EBC

Energy in Buildings and
Communities Programme

Annual Report 2019

EBC

Energy in Buildings and Communities Programme

International Energy Agency

EBC Annual Report 2019

Energy in Buildings and Communities Programme

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Front cover image: The University of Wollongong's Sustainable Buildings Research Centre in Australia, which has achieved full marks under the Living Building Challenge sustainability standard for buildings.
Source: COX Architecture
Photographer: Jenny Yip, Gollings Photography Pty Ltd

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Contents

EBC Executive Committee Chair's Statement

According to the IEA Energy Technology Perspectives (2017), the energy use intensity (expressed as energy use per unit floor area) has decreased by 25 % in OECD countries and by 35 % in non-OECD countries since 1990. But, the world total energy use in buildings has increased by 35 % due to an increase of total floor area by 61 % and 128 % respectively in each group of countries (up to 2014). This means that while the buildings sector has achieved some successes, its efforts need to be sustained.

As part of the major international R&D efforts taking place for the buildings sector, EBC's innovation approach is conducted mainly through development of theory, reproduction of physical phenomena, and validation by experiments, field measurements, and demonstration projects. Sometimes, it is difficult to fully validate a theory, but their development sits at the core of the EBC's activities. Validated theories are not only essential for explaining fundamental physical phenomena, but also for achieving reliable design and installation practices for buildings, including systems such as heating, ventilation, air conditioning, domestic hot water, lighting, energy generation, controls, and so on.

Existing design and installation practices require improvement with the help of external researchers through scientifically based analysis. The scientific basis of many conventional design and installation practices in the building sector is not well documented, nor is it sufficiently transparent. Therefore, it takes significant effort by researchers to approach and improve such practices. This is the main reason why certain existing standards need to be revised, or even new standards created. However, it is not always straightforward for researchers, who sometimes lack practical experience of design and installation, to intervene in and improve conventional practices that are critically influential on energy efficiency in the buildings sector.

R&D themes often tend to focus on so-called new technologies. But, when thinking about their implementation in the real world, performance comparisons are needed with conventional alternatives and they must be harmonized with other parts of buildings and their systems. Such unproven technologies cannot form the core of EBC's research. Rather, commitment by the EBC R&D programme to improving conventional practices is the short cut to untap the potential of the buildings sector for substantially improving its energy efficiency to realise the goal of energy use reduction by 2050. In this way, EBC is helping to establish reliable design and installation practices for buildings, ready for deployment by government and industry to reduce energy use at scale.

Dr Eng Takao Sawachi
EBC Executive Committee Chair
and Member for Japan

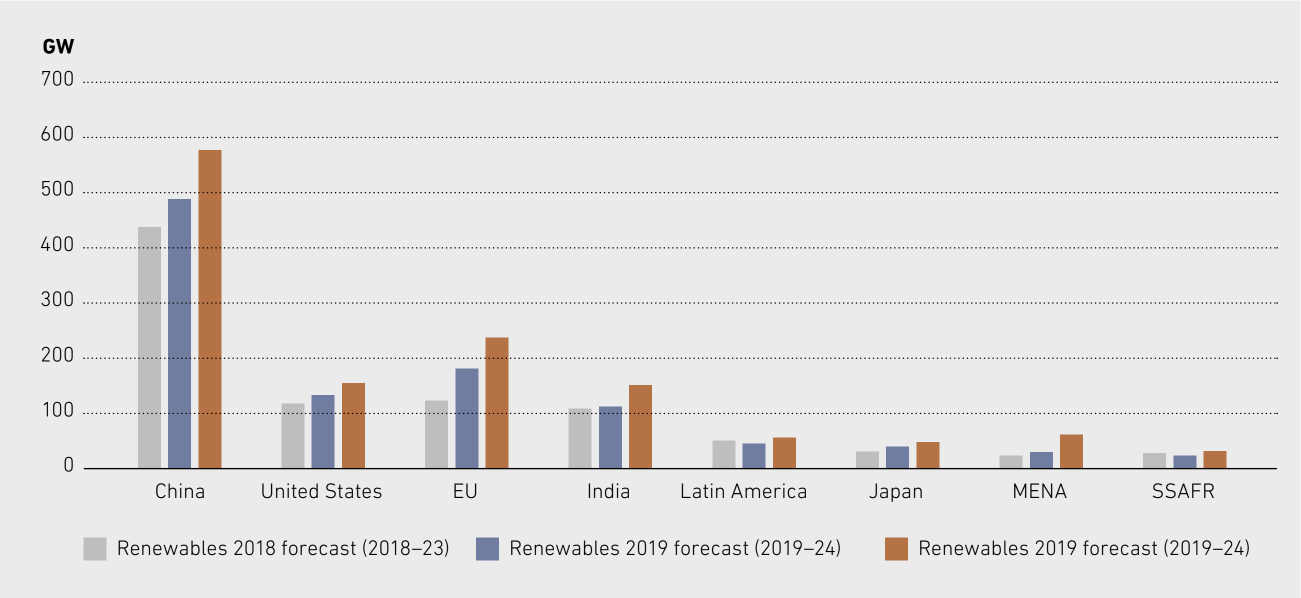
Change is a Constant – Flexibility is a Must

USING BIG DATA TO UNLOCK ENERGY FLEXIBLE BUILDINGS

Energy systems are evolving on a global scale. To meet the growing energy needs of consumers, businesses, and governments around the world, the importance of a reliable, low-cost, and low-greenhouse gas emissions energy system is a top priority that transcends international borders. This is especially true for electricity use in the buildings sector, which currently accounts for over 60 % of all electricity used in member countries of the OECD (IEA, 2020). Furthermore, as energy access expands in developing countries with greater focus on decentralized power generation, and as climate change impacts affect more and more communities regardless of socio-economic status, the availability of dependable, affordable, and clean energy sources is becoming increasingly valuable to both urban and rural populations.

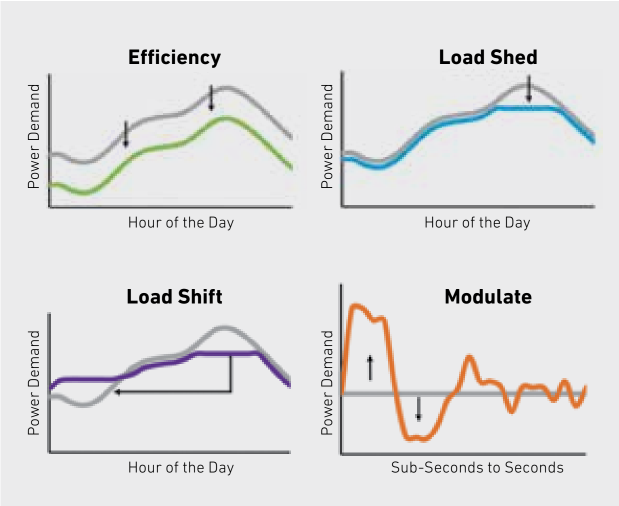
In addition, the growth in deployment of renewable energy and distributed energy resources, including energy storage, combined heat and power, and electric vehicles has introduced cleaner and more cost-competitive energy sources than ever before (IEA, 2019). However, this comes with trade-offs in the form of power supply fluctuations and corresponding energy price oscillations, all while serving a diverse set of occupant needs in commercial and residential buildings alike. Given the rise in variable renewable energy sources and the need to balance key factors related to power demand, supply, and occupant needs, the potential to leverage buildings' energy demand flexibility is emerging as an invaluable response to the evolving energy needs of the future.

A recent study on energy demand flexibility identified nearly 200 GW of cost-effective load flexibility potential in the U.S. alone by 2030. This load flexibility potential equates to roughly 20 % of estimated U.S. peak load in 2030 – more than tripling the existing demand response capability – and could yield over $15 billion in annual avoided system costs (Brattle, 2019). As existing energy systems are upgraded and new infrastructure is deployed, an opportunity exists to implement building technologies that enhance the energy efficiency of commercial and residential buildings by making them smarter, more connected, and flexible.



Renewable energy capacity growth by country / region, 2018 – 2024.

Source: IEA, 2019



Building flexibility load curves – examples of load curve manipulation.
Source: US Department of Energy

Advancements in sensor and control technologies have enabled broader building-to-grid capabilities, including greater communication between buildings and coordination across portfolios of buildings to stabilize power supplies more effectively and simultaneously avoid higher time-of-use rates at peak periods of the day. This emerging field of energy flexibility in buildings represents the capacity of a building (or group of buildings) to react to one or more signals without compromising occupant comfort within the technical constraints of the building and its inherent energy-using systems (HVAC, lighting, and so on). By increasing their energy flexibility, buildings can help to avoid electricity generation and / or delivery costs by supporting more efficient generation, transmission, and distribution of electricity without impacting occupant comfort.

Although this opportunity is becoming more tangible and quantifiable, more research and data are needed to frame the potential benefits of energy-flexible buildings (also called grid-interactive efficient buildings, DOE, 2020) can provide to future energy systems. Further evaluations and demonstrations of services that energy-flexible buildings can deliver could provide answers to other challenging questions that will shape the deployment of these technologies moving forward, such as who should be in control of energy flexibility in buildings – utilities, consumers, or a third party that has yet to emerge. What is the best approach to incorporating parameters specific to building occupants: a focus on behaviours, signals, routines, or a combination of these factors?

With Big Data Comes Big Responsibility

We are living in the age of information, in which data is the raw material much like iron was the raw material of the industrial age. By the end of 2019, the Internet of Things (IoT) was generating over 500 zettabytes (a zettabyte is equal to 1 trillion gigabytes) of structured and unstructured data every year – a number that is expected to grow exponentially – and several industries expect to see 50 billion new devices connect to the IoT by the end of 2020 (Djedouboum et al, 2018). Much like the financial sector and other industries on the forefront of the big data revolution, the built environment can also benefit from the abundance of data and the insights they can provide. The amount of data generated daily could unlock a new frontier in the design, construction, and operation of energy-flexible buildings to more precisely and effectively control and manage building energy performance.

As a result, the global buildings sector is poised to make notable technological advances in the coming years. Enabled by the prevalence of smart devices, the IoT, and low-cost, advanced sensors and controls technologies, stakeholders will be able to leverage the benefits of big data for real-time decision-making to enhance overall building and energy system performance. Whether through physical connection (a cluster of buildings connected to the same energy infrastructure), or through market aggregation (a common agent or organization that can exploit the energy flexibility of the whole cluster), these technologies empower building operators, utilities, and homeowners, while also providing grid services and other system-wide benefits on a scale never seen before.

The huge volume of data collected from two-way communication in smart grids, for example, will rely on advanced data analytics to extract valuable information not only for billing information, but also on the status of the electricity network. High-resolution usage data can also be used for customer behaviour analysis, demand forecasting, and energy generation optimization. Predictive maintenance and automated fault detection based on analytics with advanced metering infrastructure can also bolster the security of the power system.

However, these benefits do not come without challenges. Highly granular data could be used in malicious ways, highlighting the importance of data security and data privacy issues. Power grids are a major target – 90 % of critical infrastructure providers report their information technology and operational technology environment has been damaged by a cyberattack over the past two years (Forbes, 2019), emphasizing the importance of securing these critical systems. To ensure data security and privacy, the systems that generate this data must be secured from cyber-attacks, whether connected devices, smart meters, or otherwise. While no system is un-hackable, it is critical that governments and industry come together to establish best practices for securing user data.

Transparency, Reliability, and Resiliency

In addition to enabling a low-cost and low-emissions energy system, this energy flexibility in buildings will also make the energy system more reliable and resilient. More up-to-date monitoring of the status of the electricity grid and high-resolution usage data can improve demand forecasting and outage detection, which can then be used to optimize energy generation to reduce stress and congestion on the grid. Pairing high-resolution and real-time demand-side data with advanced forecasts of renewable energy generation can also support regulation and dispatch planning to better align power supply with demand, for a more efficient electricity distribution system.

Further studies in this field are needed to bolster the business case for increased resilience in terms of cost reduction and risk management and mitigation. Two potential areas that may prove fruitful for future study include exploring the case for ensuring continuity of operations when power is disrupted and analyzing power quality at the building-level to identify distribution system issues. Ensuring continuity may be a particularly strong value proposition for critical building functions to provide essential services at hospitals, fire stations, or police stations, for example. The value of grid services that buildings can provide will vary from one stakeholder to another, so defining and further quantifying benefits for key stakeholders will be important for deploying this capability where it can make the greatest impact.

Flexibility is the Future

Overall, the potential for energy-flexible buildings to help strengthen the energy system and improve its performance is immense. Consider the following system-wide benefits that flexible buildings can provide:

- reduced down-time and improved prioritization of critical loads when the electricity system is under stress;
- optimized energy use to minimize greenhouse gas emissions and take full advantage of variable renewable energy sources;
- enhanced management and control for building owners and occupants by leveraging big data to improve system performance, while also meeting comfort and other occupancy needs.

We are at the forefront of a major transformation of our energy system, and energy flexibility in buildings is emerging as a critical element – and a driver – for the successful transition to the energy system of the future.

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Prof Paul Ruyssevelt, EBC Executive Committee Vice Chair and Member for the United Kingdom

Meli Stylianou, EBC Executive Committee Member for Canada

David Nemtzow, EBC Executive Committee Member for the USA

New Research Projects

BUILDING ENERGY CODES
(EBC WORKING GROUP)

POSITIVE ENERGY DISTRICTS
(EBC ANNEX 83)

ENERGY FLEXIBLE BUILDINGS
TOWARDS RESILIENT LOW CARBON ENERGY SYSTEMS
(EBC ANNEX 82)

DATA-DRIVEN SMART BUILDINGS
(EBC ANNEX 81)

Building Energy Codes

EBC WORKING GROUP

It is widely recognized and well documented that building energy codes, also known as building energy standards or building regulations, are an effective policy tool for improving the energy efficiency of buildings, residential and commercial alike. However, even in jurisdictions with extensive history in this area, building energy codes are facing key issues, including:

- a need for faster and easier methods to check the compliance of buildings with the code; a need for greater reliability in the evaluation of code compliance;
- the substantial amount of time it takes for building odes to integrate research and technology breathroughs, limiting the energy savings potential of building energy codes;
- the long-life of buildings and thus attending to the resulting challenge of incorporating energy efficiency into major retrofits of older buildings, and the role of buildings energy codes in this;
- the need to meet ambitious policy objectives such as zero net energy construction standards;
- The challenge of integrating various distributed energy resources including solar, electric vehicles, and grid-interactive and flexible technologies.

The EBC programme has identified building codes as a priority theme, including implicit recognition that a broad-based policy mechanism such as building energy codes intersects with numerous EBC activities and projects. Against this backdrop, the EBC Executive Committee formally launched the Building Energy Codes Working Group in June 2019. The creation of a Working Group dedicated to the consideration of building energy codes in EBC Annexes and the integration of Annex results into building codes can leverage this impactful tool for use in collaboratively advancing energy efficiency in buildings and communities.

Building research engineers develop and demonstrate advanced technologies and methods for evaluating building performance.

Source: Pacific Northwest National Laboratory, 2017

Objectives

The project objectives are to:

- enhance understanding of impactful options and practices regarding building energy codes across different countries;
- provide methods for cross-national comparisons that lead to meaningful information sharing;
- foster collaboration on building energy code issues that leads to enhanced building energy code programmes by incorporating new technologies, practices and issues.

Deliverables

The project is undertaking three major umbrella activities to achieve these objectives, which are listed below:

- Activity 1: Exchange on Building Energy Code Practices – This activity involves several opportunities for countries to exchange information on their building energy code systems, including a quarterly webinar series, as well as in-person meetings associated with EBC Executive Committee meetings to better coordinate and share research progress. One recurring meeting will be the new Annual Building Energy Code Symposium.
- Activity 2: Comparative Analysis – As part of this activity, the project is developing a survey and reports around various topics of interest. Examples of planned topics include an overview comparing building energy codes in project participating countries and defining methods and terminology; building energy codes in existing buildings; building energy code compliance best practices, including means of assessing code compliance post construction; case studies of how new technologies impact and are integrated into national codes.
- Activity 3: Dissemination – Through the use of multiple communication platforms (for example EBC website, conference papers, journals), the project is working on disseminating the analysis and knowledge obtained back to the community and collaborate with a diverse group of stakeholders to encourage improvements and innovation in practices.

