building Simulation, and a presentation at a UNFCCC COP23 side event on energy and buildings.

Meetings

- The 1st Working Phase Meeting took place in February 2017, in London, UK.
- The 2nd Working Phase Meeting was held in August 2017 in Berkeley, California, USA.
- The 3rd Working Phase Meeting was held on in December 2017 in Ghent, Belgium.

Project duration
2016–2020

Operating Agent
Ian Hamilton, University College London, UK

Participating countries
Austria, Belgium, P.R. China, Denmark, France, Germany, the Netherlands, Sweden, Switzerland, UK, USA

Further information
www.iea-ebc.org

Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings

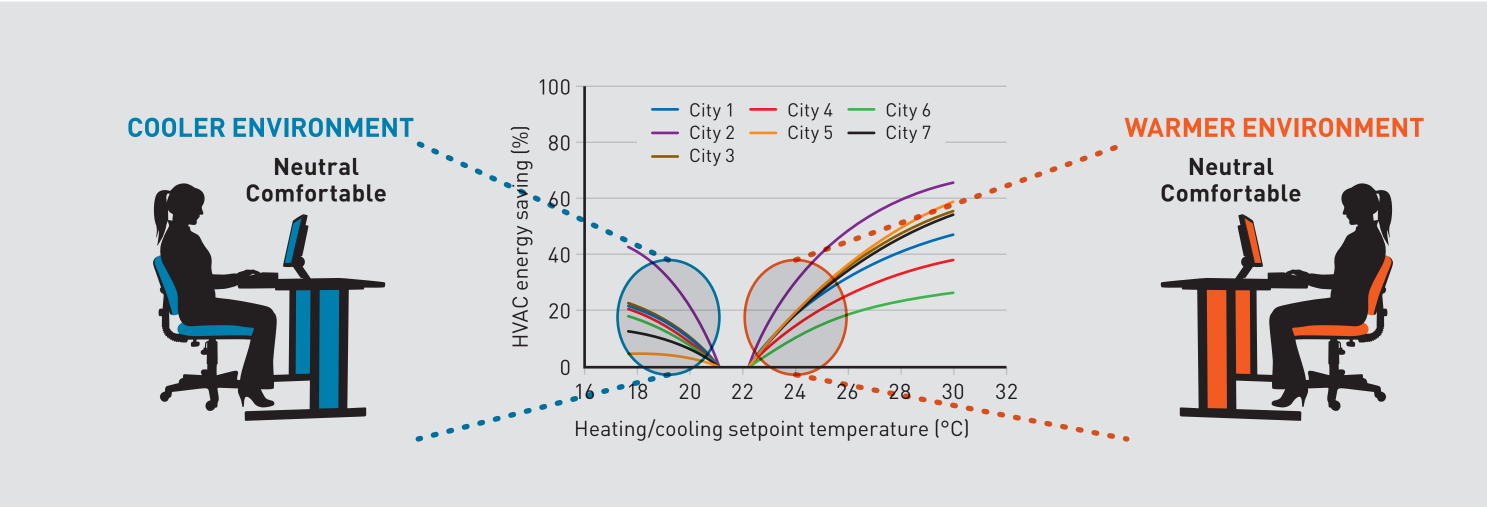
EBC ANNEX 69

A good understanding of adaptive thermal comfort is a key point to establish the appropriate balance between reductions in energy use and provision of comfortable indoor environments in buildings. Sufficient evidence exists to show that tight control of indoor temperatures drives high energy costs and greenhouse gas emissions, and may not always benefit occupant comfort or health. Adaptive thermal comfort is regarded as a valuable concept that may play an important role in low energy building design and operation. Indoor temperatures should be maintained within acceptable ranges that are related to the outdoor climate and change through annual seasonal cycles. It is then possible for people to achieve thermal comfort through the three adaptive approaches: physiological, psychological and behavioural. That means a steady indoor thermal environment achieved with mechanical cooling or heating is not always necessary, so that energy use can be reduced. Furthermore, the degrees of freedom for individual personal environmental control have positive impacts through both psychological and behavioural adaptive approaches, which could further enhance occupants' satisfaction with their indoor thermal environments. If a building's services systems can operate in a 'part-time and part-space' mode depending on its occupants' individual demands instead of the 'whole-time and whole-space' mode prevalent in many buildings today, energy use could also be lessened.

Objectives

How to develop an analytical and quantitative description of adaptive thermal comfort for occupants in buildings is a fundamental scientific question. Answering this would inform more appropriate design strategies, evaluation approaches, and control algorithms for the indoor environment, all of which can reinforce reductions in building energy use. The specific objectives of the project are to:

- establish a worldwide database with quantitative descriptions of occupants' thermal adaption;
- develop new or improved indoor thermal environment criteria based on the adaptive thermal comfort concept;



Using personal thermal comfort systems to satisfy occupant comfort leads to potential for energy savings by allowing the 'deadband' to be widened between heating and cooling setpoints in a space conditioning system that provides active heating or cooling.
Source: Adapted from Edward Arens and Hui Zhang, EBC Annex 69

- propose how adaptive methods can be used in building design strategies to achieve thermal comfort with low energy use;
- provide guidelines for developing personal thermal comfort systems based on perceived or individual control adaptation.

Deliverables

The following project deliverables are being produced:

- global thermal comfort database with a user interface;
- a developed model and criteria for adaptive thermal comfort in buildings;
- guidelines for low energy building design based on the adaptive thermal comfort concept;
- guidelines for personal thermal comfort systems.

Progress

In the past year, the global thermal comfort database has been finalized and quality checked. Adaptation under elevated metabolic rates has been evaluated to further reveal the mechanisms behind thermal adaptation. Development of design guidelines on how to apply adaptive comfort for lowering energy use in buildings is ongoing. Exemplary adaptive and low-energy case study buildings have been recruited in 11 participating countries, including diverse climate zones. Further, longitudinal field studies and data collection have begun.

Meetings

- The 3rd working phase meeting was organized in Copenhagen, Denmark, in May 2017. Thirty participants from 11 countries attended the meeting.
- The 4th working phase meeting was held in Karlsruhe and Heidelberg, Germany, in November 2017, and was attended by 39 participants from nine countries.

Project duration
2015–2019

Operating Agents
Yingxin Zhu, Tsinghua University, China
Richard de Dear, the University of Sydney, Australia

Participating countries
Australia, Canada, P. R. China, Denmark, Germany, Japan, R. Korea, the Netherlands, Norway, Sweden, UK, USA
Observer: India

Further information
www.iea-ebc.org

Indoor Air Quality Design and Control in Low Energy Residential Buildings

EBC ANNEX 68

Highly energy efficient residential buildings need to include controls to ensure that the need for ventilation is met in an optimal way, such that good indoor air quality (IAQ) can be provided with minimal use of energy. The project is collecting data and tools needed to carry out optimization of energy use for ventilation of buildings, while considering sources, sinks and transport of relevant indoor pollutants.

Objectives

The key project objectives are to:

- establish a set of performance metrics required to combine very high energy performance with good IAQ;
- develop guidelines regarding design and control strategies for energy efficient buildings with good IAQ, taking into account means for ventilation and its control, thermal and moisture control, air purification strategies, and how these can optimally be combined;
- gather data on indoor pollutants and their properties pertaining to heat, air and moisture transfer;
- identify or further develop digital tools that can help building designers and managers to improve building energy performance and to provide comfortable and healthy indoor environments;
- identify and investigate relevant case studies, in which the above-mentioned performance can be examined and optimized.

Deliverables

The project deliverables are as follows:

- a report 'Defining the Metrics',
- a guidebook on design and operation for high IAQ in energy efficient residential buildings,
- a report and databases containing information about pollutants in buildings and their transport properties,
- a report on contemporary tools for combined prediction of IAQ and energy efficiency of residential buildings, and
- a report on documented field tests and case studies of residential buildings in which optimal combinations of good IAQ and low energy use have been pursued.

Indoor air quality monitoring in the 'P+ building' comprising measurements of VOCs, particulate matter (PM2.5), thermal and humidity conditions, as well as energy performance.
Source: Student work, Nanjing University, P.R. China

Progress

In 2017, the project report, 'Defining the Metrics' was published, which defines the target pollutants of interest and sets the metrics needed to quantify IAQ and energy use in low-energy residential buildings. A main focus of activity during 2017 has been to establish 'common exercises' that have been created for use throughout the project, using reference houses and test cells as common study objects across several of the exercises. Specific progress is summarised below.

Pollutant loads in residential buildings: This part of the project has carried out a literature review on existing data on material emissions and sorption, and a set of databases has been identified. Experiments are ongoing in the form of laboratory tests of combined effects of temperature and humidity on emissions of volatile organic compounds (VOCs) from different building materials. Field measurements in a demonstration building are being used to study the relationship between IAQ and different ventilation, air cleaning strategies and building energy use. These measurements are taking place over four seasons.

Modelling review, gap analysis and categorization: The focus of this current activity is on interoperability of existing models and development of quality assurance criteria for optimal use of tools. The models consider heat, air, moisture and VOC flows, coupled walls and rooms, and are gradually being developed with increasing complexity.

Strategies for design and control of buildings: This aspect is active in investigating possible IAQ design strategies using tools and methods already examined in the project to evaluate design alternatives for several building types. An activity on investigation of operational strategies for residential ventilation systems is being based on collected case studies.

Field measurements and case studies: This is concerned with testing and validating findings from other project work through case studies on IAQ in new, low energy residential buildings. Three levels of validation experiments are being carried out with increasing complexity in terms of spatial extent (single room, double room, and full dwelling), and pollutants (single and multiple pollutants from materials).

Meetings

- The 3rd project working meeting took place in Dresden, Germany, in March 2017, which was supplemented by a tools training workshop for participants and other invited experts.
- The 4th project working meeting took place in Nottingham, UK, in September 2017, and was held alongside a workshop open to external stakeholders and non-participating researchers.

Project duration
2016–2019

Operating Agent
Carsten Rode, Technical University of Denmark, Denmark

Participating countries
Austria, Belgium, Canada, P.R. China, Czech Republic, Denmark, France, Germany, Japan, R. Korea, the Netherlands, Norway, UK, USA

Further information
www.iea-ebc.org

Energy Flexible Buildings

EBC ANNEX 67

The energy flexibility of buildings is commonly suggested as part of the solution to alleviate some of the upcoming challenges in future energy systems (electrical, district heating and gas grids) with large shares of fluctuating renewable energy sources. Buildings can supply flexibility services in different ways, e.g. utilization of thermal mass, adjustability of HVAC system use (e.g. heating, cooling, or ventilation), charging of electric vehicles, and shifting of plug-loads. Recently for example, the European Union has announced the introduction of a Smart Readiness Indicator in the Energy Performance of Buildings Directive, which also should consider the readiness of a building to participate in demand response to connected energy networks.

