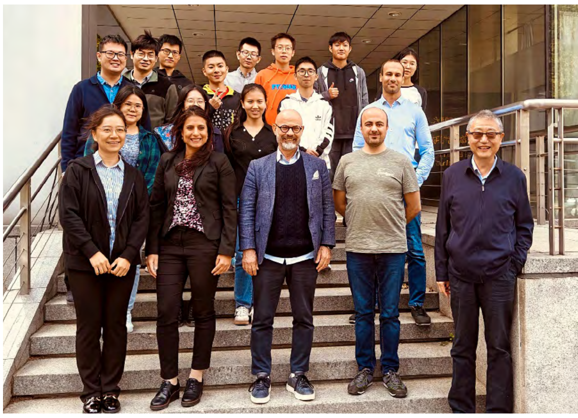
EBC

Energy in Buildings and
Communities Programme

Annual Report 2023



Technology Collaboration Programme
by iea

Energy in Buildings and
Communities Programme

International Energy Agency

EBC Annual Report 2023

Energy in Buildings and Communities Technology Collaboration Programme

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

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

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Front cover:
Some of the current EBC project participants and recent event attendees. The EBC projects arranged hybrid international in-person and online meetings in 2023 to progress their work after the global pandemic hindered travel in the preceding years, with a total of approximately 500 participants at present.

Sources (clockwise from top left):
EBC Annex 86; EBC Annex 85; EBC Annex 79; EBC Annex 79; EBC Annex 81; AIVC EBC Annex 5

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EBC Executive Committee Chair's Statement

The IEA Technology Collaboration Programme on Energy in Buildings and Communities is at the forefront of international research into how energy efficiency measures and renewable energy generation can be fully integrated for buildings operating within decarbonised energy systems. EBC's projects strengthen the key actions identified in the IEA's World Energy Outlook 2023 needed to ensure greenhouse gas emissions peak and then trend downwards to 2030. More specifically, the EBC Annexes' collectively generated knowledge supports the IEA's policy- and technology-actions that include, among others, doubling the pace of energy efficiency improvements to 4% per year, tripling renewable energy capacity, and ramping up electrification.

Therefore, I am honoured to have recently been appointed as the Executive Committee Chair for the EBC TCP. I am very excited to take on this role and look forward to building on the high calibre work of the Chairs that have gone before me. In this respect, I would like to deeply thank my predecessor, Dr Takao Sawachi, for his excellent leadership and guidance over the past six years. In my new role, it is a pleasure to continue to work with my EBC colleagues, and I greatly appreciate the breadth and depth of knowledge they bring to the table.

EBC's collective knowledge forms the foundation for the success of our recently approved Strategic Plan for 2024–2029, and is key to increasing the impact of the work carried by the researchers delivering our many projects, supported by industry representatives: Examples of its application in our research include the development of guidance for better building energy codes and the technical basis of standards, improved performance in evaporative cooling systems, improved performance of buildings based on leveraging data taking the occupants into consideration, and making sure that positive energy districts meet high performance thresholds.

As one of the important themes identified in the new Strategic Plan, our projects will greatly benefit from collaborating with other IEA TCPs. To this end, I am encouraged by the initiation of new, focused TCP Co-ordination Groups that are well-aligned with our scope, including on heat pumps, heat networks, and energy system flexibility. This initiative came out of the latest IEA Universal TCP meeting held in October 2023. As EBC is active in these three areas, I anticipate there will be significant opportunities to benefit from and create greater external impact with these interactions with the other TCPs.

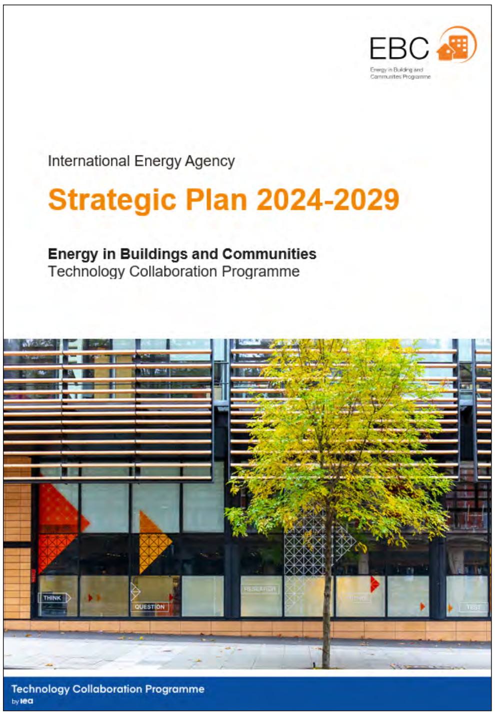
Beyond this, and given the tight timelines for reaching net zero emissions, it is important to rapidly translate our research findings into robust evidence to inform the design of public policy. Such policies need to ensure measurable improvements are made to the effectiveness of national and regional implementation programmes to increase the energy performance of buildings and communities. I am proud to support this essential work.

Meli Stylianou
EBC Executive Committee Chair and Member for Canada

EBC Strategic Plan 2024–2029

SUMMARY

Within the framework of the International Energy Agency (IEA) Technology Collaboration Programmes (TCPs), the Energy in Buildings and Communities (EBC) TCP is conducting collaborative research projects among its 26 member countries. The vision of the EBC TCP is that 'by 2030, new buildings and communities have adopted sustainable solutions with near-zero primary energy use and greenhouse gas emissions, and a wide range of reliable technical solutions have been made available for the existing building stock taking a lifecycle perspective'. Its mission is 'to accelerate the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by developing new knowledge and technologies through international collaborative research and open innovation'.



The Strategic Plan 2024–2029 was jointly developed for the benefit of all of the EBC participating countries.

Source:
IEA Energy in Buildings and Communities (EBC)
Technology Collaboration Programme

Overall control of the EBC TCP is maintained by an Executive Committee (ExCo), which not only monitors existing projects, but also identifies new areas where collaborative efforts may be beneficial. To date, 91 major international research and development (R&D) projects have been initiated within the Programme since 1977. The EBC TCP follows an open innovation R&D model, and works cooperatively with industry in its member countries, including designers and manufacturers.

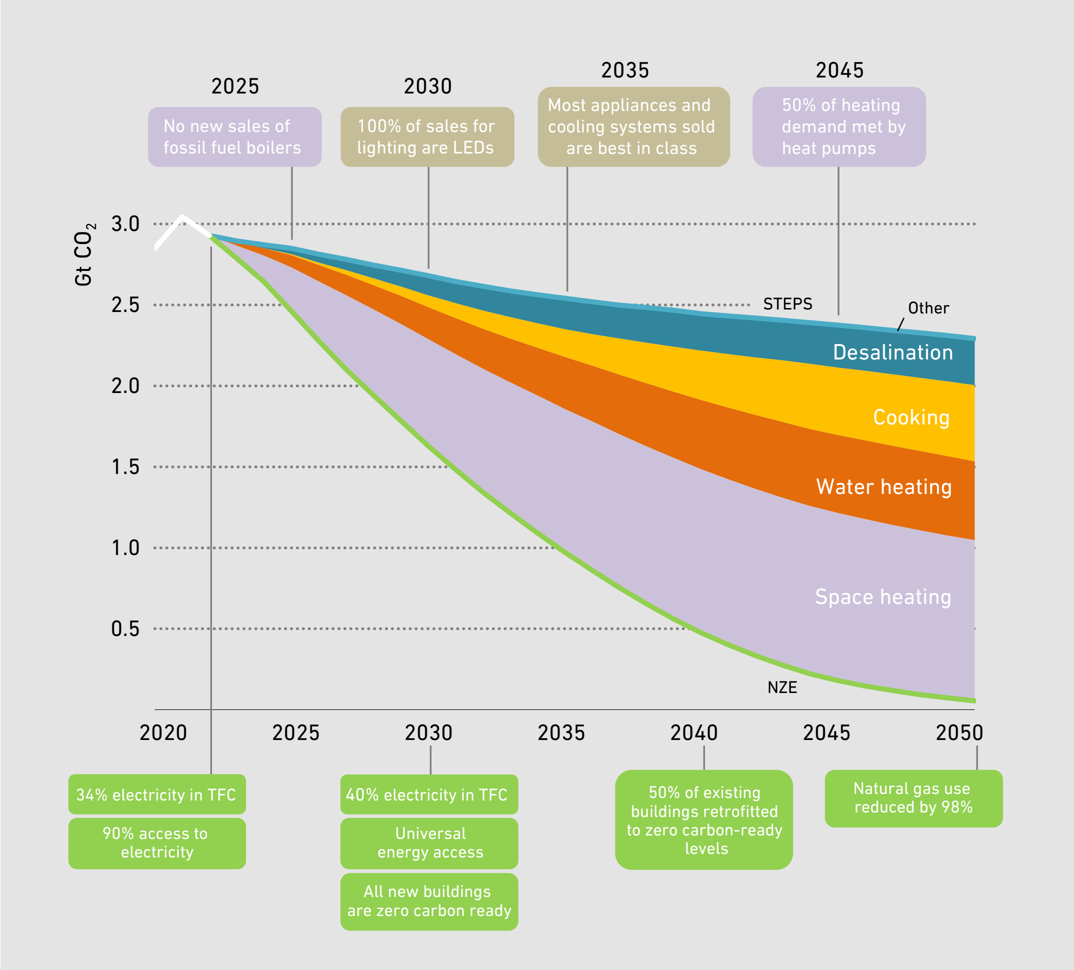
The R&D strategy of the EBC TCP for the five-year period from 2024 to 2029 is derived from the Future Building Forum Think Tank Workshop held in October 2022 in Gatineau, Canada, convened jointly with the other buildings-related TCPs as the members of the IEA Buildings Co-ordination Group, as well as the strategic planning workshops held at the EBC ExCo meetings in Istanbul, Türkiye, in November 2022, and in Copenhagen Denmark, in June 2023. The R&D strategy is also based on the IEA Medium-Term Strategy.

Four main themes form the basis of this latest EBC Strategic Plan, and a series of actions are proposed for each. These themes are as follows:

1. Collaboration with related TCPs
2. Refreshing the Priority Research Topics
3. Achieving impact from EBC research activities
4. Developing EBC Governance

Collaboration with Related TCPs

- Introduce a process for evaluating, and if appropriate, proposing collaboration with other TCPs as part of the review of proposals at the Project Concept stage to ensure early communication with other TCPs.
- Introduce a process by which ExCo members from EBC can work with ExCo members from other TCPs to propose fully collaborative projects.
- Introduce a process to scrutinise concepts put forward to the ExCo to decide if they are more relevant to another TCP and should be directed accordingly.



Emissions reductions and key milestones in the buildings sector in the Net Zero Emissions by 2050 (NZE) Scenario relative to the Stated Policies Scenario (STEPS), 2020–2050. Space heating delivers 50% of emissions reductions in buildings, driven by electrification and demand reductions from efficiency and behavioural changes.
Notes: TFC = total final consumption; LEDs = light emitting diodes.

Source:
International Energy Agency World Energy Outlook 2022, License CC BY 4.0 (report); CC BY NC SA 4.0 (Annex A)

Refreshing the Priority Research Topics

The overall objective should follow the IEA's 'Net Zero by 2050 – A Roadmap for the Global Energy Sector', with a demand-led approach that focuses on reduction in energy use and energy demand.

- Members countries should be asked to actively propose topics for research based on their priorities and the research priorities of other bodies will be taken into account, such as the European Union (EU) and the American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE).
- In developed countries, the overriding objective must be to address the retrofit of the existing building stock. Whilst in emerging economies, more emphasis should be placed on delivering net-zero new buildings.
- Address globally the increasing importance of embodied greenhouse gas ('carbon') emissions in new construction and retrofit.
- Develop research to support a significant extension of electrification. Recognising the need to deliver energy security and to fully utilise fluctuating renewable energy supplies, which will require equal attention to demand management and flexibility alongside energy efficiency.
- Digitalisation will affect all aspects of building construction, building operation and interactions with energy systems and other utility infrastructure. Future research will be required to ensure digitalisation delivers the expected outcomes and benefits.
- Achieving performance in practice by closing the performance gap will be vital to delivering net zero greenhouse gas emissions by 2050.
- Ensuring that energy efficiency / decarbonisation measures for buildings and the built environment are future-proof and take account of adaptation to a changing climate.

Achieving Impact from EBC Research Activities

- The main responsibility for delivering impact to rest with each Annex.
- Encourage Annexes to engage early with stakeholders that facilitate the introduction of the developed technologies and processes to practising engineers, architects, designers, and the market.
- Include criteria in evaluating Annex Texts that scrutinise pathways to impact.
- Use 'Theory of Change' to identify relevant actors and their information needs for Annex outputs.
- Tailor outputs to the information needs and literacy of the relevant stakeholders, for example policy briefings to follow best practice guidance.
- Work with established channels for dissemination, for example ASHRAE, Representatives of European Heating and Ventilation Associations (REHVA), Chartered Institution of Building Services Engineers (CIBSE), and so on.

Developing EBC Governance

- Adopt the modernised EBC Implementing Agreement, including introducing 'Limited Sponsors' with their benefits and obligations to be defined.
- Develop EBC policy on equality, diversity and inclusion.
- Nominated ExCo members to review new project proposals and to be selective.
- Create a platform for Operating Agents (OAs) to share experience.
- Consider proposals for funding ExCo 'Strategic Items'.

Further information

www.iea-ebc.org

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

New Research Projects

SMART MATERIALS FOR ENERGY-EFFICIENT HEATING, COOLING AND INDOOR AIR QUALITY CONTROL IN RESIDENTIAL BUILDINGS (EBC ANNEX 92)

OPEN BUILDING INFORMATION MODELLING FOR ENERGY EFFICIENT BUILDINGS (EBC ANNEX 91)

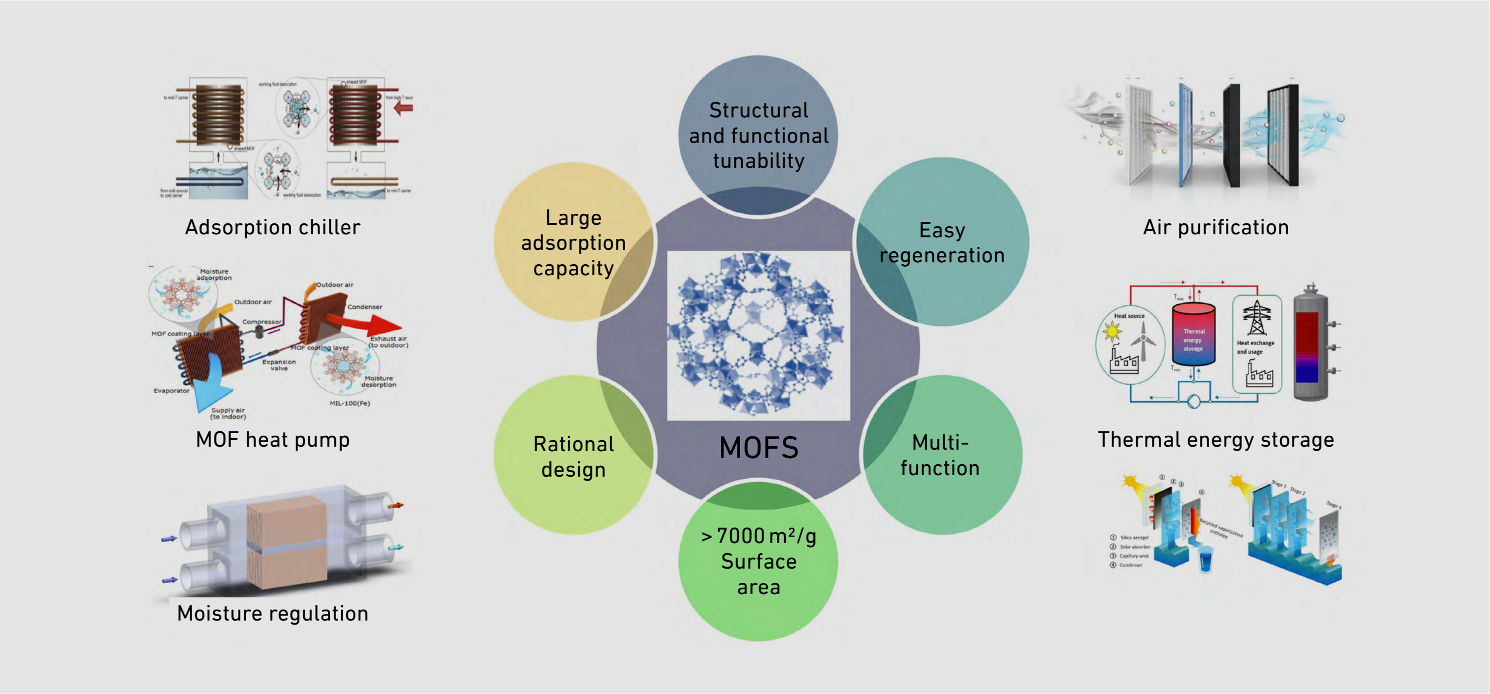
LOW CARBON, HIGH COMFORT INTEGRATED LIGHTING (EBC ANNEX 90)

Smart Materials for Energy-efficient Heating, Cooling and Indoor Air Quality Control in Residential Buildings

EBC ANNEX 92

The fast-growing use of heating, ventilation and air-conditioning (HVAC) systems in buildings worldwide has become one of the main drivers of increases in global energy demand. Many new air-conditioning units are energy inefficient and will significantly burden electricity grids and our climate. Using air conditioners for cooling and dehumidification already accounts for more than 30% of total building electricity consumption. When combined with the atmospheric impact of refrigerants, the energy consumption associated with cooling represents one of the largest end-use risks to our climate. The common technology used for mechanical cooling in buildings has not changed much since it was invented 100 years ago. Drastic transformation of cooling / heating technology by using new functional materials and new physical-chemical processes can significantly reduce HVAC systems' energy demand, improving indoor air quality (IAQ) and minimizing the negative impacts on the environment and climate.