The project intends to collaborate closely with the International Code Council, ASHRAE and European Union activities.

Progress

The USA hosted the first in-person meeting in November 2019. At this meeting, project members discussed a draft work plan and featured presentations on various topics of shared interest, including code compliance approaches, transnational energy standards and energy performance initiatives, and their impacts on national building codes; code integration of new technologies in building energy codes, and linking voluntary energy rating programmes with building energy codes. Since its inception, the project has also held three webinars.

Meetings

The first project meeting was held in Colorado, USA, in November 2019.

Project duration
2019–2022

Operating Agents
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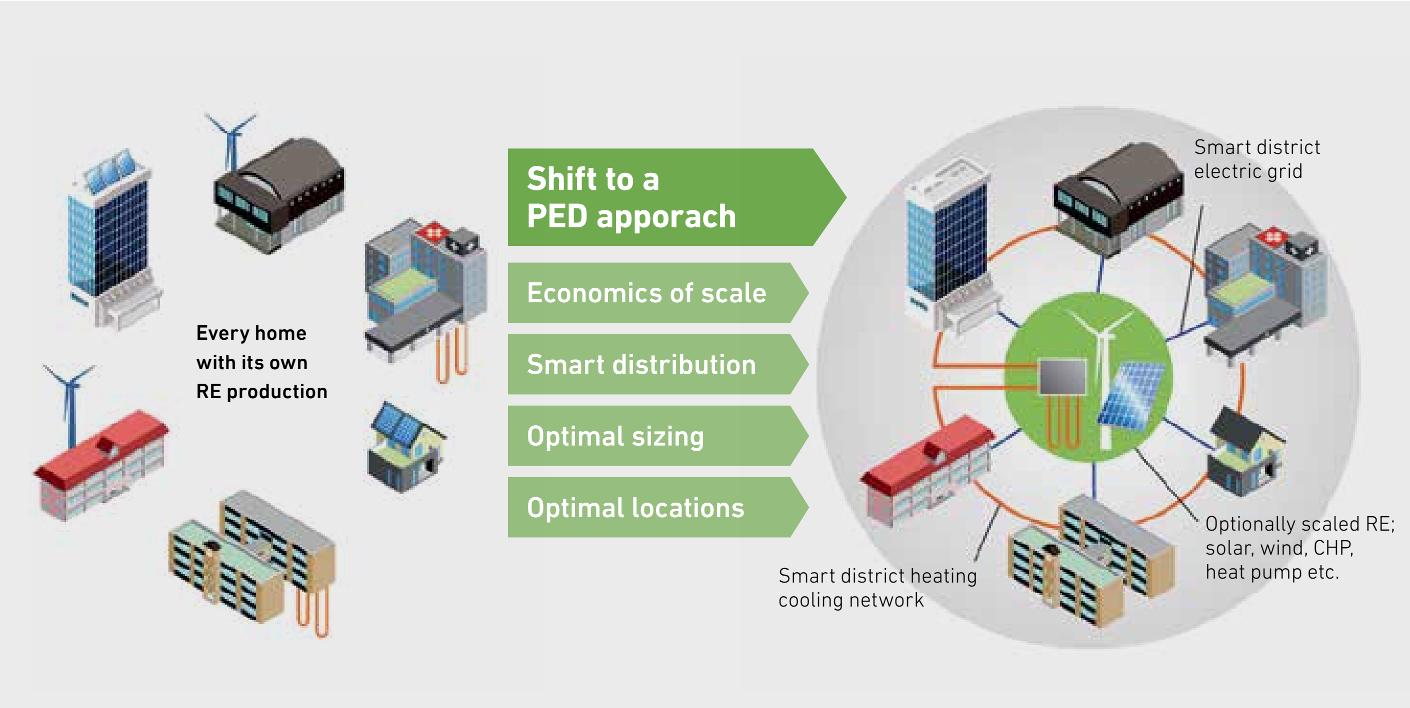
Participating countries (provisional)
Australia, Brazil, Canada, P.R. China, Ireland, Italy, Japan, New Zealand, Portugal, Singapore, Sweden, UK, USA

Further information
www.iea-ebc.org

Positive Energy Districts

EBC ANNEX 83



Positive energy districts offer opportunities for improved optimization and higher cost-efficiency in providing urban energy solutions.

Source: VTT Technical Research Centre of Finland

The EBC project, 'Positive Energy Districts' started its preparation phase in November 2019. The basic principle of a positive energy district (PED) is to create an area within the city boundaries, capable of generating more energy than is used, and agile/flexible enough to respond to energy market variations. Rather than simply achieving an annual net energy surplus, it should also support minimizing impacts on the connected centralized energy networks by offering options for increasing onsite load-matching and self-use of energy, technologies for short- and long-term energy storage, and providing energy flexibility with smart control. PEDs can include all types of buildings present in the urban environment and they are not isolated from the energy grid. Within the research community, the PED is an emerging concept intended to shape cities into carbon neutral communities in the near future. Reaching the goal of a PED requires firstly improving energy efficiency, secondly cascading local energy flows by making use of any surpluses, and thirdly using low-carbon energy production to cover the remaining energy use. Smart control and energy flexibility are needed to match demand with production locally as far as practical, and also to minimize the burdens and maximize the usefulness of PEDs on the grid at large.

The urban energy infrastructure transition towards carbon neutral communities has an intrinsic multi-sectoral dimension. It embraces a synchronized and parallel development of instrumental technologies, public perceptions of building energy technologies, a new economic paradigm and tailored business models. Cities can play a unique role as hosts, facilitators and incubators of new technologies and solutions. This is essential to co-create all-inclusive packages of citizen-centric carbon-free energy solutions.

Objectives

Through the EBC programme, the project is enhancing international co-operation on PED development. The main objectives and scope are as follows:

- Map the relevant city, industry, research, and governmental (local, regional, national) stakeholders and their needs and roles to inform the specific project objectives. The main purpose is to ensure the involvement of the principal stakeholders in the development of relevant definitions and recommendations.
- Create a shared in-depth definition of a positive energy district by means of a multi-stakeholder governance model. So far, international activities have developed generalized definitions that leave many questions open.
- Develop the required information and guidance for implementing the necessary technical solutions (at building, district and infrastructure levels) that can be replicated and ultimately scaled up to the city level, giving emphasis to the interaction of flexible assets at the district level and also economic and social issues such as acceptability.
- Explore novel technical and service opportunities related to monitoring solutions, big data, data management, smart control and digitalisation technologies as enablers of PEDs.
- Develop the required information and guidance for the planning and implementation of PEDs, including both technical and urban planning. This includes economic, social and environmental impact assessments for various alternative development paths.

Deliverables

The planned main project outcomes are as follows:

- definitions and key concepts for positive energy districts,
- methods, tools and technologies for realizing positive energy districts,
- governance principles and impact assessment for positive energy districts, and
- case studies on positive energy districts and related technologies.

Progress

During 2019, the project proposal and draft workplan were developed by gathering contributions through an online platform and in a workshop arranged at the Building Simulation 2019 conference. The project proposal and workplan together describe the need, aims, approaches and planned outcomes of the project.

Meetings

- A preparatory workshop was held in Rome, Italy, in September 2019.

Project duration
2019 – 2024

Operating Agents
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Participating countries (provisional)
Australia, Austria, Belgium, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK

Further information
www.iea-ebc.org

Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems

EBC ANNEX 82

The anticipated deployment of large amounts of renewable energy sources (RES) may significantly affect the stability of existing energy networks due to their intermittent availability at times. It is therefore necessary to control energy demand profiles to more closely match those of instantaneous energy production. The intrinsic energy flexibility of buildings is attractive due to the limited infrastructure needed to operationalize such resources, which may be utilized for stabilizing energy grids and thereby allowing for a large-scale roll-out of RES by making energy networks resilient through their ability to shift energy demands in time.

Through these means, resilient energy networks can be created and withstand the challenges associated with the transition to energy systems with large-scale penetration of RES. Energy flexible buildings and communities increase the resilience of energy networks, which in turn are more resilient to fluctuations in the energy supply.

The energy flexibility of a building is its ability to manage its demand and supply according to local climatic conditions, occupant and operator needs and energy network requirements. Energy flexible buildings are able to provide demand side management and load control and thus can satisfy requirements of their surrounding energy networks and contribute to resilience of the energy systems.

During the concluding EBC Project, 'Annex 67: Energy Flexible Buildings' (see page 46), energy flexibility in single buildings and to some extent clusters of buildings were investigated. The value of energy flexibility for energy networks was also considered at a preliminary level. The motivations of and perceived barriers for stakeholders were investigated via interviews and questionnaires, but additional research is needed to fully understand how the stakeholders' viewpoints may be utilized in the development of feasible technical solutions. The EBC Annex 67 project has revealed areas where further work is needed to ensure that energy flexibility from buildings will actually be an asset for future energy networks. The areas identified are listed below:

1. scaling from single buildings to clusters of buildings (aggregation);
2. energy flexibility and resilience in multi-carrier energy systems (electricity, district heating/cooling and gases);
3. acceptance/engagement of the stakeholders;
4. business models.

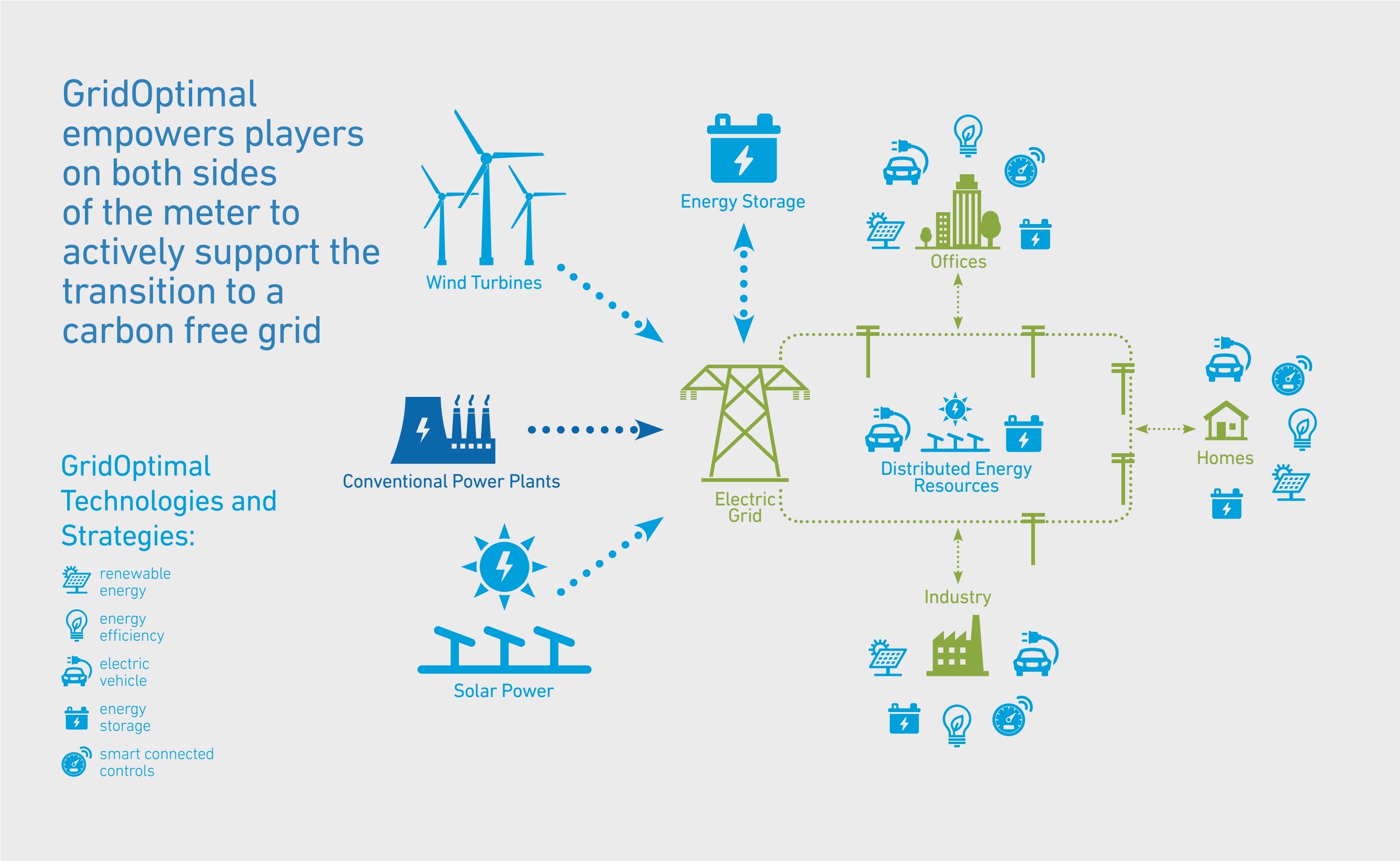
Based on the above research areas, the following project tasks are planned:

- Subtask A: Scaling from single buildings to clusters of buildings
- Subtask B: Flexibility and resilience in multi-carrier energy systems
- Subtask C: Stakeholder acceptance and engagement
- Subtask D: Development of business models

Objectives

The project objectives are as follows:

- demonstration and further development of the project characterization and labelling methods in order to make them commonly accepted;
- investigation of aggregation of energy flexibility from clusters of buildings both physically connected and commercially connected (not necessarily physically connected) via an aggregator;
- investigation of the aggregated potential of energy flexibility services from buildings and clusters of buildings located in different multi-carrier energy systems;
- demonstration of energy flexibility in clusters of buildings through simulations, experiments and field studies;
- mapping the barriers, motivations and acceptance of stakeholders associated with the introduction of energy flexibility measures in buildings and clusters of buildings;
- investigation on how to include the views of stakeholders in the development of feasible technical solutions;
- investigation and development of business models for energy flexibility services to energy networks;
- recommendations to policy makers and government entities involved in the shaping of future energy systems.



The GridOptimal™ Buildings Initiative project is developing metrics by which building features and operating characteristics that support more effective grid operation can be measured and quantified. This supports the least-cost decarbonization of the grid through better integration of both distributed energy resources (DER) and utility-scale wind and solar energy. newbuildings.org/resource/gridoptimal

Source: New Buildings Institute

Deliverables

The provisional deliverables to be produced in the project are as follows:

- a common methodology for characterization of energy flexibility,
- services offered to (multi-carrier) energy networks,
- stakeholder viewpoints,
- a collection of case studies,
- business models, and
- recommendations for policy makers and government entities.

Progress

A proposal definition workshop was carried out in November 2019. A one-year preparation phase for the project was approved at the November 2019 EBC Executive Committee Meeting.

Meetings

- A proposal definition workshop was held in Lyngby, Denmark, in November 2019.

Project duration
2019 – 2024

Operating Agents
Søren Østergaard Jensen, Danish Technological Institute, Denmark

Participating countries (provisional)
Austria, Belgium, Canada, P.R. China, Denmark, Finland, France, Germany, Ireland, the Netherlands, Portugal, Spain, Switzerland, UK, USA

Further information
www.iea-ebc.org

Data-Driven Smart Buildings

EBC ANNEX 81

Poorly maintained, degraded, and improperly controlled heating, ventilation and air conditioning (HVAC) equipment wastes an estimated 15% to 30% of the energy used in commercial buildings. Improved building management practices and building controls are known to deliver cost-effective energy and emissions savings.

Digitalization of building services, including HVAC, has the potential to further reduce costs, and increase energy savings, by automating building operation with embedd -ed intelligence and by enabling new 'software-as-a-service' business models. Relevant emerging digital technologies include:

- the Internet of Things (IoT), which can provide access to more diverse, and low-cost data on the statuses and activities of equipment, appliances and people in buildings;
- cloud computing, artificial intelligence (AI) and data analytics, which can enable more comprehensive energy performance assessment and predictive management of assets;
- social media and digital market-platforms, which can provide new ways of engaging with building operators and occupants, and business models for promoting energy saving behaviour amongst buildings industry stakeholders.