There is, however, a need for improved knowledge on and demonstration of the energy flexibility that buildings can provide to energy networks. At the same time, there is a need for identifying critical aspects and possible solutions to manage this energy flexibility, while maintaining the comfort of the occupants and minimizing the use of non-renewable energy.

Objectives

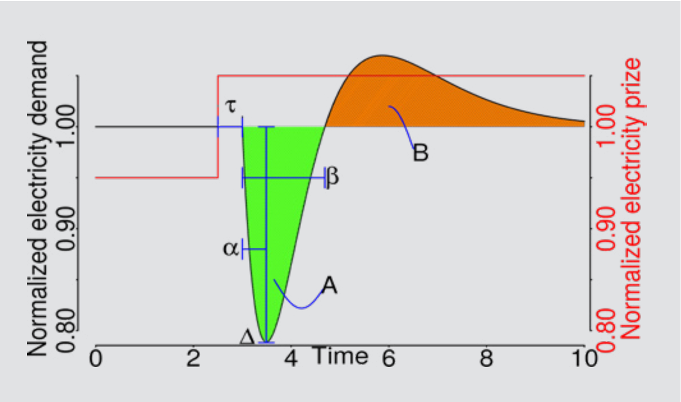
The project objectives are listed below:

- the development of a common terminology, a definition of 'energy flexibility in buildings' and a classification method;
- investigation of occupant comfort, motivation and acceptance associated with the introduction of energy flexibility in buildings;
- investigation of the energy flexibility potential in different buildings and contexts, and development of design examples, control strategies and algorithms;
- investigation of the aggregated energy flexibility of buildings and the potential effect on energy grids;
- demonstration of energy flexibility through experimental and field studies.

Deliverables

The following project deliverables are planned:

- Principles of Energy Flexible Buildings source book,
- Terminology, Definition and Flexibility Indicators for Characterization of Energy Flexibility in Buildings technical report,
- Guidelines on Modelling of Energy Flexibility in Buildings technical report,
- User Perspectives technical report,
- Control Strategies and Algorithms technical report,
- Test Procedures and Results technical report,
- Design Examples on Optimization of Energy Flexibility in Buildings technical report, and
- Project Summary Report.



An example of an aggregated energy flexibility response when a cluster of buildings receive a penalty signal, in this case a price signal (a step function according to the right hand vertical axis). The parameters shown are: τ is the elapsed time from submission of the penalty signal to when a response starts, Δ is the maximum response in terms of electricity demand reduction, α is the time period from the start of the response to the maximum response, β is the total time duration of the response, A is the shifted electrical energy, and B is the rebound effect in terms of electrical energy needed to return the situation back to the 'reference' level.
Source: Rune Grønborg Junker, CITIES project, DTU Compute, Denmark

Progress

Literature reviews on key performance indicators for energy flexibility in buildings, clusters of buildings and on control possibilities for obtaining energy flexibility have been carried out. During the past year, the main focus of the work has been on characterization and labelling of energy flexibility in buildings. A major project deliverable is a methodology for characterization and labelling of energy flexibility in buildings. The methodology is being documented together with a 'cookbook' for carrying out characterization. The methodology is based on the fact that the energy flexibility of a building is not set at a fixed value, but varies with the daily and seasonal weather conditions, the use of the building, the requirements of the occupants (e.g. comfort range), the requirements of the energy networks, etc.

The energy flexibility response of a building or the aggregated response of a cluster of buildings can be controlled by what is known as a 'penalty signal'. The penalty signal can be chosen according to specific conditions: Often this is a price signal, but it can also be a signal based on the actual level of CO_2 emissions or actual level of energy from renewable energy sources (RES). For these signals the controller should minimize the price or CO_2 emissions, or maximize the utilization of RES.

The penalty signal may be a step response (a sudden change in the energy price for example) to test different aspects of the available energy flexibility in a building or clusters of buildings, or alternatively a temporal signal varying over the day and time of year according to energy network requirements. A step response may be applied for instance in simulations to test thermal storage capacity. Temporal signals would typically be used when utilizing the energy flexibility in an area within an energy network and would concurrently feedback information about the available energy flexibility in that area.

The developed methodology may be used in the building design phase when conducting simulation work to optimize the available flexibility, or it may be applied based on measurements from a building or neighborhood to evaluate and quantify existing flexibility. The methodology is expected to be generic and it may, therefore, be utilized for various applications, especially for use with different penalty signals. The methodology is intended to work from on an individual component level (e.g. heat pump), up to a district or community level (e.g. an aggregator controlling thousands of buildings). However, further research is needed to determine how the methodology scales with the size of the envisioned system.

Based on the methodology described above, the project has provided input to a European Union funded study for possible implementation in the updated Energy Performance of Buildings Directive: It has agreed a position paper explaining the view of the participants regarding how to consider energy flexibility within in a Smart Readiness Indicator. In fact, an approach is needed that takes into account the dynamic behaviour of buildings, rather than simply static counting and rating of control devices. Further, it is crucial to minimize the total CO_2 emissions from the overall energy networks, rather than attempt to individually optimize the energy efficiency of the single energy-related building components.

Meetings

- The 4th project meeting was held in Freiburg, Germany, in March 2017.
- The 5th project meeting was held in Graz, Austria, in September 2017.

Project duration
2014–2019

Operating Agent
Søren Østergaard Jensen, Danish Technological Institute, Denmark

Participating countries
Austria, Belgium, Canada, P.R. China, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Switzerland, UK

Further information
www.iea-ebc.org

Definition and Simulation of Occupant Behavior in Buildings

EBC ANNEX 66

Occupant behaviour in buildings has a substantial impact on building energy use and occupant comfort. However, the behavioural dimension is much poorer understood than technological solutions. Design and operation of low energy buildings is a great challenge due to the commonly witnessed performance gap in buildings. Building performance simulations often employ static and oversimplified assumptions and models, which do not capture the temporal or spatial diversity and uncertainty associated with occupant behaviour in buildings. This leads to inaccurate estimates of energy use due to building technologies or designs.

Objectives

This project aims to develop novel methods and tools for standardized occupant behaviour representation, modelling and simulation. It is also producing case studies demonstrating the importance and significance of integrating occupant behaviour insights in the building life cycle to inform decision-making on building energy efficiency and occupant comfort. The project has five main research activities:

- occupant behaviour monitoring and data collection;
- behaviour modelling and model evaluation;
- development of behaviour modelling tools and integrating these with building performance simulation programs;
- case studies of occupant behaviour in buildings;
- integration of social science theories and practices into occupant behaviour studies.

Deliverables

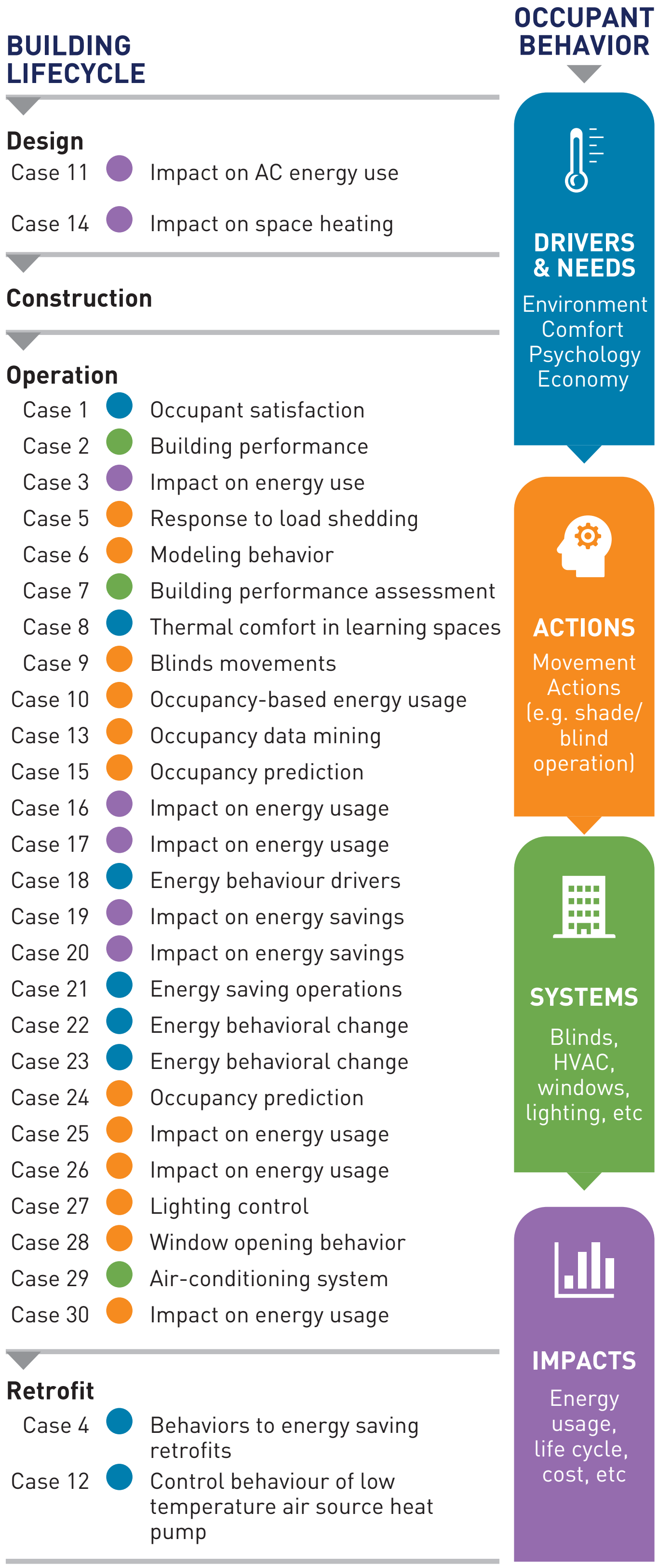
The main project outcomes are as follows:

- a guidebook on occupant behaviour monitoring and data collection, providing best practice;
- guidance on occupant behaviour diversity, modelling approaches, methods to evaluate the models, as well as fit-for-purpose selection of occupant behaviour models, ensuring robust and accurate application of models;
- a suite of occupant behaviour modelling tools, including an occupant behaviour XML schema (obXML), an occupant behaviour functional mockup unit (obFMU), and the Occupancy Simulator, which are used and integrated with the EnergyPlus and ESP-r programs;
- thirty case studies covering diverse applications of occupant behaviour data, analytics, monitoring, controls, as well as modelling and simulation in the building life cycle to demonstrate successful reduction of energy use and improvement of occupant comfort;
- an international survey of occupant behaviour in buildings, providing insights from social and behavioural science perspectives.

Progress

The project has provided comprehensive information on existing work in this field, including existing available data sets, occupant presence models used for simulation, and technologies for collecting data. Part of the work has focused on occupant action models in residential buildings. To this end, a guidebook on stochastic modelling of occupant behaviour has been produced, which introduces the techniques most frequently used for modelling occupant behaviour.

