EBC

Energy in Buildings and Communities Programme

Annual Report 2018

International Energy Agency

EBC Annual Report 2018

Energy in Buildings and Communities Programme

Published by AECOM Ltd on behalf of the International Energy Agency
Energy in Buildings and Communities Programme

Published by AECOM Ltd, St George's House, 5 St George's Road, Wimbledon, London SW19 4DR, United Kingdom.

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 DIAL headquarter office building atrium as an example design project for an integrated lighting solution.
Source: Thomas Bach

Further copies may be obtained from:
EBC Bookshop
C/o AECOM Ltd
The Colmore Building
Colmore Circus Queensway
Birmingham B4 6AT
United Kingdom
www.iea-ebc.org
essu@iea-ebc.org

Contents

EBC Executive Committee Chair's Statement

I first took part in the activities of the EBC Programme in 1994, when I joined the project 'Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems', which ran from 1993 until 1997. In this work, I was able to share advanced practical experiences and knowledge with senior international researchers. At the same time, through intensive discussions I could check whether my understanding of the subject matter was reasonable. Sometimes I gained confidence about my existing understanding, while at other times I realised my thinking would need to be updated.

After that project, I later joined EBC Annex 35 on hybrid ventilation, EBC Annex 44 on environmentally responsive elements and EBC Annex 57 on embodied energy and CO_2. In fact, the scientific and technical information I have obtained through such participation has always been valuable every time when I have been engaged in my national R&D projects to establish buildings-related policies. For example, later on when my country amended our Building Standards Law in 2003 by introducing mandatory installation of mechanical ventilation systems and limiting formaldehyde emissions from interior finishing materials, the knowledge created in Annex 27 was fully utilized.

Nowadays, most countries are facing the need to strengthen the effectiveness of their policies to reduce building energy use and to enhance practitioners' skills by providing various guidelines. Such measures should be based on firm and unbiased technical information, validated through experiments and field measurements. Due to resource limitations a single country alone can rarely afford to carry these out, while it has been realised that the necessary human resources for ambitious and open-minded research can hardly be satisfied without international collaboration. To this end, among Annex participants a common philosophy and an interest in advancing a certain topic have proven to be much more powerful influences than differences in cultural backgrounds or languages.

EBC's R&D activities cover thermal performance of building envelopes, space heating and cooling systems, indoor air quality, renovation strategies, analysis of real building energy use, occupant behaviour, lighting, community-scale strategies, experimental validation of energy performance, and so on. At present, there are 16 active Annexes and two Working Groups on these topics within the EBC Programme. You may find a general overview of these within our Annual Report for 2018. I hope you are able to find some hints for your future approaches for your own technical themes and policies.

Dr Eng Takao Sawachi
EBC Executive Committee Chair

Introducing the EBC Strategic Plan 2019-2024

A SUMMARY OF PRIORITY RESEARCH THEMES

Within the framework of the International Energy Agency (IEA) Technology Collaboration Programmes (TCPs), the Energy in Buildings and Communities (EBC) Programme is conducting collaborative research projects among its 24 member countries. The vision of the EBC Programme is that for new buildings and communities sustainable solutions have been adopted by 2030 giving near-zero primary energy use and carbon dioxide emissions, and a wide range of reliable technical solutions have been made available for the existing building stock. Its mission is to accelerate the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development of knowledge and technologies through international collaborative research and open innovation.

Overall control of the EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new areas where collaborative efforts may be beneficial. To date, 80 major international research and development (R&D) projects known as 'Annexes' have been initiated within the Programme since 1977. The EBC Programme follows an open innovation R&D model, and works cooperatively with industry in its member countries, including designers and manufacturers.

Developing the new Strategic Plan

During the five year period from 2014-2019, new EBC Annexes addressed the key themes of:

- integrated planning and building design,
- building energy systems,
- building envelope,
- community scale methods, and
- real building energy use.

Whilst these themes reflected the broad scope encompassed by the EBC Programme, they served primarily as a means of categorising projects that were developed on a 'bottom-up' basis, reflecting the prevailing interests of researchers. In the development of the new EBC Strategic Plan, which runs from 2019 to 2024, more emphasis has been placed on addressing global priorities that will have direct relevance to policy makers and industry throughout the developed and developing world. Until now, EBC activities have depended strongly on the engagement of researchers within the buildings field. Motivated researchers would propose new Annexes, organise research groups and apply for funding. Good cross-linking with other researchers and with the EBC Executive Committee ensures the mutual cooperation. Moreover, the completion of one Annex would often lead to the creation of a new Annex, as a continuation of the work of the well-established research group.

This 'bottom-up' approach has many advantages, but it can lead to proposals for activities that do not necessarily cover the most important and urgent research topics, and do not necessarily address the key policy issues of the day. With the new Strategic Plan, the Executive Committee has set new research priorities with direct policy relevance, and mechanisms are defined to improve the real-world impact of the Annexes.

Policy relevant priorities

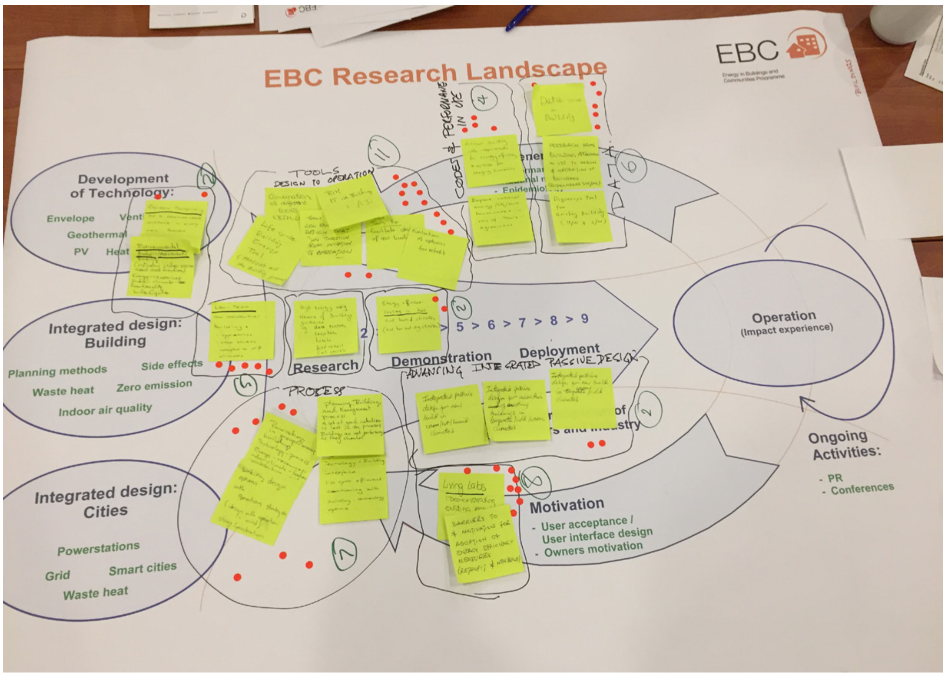
The five high priority research themes are described below.

1.Refurbishment of existing buildings, focusing on finance, stakeholders and co-benefits

Many governments are interested in accelerating the renovation of their existing building stocks to reduce carbon dioxide emissions and improve indoor environmental quality for health, well-being and productivity. Many renovation projects have already been performed that demonstrate technical and economic viability. However, delivery at scale is still rare and much needs to be done to increase market uptake and develop solutions which can be deployed to meet the fast rate of renovation necessary for achieving accepted climate change targets. Such solutions must address the provision of affordable finance, the delivery of the co-benefits that reinforce the demand, and the engagement of stakeholders involved in all aspects of the process. Platforms are needed that enhance the promotion of energy efficiency service provision and improve the continuous flow of accurate information to decision makers in industry and policy making. The research challenge is to develop efficient and intelligent auditing, monitoring, benchmarking and diagnosis methods and tools covering the whole system, including funding and the motivation of stakeholders.

2. *Planning, construction and management processes reducing the performance gap*

There is clear evidence that buildings do not function as desired. The resulting 'performance gap' between predictions and reality is significantly undermining policymakers' efforts to move towards net zero carbon through a process of tightening codes and regulations. The reasons for the performance gap include: unclear targets at the design and construction stages, poor quality construction and inadequate construction supervision, less than effective commissioning and handover, and deficiencies in operation and maintenance. The management of targets and in-use performance over the whole life cycle of a building demands effective monitoring, instrumentation and reporting. Concepts, models and diagnostics for the extensive management of performance characteristics and for the guaranteed performance need to be further developed. There is a need for tools that identify sources of performance gaps and provide feedback to designers, as well as to building owners and operators.



The Research Landscape employed in the development of the EBC Strategic Plan 2019-2024.
Source: Paul Ruyssevelt

3. Low tech, robust and affordable technology

There is a strong tendency to focus policy support on the development and application of new and innovative technologies that, in principle, have the potential to significantly reduce energy demand and carbon dioxide emissions in buildings. But, in practice some new technologies can be 'fragile' if they require sophisticated management that is just not present and the application of too many 'bells and whistles' can often lead to conflicts in operation that increase rather than reduce energy demand. There is scope for new and enhanced tools to adopt feedback from previous projects to simplify solutions and ensure they are robust. Work is required to specifically examine robustness, occupant comfort and satisfaction with low tech solutions. At present there is limited use of smart controls and technologies to ensure robust performance without overcomplicating solutions. Data are needed to demonstrate robustness of performance for energy, the environment and durability.

4. Energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible

Global cooling energy use in buildings has doubled since 2000, from 3.6 EJ to 7.0 EJ, making it the fastest growing end-use in buildings, led by a combination of warmer atmospheric temperatures and increased activity due to population and economic growth. Without efficiency gains, space cooling energy use could more than double again between now and 2040. Policy action to limit the impact of cooling is critical for many emerging economies. Simplified and sophisticated tools need to be developed for the minimisation or elimination of cooling demand and advantage taken of passive solutions. Smart controls and technologies to enable passive and low energy cooling are also required. The real energy performance has to be clarified for space cooling and dehumidification systems, so that correct design decisions can be taken by comparing cost effectiveness and life cycle environmental impacts of passive and mechanical cooling methods.

5. Holistic solution sets on a district level: energy grids, overall performance, business models, stakeholders, transport energy system implications

Policies to develop sustainable local solutions for districts and neighbourhoods are increasingly required to limit and effectively manage energy demand and use, to ensure building performance and deliver financial and other benefits. The adaptability of different solutions and technologies to developing and transition economies needs to be studied through a holistic approach. Solution databases of best practices applicable in different regions need to be developed. Tools are needed that link individual building design and operational performance to community systems for energy delivery and related infrastructure.

Means of Delivery

To deliver on the priority themes, the new Strategic Plan identifies a set of research methods, or means, which can be employed. These include:

- the development of tools to support all stages from design to building operation, including life-cycle assessment, finance and business case preparation;
- the use of 'Living Labs' to provide direct experience of the impact of energy efficiency measures and the barriers to their adoption;
- research involving smart control of building services technical installations, including occupant and operator interfaces;
- data collection and analysis in depth or at scale to evaluate opportunities for performance improvement in individual buildings or across building stocks;
- the role of Building Information Models (BIM) to act as a game changer for building performance from design to operation.

Impact

The impacts of research occur in many ways - through knowledge exchange, new innovative products and processes, new companies and job creation, skills development, increasing the effectiveness of public services and policy, enhancing quality of life and health, international development and so on. For all new projects, the new EBC Strategic Plan encourages the consideration of potential impacts and the pathways to achieving them from the outset. Engagement will be sought with stakeholders in user communities, industry, government and other national and international agencies to ensure the relevance of the proposed research and to establish the means by which it can lead to new or improved products, services and policies.

Prof Paul Ruyssevelt
EBC Executive Committee Vice Chair

New Research Projects

RESILIENT COOLING
FOR RESIDENTIAL AND SMALL COMMERCIAL BUILDINGS

(EBC ANNEX 80)

OCCUPANT BEHAVIOUR-CENTRIC BUILDING DESIGN AND OPERATION
(EBC ANNEX 79)

SUPPLEMENTING VENTILATION WITH GAS-PHASE AIR CLEANING,
IMPLEMENTATION AND ENERGY IMPLICATIONS

(EBC ANNEX 78)

Resilient Cooling for Residential and Small Commercial Buildings

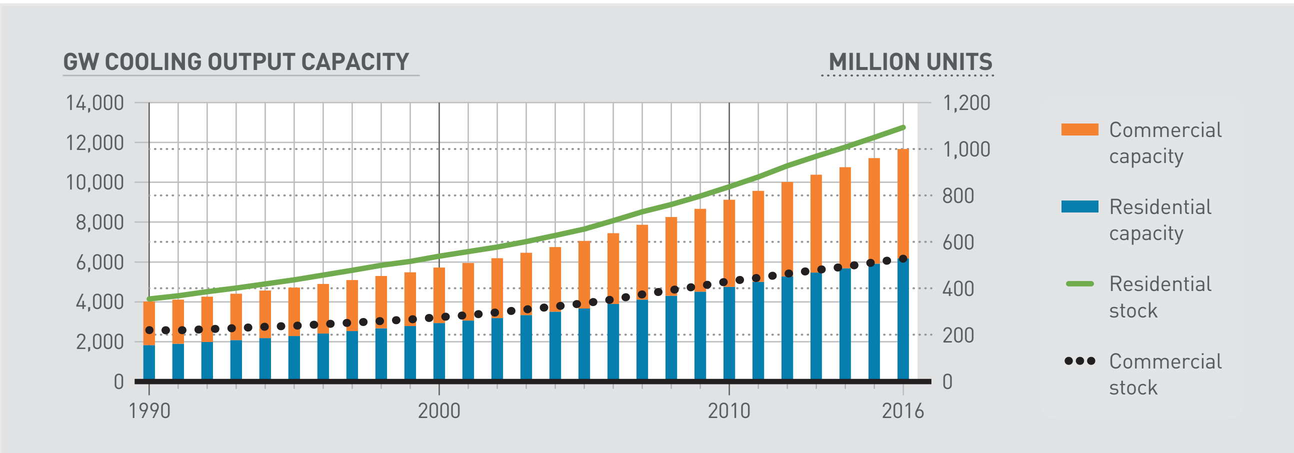
EBC ANNEX 80

The use of energy for space cooling is growing faster than for any other end use in buildings, more than tripling between 1990 and 2016. Rising demand for space cooling is already putting an enormous strain on electricity systems in many countries, as well as driving up emissions. Growing demand for cooling is particularly driven by economic and population growth in the hottest parts of the world. There is no doubt that global demand for space cooling and the energy needed to provide it will continue to grow for decades to come. These are the alarming findings of the IEA Global Exchange on Cooling report, 'The Future of Cooling', published in May 2018.
With current policies and targets, energy needs for space cooling would triple by 2050. Meeting the associated peak electricity requirements would additionally become a major challenge. Still, there are realistic opportunities to curb the rapid growth in the demand for air conditioning and to achieve much more sustainable development to respond to the desire for cooling. The project is therefore addressing this multi-disciplinary challenge, and is boosting the development and implementation of robust low-energy and low-carbon cooling solutions in anticipation of deployment on a large scale.

Objectives

The general objective of the project is to support a rapid transition to an environment in which resilient low energy and low carbon cooling systems are the mainstream and are the preferred solutions for cooling and avoiding overheating issues in buildings. The specific objectives of the project are to:

- quantify the potential benefits of resilient cooling for a wide range of building typologies, climate zones, functional specifications and other boundary conditions;
- systematically assess benefits, limitations and performance indicators of resilient cooling;
- identify barriers to implementation and conduct research to overcome such barriers and facilitate implementation on a large scale;
- provide guidelines for the integration of resilient cooling systems in energy performance calculation methods and regulations. This includes specification and verification of key performance indicators;
- extend the boundaries of existing low energy and low carbon cooling solutions and their control strategies, and develop recommendations for flexible and reliable



Worldwide stock and capacity of air conditioning units by sector. Sales of these units, particularly to households, continue to grow briskly, pushing up the total stock of units and global cooling capacity.
Source: Adapted from 'Future of Cooling: Opportunities for Energy-efficient Air Conditioning', IEA 2018

resilient cooling solutions that can create comfortable conditions under a wide range of climatic conditions;
- investigate the real performance of resilient cooling solutions through field studies, and analyse performance gaps and develop solutions to overcome them;
- analyse, exchange and encourage policy actions, including minimum energy performance standards, building codes, financial incentives and product labelling programmes, educational initiatives, as well as others;
- establish links with other international programmes, such as KIGALI – Cooling Efficiency Programme, Mission Innovation Challenge #7 and other related IEA Technology Collaboration Programmes.

The project research is studying the following technologies:
- advanced solar shading, cool materials, advanced glazing technologies, ventilated facades for reducing external heat gains to indoor environments;
- ventilative cooling by comfort ventilation and elevated air movement, and micro-cooling and personal comfort control for increasing personal comfort excluding space cooling;
- ventilative cooling by night flush ventilation, thermal mass utilization, including phase change materials and off-peak ice storage, adiabatic / evaporative cooling, high performance compression refrigeration machines, including single split, multiple split, VRV units and chillers, high performance absorption chillers, including desiccant cooling, natural heat sinks, such as ground water, borehole heat exchangers, ground labyrinths, earth tubes, sky radiative cooling, roof ponds, green roofs, green façades and others for removing heat from indoor environments (production, emission and combined);
- high performance dehumidification including desiccant humidification for removing humidity from indoor environments.

Deliverables

The project is producing the following deliverables:
- an overview and state-of-the-art report for resilient cooling,
- a resilient cooling source book,
- a report on resilient cooling field studies,
- resilient cooling design and operation guidelines, and
- recommendations for policy, legislation and standards.