Despite the energy saving potential of digitalisation, the building services industry has been a relatively slow adopter, and several barriers still exist to industry growth. Data access, data quality and data governance issues significantly influence the transaction cost and risk of providing data-driven services. Siloed provision of the various commercial building-service offerings (energy, fire, security, maintenance, and so on) also impacts on the business case for digitalisation.

In response, this EBC international research project conceives of a transformational framework for overcoming these barriers, in which open data sharing provides a digital 'Platform' for a wide range of building software service 'Applications' that delivery energy efficiency and demand management outcomes. Thus, the project is focusing on unlocking the energy saving potential of digitalization through the investigation of innovative data management strategies and through the development of cloud-based data-driven HVAC equipment management software 'Applications'.

Objectives

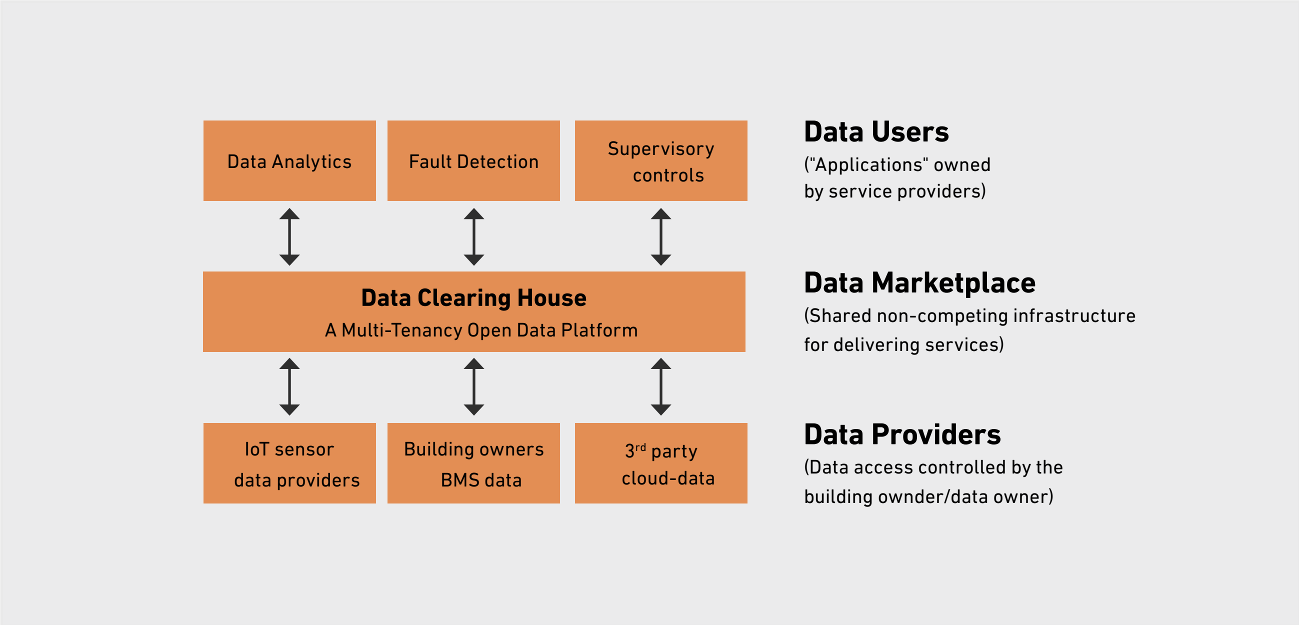
The project is increasing access to low-cost high-quality data from buildings and supports the development of data-driven energy efficiency Applications and analytics. This enables real-time building energy efficiency control optimization and provides energy efficiency data and decision support for building facilities managers. Specific objectives are to:

- provide knowledge, standards, protocols and procedures for low-cost high-quality data capture, sharing and utilization in buildings;
- develop a methodology for control-oriented building modelling that facilitates testing, developing and assessing the impacts of alternative energy efficient building HVAC control strategies in a digital environment;
- develop building energy efficiency (and related) software Applications that can be used and ideally commercialized for reducing energy consumption in buildings;
- drive adoption of project results through case studies, business model innovation and results dissemination.

Deliverables

The planned deliverables from this project include:

- a proposal for governments to lead by example in the use of data-driven smart building solutions in their own buildings and, particularly, to adopt the HVAC data-sharing principles and processes developed in this project;
- a report on functional-requirements for a 'minimum viable product' (MVP) Open Data Platform that could support low transaction cost data-sharing amongst an ecosystem of building services innovators;



Data sharing Platform and Application services innovation ecosystem framework.
Source: CSIRO

- an online repository of exemplar data sets for building analytics research;
- data-driven control-oriented building models suitable for model predictive control in different building typologies and scenarios;
- a software repository, containing prototype software implementations and Application descriptions for energy saving HVAC services;
- a grand challenge/hackathon style competition for incentivizing innovators to develop data-driven Applications.

Progress

Building on the work of the Mission Innovation 'Affordable Heating and Cooling' Innovation Challenge, the concept of a Data-Driven Smart Buildings project within the EBC programme was developed over the past year and was promoted amongst the international research and innovation community. Meetings were held in 2019 in Delft, the Netherlands, and London, United Kingdom to define the key issues, the subtask and activity structure, and the work plan of the proposed project.

With substantive agreement on the transformational potential of the project concept, and an agreed plan of work, a project proposal was developed, and commitments were sought for delivering the work. Around 30 organisations, represent-ing 14 countries, have expressed an intention to participate, with participation already confirmed by 17 organisations. Based on this support, the project has entered its preparation phase with the aim of commencing working phase in June 2020.

Meetings

The following meetings were held in 2019:

- a proposal development workshop was held in Delft, Netherlands, in April 2019, to determine the appetite for participation and to develop the project structure;
- the first preparation-phase expert meeting took place in London, United Kingdom, in September 2019.

Project duration
2020 – 2024

Operating Agents
Stephen White, CSIRO, Australia

Participating countries (provisional)
Australia, Austria, Belgium, Canada, P.R. China, Denmark, Ireland, Japan, the Netherlands, Norway, Singapore, Sweden, UK, USA

Further information
www.iea-ebc.org

Ongoing Research Projects

RESILIENT COOLING OF BUILDINGS
(EBC ANNEX 80)

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

SUPPLEMENTING VENTILATION WITH GAS-PHASE AIR CLEANING,
IMPLEMENTATION AND ENERGY IMPLICATIONS
(EBC ANNEX 78)

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)

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

Resilient Cooling of 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 enormous strain on electricity systems in many countries, as well as driving up greenhouse gas emissions. Growing demand for cooling is driven by economic and population growth in the hottest parts of the world. There is no doubt that the global demand for space cooling will continue to grow for decades to come. These are the alarming findings of the IEA Technology report 'The Future of Cooling', published in May 2018.

With current policies and targets, energy needs for space cooling would triple by 2050. Meeting peak electricity demand would become a major challenge. It is mandatory to curb the rapid growth in demand for air conditioning and achieve a sustainable development of the sector of cooling.

The project is addressing this multi-disciplinary challenge and is boosting the development and implementation of robust low-energy and low-carbon cooling solutions 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 resilient cooling solutions that can create comfortable

Group photo from the 1st Expert Meeting in Vienna, Austria, in October 2019.
Source: EBC Annex 80

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 research is covering a range of technologies to:
- reduce heat loads to people and indoor environments;
- remove sensible heat from indoor environments;
- enhance personal comfort apart from space cooling;
- remove latent heat 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
In the first half of 2019, the project planning was further developed, regarding both content and project management, with Subtask Leaders assigned. National research items were defined and overarching national research identified. Following this, the project working phase was approved at the EBC Executive Committee meeting held in Ghent, Belgium, in June 2019. 30 participating teams from 13 countries are expected to participate in the project. The practical work started with the 1st Expert Meeting, which took place in October 2020 in Vienna, Austria.

Activities were commenced in 2019 on the development of three review papers on the topic of criteria and qualities of resilience as regards to cooling and on the topic of resilient cooling technologies. Furthermore, a task force was established from within the project participants to develop a systematic approach towards climate data sets that may be used for further analysis. A professional panel is being convened to connect the project to industry, advocacy groups and individual professionals. The project was presented at the International Conference CATE – Comfort at the Extremes in Dubai, United Arab Emirates.

Meetings
The following meetings were held in 2019:
- Topical Session on Resilient Cooling at the International Conference CATE – Comfort at the Extremes, held at Harriot Watt University, Dubai, United Arab Emirates, in April 2019.
- 2nd Annex Preparation Meeting, held in Dubai, United Arab Emirates, in April 2019.
- Presented EBC Annex 80 at Austria's National IEA Network Meeting, held in Innsbruck, Austria, in September 2019.
- 1st Expert Meeting, held in Vienna, Austria, in October 2019.
- Subtask Leaders Web meetings took place in January, July, August, and December 2019.

Project duration
2019 – 2023

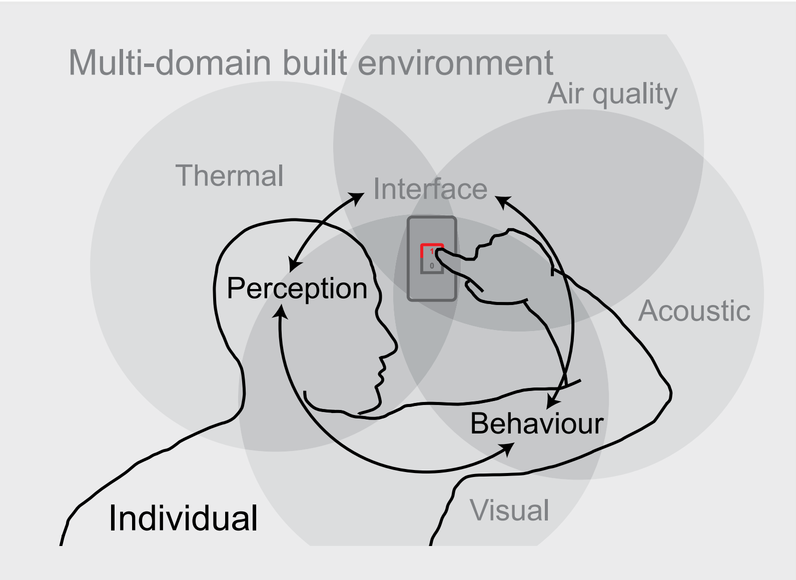
Operating Agent
Peter Holzer, IBR&I Institute of Building Research and Innovation, Austria

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

Further information
www.iea-ebc.org

Occupant-centric Building Design and Operation

EBC ANNEX 79



The relationship between occupant perception of the indoor environment, their behaviour, and building interfaces.
Source: Marcel Schweiker, KIT

Occupants' interactions with their interior environments have been identified as a major influence on building performance. Reasons for these interventions are mostly comfort-related, including among others, dissatisfaction with the building automation or system controls, inappropriately designed or malfunctioning interfaces, or disregard of occupants' needs in buildings design and operation. According to different studies, the energy use of buildings can vary by up to a factor of two as a result of occupants' interventions.

Consequently, occupant behaviour in buildings has emerged as a prominent research topic during recent years. In this context, the completed project, 'EBC Annex 66: Definition and Simulation of Occupant Behavior in Buildings', laid a sound foundation on experimental methods, modelling and implementation of occupant behaviour models in building simulation platforms. However, open research questions remain, for example with regard to multi-domain comfort or data-driven modelling approaches, and there is a lack of sustainable implementation of occupant-centric building design and operation strategies in practice. The purpose of the project is therefore to provide new insight into comfort-related occupant behaviour and interactions in buildings and its impact on building energy performance.

Objectives

With the overall goal to integrate and implement knowledge and models of occupancy and occupant behaviour into the design process and building operation to simultaneously improve energy performance and occupant comfort. Within this objective, key areas of focus include:

- multi-domain indoor environment exposure and its impact on energy-related behaviour;
- interfaces and the design features that affect usability and promote energy-efficient behaviours;
- application of 'big data' and sensing to generate new knowledge about occupants;
- development of occupant-centric building design and control strategies.

Deliverables

The main planned project outcomes are as follows:

- comprehensive literature reviews for the topics tackled;
- a unified theoretical framework for perceptual and behavioural theory of building occupants;
- guidelines for research methods to evaluate occupant comfort and building interfaces, perform occupant data collection, and apply data analytics to occupant data;
- a report on best practices for building interfaces, occupant-centric design workflows, and optimal building 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 occupant metering/ sensing infrastructure and controls.

Progress

The project work in 2019 has been dominated by comprehensive literature reviews in the four Subtasks in a special issue of the journal of 'Building and Environment'. In the field of multi-aspect environmental exposure, building interfaces, and human behaviour, the reviews include historically important instances of high-level perception and behaviour theories, human-building interfaces and occupant behaviour, multi-variable approaches to indoor environmental perception and behaviour, and psychological theories of percept -ion and behaviour.

Literature reviews on data-driven methods include urban-scale data collection methods, methods for modelling and simulating occupant presence and actions in buildings, and practices for open data and existing open data sources and infrastructure. Literature reviews on occupant-centric design address codes and standards involving performance-based design, simulation-based occupant-centric design procedures, occupant-centric high-performance building development from building stakeholders' perspectives, and field implementations of occupant-centric building controls. A survey is underway to investigate occupants' willingness to share personal information and data, for instance, in residential versus office conditions, depending on their 'cultural' background, and in relation to (perceived) benefits. A second survey aims to learn about common practice of using (or not using) occupant information and data in the early building design process. It will help to decide which types of occupant models are most helpful for which step in the design process and which data need to be collected and then provided for modelling.

Furthermore, there has been significant progress on data collection and metadata schema to properly describe occupant presence and action datasets in a way that the research community can understand and use them. Open datasets have been shared on an initial GitHub page including their representation in different metadata schemas. Finally, data competitions on occupant presence and action data are being prepared and discussed with relevant organizers for the BuildSys 2020 conference and the ASHRAE Competition in 2021.

Activities on occupant-centric control include the identification of common occupant sensing technologies for energy management by determining how these technologies are used and supplemented with operator expertise white-space for future R&D is being defined. Currently, a simulation environment for the development and assessment of occupant-centric control algorithms is being developed. This simulation environment is intended for implementation in the building performance simulation tool EnergyPlus.

Nine seminars, workshops, and panels at seven different international conferences were organized in 2019 to present project research and related topics. Additionally, a REHVA Task Force on 'Occupant Behaviour in Building Design and Operation' was proposed at the REHVA Technology and Research Committee meeting in Brussels, Belgium, in early November 2019. Meanwhile, project participants are collaborating with ASHRAE MTG.OBB to add a section on occupant modelling to the Fundamentals Handbook.

Meetings

The following meetings were held in 2019:

- The 2nd Preparation Phase Expert Meeting took place in San Antonio, USA, in March 2019.
- The 1st Working Phase Expert Meeting took place in Perugia, Italy, in September 2019.