This project is developing energy-efficient heating, cooling and air purification strategies by using novel smart materials, especially advanced sorbents, such as metal-organic frameworks (MOFs) and their related composites, through cross-disciplinary international collaboration. It is gathering the existing scientific knowledge and data on novel sorbent materials for cooling / dehumidification, pollutant removal, heating and energy storage. It is studying current and innovative use of these materials in air-conditioning, air purification, and thermal storage systems. It is also identifying and bridging the knowledge gaps by establishing links between different disciplines. In the project, experts from building science, materials chemistry, mechanical engineering, material sciences, and environmental health are working together with other stakeholders to accelerate the development of better and more energy-efficient heating, cooling, and IAQ control systems by using advanced materials.



Metal-organic frameworks (MOFs) and their application for built environment control.

Source: EBC Annex 92

The project consists of five tasks:
- Materials preparation and characterization
- Applications: Cooling and dehumidification
- Applications: Air purification and ventilation
- Applications: Heating and energy storage
- Dissemination, management and interaction

Objectives

The main aim of the project is to develop energy-efficient heating, cooling and air purification strategies by using novel smart materials, especially advanced sorbents (MOFs and hydrogels) and their related composites, through a cross-disciplinary international collaboration. The project objectives are to:
- establish a cross-disciplinary international collaboration platform to develop breakthrough cooling / heating technologies by using smart materials;
- review, analyze, and evaluate novel sorbent materials suitable for energy-efficient heating, cooling, and air purification – selection criteria will be set up for different applications;
- develop or further improve the performance of the selected materials for specific applications in different climates;
- develop suitable shaping methods of the best sorbents to adapt to the criteria of the different applications;
- identify or further develop innovative cooling systems using new materials, which avoid conventional vapor compression refrigeration;
- develop innovative air purification systems using new sorbent materials. Both the active system and passive approaches will be studied;
- develop innovative heating and heat storage systems using new sorbent materials;
- carry out laboratory tests to measure the performance of the new solid cooling, heating, and air purification systems – numerical modeling and optimization will also be conducted;
- develop guidelines regarding design and control strategies for novel cooling, heating and air purification systems using novel sorbent materials;
- identify or further develop models and tools that will be needed to assist designers and managers of buildings in using the guidelines;
- identify and investigate relevant case studies where the above-mentioned performance characteristics can be examined and optimized.

Deliverables

The project is creating the following four deliverables:
- A literature list for energy efficient energy management: This deliverable will provide a comprehensive overview of all the literature that was used and highlighted during the project.
- An overview report on methods and tools for selecting smart materials for energy-efficient cooling, dehumidification, IAQ control and thermal energy storage strategies: This deliverable will provide professionals and practitioners with a collection of methods and tools for IAQ management strategy.
- A collection of scientific publications in high-level journals: This deliverable will bring together scientific publications from all project subtasks.
- A collection of case studies and demonstrations of energy-efficient heating, cooling and thermal energy storage using smart materials: This deliverable will provide both policy makers and industry practitioners with an overview of current practices and real-life examples of energy-efficient built environment control strategies using novel smart materials.

Progress

An international workshop for the preparation of the project proposal was held in Copenhagen, Denmark, in October 2023.

The project preparation phase was approved at the EBC Executive Committee meeting held in Beijing, P.R. China, in November 2023.

Meetings

A number of initial preparatory project meetings took place in December 2023.

Project duration
2024 – 2028

Operating Agent
Menghao Qin, Technical University of Denmark (DTU), Denmark

Participating countries (provisional)
Australia, Austria, Belgium, Brazil, Canada, P.R. China, Denmark, France, Germany, R. Korea, Norway, Portugal, Sweden, USA

Further information
www.iea-ebc.org

Open Building Information Modelling for Energy Efficient Buildings

EBC ANNEX 91

Building information modelling (BIM) represents a transformative approach in digital construction planning, offering substantial enhancements in managing building energy efficiency. This methodology integrates inputs from various stakeholders such as architects, engineers, planners, modellers, constructors, and facility managers into a unified BIM model. The model serves as a central repository during the planning stage, encompassing details such as geometric data, thermal characteristics of building components (walls, slabs, exterior structures, and so on), and energy systems (space heating, cooling, automation). BIM exists in two variants:

- 'closed BIM', limited to specific software tools, offering minimal external cooperation;
- 'open BIM', aligning with the globally recognized IFC Schema (Industry Foundation Classes, ISO 16739-1), facilitating data exchange across diverse software platforms. Additionally, open BIM adheres to smart building standards like BCF (BIM-Collaboration Format), IDS (Information Delivery Specification), and IDM (Information Delivery Manual), promoting broader interoperability.

This project tackles the technological and procedural challenges inherent in successful open BIM initiatives. The focus areas include:

- establishing a BIM library, i.e. a set of common data definitions for BIM, to enhance seamless data transfer across different software;
- research aimed at refining planning procedures and developing collaborative guidelines;
- practical application of BIM methods in building planning and management, with a particular emphasis on thermal simulation.

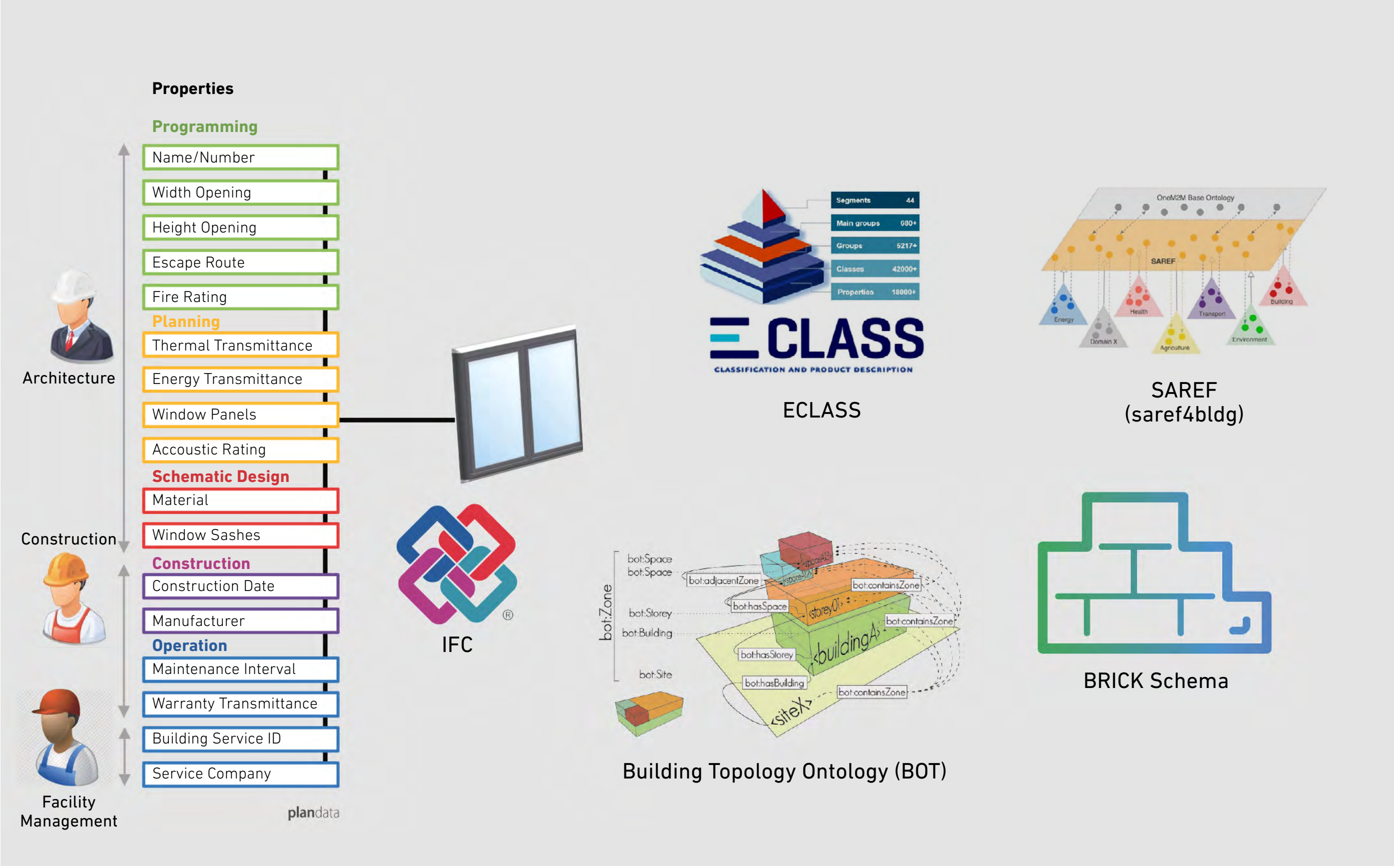
BIM is the key technology to improving the overall energy efficiency of buildings by:

- bringing together domains such as architectural design and building services engineering by working on the same data – this helps to reduce the number of inconsistencies by basing all data on a 'single source of truth', and improves the overall model quality, fostering a fully interdisciplinary approach and enabling designs to be audited and checked against building operation, potentially facilitating the tracing of liabilities involved the design and operation processes;
- enabling seamless integration of simulation tools with open BIM – such processes can provide timely answers during the planning process and remove the need for parallel energy modelling processes;
- linking planning data with the commissioning process of building services throughout the complete life cycle of buildings;
- enabling more comprehensive analysis of operational data and more straightforward optimization of building energy systems.

Objectives

The project objectives are as follows:

- making energy efficiency assessment and optimization become an integral feature of open BIM,
- building the foundations for open BIM processes and data models that are beneficial especially for small and medium enterprises (SMEs), and which enable seamless cooperation of all stakeholders in a common open BIM project, and
- advancing the interoperability and harmonization of open BIM processes and data models both on national and international levels.



Open BIM builds on IFC (Industry Foundation Classes) and allocates alphanumeric information within the BIM model. It can also interact with other ontologies such as ECLASS, SAREF, BRICK or BOT.

Source: EBC Annex 91

Deliverables

The following project deliverables are planned:

- identification of the common BIM library scope;
- analysis of use cases and information requirements;
- developing ontologies for establishing the relationships between key concepts;
- testing and validating the BIM library;
- definition of BIM use cases for building energy performance;
- development of modelling process and guidelines;
- identification and application of pipelines and toolchains;
- case studies of use cases;
- evaluation of the common library, ontologies, and processes;
- identification of potentials and required future developments.

Progress

The project preparation phase was concluded in 2023, and the working phase will start in 2024.

Meetings

No project meeting were held in 2023.

Project duration
2024–2026

Operating Agent
Gerhard Zucker, AIT Austrian Institute of Technology, Austria

Participating countries
Austria, Australia, Belgium, Brazil, Germany, Ireland, Italy, Sweden, United Kingdom

Further information
www.iea-ebc.org

Low Carbon, High Comfort Integrated Lighting

EBC ANNEX 90

The carbon footprint of lighting has a significant impact on global warming, and accounts for about 5% of global greenhouse gas (GHG) emissions. Also, in the transition to mainly electricity-based energy systems, with about 15% of electrical energy use lighting is of comparable magnitude to other existing or new end uses, for example electric vehicles and heat pumps. With rising electricity prices and increasing directly-taxed GHG emissions, lighting also results in significantly higher energy costs. Thus, to make current high comfort lighting installations more efficient, the consumption of electric lighting systems must be cut further, and the benefits of daylight better exploited. Moreover, embodied energy must be considered for electric lighting and for façade technologies for daylighting. Thus, widening the rating perspective of lighting solutions to a more holistic view of their impacts on GHG emissions is urgently required. This needs to encompass the whole life cycle (the 'lighting value chain'), and also characteristics of regional energy markets, interactions with other building trades, and so on. This goes far beyond purely LED lamp driven efficiency gains, and can provide large additional benefits.

Objectives

The aim of the international research project EBC Annex 90 / SHC Task 70 is to identify and support implementing the potentials of lighting (electric lighting, and daylighting and passive solar through façades) for decarbonization with a global perspective, while aligning the new integrative understanding of human light needs with digitized lighting on a building level and a building-related urban scale. The project objectives are as follows:

- Support broadening the view on lighting solutions for decarbonization as a whole: bridge the gap between a component view from a manufacturer's focus and design-oriented system approaches; support the transition from energy focused views to a life cycle analysis perspective; identify key impact factors and develop the most effective strategies and roadmaps while including regional specifics.
- Contextualize broadening the view on lighting solutions with the fast-developing digitization of buildings / lighting installations on the technology, design, and operational side; address selected unresolved problems with the digital chain, such as better design processes.
- Align broadening the view on lighting solutions with the still developing understanding of occupant and operator needs, and especially build upon the findings from earlier projects, for example 'SHC Task 61: Solutions for Daylighting and Electric Lighting'.
- Integrate competencies: bring together the different players involved (electric lighting, façade, industry, controls) to create low carbon solutions through workshops and specific activities; create impact by transferring the project outcomes into standardization, regulations, and building certification.

The project is a collaborative research activity with the IEA Solar Heating and Cooling Programme, through which SACREEE (Southern African Development Community Centre for Renewable Energy and Energy Efficiency) also participates.

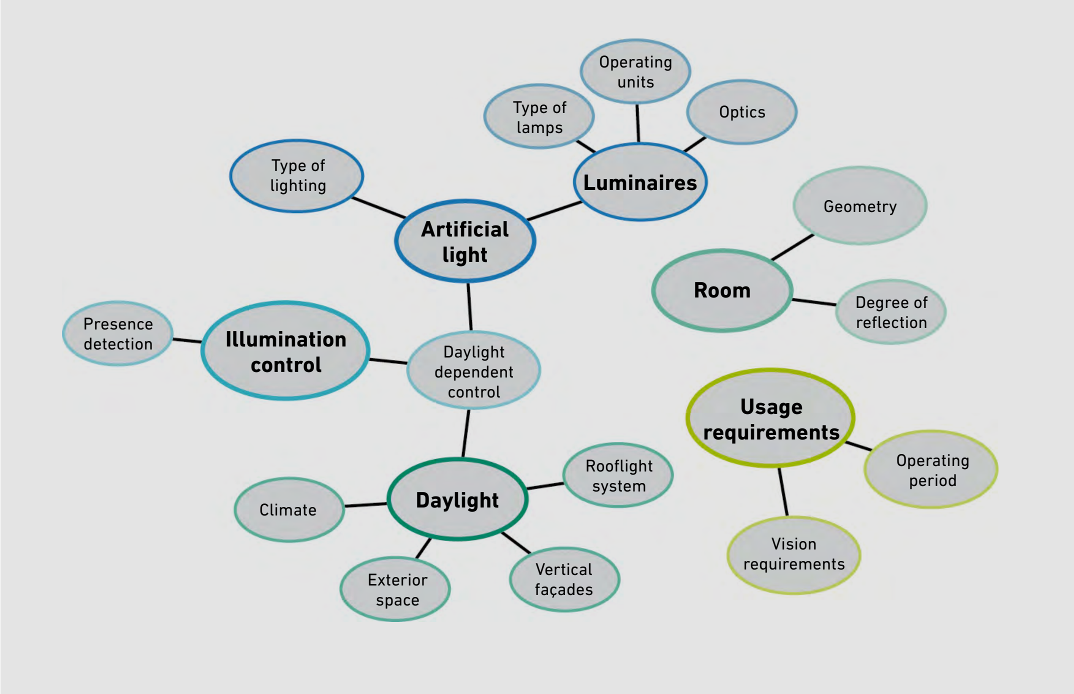
Deliverables

The following documents are planned to be published, along with information dissemination activities:

- reports on 'Low Carbon Lighting: Scenarios, Strategies and Roadmaps', 'Visual and Non-Visual User Requirements', 'Digitalized Lighting Solutions for low carbon build environments', 'Low carbon daylighting and lighting solutions: practical applications',
- a white paper on current state-of-the-art of lighting simulation software tools for visual and non-visual performance evaluation,
- a simple software tool to rate low carbon scenarios,
- standardization: initiation of new work items by appropriate standardization bodies on bidirectional scattering distribution function (BSDF) daylight system characterization, and
- industry workshops and seminars for practitioners.

Progress

The project started in 2023 with two well attended industry workshops held in conjunction with expert meetings in Aversa, Italy, in spring 2023 and London, UK, in autumn 2023. Contributions from lighting-, façade-, control-system manufacturers, lighting and building designers, and public authorities were combined with presentations from project experts. Deep insights into how different stakeholders tackle



Factors influencing lighting and associated energy consumption addressed in the brochure 'LED Guideline for the Promotion of Lighting Retrofitting'.

Source: © Fraunhofer IBP

sustainable integrated lighting solutions at present were given and discussed from different perspectives.

A new guideline on lighting retrofits: The new brochure 'LED Guideline for the Promotion of Lighting Retrofitting' was published in 2023. This provides suggestions for accelerating the replacement of old lighting systems, 'harvesting the low hanging fruits', and managing daylight. With lighting being responsible for about 15% of electricity consumption and about 5% of global GHG emissions, it needs to be brought up to date with climate protection, energy sovereignty, and economic efficiency, while ensuring occupant comfort at the same time.

In new buildings, almost only LED systems are now being designed and installed. However, many existing buildings have not yet been converted to LED technology despite offering great and often easy-to-develop climate protection potential, so-called 'low hanging fruits'. With such conversions forced by the phasing out of fluorescent lamps (by 2023 in the European Union for instance), the main question is whether 'transitional solutions' in the form of LED replacement lamps make sense, or whether it would be better to switch to more efficient and effective LED systems right away? When answering this question, the focus should not be solely on the high efficiency of the LEDs, but also on new control options and the most sustainable light source, daylight.

Meetings

The following meetings were held in 2023.

- 1st Task Meeting was held in Aversa, Italy, in April 2023.
- 2nd Task Meeting was held in London, UK, in October 2023.