Progress

The project proposal was developed during 2017 and 2018 and it was then approved to begin in July 2018, starting a one-year preparation phase. During 2018, the project was presented internationally at the NCEUB Rethinking Comfort Conference 2018 in Windsor, United Kingdom, at a UNEP workshop in Vienna, Austria, at the AIVC Annual Conference in Juan-les-Pins, France, and at the National Energy Efficiency Conference held in Sydney, Australia. Since August 2018, the project website has been online. Furthermore, progress in the project has been disseminated by two newsletters.

Meetings

The following meetings were held in 2018:
- A workshop to advance the project proposal took place in Vienna, Austria in April 2018.
- The 1st project preparation phase meeting took place in Juan-les-Pins, France, in September 2018.

Project duration
2019–2023

Operating Agent
Peter Holzer, IBR&I Institute of Building Research and Innovation, Austria

Participating countries (provisional)
Austria, Australia, Belgium, Canada, P.R. China, Denmark, France, Italy, Japan, UK

Further information
www.iea-ebc.org

Occupant-centric Building Design and Operation

EBC ANNEX 79

Although various policies have been introduced in many industrialised countries during the last three decades to improve the quality of building envelopes and HVAC efficiency, concerning for instance building codes and incentives, buildings still account for a very large portion of energy use. Depending on the building type and degree of automation, occupants remain one of the greatest influences on building energy use and a leading reason for discrepancies between predicted and measured energy performance.

While modern automation technologies have been introduced into buildings, in part to reduce absolute energy use and uncertainty of energy use associated with occupants, emerging evidence suggests that occupants are often dissatisfied with automation and may intervene. Such energy interventions can have major energy use repercussions. Designers often overlook or do not understand that providing greater control to occupants increases their acceptance and preference for a wider range of indoor environmental conditions. In general, occupants are often an afterthought when building designers and operators are making key decisions affecting energy performance, indoor environmental quality, and building usability.

Recent research has identified the strong influence of occupants on building performance and has provided a sound framework for experimentally studying and modelling different behavioural actions, including the implementation of these models into simulation platforms. This has included the outcomes from the completed EBC project 'Annex 66: Definition and Simulation of Occupant Behavior in Buildings'. However, design and building operation practice shows that many of the models do not represent the manifold human interactions with a building appropriately, and that there is no guidance for designers and building managers on how to apply occupant models (including behaviour and presence) in standard practice.

Objectives

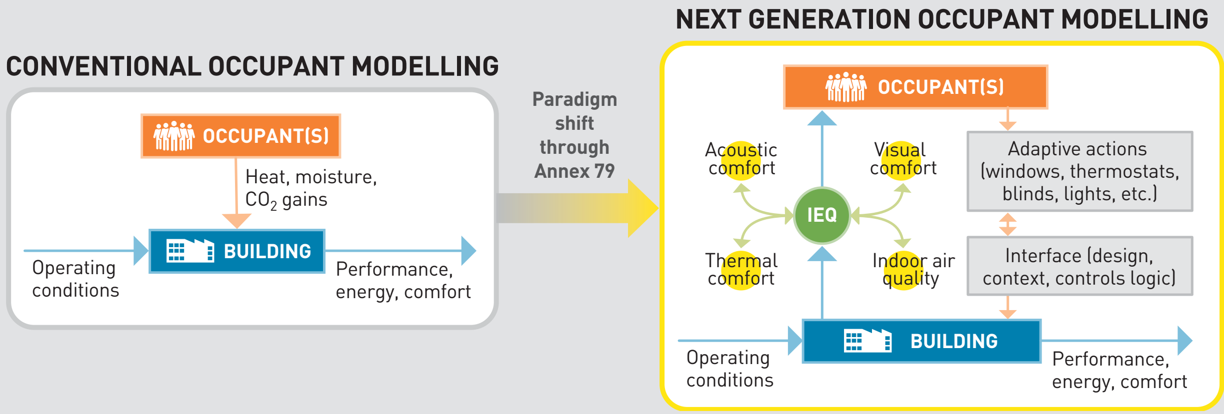
The project is concentrating on studying, designing, and operating occupiable spaces at the room, zone, and building scales. It is building up a solid framework in which the main influencing factors of occupancy and occupants' actions in buildings are systematically identified and described. First, this is being done independently from the building type. Then, depending on available data and case study buildings, exemplary use cases will be investigated starting most likely with office and residential buildings, although the scope is not explicitly limited to any building type. The objectives of the project are:

- Improvement of knowledge about occupants' interactions with building technologies. A specific focus is on comfort-driven actions caused by multiple and interdependent environmental influences that are not yet covered by current models.
- Understanding of how building technologies' interfaces and their underlying logic play a role in whether occupants take advantage of adaptive opportunities and promote energy-saving behaviour.
- Exploitation of 'big data' from emerging data sources to apply data mining and machine learning to advanced occupant modelling.
- Sustainable implementation of occupant models (behaviour and presence) in building practice by developing guidelines and preparing recommendations for standards for applying these models for building design and operation. Focused case studies are being used to implement and test the new models in different design and operation phases to obtain valuable feedback for the research community, while also demonstrating the value of more advanced methods to industry and government.

Deliverables

The planned main project outcomes are as follows:

- a comprehensive literature review to inform the whole project;



The project EBC Annex 79 is stimulating a paradigm shift in the way occupants are considered during the building design process and operation.
Source: Adapted from EBC Annex 79

- a unified theoretical framework for perceptual and behavioural theory of building occupants;
- guidelines for research methods related to evaluating occupant comfort and building interfaces, occupant data collection, and applying data analytics to occupant data;
- a report on best practices for building interfaces, occupant-centric design workflows, and optimal control strategies;
- a report on best practices for interface design and evaluation criteria of new products considering multi-aspect comfort;
- recommendations on occupant modelling in building energy codes;
- recommendations for standards on metering, occupant sensing infrastructure and controls.

Progress

Based on the objectives and the intended outcomes, related activities have been defined for the different parts of the project. Regarding multi-aspect environmental occupant exposure and its impact on energy-related behaviours and comfort, a comprehensive overview of existing theoretical and experimental work relevant to multi-domain models has been started. In order to unlock the many opportunities of new sensing modalities and machine learning techniques for occupant presence and action (OPA) modelling, the investigation of suitable computing platforms is now underway. Data-driven outcomes will also ultimately provide recommendations for the occupant modelling methodologies in the other parts of the project.

In terms of realising an occupant-centric building design process, codes, standards, practices, and exemplary projects involving performance-based simulation-assisted design are being reviewed with attention being paid to representation of occupants. For implementing occupant-centric building controls, case study buildings are being identified, looking at different buildings uses, control systems, and building automation system sensor and actuator configurations.

Meetings

The following meetings were held in 2018:

- A workshop to the advance project proposal was held in London, UK, in April 2018.
- The 1st Preparation Phase Expert Meeting took place in Ottawa, Canada, in October 2018.

Project duration
2018 – 2023

Operating Agents
Andreas Wagner, Karlsruhe Institute of Technology, Germany
Liam O'Brien, Carleton University, Ottawa, Canada

Participating countries (provisional)
Australia, Austria, Belgium, Canada, China, Denmark, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Singapore, Sweden, Switzerland, UK, USA

Further information
www.iea-ebc.org

Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications

EBC ANNEX 78

Ventilation accounts for approximately 20% of the global energy use for providing acceptable indoor environments. The requirements for ventilation in most standards and guidelines assume acceptable quality of (clean) outdoor air. However, in many locations in the world, the outdoor air quality is of poor quality. In such cases, an alternative to using ventilation may be to substitute part of the requirements with air cleaning to keep the indoor air at high quality. Even when outdoor air is of good quality, the use of air cleaning substituting for ventilation air could reduce the rate of outside air to be supplied indoors, and thereby decrease energy for heating or cooling the ventilation air and reduce fan energy when mechanical ventilation systems are used.

Worldwide, there is increasing research interest in air cleaning and there are also rising sales of gas-phase air cleaning products. This places a demand for verifying the influence of using air cleaning on indoor air quality, comfort, well-being and health. It is thus important to learn whether air cleaning can supplement ventilation with respect to improving air quality, specifically whether it can partially substitute for the ventilation rates required by standards and guidelines. Importantly, the energy impact of using air cleaning to supplement ventilation needs to be estimated. There is also a need to develop standard test methods of the performance of air cleaning devices. Consequently, this project has been established on the use of gas-phase air cleaning technologies. It is focusing on gas-phase air cleaning, but will not include filtration.

Objectives

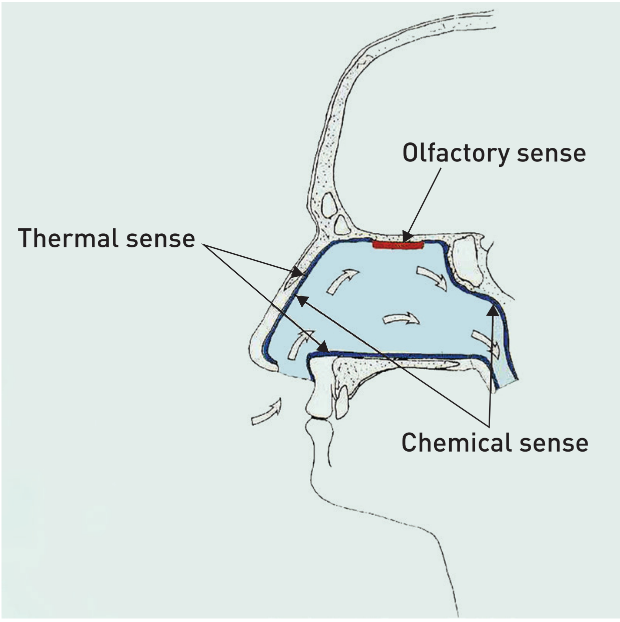
The project objectives are to:

- bring researchers and industry together to investigate the possible energy benefits by using gas-phase air cleaners (partially substitute for ventilation);
- establish procedures for improving indoor air quality or reduced amounts of ventilation by gas-phase air cleaning;
- establish a test method for air cleaners that considers the influence on the perceived air quality and substances in the indoor air.

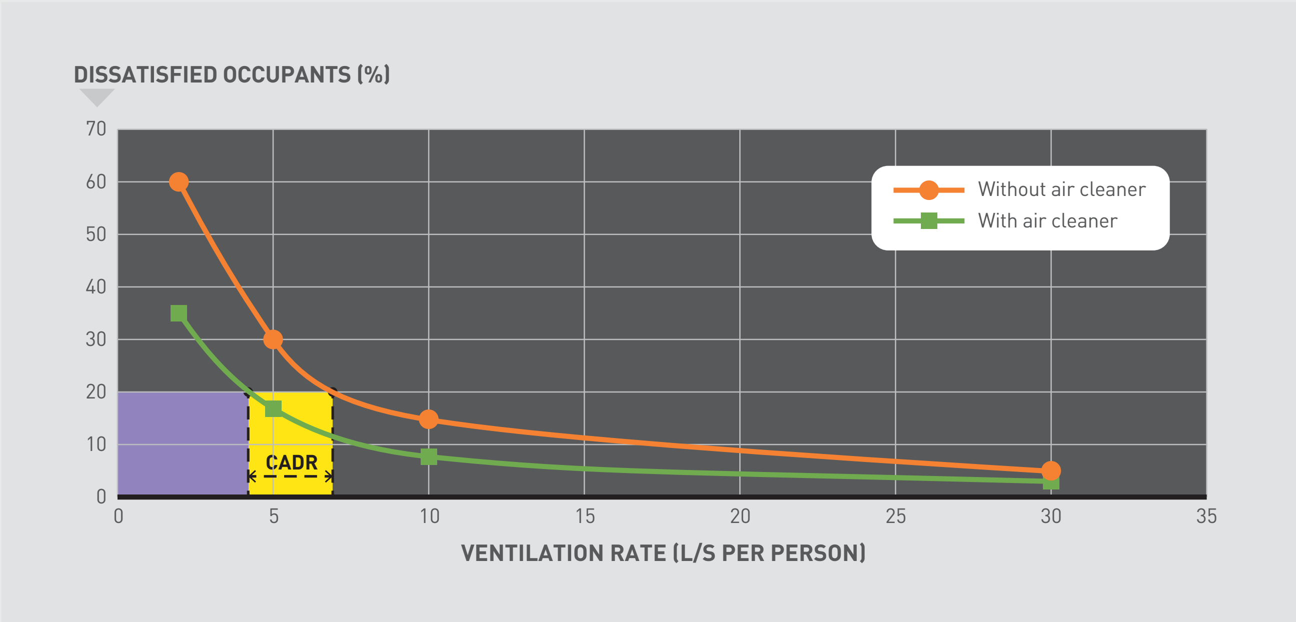
Deliverables

The following deliverables are being produced in the project:

- a method for predicting the energy performance of gas-phase air cleaning technologies and the possible reduction of energy use for ventilation;
- a validated procedure for supplementing (partially substituting) required ventilation rates with gas-phase air cleaning;
- a test method for air cleaning technologies that include chemical measurements and perceived air quality as measures of performance;
- a report on the long-term performance of air cleaning;
- models for predicting the performance of gas-phase air cleaning.



Perceived air quality is experienced in the brain based on signals from the olfactory and chemical senses.
Source: ICIEE.DTU



An example of test results, in which the performance of the tested air cleaner is equivalent to 3 l/s per person of clean air, which is called the clean air delivery rate (CADR).
Source: Adapted from ICIEE.DTU

Progress

The project preparation phase started in July 2018. The focus in the past year has been to present the project plans at conferences and organize face-to-face and web meetings with interested potential participants. The project is intending to develop a test method for gas-phase air cleaning technologies that includes measurement of 'perceived air quality' (PAQ) as a measure of performance. Therefore, contact has been established with ISO Technical Committee 142 'Testing of Gas-phase Air Cleaning', who agreed to start a preliminary new work item to develop a standard for testing of gas-phase air cleaning technologies at their meeting in September 2018, based on using PAQ. In the same month, ISO Technical Committee 146 Sub-committee 6 'Air Quality - Indoor Air Quality' agreed to establish a new ad hoc group to develop a standard for measuring PAQ in relation to testing gas-phase air cleaning. The intention is for the project to work in parallel with the development of these test standards.

Meetings

The following meetings were held in 2018:

- A workshop to advance the project proposal was held at the RoomVent 2018 conference in Helsinki, Finland, in June 2018.
- A short project preparation meeting was held in July 2018 during the Indoor Air 2018 conference held in Philadelphia. USA.
- A workshop on the project was held at the AIVC Conference 2018 in Juan-les-Pin, France, in September 2019.

Project duration
2018–2023

Operating Agents
Bjarne W. Olesen and Pawel Wargocki, Intl. Centre for Indoor Environment and Energy, Technical University of Denmark, Denmark

Participating countries (provisional)
Czech Republic, Denmark, Italy, Japan, P.R. China, Singapore, USA

Further information
www.iea-ebc.org

Ongoing Research Projects

ASSESSING LIFE CYCLE RELATED ENVIRONMENTAL IMPACTS
CAUSED BY BUILDINGS
(EBC ANNEX 77 - SHC TASK 61)

CITIES AND COMMUNITIES
(EBC WORKING GROUP)

DEEP RENOVATION OF HISTORIC BUILDINGS
TOWARDS LOWEST POSSIBLE ENERGY DEMAND AND CO_2 EMISSION
(EBC ANNEX 76 - SHC TASK 59)

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)

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

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

Integrated Solutions for Daylighting and Electric Lighting

EBC ANNEX 77 - SHC TASK 61

This project is focusing on research 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.

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

The office room at the DIAL headquarter office building as an example design project for an integrated lighting solution.
Source: DIAL GmbH

- 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 officially started with the kick-off meeting in Lund with 29 participants from 13 countries. Following the workplan the first activities were started. This encompassed for instance literature reviews as in Subtask A on user needs with regard to daylight and electric lighting, looking at the aspects: Visual perception, Visual comfort, Psychological aspects, Non-visual aspects of lighting. In subtask B a questionnaire was prepared, handed out to first stakeholders and evaluated. The aim is to identify opportunities and barriers of existing and emerging lighting technologies in the market. A Review of state of the art design workflows for integrated lighting solutions was started in Subtask C based on the Bartenbach R&D building and the DIAL headquarters. Also work in the field of BSDF daylight system characterization was started. In Subtask D a collection of possible case studies and living labs was identified - work on a monitoring procedure commenced. In the joint working group a first draft generic model for an hourly lighting and energy rating method was developed. For the "Virtual Decision Guide" the group was asked to get involved with first ideas of relevant cases studies, i.e. scenes (even stories) to be then later be implemented into an VR environment. Connected to the meetings in Lund and Lausanne two half day industry workshops were organized. With the industry workshops it is aimed at continuously mirroring the work of the task with respect to the needs of industry.

Meetings

The following meetings were held in 2018:

- The 1st Task Meeting was held in February - March, 2018 in Lund, Sweden.
- The 2nd Task Meeting was held in Lausanne, Switzerland, in September 2018.

Project duration
2018–2021

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

Participating countries
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

Cities and Communities

EBC WORKING GROUP

Cities face extensive challenges when it comes to transformation processes of their energy and mobility systems, such as the creation of suitable decarbonisation strategies and the selection of the best-fit solutions for their specific and individual prerequisites. They require comprehensive skills, knowledge and resources, which are fairly often lacking in smaller communities. In addition, the necessary decision making and planning processes take place in a commonly highly dynamic environment with a large number of further requirements that often have higher priorities. This complexity often leads to uncoordinated decision-making 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 adopted. The 'Working Group on Cities and Communities' (WGCC) is improving this situation by integrating these 'urban issues' into the research of the IEA Technology Collaboration Programmes (TCPs).