To enhance the reliability and usability of occupant presence and behaviour models, a number of activities have been conducted: a review of different modelling approaches for occupant behaviour in buildings; approaches to address occupants' behaviour diversity in model development; recommendations for evaluation of occupants' presence and behaviour models; documentation of best practices in occupancy model testing and evaluation. The project has also developed quantitative descriptions and models of occupant behaviour to analyze, evaluate and understand the impact of occupant behaviour on building energy use, as well as helping to reduce discrepancies between the simulated and measured energy use in buildings.



The 30 project case studies organized according to the building life cycle.
Data source: EBC Annex 66

A further project activity has characterized the range of applicability for occupant behaviour modelling, developed guidance regarding the most appropriate fit of tools to specific applications, and assembled succinct case studies of these applications. A total of 30 case studies have been developed to illustrate key insights from the experience of applying occupant behaviour modelling, simulation and insight to real specific problems.

Meetings

- The 5th Experts Meeting in the Working Phase took place in Lyngby, Denmark, in May, 2017
- The 6th Experts Meeting in the Working Phase took place in Beijing, P.R. China, in September 2017
- A panel discussion on perspectives of future occupant behavior modeling and simulation was organized during the IBPSA Building Simulation conference in August 2017 in San Francisco, USA.

Project duration
2013–2018

Operating Agent
Da Yan, Tsinghua University, P.R. China
Tianzhen Hong, Lawrence Berkeley National Laboratory, USA

Participating countries
Australia, Austria, Canada, P.R. China, Denmark, Germany, Italy, R. Korea, the Netherlands, New Zealand, Norway, Poland, Singapore, Spain, United Kingdom, USA
Observer: Hungary

Further information
www.iea-ebc.org

Long-term Performance of Super-insulating Materials in Building Components and Systems

EBC ANNEX 65

According to the IEA Technology Roadmap for Energy Efficient Building Envelopes (2013), the building envelope can be significantly improved to reduce heating and cooling loads that represent the largest building-sector energy end-use in most regions of the world. The most efficient way to reduce unwanted heat losses or gains is to install thermal insulation. While this is true for new buildings, it has even greater importance for existing ones. Moreover, by doing so, comfort and quality of life for occupants is drastically improved.

The question may be asked, why develop new insulating materials, when a large number of products are already available on the market, ranging from mineral wool to cellular foam? In spite of traditional insulating materials offering a wide spectrum of solutions, unfortunately a few weaknesses still degrade the efficiency of such solutions. Indeed, the performance of a thermal insulation system is highly dependent on the continuity of the insulation layer, similarly to ensuring an airtight envelope. Moreover, due to the complexity of the building envelope, many thermal bridges remain even when external insulation is applied on site. Window reveals, balconies, acroteria, decorative elements, etc, are among the most commonly encountered thermal bridges. Another challenge is the renovation of existing buildings with architectural façades, as often exist in urban areas. In these cases, only interior insulation is possible and thin materials are required to ensure high insulating performance. A further third area of interest for new insulating materials is the fire behaviour when external insulation is installed on high rise building, as the flammable mass can be very high when using thick and sometimes combustible traditional insulating materials.

In order to tackle all these challenges, a new generation of so-called super-insulating materials (SIMs) has emerged on the market during the past few decades, mainly based on vacuum insulation panels or advanced porous materials such as aerogels. To give confidence to end-users, this project is delivering a set of procedures applicable from test laboratories through to building sites: firstly, a detailed methodology for characterizing thermal properties and evaluating their durability, secondly design tools to safely use SIMs on site, and finally an approach to conducting life cycle assessments for SIMs.

Objectives

SIMs are expected to form part of new advanced solutions to transform building envelopes from heat-losing to heat-retaining surfaces and consequently to play a major role in responding to the energy efficiency challenge in the buildings sector. But, three mains conditions must be fulfilled for a successful outcome, as follows:

- reliable data should be available about initial and whole life performance;
- secure handling and system design approaches for installation are required;
- sustainability of SIMs should be demonstrated through life cycle analysis.

Deliverables

The project is now in its reporting phase and four deliverables are due to be published in 2018:

- a state-of-the-art and case studies report;
- a report containing scientific Information for standardization bodies dealing with hygro-thermo-mechanical properties and ageing;
- guidelines for design, installation and inspection with a special focus on retrofitting;
- a report on sustainability aspect (life cycle analysis, life cycle cost, embodied energy).

Progress

In 2017, the project entered the reporting phase. Information gathered on the state-of-the-art clearly shows that while applications for SIMs are spreading rapidly around the world, in absolute terms the market for SIMs is growing only slowly.

The International Vacuum Insulation Symposium 2017 delegates.
Source: CSTB

A comprehensive analysis of methods and procedures that must be used to fully characterize SIMs has been carried out based on a large number of tests performed by project participants. These results have been transferred in part to CEN Technical Committee 88 (Working Group 11), which has drafted a standard that is now being considered for approval by the national standardization bodies in Europe, for possible publication in 2018.

As the performance of SIMs is expected to strongly depend on the quality of installation on site, both a design procedure and guidelines for handling and installation are needed. Because temperature and humidity are the main degradation factors for SIMs, the design procedure is based on heat and moisture simulation in order to avoid extreme surface conditions for the SIMs. This can be realized, either by defining the correct position of a SIM in a wall, or by using a thin layer of traditional insulating material to limit high temperature and high humidity close to the SIM surface.

Life cycle impact assessment (LCIA) results have been derived for a life cycle inventory (LCI) created for SIMs. The LCIA results for fumed silica vacuum insulation panels with mass-based allocation showed reasonably good agreement with published Environmental Product Declarations (EPDs), at less than 10 kgCO_2-eq/kg. Meanwhile, the results with economic-based allocation showed higher values than any of the published EPD results. This suggests that the created representation of the LCI properly represents such products in the market when the impact is calculated by mass-based allocation.

For both drying methods used in the manufacturing of aerogels, however, the LCIA results based on their LCIs deviated significantly from published EPD values. This is due to the fact that the best available LCI data collected during the project were from pilot scale manufacturing. Thus, these may be inappropriate to be used for comparisons with other insulation materials, as data for full scale manufacturing of aerogels has not yet been characterised. But, the conducted 'hotspot' analysis has given a good insight into potential improvement opportunities for the environmental performance of aerogels, such as the benefits of production in a country with a low carbon electricity grid, such as France or Sweden.

Meetings

- The 5th Project Meeting took place in Osaka, Japan, in March 2017.
- The 6th Project Meeting took place in Paris, France, in September 2017.
- The International Vacuum Insulation Symposium (IVIS) was convened in Paris, France, in September 2017, at which around 180 delegates gathered from North America, Europe and Asia. Abstracts from the presented papers are available at: http://ivisparis2017.org.

Project duration
2013–2018

Operating Agent
Daniel Quenard, CSTB, France

Participating countries
Belgium, Canada, P.R. China, France, Germany, Italy, Japan, R. Korea, Norway, Spain, Sweden, Switzerland
Observers: Greece, Israel

Further information
www.iea-ebc.org

LowEx Communities – Optimised Performance of Energy Supply Systems with Exergy Principles

EBC ANNEX 64

Optimizing energy systems and services at the level of communities (neighborhoods, blocks, districts) rather than at the level of individual buildings can facilitate a more efficient use of energy resources and more cost efficient energy systems. Furthermore, the integration of higher shares of renewable and waste energy sources is achieved in a more cost efficient way at the community level. This is especially true for the utilization of thermal energy in the building sector, which is characterized by large heating and cooling energy demands. Commonly this energy is provided by the combustion of fossil fuels, which involves related greenhouse gas (GHG) emissions. At the community level, different energy sources are available that do not involve combustion processes. For heating purposes, low temperature energy sources (low-exergy) as heat e.g. from solar energy or waste heat sources are sufficient.

Low quality energy sources are of particular interest, because these can supply most heating and cooling demands very efficiently. This is a good reason to further investigate the utilization of these sources and the related energy systems on a community scale. The application of exergy principles is especially important, allowing the detection of different available energy-quality levels and the identification of optimal contributions to efficient supply. From this, appropriate strategies and technologies with great potential for the use of low valued energy sources ('LowEx') and a high share of renewable energy for heating and cooling of communities and cities can be derived. To bring that about, existing and advanced technologies have to be adapted and further developed to realize the potentials in real projects.

A key focus area is the development and testing of appropriate business models for the implementation on energy systems based on low exergy principles. Only with the right business opportunities will investments in innovative systems be made. For this reason, it is important to demonstrate the potential of low exergy thinking on a community level as an energy- and cost efficient solution to achieve 100% renewable and GHG emissions-free energy systems.

Objectives

The project objectives are to:

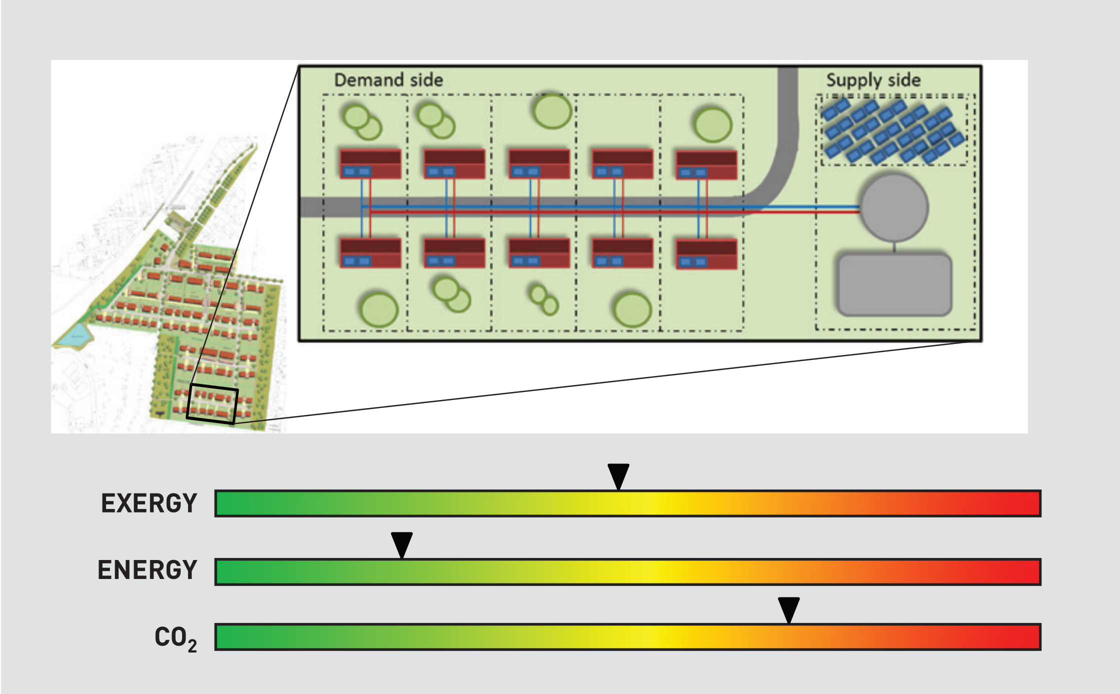
- increase the overall energy and exergy efficiency of community systems;
- identify and develop promising LowEx technical solutions and practical approaches to future network management;
- identify business models for distribution and operation;
- develop assessment methods and tools for various stages of planning;
- transfer knowledge to community stakeholders.