Project duration
2018 – 2023

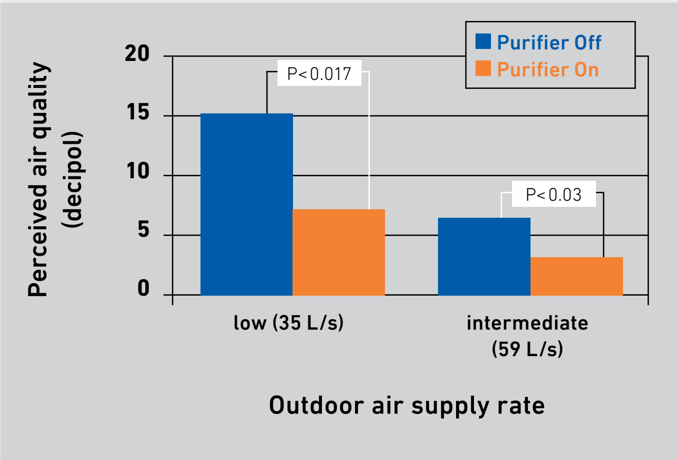
Operating Agents
Andreas Wagner, Karlsruhe Institute of Technology, Germany
Liam O'Brien, Carleton University, Ottawa, Canada

Participating countries
Australia, Austria, Belgium, Canada, China, Denmark, Germany, Italy, the Netherlands, Norway, Singapore, Sweden, Switzerland, UK, USA

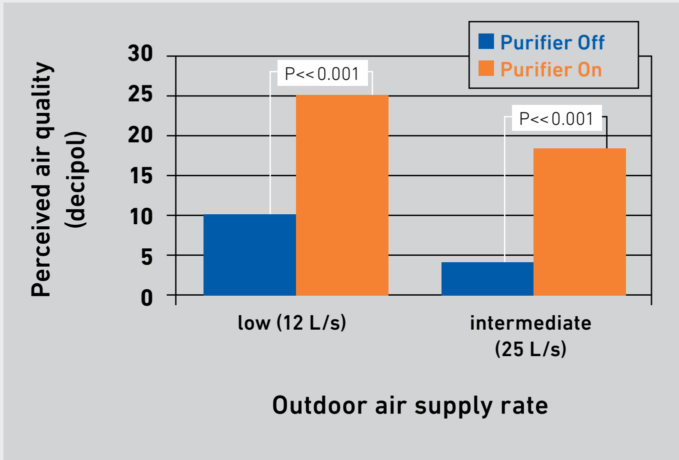
Further information
www.iea-ebc.org

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

EBC ANNEX 78



Test 1: Pollution sources are building materials, PCs and filters



Test 2: Pollution sources are human bio-effluent emissions

Examples of test results with an air cleaner exposed to different pollution sources. With building materials, the air cleaner improves the perceived air quality, whereas with human bio-effluents, the air cleaner makes the perceived air quality worse.

Source: EBC Annex 78

Ventilation accounts for approximately 20% of the global energy use for providing an acceptable indoor environment. Moreover, the requirements for ventilation in most standards and guidelines assume acceptable quality of (clean) outdoor air.

Worldwide, there is an increasing number of publications related to air cleaning and there are also increasing sales of gas-phase air cleaning products. This introduces 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, i.e. whether it can partly substitute the ventilation rates required by standards. Finally, the energy impact of using air cleaning as a supplement to ventilation needs to be estimated. This project is focusing on gas-phase air cleaning, but does not include filtration.

In some locations in the world, the outdoor air quality is so bad that may be better to avoid ventilation. In such cases, the alternative to using ventilation is to substitute it with air cleaning, so that the indoor air can be kept at high quality. Even when outdoor air is of good quality, the use of air cleaning substituting ventilation air could reduce the rate of outside air supplied indoors and thereby energy for heating / cooling of ventilation air and for transporting the air (fan energy) can be saved.

Since it is expected that air cleaning may in parallel improve the indoor air quality and reduce energy use for ventilation, it should be considered as a very interesting technology that can be used in the future. There is, however, a need for better evaluation of its potential to improve indoor air quality (and substituting for ventilation) and the energy implications of using gas-phase air cleaning. There is also a need to develop standard test methods of the performance of air cleaning devices. Consequently, this EBC project has been established on the use of gas-phase air cleaning technologies.

Objectives

The project objectives are to:

- bring researchers and industry together to investigate the possible energy benefits of using gas-phase air cleaners (partly substitute for ventilation);
- establish procedures for improving indoor air quality, or reduced amount 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 (partly substituting) required ventilation rates with gas-phase air cleaning;
- a test method for air cleaning technologies that includes chemical measurements and perceived air quality as measures of performance;
- a report on the long-term performance of air cleaning.

Progress

The project working phase started in July 2019. The focus in 2019 has been to present the project at conferences and to organize several face-to-face and web meetings with interested parties. Some of the interested parties have obtained their own national funding to participate in the project. It is important to get input from and to work with industry during the project, especially when developing test methods and standards. Efforts are therefore being made to integrate industry within the project.

The project is developing a test method for gas-phase air cleaning technologies that includes the measurement of Perceived Air Quality (PAQ) as a measure of performance. It should also take into account bio-effluents from people as a source. The Operating Agent is working with ISO TC142WG8 'Testing of Gas-phase Air Cleaners', and a preliminary new work item has been established to develop a standard for testing of gas-phase air cleaning technologies using PAQ as a measure of performance. Likewise, contact with ISO TC146 SC6 'Air Quality-Indoor Air Quality' has been established. In September 2019, TC146 decided to establish a new working group to develop a standard for measuring PAQ in relation to testing gas-phase air cleaners. The intent is to execute this project in parallel with the development of the test standards.

Meetings

The following meetings were held in 2019:

- A face-to-face and web meeting was held in April 2019 at CLIMA2019 in Bucharest, Romania.
- A workshop was organised at the ISHVAC 2019 conference, in held in Harbin, P.R. China in July 2019.
- A topical session as held at the AIVC2019 conference in Ghent, Belgium, in October 2019.
- The 1st working phase project meeting was held in Ghent, Belgium, in October 2019.

Project duration
2018–2023

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

Participating countries
Czech Republic, Denmark, Italy, Japan, P.R. China, Singapore, Sweden, USA

Further information
www.iea-ebc.org

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

It has brought together international experts and companies involved in dynamic daylighting, lighting and their controls.

Objectives

The overall objective of the activity is to foster the integration of daylight and electric lighting solutions for the benefits of higher occupant satisfaction and at the same time energy savings. This is subdivided into the following specific objectives:
- review the relationships between occupant perspectives (needs and acceptance) and energy in the emerging era of 'smart and connected lighting' for a relevant sample of buildings;
- consolidate findings from use cases and create 'personas' reflecting the behaviours of typical occupants;
- based on a review of specifications concerning lighting quality, non-visual effects, as well as ease of design, installation and use, provide recommendations for energy regulations and building performance certificates;
- assess and improve the technical, environmental and financial robustness of integrated daylight and electric lighting approaches;
- demonstrate and verify, or reject concepts through laboratory studies and real use cases based on performance validation protocols;
- develop integral photometric, occupant comfort and energy rating models (spectral, hourly) as pre-normative work linked to relevant bodies, including CIE, CEN, ISO, and initiate standardization activities;
- provide decision making and design guidelines incorporating virtual reality sessions; integrate approaches into widespread lighting design software;
- combine competencies: bring electric lighting and façade component manufacturers together using workshops and specific projects, and thereby promote the added value of integrated solutions in the market.

Deliverables

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

Progress

Position Paper 'Daylighting of Non-Residential Buildings': This position paper provides an inside view for energy policy makers and decision makers in the private sector to understand why and how the targeted use of daylight in the built environment (non-residential buildings) should be supported and promoted. Different actions at the government, non-governmental organisations and private (industry) levels to significantly drive up this market are recommended. These actions encompass recognizing daylight as a 'renewable energy source', revising building codes, and including it in sustainability certification schemes, memoranda of understanding, and advanced (automated) building design processes.

First report published: 'Workflows and software for the design of integrated lighting solutions': Practitioners are using a wide variety of different workflows, methods and tools in the planning of integrated lighting solutions. Lighting design projects cover a huge variety of applications with different requirements, as well as project types and sizes. Currently applied workflows in practical applications have been reviewed. As a first step, three different building projects in Austria, Germany and P.R. China with integrated lighting solutions have been selected and analyzed. They represent modern office spaces, thus representing state-of-the-art technology. In a second step, based on these design projects, typical workflows for the planning process have been collected and discussed. Finally, as all described workflows utilize software tools to a greater or lesser extent to support the planning and design process an overview of the possibilities, strengths, weaknesses and barriers of the state-of-the-art in lighting simulation is provided.

Strong Industry Involvement: As part of the project activities, two industry workshops in Beijing, P.R. China, and Gdansk, Poland were organized and hosted, with 20 presentations in total on different daylighting and electric lighting topics. In Beijing, the 2019 International daylighting and electric lighting innovation technology conference and IEA SHC Task 61 3rd industry workshop was held in March 2019. Altogether 150 participants, including researchers, engineers, designers, other technical staff, attended ten presentations, with over 2500 viewers following the presentations live online. In Gdansk, the 4th industry workshop was held in September 2019, with 45 participants attending nine presentations.

The first published report on 'Workflow and software for the design of integrated lighting solutions'.
Source: EBC Annex 77 / SHC Task 61

Meetings

The following meetings were held in 2019:

- 3rd Task Meeting was held in Beijing, P.R. China, in March 2019.
- 3rd Conference Industry Workshop was held in Beijing, P.R. China in March 2019.
- 4th Task Meeting was held in Gdansk, Poland, in September 2019
- 4th Conference Industry Workshop was held in Gdansk Poland in September 2019.

Project duration
2018–2021

Operating Agent
Jan de Boer, Fraunhofer Institute 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. The generation of suitable decarbonisation strategies and the selection of the best-fit solution for their specific framework conditions require comprehensive skills, knowledge, and resources, which smaller communities often lack. In addition, these decision-making and planning processes take place in a highly dynamic environment with many 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 mostly provided at a strategic level, decisions at the urban scale can have substantial impacts on individual approaches and technologies.

The EBC Working Group on Cities and Communities is therefore improving this situation by integrating these 'urban issues' into research within the IEA Technology Collaboration Programmes (TCPs), including the EBC TCP. This open project is a hosted, single-leadership, delegating structure that can share information across multiple TCPs and cities in a bi-directional approach, in which information can be provided and received in both directions. The group is also linked to existing IEA Co-ordination Groups and other structures, either directly, through the EBC Executive Committee Chair, or through nominated experts, and is feeding into various IEA publications and workshops.

Objectives

The project goal 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. It has the following objectives:

- 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.

Deliverables

The project 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 project is identifying the crucial needs of cities, which in turn is being translated into research questions for short term projects and research within the group.

Progress

Three subgroups have been established as working structures that deal with technological and non-technological aspects. This division has enabled the project to cover the different and diverse needs and expectations of the participants. On the one hand, the experts from the various disciplines have been given an opportunity for direct and in-depth exchanges with each other; on the other hand, there have been sufficient exchanges with external participants through joint workshops organized by the subgroups. In 2019, the orientation of the subgroups shifted slightly and new subgroup leaders took over. The three subgroups include:

Subgroup 1: Decarbonisation Strategies
Subgroup 2: Integrated Planning Concepts
Subgroup 3: Data, Tools and Methods

Workshop discussion on integrated planning, held in Berlin, Germany, in April 2019.
Source: Salzburg Institute for Regional Planning and Housing (SIR), 2019

Each subgroup has adjusted its work plan within its scope. The subgroups have conducted the necessary, active exchanges between each other. By identifying synergies between the subgroups, the long-term linkage of the thematic areas has been ensured. In addition, based on the previously completed analysis of the needs of cities, the project has further structured, and divided them into stakeholder groups. These findings support the necessity for a more targeted orientation towards and (external) support for cities in the form of a permanent activity. A significant, more extensive effort has to be undertaken to enable cities to identify the level of support needed, to establish effective communication and exchange strategies, and ways to ask themselves better questions to further define and distil their needs.

In 2019, the project subgroups have planned and implemented four workshops on (1) integrated planning, (2) decarbonisation strategies, (3) data, tools, and planning, and (4) investments and financing of decarbonisation measures in cities. While the workshop on technologies discussed current research findings in relation to different technology-oriented TCPs, as well as their potential links, the workshop on integrated planning identified key steps, success factors, participants, and benefits of integrated planning. The workshop on data, tools and methods identified ways to improve data competence in administration at all levels. In the fourth workshop, the project conjointly presented and discussed best practice examples of proactive financing approaches and explored ways to finance decarbonisation measures.

The main progress in 2019 was the extensive range and variety of topics addressed by the subgroups. In addition, the project identified a significant gap between existing available knowledge and its practical application in cities. However, this successful knowledge transfer is a major requirement for continuously advancing decarbonisation of cities' prevailing energy and mobility systems. Only through this can cities develop holistic decarbonisation strategies and suitable and effective implementation instruments, geared directly to their specific and unique contexts, preconditions, priorities, needs, and social environments. The project has thus revealed the need for a new TCP that intends to help cities to adopt, monitor and enforce policies and strategies for decarbonisation and to understand and implement existing and emerging solutions for decarbonisation, based on existing knowledge. The proposed new TCP is currently being developed and preliminary discussions are underway in the supporting countries.

Meetings

The following meetings were held in 2019:

- The 3rd meeting was held in Berlin, Germany, in April 2019
- The 4th meeting was held in Paris, France, in October 2019.

Project duration
2017–2020

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

Participating countries
Austria, Canada, Denmark, Finland, France, Germany, Italy, Ireland, Japan, People's Republic of 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 they 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. Standard energy saving measures are often not compatible with preserving the historic buildings' character. Nevertheless, the energy performance can be improved considerably if the right package of solutions for the specific building is identified. Also, the possibilities to use solar energy in historic buildings are greater than one might expect.

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 that 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.

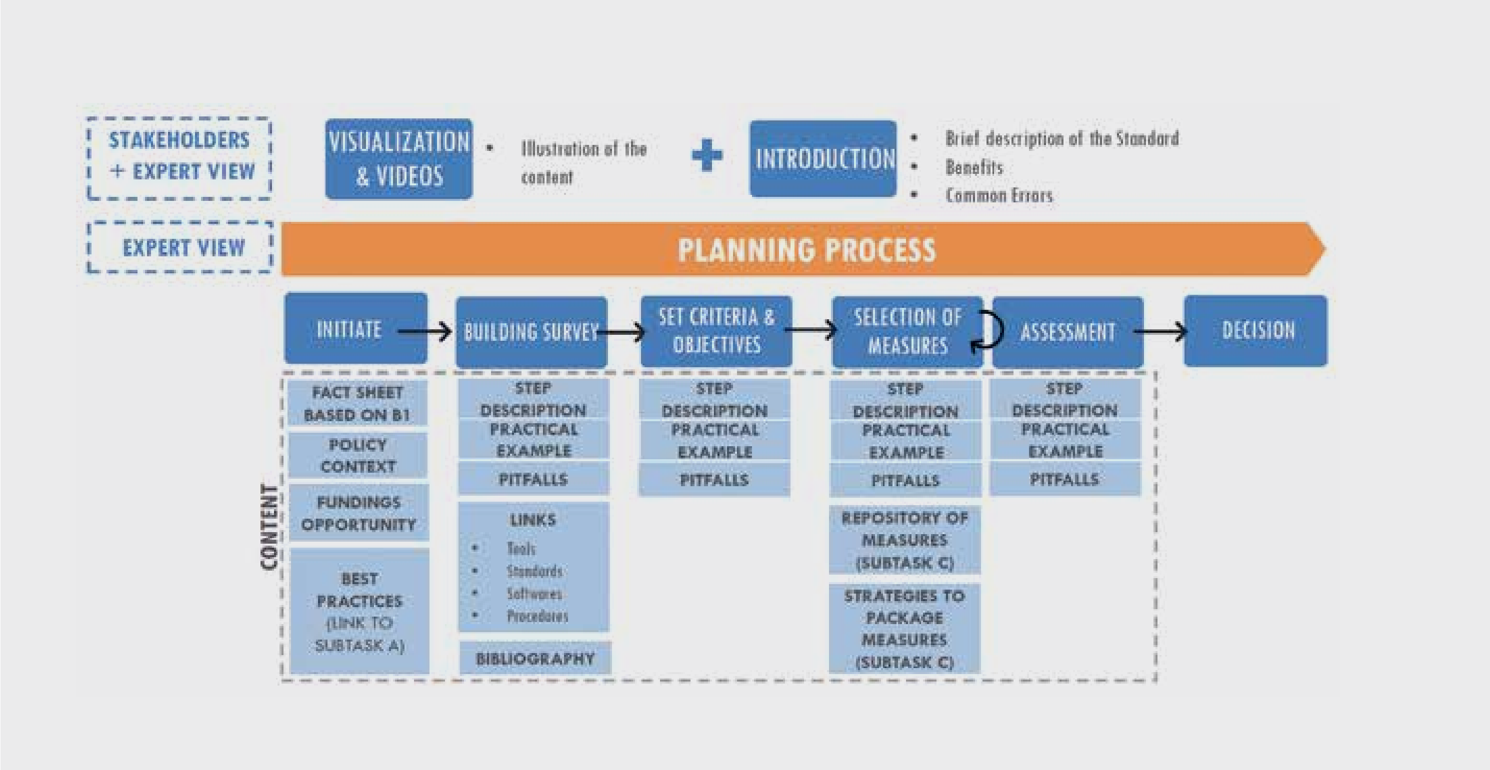
Deliverables

The following deliverables are planned:

- a web-based collection and documentation on approximately 50 best practice case studies 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) 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 net zero energy buildings;
- conservation compatible energy retrofit technologies report, focusing on restoration and thermal enhancement of window systems, documentation and assessment of materials for robust and economically viable internal insulation, and evaluation of energy and cost-efficient heating ventilation and air conditioning (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;
- communications and dissemination of the results by means of a workshop series, participation in stakeholder events and a touring exhibition for use by all participating experts.