The WGCC is a single-leadership delegating structure hosted by the EBC TCP. It is sharing information between multiple TCPs and cities in a bi-directional approach by mutually providing and gaining know how. It is also linked to existing IEA Working Parties and TCP Co-ordination Groups, by direct involvement, through the EBC Executive Committee Chair, or through nominated experts, and is contributing to IEA publications and workshops. As an open group, the WGCC has invited experts to join from the various relevant TCPs and , as well as external experts not affiliated with the IEA or its TCPs. Moreover, membership of the WGCC does not depend on national TCP participation.

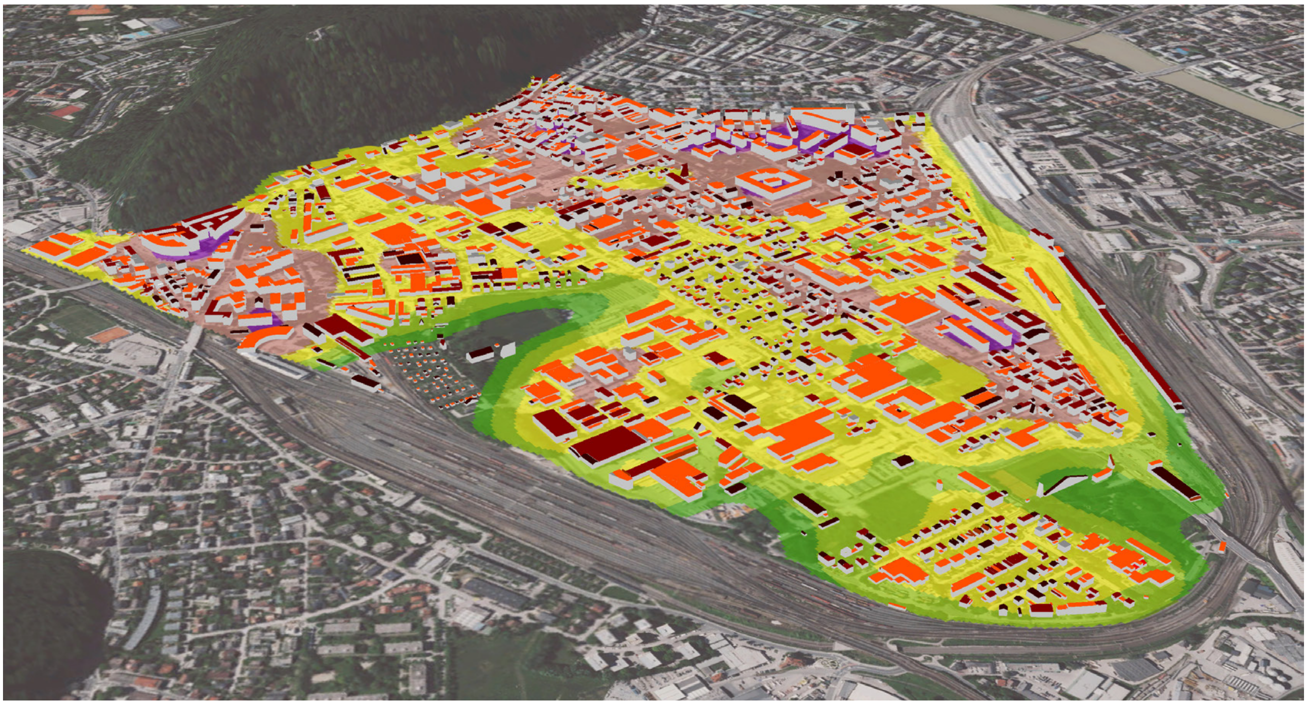


Illustration of heat demand and solar potential as a basis for the development of a decarbonisation strategy for the heat supply of a district of the City of Salzburg, Austria.
Source: ispace, 2018

Objectives

The goal of the WGCC is to contribute to an essential step in IEA TCP research to meet cities' non-technical needs that extends well beyond providing technical solutions for energy systems. The WGCC has the objectives as follows:

- assess and identify the needs of cities, their actors, and associated stakeholders;
- generate appropriate non-technical ideas for 'on demand' inputs and services for cities;
- identify and discuss bottlenecks and barriers for the transformation of cities' energy and transport systems;
- provide results and recommendations on energy and mobility systems that may inform policy development;
- close the gap between the needs of cities and research outputs;
- connect TCP technical researchers with non-technical experts and city representatives.

The WGCC is primarily targeting the following audiences:

- urban decision makers (administrative, planning staff, and so on),
- intermediaries (local and national), and
- IEA Secretariat staff and the wider IEA research community within the TCPs.

Deliverables

The WGCC is making use of a range of collaboration mechanisms, such as those listed below:

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

Through these means, the WGCC is identifying the crucial needs of cities, which in turn will be translated into research questions for short term projects and research within the group.

Progress

The proposal for the WGCC was developed throughout 2017 and was approved in November 2017. The WGCC then started in early 2018. At the first meeting, the needs of cities were discussed and topics of interested were collated, with three Sub-groups for further work formed as listed below:

Sub-group 1: Decarbonisation Strategies
Sub-group 2: Integrated Planning Concepts
Sub-group 3: Data, Tools and Methods

Each sub-group has developed a work plan to deliver its planned activities, which was finalized at the second meeting. An analysis of the needs of the cities was also conducted at the second meeting.

Meetings

The following meetings were held in 2018:

- The 1st meeting was held in Vienna, Austria, in April 2018.
- The 2nd meeting was held in Dundee, UK, in October 2018.

Project duration
2018–2020

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

Participating countries
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

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 or so, 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' (European Standard EN16883). It is therefore timely to identify and promote good approaches and solutions.

Completed examples have shown that a reduction of 'Factor 4', which means to 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.

Objectives

The IEA Solar Heating and Cooling Technology Collaboration Programme (TCP) is working on the project with the EBC TCP at a 'Moderate Level Collaboration', and with the Photovoltaic Power Systems TCP at a 'Minimum Level Collaboration'. The objectives are as follows:

- 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;
- 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 typology studied (residential, administrative, cultural, and so on);
- 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.

Deliverables

The following deliverables are planned:

- a web-based collection and documentation of approximately 50 case studies of best practice from all participating countries;
- an assessment report of the best practices including evaluation of the cases' replicability and the transferability of specific favourable framework conditions and incentives;
- assessment of EN16883 with improvement proposals;
- an assessment of the existing tools, methods and guidelines that are relevant in relation to standard EN16883 and others (for example ASHRAE Guideline 34P, 'Energy Guideline for Historical Buildings') in the form of a report including 'fact sheets';
- an integrated platform with tools for holistic retrofit of historic buildings 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

Villa Castelli at Lake Como, Italy, a best practice case study with conserved historical characteristics. This has been retrofitted to very low energy demand, met by a geothermally-driven heat pump and solar energy.
Source: Valentina Carì

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 communications 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;
- communications and dissemination of the results by means of a workshop series, participation in stakeholder events and a touring exhibition to be used by all participating experts.

Progress

During 2018, the work on the development of a 'Knowledge base' started with the definition of 'best practice' and the minimum criteria needed for the description of relevant examples. An interim list of potential examples of best practice for inclusion in the future database has been elaborated. This list collates about 30 examples from all of the participating countries.

A new template has been developed to gather relevant information on existing tools and methodologies. The format of the template has been designed to allow collection of all information relating to the best practice database and also including specific information for the assessment of single retrofit measures. This template has been circulated to all project partners to continue with the compilation of conservation compatible retrofit solutions, focusing specifically on internal wall insulation. This approach is based on the development of a novel laboratory test to quantify the drying potential of materials and with that to ensure the durability of retrofitted walls. The next steps are focusing on the development of analogous assessment procedures for the other retrofit solutions studied (windows, ventilation and solar integration).

Meetings

The following meetings took place in 2018:

- The 2nd experts meeting was held in Dublin, Ireland, in March 2018.
- The 3rd experts meeting was held in Visby, Sweden, in September 2018.

Project duration
2017–2021

Operating Agent
Alexandra Troi, Eurac Research, Italy

Participating countries
Austria, Belgium, Denmark, Ireland, Italy, Spain, Sweden, Switzerland, UK, USA

Further information
www.iea-ebc.org

HVAC Energy Calculation Methodologies for Non-residential Buildings

EBC WORKING GROUP

When improving the impact of building energy codes and other similar key indices, energy calculation methodologies need to be focused upon as the principal index for performance evaluation. As the first step to examining the technical and scientific basis of building energy codes in different countries, heating, ventilation and air conditioning (HVAC) energy calculation methodologies for non-residential buildings are being studied as one of the most challenging aspects of building energy calculations.

Objectives

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

- collect world-wide technical documents on the calculation methodologies of energy use for HVAC systems in non-residential buildings and on their scientific basis, including existing research on their validation;
- analyse the collected documents and determine characteristics of methodologies that are appropriate as good examples for broader application;
- identify any lack of scientific basis or other problems in HVAC energy calculation methodologies to inform future research themes.

Deliverables

The following project deliverables are being prepared:

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

Progress

The project has found certain key aspects of existing national energy calculation methodologies and relevant international standards, which are summarized below.

Space unit and zoning rules for the thermal load calculations: The building is to be divided into zones taking into consideration conditions of space usage (schedule, internal heat gains, and so on) and environmental conditions for heating, cooling, ventilation, lighting and domestic hot water supply. The rule for zoning is a fundamental part of every methodology.

Classification of HVAC systems: The ways of classifying HVAC systems differ between national calculation methodologies. Major HVAC systems are commonly included in different national classifications, but each classification seems to be influenced by practices in national HVAC industries.

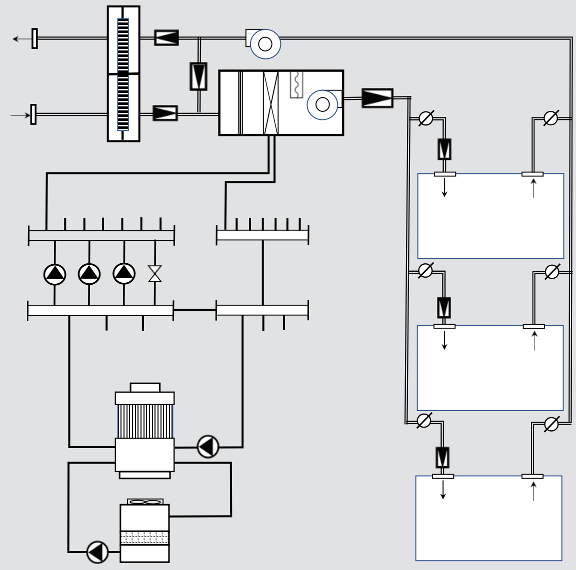
Determination of ventilation rate including when demand controls are applied: There are two ways for setting the input value for outdoor air intake, either assuming design values for the evaluated building, or making assumptions on outdoor air intake given in the schedule and condition of space usage. While demand control of the ventilation rate is a promising technique, not all calculation methodologies can evaluate its effectiveness.

Expression of energy efficiencies of heat sources including sizing and partial load effect: There are three ways to express energy efficiencies of heat sources. The first way is to use seasonally integrated values for efficiencies of heat generators, such as SEER, which is to be determined for each product of heat generators independent from evaluated buildings. The second way is to use test results of energy efficiencies for different part load ratios, such as according to EN 14825. The third way is to use the energy efficiency at the rated condition and curves representing the influence of the part load factor and air / water temperatures for each generator type. Further studies seem necessary for future improvement. Expression of energy efficiencies of air and water conveyance including sizing, partial load effect and control of fans and pumps: The influence of controls of HVAC systems on their energy performance should not be underestimated, but it seems to be still very difficult to define clearly various kinds of control methods for HVAC systems. One calculation methodology found clearly states that ideal functions of the controlled HVAC systems are assumed, while another methodology states that 'safety side' evaluations of the functions should be made, because of a lack of clear definitions of the control methods.

Consideration of commissioning and initial adjustment of HVAC systems: Especially for centralised HVAC systems, initial adjustments before starting using those systems seems to be indispensable, even though the time and resources for carrying out the initial adjustments are sometimes limited. A reference to initial adjustment for any HVAC subsystems and components could not be found in any national energy calculation methodologies, except that the German methodology sets a coefficient to discriminate whether the initial adjustment has been done or not. In that methodology, a correction factor for hydraulic adjustment is applied in the calculation method for energy use by pumps, and if the hydraulic adjustment for pipes is not carried out, a 25% larger coefficient should be applied.

Referenced standards for test and design of components and systems: Among national energy calculation methodologies examined, a consensus has not yet emerged on which product standards for testing and calculating the performance indices should be referenced and used. This decision should be made on the basis of the observation on the phenomena, which proves how actual behaviour of the evaluated systems can be simulated correctly by using the appropriate indices based on testing and other kinds of standard.

Schemes to simplify the preparation of input data: Most national building energy calculation methodologies are used for mandatory regulations. Availability of detailed design information depends on at which design stage the calculation is to be carried out. If it is carried out before starting construction, such as for obtaining permission to build, it is probable that full specifications of the building envelope and energy systems have not yet been finalized and there is a possibility for changes to happen during the construction phase. In the case of large buildings, the construction phase can be a very long process and changes of the design usually occur.



A typical configuration of a centralised HVAC system (heat source, water and air transport, heat emission).
Source: EBC Working Group on HVAC Energy Calculation Methodologies for Non-residential Buildings

Information on validation of the calculation logic: It is necessary to collect samples of calculated energy use and actual energy use after starting occupation of the buildings. There are some trials underway to compare calculated and actual energy use for residential buildings, but it is still very rare to find such comparisons for non-residential buildings. As such, it may be a little early to proceed to this type of validation in non-residential cases.

Meetings

No meetings were held in 2018.

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 high energy performance in existing buildings is often lower than in the construction of new buildings. However, there are specific opportunities for district-level solutions in cities that must 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 this level, finding the balance between these two types of measures for the existing building stock is a complex task and many research questions still need to be answered related with the strategies to be adopted.

Objectives

The project has general objectives that are to:

- investigate cost-effective strategies for reducing greenhouse gas emissions and energy use in buildings in cities at district level, combining both energy efficiency measures and renewable energy measures;
- provide guidance to policy makers and companies working in the field of the energy transition, as well as to 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 on various existing and emerging technology options and on 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 companies 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;
- 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 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

An aerial view of the Nyhavn neighbourhood in Copenhagen, Denmark.
Source: Colourbox

investors about cost-effective renovation strategies, including district-based solutions.

Progress

The project is completing the first year of its working phase. During this period, comprehensive efforts have been made to identify the most significant technologies suitable to be used at the district level. These were compiled into a preliminary report consisting of renovation solutions in terms of building envelope, building systems, energy production and energy storage. Also in this period, the first inputs for the framework and methodological guidelines for the cost-optimization of the renovation solutions were defined. These include characterization of the districts to be analysed, and definitions of the main indicators and country-specific targets. Criteria for the definition of 'virtual districts' are being established for developing and testing the methodology. A common tool, which is in an early phase of development, is being applied for the analysis. In 2018, 17 potential case studies and success stories have been identified from among the participating countries, located in Austria, Denmark, Italy, Norway, Portugal, Spain and Sweden.

In the past year, policy instruments have been identified that can support district renovations based on the analysis of benchmarking projects. In this regard, some project participants held a workshop in Delft, the Netherlands, in November 2018, together with local authorities at the Sustainable Urban Energy Systems Conference, focusing on advances in the cost-effective approaches of local authorities for home renovations at a district level. In October 2018, the project organised a joint Workshop with the EBC project 'Annex 73: Towards Net Zero Energy Public Resilient Communities', in Graz, Austria, with the aim of identifying possible synergies. Common areas of interest include the characterization of technologies, case studies and success stories and integration of simulation and modelling tools. The first project newsletter has been launched and disseminated through social media (LinkedIn, Facebook and Twitter).

Meetings

During 2018, the following project meetings were convened:

- Madrid, Spain, in March 2018, and
- Graz, Austria, in October 2018.

Project duration
2017 – 2022

Operating Agent
Manuela Almeida, University of Minho, Portugal

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

Further information
www.iea-ebc.org

Competition and Living Lab Platform

EBC ANNEX 74

Competitions are intended to stimulate innovation and the next generation workforce as well as generate public visibility of sustainable architecture, building engineering and associated sciences. Living labs with building prototypes allow for valuable tangibility and testing of innovative ideas. The project starting point was the success story of the Solar Decathlon series of international student competitions. The Solar Decathlon is based on an initiative of the U.S. Department of Energy started in 2000. In this competition format, universities from all over the world design, build and operate solar-powered houses designed to meet the rules of ten contests, hence the name 'Decathlon'. It is the only student competition worldwide addressing the realization and performance assessment of buildings and not only the design. It is also a powerful, real-world experience for students to prepare for careers in clean energy and building design. During each competition's final phase, the interdisciplinary teams assemble their houses in a common Solar Village that lends itself to an engaging and inspiring public event. The final phase includes a public exhibition and a head-to-head competition that involves monitoring and judging across the ten contests. Fifteen such competitions have been conducted up to the end of 2018.