Deliverables

As an outcome from the research work, the main project deliverable is the 'Design Guidebook for Low Exergy Communities', which is intended for decision makers and key stakeholders within communities. A short Project Summary Report summarises the key issues explained in the Guidebook.

Progress

The research work is based on actual on-going projects within the participating countries. Within this project, the work over the past year has concentrated on finalizing the Guidebook. The research focus is on thermal energy at different exergy levels. Electricity from a renewable fluctuating supply is discussed as a contribution to the heat and cold supplies for a community, if it is thermally stored and used for heating or cooling purposes. The identification of the most promising and efficient technical solutions for practical implementation, aspects of future network management and business models for distribution and operation have emerged from the work as challenging objectives.



Exergy assessment of community supply by linking the exergy concept to economic and environmental evaluation parameters
Source: Anna Kallert, Fraunhofer IWES, Germany

Since the analysis of energy systems and modelling of low exergy communities are important parts of the research work, a collection of models and tools has been created. To continue the work, it is important to better adapt these models to the needs of planners and decision makers in communities. A number of heat generation and distribution technologies based on the utilization of low exergy sources have been identified and analyzed. The role has been pointed out for low temperature district heating schemes, especially in future community energy systems based on high shares of integrated renewable energy sources.

The analyzed cases show the potential in terms of improved energy efficiency and GHG emissions reductions. Some successfully conducted studies indicate a cost reduction potential for innovative low temperature heat grid community solutions based on the 'exergy thinking' concept and a CO_2-emissions free heat delivery process. Exergy indicates how well the useful work-delivering potentials of resources are being used. This insight cannot be retrieved solely with energy analysis. The exergy concept can be linked with economic and environmental parameters, but does not inherently include other objectives, such as maximizing the use of renewables, or minimizing GHG emissions, or costs. For that reason, additional technological and planning evaluation parameters have been identified and added to the exergy-based analysis developed in this project.

The cases studied were discussed in workshops with industry partners. The output from these workshops has been used to explore the possibilities for application in practice of the approaches developed through the project research. To that end, community energy systems need to be established through energy planning at scale to be successfully implemented, with strong links to urban planning processes. Low-exergy systems can introduce additional supply options for community energy systems and thus contribute to decarbonisation of heat supplies.

Meetings

- The 6th meeting for the working phase took place in Darmstadt, Germany, in March 2017.
- A special session was organized jointly with EBC Annex 63, 'Rethink Energy in Urban Areas: Community Energy Supply Systems and District Heating' at 12th IEA Heat Pump Conference 2017, held in Rotterdam, the Netherlands, in May 2017.

Project duration
2013–2018

Operating Agents
Dietrich Schmidt and Christina Sager-Klauss
Fraunhofer Institute for Energy Economics and Energy System Technology IEE, Kassel, Germany

Participating countries
Austria, Denmark, Germany, Italy, the Netherlands, Sweden, USA
Observer: Turkey

Further information
www.iea-ebc.org

Implementation of Energy Strategies in Communities

EBC ANNEX 63

Cities are major contributors to greenhouse gas (GHG) emissions and following the COP21 Agreement, drastic reductions of both energy use and emissions are essential. The IEA Energy Technology Perspectives 2016 indicates the main potentials for emissions reduction, which shows that issues of power and heat, transport and buildings contribute to more than two thirds of these reduction potentials. However, this transition of urban areas needs high investments in buildings, energy and transport infrastructure that only can be generated when further benefits are taken into account. To be successful and effective, a close link between energy and urban planning is essential. But this is not yet obligatory due to the complexity of integrated planning. While the completed R&D project 'EBC Annex 51: Energy Efficient Communities' focused on the optimization of energy systems at community scale, this project is providing recommendations on procedures for implementation of optimized energy strategies at the scale of communities in urban development. The project is intended to primarily serve the needs of urban decision makers and energy planning departments.

Objectives

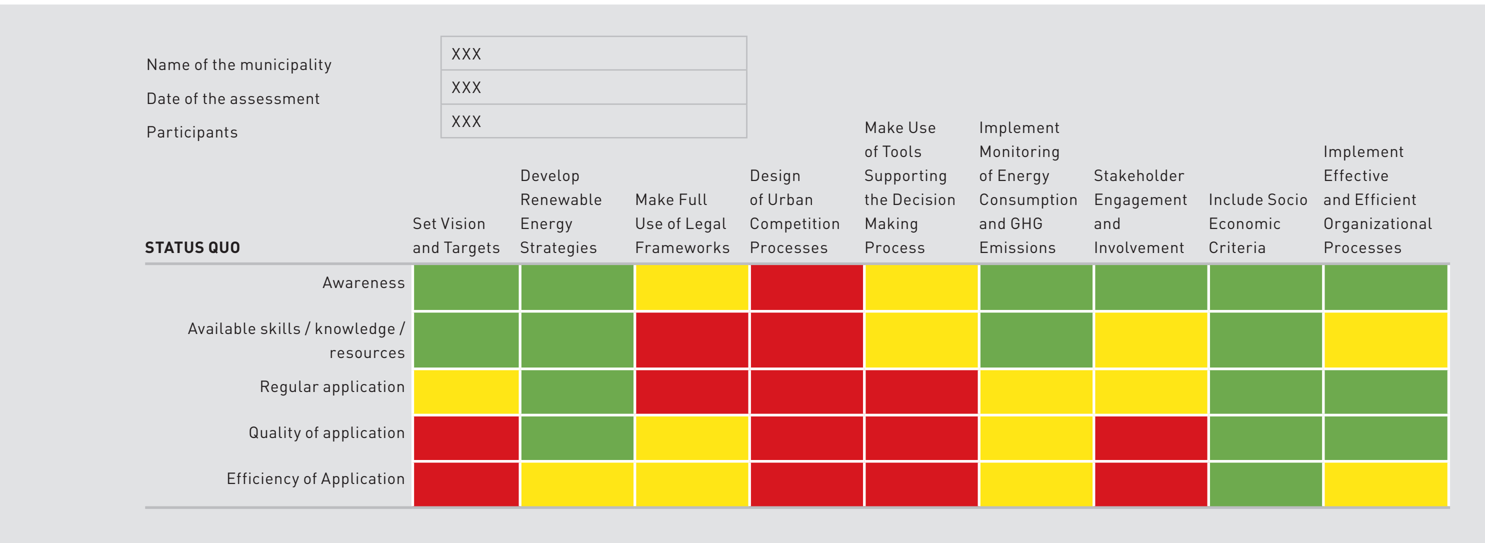
The general goal of the project can be described as to 'put energy in urban planning processes'. The following sub-goals aim to tackle the overall problem with respect to the different challenges:

- analyse the status-quo by involvement of cities in order to integrate practical knowledge on urban and energy planning procedures;
- develop recommendations for implementation of optimized energy strategies;
- develop stakeholder support materials to support the implementation process.

Deliverables

The following project deliverables are being prepared:

- Report Volume 0: Documentation of workshops and involvement of cities



Visualisation of the results of the self-assessment tool, intended to guide cities in setting priorities for further actions. These are explained in the reports of the strategic measures. In this example, to integrate energy-related issues into planning processes the municipality is recommended to work on the topics shown in red, particularly those under the design of urban competitions processes. Source: Adapted from SIR, 2017

- Report Volume 1: Inventory of measures
- Report Volume 2: Development of strategic measures
- Report Volume 3: Application of strategic measures
- Report Volume 4: Stakeholder support materials
- Report Volume 5: Recommendations

Progress

A highly practical approach has been provided by several feedback loops with 31 involved cities. In total, 143 information exchange activities between 2,394 people were carried out from 2014 to 2017. Based on a greatly improved understanding of current energy and urban planning processes, 89 measures for success from 11 countries were analyzed. Due to being identified as key for improved implementation of energy strategies at community scale, nine strategic measures were then clustered from these as given below:

- set visions and targets;
- develop renewable energy strategies;
- make full use of legal frameworks;
- design urban competition processes;
- make use of tools supporting the decision making process;
- implement monitoring of energy consumption and GHG emissions;
- undertake stakeholder engagement and involvement;
- include socio-economic criteria;
- implement effective and efficient organizational processes.

For each of the identified strategic measures, information on problems and challenges, description of actions, links to case studies and recommendations has been produced. Additionally, each strategic measure has been placed in relation to the generalized steps of planning processes to give better guidance on implementation. Contextualization of 29 case studies has led to better knowledge of boundary conditions for implementation and application of the strategic measures. Moreover, a range of stakeholder focused materials has been produced to support energy strategy implementation.

A self-assessment tool for cities has been created that includes six questions for each of the strategic measures to allow first indicative analyses of their strengths and potentials. These cover the following topics for each strategic measure:

- awareness of benefits and content,
- available skills, knowledge and resources for its implementation,
- regular application,
- quality of the application,
- efficiency of the application in the municipality (any impact), and
- barriers and success factors of the application in the municipality.

Additionally, the project has provided support on relevant accompanying information, such as workshop formats, content for presentations, examples for syllabuses and educational materials, and information on capacity building and skills.

Meetings

- The 6th project meeting took place in April 2017, in Kitakyushu, Japan.
- The 7th project meeting took place in October 2017. in Trondheim, Norway.

Project duration
2014–2018

Operating Agent
Helmut Strasser, Salzburg Institute for Regional Planning and Housing (SIR), Austria

Participating countries
Austria, Canada, Denmark, France, Germany, Ireland, Japan, the Netherlands, Norway, Switzerland, USA

Further information
www.iea-ebc.org

Ventilative Cooling

EBC ANNEX 62

Ventilative cooling can be an attractive and energy efficient natural cooling solution to reduce cooling loads and to avoid overheating in buildings. Ventilation is already present in most buildings through mechanical and / or natural systems and by adapting these for cooling purposes, cooling can be provided in a cost-effective way.

Naturally, expectations of ventilative cooling performance will vary between different countries because of climatic variations, energy prices and other factors. In countries with cold and temperate climates, ventilative cooling can avoid a common trend to use mechanical air conditioning in new buildings, which has occurred in response to heavily insulated and air tight building designs, higher occupant expectations and the requirements of building regulations, codes and standards. In countries with warm climates, it can reduce reliance on air conditioning and reduce the cost, energy penalty and the consequential environmental effects of full year-round air conditioning.

