Energy in Buildings and Communities Programme

EBC Annual Report 2024

Technology Collaboration Programme
by iea

Energy in Buildings and Communities Programme

International Energy Agency

EBC Annual Report 2024

Energy in Buildings and Communities Technology Collaboration Programme

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Energy in Buildings and Communities Technology Collaboration Programme

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Front cover: An example of a green facade on a residential building in Vienna, Austria, a technology investigated within EBC Annex 80 'Resilient Cooling of Buildings'.

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Contents

1 EBC Executive Committee Chair's Statement
3 Whole Life Climate Change Mitigation Support for Buildings

7 NEW RESEARCH PROJECTS
8 Sustainable Cooling in Cities
10 Grid Integrated Control of Buildings
12 Human-centric Building Design and Operation for a Changing Climate
14 Validation and Verification of In-situ Building Energy Performance Measurement Techniques
16 Energy Resilience of the Buildings in Remote Cold Regions

18 ONGOING RESEARCH PROJECTS
20 Smart Materials for Energy-efficient Heating, Cooling and Indoor Air Quality Control in Residential Buildings
22 Open Building Information Modelling for Energy Efficient Buildings
24 Low Carbon, High Comfort Integrated Lighting
26 Ways to Implement Net-zero Whole Life Carbon Buildings
28 Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings
30 Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems
32 Energy Efficient Indoor Air Quality Management in Residential Buildings
34 Indirect Evaporative Cooling
36 Demand Management of Buildings in Thermal Networks
38 Building Energy Codes
40 Positive Energy Districts
42 Energy Flexible Buildings towards Resilient Low Carbon Energy Systems
44 Data-Driven Smart Buildings
46 Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications
48 Air Infiltration AND Ventilation Centre – AIVC

50 COMPLETED RESEARCH PROJECTS
51 Occupant-centric Building Design and Operation
53 Resilient Cooling of Buildings

55 BACKGROUND INFORMATION
56 EBC and the IEA
59 Recent Publications
60 EBC Executive Commitee Members
61 EBC Operating Agents
63 Past Project

EBC Executive Committee Chair's Statement

Highly energy-efficient buildings are broadly cost-competitive over their lifetimes, according to the 2024 Breakthrough Agenda Report, and yet they represent the minority of buildings currently being designed, built, and operated.

Although tremendous advancements have been made with respect to envelopes and mechanical systems such as heat pumps, real-world building performance is significantly lower than expected based on the potential offered by these technological efficiency improvements. This is a consequence of building design and operation. Designing a high-performance building is a complex process in which designers need to consider the uses of the building and, based on its location, define appropriate characteristics of the envelope and coordinate mechanical, electrical, and plumbing systems. These include HVAC systems to supply and extract heat, lighting systems, and increasingly, systems to support security and smart technologies. Together, these components must ensure that the occupants have a healthy, comfortable, and secure space in which to live or work.

The complexity of the design process requires time from the designers to evaluate options. However, in general, they do not have the luxury of taking the time to explore these higher performing options, given that the design needs to be completed within a limited budget.Consequently, designers tend to re-use designs that although familiar are often suboptimal, with high-performance building design undertaken only for the most prestigious projects. In fact, although a few buildings do reach high performance levels at equivalent or lower costs, the vast majority of buildings built to date are designed to meet the mandated minimum level of performance of their individual jurisdiction's energy code.

Designing high performing buildings is a necessary but not sufficient requirement for limiting the carbon footprint of buildings. Effective operation is also required for this to happen.

The design of high performing buildings and their operation to maintain the health, comfort, and security of occupants are subjects that are addressed in many current and past projects within our IEA Technology Collaboration Programme.

For example, IEA EBC Annex 93 'Energy Resilience of the Buildings in Remote Cold Regions' is exploring the building as a system in remote arctic communities, while IEA EBC Annex 90 'Low Carbon, High Comfort Integrated Lighting', which is jointly managed with the IEA Solar Heating and Cooling TCP, explores how the design of high comfort integrated lighting can be achieved by utilizing enhanced façade technologies.