Many of the experimental houses are studied as 'living labs' when transferred back to their home universities. Living labs are characterized by a user-centred testing, educational, research and innovation approach. This format intensively stimulates research and education by supplying valuable experience, monitoring data and user feedback. The interdisciplinary approach stimulates integrated education crossing disciplines and faculties. By mobilising the creativity and dynamism of university students, competitions and living labs generate good opportunities to:

- generate new knowledge and demonstrate innovative clean-energy solutions;
- encourage commitment from university students;
- make students, professionals, and the general public, more aware about energy efficiency and sustainability;
- develop a well-trained workforce dedicated to implementing sustainable technologies.

Objectives

The project aims 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 establishing the link to knowledge from previous and current IEA activities. The project, in addition to making full information and previous experiences available to the scientific community, industry, professionals, and the general public, is carrying out a critical analysis of the gathered information. It is producing reports with conclusions, recommendations, and lessons learnt from these experiences to improve the staging of future competitions and is creating new initiatives to foster energy efficiency and sustainability for buildings. The project has a three-year duration and is structured as three subtasks with the creation of the knowledge platform as a cross-cutting activity.

Deliverables

The following project deliverables are being produced:

- 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,
- educational material.

Workshop on the Solar Decathlon Middle East, held in Dubai, United Arab Emirates, in November 2018.
Source: University Wuppertal, Germany

Progress

The working phase of the project started in January 2018. The web-based knowledge platform to disseminate information from past and future competitions has been created and made available online. The collection and structuring of the source material to populate this has formed a major project activity. Beside the publicly visible information, competition organizers and teams, as well as researchers, can view more information with a user specific login. The Solar Decathlon Middle East is the first competition that is already benefitting from the work, in which teams directly enter information into the new platform. The same is planned for the competition to be launched in Europe in 2019.

A first workshop was held in connection with a project meeting on the site of the Solar Decathlon Middle East 2018 to stimulate the scientific knowledge of the participating student teams. This was titled, 'Solar Decathlon Building Simulation and Monitoring – Status and Perspectives'. Experts from the Building Science Groups of Wuppertal University and Fraunhofer ISE (both Germany), Ghent University (Belgium), Polytechnic Madrid and Polytechnic Catalonia (both Spain) organized and guided the workshop. It began with a reflection on methods applied for building simulation and monitoring in the past and current Solar Decathlons. The lectures and discussions that followed aimed to identify the possible evolution of future competitions.

Meetings

The following meetings took place in 2018:

- The 1st meeting in the Working Phase was held in Szentendre, Hungary, in May 2018.
- The 2nd meeting in the Working Phase was held in Dubai, United Arab Emirates, in November 2018.

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 building basis without consideration of community-wide goals relevant to energy sources, renewables, storage, or future energy generation needs. 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. Major disruptions of electric and thermal energy supplies have degraded critical mission capabilities and caused significant economic impacts at military installations, for example.

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.

Objectives

The project scope includes the decision-making process and computer-based modelling tools for achieving net zero energy resilient publicly-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 indices 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;
- 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', enhancing 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;
- collate 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 are intended to 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 is producing the following deliverables:

- a guide for net zero energy planning in public and military building communities,
- an energy master planning tool module,

A large thermal solar array powering a low temperature micro-grid in Toftlund, Denmark.
Source: Helmut Boehnisch, Stuttgart, Germany

- a book of case studies with examples of energy master plans, and
- results from several realized, or partially realized schemes.

Progress

The project Working Phase started in February 2018. Since then, the team has been developing internationally-consistent building energy use benchmarks and targets, including assembly of an international database of energy use intensities for common building types. Special attention is being given in the project to energy resiliency requirements for thermal and electrical energy supply systems. Lessons learned are also being summarized from implemented energy master plans to document processes and elements that are vital for a successful planning process. Further, a list of 25 case studies has been agreed by the participants, along with a documentation template and definitions of specific parameters to be reported.

A template has also been developed describing different energy supply technology categories, their technical characteristics and their costs. This has already been populated with certain technologies from Denmark, Austria and the USA. The list includes electrical technologies, heat pumps and chillers, energy systems, energy storage technologies, district heating and cooling networks, other energy technologies and non-energy related technology protection measures to provide enhanced system resilience. Work has also commenced on the Energy Master Planning Guide. This has included reviewing existing modelling approaches for energy and resiliency planning, for example 'NZI-Opt / System Master Planning Tool' (USAC-ERDC), 'Energy Resilience Analysis Tool' (MIT Lincoln Laboratory), 'Microgrid Design Toolkit' (Sandia National Laboratory), 'energyPRO' (EMD International A/S). The energy master planning module is intended to be a standalone tool for integrated resiliency analysis, focusing on supply, distribution and storage technologies, addressing both thermal and electrical systems and providing performance and cost optimization.

Meetings

The following meetings took place in 2018:

- The 1st Working Meeting was held in Frankfurt, Germany, in April 2018.
- The 2nd Working Meeting was held in Graz, Austria, in September 2018.

Project duration
2018–2022

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

Life cycle assessment (LCA) approaches are used to assess the environmental impacts of buildings during their entire life cycles, both new and retrofit. Quantifying their environmental impacts is important to support decision making towards more resource efficient and climate friendly buildings in future. Nowadays, there is disparity in the level of application of LCA on buildings, the embedding of environmental LCA data in planning tools and the existence of LCA databases targeted to the buildings sector worldwide. The project objectives are thus to foster the discussion and harmonisation of methodology guidelines, the use of environmental information during early design stages and the development of national databases.

Objectives

The project has 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 and 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.

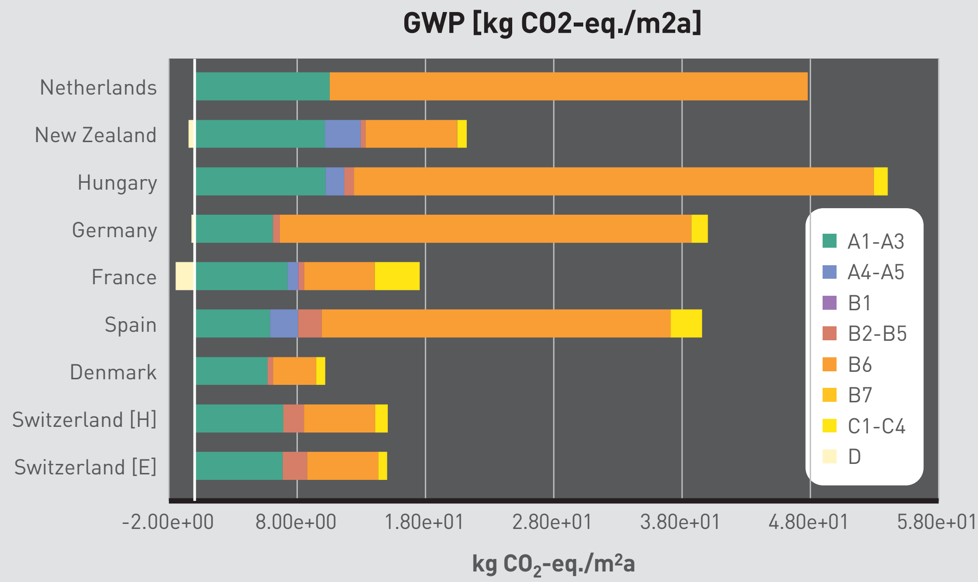
Deliverables

The project outcomes are intended to foster the use of environmental information in the building design process, so leading to greater resource efficiency. The deliverables are being created to promote the importance of and best practices for environmental life cycle assessment of buildings. They include publicly available default national data sets of LCAs based on environmental indicators and a series of reports as follows:

- 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), with guidelines with good examples on the application of LCA in different stages of the design process;
- how to establish national and regional LCA databases targeted to the construction sector, including recommendations for data exchange.

Progress

In 2018, the focus has been on preparing and completing questionnaires for LCA experts, designers and building owners. One part of the survey relates to the methodologies applied to assess the environmental impacts of buildings with regard to modelling aspects, system boundaries and environmental indicators. In addition, the degree of dissemination of the applied methodologies, the frequency of use among designers and their demand for assessment results has been investigated. A second part is on national practices for workflows and planning tools, methods, data formats, and so on, used by LCA experts and design decision makers. Lastly, the surveys include a section on national and regional LCA databases and are exploring the national



Preliminary results for the greenhouse gas emissions of the reference 'be2226 office building' assessed according to the national guidelines of various countries. The emissions are shown normalised per unit floor area and year, covering manufacture, construction, operation and end of life. Note that the comparisons are mainly intended to investigate the national assessment methodologies rather than to compare the absolute values of the results. Source: Adapted from EBC Annex 72

needs (data gaps), and the driving forces for the demands on LCA data and databases. The public questionnaire for designers has been made available in 25 national versions and 8 languages. The answers received provide guidance for future research activities, international knowledge sharing between design professionals, as well as contributing to future standards, regulations and construction industry policies. Further, preliminary results of on the state of life cycle assessment databases worldwide show that about 10 countries maintain their own dedicated LCA databases.

To compare national assessment methods, the 'be2226 office building' in Lustenau, Austria, and a high-rise residential building in P.R. China, are serving as project reference buildings. The inventory data and BIM models for each of the two buildings have been established. Several countries have already assessed the be2226 reference building according to different reference calculation study periods and LCA databases in line with national guidelines. The study period has an influence on the importance of the manufacture, construction and end of life stages, as well as on the replacement rates of the building materials. The findings of the comparisons allow better targeting of harmonisation efforts and identify areas of potential disagreement. The main methodological differences have been seen to occur in the assessment of the operation stage, which is influenced by the carbon intensity of the electricity mix applied when following the national guidelines.

Meetings

The following meetings took place in 2018:

- The 3rd Expert meeting was held at Carl Friedrich von Siemens Stiftung, Munich, Germany, in April 2018.
- The 4th Expert meeting, was held at KU Leuven, Ghent, Belgium, in October 2018, alongside a mini-symposium convened as part of the IALCCE conference.

Project duration
2016–2021

Operating Agent
Rolf Frischknecht, treeze Ltd., Switzerland

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

Further information
www.iea-ebc.org

Building Energy Performance Assessment Based on In-situ Measurements

EBC ANNEX 71

In recent years, policy makers in many industrialised countries have imposed increasingly stringent requirements with regard to the energy performance of new and renovated buildings. In those countries, thick insulation layers, with more efficient heating systems and appliances have become common practice. Until now though, building energy performance assessments have been mainly performed in the design phase. Only recently, awareness has grown that more attention should be given to the actual energy performance of buildings in use.

The project aims to develop replicable methodologies embedded in a statistical and building physics framework to characterize and assess the actual energy performance of buildings. It focuses on residential buildings at the level of individual dwellings, as well as at the level of building communities. At both levels, the development of characterisation and quality assurance methods is being explored. Characterisation methods aim to translate the (dynamic) behaviour of a building into a simplified model that can be used in model predictive control, fault detection, and optimisation of district energy systems. Quality assurance methods aim 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, airtightness and solar insolation.

Objectives

The project objectives are to:

- develop methodologies to characterize and assess the actual as-built energy performance of buildings;
- collect 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

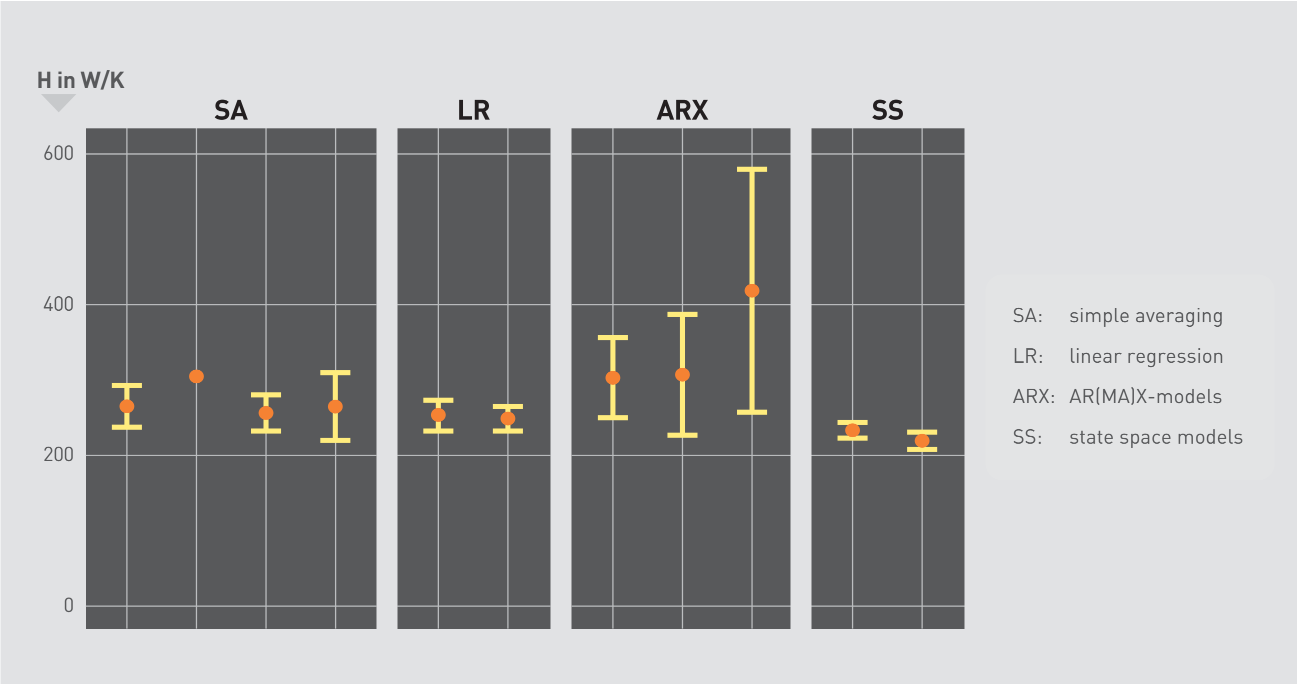
The main outcomes of the project are as follows:

- an overview of the availability and reliability of input data for onsite building performance assessment,
- dynamic data analysis methods to characterise and assess building energy performance,
- guidelines to apply the methods in quality assessment procedures, and
- 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 help to ensure practical application of the project outcomes, extensive effort has gone into the development of a framework that links the requirements for a specific application (for example requested accuracy for the determination of the overall heat loss coefficient based on in-situ data) to available methods with corresponding required measurement accuracy and data acquisition techniques. To get a broader view on relevant practical applications, a survey is underway amongst stakeholders in the different countries to identify possible use cases and their requirements.

Determination of the actual overall heat loss coefficient of a building is considered as one of the important parameters with respect to quality assurance. Therefore, two data sets, one from a well-insulated social house in Gainsborough, UK, and the other from a poorly insulated traditional dwelling in Loughborough, UK, have been used to explore the reliability of current identification techniques. Both very simple methods, as well as more advanced dynamic methods, have been used on the measured in use data to derive the heat loss coefficient of the dwellings.



Early results based on in-use data for different methods to determine the actual heat loss coefficient (H) for a poorly insulated dwelling in Loughborough, UK. Since a wide spread in the results has been observed, the project is investigating possible causes in detail including the impact of pre-processing the data, selection of data subsets, impact of internal and solar heat gains, and so on.
Source: Adapted from EBC Annex 71

In parallel with the above, the project is working on a new building energy simulation (BES) validation exercise based on real measured data. An earlier example of such a validation exercise was previously performed within the EBC project 'Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements'. While that exercise was successful and is considered as an important addition to the standard global BESTEST protocols, it dealt with an unoccupied building with electrical space heaters. In the current project, a validation exercise is being carried on the same dwelling (the Fraunhofer test house in Holzkirchen, Germany), but now heated with a real heating system and artificial occupants. As for EBC Annex 58, there is again a large interest from modelling teams to participate in a blind BES-validation exercise on the results, both from inside and outside this project. The test case of the BES-validation exercise is also being extended as test case for building characterisation methods for fault detection. A common exercise for this latter case based on the Fraunhofer test house results is under development.

Meetings

Two meetings were organised in 2018 as follows:

- The 4th expert meeting was held in Brussels, Belgium, in April 2018 and was hosted by LOCI.
- The 5th expert meeting was held in Innsbruck, Austria, in October 2018 and was organised by the University of Innsbruck.

Project duration
2016–2021

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

Participating countries
Austria, Belgium, Denmark, France, Germany, Norway, Spain, Switzerland, the Netherlands, United Kingdom
Observers: Estonia

Further information
www.iea-ebc.org

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

EBC ANNEX 70

To reduce greenhouse gas (GHG) emissions related to energy use in buildings, information on the building stock is needed to provide a baseline from which to improve, along with knowledge of which features can achieve the greatest improvements in performance, comfort and GHG emissions mitigation. There is therefore a growing need for countries and cities around the world to have better quality and higher frequency data on their building stocks, underpinned by improved access to those data.

This project is supporting the development of a robust evidence base on energy and the building stock through established data collection, study methods and modelling techniques to better inform decision-makers, researchers and businesses. The aim is to develop methods for improving the empirical evidence on energy demand in the building stock. The work 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, occupancy 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 outcomes facilitate the use of empirical energy and building stock data in undertaking international energy performance comparisons, policy reviews, and national stock modelling, as well as technology and product market assessments and impact analyses. The deliverables are intended to promote the importance of and best practices for collecting and reporting energy and building stock data.

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 building stock 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.