Objectives

The overall project objectives are to:

- analyse, develop and evaluate suitable design methods and tools for prediction of cooling need, ventilative cooling performance and risk of overheating in buildings;
- give guidelines for integration of ventilative cooling in energy performance calculation methods and regulations, including specification and verification of key performance indicators;
- develop recommendations for flexible and reliable ventilative cooling solutions that can create comfortable indoor conditions under a wide range of climatic conditions;
- demonstrate the performance of ventilative cooling solutions through analysis and evaluation of well documented case studies.

Deliverables

- Overview and state-of-the-art report on ventilative cooling,
- Ventilative cooling source book,
- Ventilative cooling case studies,
- Ventilative cooling design guide, and
- Recommendations for legislation and standards.

Progress

During the last year, the main emphasis in the project has been devoted to completion of the documentation of 15 case studies from 10 different countries across the world. For these case studies, rich information is available about their design, construction and operational performance. The intention is to present detailed factsheets that explains the rationale for the strategies chosen, as well as their verified performance. From these well-documented case studies, a number of key lessons have been learned. Several of these relate to the issue that a design incorporating ventilative cooling can be challenging and may require a great deal of detailed information about the building.

Most case studies analysed highlighted the need for reliable building simulations in the design phase of a system. This was considered most important when designing for hybrid ventilation strategies in which multiple mechanical systems need harmonization. Some studies also stated that simulating the window opening in detail was important.

Customisation may be an important factor in designing a ventilative cooling system. Some case studies highlighted the need to have custom designed systems that were specific to national regulations and the use of a building or space. Consideration should also be given to the clients expectations around specific issues like rain ingress and insect exclusion.

Ventilative cooling systems were considered to be a cost-effective and energy efficient type of design by most case studies, but particularly with naturally ventilated systems. It was indicated that designing with the integration of manual operation and control was important, particularly in a domestic setting.

While systems may be designed to have high levels of comfort, indoor air quality and energy performance, achieving these simultaneously has been found to be difficult. All of the case studies emphasised that monitoring a building's performance post occupancy is important, if not essential, in building performance optimisation. Engaging with the building owners or operators as soon as possible, even during the design stage, is integral to guaranteeing building performance for indoor air quality, thermal comfort, or energy savings. In some case studies, this specifically meant educating or working with the facilities operator or manager for the building, in others it meant educating the building occupiers themselves.

Ventilative cooling in operation is generally a good option. A reduction of overheating and improvement of thermal comfort conditions were evident in the case study buildings that used outside air. However, correct calibration of the systems and maintenance were integral to maintaining performance.

While some case studies highlighted the need to better exploit outside air with lower external air control limits during typical and night-time operation, others suggested that exploiting the thermal mass of a building was key. But, it was noted that care must be taken with lower temperatures, as some case studies, particularly in cold climates observed more incidences of overcooling than overheating. The best contemporary designs combine natural ventilation with conventional mechanical cooling. When properly designed, and implemented, these hybrid approaches maximize the ventilative cooling potential while avoiding overheating during the warmer months. Much can also be learned from collecting information about case studies that have demonstrated through measurements that they perform well and their internal environments are comfortable. However, due to the heterogeneity of the cases analyzed, it was difficult to draw general conclusions regarding recommendations for designers.

In the CML Kindergarten in Lisbon, Portugal, the ventilative cooling system consists of two different naturally driven ventilation and air distribution strategies: Displacement ventilation with chimneys to enhance air flow and single-sided ventilation.
Source: Guilherme Carrilho da Graça

Meetings

- The 7th Expert Meeting took place in Lisbon, Portugal in May 2017.
- The 8th Expert Meeting took place in Gent, Belgium in October 2017.

Project duration
2013 – 2018

Operating Agent
Per Heiselberg, Aalborg University, Denmark

Participating countries
Australia, Austria, Belgium, P.R. China, Denmark, Finland, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Switzerland, UK, USA

Further information
www.iea-ebc.org

Air Infiltration and Ventilation Centre

EBC ANNEX 5

Adequate ventilation provision is vital in providing acceptable indoor air quality (IAQ), but this also has a high energy cost. Given the challenges faced by many countries to contain the energy losses by ventilation and air infiltration while providing good indoor environmental quality, the EBC Executive Committee approved the continuation of the 'Air Infiltration and Ventilation Centre' (AIVC) for the period 2017 - 2021.

Inaugurated in 1979 with a focus on air infiltration losses, the goal of AIVC is now to provide reference information on ventilation and air infiltration in buildings, including energy and IAQ impacts of all ventilation strategies in new and existing buildings.

Objectives

The objectives of AIVC are to:

- identify emerging issues on ventilation and infiltration in new and renovated buildings;
- help better design, implement, hand-over and maintain ventilation systems;
- provide discussion platforms, including conferences, workshops and webinars.

Deliverables

- Events: Annual Conference, one to two workshops per year on specific topics and one to two webinars per year
- Publications: conference and workshop proceedings, technical notes and contributed reports (one per year), and a six-monthly newsletter

Progress

In 2017, the AIVC focused its work on six projects, the Annual Conference, and support for discussions and dissemination for the EBC R&D projects, 'Annex 62: Ventilative Cooling' (page 42) and 'Annex 68: Design and Operational Strategies for High IAQ in Low Energy Buildings' (page 30).

The six projects are entitled 'Indoor Air Quality Metrics', 'Rationale Behind Ventilation Requirements and Regulations', 'Utilization of Heat Recovery', 'Residential Cooker Hoods', 'Integrating Uncertainties Due to Wind and Stack Effect in Declared Airtightness Results' and 'Competent Tester Schemes for Building Airtightness Testing'.

A workshop was held in March 2017 to specifically address the IAQ Metrics project. The resulting publication, 'VIP 36 Metrics of Health Risks from Indoor Air', gives the key outcomes of discussions during the workshop. The workshop was firmly based on contributions of several experts, as well as on many structured discussions using a voting system with prepared multiple-choice questions to collect feedback from the audience.Regarding the rationale behind ventilation requirements, work has started with the collection of information from among the AIVC Board experts. It is anticipated this will result in a publication in the course of 2018.

The 38th AIVC Annual Conference was held in Nottingham, UK in September 2017. 185 people from 25 countries attended the conference. Several topical sessions related to AIVC projects were organized during this event, relating to:

- assessing how differences in space conditioning controls and set-points between rooms can affect the effectiveness of heat recovery systems;
- discussing challenges regarding cooker hoods, from performance characterization to practical implementation and actual use;
- quantifying how wind and stack effect can affect declared building airtightness indices, and how this could be taken into account in regulations.

The latest project publications published in 2017.
Source: EBC Annex 5

In 2017, AIVC collaborated with EBC Annexes 62 and 68 to co-produce two reports:

- VIP 35: Ventilative Cooling State-of-the-art Review Executive Summary
- CR 17: Indoor Air Quality Design and Control in Low-energy Residential Buildings – EBC Annex 68 Subtask 1: Defining the Metrics

Further, EBC Annexes 62 and 68 convened specific sessions during the Annual Conference to discuss their approach and findings with a wider audience. Regarding the AIVC project "Competent tester schemes for building airtightness testing", AIVC has pursued its efforts on the quality of building airtightness measurements in collaboration with TightVent, which is an information platform aiming at raising awareness on the building and ductwork airtightness.

Meetings

The AIVC Board met twice in 2017:

- Brussels, Belgium, in March 2017, and
- Nottingham, UK, in September 2017.

AIVC Newsletter

March 2017

September 2017

Project duration

1979–2021

Operating Agent

Peter Wouters, INIVE eeig, Belgium

Participating countries

Belgium, Denmark, France, Italy, Japan, R. Korea, the Netherlands, New Zealand, Norway, Spain, Sweden, UK, USA

Further information and reports

www.iea-ebc.org

www.aivc.org

Completed Research Projects

BUSINESS AND TECHNICAL CONCEPTS FOR
DEEP ENERGY RETROFITS OF PUBLIC BUILDINGS
(EBC ANNEX 61)

NEW GENERATION COMPUTATIONAL TOOLS
FOR BUILDING AND COMMUNITY ENERGY SYSTEMS
(EBC ANNEX 60)

COST EFFECTIVE ENERGY AND CARBON DIOXIDE EMISSIONS
OPTIMIZATION IN BUILDING RENOVATION
(EBC ANNEX 56)

Business and Technical Concepts for Deep Energy Retrofits of Public Buildings

EBC ANNEX 61

To meet ambitious energy policy targets the energy savings and the number of building refurbishments and the energy saving targets must be dramatically increased in the coming years. Reductions in energy use achieved under 'business as usual' typically vary between 10% and 20% including heat and electricity. EBC Annex 61 has successfully explored cost-effective technical and business concepts for deep energy retrofits (DERs) aiming at a reduction of at least 50%.

Cost-effectiveness is the major criterion in the decision-making process in the public sector, with the criteria most frequently used being dynamic cash flows and net present value. The evaluation of DER projects shows however that cost- effectiveness is still a major challenge which has to be solved at first hand and from both ends of the equation.

In order to optimize the investment costs the technical aspect is to identify highly effective DER measure bundles of measures by a modelling process. Within the modeling the technical specifications of the major bundle components such as building envelope, ventilation with heat recovery, lighting design, building automation and other high performance equipment will be defined.

Achievements

EBC Annex 61 has achieved its objectives by the following means:

- provided a framework and selected tools and guidelines to significantly reduce energy use by more the 50% and improve indoor environmental quality in government, public buildings and building clusters undergoing major renovation;
- researched, developed and demonstrated innovative and highly effective DER bundles of core technologies and energy efficiency measures for selected building types and climatic conditions;
- developed and demonstrated innovative, highly resource efficient business models for refurbishing buildings and community systems using appropriate combinations of public and private funding;
- supported decision makers in evaluating the efficiency, risks, financial attractiveness and contractual and tendering options.
- The specific achievements of EBC Annex 61 include the completion of a number of key outcomes:
- a prescriptive technical guide providing information on cost-effective technology bundles for DER projects,
- business models guide providing information on LCC benefits, financing instruments, and advanced DER business models, and
- best practice guideline with more documented results of several realized projects and DER case studies in different climate zones and with different usages;

In EBC Annex 61, several projects were documented that use energy performance contracting (EPC) business models: In these cases, the energy service company (ESCo) provides the investment funds, the implementation and the commissioning of energy saving and supply measures; the ESCo would be remunerated by the energy cost savings, which together with the investment costs have been guaranteed by the ESCo and are measured and verified according to standardized methodologies.

Within the research work program, the scope of existing and well proven EPC business schemes have been advanced towards a DER EPC business model. By providing performance guarantees the energy and non-energy related cost savings become reliable and accountable; as the remuneration of the ESCo is related to the achieved energy and LCC, the DER EPC business model provides a financing scheme which has mostly no negative impacts on the liabilities of the public building owner. The advanced DER EPC business model has been successfully implemented in public buildings in the USA and Germany providing energy savings between 50% and 70% in affordable pay back periods.