Project duration
2023–2026

Operating Agent
Dr. Jan de Boer, Fraunhofer Institute for Building Physics, Germany

Participating countries
Australia, Austria, Belgium, Brazil, P.R. China, Denmark, Germany, Italy, Japan, Norway, Poland, South Africa, Spain, Sweden, Netherlands, Türkiye, USA
Observers: Greece

Further information
www.iea-ebc.org

Ongoing Research Projects

WAYS TO IMPLEMENT NET-ZERO
WHOLE LIFE CARBON BUILDINGS
(EBC ANNEX 89)

EVALUATION AND DEMONSTRATION OF ACTUAL ENERGY
EFFICIENCY OF HEAT PUMP SYSTEMS IN BUILDINGS
(EBC ANNEX 88)

ENERGY AND INDOOR ENVIRONMENTAL
QUALITY PERFORMANCE OF
PERSONALISED ENVIRONMENTAL CONTROL SYSTEMS
(EBC ANNEX 87)

ENERGY EFFICIENT INDOOR AIR QUALITY MANAGEMENT
IN RESIDENTIAL BUILDINGS
(EBC ANNEX 86)

INDIRECT EVAPORATIVE COOLING
(EBC ANNEX 85)

DEMAND MANAGEMENT OF BUILDINGS
IN THERMAL NETWORKS
(EBC ANNEX 84)

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)

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)

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

Ways to Implement Net-zero Whole Life Carbon Buildings

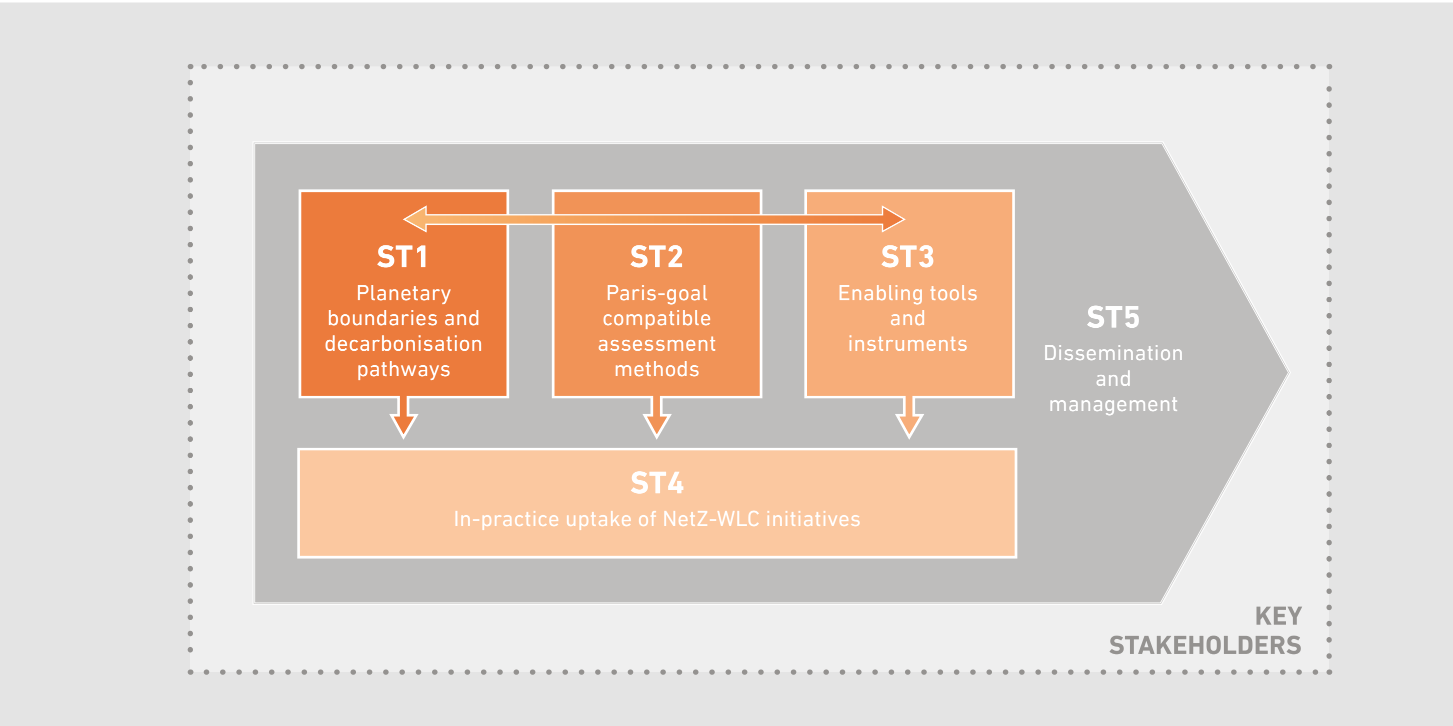
EBC ANNEX 89

This project focuses on the pathways and actions needed by various stakeholders and decision-makers to implement whole life cycle based net-zero greenhouse gas (GHG) emissions from buildings in policy and practice. This means explicitly considering both embodied and operational GHG emissions across all stages of the built asset life cycle, referred to as 'whole life carbon' (WLC) for brevity. The ultimate ambition is to achieve the overarching goal of the United Nations Climate Change Conference (COP21), held in Paris, France, in December 2015 ('the Paris Agreement'). This goal is to limit global warming to well below 2° C, and preferably to 1.5° C , above pre-industrial levels by aiming to achieve climate neutrality ('net zero', NetZ) at latest by 2050. The policies, initiatives and actions that share, support and contribute to this goal are referred to here as 'Paris-goal compatible'. There is a critical and urgent need to effectively implement science-based targets, assessment methods, and solutions into policy and practice to enable a broad range of stakeholders and key decision-makers across the world to promote and support the delivery of NetZ-WLC buildings at speed and at scale.

Objectives

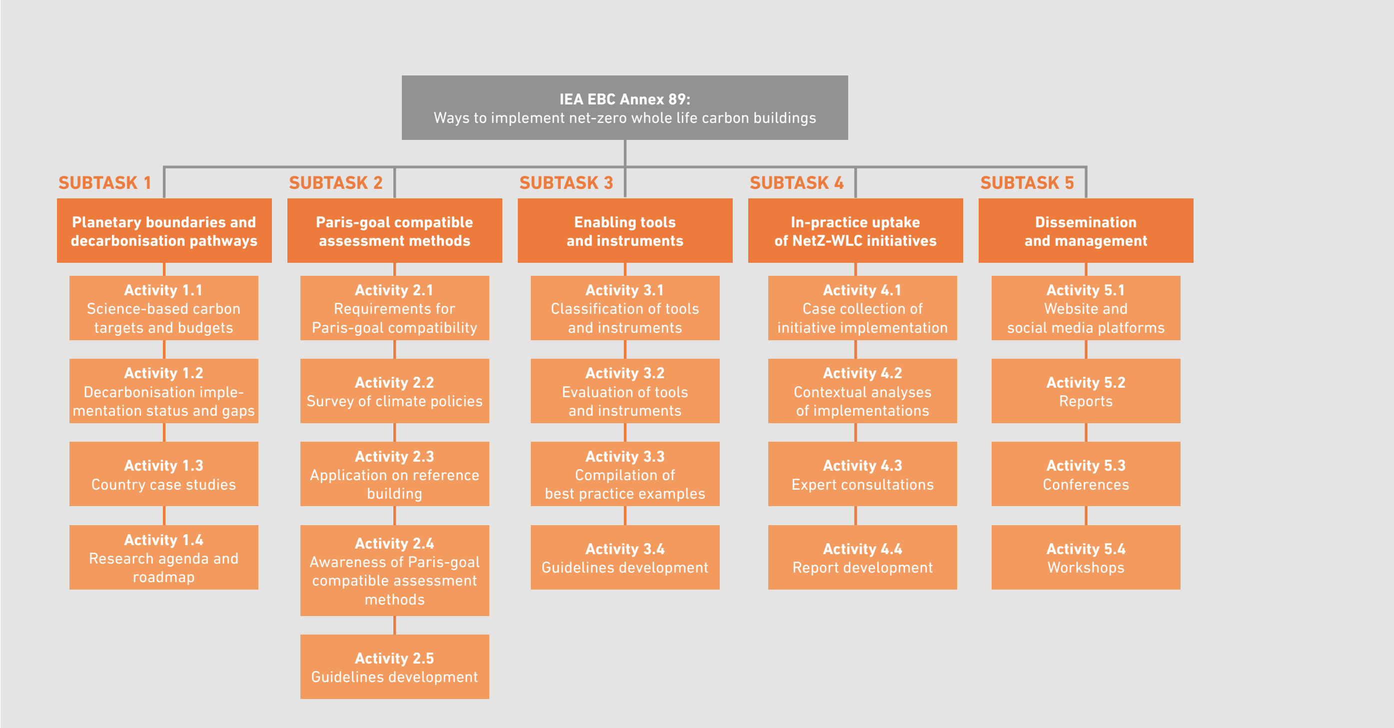
The project objectives are to:

– develop guidelines and recommendations on establishing WLC targets (including remaining total allowable GHG emissions, 'carbon budgets') for the building and real estate sector at various scales and perspectives and identifying critical GHG reduction pathways and actions;
– establish Paris-goal compatible assessment frameworks and evaluating the suitability and applications of different assessment methods to achieve NetZ-WLC buildings at various scales;
– map and assess the relevance and effectiveness of a range of tools, aids, and instruments available to different stakeholders in their decision-making contexts and objectives;



Structure of the EBC Annex 89 project.

Source: EBC Annex 89



Activities in the EBC Annex 89 Subtasks

Source: EBC Annex 89

- understand the conditions that are conducive for in-practice uptake and more effective implementation of context-based solutions and actions by key stakeholders;
- ensure efficient and effective engagement and knowledge exchange with diverse stakeholder groups and disseminating project outputs that maximize opportunities to 'get it to the ground' from local to global scales.

Deliverables

The planned deliverables for the project include:

- a report on guidelines and recommendations on establishing GHG reduction paths and actions towards NetZ-WLC buildings based on relevant contexts of countries and jurisdictions,
- a report on guidelines for selection and application of assessment methods to estimate and determine Paris-goal compatible NetZ-WLC status of buildings,
- a report on enabling tools and instruments to increase NetZ-WLC building implementation at national and regional (for example European Union) level, and
- a report on enabling and disabling factors for implementation of NetZ-WLC initiatives, and lessons learnt for transferring to different contexts.

Progress

The preparation phase of the project was successfully completed in early 2023, and the project was approved to transition to the working phase in June 2023. Work is now actively underway within the project tasks, with detailed activities already defined. There is regular communication between the project tasks, covering both content and organisational aspects.

In terms of dissemination, the project has shown considerable activity through digital channels. This includes the creation of the project website and a presence on social media platforms such as LinkedIn. Further initiatives for additional dissemination activities are also underway.

Meetings

The following meetings were held during 2023:

- a Preparation meeting in Vienna, Austria in April 2023, and
- 1st Expert Meeting in Copenhagen, Denmark, in October 2023.

Project duration
2023–2027

Operating Agent
Alexander Passer, Graz University of Technology, Austria

Participating countries
Australia, Austria, Belgium, Brazil, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Italy, Japan, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Türkiye, United Kingdom, USA

Further information
www.iea-ebc.org

Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings

EBC ANNEX 88

Heat pump technology has been recognized as one of the most promising technologies to improve building energy performance for application in 'zero-carbon-ready' buildings, which is defined as the target to be achieved by 2030 in 'Net Zero by 2050' (IEA, May 2021). This view is shared by the participants in this project, but previous monitoring projects carried out in recent years have shown a gap between their actual energy efficiency in buildings and conventional indices expressing annual or seasonal average energy efficiencies. The latter are calculated according to product standards including test methods. Two major reasons for the gap have been identified during the preparation phase of this project as follows:

- The first reason is the prescriptive conditions applied in test standards. For the sake of reproducibility and practicability of the test requirements, a heat pump under test conditions is controlled so that its status is stabilized including its compressor speed. This kind of control is special, and differs from when a heat pump is in normal operation in a building.
- The second reason is that conventional indices such as seasonal energy efficiency ratio (SEER), seasonal coefficient of performance (SCoP), and so on, are calculated without information on the building in which a heat pump is to be installed, and without including relevant whole system properties such as on the relationship between the maximum capacity of the heat pump and the maximum thermal needs to be dealt with by the heat pump – These are assumed to be equal (for cooling) in the standards, even though the former is much larger to meet the latter with enough spare capacity based on typical sizing practices.

Therefore, there is a need to share information on the characteristics of conventional testing methods, and current proposals for new testing and calculation methods of energy use by heat pumps, such as those applied for building energy codes and standards. There is also a need to share information on methods for field monitoring of heat pump systems in buildings and to create a database of field monitoring case studies.

Objectives

The overall objective of this project is to establish the scientific basis for more accurate estimation of the energy efficiency of heat pump systems for heating and cooling of buildings and for more reliable and transparent design strategies for building applications of heat pump systems.

Deliverables

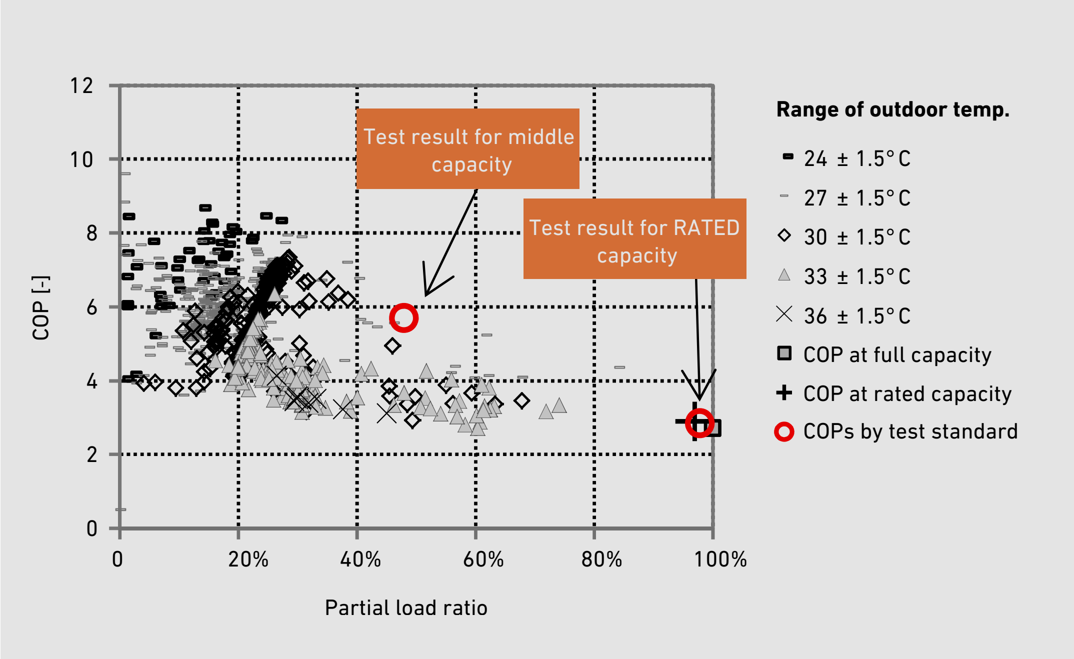
The project deliverables are expected to be as follows:

- state-of-the-art report on the evaluation and demonstration of actual energy efficiency of heat pump systems in buildings,
- recommendations of load-based test methods for heat pump systems,
- recommendations of protocols to monitor actual characteristics and behaviour of heat pump systems,
- database of monitoring results on heat pump systems and on other heat generators in buildings,
- design guidelines of heat pump systems in buildings based on the evaluation of energy use and efficiency, and;
- recommendations for policy and decision makers.

Progress

The following progress was made in 2023:

- Load-based testing methods for air conditioners: Load-based testing is a newly developed method in which no special control of air conditioners such as fixing compressor frequency is applied. A method for room air conditioners has been standardized as CSA SPE-07:23. Two other projects for room air conditioners and variable refrigerant systems are ongoing in Japan. A fourth method examined within the project is being developed in Germany for air-to-water heat pumps. To measure the capacity of the room air conditioners used in the monitoring, the relationships between discharged airflow rate and fan rotation frequency were obtained for each in a test facility beforehand using a method compliant with a product test standard. In addition, performance indices such as the 'middle capacity' coefficient of performance (CoP) were obtained according to the product test standard and compared with the natural behaviour of the room air conditioner.



An example of the relationship between partial load ratio and coefficient of performance (CoP) for a room air conditioner for cooling in a detached house for different outdoor temperature ranges.

Source: EBC Annex 88

These monitoring data demonstrate that evaluating CoPs at lower partial load ratios such as 10% to 30% is more influential than at higher ones such as 50% to 100%.

- Monitoring methods and database of energy performance of heat pump systems: Monitoring of heat pump systems in buildings has the potential to directly provide facts on the actual energy performance of heat pump systems installed in buildings. A database of monitoring results is being developed and analysed as practical guidelines for heat pump systems is being developed.
- Energy use calculation methods for heat pump systems: In many national building energy codes and standards, energy use calculation methods have been developed and utilized. When such methods aim to predict as close as possible to real energy use, they should be regularly improved upon based on new findings on actual energy performance of equipment. Several international and national methods are being reviewed in the project.
- Design Guidelines of heat pump systems in buildings for HVAC designers and other building practitioners: It can be considered that building practitioners including HVAC designers have not yet been provided with reliable quantitative technical information on heat pump systems. So, the project is developing design guidelines that contain information on how energy efficiency of heat pumps should be determined based on key factors such as partial load ratio and temperature conditions.
- State-of-the-art review: Preparation for the first project deliverable was underway, which covers the four key areas listed above. An example to be included in the state-of-the-art review report is given above, which summarises a monitoring project for room air conditioners. Four types were monitored in a detached house with mechanically simulated occupants behaviour including indoor heat emissions and appliance operation.

Meetings

The following meetings were held during 2023:

- The second series of meetings was held online in April and May 2023.
- The third series of meetings was held online in September, October and November 2023.