Progress

After the previous preparation and structuring work for the Knowledge base, the Historic Building Energy Retrofit



The planning process workflow for deep renovation of historic buildings.
Source: EBC Annex 76 / SHC Task 59

Atlas (HibERATLAS) was fully developed and implemented in 2019, which collects Best Practice Cases in a visual and 'fun to read' way. The website was launched in October 2019 with around 25 best practice cases collected, and many more still being documented. In parallel, questions on privacy and intellectual property rights have also been clarified and a respective workflow has been defined. This is available for continuing use of the best practice database after the project end. The info sheet with basic information for architects and building owners has been prepared.

With regards to the assessment of best practice cases, an overview of the published case studies and the detailed structure of the assessment report was developed. Besides this quantitative assessment, a qualitative part of the analysis is being developed that focuses on the 'Replicability of Case Studies' and 'Transferability of favourable framework conditions'. It is based on a number of hypotheses and defines the key factors for successful renovation projects, which are verified by the cases. Finding case studies suitable for the assessment of the implementation of EN16883 in practice has shown to be more difficult than expected, with experts trying several approaches on a national level. A concept for the integrated platform has been developed, which follows the planning process as also described in EN16883. The platform enriches the quite abstract planning process with examples, tools, recommendations, and so on. A paper has been published by the International Journal on Building Pathologies that presents the central postulates of the project.

Working groups on solar, HVAC, walls, windows and strategies became fully operational in 2019. A mechanism to collate and document retrofit solutions has been integrated within the HiBERATLAS functionality and is being used by the project participants. For the documentation of these solutions, simple, open questions need to be answered to enable flexible responses. Furthermore, the project participants has decided to apply the Decision Guidance Tool (originating with the Interreg project ATLAS) for this project and thus 'upgrade' the originally planned static report to become a more interactive tool.

Meetings

The following meetings were held in 2019:

– The 4th Expert Meeting was held in Copenhagen, Denmark, in April 2019
– The 5th Expert Meeting was held in Vienna, Austria, in October 2019

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 effectiveness of building energy codes and their assessment indices for performance, energy calculation methodologies need to be the focus as the principal method for performance evaluation. As the first step to examining the technical and scientific basis of such methodologies in different countries, heating, ventilation and air conditioning (HVAC) 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 had become 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

HVAC energy calculation methodologies in five countries have been analyzed from the following viewpoints:

- space unit and zoning rules, and categories of building and space for schedule and condition of usage;
- types of HVAC systems and heat sources;
- determination of ventilation rates including when demand controls are applied;
- representation of energy efficiencies of heat sources including sizing, partial load effect and control of multiple generators;
- representation of energy efficiencies of air and water conveyance including sizing, partial load effect and controls of fans and pumps;
- consideration of initial adjustment and its effect on improving energy efficiencies of HAVC systems;
- referenced standards for test and design of HVAC system components and assemblies;
- simplification of input data with less worsening of energy calculation accuracy;
- completeness of documentation on the calculation rationale and algorithm;
- information on calculation process validation.

The first of the main findings from the project concerns how to estimate more accurately energy use by heat and cold generators. In energy efficiency tests at partial load conditions according to testing standards for compressor type equipment and heat pumps, to maintain reproducibility of the tests and stable conditions, manufacturers cannot avoid setting and fixing the status of components of the heat and cold generators, such as compressor speed and valves' opening. However, in actual situations, due to various realistic controls of the machines for failure prevention, it is possible that such stable conditions may not always be maintained, and the machines work intermittently.

In this context, the test results should be used carefully, especially for lower partial load ratios in HVAC energy calculations. It remains a very important issue how the actual energy efficiency of compressor type equipment and heat pumps should be evaluated at lower partial load ratios to realize much more realistic HVAC energy calculations. To solve the problem, actual behaviour of heat and cold generators should be monitored in real buildings, and further development of related calculation methodologies should reflect these results.

The second of the main findings from the project relates to how to more accurately estimate energy use by fans and pumps with variable volume controls. The influence of HVAC system controls on their energy performance should not be neglected, but it is still very difficult to define various kinds of control methods and analyze value setting of key parameters in the controls. Some calculation methods clearly state that ideal functions of the controls are assumed, while another has adopted a cautious approach in evaluating the components affected by the controls. However, such compensations due to lack of information may be inevitable at present.

An air handling unit being monitored for fan speed, airflow rate and energy use.

Source: EBC Working Group on HVAC Energy Calculation Methodologies for Non-residential Buildings

A variable air volume unit being monitored for signal exchanges and the angle of the opening control valve.

Source: EBC Working Group on HVAC Energy Calculation Methodologies for Non-residential Buildings

Especially when recirculated air is used as a heat and cold transfer medium between air handling units and rooms, the amount of energy used for fans can be large. Countermeasures to reduce the fan energy by using variable air volume systems and variable frequency drives is one of the promising techniques to save energy. There is a strong need for developing much clearer design guidelines and standards to define many promising control strategies, by which much more accurate calculations for energy saving can be made.

Meetings

No meetings were held in 2019.

Project duration
2016–2020

Operating Agent
Takao Sawachi, Building Research Institute, Japan

Participating countries
Australia, Canada, P. R. China, Germany, 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

EBC Annex 75 Workshop on Upscaling Energy Renovation to the District Level, held in Delft, the Netherlands, in September 2019.
Source: EBC Annex 75

Buildings are a major source of greenhouse gas emissions. Reducing their energy use and associated greenhouse gas emissions is particularly challenging for the existing building stock. In contrast to the construction of new buildings, there are often architectural and technical hurdles for achieving low emissions and low energy use in existing ones. Also, the cost-effectiveness of reaching a high energy performance in existing buildings is often lower than in the construction of new buildings. 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, companies working in the field of the energy transition, as well as building owners, on how to cost-effectively transform existing urban districts into low-energy and low-emission 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, renewable energy measures, and guidelines for building owners and investors about cost-effective renovation strategies, including district-based solutions.

Progress

The project has completed the second year of its working phase. In this period, a significant number of existing and emerging technologies were identified and characterized for further use in subsequent analyses. The technologies identified (building envelope, building systems, energy production and energy storage) were documented. In the report, the main characteristics of the technologies, interdependencies, obstacles and success factors have been identified, as well as potential for application and future developments.

The methodological guidelines for the cost optimization of the renovation solutions are now well established and parametric assessments have been initiated by project participants. Using pre-defined criteria, virtual districts were delineated and are being assessed for Austria, Denmark, Norway and Portugal. Following the definition of the characteristic parameters and the creation of the methodological guidelines, case studies from Austria, Norway, Portugal and Spain are also being investigated concerning cost-effective packages of renovation measures. A first version of the common project tool to support the calculations, which is being developed using modular functionalities, is already available and is being tested by participants.

In 2019, two workshops for stakeholders were organized to help identify the most relevant policy instruments based on benchmarking projects. The workshop, 'District renovation towards NZEB', was held in Vitoria-Gasteiz, Spain, in the Laboratory for the Quality Control of Buildings, Department of Housing of the Basque Region Government. This workshop convened more than 20 participants from public institutions, research centres and private companies to discuss and gather information on best practices and policy instruments to promote cost-effective renovations at the district scale. The workshop, 'Upscaling energy renovation to the district level', was organized in September 2019 at the Faculty of Architect-ure and the Built Environment, at Delft University of Technology in the Netherlands. Besides the project participants, a further 50 attendees took part in the discussions on business models, policy instruments and the main obstacles to be considered in upscaling energy renovation to districts. Participants included national and local authorities, businesses developers (including ESCOs), neighbourhood ambassadors, as well as policy makers and researchers. These workshops are of the utmost importance in developing the Guidelines for Policy Instruments and Stakeholder Dialogue, as they enable the collection and validation of relevant information on policies and business models in a real-world context.

Meetings

During 2019, the following project meetings were convened:
– Bilbao, Spain, in March 2019, and
– Delft, the Netherlands, in September 2019.

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

The success story of the Solar Decathlon forms the background to this project. The Solar Decathlon is an ongoing international competition for students based on an initiative of the U.S. Department of Energy that started in 2002. In this competition, universities are challenged to design, build and operate solar powered houses. It is the only student competition worldwide addressing the realization and performance assessment of buildings and not only the design. During an edition of the competition's final phase, each interdisciplinary team assembles its house in a common Solar Village. The final phase includes a public exhibition, monitoring, and 10 competing teams, which is the reason why the competition was named a 'Decathlon'.

Eighteen competitions have been conducted up to the end of 2019, of which eight took place in the USA, four in Europe, two in P.R. China and two in Columbia. Two countries in hot climates have also recently held competitions, the United Arab Emirates and Morocco. Many of the experimental houses are used as 'living labs' when transferred back to their home universities.

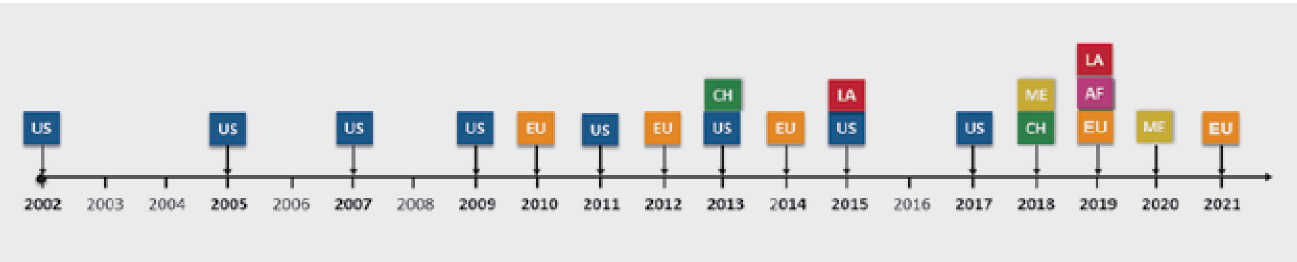
Objectives

This project is establishing a platform for mapping and linking the competition and living lab experiences worldwide and working towards improving competition formats. It intends to stimulate technological knowledge, scientific level and architectural quality within future competitions and living labs based on the development of a systematic knowledge platform, as well as creating a link to knowledge from previous and current IEA Technology Collaboration Programme (TCP) activities. Furthermore, the project aspires to increase the impact of competitions and living lab formats worldwide by means of communication and development of educational material. Parts of the project are linked to a European Commission funded project running in parallel to document the results and lessons learned especially from the European Solar Decathlon edition and to communicate these within the 'Smart City Information System' of the European Commission.

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.



Global Solar Decathlon events timeline. US: United States of America; EU: Europe; CH: China; LA: Latin America and Caribbean; ME: Middle East; AF: Africa

Source: University of Wuppertal, Susanne Hendel

Progress

The work achieved in 2019 circles around the planned deliverables. The project reports have been structured, drafted and discussed. The online knowledge platform (www.building-competition.org) has been continuously improved and new material such as organizers information and harmonized monitoring data files from past competitions have been published. A selected set of material from the European competitions has been restructured and transferred to the Smart City Information System (www.smartcities-infosystem.eu).

A set of eight thematic papers related to selected building science topics from Solar Decathlon competitions have been created. This stimulated the further development of the concept, disciplines and rules for the upcoming competition in Germany, SDE21 (www.sde21.eu), to include more scientific aspects. An example is the 'performance gap experiment' including a comparison of monitoring and simulation data for all of the competition buildings and triggered by co-heating tests. Participants within this project have explored initial experimental and simulation work to prepare the test procedure. Additional monitoring tasks have been established within the competition calendar, such as checking the PV performance ratio, or the flexibility of energy exchange with the grid. A living lab phase following the competition will allow further experimental work with the demonstration houses.

An online survey addressing the worldwide Solar Decathlon community has been developed and distributed to summarize experiences and lessons learned from past competitions. A further survey is addressing education activities and material. Contacts with organizers from competitions in P.R. China, Colombia and Morocco have been established to include the documentation and results into the Knowledge Platform. Futhermore, semi-structured interviews were performed at Solar Decathlon Europe 2019 to summarize and document the experiences of the participating teams.

Professor Sergio Vega highlighted EBC Annex 74 at COP-25, the UN Climate Change Conference in Madrid.
The presentation was part of the exhibition area of the Spanish Ministry of Innovation and Technology.
Source: Sergio Vega, UPM

Meetings

The following meetings took place in 2019:

- The 3rd Project Meeting was held in Ghent, Belgium, in April 2019,
- The 4th Project Meeting was held in connection with SDE19 in Szentendre, Hungary, in July 2019.

Project duration
2018–2020

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

Participating countries
Belgium, P.R. China, Germany, the Netherlands, Spain, Switzerland, USA
Observers: Hungary, United Arab Emirates, Colombia, Morocco

Further information
www.iea-ebc.org

Towards Net Zero Energy Resilient Public Communities

EBC ANNEX 73

Until recently, most planners of public communities (military bases, universities, and so on) addressed energy systems for new facilities on an individual facility basis without consideration of community-wide goals relevant to energy sources, renewables, storage, or future energy generation needs. Building-centric planning also falls short of delivering community-level resilience. For example, many building code requirements focus on hardening to specific threats for the 'mission-critical' buildings in a multi-building community. Recovery and adaptation should be addressed as effective energy resilience solutions. Futher, major disruptions of electric and thermal energy supplies have degraded critical mission capabilities and caused significant economic impacts at military installations.

Significant additional energy savings and increased energy security can be realized by considering holistic solutions for the heating, cooling after reducing the heating, cooling, and power needs of building communities. The status quo in planning and execution of energy-related community projects does not support the attainment of current energy goals, or the minimization of costs for providing energy security. In the future, primary and end use energy, as well as carbon footprint targets, have to be made available by transformation from the single building target framework.