EBC Annex 61 DER case study of Dormitories in Mannheim 2017.
Source: Martina Riel, KEA, Germany

For a deep energy retrofit (DER) project with savings of 50% against a forecast energy baseline, the ways of financing, implementation through a business model and the cost-effectiveness are closely interdependent. An important approach to improve the cost-effectiveness of a DER project is to combine it with a major renovation project that aready has allocated funding sources to deliver minimum energy requirements. The funding (seed money) may be provided through a grant or loan. Grant programmes usually support the incremental investment costs to upgrade to a better level of energy efficiency than minimum requirements. Such incremental investment costs are necessary to improve from minimum requirements to a DER.

If sufficient seed money is not available, the cost-effectiveness can only be achieved by considering combined benefits through energy savings, additional monetary life-cycle cost (LCC) benefits and additional incomes from fuel switching and appropriate use of renewable energy produced and used on site. Best practice projects show that LCC savings can amount to 30% to 80% of the value of the energy savings, which means in the best case the cost-effectiveness could increase by a factor of almost two. The cost-effectiveness can be made robust through business models that provide securing mechanisms for both the investment and the LCC benefits. However, the basic requirement for any benefits is that they can be measured and verified.
In administrative buildings for example, staff costs per unit floor area are about a factor of 20 to 50 greater than the energy costs. Recently developed approaches provide simple models of how to monetize the assumed reduction of absenteism and increased productivity by frequently evaluating the building occupant satisfaction index for the indoor building environment. To further strengthen the business model, the remuneration for an energy service company in charge of the operation and savings may be related to an assumed conservative rate of productivity increase and reduction of absenteism per index unit and in the best case can even increase the cost savings associated with a DER by a factor of 10.

Publications

The following deliverables have been published:
- Deep Energy Retrofit: A Guide for Decision Makers
- Deep Energy Retrofit Pilot Projects
- Deep Energy Retrofit Business Guide for Public Buildings
- Deep Energy Retrofit: Case Studies
- A Guide to Achieving Significant Energy Use Reduction with Major Renovation Projects

Project duration
2012–2017

Operating Agents
Alexander Zhivov, US Army Engineer Research and Development, USA, and
Rüdiger Lohse, KEA - Climate protection and energy agency of Baden - Württemberg GmbH, Germany

Participating countries
Austria, Denmark, Germany, USA
Observers: Estonia, Finland, Latvia

Further information
www.iea-ebc.org

New Generation Computational Tools for Building and Community Energy Systems

EBC ANNEX 60

In many industrialised countries, the design and operation of building level and district energy systems are undergoing fundamental changes for the following reasons:

- targets are being introduced to achieve net zero energy systems;
- energy generation and delivery are shifting away from fossil fuel-based sources towards electricity with a large share of intermittent renewable sources;
- the building delivery process is becoming more integrated, based on digital planning and design tools, such as building information modelling (BIM).

Consequently, a new generation of tools is required to support planning, engineering design and operation that can handle these issues. The trends towards net zero energy and electrification of the energy supply system require that buildings and district energy systems should be increasingly integrated through active facades, energy storage, waste heat utilization and heat pumps that boost waste heat and renewable sources to usable temperatures. Advanced controls are needed to orchestrate this operation, while providing electrical load shifting capabilities.

Achievements

In response to these trends, EBC Annex 60 has successfully developed, demonstrated and disseminated new generation computational tools for the design and operation of building and community energy systems. Receptors of the outcomes are the building energy research community, design firms, energy service companies, equipment and control manufacturers and students of engineering, building science and control systems.

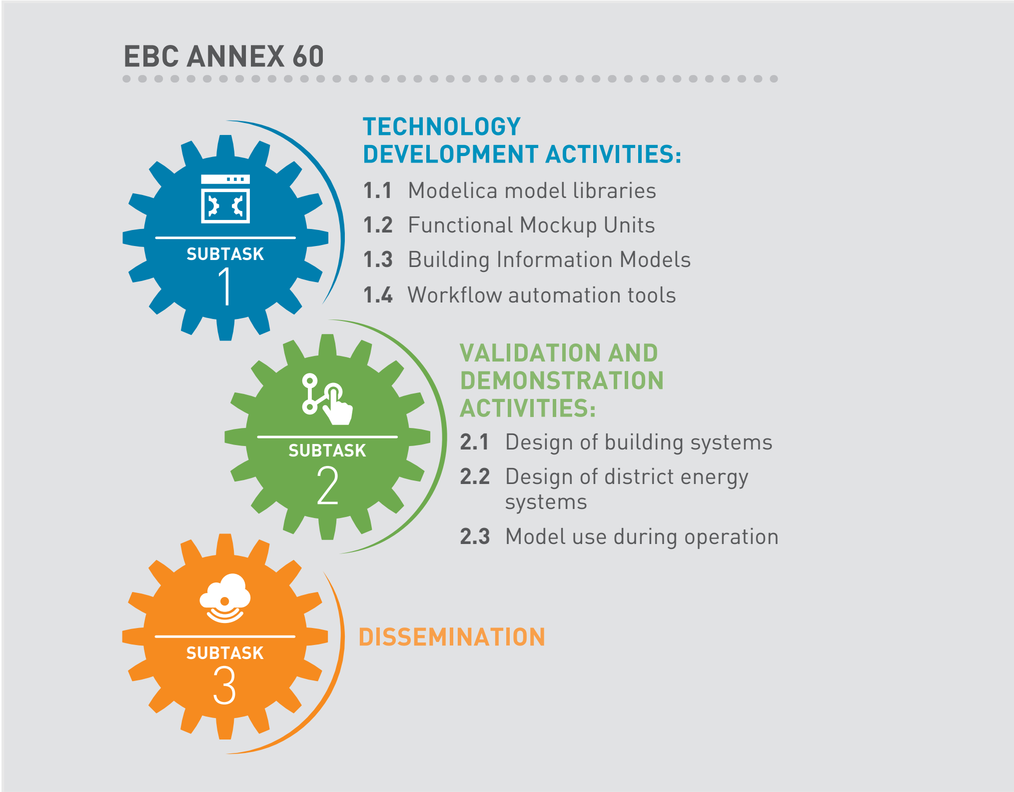
With building performance modelling and simulation as a key technology, the project relates to all five R&D focus areas of the EBC Strategic Plan: integrated planning and building design, building energy systems, building envelope, community scale methods, as well as to real energy use for any type of building.

The project has led to open-source, freely available, documented, validated and verified new generation computational tools. They allow buildings and community energy grids to be designed and operated as integrated, robust, performance based systems with low energy use and low peak demand.

The developed tools are all based on three non-proprietary, open standards:

- the Modelica modelling language was used for model implementation;
- the Functional Mockup Interface (FMI) standards were used to couple different simulation programs to prevent re-implementation and to facilitate re-use of program codes;
- the Industry Foundation Classes (IFC) were used as data exchange formats to improve interoperability within the integrated building life cycle process.

Using such open standards provides industry with a stable basis in which to invest and avoids proprietary vendor lock-in. Overall, EBC Annex 60 has answered the research problem of how the essential changes needed for the design and operation of building level and district energy systems can be reflected by a new generation of computational tools. It has delivered a solid foundation of tools and has demonstrated their application. However, tool development and maintenance require ongoing efforts, and need to respond to new system technologies. Further research, development and dissemination is now being coordinated under the umbrella of the International Building Performance Simulation Association (IBPSA).



Overview of tasks addressed by EBC Annex 60.
Source: Adapted from EBC Annex 60.

Publications

The project outputs include the following official deliverables:

- New Generation Computational Tools for Building and Community Energy Systems Final Report: This is freely available online, or can be ordered as a conventional book. It comprehensively describes the computational tools developed, summarizes the development of Modelica models, approaches and tools for co-simulation based on the FMI standard, BIM technologies based on IFC. It also describes tools for workflow automation that have been developed. The report then explains how these technologies have been used in various applications.
- A Modelica library and various software: This free library contains more than 300 models and more than 260 examples. It is successfully integrated into the four Modelica libraries that are distributed by the participants Lawrence Berkeley National Laboratory (USA), Berlin University of the Arts (Germany), KU Leuven (Belgium) and RWTH Aachen University (Germany).
- In addition, during the project participants authored 11 journal articles and organized several tracks at national and international conferences to disseminate results, leading to 38 conference papers.

Project duration
2012–2017

Operating Agents
Michael Wetter, Lawrence Berkeley National Laboratory, USA, and Christoph van Treeck, RWTH Aachen University, Germany

Participating countries
Austria, Belgium, P.R. China, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland, USA
Observers: Brazil, Slovakia, United Arab Emirates

Further information
www.iea-ebc.org

Cost Effective Energy and Carbon Dioxide Emissions Optimization in Building Renovation

EBC ANNEX 56

Existing buildings present a tremendous potential, not only to reduce energy use and carbon dioxide (CO_2) emissions, but also on other areas of the political agenda. In many industrialised countries, the renovation of the existing building stock is a relevant and important action needed to mitigate climate change. Regardless of this significant potential, it has been hard to fully exploit this.

Encouragingly, in recent years standards and regulations related to energy use in new buildings in industrialised countries have commonly increased their levels of exigency based on energy efficiency measures involving a significant investment in the building envelope and services systems, as well as on-site generation of energy from renewable sources. However, the application of existing standards and regulations in building renovation, with requirements and measures adapted from new buildings, often result in expensive processes and complex procedures hardly supported by occupants, owners, or developers.

In existing buildings, the optimal balance between measures to reduce energy use and energy harvesting from renewable sources differs from the case of new buildings, as it strongly depends on their many constraints. It is then relevant to investigate the balance between these two kinds of measures to discover how to achieve the best results (reduction of energy use, reduction of CO_2 emissions, comfort improvement, overall added value) with less effort (financial investment, depth and duration of the intervention, occupants' disturbance). This project has explored the cost-effective optimization of energy use and CO_2 emissions related to building renovation for the following purposes:

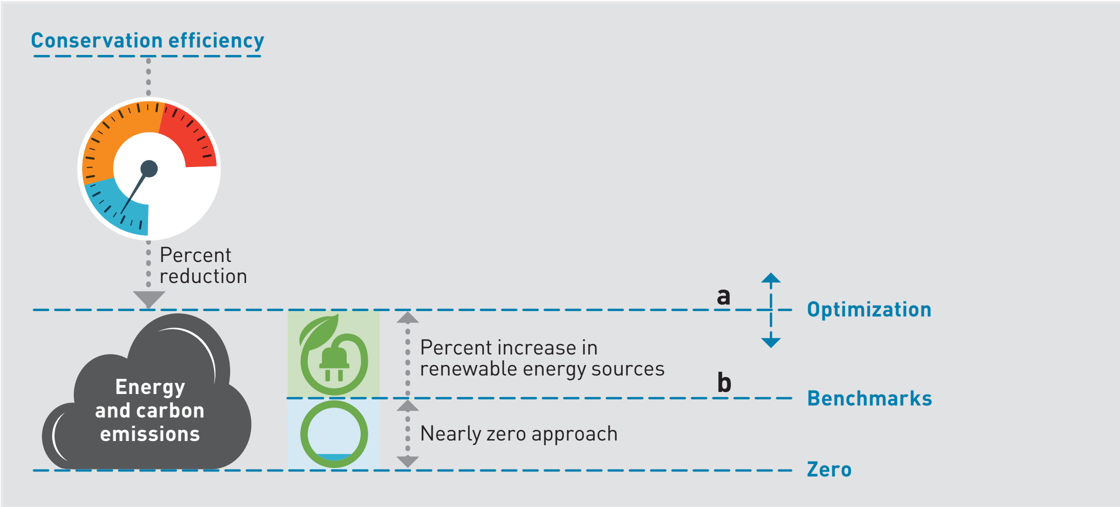
- definition of a methodology for the establishment of cost optimized targets for energy use and CO_2 emissions in building renovation;
- clarification of the relationship between the emissions and the energy targets and their eventual hierarchy;
- determination of the cost-effective combinations of energy efficiency and emissions reduction measures;
- highlight the relevance of the additional benefits (co-benefits) achieved in the renovation process;
- development and adaption of tools to support decision makers in accordance with the developed methodology;
- selection of exemplary case-studies to encourage decision makers to promote efficient and cost-effective renovations.