Project duration
2022–2027

Operating Agent
Takao Sawachi, Building Research Institute, Japan

Participating countries
Australia, Brazil, Canada, P.R. China, Denmark, Germany, Italy, Japan, the Netherlands
Observers: Philippines

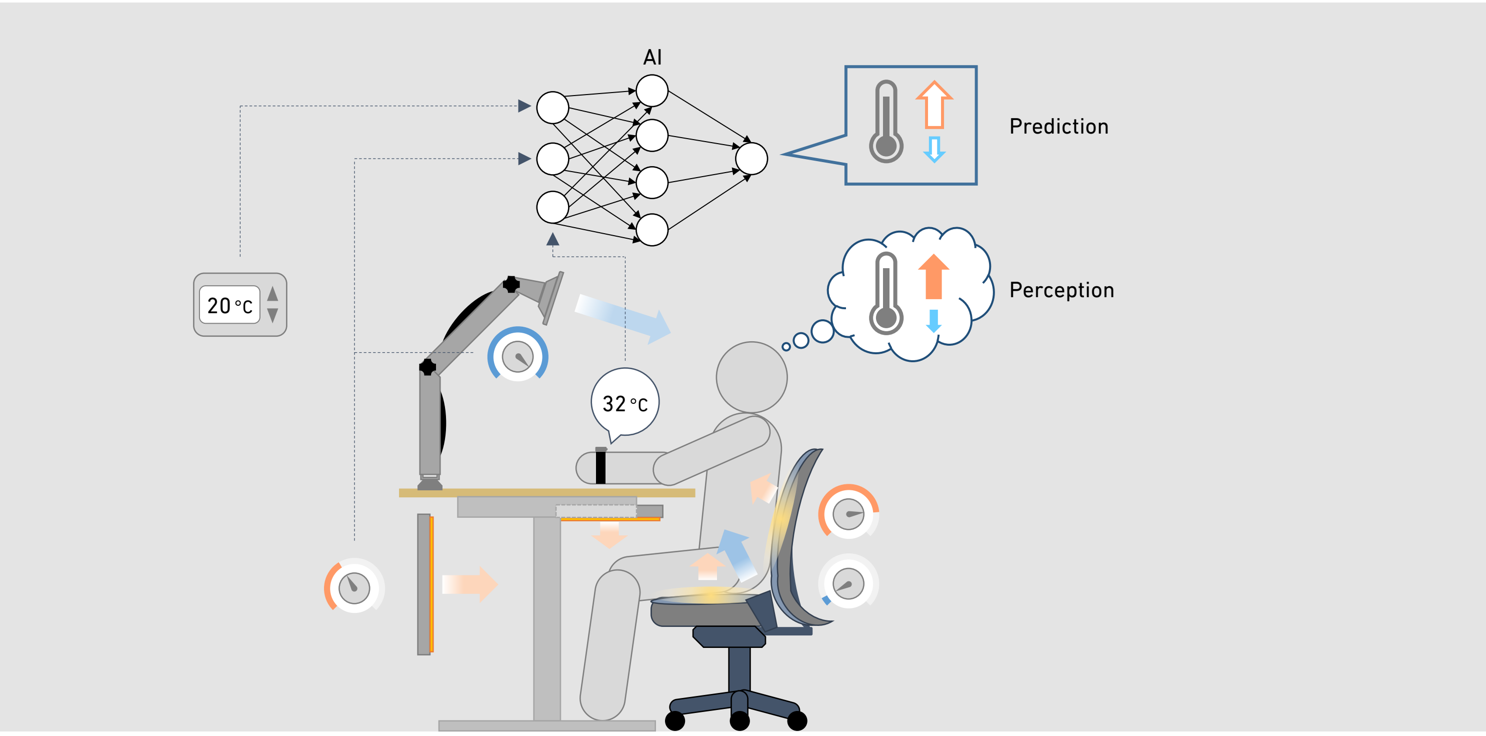
Further information
www.iea-ebc.org

Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems

EBC ANNEX 87

Personalised environmental control systems (PECS) with the functions of heating, cooling, ventilation, lighting and acoustics have advantages of controlling the localized environment at occupants' workstations by their preference instead of conditioning an entire room to uniform conditions. This may substantially improve comfort, satisfaction, health of the occupants, and energy efficiency of the entire heating, ventilation and air-conditioning (HVAC) system. Personalised ventilation can also protect against cross-contamination, which is critical in open-plan offices and workplaces with close distances between occupants. It is foreseen there will be an increasing interest and market for PECS in the future, as buildings will need to be future-proofed (for example against pandemics, heat waves, and power outages). The main application of PECS is for workplaces with mainly sedentary activities such as offices (such as open-plan spaces, banks, and control centres). Due to the COVID-19 pandemic when many people started to work at home, there will also be home working places where PECS may be a solution.

The project has now entered its working phase and has the overall objective to establish design criteria and operation guidelines for PECS, and to quantify the benefits of PECS regarding health, comfort, energy, and costs. This includes control concepts and guidelines for operating PECS in spaces with general ambient systems for heating, cooling, ventilation and lighting. The scope includes all types of PECS for local heating, cooling, ventilation, air cleaning, lighting and acoustics. It includes desktop systems, which are mounted on desks or integrated in furniture or chairs with heating / cooling and ventilation functions. It also includes wearables, where heating / cooling and ventilation are included in garments or devices attached to occupants' bodies.



A generic example of a personalized environmental control system (PECS) and its control methods.

Source: EBC Annex 87

Objectives

The project objectives are to:
- define design criteria for PECS;
- develop operation guidelines for PECS;
- establish control concepts and guidelines for operating PECS in spaces with general ambient systems for heating, cooling, ventilation, and lighting;
- quantify the benefits of PECS regarding health, comfort, energy, and costs.

Deliverables

- The deliverables from the project are expected to be as follows:
- a state-of-the-art report on PECS;
- a guidebook on requirements for PECS;
- a guidebook on PECS design, operation and implementation in buildings (including integration of PECS with ambient conditioning systems);
- a report on test methods for performance evaluation of PECS;
- universal criteria about requirements, characteristics, and performance of PECS to be used in national and international standards.

Progress

The project completed the first year of its working phase in 2023. Specific activities within the project tasks were refined and new activities were defined over the year. Synergies between the project tasks were also identified, and preparation of the first project publications was commenced.

The project participants started a very comprehensive and thorough review activity to collect existing knowledge related to almost all aspects of PECS. This activity is formulated in a such a way that all project tasks can benefit from this simultaneously. This is allowing the team to identify the state-of-the-art in detail and guiding the rest of the work during the project to reach the objectives. The team also developed and agreed upon a universal definition of PECS, which is easily understandable and relatable. The project has been very active in dissemination and held several workshops and seminars in international conferences in 2023, which were all well-attended.

Meetings

The following meetings were held during 2023:
- The first meeting of the working phase was held as a hybrid meeting in Tokyo, Japan, in May 2023.
- The second meeting of the working phase was held as a hybrid meeting in Lausanne, Switzerland, in September 2023.

Project duration
2022–2026

Operating Agents
Ongun Berk Kazanci and Bjarne W. Olesen, International Centre for Indoor Environment and Energy (ICIEE), Department of Environmental and Resource Engineering, Technical University of Denmark, Denmark

Participating countries
Australia, Belgium, Brazil, Canada, P.R. China, Denmark, Finland, France, Germany, Italy, the Netherlands, R. Korea, Singapore, Sweden, Switzerland, Türkiye, United Kingdom, USA

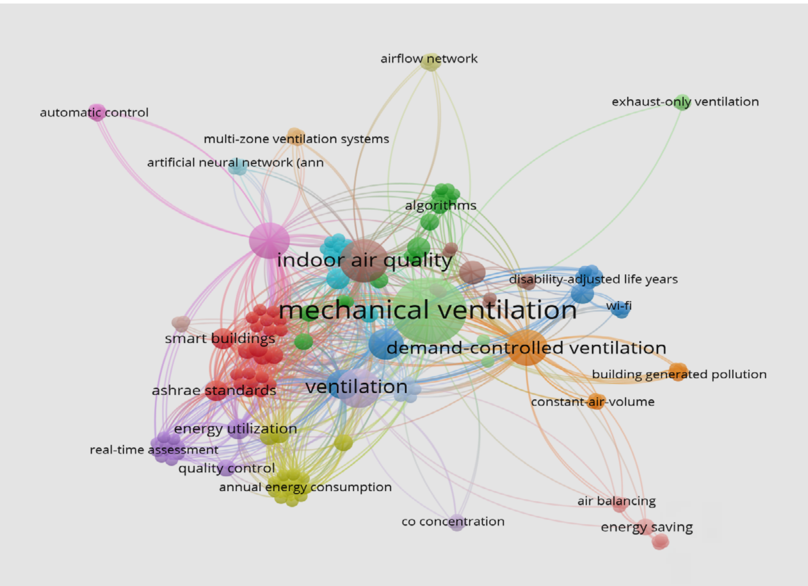
Further information
www.iea-ebc.org

Energy Efficient Indoor Air Quality Management in Residential Buildings

EBC ANNEX 86

The energy performance of new and existing residential buildings needs to be radically improved to meet ambitious greenhouse gas emissions reductions goals while maintaining healthy, acceptable and desirable indoor environments. While ventilation is the main strategy that is adopted for indoor air quality (IAQ) management, other technologies influencing IAQ are available as well, for instance air filtration. However, there is no existing coherent assessment framework to rate and compare the performance of IAQ management strategies. This project is therefore focusing on assessing the IAQ performance and identifying optimal solutions for maximizing energy savings while guaranteeing a high level of IAQ in new, renovated and existing residential buildings. To achieve this, its aims are to:

- gather existing scientific knowledge and data on pollution sources in buildings;
- investigate opportunities of applying 'Internet of Things' (IoT) connected sensors;
- study current and innovative case studies of IAQ management strategies;
- develop road maps to ensure the continuous performance of the proposed solutions over their lifetimes.



Thematic mapping of the 'smart ventilation' literature identified in EBC Annex 86.

Source: TBC D. Mortari, EBC Annex 86

The project is focused on residential buildings, because these represent the largest section of the building stock. They are also understudied and have the broadest range of uses. Additionally, residential building projects often lack the funds for extensive bespoke engineering, and therefore require robust cost-effective standardised solutions that can be implemented at large scale.

For the study of specific IAQ management strategies, the project is mainly focusing on the use of smart materials (materials that have an ability to actively or passively influence IAQ in the space) and smart ventilation (as defined by AIVC VIP38), since these are strategies that have a high energy efficiency potential. Air cleaners are being studied separately in the project 'EBC Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications', and are therefore not studied in detail in this project.

The project has brought together experts from mechanical engineering, building science, chemistry, data science and environmental health with other stakeholders to form a consensus on the basic assumptions that underlie such a performance assessment, and to develop practical guidelines and tools to bring the results into practice. It is continuing the work of the project, 'EBC Annex 68: Indoor Air Quality Design and Control in Low Energy Residential Buildings', and is collaborating with 'EBC Annex 5: Air Infiltration and Ventilation Centre' by co-organizing meetings and in disseminating the project outcomes.

Objectives

The specific project objectives are as follows:

- develop a consistent set of metrics to assess energy performance and IAQ for an IAQ management strategy;
- propose an integrated rating method for the performance assessment and optimization of energy efficient strategies of managing the IAQ in new and existing residential buildings;
- identify or further develop tools to assist designers and managers of buildings in assessing the performance of an IAQ management strategy using the rating method;
- gather existing scientific knowledge and data on pollution sources in buildings to provide new standardized input data for the rating method;

The in-person EBC Annex 86 participants, who attended the hybrid working meeting held in Copenhagen, Denmark, in October 2023.

Source: EBC Annex 86

- study the potential use of smart materials as an IAQ management strategy;
- develop specific IAQ management solutions for retrofitting existing residential buildings;
- improve the energy efficiency of IAQ management strategies in operation and improve their acceptability, control, installation quality and long-term reliability;
- disseminate the project findings.

Deliverables

The planned deliverables for the project include:

- a comprehensive overview of all literature that was used and highlighted during the project;
- a set of open databases that brings together all the (references to) data collected to support the work in the project;
- an overview report on methods and tools for the rating of IAQ management strategies;
- a collection of case studies and demonstrations of energy efficient IAQ management strategies.

Progress

During 2023, the project convened two hybrid working phase expert meetings in Tokyo and Copenhagen connected to an AIVC workshop and the AIVC 2023 Annual Conference respectively. The intermediate results and project activities were reported through sessions at the AIVC Conference. Also during the year, the Danish participants held a very well attended national dissemination symposium.

The new 'harm-based acceptable risk indicator' and associated metric 'harm intensity' were further developed and published. Additional data were collected to populate the open IAQ database and statistical analysis modules also created. Common exercises for testing were carried out to assess the implications for real cases embedded in a local context. Further, a systematic literature review on smart ventilation was undertaken.

Meetings

The following hybrid expert meetings were held during 2023:

- Tokyo, Japan, in May 2023.
- Copenhagen, Denmark, in October 2023

Project duration
2020–2025

Operating Agents
Jelle Laverge, Ghent University, Belgium

Participating countries
Australia, Austria, Belgium, Brazil, Canada, P.R. China, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Türkiye, United Kingdom, USA
Observer: Greece

Further information
www.iea-ebc.org

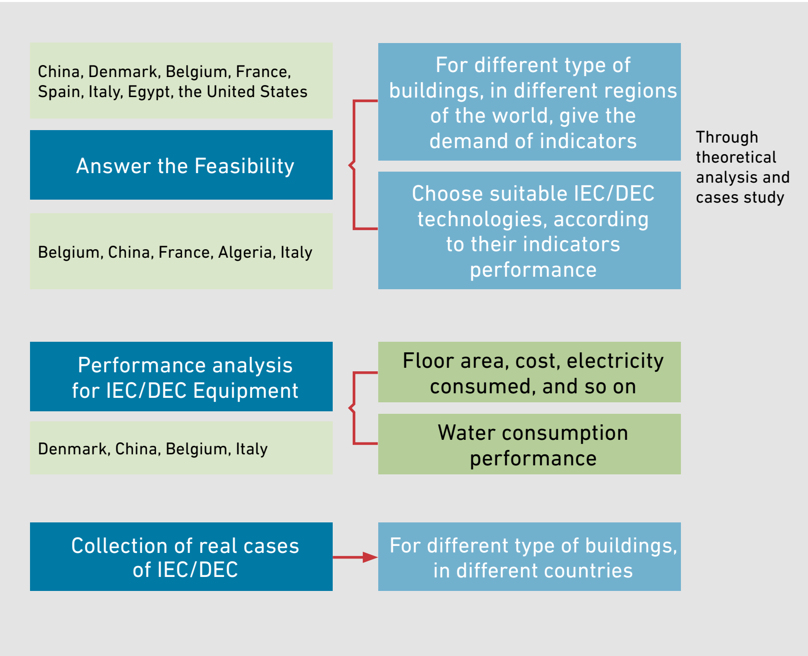
Indirect Evaporative Cooling

EBC ANNEX 85

Buildings account for almost one-third of total energy consumption, and over 10% of building energy consumption is used for air conditioning and indoor thermal comfort in hot seasons. So, changing the approach to air conditioning is one of the essential solutions to meeting cooling demands without increasing power consumption and greenhouse gas (GHG) emissions. Although over 85% of cooling worldwide is achieved by mechanical vapour compression refrigeration, more than 40% of the cooling could be provided by evaporative cooling, especially in dry climate zones.

Thus, this project aims to study the feasibility of indirect evaporative cooling (IEC) technologies and provide the roadmap of using evaporative cooling technologies in various dry climate zones. The target audience includes design and planning practitioners, scientific communities, product, manufacturers, and policy and decision makers.

The following project tasks are underway:
- definition and field studies,
- feasibility study of IEC technologies,
- study on IEC fundamentals, and
- simulation tool and guidelines.



Summary of national contributions to the EBC Annex 85 work programme.

Source: EBC Annex 85

Objectives

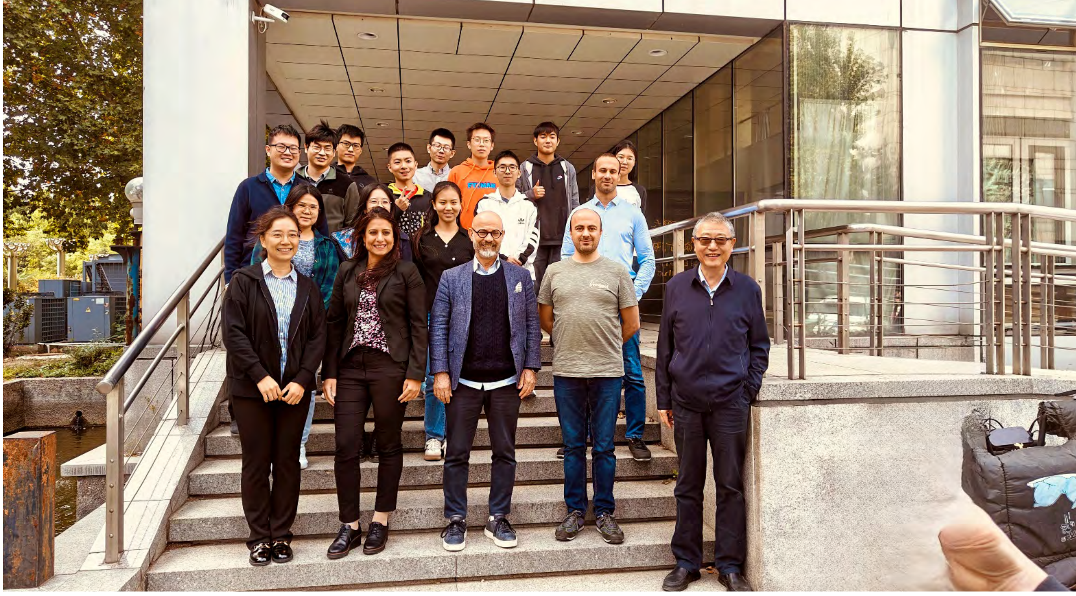
The project objectives are as follows:
- Conduct field study to carry out deep and wide investigations of IEC systems, and field testing of existing IEC systems.
- Carry out a feasibility analysis and a study on fundamentals under different climate conditions for different type of buildings to answer which kind of IEC or direct evaporative cooling (DEC) process is most suitable, leading to evaluation of the whole cooling season energy consumption performance; evaluate the water and electricity consumption of IEC processes; a possible standard for IEC / DEC technologies may be established.
- Create a simulation tool based on setting up system simulation models for different kinds of IEC processes and systems.
- Develop guidelines for designing IEC systems.