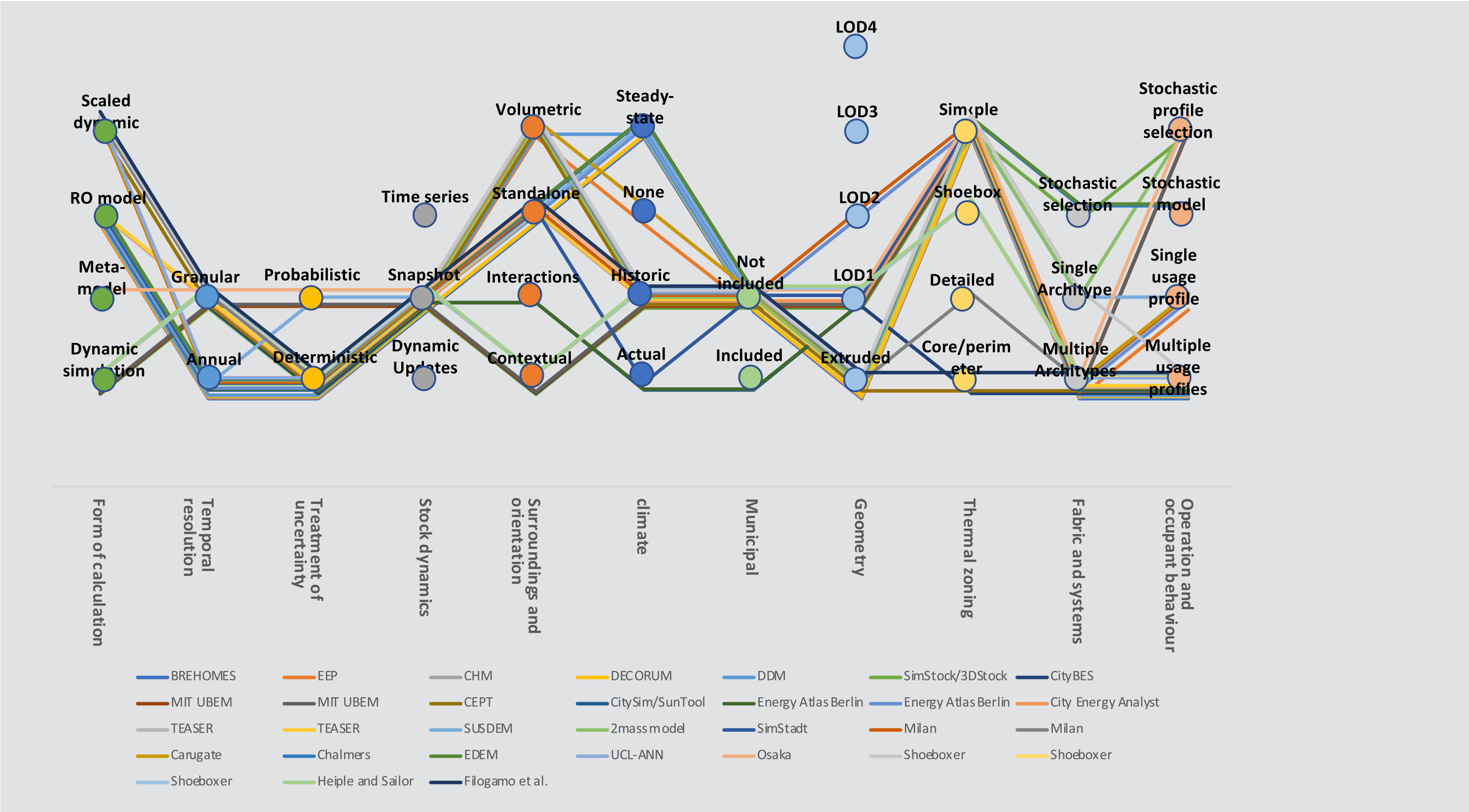
Deliverables

The following project deliverables are being created:

- a register of energy and building stock data among the participating countries and more widely;
- a register of energy and building stock models;
- a data schema for energy and building stock data for developing countries and emerging economies;
- guidelines for energy and building stock model reporting and metrics for stock model comparisons;
- 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.

Progress

The project has completed the second year of its working phase. Each part of the project is in the process of completing user surveys, and classifications for data and models. An 'Energy and Buildings Stock Data: Users and Needs' survey has been completed, with over 500 responses received from the project member countries. This survey sought information on what energy and buildings data are in use and what is needed to support their activities, including research, decision-making and performance improvement. A literature review on issues around data use and needs is continuing. These



Map of characteristics of the urban building energy models reviewed. This is an example of the output of a review that illustrates the wide range of models and their structures that exist for modelling energy use in the urban building stock.
Source: Dr Pamela Fennel, University College London

activities are informing the development of the 'Energy and Building Stock Data Registry', which provides an online platform for identifying, describing and sharing such data. The project is now working on best practice guidance for different forms of energy and building data collection.

The project has also developed a model classification for incorporation into the Registry to enable researchers to identify and describe building energy stock models. This work has highlighted that the classification and process of reporting model findings need to be comprehensive and flexible. A set of common exercises has also been defined that focus on model uncertainty and sensitivity, with these currently in progress. Further, guidance for how to report stock models is being developed by those publishing model findings. The project participants have been engaged in disseminating the concept of energy epidemiology along with the early outputs of the effort. Moreover, participants have held workshops on building energy epidemiology in Brazil, the European Union, and the USA.

Meetings

The following meetings took place in 2018:

- The 4th Working Phase meeting took place in Delft, the Netherlands, in March 2018, and was hosted by Delft University of Technology.
- The 5th Working Phase meeting was held in Gothenburg, Sweden, in June 2018, and was hosted by Chalmers University of Technology.
- The 6th Working Phase meeting was held in Washington DC, USA, in November 2018, and was hosted by NREL.

Project duration
2016–2020

Operating Agent
Ian Hamilton, University College London, UK

Participating countries
Australia, Austria, Belgium, P.R. China, Denmark, Germany, Ireland, Japan, Netherlands, Portugal, Norway, Sweden, Switzerland, UK, USA

Further information
www.iea-ebc.org

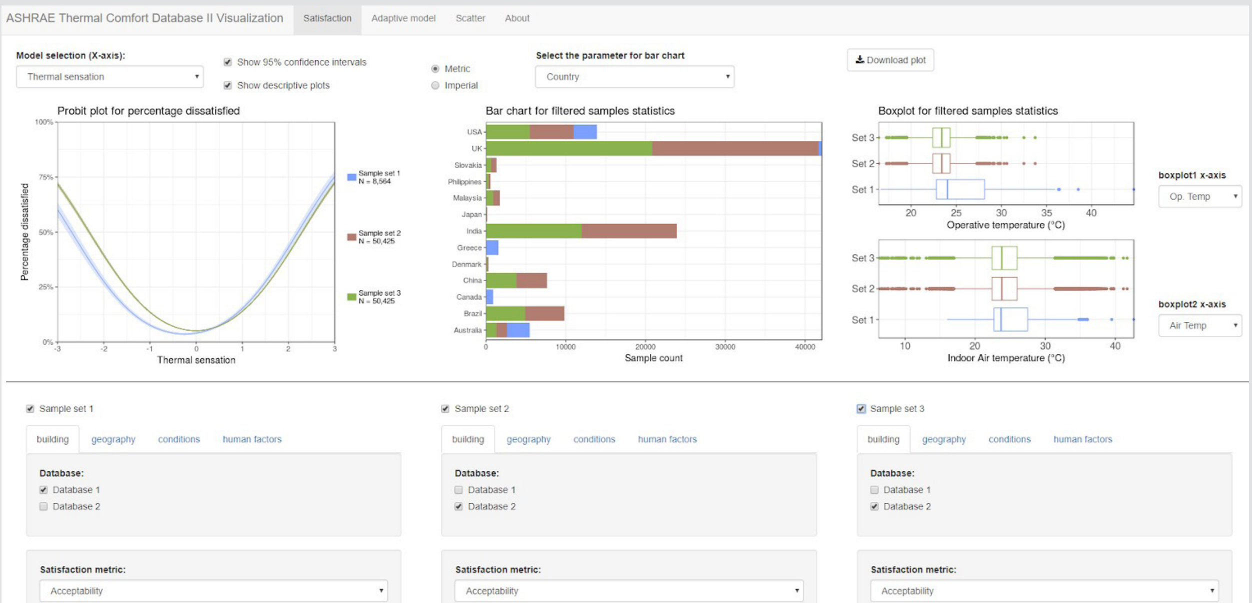
Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings

EBC ANNEX 69

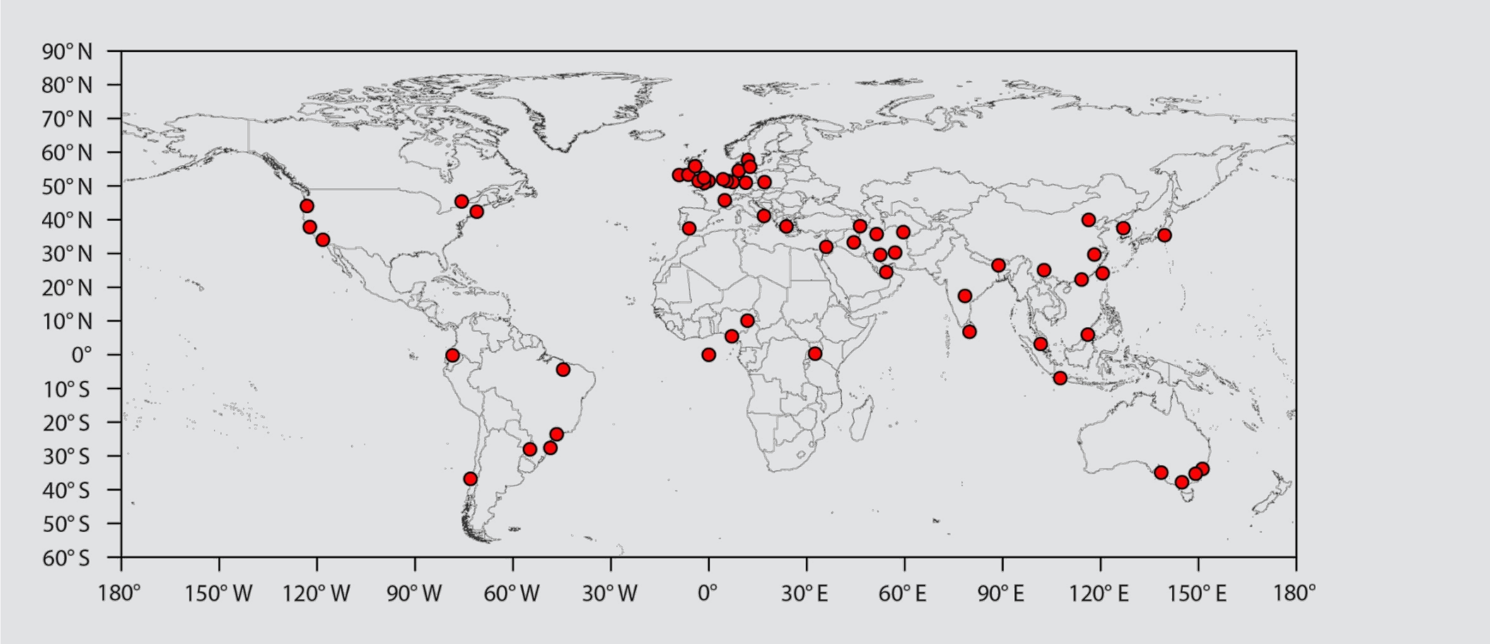
The challenge is to establish a reasonable balance between limiting building energy use and providing a comfortable and healthy indoor environment for occupants. Certain indoor environmental standards applicable to mechanically heated or cooled buildings are based on steady-state methods to specify an acceptable comfort temperature range during occupation, which requires the maintenance of stable indoor thermal environments. But, there is good evidence that strict control of indoor temperatures carries high energy costs and greenhouse gas emissions, and may not always be conducive to the comfort and health of occupants. Previous studies on adaptive thermal comfort have shown that acceptable ranges of indoor temperature are related to the annual seasonal cycle and outdoor climatic zone. As long as indoor temperatures are maintained within acceptable ranges appropriate to season and climate zone, people can achieve thermal comfort through three kinds of adaptive methods: physiological, psychological and behavioural response mechanisms. To this end, adaptive thermal comfort for occupants can provide an important framework for understanding how to balance that aspect of comfort with the other objectives, with which it often competes. Accommodating individual comfort differences through adaptive processes can improve occupants' satisfaction with the indoor thermal environment beyond levels normally achieved by existing standards. If the building services can operate in a 'part-time and part-space' mode according to individual occupant demands, instead of the 'whole-time and whole-space' mode commonly adopted, they can achieve improved thermal comfort while simultaneously reducing energy use.

Objectives

This project is developing an analytical and quantitative description of building occupants' adaptive thermal



An example of the thermal comfort visualization tool's 'satisfaction' page.
Source: Adapted from Földváry Ličina, V, Cheung, T, Zhang, H, de Dear, R et al. (2018) Development of the ASHRAE Global Thermal Comfort Database II, Building and Environment, vol 142, pp 502-512



The locations for which 84 researchers from 53 teams participating in EBC Annex 69 have applied the contextualized thermal comfort questionnaire in 59 cities distributed across 32 countries.
Source: Adapted from Marcel Schweiker, EBC Annex 69

comfort, predicated on reducing energy use while providing comfortable indoor environments. The objectives include the following:

- establish a global thermal comfort database with quantitative descriptions of adaptive responses;
- propose revised indoor environmental standards based on the adaptive thermal comfort concept;
- apply the adaptive thermal comfort concept for achieving low energy use intensities in buildings;
- provide guidelines for developing personal thermal comfort systems with perceived-control adaptation.

Deliverables

The following project deliverables are being produced:

- global thermal comfort database with 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 2018, the work on the global thermal comfort database has been documented in a journal paper, while the associated deliverable of an Internet database has been published. Regarding the work on contextual differences in the perception of thermal comfort scales, a large-scale international questionnaire-based study is ongoing. The survey includes 19 different language versions of the standard thermal comfort questionnaire with data collection ongoing. The longitudinal surveys of exemplary adaptive comfort case study buildings by 11 participating countries are finished and their detailed data analysis plan is on the way towards completion.

Meetings

The following project meetings took place in 2018:

- The 5th working meeting took place in Vancouver, B.C., Canada, in May, 2018, alongside a symposium, 'Field Studies on Low-Energy Systems in Buildings: Challenges and Opportunities for Thermal Adaptation'.
- The 6th working meeting took place in Ahmedabad, India, in October, 2018.

Project duration
2015–2019

Operating Agents
Yingxin Zhu, Tsinghua University, P.R. China
Richard de Dear, University of Sydney, Australia

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

Further information
www.iea-ebc.org

Indoor Air Quality Design and Control in Low Energy Residential Buildings

EBC ANNEX 68

Increasingly in many industrialised countries, contemporary new and fully-renovated existing residential buildings are designed to meet near zero energy targets, and thus are constructed with airtight building envelopes and controlled fresh air supply rates, provided for instance by mechanical ventilation systems. This project is investigating whether such energy optimisation places too high a burden on the operation of ventilation systems, leading to issues due to excessive indoor pollutant loads. With this in mind, the project is creating practical guidance on how to best operate buildings under such conditions, with particular emphasis on the ventilation. To this end, the project is gathering new information on pollutant sources in buildings, as well as documenting computational tools to assess indoor climatic conditions with respect to combined thermal, air, and moisture conditions and how these influence the emission and removal of indoor pollutants such as volatile organic compounds (VOCs).

Objectives

The project objectives are to:

- establish a set of performance metrics required to combine very high energy performance with good indoor air quality (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 provide comfortable and healthy indoor environments;
- identify and investigate relevant case studies, in which the above-mentioned performance can be examined and lessons learnt for the required optimisations.

Deliverables

The project deliverables are as follows:

- a report that defines the performance 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.

Progress

Ongoing work in 2018 has been pursuant to collecting and analysing source material as a basis for later reporting. Particular emphasis has been placed on developing 'common exercises'. These serve not only as platforms for structuring the project participants' use of the developed data and models, so helping with quality assurance of the project outcomes, but also for the benefit of the target audiences upon completion of the project. The specific topics of these exercises are as follows:

- definition of a reference house as a baseline for IAQ and energy use;
- a room scale exercise as an emissions modelling case;
- estimation of parameters for physical emissions source models from measured test chamber data;
- model comparisons of cases on combined heat, air and moisture transfer with pollutant emissions;
- a stakeholder survey mapping current practices, barriers and challenges related to residential ventilation;
- experimental data on hexane emissions in the 'PASSYS' test cell.

An example of decentralized ventilation with demand control.
Source: Sustain Solutions A/S, Denmark

Supplementing the above-mentioned model comparisons, extensive work has been carried out on implementing models for VOC transport and storage in an existing multi-dimensional simulation program. Moreover, the project has collected and analysed a set of case studies related to design and operation, with an example of these including demand based control of an innovative solution for decentralized ventilation. In a further example, VOCs have been measured in a study relying on metal oxide semiconductor sensors. Commercially available sensors have been investigated under typical residential activities. The results show that such sensors are capable of detecting VOC emissions events, but there are challenges with their use for ventilation control, since they mainly measure relative rather than absolute VOC concentrations, and there is a lack of calibration data. Results from this study were presented at a joint EBC Annex 68 and AIVC webinar.

Meetings

The following meetings took place in 2018:

- The 5th project working meeting took place in Shanghai, China, in March 2018 and was hosted by the Shanghai University for Science and Technology.
- The 6th project working meeting took place in September 2018 and was hosted by Syracuse University, NY, USA.