Meanwhile, IEA EBC Annex 95 'Human-Centric Buildings for a Changing Climate', jointly run with the IEA User-Centred Energy Systems TCP, carries out research to fully address the needs of the occupants both at the design stage and during operation of buildings, an essential aspect that is sometimes overlooked. EBC TCP projects also go beyond individual buildings to consider how multiple buildings form parts of larger systems such as cities (IEA EBC Annex 97 'Sustainable Cooling in Cities', run jointly with the IEA Decarbonising Cities & Communities TCP), as well as electricity grids (IEA EBC Annex 96 'Grid Integrated Control of Buildings') and thermal networks (IEA EBC Annex 84 'Demand Management of Buildings in Thermal Networks'). Our project with the broadest scope with respect to time and industries covered is IEA EBC Annex 89 'Ways to Implement Net-zero Whole Life Carbon Buildings.' This covers the carbon footprint of buildings from the extraction of the raw materials, through the construction of the building, to either its demolition or refurbishment and disposal of construction waste. An introductory article on this work leads our 2024 Annual Report. Although I have only mentioned some of our projects, it is evident that the work carried out by the many researchers working within the EBC family aligns with the needs identified in the 2024 Breakthrough Agenda Report and impacts the ways we design and operate buildings.

I am pleased to invite you to read our latest Annual Report to learn about all our work!

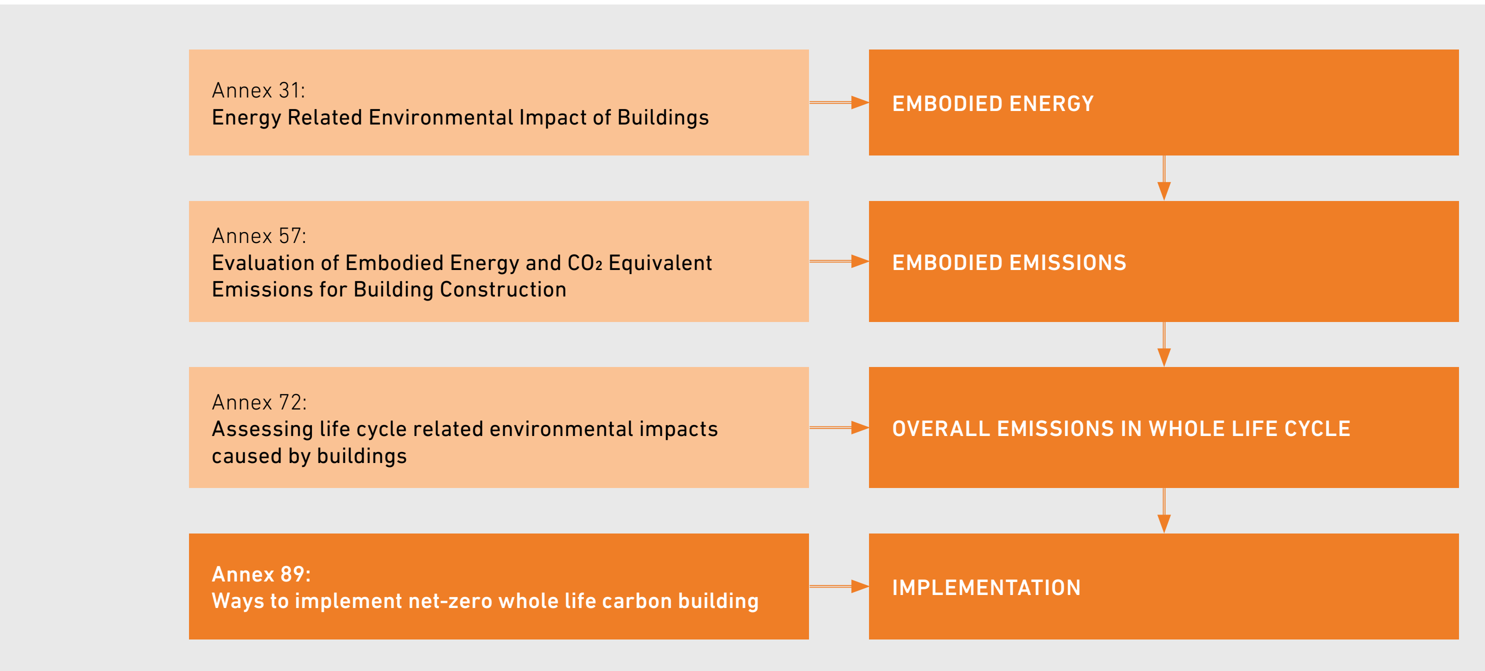
Meli Stylianou
EBC Executive Committee Chair and Member for Canada