Deliverables

The planned main deliverables of the project include:
- a book, provisionally entitled 'The Indirect Evaporative Cooling Source Book', including all the outputs of the project;
- a simulation tool for various types of IEC technologies for different types of buildings and dry climate zones;
- a simulation tool for various types of IEC technologies for different types of buildings and dry climate zones;
- a collection of case studies and feasibility analysis of indirect evaporative cooling technologies worldwide;
- reports of fundamental analysis result through thermal analysis and optimisation;
- design guidelines for indirect evaporative cooling technologies.

Progress

During 2023 the project goal was refined. The key difference between common mechanical vapour compression refrigeration and evaporative cooling processes is that while establishing feasibility is critical for evaporative cooling, for mechanical refrigeration there is no such feasibility problem. Therefore, establishing the feasibility for evaporative cooling is the most important project goal, after which the performance can be determined in terms of energy and water consumption, and so on.



The in-person EBC Annex 85 participants, who attended the hybrid working meeting held in Beijing, P.R. China, in October 2023.

Source: EBC Annex 85

The participants have agreed definitions relating to determining the feasibility of direct and indirect evaporative cooling: fully feasible, in which all cooling demand in a region can be met independently by evaporative cooling technology; part feasible, in which evaporative cooling is feasible for most of the climates in a region with a few exceptions; fully combined feasible, in which evaporative cooling can be used in combination with mechanical chillers at all times.

During the past year, the project team worked on establishing the methods, indicators and common conditions needed for feasibility analysis. Methods to analyse feasibility need to provide clear and unified performance assessments based on indicators that express the real performance of evaporative cooling processes. The main feasibility analysis concept being developed uses such indicators to express the performance of an evaporative cooling process, and calculates the desired indicators under different climate conditions for a region.

Following on from the feasibility analysis, work on performance analysis of detailed evaporative cooling technologies has been taking place, including for electricity use, water consumption, and so on. Case studies from Denmark, Belgium and China have been documented with field test data showing the electricity use and water consumption, and any existing problems.

Meetings

Meetings were held in 2023 as follows:

- An online workshop in was held in May 2023.
- In-person meetings were held in Denmark, Belgium, and France, in June 2023.
- Online meetings were held in September 2023.
- A hybrid workshop was held in Beijing. P.R. China, in October, 2023.

Project duration
2020–2025

Operating Agents
Xiaoyun Xie, Building Energy Research Center, Tsinghua University, P.R. China

Participating countries
Belgium, P.R. China, Denmark, France, Italy, Spain, Türkiye, USA

Further information
www.iea-ebc.org

Demand Management of Buildings in Thermal Networks

EBC ANNEX 84

For the design and operation of typical existing thermal networks, district heating and cooling (DHC) systems, buildings and end-users are often treated only as simple load points or demand-side variables. By instead considering them as individuals and communities capable of enabling systemic interventions and delivering flexibility to the system, progress can be accelerated towards carbon-neutral societies. With this in mind, demand management for heating and cooling has the potential to facilitate the expansion of DHC networks without needing additional pipework, increasing use of renewable energy sources and waste, and reducing peak periods and capacity challenges. These effects when combined could increase the optimization opportunities considerably by adding an untapped energy efficiency potential of more than 20%. Thus, integrating buildings and end-users is crucial for the smooth, cost and energy-efficient transition to next generation DHC systems.

The project is investigating both the social and technical challenges of this approach and how these can be overcome for various building typologies, climate zones and local conditions, as well as how digitalization of heating and cooling demands facilitates demand management activation. The work is divided into four tasks:

– collaboration models ('who'),
– technology at the building level ('how with hardware'),
– methods and tools ('how with software'), and
– case studies.

Objectives

The project objectives are divided into four categories representing the social, technological, methodological, and practical aspects leading to successful demand management as follows:

– provide knowledge about the participants involved in the thermal network value chain, and on collaboration models and instruments;
– classify, evaluate and provide design solutions for new and existing heating and cooling installations in buildings connected to various types of DHC system;
– develop methods and tools to utilize data from energy and indoor environmental quality monitoring equipment for real-time data modelling of thermal demand response potential in buildings and urban districts;
– drive adaptation and visualization of project results through case studies and best practices, and draw conclusions from them.

Deliverables

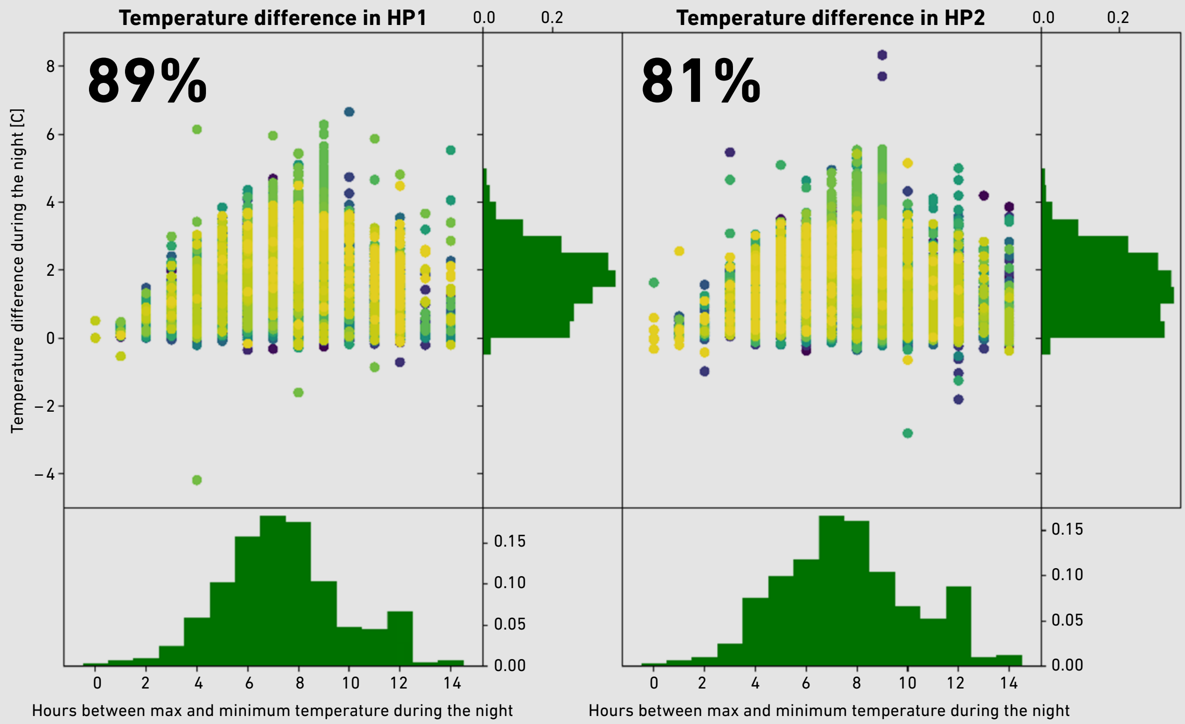
The planned project outcomes are as follows:

– a technical report on collaboration models, including an overview of the actors involved, existing practices, potential barriers and limitations, and recommendations for promising solutions for different building typologies and local contexts;
– a technical report on building technology for activation of the demand response in thermal networks, including status, classification and development guidelines;
– a technical report on smart algorithms that realise the thermal demand response potential in buildings by manipulating thermal actuators for heating and cooling systems in buildings;
– a technical report on case studies of demand management of buildings in thermal networks;
– a project summary report.

Progress

In 2023, the project participants joined the DHC+ Digitalization Working Group and contributed their expert knowledge to produce the report, 'Digitalisation in DHC systems: A Tangible Perspective to Upgrade Performance'. This was launched at the Euroheat and Power Congress, which took place in Torino, Italy, in May 2023. The main highlights from the report are provided below:

– In modern district heating and cooling systems, digitalization is gaining a key role in everyday operation challenges.
– While digitalization opens up new opportunities, it also entails new complexity that might be overwhelming especially for small utilities.
– End-customers and buildings should be taken into account if the full potential of digitalization is to be tapped.
– Legal framework and data protection (for example the European Union General Data Protection Regulation) are crucial aspects to be considered before customer data exploitation.
– There are several good examples of best practices included for inspiration.



Features of the demand response event for heating period 1 (HP1) and heating period 2 (HP2), in a study for single family houses in Denmark as presented by EBC Annex 84 participants at the CISBAT 2023 conference.

Source: https://doi.org/10.1088/1742-6596/2600/13/132003

The project work was presented during the CISBAT 2023 conference. The presented conference article described a field study including 72 single-family houses connected to the 3GDH network in southern Denmark, in which the demand response strategy 'night setback' was applied for two heating periods. The houses were equipped with control and monitoring equipment, which allowed the deactivation of the heating system while monitoring the indoor temperature, so it did not drop below the defined value. The occupants controlled the demand response events settings and could stop utilisation of the night setback strategy at any time (implicit participation in the demand response). All 72 houses applied the night setback during both heating periods. Yet, the participation time was found to decrease from 89% to 81%. The lowest participation rate was noted for a farm house, 60% and 9% of heating periods 1 and 2, respectively. In around 60% of the demand response events, the night setback strategy was activated at 20:00.

Meetings

The following meetings were held in 2023:

- The 4th working meeting was held in Torino, Italy in May, 2023.
- The 5th working meeting took place in Berlin, Germany in November 2023.

Project duration
2020–2025

Operating Agents
Anna Marszal-Pomianowska, Aalborg University, Denmark

Participating countries
Austria, Belgium, Denmark, Germany, Italy, the Netherlands, Singapore, Spain, Switzerland, Türkiye, United Kingdom

Further information
www.iea-ebc.org

Building Energy Codes

EBC WORKING GROUP

Several countries are adopting increasingly stringent, yet cost-effective building energy codes (sometimes known as regulations or standards). This is a result of the significant reductions in energy use these countries have observed after introducing updated codes. However, even in jurisdictions with extensive history in this area, building energy codes are facing key challenges, including the need to meet ambitious policy objectives, such as zero net energy construction standards and the substantial amount of time it takes for building codes to integrate research and technology breakthroughs, thus potentially limiting the energy savings potential of building energy codes.

The project was launched to address these challenges. Its goals are centered around furthering research and collaboration efforts for building energy codes to advance energy efficiency in buildings and communities. It is dedicated to widening the consideration of building energy codes in EBC projects, along with the integration of project results into enhancing the existing building energy codes.

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 activities to achieve these objectives, which are listed below:

- Analysis and technical reports: The project is conducting surveys on basic codes information to understand the range of practices across participating nations. Drawing on the results of these surveys, the project is developing reports around various topics of interest, such as building energy codes for existing buildings and best practices for code compliance.
- Organization and facilitation of webinars: The project is hosting and facilitating several workshops and webinars for participating countries to exchange information on their building energy code systems. It is also hosting an Annual Building Energy Code Symposium, which allows the project members to exchange ideas on relevant topics of interest.
- Dissemination: In addition to conducting analyses and facilitating webinars, the project is working towards disseminating its research findings to wide range of regional stakeholders and collaborating with them closely to promote code improvements and implementation of best practices. The project is disseminating its findings through the EBC website, conference papers, and quarterly newsletters.

Progress

The project released a report, 'Scan of Code Requirements to Address Greenhouse Gas Emissions', in June 2023. This provides a scan of building codes and explores how different jurisdictions deal with limiting carbon emissions through codes and support GHG reduction targets.

Additionally, the project published a report, 'Resilience Issues in Building Energy Codes', in August 2023. This addresses critical concerns related to the impacts of climate change on our built environment and the importance of building energy codes in mitigating these risks.

In the past year, the project started to develop three further topical reports. The topics include new technology integration in building energy codes, global building energy codes impact analysis, and carbon requirements in building energy codes. Furthermore, work was begun on a Nature World View article, which highlights the importance of resilience in building energy codes

In May 2023, the project made a presentation at the IEA User-Centred Energy Systems Technology Collaboration Programme's Executive Committee meeting, which took place in Halifax, Nova Scotia. The presentation centered around the topic of 'Building Energy and Carbon Codes: considerations, opportunities, and challenges'.

The project hosted a webinar on 'Building Energy Codes and Resilience – An International Review', in September 2023. The webinar highlighted the recent US Department of Energy research on how improving passive energy efficiency performance in buildings can prevent deaths and keep occupants safe during extreme weather events.

In 2023, the EBC Working Group on Building Energy Codes delved into the issue of performance gaps in building energy codes, anticipating its increasing importance. Despite being resource intensive and costly to implement, monitoring and verification stand out as crucial strategies to address these gaps.

Source: Andrea Starr, Pacific Northwest National Laboratory, 2023

The project held its fifth Annual Symposium in November 2023, hosted in Beijing, P.R. China. This was a hybrid event with two technical sessions focusing on performance gaps in building energy codes, and new technology integration in building energy codes.

The project participated in the 2023 American Geophysical Union annual meeting, held in San Francisco, California, USA, and presented a poster on 'Resilience Issues in Building Energy Codes'. In addition, they presented a poster titled, 'What, why, when to go virtual: An international analysis of virtual building energy code inspections' at the 2023 BECCS conference, in Sacramento, California, USA.

In 2023, the project published two newsletters, communicating the details of past and future webinars and topical reports to the regional stakeholders. Project participants also held conversations on simplified building energy codes for hot climates with ASHRAE, Pacific Northwest National Laboratory, and other interested stakeholders during the year.

Meetings

In 2023, the project held the following meetings:

- Webinar on 'Building Energy Codes and Resilience – An International Review', in September 2023,
- Fifth EBC Building Energy Codes Working Group Annual Symposium, Beijing, P.R. China, in November 2023, and
- American Geophysical Union Annual Meeting, San Francisco, California, USA in December 2023.

Project duration

2018–2022

Operating Agents

Michael Donn, Victoria University of Wellington, New Zealand (Co-Chair)
Meli Stylianou, Natural Resources Canada, Canada (Co-Chair)
Jeremy Williams, U.S. Department of Energy, USA (Co-Chair)
Meredydd Evans, U.S. Pacific Northwest National Laboratory, USA (Research Lead)

Participating countries

Australia, Brazil, Canada, P.R. China, Denmark, France, India, Ireland, Italy, Japan, New Zealand, Portugal, Singapore, Spain, Sweden, Türkiye, United Kingdom, USA

Further information

www.iea-ebc.org

Positive Energy Districts

EBC ANNEX 83

The concept of a positive energy district (PED) describes an area within a city's boundaries that is capable of generating more energy than is consumed, while being agile and flexible enough to respond to energy market price variations. However, the formulation of PED definitions cannot be based merely on a numerical annual net energy balance: Firstly, PEDs should also be based on energy efficiency solutions, and should support the minimization of impacts on the connected centralized energy networks by offering options to increase onsite load-matching and self-use of energy, technologies for short- and long-term energy storage, as well as providing energy flexibility with smart controls and techniques. As a novel area of research, the PED concept needs further refinement of definitions, improvement in energy and systems modelling for truly holistic design of neighbourhoods, development of new integrated sustainability assessment approaches. Further, testing within case studies is needed for bi-directional improvements between practical application and methodological advances.

Objectives

The main objectives and scope of this project are as follows:

- Map the city, industry, research and government (local, regional, national) stakeholders, and their needs and roles against the specific project objectives to ensure the principal stakeholders are involved in the development of relevant definitions and recommendations.
- Create a shared in-depth definition of a PED through a multi-stakeholder governance model.
- 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 to 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 PEDs,
- methods, tools and technologies for realising PEDs,
- governance principles and impact assessment for PEDs, and
- case studies on PEDs and related technologies.

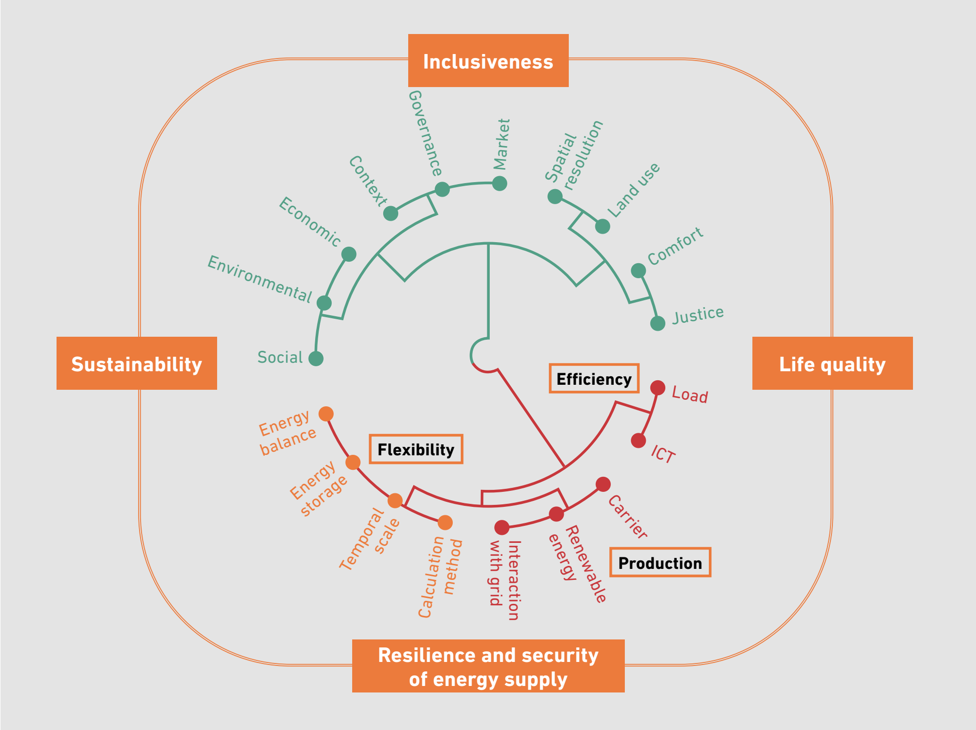
Progress

There was significant advancement on the project activities in 2023. Regarding the PED definition and quantitative PED assessment methods, wide application and testing of different methodologies were performed to assess benefits and limits for PED applications. Each method was found to have its own merits and shortcomings, and there is a trade-off between simplicity and integrity of the assessment. Differences between them are being investigated involving hourly energy data, because an analysis based on temporally resolved profiles offers good insights into the energy system interactions.