Objectives

The project scope includes the decision-making process and computer-based modelling tools for achieving net zero energy resilient public-owned communities (military bases, universities, and so on). The 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. Specific objectives are to:

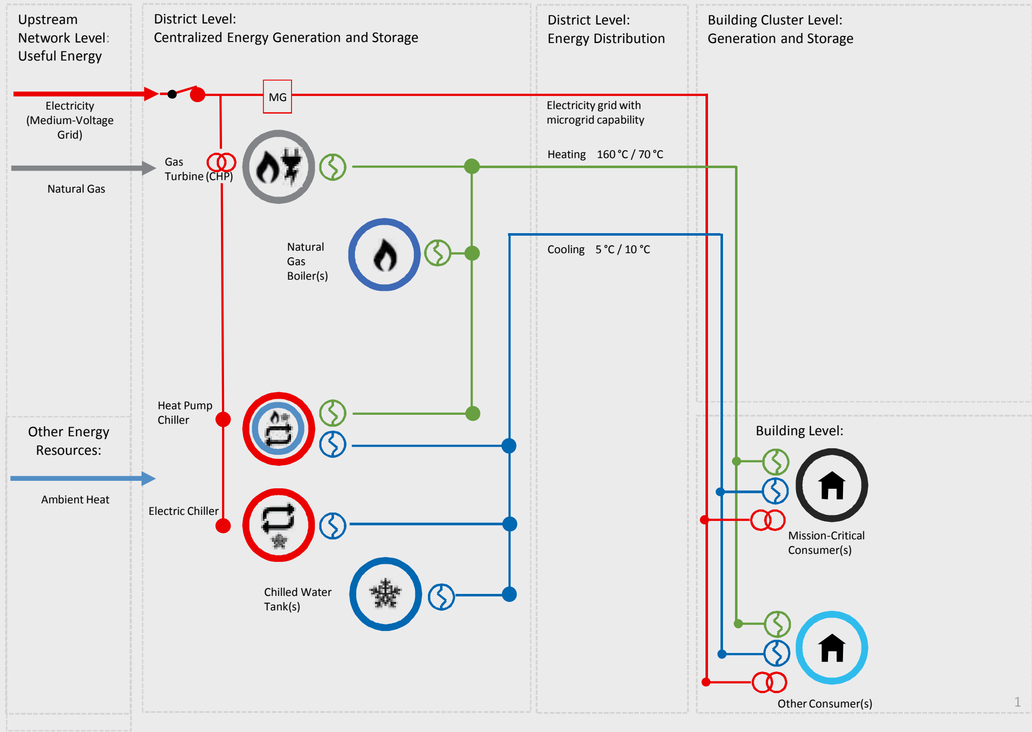
- assess and evaluate existing case studies with regard to replicable technical solutions, costs, and performance data for certain usage cases;
- develop a database of energy utilization indexes for public, education, and military building types and communities;
- develop energy targets for certain community usage cases based on the single building 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 architectures for different applications and climates;
- develop guidance for energy master planning;
- develop a functional modelling tool to facilitate the 'net zero energy master planning process', which will enhance currently used building modelling tools to address resiliency of combined energy supply and energy efficiency solutions, integrate a capability for computation of thermal and electrical network characteristics, with visualization of different architectures to support resilience decisions without significant post processing;
- collect and describe business and financial aspects, legal requirements, and constraints relevant to the implementation process of net zero energy concepts for public communities in participating countries;
- disseminate this information and train end users in the participating countries, mainly decision makers, community planners, energy managers, and other market partners.

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

Deliverables

The project is producing the following deliverables:

- a guide for net zero energy planning in public and military building communities,



Example of district heating, cooling and power systems architecture template based on the Case Study from University of Texas, Austin Medical Center.
Source: EBC Annex 73

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

Progress

In 2019 the project has achieved the following:

- summarized internationally-consistent building energy use benchmarks and targets including for common building types;
- summarized typical community level framing goals and energy-related concerns for selection of energy systems architectures, and technologies;
- developed resilience matrices, resilience requirements for representative mission critical facilities, and
  resilience analysis methodologies for use in the Guide and the modelling tool;
- collected and summarized information from more than 25 case studies from six countries that have implemented energy master plans; these case studies document processes and elements that are vital for a successful planning process;
- developed more than 60 examples of 2nd to 4th generation energy system architectures for communities with and without mission critical facilities provided with power, heating, and cooling from centralized and decentralized energy sources;
- created a database of energy supply, distribution and storage technologies with their technical, cost and reliability characteristics;
- developed the first draft of the Energy Master Planning Guide for Resilient Public communities;
- reviewed existing modelling tools for energy and resiliency planning;
- developed a concept and several parts of the calculation engine for the tool, which is a standalone module that focuses on supply, distribution, and storage technologies, addresses both thermal and electrical systems, provides performance and cost optimization, and integrates both the resiliency analysis and the results from the project's subtasks.

Meetings

The following meetings took place in 2019:

- The 3rd Working Meeting was held in New Orleans, USA, in February 2019.
- The 4th Working Meeting was held in Copenhagen, Denmark, in September 2019.

Project duration
2018–2022

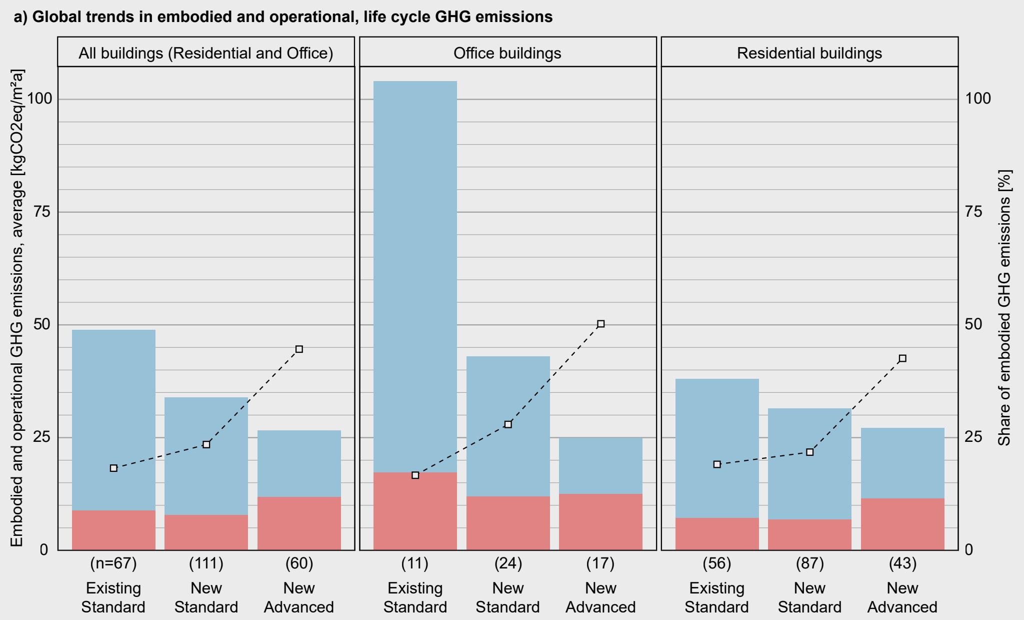
Operating Agents
Alexander Zhivov, US Army Engineer Research and Development, USA, and
Rüdiger Lohse, KEA - Climate protection and energy agency of Baden - Württemberg GmbH, Germany

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

Further information
www.iea-ebc.org

Assessing Life Cycle Related Environmental Impacts Caused by Buildings

EBC ANNEX 72



Global trends in embodied and operational life cycle greenhouse gas emissions of buildings.

Source: Röck et al (2019) 'Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation', Applied Energy (doi.org/10.1016/j.apenergy.2019.114107)

Buildings are a significant cause of environmental impacts. Nearly 40 % of all greenhouse gas emissions worldwide are caused by buildings and their supply chains. This project aims at providing the basis and tools to support architects and designers in minimising greenhouse gas emissions, environmental impacts and resource consumption caused during the entire life cycle of buildings. Through its work, the project contributes to the United Nations Sustainable Development Goals 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production) and 13 (Climate Action).

Objectives

The project has the following specific objectives:

- establish a harmonised methodology guideline to assess the life cycle based environmental impacts caused by buildings;
- establish methods for the development of specific environmental benchmarks for different types of buildings;
- derive guidelines and tools (building design and planning tools, such as building information modelling) for design decision makers;
- establish a number of case studies;
- develop national / regional databases with regionally differentiated life cycle assessment (LCA) data tailored to the construction sector.

Deliverables

The following deliverables are planned:

- a report on harmonised guidelines on the environmental life cycle assessment of buildings;
- a report on establishing environmental benchmarks for buildings, including case study examples;
- a report on national LCA databases used in the construction sector;
- a report on design decision maker's guidelines on optimization using building assessment workflows and tools,
- a report on building case studies on the application of LCA in different stages of the design process;
- a report on how to establish national/regional LCA databases targeted to the construction sector;
- default publicly available, national data set(s) of LCA-based environmental indicators.

Progress

The project has started the second year of its working phase and the participants have analysed responses to public questionnaires circulated to designers and LCA experts, documented case studies and discussed methodological questions.

It has been found that a request by clients and the public sector for relevant comparisons of alternative design solutions is decisive for making progress in integrating the aspects of resource conservation and climate protection using LCA approaches. The preliminary results of a questionnaire targeting design professionals showed that in the everyday design practice, a significant share of designers provide such services if they are required to by law, or if they are directly demanded by the client. However, it has also become clear that such activities must be sufficiently supported by data and tools, and integrated into design and decision-making processes. The findings from the questionnaire are being used to develop guidelines and tools for design decision makers.

Current LCA approaches applied in the participating countries have been analysed to develop and describe a harmonized method for the calculation and assessment of environmental impacts in the life cycle of buildings. The evaluation of the data clearly revealed that there are differences in the scope of the building elements and life cycle stages considered in the assessments, there are methodological issues in dealing with technological progress, and that issues related to physical discounting of greenhouse gas emissions need to be clarified. The project participants have agreed to recommend that the same global warming potentials should be applied for present and future greenhouse gas emissions. Furthermore, a system of performance levels (limit, reference, target value) was developed. The discussion is currently focused on deriving target values from a global carrying capacity perspective. Another goal is the development of a definition of climate or greenhouse gas neutrality, including the determination of system boundaries and compensation options.

A guidance document is being drafted on how to establish an LCA database targeted to the construction sector. This guidance document describes the needs, contents and organisational aspects of a national LCA database with special focus on the situation in India.

In late 2019, a meta-analysis was published on the relevance of construction related (so-called embodied) greenhouse gas emissions of buildings. The analysis revealed that specific embodied greenhouse gas emissions tend to increase with new and advanced building standards and thus are likely to contribute up to half or more of the life cycle greenhouse gas emissions of buildings.

Meetings

In 2019, the following meetings took place:

- The 5th Expert Meeting was held at the University of Seville in April 2019, in Seville, Spain.
- The 6th Expert Meeting was hosted by the Slovenian national building and civil engineering institute in Ljubljana, Slovenia.

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

It is essential that the energy-efficient technologies in buildings do more than simply satisfy regulations based on theory. They must make genuine differences in real-world applications. Building owners, investors and governments need to know that the investments they make are actually delivering as expected. Hence, ensuring that real performance matches design performance is critical.

Recently, statistical methods and system identification techniques have shown to be promising tools to characterise and assess the as-built performance of buildings. So far though, the studies remain dispersed. A thorough analysis of the applicability of the methods is lacking, investigating the balance between cost of data gathering versus achieved precision and reliability.

The project is evaluating and improving replicable methodologies embedded in a statistical and building physical framework to characterize and assess the actual energy performance of buildings. For residential buildings, the project is exploring the development of characterisation methods, as well as of quality assurance methods. Characterisation methods translate the (dynamic) behaviour of a building into a simplified model that can be used in modelling predictive control, fault detection, and so on. Quality assurance methods pinpoint some of the most relevant actual aspects of building performance, such as for example the overall heat loss coefficient of a building, or the solar aperture.

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

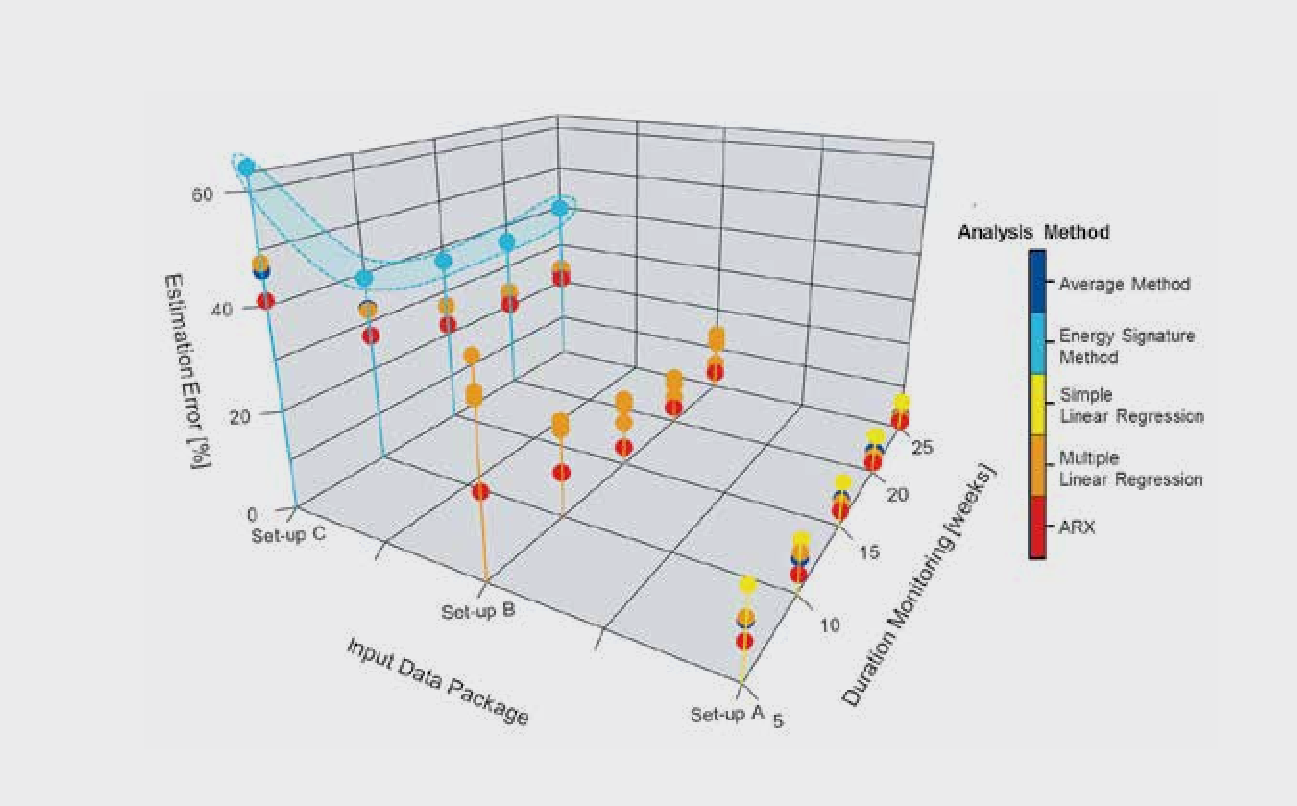
The main outcomes of the project are as follows:

- an overview of the availability and reliability of input data for on-site 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

A survey has been carried out involving more than 250 stakeholders, ranging from policy makers, housing associations, certification bodies, architects to consulting engineers. It revealed that almost 70 % of them are very interested in a method to measure the actual energy performance of a building after delivery. Main interests ranged from insulation quality (of interest for 40 % of the survey participants), overall heat loss coefficient (60 %) to energy use (72 %) and energy savings after retrofitting (75 %). Quality assurance and retrofit guidance where put forward as the most important services that could benefit from on-site assessment. Regarding the heat loss coefficient of the building envelope, more than 80 % indicated their interest in a method that would allow its on-site determination. As an acceptable cost, a range of 100 to 2000 Euro was put forward, while between one and a few days was mentioned as most preferable as an acceptable duration. Such input on acceptable cost and duration of on-site assessments is very valuable.

A major aim is to develop guidelines that link the requirements for a specific application to available methods and corresponding data acquisition techniques. Current applications regarding building behaviour identification are focusing on model predictive control (MPC) and fault detection



Exploration of different methods to determine the actual heat loss coefficient of a detached dwelling with slab on ground based on in-use data. The accuracy that can be achieved by each of the methods is evaluated as a function of the available data (data packages) and monitoring time. Based on this kind of graph, a motivated choice can be made regarding data package and monitoring time for a specific application with its corresponding required accuracy.

Source: Marieline Senave, KU Leuven, Belgium

and diagnosis (FDD). Artificial and real life data are being used to investigate possibilities and limitations of data driven prediction models for MPC and FDD-applications.

Regarding quality assessment, the main focus is on the on-site characterization of the overall heat loss coefficient (HLC). On-site measured data in artificially and actually occupied dwellings are used to explore and optimize statistical methods to characterize the actual performance. Currently, different case studies are being documented in the project, a review of which is forming the basis of the development of a matrix that links the model accuracy expected for a specific application to a list of required measurements and a statistical method. So, the project is not only exploring very advanced techniques, but it is also investigating the possibilities of simple methods that could be used with a limited budget in a broader context.

In parallel, the project is running a new building energy simulation validation exercise based on real measured data. A first example of such a validation exercise within the completed EBC project, 'Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements', dealt with an unoccupied building, heated with electrical heaters. In the current project, an experiment was set up on the same dwelling (a test house at the Fraunhofer site in Holzkirchen, Germany), but now heated with a real heating system and occupied by artificial occupants. The results of the blind validation phase are currently being compared.