Whole Life Climate Change Mitigation Support for Buildings

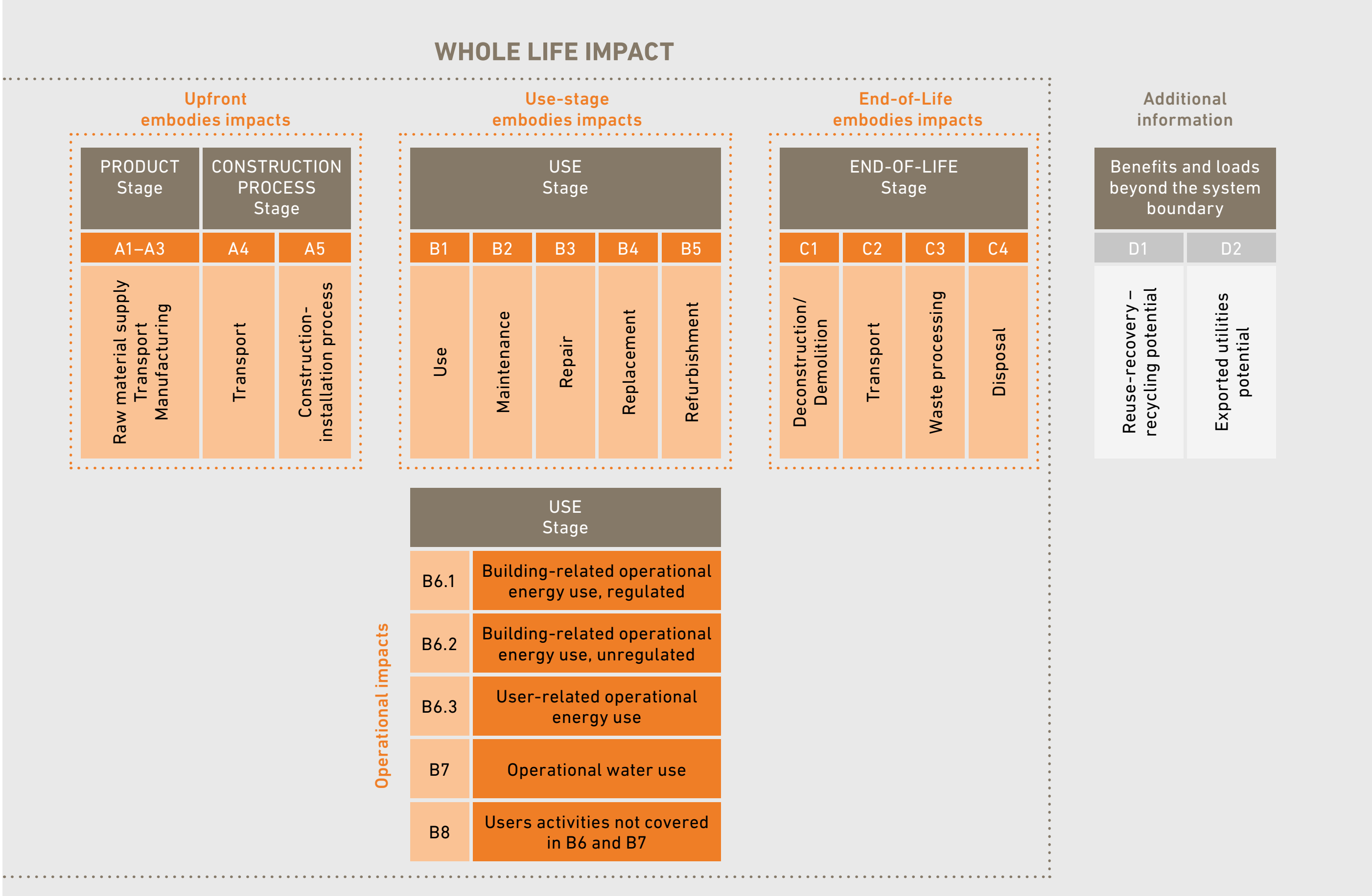
With the consequences of global warming already being experienced and increasing in intensity, there is growing interest in the topic of climate protection. Thus, there is an urgent task to limit global warming by reduce greenhouse gas emissions. To this end, the construction and building industry is of particular importance, including all the branches in the upstream and downstream processes within the supply chain. This sector causes significant greenhouse gas emissions, is directly affected by the consequences of climate change, and at the same time has a great potential to contribute to mitigation actions. Crucially, up to 40% of greenhouse gas emissions can be influenced directly and indirectly by the actors involved in shaping the built environment. However, compared to other sectors this was recognized comparatively late by many public policy makers.