A data management and organization structure for modelling PEDs is also in development: Ontologies for simulated and monitored data are being developed for applications in PEDs. Datasets have a specific multidisciplinary nature, which makes it challenging to define a consistent ontology and set of metadata elements able to fulfil all requirements. As data models are part of the ontology, it is thus possible to interconnect different project data while keeping the same ontology. A specific PED-tailored data management ontology is currently under development following a state-of-the-art technological and data assessment of more than 50 international case studies.

Methodologies and frameworks for assessment have been developed for PEDs from a sustainability perspective: Three different environmental, economic, social frameworks have been developed aimed at quantifying the sustainability performance of PEDs and harmonizing various existing sustainability assessment methodologies.

The PED database is growing as a joint activity of EBC Annex 83, with the European Union projects 'PEDEU NET' and 'JPI Urban Europe' to map existing PEDs, and as a cornerstone for both researchers and practitioners to learn more about PEDs. The inclusion of more PEDs in the database is



Core elements within positive energy districts.

Source: EBC Annex 83, Vicky Albert Seifried, Caroline Cheng, Xingxing Zhang

continuing in a coordinated manner, with information reported on the location, energy balance, publications and further information on design methodologies and tools used for the design.

Among the dissemination activities, the Second EBC Annex 83 Ph.D. Summer School, 'Principles of energy system modelling for Positive Energy Districts', took place in Catania, Italy, in June 2023. The Summer School had 23 participants and topics were addressed related to urban planning, mobility, renewable energy-based systems, energy control and monitoring, urban carbon footprint and market impact of PEDs.

During the CISBAT2023 conference, held in Lausanne, Switzerland, in September 2023, the project convened a stakeholder workshop with around thirty participants on the topic of PEDs in cooperation with the organizing committee of the conference. The project received feedback on definitions, modelling, sustainability, and business models, as well as on demonstration, implementation, guidelines, and stakeholder outreach.

In the same conference, the project chaired a special session on PEDs and energy communities: It was expressed during the session that the need for interoperability of tools in the early design of PEDs is clearly felt, together with the need for new and innovative tools capable to interpret the complexity behind PEDs, while performing design parameters optimization.

Meetings

The following meetings were held in 2023:

- 6th Working Meeting, held in Palermo, Italy, in April 2023, and
- 7th Working Meeting held in Lausanne, Switzerland, in September 2023.

Project duration
2020–2025

Operating Agents
Francesco Reda, VTT Technical Research Centre of Finland, Finland
Francesco Guarino, University of Palermo, Italy

Participating countries
Australia, Austria, Belgium, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom

Further information
www.iea-ebc.org

Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems

EBC ANNEX 82

Demand side energy flexibility is increasingly being viewed as an essential enabler for the swift transition to resilient low-carbon energy systems that displace conventional fossil fuels with renewable energy sources while maintaining, or even improving, the operation of the energy system. Building energy flexibility may address several challenges facing energy systems and electricity consumers as society transitions to low-carbon energy systems, characterized by distributed and intermittent energy resources. For example, by changing the timing and amount of building energy consumption through advanced building technologies, electricity demand and supply balance can be improved to enable greater integration of variable renewable energy. Although the benefits of utilizing energy flexibility from the built environment are generally recognized, solutions that reflect diversity in building stocks, customer behaviour, and market rules and regulations need to be developed for successful implementation.

During an initial stage, the project provided an overview of the technological, social, commercial, and regulatory barriers to the development of energy flexibility related projects. In a peer reviewed paper published in the journal Energy and Buildings, the project disseminated the output of this initial work, in which it addressed the concept of energy flexibility at an aggregated level, and analysed barriers and research gaps throughout three distinct stages of design and development for energy flexibility related projects, namely: market and policy, early planning and design, and operation. The conclusions obtained show that most tools and methods are dedicated to the building level, and that findings from pilot demonstrations are not adequately disseminated nor used to inform subsequent research.

The project work is now focusing on the aggregated scale, to provide characterization methods, analysis of the dominant factors impacting available flexibility, control strategies, examples of business models and opportunities for the different stakeholders within the following tasks:

- building clusters and multi-carrier energy systems for energy flexibility and resilience;
- a common exercise on flexibility characterization methods and case studies;
- stakeholder acceptance and engagement;
- development of appropriate implementation (business) models.

Objectives

The project objectives are to:

- demonstrate and further develop the project characterisation and labelling methods to increase their common acceptance;
- investigate aggregation of energy flexibility from clusters of buildings, both physically connected and commercially connected (not necessarily physically connected) via an aggregator;
- investigate the aggregated potential of energy flexibility services from buildings and clusters of buildings located in different multi-carrier energy systems;
- demonstrate energy flexibility in clusters of buildings through simulations, experiments and field studies;
- map the barriers, motivations and acceptance of stakeholders associated with the introduction of energy flexibility measures in buildings and clusters of buildings;
- investigate how to include the views of stakeholders in the development of feasible technical solutions;
- investigate and develop business models for energy flexibility services to energy networks;
- formulate recommendations to policy makers and government entities involved in the shaping of future energy systems.

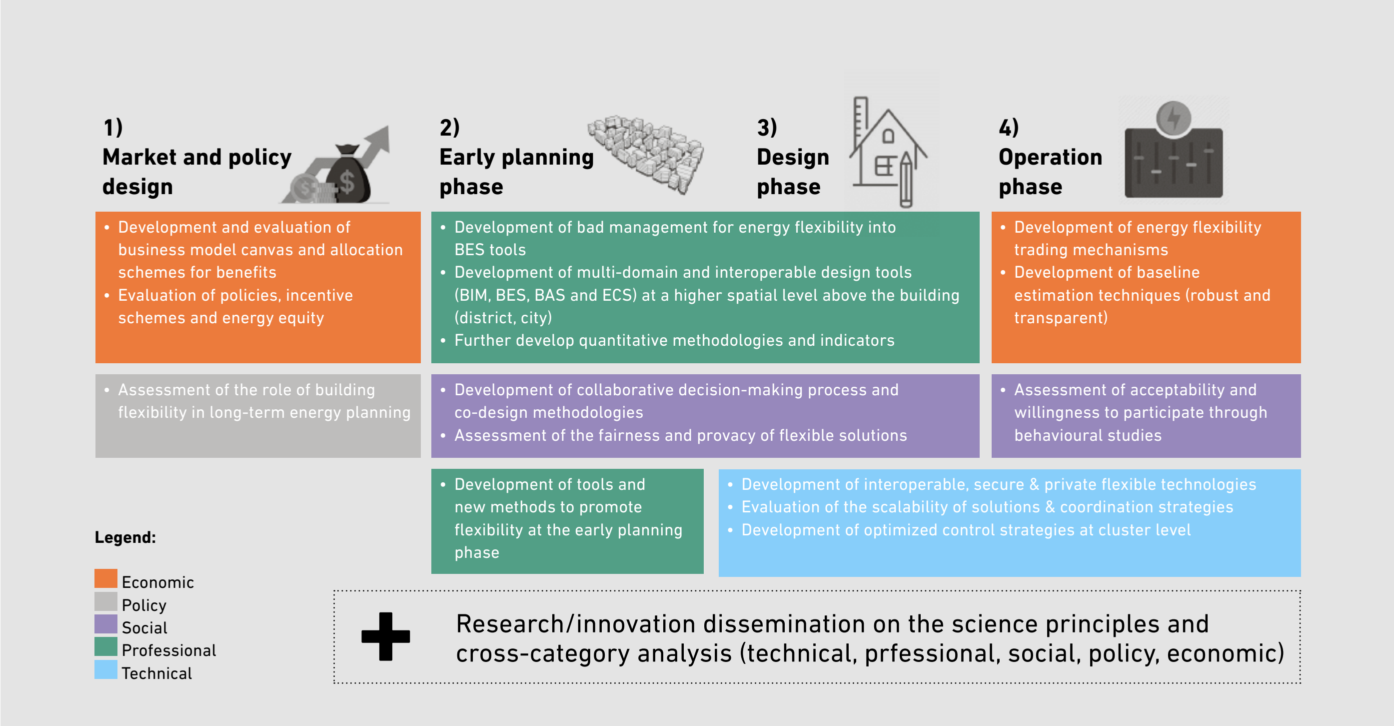
Deliverables

The planned deliverables from this project include:

- a summary of the project findings;
- a collection of case studies;
- recommendations for policy makers and government entities;
- a project summary report.

Progress

Various literature reviews were finalized during 2023, including works on the barriers ('Developing energy flexibility in clusters of buildings: a critical analysis of barriers from planning to operation', published in Energy and Buildings), on the concept of resilience ('Energy Resilience in the Built Environment: A Comprehensive Review of Concepts, Metrics,



Example of research gaps found during the EBC Annex 82 literature review.

Source: Le Dréau et al., Developing energy flexibility in clusters of buildings: A critical analysis of barriers from planning to operation, Energy and Buildings, Volume 300, 202

and Strategies'), on the dominant factors, and on reward and penalty signals. Part of the work was performed jointly with participants from EBC Annexes 81 and 82. A review on customer enrolment and participation in building demand management programs has also been conducted.

Simulation work on clusters of buildings is being conducted by teams within the project. The results of a common exercise are being analyzed to disseminate the main findings, and other activities are bringing together participants with different backgrounds to reach new findings, for example for the activity on assessment of forecasting methodologies.

Regarding stakeholder acceptance and engagement, and business models, various analyses are being performed among the participants. A survey on electricity pricing and tariff structures has been conducted, with the objective to understand the effect on consumption patterns and the emerging pricing designs. Moreover, around 25 case studies were collected on business cases around energy flexibility. The objective is to analyze the created value for the different stakeholders.

Meetings

The following meetings were held in 2023:

– 4th working meeting, online and La Rochelle, France in April 2023
– 5th working meeting, online and Vienna, Austria, in September, 2023

Project duration
2019–2025

Operating Agents
Rongling Li, Technical University of Denmark, Denmark
September 2023–April 2024:
Rui Amaral Lopes, Nova University of Lisbon, Portugal
Jérôme Le Dréau, La Rochelle University, France

Participating countries
Australia, Austria, Belgium, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Türkiye, UK, USA

Further information
www.iea-ebc.org

Data-Driven Smart Buildings

EBC ANNEX 81

Digital technology has potential to save energy through advanced control and operation of building heating, ventilation and air-conditioning (HVAC) systems. Digitalisation fundamentally takes a data-driven approach to the management and control of energy consuming equipment in buildings. This data-driven approach includes steps for (i) data capture, (ii) data management, (iii) data analysis, and (iv) data-driven decision implementation.

The project aims to accelerate the adoption of digitalisation and energy saving data-driven services in non-residential buildings. It seeks to optimise energy consumption from HVAC equipment through data-driven control strategies and equipment fault diagnostics. It also aims to address interoperability and other data management barriers that prevent digital technologies from being adopted at scale. In collaboration with the Mission Innovation Affordable Heating and Cooling Innovation Challenge, the project is supporting researchers and innovators through the hosting of AI-themes competitions.

Objectives

The project objectives are to:

- provide knowledge, standards, protocols and procedures for low-cost high-quality data capture, sharing and utilisation 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 and ideally commercialise them for reducing energy consumption in buildings;
- drive adoption of project results through case studies, business model innovation and results dissemination.

Deliverables

Planned deliverables include the following:

- a report on suggested functional requirements for data platforms that can be used to help to advance data sharing;
- 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 scenarios;
- a software repository, that catalogues and describes relevant data-driven software implementations;
- a proposal for governments to lead by example in the use of data-driven smart building solutions in their own buildings;
- competitions for incentivizing innovators to develop data-driven 'applications'.

Progress

The focus of the project work in 2023 was on consolidating research into key publications and disseminating findings. The 'Data Driven Smart Buildings State-of-the-Art Review' report was published. This provides an overview of current knowledge on key project topics, and is a valuable initial resource for people interested in the field.

A report was published in the past year, 'A Data Sharing Guide for Buildings and HVAC Systems'. It explores various data-management and data-governance issues (including privacy and intellectual property), which underpin the utility of data and the ability to implement digitalization services. It recommends that building owners pursue 'findable, accessible, interoperable and re-useable' (FAIR) data principles. This can be achieved using open data standards, deployed on an independent cloud-based data platform. Ideally, procurement of data platform infrastructure should be separated from procurement of software applications.

Industry consultation activities provided further understanding of barriers and solutions to the adoption of digitalization in buildings. This included numerous interviews with industry experts, across three continents. Building on a previous EBC Annex 81 pilot survey, ASHRAE issued a research project call '1934-TRP: A Survey Study on the Development and Application of Data-Driven Model Predictive Control in Buildings'. Also, data-set collection continued. A repository, the 'Building Data Genome Directory', was created to provide links to identified datasets. The repository includes data sources relating to measured building energy and water consumption, electric vehicle charging, fault detection and diagnosis and building information text mining.

Further, the project work on providing support to competitions continued. New data were collected for the ADRENALIN competitions. Over 600 participants (105

Dissemination of EBC Annex 81 findings at National Symposium and Conference Events in Australia.

Source: EBC Annex 81

teams), participated in the CityLearn Challenge, developing control agents for simultaneous control of electrical batteries, domestic hot water storage systems, and heat pumps in buildings – all with the goal of maintaining thermal comfort, reducing carbon emissions, increasing energy efficiency and providing resilience in the event of power outages.

The dissemination activities of the project included:

- Populating the EBC Annex 81 website with project deliverables: This includes direct links to (i) the Building Data Genome Directory and (ii) the Data Smart Buildings case-studies site. The number of reported case studies grew to 15.
- Themed workshops, symposium, and special conference sessions: including (i) project experts participating, as panelists at Australia's National Energy Efficiency Conference, and (ii) a dedicated project session at the Energy Informatics.Academy Conference 2023 in Brazil.
- A written response to the Australian Government's National Energy Performance Strategy Consultation: responding to the consultation question, "How can government support businesses to better utilise digitalisation to improve energy performance?".
- Publications: These included a special issue on 'Data-driven approaches to building simulation for enhanced building operation and grid interaction', published in the Journal of Building Performance Simulation.

Meetings

The following meetings were held in 2023:

- Sixth Expert Meeting, held in Newcastle, Australia in May 2023
- 'Data-Driven Smart Buildings' Symposium, held in Sydney, Australia, in May 2023
- Seventh Expert Meeting, held in Istanbul, Türkiye, in November 2023
- Workshop on 'Smart Building-to-Grid Services and Applications', held in Istanbul, Türkiye, in November 2023

Project duration
2020–2024

Operating Agents
Dr Stephen White, CSIRO, Australia

Participating countries
Australia, Austria, Belgium, Canada, P.R China, Denmark, Finland, Ireland, Italy, Japan, the Netherlands, Norway, Singapore, Spain, Sweden, Türkiye, United Kingdom, USA

Further information
www.iea-ebc.org

Resilient Cooling of Buildings

EBC ANNEX 80

The project is investigating resilient cooling applications with reference to a variety of external parameters such as climate, building typologies, internal loads and occupancy profiles, various levels of building management system (BMS) capabilities and automation, new buildings, and retrofitting of existing buildings.

Objectives

The general project objective 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 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, 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 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.

Examples of resilient cooling related features.

Source: Institute of Building Research & Innovation, 2023

Deliverables

The project is producing the following deliverables:

- an overview and state-of-the-art report for resilient cooling,
- a resilient cooling source book,
- technology profiles,
- a report on resilient cooling field studies,
- resilient cooling design and operation guidelines, and
- recommendations for policy, legislation and standards.

Progress

In 2023, the project reached the final year of its working phase. During the year, the final project deliverables and reports were under review in preparation for publication. The Resilient Cooling Guidelines is planned to be published as a REHVA guidebook in cooperation with the Federation of European Heating, Ventilation and Air Conditioning Associations.

Participants were very active in reaching out to organisations and individuals to share the policy recommendations arising from the work. This included the organisation 'Sustainable Energy for All', are planning to incorporate the project resources into teacher training for their 'Cooling for All' programmes in developing countries, and in featuring policy recommendations in their take action campaign #ThisIsCool.

A peer-reviewed paper was published by the project in the past year, 'Ten Questions Concerning Thermal Resilience of Buildings and Occupants for Climate Adaptation, in the journal Building and Environment'. Moreover, the project task group on weather data successfully submitted a paper to Nature's peer-reviewed open-access journal Scientific Data.

Meetings

The following meetings were held in 2023:

- The 8th Expert Meeting was held in Vienna, Austria, in April 2023.

Project duration
2019–2024

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

Participating countries
Australia, Austria, Belgium, Brazil, Canada, P.R. China, Denmark, France, Germany, Italy, Norway, Singapore, Sweden, Türkiye, Switzerland, United Kingdom, USA

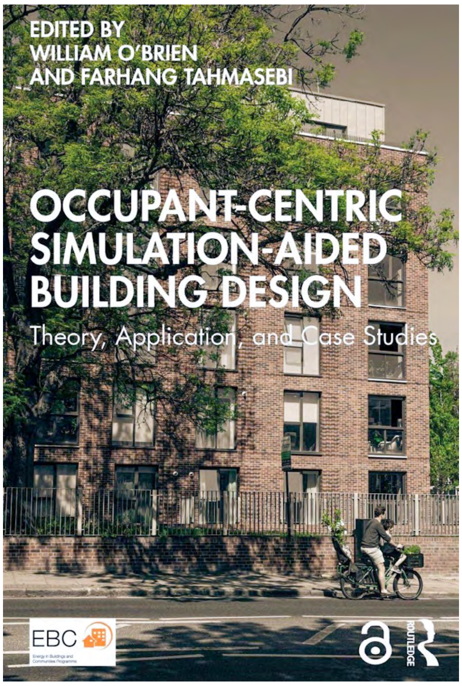
Further information
www.iea-ebc.org

Occupant-centric Building Design and Operation

EBC ANNEX 79

Occupants and their interactions with buildings can play a major role in building performance, as measured by energy use, greenhouse gas emissions, comfort, peak loads, and so on. Many of these interactions are comfort driven. Undesirable conditions can cause occupants to act in ways that negatively affect energy use and even indoor environmental quality (IEQ). According to numerous field studies, the energy consumption of otherwise identical buildings can vary by up to a factor of two as a direct result of occupants' interventions, for example their window-opening behaviour. Meanwhile, occupants are often faced with conflicting IEQ conditions, whereby their actions to improve one domain of IEQ, for instance thermal comfort, can affect other domains.