Meetings

Two meetings were organized in 2019:

- The 6th Expert Meeting took place in Bilbao and Vitoria-Gasteiz, Spain, in April 2019, and was hosted by the University of the Basque Country.
- The 7th Expert Meeting was held in Rosenheim and Holzkirchen, Germany, in October 2019, and was hosted by the Rosenheim Technical University and Fraunhofer IBP.

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

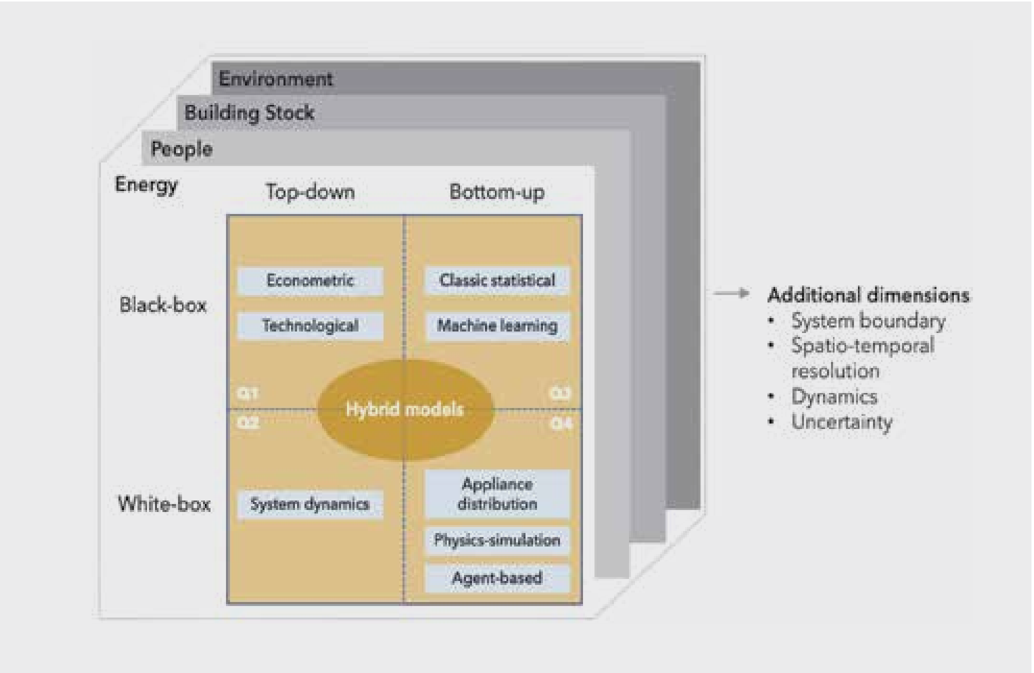
To reduce carbon dioxide emissions related to energy use in buildings, information on the building stock is needed to provide both a baseline from which to improve, along with knowing what features can achieve the greatest improvements in performance, comfort and carbon mitigation. There is therefore a growing need for countries and cities around the world to have better quality, higher frequency and greater access to data on building stocks.

The project is focused on identifying, reviewing, evaluating and producing leading edge methods for studying and modelling the building stock including: data collection techniques on energy use, building features and occupant features, and building morphology; analysis of smart meter energy data, building systems, and user behaviour; and modelling energy demand among sub-national and national building stocks. The project is divided into three parallel subtasks:
– user engagement (needs and provisions),
– data mechanisms and foundations, and
– building stock modelling and analysis.

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

What is energy epidemiology? Building energy epidemiology is the study of energy use among a population of buildings to better understand its trends and the drivers that result in variations in building energy performance across the stock. This approach can be used to study and describe the mechanisms of energy demand, as well as determinants of conditions that lead to different levels of demand.

An energy epidemiology approach is well-suited to dealing with uncertainty through the use of methodological tools and analysis techniques that include: common definitions and metrics, population selection techniques, study designs for data collection, comparison and analysis, approaches to



An updated classification scheme for building stock energy models.
Source: Courtesy of LBNL and NREL.

dealing with bias, guidelines for working towards identifying causal relationships, and systematic approaches to reviewing evidence.

Objectives

The project objectives are to:

- support countries in developing realistic decarbonisation 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 its third operating year and is now entered its reporting phase. Each subtask is in the process of reporting on their activities including users needs, energy and building stock data and models.

An Energy and Buildings Stock Data Users and Needs survey has been completed with over 800 responses received from across the project participating countries. The survey sought information about which energy and building data they use and what they need to support their activities, including research, decision-making and performance improvements. A global literature review has identified key themes and uses of published on data use and needs and a network analysis of these over time. Finally, a set of case studies on the uses of energy and buildings data from across the participating countries have been prepared to illustrate the latest approaches to using, analysing and modelling. These activities have informed the online Energy and Building Stock Model Registry under development within the project.

The Registry provides an online platform for identifying, describing and sharing energy and building stock data. As of the end of 2019, the Registry contained information on over 1000 datasets across the themes of energy, buildings, people, environment, and other important data for energy and buildings analysis. The project has also completed a set of best practice guides that focus on remote sensing, user surveys, energy metering data, geospatial energy and buildings data and more. The project has also developed a model classification that forms the basis of the Registry, enabling researchers to describe building energy stock models. In a journal submitted paper, project participants have described an example of a model classification concept for stock models. Following this work, a further journal paper is being completed providing guidance on reporting energy and building stock models. Finally, the project is reporting on a set of common exercises that focus on model uncertainty and sensitivity. During the past year, the project participants have continued to be engaged in disseminating both the concept of energy epidemiology along with the initial outputs of the effort.

Meetings

The following meetings took place in 2019:

- The 7th Operating Phase workshop took place in Delft, the Netherlands, in February 2019, and was hosted by Delft University of Technology.
- The 8th Operating Phase workshop was held in Cork, Ireland, in June 2019 and was hosted by the International Energy Research Centre.
- The 9th Operating Phase workshop was held in Cologne, Germany, in November 2019, at the DLR.

Project duration
2016–2020

Operating Agent
Ian Hamilton, University College London, UK

Participating countries
Australia, Austria, Belgium, Canada, 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

How to balance achieving a comfortable indoor environment with building energy efficiency is always a challenging issue. Previous research has suggested that strict indoor temperature control can lead to higher energy costs and greenhouse gas emissions, however, this may not always contribute to the comfort and health of occupants. Adaptive thermal comfort is considered to be an important development and is expected to play an important role in the design and operation of low energy buildings. Therefore, the actual mechanism of the adaptation process needs to fully understood. People who live in different climates may have significant differences in their adaptive responses. This also indicates that different architectural design strategies and indoor environment solutions may be appropriate in different regions.

Predicted mean vote (PMV) is generally considered to be a suitable metric for stable indoor thermal environments. Moreover, it represents the statistical average thermal demand of occupants, not the actual demand of specific occupants or individuals. To overcome the difficulties in the development of building energy saving technologies, the point is to understand the actual thermal demand of occupants. People are not passive acceptors of a given environment, rather they are active participants interacting with 'the human-environment system' through multiple feedback loops.

The theoretical framework of thermal adaptation and adaptive models have had extensive global influence and have greatly promoted research into international thermal adaptation theory. Adaptive thermal comfort provides occupants with the means to control their personal environments through the three modes of physiological adaptation, psychological adaptation and behavioral adjustment. It can improve the satisfaction of occupants with the indoor environment.

Thus, systematic and in-depth research on adaptive thermal comfort is needed. Whether the building services systems can be operated in a 'part-time, part-space' mode depends on the individual needs of the occupants, and would replace the 'whole-time, whole-space' model commonly used in many buildings. In this way, the energy use of a building can be reduced while thermal comfort for occupants can be achieved.

Objectives

This project is developing an analytical and quantitative description of building occupants' adaptive thermal 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 2019, the whole team focused on completing the project deliverables. The global thermal comfort database with user interface has been finished and complete drafts of the three remaining deliverables were prepared ready for editing. A special issue of the journal Energy and Buildings on 'Adaptive Thermal Comfort' was initiated, with more than 80 submissions received, which shows the broad interests in this topic from the international research community.

The University of Wollongong's Sustainable Buildings Research Centre in Australia, which is a case study building of EBC Annex 69.

Source: COX Architecture www.coxarchitecture.com.au/latest/university-of-wollongong-home-to-australias-most-sustainable-building/
Photographer: Jenny Yip, Gollings Photography Pty Ltd.

Meetings

The following project meetings took place in 2019:

- An EBC Annex 69 topical workshop was held in Harbin, P.R. China during the ISHVAC conference, in July 2019.
- The 7th working-phase experts meeting was held in Bari, Italy, in conjunction with the IAQVEC conference, in September 2019.

Project duration
2015–2020

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

In the near future, new and existing buildings must have enhanced energy efficiency to reduce their energy use. Improving the airtightness of building envelopes and optimizing the supply of fresh air from ventilation systems are crucial aspects of this change. This project focuses on residential buildings, and is providing knowledge on pollutant transport in materials such that ventilation can be optimized according to demand. Materials can both emit and absorb pollutants, for which the transport mechanisms are influenced by the heat, moisture and airflow conditions within and around them.

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

The working phase of the project was completed in 2019, after which drafting of the project reports continued. Also during 2019, a 'Ventilation Information Paper' on the use of metal oxide semiconductor (MOS) gas sensors for measurement of indoor air quality was co-published with the AIVC. Further, a comprehensive suite of 'common exercises' has been developed for the benefit of the project participants, which can be used in future to train other researchers in the principles and methods created in the project.

An important aspect of the project has been the so-called 'similarity approach', by which pollutant transport can be modelled in a way that is similar to existing modelling paradigms for combined heat, air and moisture transport. This approach has been instrumental in bringing results from analysis of pollutant transport into simulation and design tools, which are already applied in thermal building analysis. This has resulted in a set of tools, which are contained in the 'CHAMPS' modelling platform for Combined Heat, Air, Moisture and Pollutant Simulation. The focus of this multi-scale and multidisciplinary modelling platform is on integration and use of free solvers developed in the scientific community. The solvers deal with building processes related to air, light, energy, HVAC operation, moisture and pollutants. For the simulation of pollutants, it uses experimental results from the project on pollutant loads, which has produced a database on such properties.

A guide has been developed that gathers information on practical applications and stakeholder perspectives on the use of the project results. This report starts with an overview of how residential ventilation is currently designed, and then elaborates on how residential ventilation could be designed in the future by applying the technology dealt with in the project. It further explains their implications for performance and

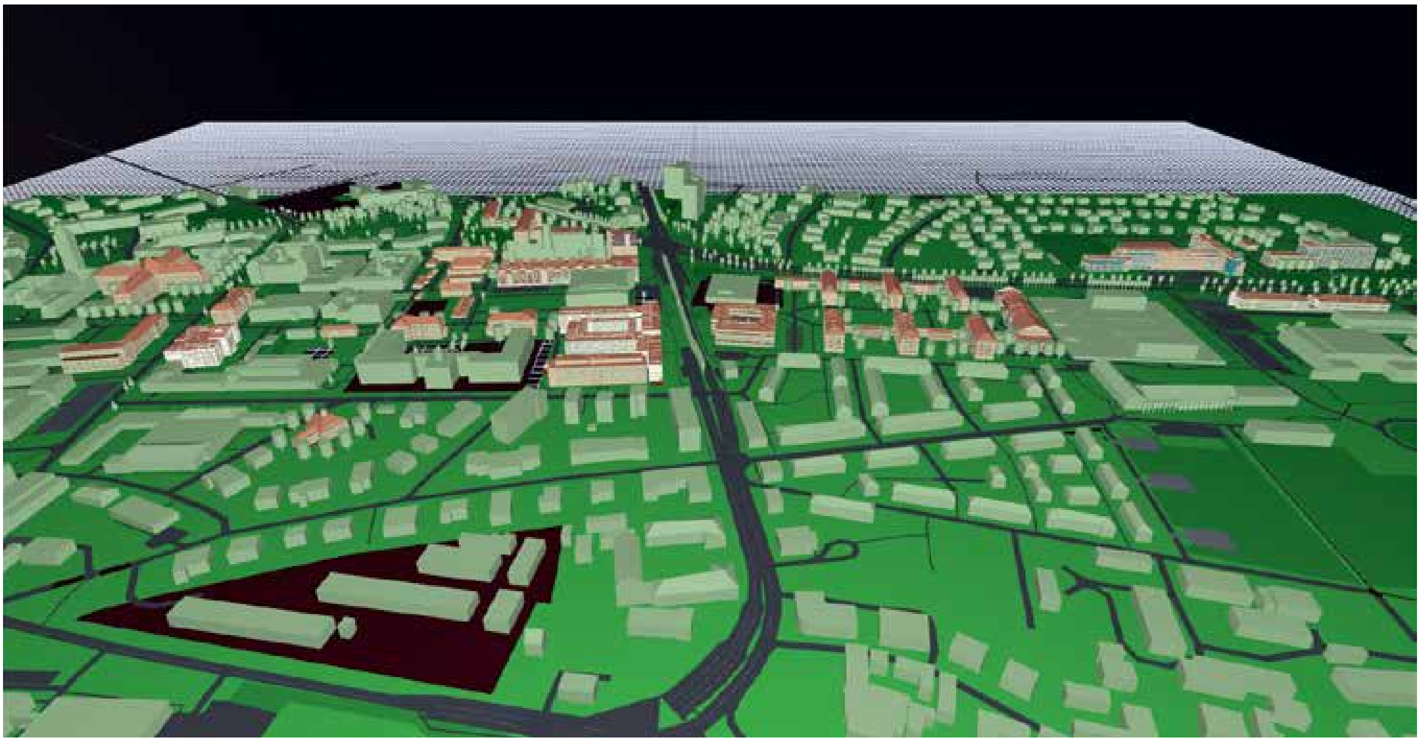


Illustration from a tool in the CHAMPS modelling platform, which highlights building complexes at a community scale that can be simulated for their combined heat, air, moisture and pollutant conditions, including an energy performance assessment.
Source: TU Dresden, Germany

occupant satisfaction. An assembly of seven case studies from practice is included in the project results, along with a presentation of five different field experiments, and an overview of measurement technologies that can be used for indoor atmospheric studies in buildings.

Meetings

- The working phase of the project was completed with an expert meeting held at the Technical University of Denmark, in March 2019.
- Subtask leaders and co-authors of the reports were in digital communication during the remainder of 2019.
- Represented by project participants, results were presented at the IAQVEC 2019 Conference held in Bari, Italy, in September 2019; at the CHAMPS 2019 Workshop in Nanjing, P.R. China, in October 2019; at the AIVC Conference in Ghent, Belgium, in October 2019.

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, United Kingdom, USA
Observers: Estonia

Further information
www.iea-ebc.org

Energy Flexible Buildings

EBC ANNEX 67

During recent decades, the development of building technologies has been concentrated on obtaining good indoor comfort and on increasing the energy efficiency of buildings including the energy services systems. In many industrialised countries, this has been forced by regular strengthening of building codes, ordinances or regulations, for example in the European Union via the Energy Performance of Buildings Directive (EPBD). However, until now, buildings have mainly been considered as passive consumers of energy (and more recently also as passive producers) where the surrounding energy networks (electricity, gas, district heating / cooling) have ensured a sufficient energy supply. While the stability of power grids was often previously supported by central fossil-fuelled energy plants, this has started to change as many countries have decided to phase out fossil fuels and replace them with renewable energy sources (RES).

However, most RES have an intrinsic variability that can seriously affect energy network stability. There is, therefore, a need for a transition from 'energy generation on demand' to 'energy use on demand' to match the instantaneous energy generation from RES with the demand. In practice, this means that energy use needs to become flexible.

Therefore, buildings will need to change from being passive consumers/producers to become active consumers/producers, which are able to adjust their energy use according to the actual available levels of energy in the networks. Specifically, they need to use more during periods with much renewable energy in the networks, for instance by storing energy for later use, and reducing use during shortages of energy in the networks. Hence, buildings need to become 'energy flexible'. As this is a new concept, there is a need for reliable knowledge on how to obtain, control and characterise energy flexibility for buildings.