Today, the goal of reducing greenhouse gas emissions from buildings is the focus of major international initiatives such as Buildings Breakthrough, and the International Energy Agency's Technology Collaboration Programmes (TCPs) of which the Energy in Buildings and Communities (EBC) TCP forms a part. The general ambition is that by 2030 buildings with minimised greenhouse gas emissions throughout their life cycles become commonplace.

Countries worldwide are called upon to integrate mitigation pathways into their Nationally Determined Contributions (NDCs) to be submitted to the United Nations Framework Convention on Climate Change's Conference of the Parties, the latest of which is being held in 2025 ('COP 30'). The EBC TCP is closely involved in creating the prerequisite technical and scientific basis for establishing NDCs through the research and development that takes places within its projects.



EBC project history on embodied and whole life impacts
Source: EBC Annex 89



Attribution breakdown for whole life impacts
Source: EBC Annex 89

Embedding the foundations

As early as 1996, EBC Annex 31 'Energy Related Environmental Impact of Buildings' opened up a new and important thematic field, thus responding to the growing interest in environmental issues over and above pure energy issues. It introduced the terms 'life cycle assessment' (LCA) and 'environmental impacts' to the EBC TCP and described them in a dedicated report. This project characterised the building as the object of investigation and explained the decision-making framework for planning and designing buildings. Finally, it made a synopsis of relevant tools that may act as interfaces between decision makers and the building as the object of investigation. Next, EBC Annex 57 started in 2011 and dealt with the evaluation of embodied energy and carbon dioxide (CO_2) equivalent emissions for building construction. The scope of this project was limited to construction related impacts and excluded the operational phase. It conducted a survey of current research results regarding embodied energy and embodied greenhouse gas emissions. Based on this survey, guidelines were developed both for evaluating embodied energy and CO_2 emissions from building construction and for designing and constructing buildings with lower embodied energy and CO_2 emissions.

The follow-up project, EBC Annex 72 'Assessing Life Cycle Related Environmental Impacts Caused by Buildings' (2016–2023) extended the scope to include the whole life cycle (construction, operation, end-of-life), as well as all environmental impacts, instead of only those relating to energy. This project delivered methodology-related guidance for the life cycle assessment of buildings, with a focus on the assessment of biogenic CO_2 withdrawals and emissions, the state of art for and guidance on benchmarking environmental impacts of buildings including net-zero greenhouse gas emission buildings, a global synopsis on LCA databases for buildings and construction, and guidance on design tools and BIM (building information modelling). Like its predecessors, EBC Annex 72 compiled and documented case study buildings using a standardised reporting template. The successor project, EBC Annex 89 'Ways to Implement Net-zero Whole Life Carbon Buildings', now focuses on implementation, given the urgency of the built environment to drastically reduce its greenhouse gas emissions.