Project duration
2016 – 2020

Operating Agent
Carsten Rode, Technical University of Denmark, Denmark

Participating countries
Austria, Belgium, Canada, P.R. China, Czech Republic, Denmark, France, Germany, R. Korea, the Netherlands, New Zealand, Norway, UK, USA
Observers: Estonia

Further information
www.iea-ebc.org

Energy Flexible Buildings

EBC ANNEX 67

Large-scale integration of decentralized electricity production from renewable energy sources is often suggested as a key technology striving towards a sustainable energy system, mitigating fuel poverty and climate change. In many industrialised countries, the growing share of renewable energy sources goes in parallel with the extensive electrification of demand, for instance replacement of traditional cars with electrical vehicles, or displacement of fossil fuel heating systems, such as gas or oil boilers, with energy efficient heat pumps. At the same time, there are trends towards low temperature district heating networks supplied by different renewable sources. These changes on both the demand and supply sides impose new challenges to the management of energy systems, such as the variability and limited controllability of energy supply from renewables, or increasing load variations over the day. Consequently, managing the energy transition following the viewpoint taken for traditional energy systems would lead to grid operations closer to their limits, with a possible consequent increase of energy use at peak periods, requiring more complex controls with shorter decision times and smaller error margins.

As buildings presently account for a significant fraction of the annual energy use worldwide, they are likely to play a significant role in providing a safe and efficient operation of future energy systems. In fact, buildings have great potential to deliver significant flexibility services to energy systems by intelligent control of their energy loads, both thermal and electric. There is, however, a need for better 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 sources.

Objectives

The project objectives are as follows:

- 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.

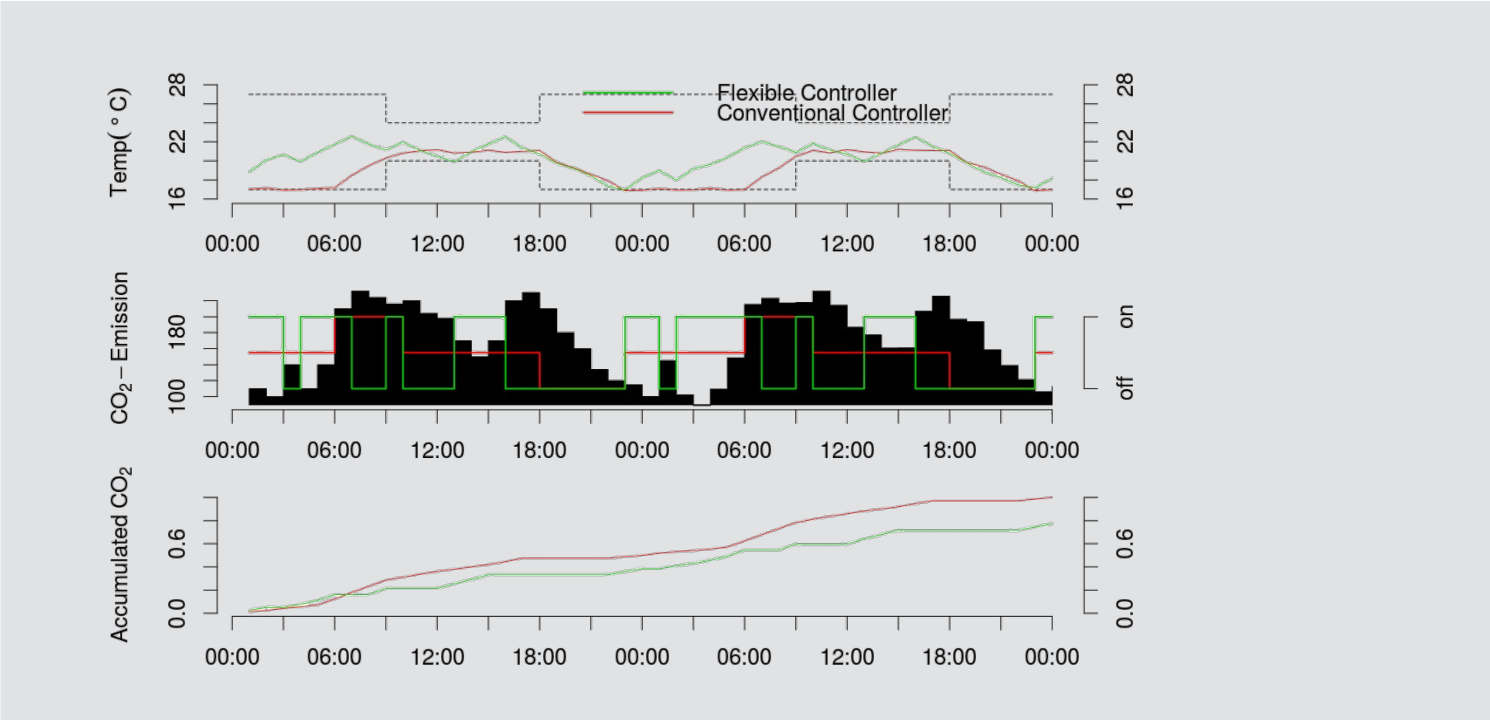
Deliverables

The following reports are being produced as project deliverables:

- principles of energy flexible buildings,
- characterization of energy flexibility in buildings,
- stakeholders' perspective on energy flexible buildings,
- control strategies and algorithms for obtaining energy flexibility in buildings,
- experimental facilities and methods for assessing energy flexibility in buildings,
- examples of energy flexibility in buildings, and
- project summary report.

Progress

During the project, a generic characterization methodology for energy flexibility has been developed and published in the paper, 'Characterizing the Energy Flexibility of Buildings and Districts' (https://doi.org/10.1016/j.apenergy.2018.05.037). For energy flexible systems (a building, for example) that are controlled to react to a penalty signal (representing energy price, for example), the methodology defines flexibility characteristics derived from the response of a system to a step change in the penalty signal, or a temporal penalty signal varying over the year. Two approaches have been introduced in the project to compute the flexibility characteristics: In the first of these, a data-



Top plot: The room temperature in a building is controlled by a penalty-aware controller (green line), or a conventional controller (red line). Both controllers are restricted to stay within the dashed lines.

Middle plot: The black columns give the penalty, while the green and red lines show when the two controllers call for heat.

Bottom plot: This shows the accumulated penalty for each of the controllers. Over the considered period, the penalty-aware controller results in about 20% lower CO_2 emissions compared to the traditional controller.

Source: https://doi.org/10.1016/j.apenergy.2018.05.037

driven approach is used, whereby system identification techniques are used to identify the response function based on time series data of the system output (energy use, for example) and the penalty signal. In the second, a simulation-based approach is followed, whereby the flexibility characteristics are derived from simulating the system responses to 'flat' and 'step' penalty signals respectively. In addition, an Excel-based tool for providing a standardized way for communicating results from the two approaches of the methodology (data driven, or simulation based) has been developed.

By means of common exercises and an intensive 'sprint week', project participants have put the developed methodology to a series of tests to evaluate its applicability and sensitivity to boundary conditions, shape and size of the penalty signal, initial conditions, and so on. The focus was on the simulation-based approach. While showing significant dependence of the flexibility characteristics to these circumstantial variables and the ability of the method to reflect this dependence for specific buildings, the study concluded that given a precise description of the calculation procedure, the methodology can be applied for inter-building comparisons as well.

Meetings

The following meetings took place in 2018:

- The 6th working meeting was held in Barcelona, Spain, in March 2018.
- The 7th working meeting was held in Montréal, Canada, in November 2018.

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

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

EBC ANNEX 65

In most industrialised countries, the thermal performance of building envelopes can be significantly improved to reduce heating and cooling loads, which together represent the largest buildings-sector energy end-use. The most efficient way to reduce unwanted heat losses or gains is the installation of thermal insulation. This is true for new buildings, as well as for existing ones. Moreover, by doing so, the comfort and quality of life for occupants can be drastically improved. The question can reasonably be asked, however, as to why new insulating materials should be developed 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, a few weak points still diminish the benefits of such solutions. Indeed, the performance of a thermal insulation system strongly depends on the continuity of the insulation layer, similarly as for airtightness. Even when external insulation is applied, due to the frequent complexity of the building envelope, in practice many thermal bridges remain with poorly insulating materials allowing heat flows to by-pass the insulation. Examples of the most commonly encountered thermal bridges include window reveals, balconies, acroteria, and decorative elements. A further challenge is the renovation of existing buildings with architecturally notable façades. In these cases, only interior insulation is possible and thin materials are required to achieve high insulating performance. An additional motivation for developing new insulating materials is the combustive behaviour when external insulation systems are installed on high rise buildings, as the flammable mass can be very high when using thick and sometimes flammable traditional insulating materials.

To tackle these challenges, a new generation of super-insulating materials (SIMs) has emerged on the market during the last few decades, mainly vacuum insulation panels (VIPs) and advanced porous materials (APMs) such as aerogels. In order to give confidence to end-users, this project is creating a set of procedures, applicable from laboratories through to construction sites. Firstly, these include a detailed methodology for characterizing their thermal properties and evaluating their durability, secondly a design tool to safely use SIMs on site, and finally an approach for life cycle assessment (LCA) of SIMs.

Objectives

SIMs are expected to form part of new advanced solutions to transform building envelope design from allowing to hindering heat transfer, and consequently playing a major role in responding to the energy efficiency challenge in the buildings sector. But, three mains conditions must be fulfilled to realise a successful outcome, which are 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 is finalising four official deliverables about SIMs:

- 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 aspects (life cycle analysis, life cycle costing, embodied energy).

Progress

In 2018, the main activity of the project has been the drafting of the four reports. The investigation of the state-of-the-art clearly shows that applications of SIMs

The installation process of the SLIMISOL system, consisting of a vacuum insulation panel with a protective layer and plaster board.
Source: www.slimisol.fr

are spreading rapidly around the world, but in absolute terms the SIM market is growing slowly. A large number of tests performed by the project participants have provided a comprehensive analysis of methods and procedures that have to be used to fully characterise SIMs. As the expected performance of SIMs will strongly depend on the installation on site, therefore, both a design procedure and guidelines for handling and installation are needed and they are being documented. As temperature and humidity are the main degradation factors for SIMs, the design procedure is based on heat and moisture simulation to avoid adverse conditions at their surfaces. This can be realized, either by defining the correct position of SIMs in the wall construction, 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 life cycle inventories (LCIs) of SIMs. The LCIA results of fumed silica VIPs with 'mass-based allocation' showed reasonably good agreement with the values published in existing Environmental Product Declarations (EPDs), at less than 10 kgCO_2eq. Meanwhile, the results based on 'economic based allocation' showed higher values than any of the published EPD results. This suggests that the LCIs collected in the project properly represent the products on the market when their impacts are calculated by mass-based allocation.

However, the LCIA results determined in the project for aerogels had quite a deviation with the published EPD values for the LCIs, actually for both of the drying methods used in their manufacture. This is because the best available LCI data collected during the project are not from full-scale production, and actually only represent pilot scale data. Thus, the LCIs collected may not be appropriate to be used for comparison with other insulation materials, as the aerogels may not yet be properly characterised. However, a 'hotspot analysis' has given a good insight into potential improvement opportunities for the environmental performance of aerogels, such as producing them in countries with low carbon electricity grids, such as France or Sweden.

Meetings

No project meetings were held in 2018.

Project duration
2013–2019

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

Air Infiltration and Ventilation Centre

EBC ANNEX 5

The principal goal of the Air Infiltration and Ventilation Centre is to provide reference information on ventilation and air infiltration in the built environment. Since its launch in 1979, the AIVC has been adjusting its scope to reflect emerging concerns, challenges and opportunities. Over that period, this major project's focus has markedly expanded beyond air infiltration energy losses to cover all building ventilation strategies with respect to efficient energy use and acceptable indoor environmental quality (IEQ) in new and existing buildings.

Objectives

The objectives of the AIVC are to:

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

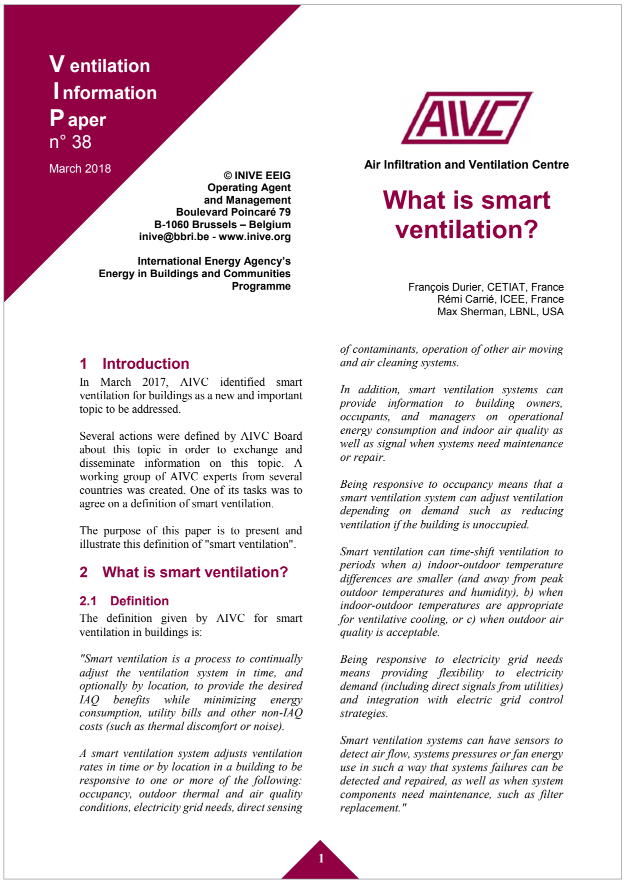
Deliverables

- Events: AIVC Annual Conference, one to two workshops per year on specific topics , with one to two webinars per year;
- Publications: conference and workshop proceedings, technical notes, contributed reports (typically one per year), and a biannual newsletter.

Progress

In 2018, the AIVC focused its work on nine projects, the 39th AIVC Annual Conference, two workshops, four webinars, and supporting discussions and dissemination for EBC Annex 62 on Ventilative Cooling and EBC Annex 80 on Resilient Cooling. The nine projects are entitled: 'BIM and ventilation and infiltration', '40 Years of AIVC', 'Smart Ventilation', 'Utilization of Heat Recovery', 'Rationale Behind Ventilation Requirements and Regulations', 'Integrating Uncertainties Due to Wind and Stack Effect in Declared Airtightness Results', 'Indoor Air Quality Metrics', 'Residential Cooker Hoods', and 'Competent Tester Schemes for Building Airtightness Testing'.

In particular, the 'Smart Ventilation' project published Ventilation Information Paper, 'What is smart ventilation?', presenting and illustrating the definition of 'smart ventilation'. The recently launched project '40 years of AIVC', is anticipated to result in Technical Note 'AIVC after 40 years', highlighting the progress and outcomes


Ventilation Information Paper
n° 38
March 2018

© INIVE EEIG
Operating Agent
and Management
Boulevard Poincaré 79
B-1060 Brussels – Belgium
inive@bbri.be - www.inive.org

International Energy Agency's
Energy in Buildings and Communities
Programme

AIVC
Air Infiltration and Ventilation Centre

What is smart ventilation?

François Durier, CETIAT, France
Rémi Carrié, ICEE, France
Max Sherman, LBNL, USA

1 Introduction

In March 2017, AIVC identified smart ventilation for buildings as a new and important topic to be addressed.

Several actions were defined by AIVC Board about this topic in order to exchange and disseminate information on this topic. A working group of AIVC experts from several countries was created. One of its tasks was to agree on a definition of smart ventilation.

The purpose of this paper is to present and illustrate this definition of "smart ventilation".

2 What is smart ventilation?

2.1 Definition

The definition given by AIVC for smart ventilation in buildings is:

"Smart ventilation is a process to continually adjust the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise).

A smart ventilation system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following: occupancy, outdoor thermal and air quality conditions, electricity grid needs, direct sensing of contaminants, operation of other air moving and air cleaning systems.

In addition, smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as signal when systems need maintenance or repair.

Being responsive to occupancy means that a smart ventilation system can adjust ventilation depending on demand such as reducing ventilation if the building is unoccupied.

Smart ventilation can time-shift ventilation to periods when a) indoor-outdoor temperature differences are smaller (and away from peak outdoor temperatures and humidity), b) when indoor-outdoor temperatures are appropriate for ventilative cooling, or c) when outdoor air quality is acceptable.

Being responsive to electricity grid needs means providing flexibility to electricity demand (including direct signals from utilities) and integration with electric grid control strategies.

Smart ventilation systems can have sensors to detect air flow, systems pressures or fan energy use in such a way that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement."

1

The latest project publication 'Ventilation Information Paper n° 38: What is smart ventilation?', published in 2018.
Source: EBC Annex 5

over these 40 years with contributions from various AIVC Board experts.

The 39th AIVC Annual Conference was held in Juan-Les-Pins, France in September 2018. The theme of the conference was 'Smart Ventilation for Buildings', attended by 207 people from 27 countries. Several topical sessions related to AIVC projects were organized during the event. Also, EBC Annex 78 'Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications' and EBC Annex 80 organized specific sessions to discuss their approaches and future plans.

Two AIVC workshops were held in March 2018:
- 'Towards higher-performing buildings: The role of airtightness and ventilation' was convened in Wellington, New Zealand co-organized with ASHRAE and BRANZ;
- 'Ventilation for Indoor Air Quality and Cooling' workshop in Sydney, Australia, co-organized with the Cooperative Research Centre for Low Carbon Living.

The AIVC also contributed to the organization of four webinars on ductwork airtightness, smart ventilation, ventilative cooling, and on low-cost sensors for ventilation control, the latter in collaboration with EBC Annex 68 'Design and Operational Strategies for High IAQ in Low Energy Buildings'.

In order to have more interaction with related organisations, AIVC is a founding member of the Indoor Environmental Global Alliance (www.ieq-ga.net). There is also close co-operation with the TightVent (www.tightvent.eu) and venticool (www.venticool.eu) platforms.