Objectives

The project objectives are as follows:

- development of 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 types of building 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

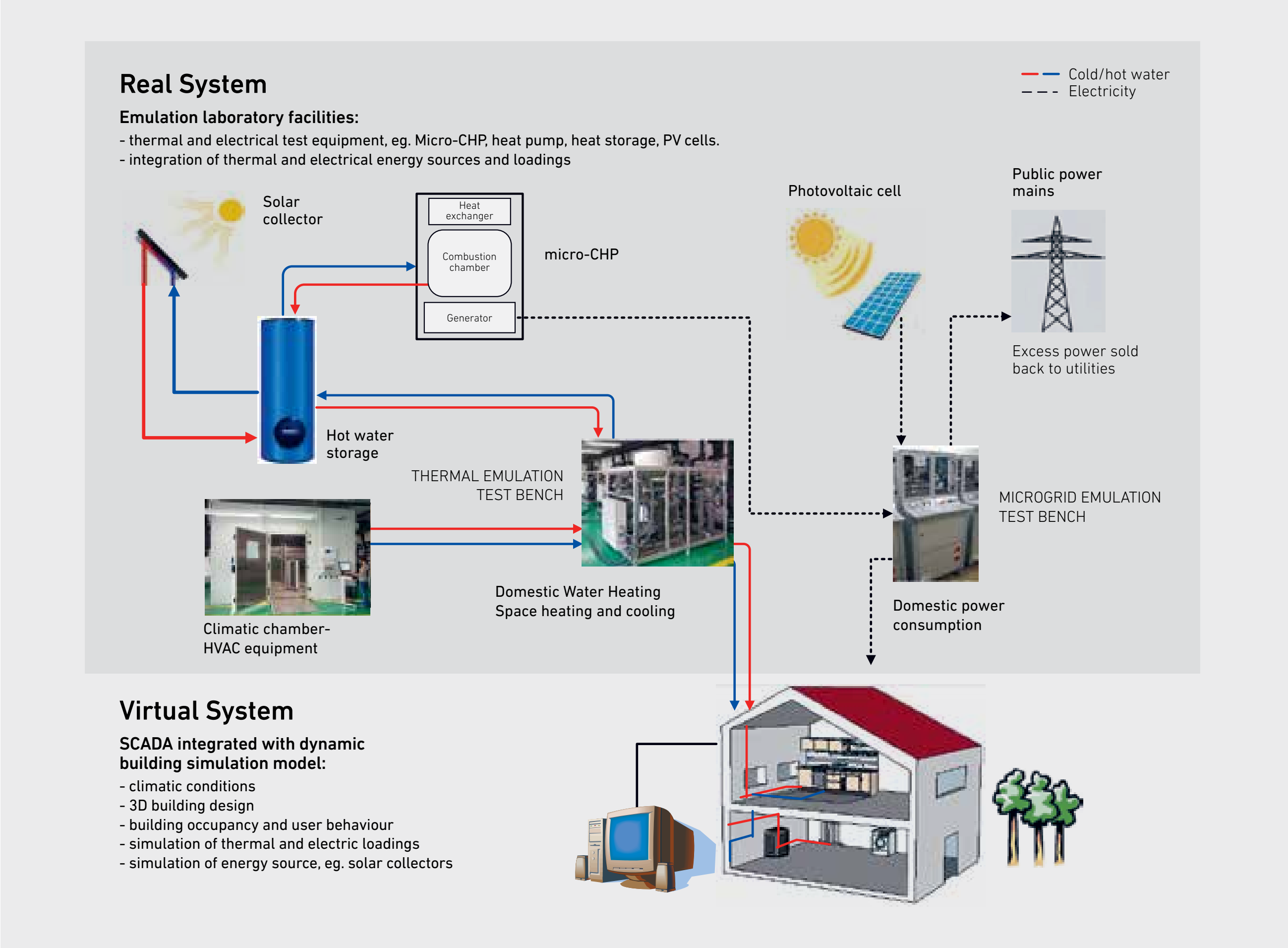
The following reports are being produced as project deliverables:

- 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

With respect to its objectives, the project has achieved the following:

- developed a methodology for characterization of energy flexibility for buildings and agreed a common terminology;
- increased knowledge about the acceptance, motivation and barriers for the stakeholders involved around energy flexible buildings, knowledge which is important when introducing energy flexibility in real buildings;



Example of a hardware-in-the-loop test facility: the Semi-virtual Energy Integration Laboratory test facility at IRAC, Spain.

Source: EBC Annex 67

- documented 33 cases of different ways of obtaining and controlling energy flexibility in buildings and clusters of buildings and determined the potential available energy flexibility;
- investigated energy flexibility mainly in single buildings, but also the aggregated energy flexibility from clusters of buildings has been studied in some cases; it has further been shown that different types of buildings perform better in some energy networks than in others depending on the actual mix of renewable energy sources in the energy network;
- tested energy flexibility in hardware-in-the-loop test facilities and in some field studies.

So, the project can be considered to have made a major step forward in integrating energy flexible buildings as important assets for future energy networks.

During the course of the project, the European Commission published proposals to include 'Smart Readiness Indicators' (SRIs) in the EPBD. The aim of SRIs is to rate the readiness of a building to adapt its operation to the needs of the occupants and the grid, and to improve its performance. As this is clearly in line with its objectives, this project participated as a stakeholder in the first study on SRIs and produced a position paper. The viewpoint of the project is that there is a need for an approach that takes into account the dynamic behaviour of buildings rather than simple static counting and rating of control devices as proposed by the EC SRI study. Furthermore, it is more important to minimize the carbon dioxide emissions from the overall energy networks than to optimize the energy efficiency of individual building components.

Meetings

The 8th working meeting was held in Aalborg, Denmark in April 2019

Project duration
2014 – 2020

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

Air Infiltration and Ventilation Centre

EBC ANNEX 5

This activity was established in 1979 under the name 'Air Infiltration Centre', and undertook technical activities and provided information services with the task of minimizing air infiltration energy losses. In 1986, its name was changed to 'Air Infiltration and Ventilation Centre' (AIVC) to reflect the importance of the coupling of good airtightness with appropriate ventilation. Over time, the AIVC has been continuously evolving to respond to emerging concerns, challenges and opportunities. Now having completed its 40th year, the AIVC's main goal is to provide reference information on ventilation and air infiltration in the built environment with respect to efficient energy use and good indoor environmental quality (IEQ).


Ventilation Information Paper n° 39

March 2019

AIVC

Air Infiltration and Ventilation Centre

A review of performance-based approaches to residential smart ventilation

1 Introduction

2 Context on smart ventilation

The latest project publication 'Ventilation Information Paper no. 39: A review of performance-based approaches to residential smart ventilation', published in 2019.

Source: EBC Annex 5

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 2019, the AIVC focused its work on eight projects, the 40th AIVC Annual Conference, a workshop and two web-inars. Furthermore, the AIVC supported discussions and dissemination for 'EBC Annex 62: Ventilative Cooling', 'EBC Annex 68: Design and Operational Strategies for High IAQ in Low Energy Buildings' (p. 44), 'EBC Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications' (p. 20), and 'EBC Annex 80: Resilient Cooling' (p. 16). 2019 was also the year that AIRBASE, the Bibliographic Database of the AIVC containing more than 16 000 documents, became freely accessible for all users.

The aforementioned eight AIVC projects are entitled, 'Air Cleaning as Alternative for Ventilation', '40 Years of AIVC', 'Influence of Zoning on the Utilization of Residential Heat Recovery Ventilation', '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'.

Following the completion of the AIVC's 'Smart Ventilation' project (2017–2018), the Ventilation Information Paper, 'VIP 39: A review of performance-based approaches to residential smart ventilation' was released in March 2019. This provides a review of performance-based approaches used around the world for the assessment of mainly smart ventilation strategies. The AIVC project '40 Years of AIVC', is expected to result in the Technical Note, 'AIVC after 40 years', highlighting the progress and outcomes over these 40 years with contributions from various AIVC Board experts.

The 40th AIVC Annual Conference was held in Ghent, Belgium, in October 2019. The theme of the conference was 'From energy crisis to sustainable indoor climate 40 years of AIVC'. 204 people from 28 countries attended the conference, and 13 topical sessions were organized during the event – the proceedings are available in AIRBASE. The event has also been a major discussion place for on-going projects, such as the current EBC R&D projects mentioned above. The conference also featured the official inauguration of the Indoor Environmental Quality Global Alliance (IEQ-GA) during a ceremony held on the evening of the first day of the event.

The workshop 'Quality ventilation is the key to achieving low energy healthy buildings' was held in March 2019, in Dublin, Ireland. The event was co-organized with the Sustainable Energy Authority of Ireland (SEAI) and drew over 80 participants. The AIVC also organized two webinars on ductwork airtightness measurements in April 2019 and kitchen ventilation in May 2019.

In order to achieve more interactions with related organizations, AIVC is a founding member of IEQ-GA. (www.ieq-ga.net). There is also a close collaboration with the TightVent platform (www.tightvent.eu) and the venticool platform (www.venticool.eu).

Meetings

The AIVC Board met twice in 2019 as follows:

- Dublin, Ireland, in March, 2019, and
- Ghent, Belgium, in October 2019.

AIVC Newsletter

- March 2019 edition
- September 2019 edition

Project duration
1979–2021

Operating Agent
Peter Wouters, INIVE eeig, Belgium

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

Further information and reports
www.iea-ebc.org

AIVC

www.aivc.org

Completed Research Projects

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

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. However, the question can reasonably be asked as to why new insulating materials should be developed when many 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 air-tightness. 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 recent decades, mainly vacuum insulation panels (VIPs) and advanced porous materials (APMs) such as aerogels. In order to give confidence to end-users, this project has created 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.

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.

Achievements

In 2019, the four official project deliverables were finalized and published as follows:

- a state-of-the-art and case studies report;
- a report containing scientific Information for standardisation 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).

The state-of-the-art review clearly shows that applications of SIMs are spreading fast around the world, but in absolute terms the market for SIMs is growing slowly. Further, a report on the results of extensive testing performed by project participants gives a comprehensive analysis of methods and procedures that have to be used to fully characterise SIMs.

Indoor renovation with vacuum insulation panels finished with a protective layer.
Source: SINIAT – CLIMISOL

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

A further report presents the life cycle impact assessment (LCIA) results from the life cycle inventories (LCIs) created for the studied SIMs. The LCIA results for fumed silica VIPs with mass-based allocation showed reasonably good agreement with those published elsewhere in Environmental Product Declarations (EPDs). Meanwhile, the results with economics-based allocation showed higher values than any of the published EPD results. This suggests that the representation of the LCI collected in the project properly represents the products in the market when the impact is calculated by mass-based allocation.

Meanwhile, the LCIA results for aerogels deviated significantly with the published EPD values for the created LCI for both of the drying methods used in their production. This is because the best available LCI data collected during the project represent-ed pilot-scale data, rather than data for full-scale manufacturing. Thus, the collected LCI data in this case may not be appropriate to be used to compare with other insulation materials, as the aerogels may not be appropriately represented. However, the 'hotspot analysis' conducted may give a good insight into potential improvement opportunities for the environmental performance of aerogels, such as producing them in a country with a low carbon electricity grid, such as France or Sweden.

Meetings

– The Operating Agent gave a presentation on the project at the EBC Technical Day, held in Brussels, Belgium, in June 2019.

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

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, and
- 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 use at least 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 use;
- 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 TCP 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)
- User-Centred Energy Systems (Users)
- 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 TCPs 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 approxi-mately 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 TCP: 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 TCP: 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 TCP addresses life cycle environmental accounting of buildings and their constituent materials and components, as well as indoor air quality, while the SHC TCP 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 buildings-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

– 40th AIVC Annual Conference, held Ghent, Belgium, October 2019

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
– VIP 39: A Review of Performance-based Approaches to Residential Smart Ventilation, 2019

Contributed Reports

– CR 17: Indoor Air Quality Design and Control in Low-energy Residential Buildings – EBC Annex 68 Subtask 1: Defining the Metrics, 2017
– CR18: Ventilation and Indoor Air Quality in New California Homes with Gas Appliances and Mechanical Ventilation, 2019

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

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

Long-term Performance of Super-insulating Materials in Building Components and Systems – EBC Annex 65

– State of the Art on Materials and Components: Case Studies, 2019
– Characterization of materials and components: Laboratory Scale, 2019
– Practical Applications: Retrofitting at the Building Scale – Field Scale, 2019
– Sustainability: LCC, LCA, EE – Risk & Benefit, 2019

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

Integrated Solutions for Daylighting and Electric Lighting – EBC Annex 77 / SHC Task 61

– Workflow and Software for the Design of Integrated Lighting Solutions, 2019

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Past Projects

Annex 1 Load Energy Determination ofBuildings
Annex 2 Ekistics and Advanced Community Energy Systems
Annex 3 Energy Conservation in Residential Buildings
Annex 4 Glasgow Commercial Building Monitoring
Annex 6 Energy Systems and Design of Communities
Annex 7 Local Government Energy Planning
Annex 8 Inhabitants Behaviour with Regard to Ventilation
Annex 9 Minimum Ventilation Rates
Annex 10 Building HVAC System Simulation
Annex 11 Energy Auditing
Annex 12 Windows and Fenestration
Annex 13 Energy Management in Hospitals
Annex 14 Condensation and Energy
Annex 15 Energy Efficiency in Schools
Annex 16 BEMS 1 – User Interfaces and System Integration
Annex 17 BEMS 2 – Evaluation and Emulation Techniques
Annex 18 Demand Controlled Ventilation Systems
Annex 19 Low Slope Roof Systems
Annex 20 Air Flow Patterns within Buildings
Annex 21 Thermal Modelling
Annex 22 Energy Efficient Communities
Annex 23 Multi Zone Air Flow Modelling (COMIS)
Annex 24 Heat, Air and Moisture Transfer in Envelopes
Annex 25 Real time HEVAC Simulation
Annex 26 Energy Efficient Ventilation of Large Enclosures
Annex 27 Evaluation and Demonstration of Domestic Ventilation Systems
Annex 28 Low Energy Cooling Systems
Annex 29 Daylight in Buildings
Annex 30 Bringing Simulation to Application
Annex 31 Energy-Related Environmental Impact of Buildings
Annex 32 Integral Building Envelope Performance Assessment
Annex 33 Advanced Local Energy Planning
Annex 34 Computer-Aided Evaluation of HVAC System Performance
Annex 35 Design of Energy Efficient Hybrid Ventilation (HYBVENT)
Annex 36 Retrofitting of Educational Buildings
Annex 37 Low Exergy Systems for Heating and Cooling of Buildings (LowEx)
Annex 38 Solar Sustainable Housing
Annex 39 High Performance Insulation Systems
Annex 40 Building Commissioning to Improve Energy Performance
Annex 41 Whole Building Heat, Air and Moisture Response (MOIST-ENG)
Annex 42 The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM)
Annex 43 Testing and Validation of Building Energy Simulation Tools
Annex 44 Integrating Environmentally Responsive Elements in Buildings
Annex 45 Energy Efficient Electric Lighting for Buildings
Annex 46 Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)
Annex 47 Cost-Effective Commissioning for Existing and Low Energy Buildings
Annex 48 Heat Pumping and Reversible Air Conditioning
Annex 49 Low Exergy Systems for High Performance Buildings and Communities
Annex 50 Prefabricated Systems for Low Energy Renovation of Residential Buildings
Annex 51 Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision Makers
Annex 52 Towards Net Zero Energy Solar Buildings (NZEBs)
Annex 53 Total Energy Use in Buildings – Analysis and Evaluation Methods
Annex 54 Integration of Microgeneration and Other Energy Technologies in Buildings
Annex 55 Reliability of Energy Efficient Building Retrofitting – Probability Assessment of Performance and Cost
Annex 56 Cost Effective Energy and CO_2 Emissions Optimization in Building Renovation
Annex 57 Evaluation of Embodied Energy and Carbon Dioxide Equivalent Emissions for Building Construction
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 65 Long-term Performance of Super-insulating Materials in Building Components and Systems
Annex 66 Definition and Simulation of Occupant Behavior in Buildings