Current challenges

The current situation is complex. On the one hand, the targets for reducing greenhouse gas emissions in the construction and building sector have been taken up by international initiatives such as the International Energy Agency. By 2030, new buildings that cause almost no greenhouse gas emissions in their life cycle are to become a matter of course. On the other hand, however, there are also new tasks, such as fulfilling the preconditions to make this a reality.

Such challenges arise in the current efforts to integrate the calculation, assessment and targeted influence of greenhouse gas emissions into the design and investment processes. Some problems in this respect are the increasing number of terms and definitions, along with ambiguities in the description and application of system boundaries. For example, in the case of the widely used term 'whole life carbon', it is not sufficiently clear that this is the calculation of greenhouse gas emissions taking into account both embodied and operational parts; in Europe, this is also called 'life cycle global warming potential'. Formally, the object under consideration is a complete building throughout its whole life cycle, but the object of assessment is a building model used alongside a life cycle model based on a reference study period, subdivided into stages and information modules.

Even more confusing is the multitude of goals and requirement levels from 'climate-neutral' to nearly-, near- or net-zero emissions, which makes it difficult to define performance classes. EBC Annex 72 had already set itself the goal of supporting the harmonization of corresponding approaches. A key finding was that indicators, system boundaries, databases, methods, objectives and level of requirements must form a coherent unit. Net-zero greenhouse gas emission buildings during the life cycle is becoming a universal benchmark, achievable by specific solutions.