Meetings

The AIVC Board met twice in 2018:
- Wellington, New Zealand, in March, 2018, and
- Sophia Antipolis, France, in September 2018.

AIVC Newsletter

March 2018
September 2018

Project duration
1979–2021

Operating Agent
Peter Wouters, INIVE eeig, Belgium

Participating countries
Australia, Belgium, P.R. China, Denmark, France, Italy, Japan, the Netherlands, New Zealand, Norway, R. Korea, Spain, Sweden, UK,USA

Further information and reports
www.iea-ebc.org

AIVC

www.aivc.org

Completed Research Projects

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

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)

Definition and Simulation of Occupant Behavior in Buildings

EBC ANNEX 66

As building envelopes and services equipment become more efficient, the relative impact of occupants on building energy use increases. Meanwhile, for many countries with trends towards teleworking, co-working and home-sharing, this means a change to vastly different occupancy patterns than at present. Finally, occupants' expectations for comfort are generally increasing, but the success of new technologies in meeting those demands is not guaranteed simultaneously with limiting energy use. The convergence of these trends has necessitated a new look at how occupants are modelled in simulation-aided building design and operations. Occupant behaviour has significant impacts on energy use and occupant comfort. Insights into occupant behaviour, developed through quantitative representation and simulation of occupant-building interactions, can help building designers, engineers, and policy makers understand and reduce the gap between building energy performance when simulated at design stage and measured during operation. This project has played an important role in formalizing research methods, modelling and model validation, and simulation of occupant behaviour.

Achievements

In response to the trends mentioned above, the major project outcome is a scientific methodological framework to guide occupant behaviour research in the areas of:

- data collection;
- model building and evaluation;
- simulation tool development, integration, and application;
- interdisciplinary issues.

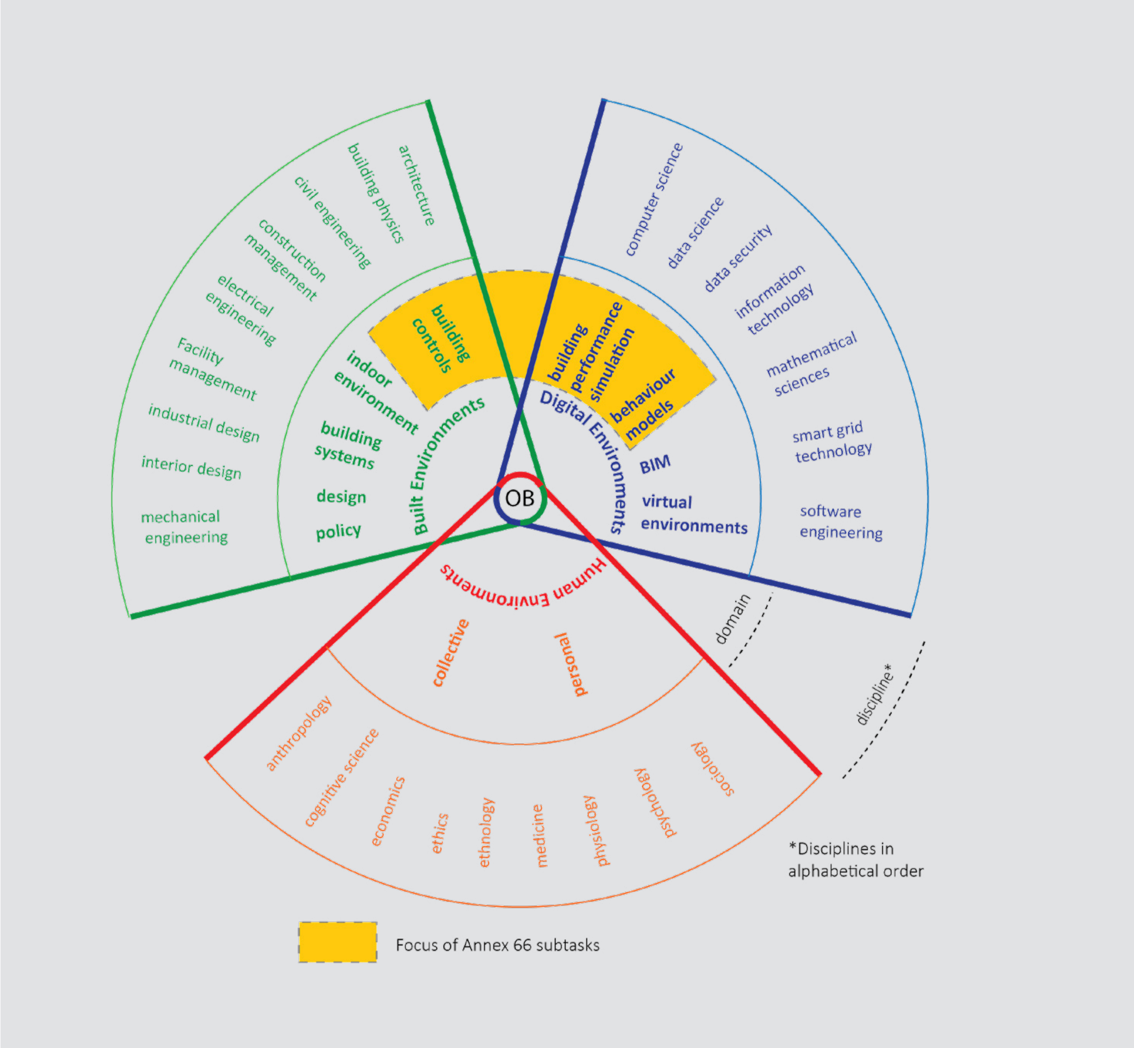
In terms of innovative aspects, it has resulted in major accomplishments, as follows:

- identified quantitative descriptions and classifications of occupant behaviour;
- developed methods for occupant behaviour measurement, modelling, evaluation and application;
- implemented occupant behaviour models in building performance simulation tools;
- demonstrated application of occupant behaviour models in design, evaluation and operational optimization using case studies.

Occupant behaviour models need to be integrated with building performance simulation programs. A standardized data representation (an 'XML schema') was developed through the project to represent occupant behaviour, enabling the interoperability of occupant behaviour models across different simulation tools and user applications. An associated occupant behaviour software module was also developed that enables co-simulation of quantitative behaviour models with building performance simulation tools such as EnergyPlus, ESP-r and DeST. In parallel, an agent-based Occupancy Simulator was also created and integrated with OpenStudio, allowing the generation of more realistic occupant schedules as inputs to building simulations.

User-friendly interfaces and modelling guides are needed for effective behaviour model application. So, a collection of 32 case studies have been compiled to show the applications of occupant behaviour sensing, data collection, modelling, simulation, and analysis in the building life cycle. Guidance on occupant behaviour modelling and application has also been developed. Energy policy makers can take advantage of occupant behaviour modelling to improve decision making. The availability of quantitative behaviour models can facilitate the development of more effective policies for reducing energy use in buildings that leverage knowledge of likely occupant actions and their influence on building performance.

Combining thermal comfort with sociological research may shed light on key socio-economic factors to be considered in modelling occupant behaviour. Therefore, the project has recommended that the evaluation of occupant behaviour models requires the use of explicit, application-specific metrics that quantify model performance under the given application.



Domains and disciplines relevant to occupant behaviour research.
Source: EBC Annex 66

Interdisciplinary research across the building, social, behavioural, data and computer sciences is needed to understand, represent, model, and quantify the impact of human behaviour on building energy use and occupant comfort. In addition to establishing an interdisciplinary research community and framework, the project has developed an interdisciplinary cross-country survey on occupant energy-related behaviour in buildings, which provides valuable insights into occupant behaviour and the basis of occupant behaviour modelling and simulation.

Publications

The project deliverables include the final report and the following:

- a guidebook on monitoring, data collection and modelling for occupant behaviour research,
- an international survey of occupant behaviour in workspaces,
- guidelines for behaviour modelling and evaluation,
- surveys to understand current needs, practice and capabilities of occupant modelling in building simulation, and
- occupant behaviour case study sourcebook.

Project participants have authored four topical issues for three journals and have published over 100 journal articles. Further research into this topic is being progressed both through the current EBC project 'Annex 79: Occupant-Centric Building Design and Operation' and the ASHRAE project 'Multidisciplinary Task Group on Occupant Behaviour in Buildings'.

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

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

EBC ANNEX 64

Commonly in industrialised countries, fossil fuel based systems using combustion processes are used directly to satisfy heating demands and indirectly via electricity generation for cooling demands. The 'exergy' (energy quality) available from fossil fuels is high, which can be used for instance to supply heat at high temperature, or to generate electricity. The exergy generated from renewable energy sources varies in quality. For example, electricity generated from photovoltaic panels is high exergy, but low temperature heat produced from other renewable energy sources is low exergy ('LowEx'). Low energy quality is of particular interest for heating applications at moderate temperatures, because LowEx systems can be very efficient. By applying exergy analysis, improved energy system designs become possible including for heating and cooling of buildings, and more rational use of available energy sources can be achieved. To exploit these potentials and synergies demands an overall analysis and holistic understanding of energy conversion processes, not only for individual buildings, but also at community scales for districts and cities.

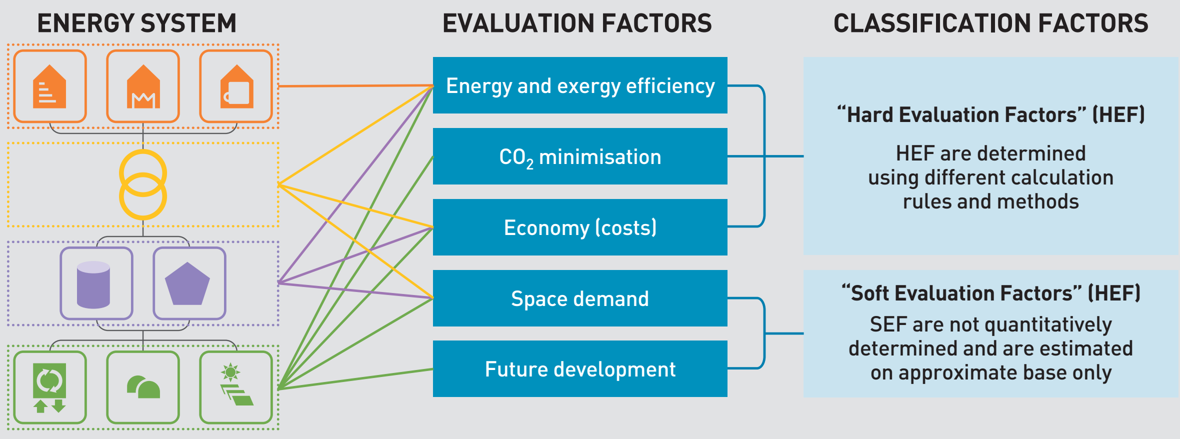
The aim of exergy analysis for community energy systems is to minimise exergy losses as much as possible and reasonable. This project has advanced the knowledge needed to significantly increase the overall energy and exergy efficiency of community systems and has also carried out technological development of promising LowEx technical solutions and practical approaches to future network management. Also, the identification of business models for distribution and operation and the development of assessment methods and tools for various stages of planning were the main objectives.

Achievements

As a framework for the research, the theoretical basis for the application of the exergy concept to analyse energy utilisation in communities was reviewed at the start of the project. Based on the outcomes of previous research, a planning approach suitable for communities was then created. The project has also shown that in addition to exergy, other criteria, such as the potential for use of renewable energy sources, energy storage, or costs are best considered separately. Specific approaches have been created for how to apply the exergy concept in different phases of the design process for sustainable energy communities, supported by a 10-step planning approach that is easy to understand and apply. Further, guidance has been provided on the use of exergy principles in the various phases of the planning process. Through techniques developed, simplified exergy analyses may be performed during early design to develop the strategy for the energy system. For application later on during detailed design and optimization, various analysis tools have also been produced.

Suitable approaches for the exergy assessment of the various system components have been explored in the project. Aside from the planning approach developed, the project has identified and documented the most promising and efficient supply technologies to allow the flexibility to respond to different energy demand profiles. Such technologies, for example solar thermal collectors, help to maximise the share of low-valued local and renewable energy sources. Decentralised and centralised supply solutions and thermal storage technologies have also been compared. As technological considerations include both demand- and supply-side aspects, the need to take into account efficient building thermal fabric and occupant behaviour has also been explained.

A range of case studies at different scales have been documented. These treat heat and electricity as a single system in a way that makes exergy calculations, comparisons between systems with similar characteristics, and interpretation of results more consistent and useful, compared to the conventional energy-based approach. The following conclusions have been drawn from them:



The main principle of the assessment of a community energy supply using the exergy assessment approach.
Source: Adapted from Anna Kallert, Fraunhofer IEE, Germany

- Buildings destroy more input exergy than they lose and produce, with typically about 84% to 93% of exergy destroyed by irreversible energy transfer processes.
- Exergy-based control is suitable to achieve energy efficient building operation. Using dynamic simulation models, exergy analysis can be fully automated and used for model-based control.
- Exergy analyses based on annual measurements have shown that ultra-low temperature district heating (ULTDH) systems with local electric temperature boosts have higher exergy efficiency compared to existing district heating (DH) systems.
- A low energy demand can be achieved by high performance building fabric and low thermal losses along the network, high fractions of energy produced from renewables and good exergy efficiency, compared to traditional thermal systems.
- Conventional energy production systems can be significantly improved in terms of exergy input and exergy efficiency by replacing part of the heat production from fossil fuels by heat production from low-exergy sources.
- Lowering the supply and / or return temperatures increases the exergy efficiency of DH networks and consequently the whole system. However, it has to be kept in mind when decreasing the supply temperature that the water flow rate should be carefully considered to avoid an increase of energy costs for pumping.
- The low-exergy approach allows the identification of which component or configuration of the system to focus on, to implement and improve low-temperature DH networks and so to reduce use of fossil fuels, resulting in a lower overall exergy input and also reduced CO_2 emissions. By implementing ULTDH, distribution heat losses can be substantially avoided.

As part of the work, the assessment methodologies behind various tools and calculation methods have been investigated and documented. In total, 14 models and tools related to exergy assessment, including five methods, six models and six tools were identified. Five of these can assess energy systems using certain optimisation algorithms. Seven models can be applied in the design stage, with nine models and tools suitable for application in the operational stage. In addition, the overall system boundaries have been explained, relating to which seven of them can assess energy systems from the building scale to community scale.

Publications

The main outcome of the project research is the 'Design Guidebook for Low Exergy Communities', which has been prepared for designers and key decision makers in the field of community energy systems.

Project duration
2013–2018

Co-Operating Agents
Dietrich Schmidt and Christina Sager-Klauss, Fraunhofer Institute for Energy Economics and Energy Systems 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 energy-related greenhouse gas (GHG) emissions and it has become evident that drastic reductions of both their energy use and the associated GHG emissions are essential. For urban areas, this transition needs high investments in buildings, energy and mobility infrastructure that can only be generated when further benefits are considered. 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 previous EBC project 'Annex 51: Energy Efficient Communities' focused on the optimization of energy systems at community scale, this project has provided recommendations on procedures for implementation of optimized energy strategies at the scale of communities in the context of urban development. The project outcomes primarily serve the needs of urban decision makers alongside urban and energy planning departments. The general goal can be described as 'to put energy in urban planning processes'. Since there is no unique solution, and hence no single objective, the following specific goals were set to tackle the overall problem with respect to the diverse challenges:

- development of recommendations for implementation of optimized energy strategies;
- effective translation of citywide energy and GHG reduction goals to the community scale;
- optimization of policy instruments for the integration of energy and GHG reduction goals into common urban planning processes;
- development of new techniques for stakeholder cooperation along with holistic business models involving a wide range of stakeholders;
- division of methods for the monitoring and evaluation of energy- and GHG-related building criteria, as well as the effectiveness of policy instruments;
- involvement of cities and urban planners in order to integrate energy planning in urban planning procedures;
- enabling win-win solutions for cities, citizens, economy and environment.

Achievements

Based on a better understanding of current energy and urban planning processes relevant measures for success were analyzed and clustered in nine strategic measures, which are identified as key for improved implementation of energy strategies at community scale. Contextualization of analyzed case studies led to better knowledge on boundary conditions for implementation of the strategic measures. A highly practical approach has been achieved by several feedback loops involving 22 cities. In general, the strategic measures describe the relevant implementation tasks. These measures are 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 greenhouse gas emissions;
- undertake stakeholder engagement and involvement;
- include socio-economic criteria;
- implement effective and efficient organizational processes.

Information on problems and challenges, description of actions, links to case studies and recommendations has been published by the project. Additionally, each strategic measure is set in relation to generalized planning process steps to give better guidance on implementation. The project has produced a self-assessment tool based on six questions for each of the strategic measures to allow cities to make initial indicative analyses of their strengths and potentials. The questions focus on the following themes:

- awareness of benefits and content of the strategic measure;
- available skills, knowledge and resources for the implementation of the strategic measure;
- regular application of the strategic measure;

Illustration of the four dimensions involved in community development.
Source: Adapted from DTU and AAU, 2017

- quality of the application of the strategic measure;
- efficiency of the application of the strategic measure in the municipality (any impact);
- barriers and success factors of the application in the municipality.

Analysis of urban and energy planning processes has shown that making changes to existing processes is very complex because these must take into account the needs of different stakeholders (for example politicians, administrators, investors, and planners) and the impacts of different topics (for example visions, goals, process flow, and organisation). Therefore, social skills and practical recommendations are necessary to initialize the change process.