Despite significant progress in experimental research and occupant behaviour modelling, design and building operation practice shows that many existing models do not represent the manifold human interactions with a building appropriately enough. It has become evident there is little guidance for designers and building managers on how to apply occupant behaviour knowledge and models in standard practice. So, the project is seeking to bridge this gap between science and building practice, to provide new insight into comfort-related occupant behaviour and interactions in buildings, through new modelling and simulation techniques and design workflows. Another major focus is on improving the performance of existing buildings through better occupant-centric controls.



The EBC Annex 79 book, 'Occupant-centric Simulation Aided Building Design'.

Source: EBC Annex 79

Objectives

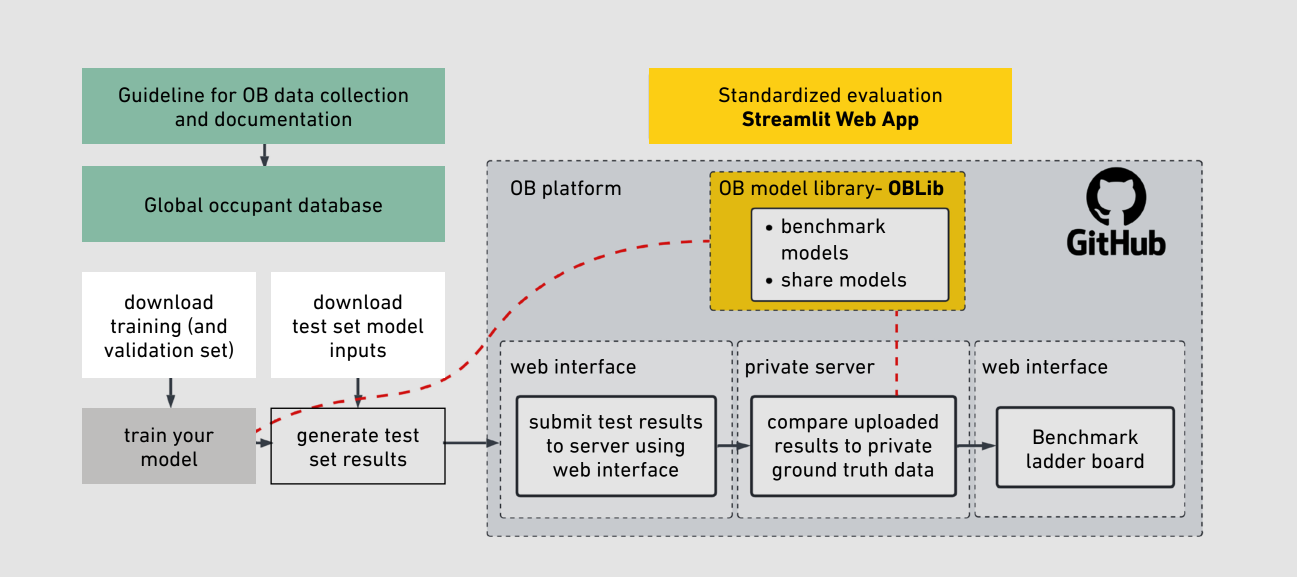
This project aims to integrate and implement knowledge and models of occupant behaviour into the design process and building operation to both improve energy performance and occupant comfort. The key areas of focus include:

- 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 following project deliverables are being produced:

- a comprehensive report giving an overview of the most significant activities and contributions of the project for different audiences;
- an open-access book titled 'Occupant-Centric Simulation-Aided Building Design', which includes fundamentals on comfort, consideration of occupants and occupant behaviour in design processes, occupant modelling and simulation, and case studies on occupant centric design;
- a guideline for technologies and best practices to collect occupant-related data for applications in occupant modelling for simulation and for occupant-centric controls;
- a database of occupancy and occupant behaviour data, the ASHRAE Global Occupant Behaviour Database;
- a database with occupant behaviour models that is based partially on the ASHRAE Global Occupant Behaviour Database;
- a collection of documented case studies of buildings and spaces that demonstrate occupant-centric controls.



Occupant Behaviour Framework for evaluating and sharing occupant behaviour models.

Source: EBC Annex 79

Progress

In 2023, the project focused on finalizing its activities, reporting, and dissemination. Platforms were developed for sharing both occupant behaviour data, 'OpenLib' occupant behaviour library and benchmark model project, and data-driven models. Moreover, a method and tool were developed to anonymize occupant data such that the occupant behaviour data cannot be used to identify the original occupants. A literature review on synthetic population models was performed to develop methods and recommendations for occupant modelling and design applications.

Given the previous lack of information about occupant-centric controls (OCC) and their use cases, an ontology for OCC case studies was developed with a case study collection completed. The project developed standardized methods to evaluate the benefits of OCC in the case study buildings. Finally, a methodology to collect occupant data longitudinally, for example from smart watches, was developed to help inform occupant-centric controls.

An overview with key research outcomes from the task on occupant-centric controls was written as a '10 questions' paper in the journal Building and Environment. In 2023, the team led seminars at numerous ASHRAE events, including the ASHRAE Annual conference held in Atlanta, Summer conference held in Tampa, and Building Performance Analysis Conference and SimBuild. The project was also well represented at the Health Buildings Europe Conference in June 2023, which was collocated with the final meeting. Further, the project led a workshop on occupant modelling at the ACM BuildSys conference in Türkiye, in November 2023.

The project continued its close cooperation with ASHRAE by leading a set of chapters on measuring occupancy and occupant behaviour in buildings in the ASHRAE Performance Measurement Protocol. Finally, the project researchers are writing a chapter on occupant modelling for a future Chartered Institution of Building Services Engineers publication.

Meetings

The 10th Expert Meeting was held in Aachen, Germany, in June 2023.

Project duration
2018–2024

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

Participating countries
Australia, Austria, Belgium, Brazil, Canada, P.R. China, Denmark, France, Germany, Italy, the Netherlands, Norway, Singapore, Sweden, Switzerland, Türkiye, United Kingdom, USA
Observers: Hungary, Poland, UAE

Further information
www.iea-ebc.org

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

EBC ANNEX 78

Globally, ventilation of buildings accounts for approximately one fifth of the energy use needed to provide an acceptable indoor environment. Moreover, the requirements for ventilation in most standards and guidelines assume acceptable quality (clean) outdoor air, which is often not the case.

There are an increasing number of publications in many countries related to air cleaning, and there are also increasing sales of gas-phase air cleaning products. This introduces a demand for verifying the efficacy of air cleaning on indoor air quality for comfort, wellbeing 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 partially 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 it 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 substitution of ventilation for air cleaning could reduce the rate of outside air supplied indoors and thereby energy used for heating / cooling of ventilation air and for transporting the air (fan energy) can be saved.

The potential of air cleaning to improve air quality while displacing ventilation energy use makes it an intriguing subject for development. This potential does, however, require more detailed evaluation. There is a need to develop standard test methods for the performance of air cleaning devices. Consequently, this 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 (partial substitution of ventilation with outdoor air);
- establish procedures for improving indoor air quality and reducing the amount of ventilation with outdoor air by gas phase air cleaning;
- establish a test method for air cleaners that considers the influence on the perceived air quality and pollutants in indoor air.

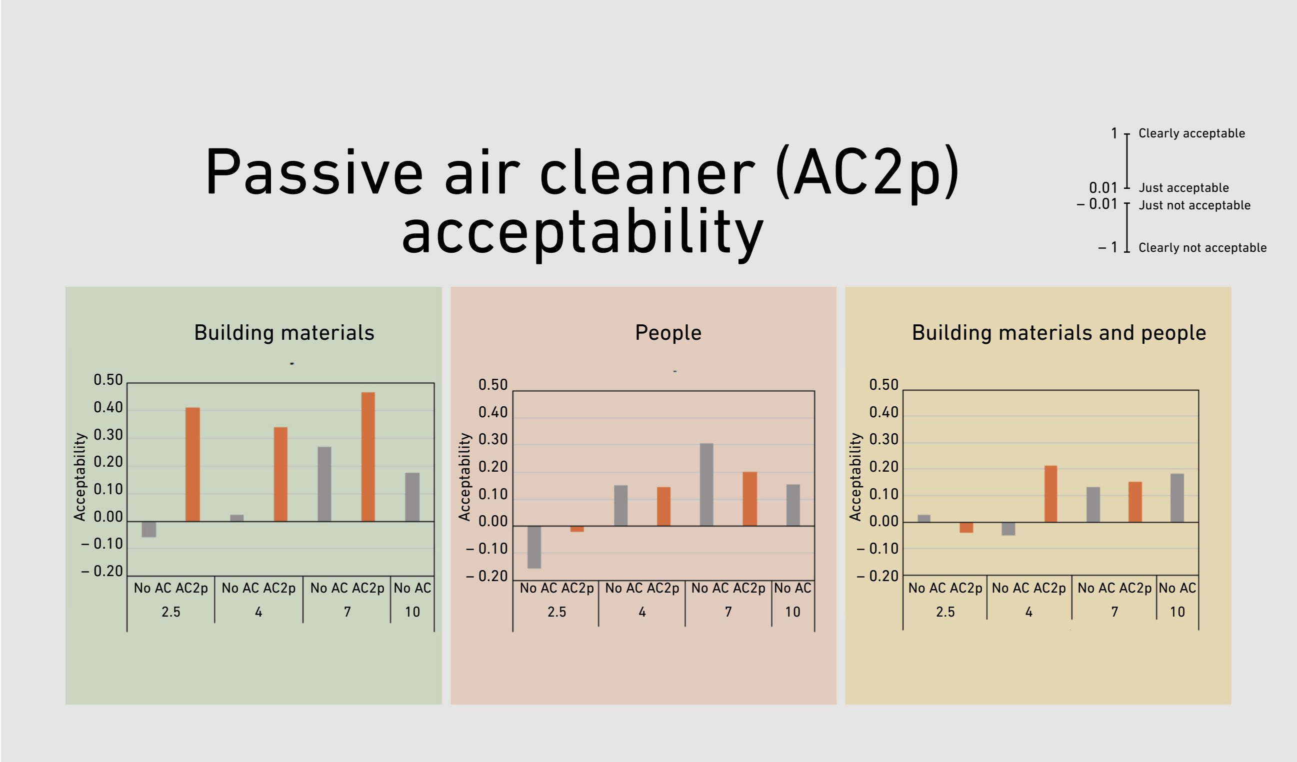
Deliverables

The following deliverables are being produced in the project:

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

Progress

A concept for partially substituting ventilation with gas phase air cleaning technology has been established and published. Energy performance of gas phase air cleaning technologies has been studied by three of the participating organisations. These studies are mainly based on computer simulations, but without any data for the systems in operation. For absorption air cleaning technologies, the pressure loss in the ventilation system was found to increase along with an increase in fan energy. However, an air cleaner may partially substitute for outside air, and hence reduce the energy needed for pre-heating or pre-cooling, and fan energy. During 2023, the energy performance was



Testing of perceived air quality with whole body exposure. This was done with three types of indoor pollution sources (building materials, bioeffluents from people, and a combination of these) at four different ventilation rates in the test room. The figure shows the recorded acceptability based on 30 subjects. With building materials, the acceptability increases at all ventilation rates when the air cleaner is on. With people as a source the acceptability improves at the lower ventilation rate when the air cleaner is on. With the combined sources, the air cleaner show a positive or no effect.

Source: International Centre for Indoor. Environment and Energy, Technical University of Denmark

investigated further. For this purpose, a new metric has been introduced, defined as the clean air delivery rate (CADR) divided by the energy used for heating, cooling and ventilation. This can be calculated for a whole ventilation system, so it is now possible to compare the energy performance of a system using an air cleaner with the energy used for increasing the air flow rate of a system with and / or without an energy recovery unit. This approach is now being applied to understand if it is more energy efficient to use an air cleaner, or to increase the flow rate of outside air.

Also during 2023, journal papers on the experimental studies based on a test procedure were submitted for publication. This includes test with 30 subjects and different air cleaning technologies. Acceptability of the air quality was measured at different ventilation rates in the test room. This was done according to ISO16000-44, which was published as a final standard in 2023. The test procedure is planned to be the basis for a new test standard under ISO TC142. A preliminary work item was accepted by TC142 in 2023 and it has been decided to develop an ISO Technical Specification, which is an official ISO document that later could be developed into a standard. The plan is to arrange for other organisations to use the test method before a standard is created.

In the past year, the field test measurements continued, and the first data analysis was underway. Project reporting was also started for the deliverables. Several presentations were made at conferences and webinars.

Meeting

In 2023, the following project working meetings were held:

- hybrid meeting, in Tokyo, Japan, in May 2023, and
- hybrid meeting, in Copenhagen, Denmark, in October 2023.

Project duration
2018–2024

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, Türkiye, USA

Further information
www.iea-ebc.org

Air Infiltration and Ventilation Centre

EBC ANNEX 5

EBC Annex 5 'Air Infiltration and Ventilation Centre' (AIVC) has been running for 44 years since its inauguration in 1979. During this extended operational period, the AIVC has been routinely reshaping its priorities to reflect emerging concerns and to answer new challenges and opportunities, serving its principal goal 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). In a world striving to achieve net zero greenhouse gas emissions by 2050, the role of energy efficient ventilation in enhancing IEQ and health in buildings is pivotal and emphasize the significance for continuing AIVC activities.

Objectives

The objectives of the AIVC are as follows:

- enabling the production of high quality and influential documents of international status regarding energy efficient ventilation and air infiltration;
- generating strategy and advice on air infiltration and ventilation related issues in new and renovated buildings;
- communicating and disseminating information in relation to smart ventilation, resilient ventilative cooling, building and ductwork airtightness and indoor environmental quality, though but not limited to conferences and workshops, webinars, databases, social media, and a high visibility web presence.

Deliverables

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

Progress

In 2023, the AIVC focused its work mainly on thirteen of its own projects, the AIVC Industry Advisory Committee, the 43rd AIVC Annual Conference, themed 'Ventilation, IEQ and health in sustainable buildings', the workshop in Tokyo, Japan, themed 'Towards high quality, low-carbon ventilation in airtight buildings', and five webinars. Furthermore, the AIVC facilitated remote discussions and supported dissemination activities for 'EBC Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications', 'EBC Annex 80: Resilient Cooling of Buildings', 'EBC Annex 86: Energy Efficient Indoor Air Quality Management in Residential Buildings', and 'EBC Annex 87: Personalized Environmental Control Systems'.

The latest AIVC projects launched include:

- Designing building ventilation for epidemic and disaster preparedness,
- EPBD revision and ventilation,
- Smart control of ventilation systems,
- Quality of installed ventilation systems, and
- Measurement for Exterior Wall Airtightness of High-Rise Buildings Using Stack Effect / Individual Air Conditioning and Outdoor Air Entering through Entrance Doors.

Previously launched projects that were running in 2023 include:

- Building and ductwork airtightness regulations in various countries,
- Building ventilation regulations in various countries,
- Energy Recovery Ventilation,
- Personalized Environmental Control Systems,
- Temperature take-back effect in the context of energy efficient ventilation strategies,
- Supplementing Ventilation with Gas-phase Air Cleaning,
- Indoor Air Quality Metrics, and
- Competent Tester Schemes for Building Airtightness Testing.

In 2023, AIVC released Technical Note 'TN 72: Ventilation Requirements and Rationale behind. Standards and Regulations of Dwellings, Office Rooms and Classrooms'.

Also, five Ventilation Information Papers were released on trends in building and ductwork airtightness in: Belgium, Latvia, France; Greece and China. Further, 'VIP 46: Building airtightness impact on Energy Performance calculations', and 'VIP 47: High-rise buildings airtightness – error due to stack effect on point measurements', were published.

Over the course of 2023, the AIVC hosted five webinars.

- In January, in collaboration with ASHRAE, AIVC organized a webinar on Sleeping Environment Indoor Air Quality (IAQ) and Sleep Quality.

The opening session at the AIVC 2023 Conference 'Ventilation, IEQ, and Health in Sustainable Buildings', held in Copenhagen, Denmark, in October 2023.

Source: AIVC

- In May and June, three webinars were dedicated to airtightness (building and ductwork airtightness trends and regulations in France, Belgium and Greece, building and ductwork airtightness trends and regulations in the Czech Republic, Latvia and Spain and alternative methodologies to evaluate airtightness).
- In December, a webinar was held on the topic, 'Smart ventilation in non-residential buildings. How to assess? How to design?'.

To further develop the aims of the AIVC and keep a broad perspective on the fields of ventilation, infiltration, and IAQ, in the beginning of 2023 the AIVC Board established an Industry Advisory Committee (IAC). The IAC is a voluntary group of industry leaders dedicated to the goals of the AIVC, representatives of industry but not exclusively advocating for industry, who are proposed and retained at the discretion of the board of the AIVC. Members cover different sectors, geographical areas, and fields of interest to AIVC activities. The mission of the IAC is to: serve as a voice for the industry in AIVC activities; provide feedback on board proposals and decisions; formulate suggestions for future work; provide advisory feedback on publications and other AIVC products; help to disseminate AIVC deliverables to industry and practitioners and amplify outreach. The IAC meets remotely twice a year to give timely feedback in advance of AIVC board meetings.

AIVC has a very close collaboration with the European Union TightVent and venticool platforms. To have more interaction with related organizations and a stronger societal impact, it is a founding member of the Indoor Environmental Global Alliance. AIVC is also facilitating collaboration between other initiatives. As an example, the Advisory Board of Practitioners, an initiative from EBC Annex 80, AIVC and venticool, launched in March 2021 seeks to establish a format for regular exchange between EBC Annex 80 researchers, with practitioners, planners and representatives from relevant industries. Starting from 2024 and onwards, and following the completion of EBC Annex 80, this will continue under the umbrella of AIVC and venticool. Editions of the AIVC newsletter were published in March and September 2023.

Meetings

The AIVC Board organized two board meetings in 2023:

- Tokyo, Japan, in May 2023, and
- Copenhagen, Denmark, in October 2023.