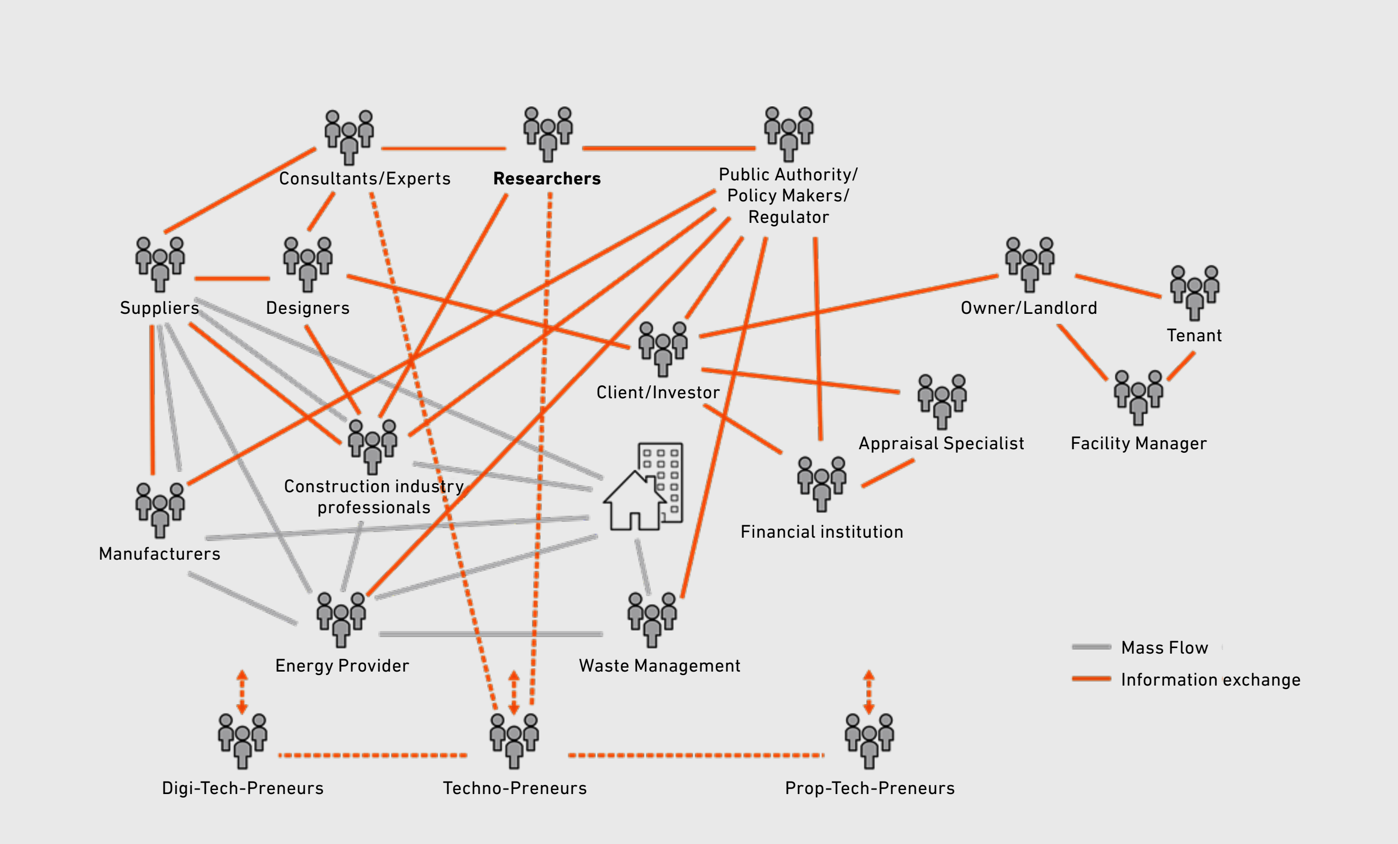
Actions and actors

The 'Monte Verità Declaration', which was initiated by EBC Annex 72, presents a detailed plan involving a wide range of participants to mitigate the environmental impact of buildings. It emphasizes the importance of reducing operational energy demand by using renewable energy sources and incorporating sustainability principles into buildings-related practices. Key measures include favouring refurbishment over new construction, applying circularity principles by using locally sourced and recycled materials, and designing buildings for easy disassembly and reuse. The selection of construction materials and technologies should prioritize low greenhouse gas emissions and minimal environmental impacts.

Cross-cutting strategies are also vital, advocating for building less ('sufficiency') and modernizing existing structures instead of constructing new ones. Environmental life cycle assessment (LCA) is recommended throughout all project stages to evaluate design options and measure environmental impacts comprehensively. Successful implementation demands the active involvement of various stakeholders.

Specific tasks as required to mitigate the environmental impact of buildings including the following:

- Governments and administrations should set enforceable emission targets, standardize LCA practices, and support research through legal and regulatory frameworks.
- Investors and financial institutions need to require environmental impact assessments, invest in sustainable projects, and incorporate LCA into their decision-making processes.
- Research institutions should focus on advancing sustainable construction technologies and integrate LCA education into relevant academic programmes.
- Designers, architects, and engineers are tasked with incorporating sufficiency, refurbishment, circularity principles, and low-energy solutions into their projects using advanced digital tools.
- Operators of environmental product declaration (EPD) programmes and certification schemes must align with international standards, ensure LCA accuracy, and set stringent environmental targets.
- Manufacturers of construction materials and technologies should aim for net-zero emissions, publicize their LCAs, and improve manufacturing processes to enhance circularity and reduce emissions.
- Construction companies should minimize emissions and resource use during building and deconstruction phases, select low-impact materials, and reduce waste.
- Real estate agents ought to promote transparency regarding a building's environmental performance to buyers and tenants.



Mass flow and information exchange network profile
Source: EBC Annex 89

– Occupiers and tenants are encouraged to reassess their space needs, make informed decisions based on environmental impact data, and use spaces efficiently.