A key recommendation for policy and decision makers arising from this project is that simple upscaling of building-level solutions to the district scale is not possible. To optimise the energy supply for urban development projects, solutions at an individual building scale are necessary, but a broader framework is needed at an early stage within urban planning. Therefore, it is important to include all relevant stakeholders early in the planning process and to understand their potential contributions. This can be done by restructuring existing urban planning processes and strengthening them with additional internal or external expertise. The well-implemented adaption of urban planning processes is likely to have a more significant impact on energy use and GHG emissions within a country compared to the optimisation of only the building stock. So, if the energy strategy recommendations are deployed at a large scale, high impacts could be achieved with low costs, and creating the basis for national or regional change management processes.

Publications

The project outcomes provide guidance for cities in setting their priorities for further actions, which are described in reports on the strategic measures, with additional support given for stakeholders. The following reports have been published as the official project deliverables:

Volume 0: Documentation of workshops and involvement of cities
Volume 1: Inventory of measures
Volume 2: Development of strategic measures
Volume 3: Application of strategic measures
Volume 4: Stakeholder support materials
Volume 5: Recommendations

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

The current trend in building energy efficiency towards nearly-zero energy buildings in many industrialised countries has inadvertently led to increased cooling demands. In fact, post-occupancy studies of high performance buildings have commonly revealed that the most frequently reported type of problem has been elevated indoor temperature levels. This situation has been encountered particularly in high performance residential buildings, because the usual design process has been too simplified and has been based to a large extent on previously acquired experience and existing rules of thumb. To reach a low energy need for heating, designers typically apply guidelines created in the past for 'passive solar' buildings. For such buildings, insulation and airtightness have not been required to achieve the more demanding current levels, and today's designers may therefore underestimate or even neglect the need for cooling loads to be addressed. For offices and other non-residential buildings, the challenges differ from residential buildings and mainly relate to the development of new approaches to reducing the existing energy use for cooling to meet high performance requirements. In high performance buildings in temperate climates, the cooling demands depend less on the outdoor temperature, and more on solar insolation and internal heat gains. This naturally gives better potential for the use of ventilative cooling, as the cooling demand not only arises in the summer, but can occur all year round.

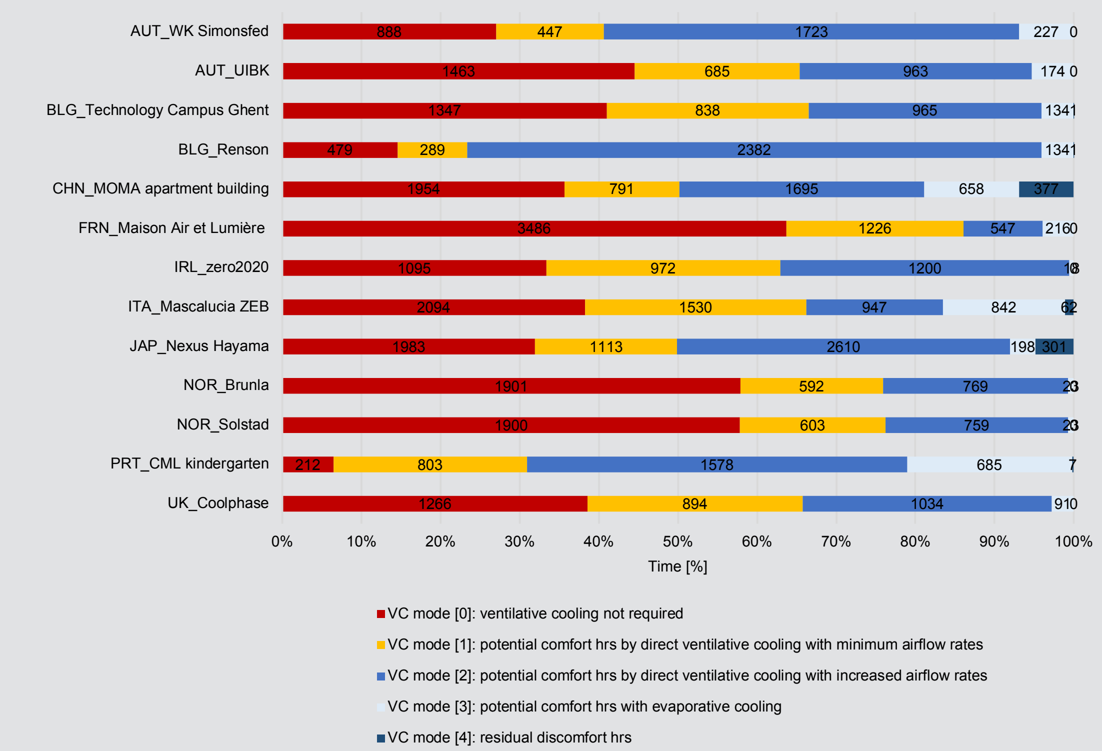
At the start of the project, the general technological development status of ventilative cooling for residential buildings was judged to be low in the participating countries, but with good potential identified for technology transfer between those countries. Moreover, there was considered to be only limited awareness among occupants and designers on how to cool such buildings in an efficient and energy optimal way. In contrast, the general status for offices and other non-residential buildings with full mechanical ventilation was thought to be reasonably advanced, although the increased use of electricity for fans would lessen the energy advantage. Again, good potential for technology transfer was identified at the outset for non-residential buildings.

In most of the participating countries, prediction tools previously developed as part of their national mandatory energy rating systems are typically used for residences and small office buildings. Such tools are capable of computing basic estimates of cooling loads and within some of them the risk of overheating as well. For the design of large offices and other non-residential buildings, more detailed thermal calculation tools are typically used for evaluating the cooling need and overheating risk. While the technological development status of these calculation methods in the participating countries was estimated to be initially low, certain countries were assessed to be more advanced, also giving the opportunity for technology transfer.

Achievements

Through the technological advances made in this project, it has been clearly demonstrated that ventilative cooling can have considerable impact on reducing the risk of overheating in all climates experienced within the participating countries. In cold and moderate climates, the risk of overheating can be eliminated completely, while in warm and hot climates supplementary cooling solutions are needed to ensure acceptable comfort levels. In cold climates, daytime ventilative cooling is sufficient to remove the cooling loads, while in most other climates it is essential to apply night cooling strategies to efficiently remove excess heat. In warm and hot climates, daytime ventilative cooling strategies have very limited effect, while night cooling strategies are more efficient.

A decision making tool has been created for assessing the potential effectiveness of ventilative cooling strategies by taking into account building envelope thermal properties, occupancy patterns, internal gains, ventilation needs and the outdoor climate. This is intended for application



An outcome of the tool, the ventilative cooling (VC) potential of the project case studies divided into the different ventilative cooling modes. Results differ even for buildings within the same climate because of their different usage characteristics.
Source: EBC Annex 62

at the conceptual design phase. Further, the project has developed new key performance indicators to characterise the energy benefits of ventilative cooling.

Following a state of the art review of the existing situation, recommendations have been devised for adequate implementation of ventilative cooling in standards, legislation and compliance tools, with the main focus on natural ventilative cooling parameters. In fact, the project has developed new work items relevant to ventilative cooling recently approved for application by the European Committee for Standardization (CEN) and the International Organization for Standardization (ISO). The outcomes include recommendations relevant for European, ISO and national standards, as well as to national and regional legislation.

The project has established an international ventilative cooling applications database that contains 91 buildings located in Europe. The entries offer illustrative descriptions of buildings of different usages, sizes and locations, which use ventilative cooling as a means of indoor thermal comfort improvement. Also, well documented case studies using ventilative cooling from across the world were collected. Within these case studies, rich information is available about their design, construction and operational performance. Several key lessons have been learned from the case studies: Some of these relate to the finding that the design of a building incorporating ventilative cooling can be challenging, requiring highly detailed building information.

Publications

The project outcomes have been reported in five publications that are available from the EBC website:

- Ventilative Cooling State of the Art Review
- Ventilative Cooling Design Guide
- Ventilative Cooling Case Studies
- Ventilative Cooling Source Book
- Recommendation on ventilative cooling for standards and regulation

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

Background Information

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 TCP 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 support the acceleration of the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge, technologies and processes and other solutions through international collaborative research and open 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:

- Mission Innovation (MI)
- 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) – EBC 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

– 39th AIVC Annual Conference Proceedings, September 2018, Antibes Juan-Les-Pins, France

Ventilation Information Papers

–VIP 35: Ventilative Cooling State-of-the-art Review Executive Summary, 2017
– VIP 36: Metrics of Health Risks from Indoor Air, 2017
– VIP 37: Impact of Energy Policies on Building and Ductwork Airtightness, 2017
– VIP 38: What is smart ventilation?, 2018

Contributed Reports

– CR 17: Indoor Air Quality Design and Control in Low-energy Residential Buildings – EBC Annex 68 Subtask 1: Defining the Metrics, 2017

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

High Temperature Cooling and Low Temperature Heating in Buildings – EBC 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 – EBC Annex 60

– Final Report, 2017

Business and Technical Concepts for Deep Energy Retrofit of Public Buildings – EBC 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 – EBC Annex 62

– Ventilative Cooling Sourcebook, 2018
– Ventilative Cooling Design Guide, 2018
– Ventilative Cooling Case Studies, 2018
– Status and Recommendations for Better Implementation of Ventilative Cooling in –Standards, Legislation and Compliance Tools, 2018

Implementation of Energy Strategies in Communities – EBC Annex 63

– Volume 1: Inventory of Measures, 2017
– Volume 2: Development of Strategic Measures, 2017
– Volume 3: Application of Strategic Measures, 2018
– Volume 4: Stakeholder Support Materials, 2018
– Volume 5: Recommendations, 2018

Definition and Simulation of Occupant Behavior in Buildings – EBC Annex 66

– Final Report, 2018
– Reference Procedures for Obtaining Occupancy Profiles in Residential Buildings, 2018
– Technical Report: An International Survey of Occupant Behavior in Workspaces, 2017
– Technical Report: Studying Occupant Behavior in Buildings - Methods and Challenges, 2017
– Technical Report: Surveys to Understand Current Needs, Practice and Capabilities of Occupant Modeling in Building Simulation, 2017
– Technical Report: Occupant Behavior Modeling Approaches and Evaluation, 2017
– Technical Report: Occupant Behavior Case Study Sourcebook, 2017

EBC Executive Commitee Members

CHAIR
Dr Takao Sawachi (Japan)

VICE CHAIR
Prof Paul Ruyssevelt (United Kingdom)

AUSTRALIA
Stanford Harrison
Department of the Environment and Energy
Stanford.Harrison@environment.gov.au

AUSTRIA
DI (FH) Isabella Warisch
Austrian Federal Ministry of Transport, Innovation and Technology
Isabella.Warisch@bmvit.gv.at

BELGIUM
Dr Peter Wouters
Belgian Building Research Institute (CSTC – WTCB)
peter.wouters@bbri.be

CANADA
Meli Stylianou
Natural Resources Canada
meli.stylianou@canada.ca

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

CZECH REPUBLIC
Hana Rambousková
Ministry of Industry and Trade
rambouskova@mpo.cz

DENMARK
Prof Per Heiselberg
Aalborg University
ph@civil.aau.dk

FINLAND
Dr Ala Hasan
VTT Technical Research Centre of Finland
Ala.Hasan@vtt.fi

FRANCE
Nicolas Doré
Agence de l'Environment et de la Maitrise de l'Energie
nicolas.dore@ademe.fr

GERMANY
Katja Riess
Forschungszentrum Juelich
k.riess@fz-juelich.de

IRELAND
Dr Brendan Cahill
Sustainable Energy Authority of Ireland
Brendan.Cahill@seai.ie

ITALY
Michele Zinzi
ENEA - UTEE ERT
michele.zinzi@enea.it

JAPAN
Dr Eng Takao Sawachi (Chair)
Building Research Institute, Japan
tsawachi@kenken.go.jp

REPUBLIC OF KOREA
Dr Seung-eon Lee
Korea Institute of Construction Technology
selee2@kict.re.kr

NETHERLANDS
Daniël van Rijn
Netherlands Enterprise Agency
daniel.vanrijn@rvo.nl

NEW ZEALAND
Michael Donn
Victoria University of Wellington
michael.donn@vuw.ac.nz

NORWAY
Mari Lyseid Authen
Norges Forskningsråd
mlau@forskningsradet.no

PORTUGAL
João Mariz Graça
Direção-Geral de Energia e Geologia
joao.graca@dgeg.pt

SINGAPORE
Tan Tian Chong
Building and Construction Authority
TAN_Tian_Chong@bca.gov.sg

SPAIN
Francisco Rodriguez Pérez-Curiel
Tecnalia Research & Innovation
francisco.rodriguez@tecnalia.com

SWEDEN
Mehmet Bulut
Swedish Energy Agency
Mehmet.Bulut@energimyndigheten.se

SWITZERLAND
Andreas Eckmanns
Bundesamt für Energie BFE
andreas.eckmanns@bfe.admin.ch

UK
Prof Paul Ruyssevelt (Vice Chair)
University College London
p.ruyssevelt@ucl.ac.uk

USA
David Nemtzow
US Department of Energy
David.Nemtzow@ee.doe.gov

EBC Executive Committee Support and Services Unit (ESSU)
Malcolm Orme
essu@iea-ebc.org

IEA Secretariat
Brian Dean
brian.dean@iea.org

EBC Operating Agents

Air Infiltration and Ventilation Centre (AIVC) – EBC Annex 5
Dr Peter Wouters
INIVE EEIG, Belgium
info@aivc.org

Ventilative Cooling – EBC Annex 62
Prof Per Heiselberg
Aalborg University, Denmark
ph@civil.aau.dk

Long-term Performance of Super-insulating Materials in Building Components and Systems – EBC Annex 65
Daniel Quenard
Centre Scientifique et Technique du Bâtiment, France
daniel.quenard@cstb.fr

Energy Flexible Buildings – EBC Annex 67
Søren Østergaard Jensen
Danish Technological Institute, Denmark
sdj@teknologisk.dk

Design and Operational Strategies for High IAQ in Low Energy Buildings – EBC Annex 68
Prof Carsten Rode
Technical University of Denmark, Denmark
car@byg.dtu.dk

Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings – EBC Annex 69
Prof Yingxin Zhu
Tsinghua University, P.R. China
zhuyx@tsinghua.edu.cn

Prof Richard de Dear
University of Sydney, Australia
richard.dedear@sydney.edu.au

Building Energy Epidemiology: Analysis of Real Building Energy Use at Scale – EBC Annex 70
Dr Ian Hamilton
University College London, UK
i.hamilton@ucl.ac.uk

Building Energy Performance Assessment Based on In-situ Measurements – EBC Annex 71
Prof Staf Roels
University of Leuven, Belgium
staf.roels@bwk.kuleuven.be

Assessing Life Cycle Related Environmental Impacts Caused by Buildings – EBC Annex 72
Rolf Frischknecht
treeze Ltd., Switzerland
frischknecht@treeze.ch

Towards Net Zero Energy Resilient Public Communities – EBC Annex 73
Dr Alexander M. Zhivov
Energy Branch US Army Corps of Engineers, USA
Alexander.M.Zhivov@erdc.usace.army.mil

Rüdiger Lohse
KEA-Climate protection and energy agency of Baden-Württemberg GmbH, Germany
ruediger.lohse@kea-bw.de

Competition and Living Lab Platform – EBC Annex 74
Prof Karsten Voss
University Wuppertal, Germany
kvoss@uni-wuppertal.de

Prof Sergio Vega
Technical University of Madrid, Spain
sergio.vega@sdeurope.org

Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables – EBC Annex 75
Dr Manuela Almeida
University of Minho, Portugal
malmeida@civil.uminho.pt

Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO_2 Emissions – EBC Annex 76 / SHC Task 59
Dr Alexandra Troi
EURAC Research, Italy
Alexandra.Troi@eurac.edu

Integrated Solutions for Daylighting and Electric Lighting – EBC Annex 77 / SHC Task 61
Dr-Ing Jan de Boer
Fraunhofer Institute for Building Physics, Germany
jan.deboer@ibp.fraunhofer.de

Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications – EBC Annex 78
Prof Bjarne Olesen
Technical University of Denmark
bwo@byg.dtu.dk

Dr Pawel Wargocki
Technical University of Denmark
paw@byg.dtu.dk

Occupant Behaviour-Centric Building Design and Operation - EBC Annex 79
Dr Liam O'Brien,
Carleton University
liamobrien@cunet.carleton.ca

Prof Andreas Wagner
Karlsruhe Institute of Technology
wagner@kit.edu

Resilient Cooling for Residential and Small Commercial Buildings - EBC Annex 80
Dr Peter Holzer
Institute of Building Research and Innovation
peter.holzer@building-research.at

HVAC Energy Calculation Methodologies for Non-residential Buildings EBC Working Group
Dr Eng Takao Sawachi
Building Research Institute, Japan
tsawachi@kenken.go.jp

Communities and Cities EBC Working Group
Helmut Strasser
Salzburg Institute for Regional Planning and Housing, Austria
helmut.strasser@salzburg.gv.at

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
Annex 58 Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurement
Annex 59 High Temperature Cooling and Low Temperature Heating in Buildings
Annex 60 New Generation Computational Tools for Building and Community Energy Systems
Annex 61 Business and Technical Concepts for Deep Energy Retrofit of Public Buildings
Annex 62 Ventilative Cooling
Annex 63 Implementation of Energy Strategies in Communities
Annex 64 LowEx Communities – Optimised Performance of Energy Supply Systems with Exergy Principles
Annex 66 Definition and Simulation of Occupant Behavior in Buildings

EBC is a Technology Collaboration Programme (TCP) of the International Energy Agency (IEA)