The methodology has been developed to be used by private entities and agencies for their renovation decisions, as well as by governmental agencies for the definition of regulations and their implementation, in line with the EBC mission of developing and facilitating the integration of technologies and processes for energy efficiency towards nearly-zero energy and carbon emissions in the built environment.

Achievements

The methodology provides the basis for the assessment and evaluation of packages of renovation measures that are intended to improve the energy performance of existing buildings. It includes the possibility of going beyond the cost-optimal level up to the limit of the cost-effective reduction of energy and CO_2 emissions. Additionally, it includes a methodological framework for the integration of embodied energy use in the lifecycle impact assessment, the inclusion of the co-benefits and the overall added value achieved in the renovation process. The development of the methodology has been supported by feedback received from realized, on-going and intended renovation projects, which have been investigated on a scientific basis.

To facilitate the use of the methodology, a new tool has been created and several existing tools were adapted to support decision makers in creating their renovation strategies and in evaluating and optimizing renovation measures for reaching and defining nearly-zero carbon emissions in building renovation. The need for a new approach to building renovation has been consolidated



Energy and carbon emissions optimized building renovation concept.
Source: Adapted from S. Geier and W. Ott

by the results of the investigations carried out. This new approach to the large-scale renovation of the existing building stock relies on three major pillars, namely to:

- consider a life-cycle perspective;
- adequately take into account CO_2 emissions in addition to primary energy;
- take into account achievable co-benefits.

The investigations conducted have revealed the high potential for cost-effective renovations. Primary energy reductions up to 97% and CO_2 emissions reductions up to 92% have been shown to be achievable. Considering that buildings are responsible for a significant share of energy use and CO_2 emissions worldwide, the expected impacts of a large scale deployment of ambitious, yet cost-effective, building renovation, combining energy efficiency measures and the use of renewable energy, are therefore very promising.

Publications

The published official deliverables, which include documents targeted to professional building owners and policy makers, are as follows:

- Guidebook and Executive Summary for Policy Makers
- Guidebook for Professional Home Owners
- Tools and Procedures to Support Decision Making for Cost-effective Energy and Carbon Emissions Optimization in Building Renovation
- Shining Examples of Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation
- Owners and Residents Acceptance of Major Energy Renovations of Buildings
- Methodology for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation
- Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation - Investigation Based on Parametric Calculations with Generic Buildings and Case Studies
- Life Cycle Assessment for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation
- Evaluation of the Impact and Relevance of Different Energy Related Renovation Measures on Selected Case Studies
- Co-benefits of Energy Related Building Renovation - Demonstration of their Impact on the Assessment of Energy Related Building Renovation

Meetings

No meetings were held during 2017.

Project duration
2010–2017

Operating Agent
Manuela Almeida, University of Minho, Portugal

Participating countries
Austria, P.R. China, Czech Republic, Denmark, Finland, Italy, the Netherlands, Norway, Portugal, Spain, Switzerland, Sweden

Further information
www.iea-ebc.org

Background Information

EBC AND THE IEA

RECENT PUBLICATIONS

EBC EXECUTIVE COMMITTEE MEMBERS

EBC OPERATING AGENTS

PAST PROJECTS

EBC and the IEA

THE INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Cooperation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster cooperation among the thirty IEA member countries and to increase energy security through energy conservation, development of alternative energy sources and energy research, development and demonstration (RD&D). The current framework for international energy technology RD&D cooperation was approved by the IEA's Governing Board in 2003. More information about the energy technology RD&D framework can be found at: www.iea.org/tcp

This framework provides uncomplicated, common rules for participation in RD&D programmes, known as Technology Collaboration Programmes, and simplifies international cooperation between national entities, business and industry. The IEA Technology Collaboration Programmes (TCPs) are established by legal agreements between countries that wish to pursue a common programme of research in a particular area. In fact, there are now over 40 such TCPs. There are numerous advantages to international energy technology RD&D collaboration through the TCPs, including:

- Reduced cost and avoiding duplication of work
- Greater project scale
- Information sharing and networking
- Linking IEA member countries and non-member countries
- Linking research, industry and policy
- Accelerated development and deployment
- Harmonised technical standards
- Strengthened national RD&D capabilities
- Intellectual property rights protection

ABOUT EBC

Approximately one third of primary energy is consumed in non-industrial buildings such as dwellings, offices, hospitals, and schools where it is utilised for the heating and cooling, lighting and operation of appliances. In terms of the total energy end-use, this consumption is comparable to that used in the entire transport sector. Hence the building sector represents a major contribution to fossil fuel use and related carbon dioxide emissions. Following uncertainties in energy supply and concern over the risk of global warming, many countries have now introduced target values for reduced energy use in buildings. Overall, these are aimed at reducing energy consumption by between 5% and 30%. To achieve such a target, international cooperation, in which research activities and knowledge can be shared, is seen as an essential activity.

In recognition of the significance of energy use in buildings, in 1977 the International Energy Agency has established a Technology Collaboration Programme on Energy in Buildings and Communities (EBC-formerly known as ECBCS). The function of EBC is to undertake research and provide an international focus for building energy efficiency. Tasks are undertaken through a series of 'Annexes', so called because they are legally created as annexes to the 'Implementing Agreement' on which the EBC TCP is established. These Annexes are directed at energy saving technologies and activities that support technology application in practice. Results are also used in the formulation of international and national energy conservation policies and standards.

OBJECTIVES AND STRATEGY

The objectives of the collaborative work conducted by the EBC Technology Collaboration Programme are derived from the major trends in construction and energy markets, energy research policies in the participating countries and from the general objectives of the IEA. The principal objective of the EBC is to facilitate and accelerate the introduction of new and improved energy conservation and environmentally sustainable technologies into buildings and community systems. Specific objectives of the EBC programme are to:

- support the development of generic energy conservation technologies within international collaboration;
- support technology transfer to industry and to other end users by the dissemination of information through demonstration projects and case studies;
- contribute to the development of design methods, test methods, measuring techniques, and evaluation/assessment methods encouraging their use for standardisation;
- ensure acceptable indoor air quality through energy efficient ventilation techniques and strategies;
- develop the basic knowledge of the interactions between buildings and the environment as well as the development of design and analysis methodologies to account for such interactions.

The research and development activities cover both new and existing buildings, and residential, public and commercial buildings. The main research drivers for the programme are:

- the environmental impacts of fossil fuels;
- business processes to meet energy and environmental targets;
- building technologies to reduce energy consumption;
- reduction of greenhouse gas emissions;
- the 'whole building' performance approach;
- sustainability;
- the impact of energy reduction measures on indoor health, comfort and usability;

– the exploitation of innovation and information technology;
– integrating changes in lifestyle, work and business environments.

MISSION STATEMENT

The mission of the IEA Energy in Buildings and Communities Programme is as follows: 'To accelerate the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge and technologies through international collaborative research and innovation.'

NATURE OF EBC ACTIVITIES

a. Formal coordination through shared tasks: This represents the primary approach of developing the work of EBC. The majority of Annexes are task-shared and involve a responsibility from each country to commit manpower.

b. Formal coordination through cost shared activities: EBC currently supports one cost shared project, Annex 5, the Air Infiltration and Ventilation Centre (AIVC). In recent times, Annex 5 has subcontracted its information dissemination activities to the Operating Agent, by means of a partial subsidy of costs and the right to exploit the Annex's past products.

c. Informal coordination or initiation of activities by participants: Many organizations and groups take part in the activities of EBC including government bodies, universities, nonprofit making research institutes and industry.

d. Information exchange: Information about associated activities is exchanged through the EBC and through individual projects. The EBC website (www.iea-ebc.org), for example, provides links to associated research organizations. Participants in each project are frequently associated with non IEA activities and can thus ensure a good cross-fertilization of knowledge about independent activities. Information exchange additionally takes place through regular technical presentation sessions and 'Future Buildings Forum' workshops. Information on independent activities is also exchanged through the EBC newsletter, which, for example, carries regular reports of energy policy development and research activities taking place in various countries.

EBC PARTICIPATING COUNTRIES

Australia
Austria
Belgium
Canada
P.R. China
Czech Republic
Denmark
Finland
France
Germany
Italy
Ireland
Japan
R. Korea
New Zealand
The Netherlands
Norway
Portugal
Singapore
Spain
Sweden
Switzerland
UK
USA

COORDINATION WITH OTHER BODIES

In order to achieve high efficiency in the EBC Technology Collaboration Programme (TCP) and to eliminate duplication of work it is important to collaborate with other IEA buildings-related TCPs. The coordination of strategic plans is a starting point to identify common R&D topics. Other actions are exchange of information, joint meetings and joint projects in areas of common interest. It is a duty of the Chairs of the respective Executive Committees to keep the others informed about their activities and to seek areas of common interest.

COLLABORATION WITH IEA BUILDINGS-RELATED TECHNOLOGY COLLABORATION PROGRAMMES

The EBC Programme continues to coordinate its research activities, including Annexes and strategic planning, with all IEA buildings-related TCPs through collaborative projects and through the BCG (Buildings Coordination Group), constituted by the IEA Energy End Use Working Party (EUWP) Vice Chair for Buildings and the Executive Committee Chairs of the following IEA Technology Collaboration Programmes:

– District Heating And Cooling (DHC)
– Demand Side Management (DSM)
– Energy in Buildings and Communities (EBC)
– Energy Conservation through Energy Storage (ECES)
– Heat Pumping Technologies (HPT)
– International Smart Grid Action Network (ISGAN)
– Photovoltaic Power Systems (PVPS)
– Solar Heating and Cooling (SHC)
– Energy Efficient Electrical Equipment (4E)

Beyond the BCG meetings, EBC meets with representatives of all buildings-related TCPs at Future Buildings Forum (FBF) Think Tanks and Workshops. The outcome from each Future Buildings Forum Think Tank is used strategically by the various IEA buildings-related Technology Collaboration Programmes to help in the development of their work programmes over the subsequent five year period.Proposals for new research projects are discussed in coordination with these other programmes to pool expertise and to avoid duplication of research. Coordination with SHC is particularly strong.