Project duration
1979–2026

Operating Agent
Prof Arnold Janssens, University of Ghent, Belgium
Peter Wouters, INIVE EEIG, Belgium

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

Further information
www.iea-ebc.org

www.aivc.org

Completed Research Projects

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

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

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

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

EBC ANNEX 75

Buildings are a major source of greenhouse gas (GHG) emissions. Reducing their energy use and associated GHG emissions is particularly challenging for the existing building stock. In contrast to the construction of new buildings, there are often architectural and technical hurdles to achieving low GHG emissions and low energy use in the existing stock. Also, the cost-effectiveness of reaching a high energy performance in existing buildings is often lower than in constructing new buildings. To address this, specific opportunities for district-level solutions in cities must be explored. In this context, the project aimed to clarify the cost-effectiveness of various approaches combining energy efficiency and renewable energy measures at the 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 need to be answered related to the strategies to be adopted.

Achievements

The project was concluded in June 2023, including publishing the reports and an online calculation tool. In October 2023, the final EBC Annex 75 Webinar was held with the support of Build Up, the European reference portal for building energy efficiency and renewable energy. In this workshop, the main findings and recommendations of the project were presented and discussed with stakeholders.

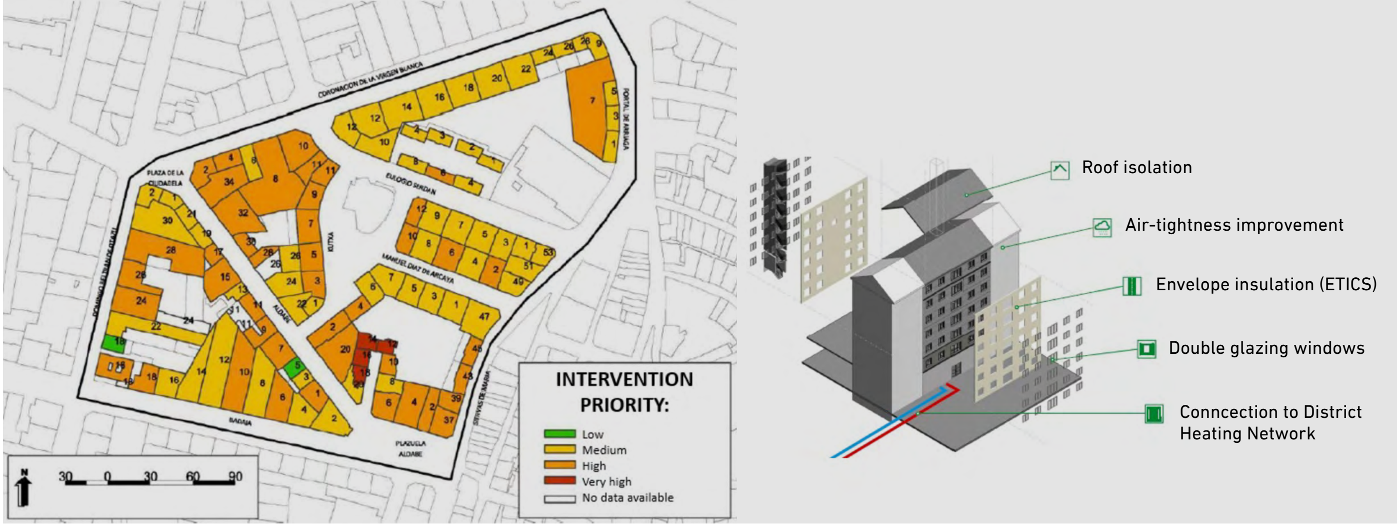
The project showed the potential of district-level approaches for cost-effectively decarbonising (reducing GHG emissions) the building sector beyond individual building renovation. The results showed that there are no single or ready-to-use solutions for building renovation. Each project must be evaluated according to its characteristics and the local context. Furthermore, the initial state of the building(s) proved to be an essential conditioning factor in choosing the cost-effective package of renovation measures to be carried out.

Compared to single-building renovation, building renovation at the district level can offer several synergies and cost-effective solutions that combine energy efficiency measures and renewable energy use. There are even indications that the potential for such synergies is greater at the district level. When it comes to accelerating the energy transition, the project demonstrated that district projects can enable easier and more cost-effective access to renewable energy, increasing flexibility in how and where energy is consumed and potentially avoiding adverse local conditions. However, as complexity grows with upscaling building renovation to the district level, harnessing synergies requires tailored strategies, appropriate business models, financing and technology combinations, integrated thinking, and stakeholder cooperation.

In this project, it was also recognised that district projects may have no evident economic advantage compared to single-building projects. However, the associated co-benefits, often related to improving general living conditions at the urban level, can be the reason to choose them. Therefore, policy frameworks and support are required to leverage the potential of district projects to accelerate the building stock's decarbonisation.

It is recommended to strengthen regulations that require the use of renewable energy whenever a heating or cooling system is newly installed or replaced, and at some point to ban the use of fossil fuel-based heating and cooling systems while strongly supporting the most vulnerable population groups during the transition. It is also recommended that favourable conditions are created for assessing, developing and deploying district solutions combining energy efficiency measures and renewables.

Furthermore, the project highlights the importance of policy action at the local level. Most concrete actions to access the potential of building renovation projects at the district level combining energy efficiency and renewables can only happen locally. Policymakers at the local level are in the front row to enable such projects. Instruments at their disposal include regulations (sometimes known as codes or standards), economic incentives, and organisational and communication support. It is recommended that local authorities actively coordinate, organise and communicate on district renovation projects. The project provided specific



Coronación district, Vitoria-Gasteiz, Spain (2016–2021) – A successful example of district renovation. At the top, delineation of the renovated district. At the bottom, a diagram of the renovation measures undertaken.

Source: Success Stories (https://annex75.iea-ebc.org/success-stories) and Domingo-Irigoyen et al., 2023, Success Stories of Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-7-3. https://annex75.iea-ebc.org/publications.

recommendations on how local authorities can best use stakeholder dialogue, process organisation and low-threshold mobilisation approaches to connect to building owners and other energy actors. A key element for success is providing know-how and linking various energy actors at the local level, especially residents, through broad and effective communication. Policymakers at the national level are advised to provide appropriate support to local authorities to engage intensely in related activities.

Publications

The main project deliverables are as follows:

- Success Stories of Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables report,
- The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables – A Short Guide for Investors and Decision-Makers report,
- The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables – A Short Guide for Policymakers,
- The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables: Making use of the Potentials – A Guide for Policy and Decision-Makers
- Barriers and drivers for energy efficient renovation at district level report,
- Cost-effective building renovation strategies at the district level combining energy efficiency & renewables – investigation based on parametric calculations with generic districts report,
- Methodology for investigating cost-effective building renovation at district level combining energy efficiency & renewables report,
- Overview of available and emerging technology for cost-effective building renovation at district level combining energy efficiency & renewables report.
- EBC Annex 75 Calculation Tool – A75CT.

Meetings

During 2023, regular online meetings of the editorial board took place to finalise the project reports.

Project duration
2017–2023

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

Assessing Life Cycle Related Environmental Impacts Caused by Buildings

EBC ANNEX 72

This goal of the project was to provide the basis and tools to support decision makers and designers to minimise environmental impacts of buildings during their entire life cycle. To achieve this goal the project provided rules and recommendations on methodological questions (i.e. producing a definition of net zero greenhouse gas emission buildings), application of tools in different design stages and to how to develop national and regional databases to assess the environmental impacts of buildings.

Achievements

In 2023, the project finalised and published the official deliverables and background reports. A strategy for design decision-makers was defined to handle and analyse uncertainty in different design phases. A categorisation for building life cycle analysis (LCA) tools for design decision makers was created. A survey was sent to tool providers and users to obtain the necessary information for the assessment of available tools. The goal is to support designers and architects when choosing a tool to assess the environmental impacts of a building.

Experts from seven countries participated in a round robin test of different typical building information modelling (BIM) -LCA workflows based on the same BIM model. This activity allowed for the assessment of differences in extracted bills of quantities and LCA results.

Guidelines were provided on establishing environmental benchmarks for buildings. An extensive survey about existing benchmarks and benchmark systems served as an important basis. Two additional final deliverables dealt with optimisation strategies to reduce the life cycle related environmental impacts of new buildings and refurbishments during the design process, and with the impact of individual, industry and political decisions on transitions towards environmental sustainability of buildings.

Guidelines for establishing an easy-to-use national LCA database for the construction sector were finalised. The report covers technical aspects (LCA related scoping, modelling and data issues), recommendations regarding the governance structure, sets out a roadmap on how to establish such a sectoral database.

The 'Monte Verità Declaration on a built environment within planetary boundaries', signed by more than 40 scientists from 20 countries was handed over to Philippe Moseley, Policy Officer at the European Commission during the final project event at the SBE'22 in Berlin, Germany.

One of the key recommendations in the declaration, addressed to governments and administrations, is the introduction of legally binding requirements to limit life cycle related greenhouse gas (GHG) emissions of new constructions and refurbishments by 2025 at the latest, with a roadmap to be established to lower these benchmarks to net zero GHG emissions by 2035. Investors, banks, and financial institutions are also encouraged to consider sufficiency ('build less') and to refurbish existing buildings and urban areas as a relevant alternative to new construction following deconstruction. The complete set of recommendations is available for download on the project website.

The final project deliverables were published in early 2023. EBC Annex 72 was then closed during June 2023. A follow-on project, EBC Annex 89 'Ways to implement net-zero whole life carbon buildings', is also described.

Publications

The project deliverables consist of the following reports:

- harmonised guidelines on the environmental life cycle assessment of buildings,
- establishing environmental benchmarks for buildings, including case study examples,
- national LCA databases used in the construction sector,
- design decision maker's guidelines on optimization using building assessment workflows and tools,
- building case studies on the application of LCA in different stages of the design process,
- how to establish national / regional LCA databases targeted to the construction sector,

– optimisation strategies to reduce the life cycle-related environmental impacts of new buildings and refurbishments,
– the impact of individual, industry and political decisions on transitions towards environmental sustainability, and
– project summary report.

Meetings

No meetings were held in 2023.

Project duration
2016–2023

Operating Agents
Rolf Frischknecht, treeze Ltd., Switzerland

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

Further information
www.iea-ebc.org

Handover of the 'Monte Verità Declaration on a Built Environment Within Planetary Boundaries' to Philippe Moseley, Policy Officer, European Commission, during the EBC Annex 72 final event on 21 September 2022 at the SBE'22 Conference in Berlin, Germany.

Source: Raquel Gomez

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

EBC ANNEX 70

To reduce greenhouse gas (GHG) emissions related to energy use in building, 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 GHG emissions 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.

EBC Annex 70 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; modelling energy demand among sub-national and national building stocks. The project was divided into three 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 review, national stock modelling and technology and product market assessments and impact analyses. The deliverables promote the importance and best practices for collecting and reporting 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 variation in building energy performance across the stock. This approach can be used to study and describe the mechanisms of energy demand and determinants of conditions that lead to different levels of demand.

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

Achievements

The project supported countries in developing realistic decarbonisation (GHG emissions reduction) transition and develop pathways through better available empirically derived energy and buildings data. Through the research, project partners informed and supported policymakers and industry in the development of low energy and low carbon solutions by evaluating the scope for using empirical stock building and energy use data. The project developed best practice in the methods used to collect and analyse data related to real building energy use, including building and occupant data. Lastly, as a collective, the project has supported the development of robust building stock data sets and building stock models through better analysis and data collection.

In the user engagement subtask, an 'Energy and Buildings Stock Data Users & Needs' survey was completed with over 800 responses from across the project's participating ember countries. The survey has provided information on what energy and building data a range of stakeholders need and use to support their energy and buildings analysis and modelling, and decision-making to address GHG emissions and improve building energy performance. A systematic literature review described the ways in which published literature describes data use and how these efforts have changed over time. Lastly, case studies describing the use of energy and buildings data from across members illustrate the latest approaches to using, analysing, and modelling with energy and buildings stock data. These activities were used in the Annex 70 energy and building stock data and model registry.

In the data mechanisms and foundations subtask, an 'Energy and Building Stock Data Registry' was built. This provides an online platform for identifying, describing, and sharing energy and building stock data. The Registry contains information on over 1000 datasets across the themes of energy, buildings, people, environment, and other important data for energy and buildings analysis. It provides a resource

The EBC Annex 70 website.

Source: EBC Annex 70

that will continue to be updated with key data attributes and information resources for the research and policymaking community. In addition, a set of best practice guides focused on remote sensing, user surveys, energy metering data, and geospatial energy and buildings data have been provided.

Finally, a model classification was developed that forms the basis of the online Energy and Building Stock Model Registry, which enables researchers to describe building energy stock models. The guidelines for reporting energy and building stock models were published and offers a framework for reporting models in peer-reviewed journal articles. Finally, a set of common exercises and guidance for undertaking model uncertainty and sensitivity tests were produced.

Throughout its duration, the project partners were engaged in disseminating the outputs of its efforts and promoting the concept of energy epidemiology.

Publications

The project deliverables are as follows:

– EBC Annex 70 Report comprising the three subtask outputs.

Meetings

No meetings were held in 2023

Project duration
2016–2023

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, United Kingdom, USA

Further information
www.iea-ebc.org

Background Information

EBC AND THE IEA

RECENT PUBLICATIONS

EBC EXECUTIVE COMMITTEE MEMBERS

EBC OPERATING AGENTS

PAST PROJECTS

EBC and the IEA

THE INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Cooperation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster cooperation among the thirty IEA member countries and to increase energy security through energy conservation, development of alternative energy sources and energy research, development and demonstration (RD & D). The current framework for international energy technology RD & D cooperation was approved by the IEA's Governing Board in 2020.

This framework provides uncomplicated, common rules for participation in RD & D programmes, known as Technology Collaboration Programmes (TCPs), and simplifies international cooperation between national entities, business and industry. The 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 around 40 such TCPs – for more information see:
www.iea.org

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
Brazil
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
Türkiye
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 RD&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 with the following other IEA buildings-related TCPs, including through strategic planning and sometimes through joint collaborative projects:

- 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)
- Decarbonising Cities and Communities (Cities)

EBC also collaborates 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 TCPs 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 greenhouse gas emissions. The areas of responsibility of the two programmes have been reviewed and agreed. EBC has primary responsibility for efficient use of energy in buildings and community systems. Solar designs and solar technologies to supply energy to buildings remain the primary responsibility of the SHC TCP.
The Executive Committees coordinate the work done by the two programmes. These Executive Committees meet together approximately every two years. At these meetings matters of common interest are discussed, including planned new tasks, programme effectiveness and opportunities

for greater success via coordination. The programmes agreed to a formal procedure for coordination of their work activities. Under this agreement during the initial planning for each new Annex / Task initiated by either programme, the other Executive Committee is invited to determine the degree of coordination, if any. This coordination may range from information exchange, inputting to the draft Annex / Task Work Plan, participating in Annex / Task meetings to joint research collaboration.

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

- EBC 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), 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

AIVC Conference Proceedings

- 41st AIVC – ASHRAE IAQ Joint Conference, held, Athens, Greece, May 2022
- 42nd AIVC Annual Conference, held Rotterdam, the Netherlands , October 2022
- 43rd AIVC Annual Conference, help in Copenhagen, Denmark, October 2023

Ventilation Information Papers

- VIP 45.1: Trends in Building and Ductwork Airtightness in Estonia, 2022
- VIP 45.2: Trends in Building and Ductwork Airtightness in Spain, 2022
- VIP 45.3: Trends in Building and Ductwork Airtightness in the Czech Republic, 2022
- VIP 45.4: Trends in building and ductwork airtightness in Belgium, 2023
- VIP 45.5: Trends in building and ductwork airtightness in Latvia, 2023
- VIP 45.6: Trends in building and ductwork airtightness in France, 2023
- VIP 45.7: Trends in building and ductwork airtightness in Greece, 2023
- VIP 45.8: Trends in building and ductwork airtightness in China, 2023
- VIP 46: Building airtightness impact on Energy Performance (EP) calculations, 2023
- VIP 47: High-rise buildings airtightness – error due to stack effect on point measurements, 2023

Technical Notes

- TN69: 40 years to build tight and ventilate right – History of the AIVC, 2022
- TN70: 40 years to build tight and ventilate right – From infiltration to smart ventilation, 2022
- TN71: Durability of Building Airtightness, 2022
- TN 72: Ventilation Requirements and Rationale behind. Standards and Regulations of dwellings, office rooms and classrooms, 2023

Working Group on Building Energy Codes

- International review of energy efficiency in Data Centres, 2022
- Scan of Code Requirements to Address Greenhouse Gas Emissions, 2023

Assessing Life Cycle Related Environmental Impacts Caused by Buildings (EBC Annex 72)

- Background information:Assessing life cycle related environmental impacts caused by buildings, 2023
- Guidelines for design decision-makers, 2023
- Case Study Collection, 2023 – Understanding the Impact of Individual, Industry & Political Decisions on Transitions Towards Environmental Sustainability, 2023
- Benchmarking and Target-setting for the Life Cycle-based Environmental Performance of Buildings, 2023
- Life-cycle Optimization of Building Performance: A Collection of Case Studies, 2023
- Guidelines for Establishing an Easy-to-use National LCA Database for the Construction Sector, 2023
- World Building Life-Cycle Based Databases and Repositories for the Building and Construction Sector, 2023
- Context-specific Assessment Methods for Life Cycle-related Environmental Impacts Caused by Buildings, 2023

Assessing Life Cycle Related Environmental Impacts Caused by Buildings (EBC Annex 75)

- Success Stories of Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables, 2023
- The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables – A Short Guide for Investors and Decision-Makers, 2023
- The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables – A Short Guide for Policymakers, 2023
- The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables: Making use of the Potentials – A Guide for Policy and Decision-Makers, 2023
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- Overview of available and emerging technology for cost-effective building renovation at district level combining energy efficiency & renewables, 2023
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- Definitions and Common Terminology on cost-effective building renovation at district level combining energy efficiency & renewables, 2023
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EBC Projects

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Working Group – Cities and Communities
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