COLLABORATION WITH THE IEA SOLAR HEATING AND COOLING PROGRAMME

While there are several IEA TCPs that are related to the buildings sector, the EBC and the Solar Heating and Cooling programmes focus primarily on buildings and communities. Synergies between these two programmes occur because one programme seeks to cost-effectively reduce energy demand while the other seeks to meet a large portion of this demand by solar energy. The combined effect results in buildings that require less purchased energy, thereby saving money and conventional energy resources, and reducing CO_2 emissions. The areas of responsibility of the two programmes have been reviewed and agreed. EBC has primary responsibility for efficient use of energy in buildings and community systems. Solar designs and solar technologies to supply energy to buildings remain the primary responsibility of the SHC TCP.

The Executive Committees coordinate the work done by the two programmes. These Executive Committees meet together approximately every two years. At these meetings matters of common interest are discussed, including planned new tasks, programme effectiveness and opportunities for greater success via coordination. The programmes agreed to a formal procedure for coordination of their work activities. Under this agreement during the initial planning for each new Annex/Task initiated by either programme, the other Executive Committee is invited to determine the degree of coordination, if any. This coordination may range from information exchange, inputting to the draft Annex/Task Work Plan, participating in Annex/Task meetings to joint research collaboration.

The mission statements of the two programmes are compatible in that both seek to reduce the purchased energy for buildings; one by making buildings more energy efficient and the other by using solar designs and technologies. Specifically, the missions of the two programmes are:

– EBC programme – to accelerate the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge and technologies through international collaborative research and innovation.
– SHC programme – to enhance collective knowledge and application of solar heating and cooling through international collaboration in order to fulfill the vision.

The two programmes structure their work around a series of objectives. Four objectives are essentially the same for both programmes. These are:

– technology development via international collaboration;
– information dissemination to target audiences;
– enhancing building standards;
– interaction with developing countries.

The other objectives differ. The EBC programme addresses life cycle environmental accounting of buildings and their constituent materials and components, as well as indoor air quality, while the SHC Programme addresses market impacts, and environmental benefits of solar designs and technologies. Both Executive Committees understand that they are addressing complementary aspects of the buildings sector and are committed to continue their coordinated approach to reducing the use of purchased energy in buildings sector markets.

NON-IEA ACTIVITIES

A further way in which ideas are progressed and duplication is avoided is through cooperation with other building related activities. Formal and informal links are maintained with other international bodies, including:

– The International Council for Research and Innovation in Building and Construction (CIB),
– The European Commission (EC) including the BUILD UP initiative,
– The International Standards Organization (ISO), and
– The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE).

Recent Publications

Air Infiltration and Ventilation Centre (AIVC) – Annex 5

Databases

AIRBASE – bibliographical database, containing over 22,000 records on air infiltration, ventilation and related areas, Web based, updated every 3 months

Technical Notes

– TN 68: Residential Ventilation and Health, 2016

AIVC Conference Proceedings

– 38th AIVC Annual Conference Proceedings, September 2017, Nottingham, UK

Ventilation Information Papers

– VIP 35: Ventilative Cooling State-of-the-art Review Executive Summary
– VIP 36: Metrics of Health Risks from Indoor Air

Contributed Reports

– CR 17: Indoor Air Quality Design and Control in Low-energy Residential Buildings – EBC Annex 68 Subtask 1: Defining the Metrics

Methodology for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation – Annex 56

– Guidebook for Policy Makers, 2017
– Executive Summary for Policy Makers, 2017
–Guidebook for Professional Home Owners, 2017
– Tools and Procedures to Support Decision Making for Cost-effective Energy and Carbon Emissions Optimization in Building Renovation, 2017
– Terminology and Definitions , 2017
– Investigation Based on Parametric Calculations with Generic Buildings and Case Studies, 2017
– Owners and Residents Acceptance of Major Energy Renovations of Buildings, 2017
– Life Cycle Assessment for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation, 2017
– Evaluation of the Impact and Relevance of Different Energy Related Renovation Measures on Selected Case Studies, 2017
– Co-benefits of Energy Related Building Renovation - Demonstration of their Impact on the Assessment of Energy Related Building Renovation, 2017
– Methodology for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation, 2017
– Shining Examples of Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation, 2017

Evaluation of Embodied Energy and CO_2 Equivalent Emissions for Building Construction – Annex 57

– Case Studies Demonstrating Embodied Energy and Embodied Greenhouse Gas Emissions in Buildings, 2016
– Case studies and recommendations for the reduction of embodied energy and embodied greenhouse gas emissions from buildings, 2016
– Evaluation Methods of Embodied Energy and Embodied GHG Emissions in Building and Construction, 2016
– Guideline for Construction Product Manufacturers, 2016
– Basics, Actors and Concepts, 2016
– Basics for the Assessment of Embodied Energy and Embodied GHG Emissions for Building Construction : Guideline for Designers and Consultants – Part 1, 2016
– Strategies for Reducing Embodied Energy and Embodied GHG Emissions: Guideline for Designers and Consultants – Part 2, 2016
– Overview of Annex 57 Results, 2016
– A Literature Review, 2016
– Guideline for Policy Makers, 2016
– Guidance to Support Educators, 2016

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

– Towards a characterisation of buildings based on in situ testing and smart meter readings and potential for applications in smart grids, 2016
– Empirical validation of common building energy simulation models based on in situ dynamic data, 2016
– Thermal performance characterisation using time series data – statistical guidelines, 2016
– Thermal performance characterization based on full scale testing - description of the common exercises and physical guidelines, 2016
– Logic and use of the Decision Tree for optimizing full scale dynamic testing, 2016
– Overview of methods to analyse dynamic data, 2016
– Inventory of full scale test facilities for evaluation of building energy performance, 2016

High Temperature Cooling and Low Temperature Heating in Buildings – Annex 59

– Final Report I. Guidebook of New Analysis Method for HVAC Systems, 2016
– Final Report II. Demand and Novel Design of Indoor Terminals in High Temperature Cooling and Low Temperature Heating Systems, 2016
– Final Report III. Novel Flow Paths of Outdoor Air Handling Equipment, 2016
– Final Report IV. Design Guide for HTC and LTH Systems, 2016

New Generation Computational Tools for Building and Community Energy Systems – Annex 60

– Final Report, 2017

Business and Technical Concepts for Deep Energy Retrofit of Public Buildings – Annex 61

– Deep Energy Retrofit - A Guide for Decision Makers, 2017
– Deep Energy Retrofit Pilot Projects, 2017
– Deep Energy Retrofit Business Guide for Public Buildings, 2017
– Deep Energy Retrofit – Case Studies, 2017
– A Guide to Achieving Significant Energy Use Reduction with Major Renovation Projects, 2017

Ventilative Cooling – Annex 62

– Ventilative Cooling Sourcebook, 2018
– Ventilative Cooling Design Guide, 2018

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Assessing Life Cycle Related Environmental Impacts Caused by Buildings – EBC Annex 72
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Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO2 Emissions – EBC Annex 76 / SHC Task 59
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Integrated Solutions for Daylighting and Electric Lighting – EBC Annex 77 / SHC Task 61
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Past Projects

Annex 1 Load Energy Determination ofBuildings
Annex 2 Ekistics and Advanced Community Energy Systems
Annex 3 Energy Conservation in Residential Buildings
Annex 4 Glasgow Commercial Building Monitoring
Annex 6 Energy Systems and Design of Communities
Annex 7 Local Government Energy Planning
Annex 8 Inhabitants Behaviour with Regard to Ventilation
Annex 9 Minimum Ventilation Rates
Annex 10 Building HVAC System Simulation
Annex 11 Energy Auditing
Annex 12 Windows and Fenestration
Annex 13 Energy Management in Hospitals
Annex 14 Condensation and Energy
Annex 15 Energy Efficiency in Schools
Annex 16 BEMS 1-User Interfaces and System Integration
Annex 17 BEMS 2-Evaluation and Emulation Techniques
Annex 18 Demand Controlled Ventilation Systems
Annex 19 Low Slope Roof Systems
Annex 20 Air Flow Patterns within Buildings
Annex 21 Thermal Modelling
Annex 22 Energy Efficient Communities
Annex 23 Multi Zone Air Flow Modelling (COMIS)
Annex 24 Heat, Air and Moisture Transfer in Envelopes
Annex 25 Real time HEVAC Simulation
Annex 26 Energy Efficient Ventilation of Large Enclosures
Annex 27 Evaluation and Demonstration of Domestic Ventilation Systems
Annex 28 Low Energy Cooling Systems
Annex 29 Daylight in Buildings
Annex 30 Bringing Simulation to Application
Annex 31 Energy-Related Environmental Impact of Buildings
Annex 32 Integral Building Envelope Performance Assessment
Annex 33 Advanced Local Energy Planning
Annex 34 Computer-Aided Evaluation of HVAC System Performance
Annex 35 Design of Energy Efficient Hybrid Ventilation (HYBVENT)
Annex 36 Retrofitting of Educational Buildings
Annex 37 Low Exergy Systems for Heating and Cooling of Buildings (LowEx)
Annex 38 Solar Sustainable Housing
Annex 39 High Performance Insulation Systems
Annex 40 Building Commissioning to Improve Energy Performance
Annex 41 Whole Building Heat, Air and Moisture Response (MOIST-ENG)
Annex 42 The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM)
Annex 43 Testing and Validation of Building Energy Simulation Tools
Annex 44 Integrating Environmentally Responsive Elements in Buildings
Annex 45 Energy Efficient Electric Lighting for Buildings
Annex 46 Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)
Annex 47 Cost-Effective Commissioning for Existing and Low Energy Buildings
Annex 48 Heat Pumping and Reversible Air Conditioning
Annex 49 Low Exergy Systems for High Performance Buildings and Communities
Annex 50 Prefabricated Systems for Low Energy Renovation of Residential Buildings
Annex 51 Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision Makers
Annex 52 Towards Net Zero Energy Solar Buildings (NZEBs)
Annex 53 Total Energy Use in Buildings – Analysis and Evaluation Methods
Annex 54 Integration of Microgeneration and Other Energy Technologies in Buildings
Annex 55 Reliability of Energy Efficient Building Retrofitting – Probability Assessment of Performance and Cost
Annex 56 Cost Effective Energy and CO_2 Emissions Optimization in Building Renovation
Annex 57 Evaluation of Embodied Energy and Carbon Dioxide Equivalent Emissions for Building Construction
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EBC is a Technology Collaboration Programme (TCP) of the International Energy Agency (IEA)