Developing EBC Governance

Achieving net-zero whole life carbon in buildings demands a comprehensive and coordinated implementation strategy. Firstly, regulatory frameworks must evolve to encompass the entire building life cycle, moving beyond initial operational energy to include embodied greenhouse gas emissions, material replacements, and end-of-life considerations. This requires standardized methodologies for whole life carbon assessment, aligning with existing frameworks and the freely available outcomes of the international research conducted within EBC Annexes 72 and 89. Secondly, access to high-quality, consistent data is crucial. This includes robust EPDs and comprehensive national generic databases covering a wide range of materials and processes, ideally in digital formats. However, generic data should be conservatively stated, so incentivizing the use of product-specific EPDs and allowing them to gain greater recognition. Thirdly, policy needs to set clear, progressively ambitious targets for whole life carbon reduction, signalling the long-term direction to the industry. Harmonization of these targets and assessment methods across regions such as the Nordic countries and the European Union fosters fair competition and accelerates innovation. Finally, significant investment in stakeholder education, capacity building, and the development of user-friendly assessment tools is essential to ensure industry readiness and effective implementation. Addressing the technical challenges and ensuring buy-in from all actors across the value chain is key to realizing net-zero whole life carbon ambitions.

The current international research project EBC Annex 89 and its outcomes is supporting all actors to take proactive, scientifically informed steps to mitigate climate change. They must not delay action while waiting for regulations to compel them; instead, they should take the initiative now to stay ahead of climate change and to contribute to a sustainable future.

Further information

www.iea-ebc.org

Alexander Passer (Operating Agent),
and Thomas Lützkendorf, Rolf Frischknecht,
Greg Foliente, Marcella Saade, Carlos Caballero,
Maria Balouktsi, and Freja Rasmussen (all
Subtask Leaders) of EBC Annex 89

New Research Projects

SUSTAINABLE COOLING IN CITIES

(EBC ANNEX 97)

GRID INTEGRATED CONTROL OF BUILDINGS

(EBC ANNEX 96)

HUMAN-CENTRIC BUILDINGS FOR A CHANGING CLIMATE

(EBC ANNEX 95)

VALIDATION AND VERIFICATION OF IN-SITU BUILDING ENERGY PERFORMANCE MEASUREMENT TECHNIQUES

(EBC ANNEX 94)

ENERGY RESILIENCE OF THE BUILDINGS IN REMOTE COLD REGIONS

(EBC ANNEX 93)

Sustainable Cooling in Cities

EBC ANNEX 97 – IEA CITIES TCP

The effects of climate change are becoming increasingly severe in urban areas, where extreme weather events, such as prolonged heat waves, are intensified by the urban heat island effect. With over 55% of the global population living in cities, addressing these climatic challenges has become critical.

EBC Annex 97 is a thematic continuation of EBC Annex 80 'Resilient Cooling of Buildings'. One of the key insights from EBC Annex 80 revealed that sustainable and resilient cooling of buildings in urban areas is intrinsically tied to heat mitigation and the introduction of cooling solutions that do not compromise the outdoor liveability by heat and noise release. This new project is tackling this challenge. It is being carried out as a fully joint project together with the IEA Technology Collaboration Programme on Decarbonisation of Cities and Communities (Cities TCP). It is addressing three key aspects as follows:

A temporary installation at the Vienna Climate Biennale 2024, as an impetus for the realization of climate-effective green and blue infrastructure, in particular urban rivers.
Source: IBR&I, Vienna, 2024

- First, it seeks to improve outdoor climate conditions in cities to create comfortable and healthy living environments. This involves interventions across different spatial scales, from city-wide urban planning to neighbourhood-level initiatives and building-specific strategies. Urban morphology optimization through design, landscaping, and the integration of green and blue infrastructure can enhance airflow, reduce outdoor temperatures, and provide shading. Additionally, the use of cool materials in outdoor spaces offers both immediate benefits for outdoor comfort and indirect improvements to indoor environments.
- Second, the project focuses on strategic solutions for sustainable cooling of buildings. Efforts prioritize reducing cooling demand and meeting this demand with energy-efficient, climate-friendly, socially equitable, and affordable approaches. Alternatives to conventional air conditioning, such as district cooling, seawater cooling, and radiative cooling, are explored to minimize energy waste and mitigate heat and noise pollution. Balanced systems that optimize seasonal environmental heat sinks can further enhance energy efficiency and reduce environmental impacts.
- Third, the project highlights the critical link between outdoor climate mitigation and sustainable cooling solutions. A conducive outdoor environment is essential for the success of sustainable cooling technologies, as extreme heat conditions can undermine their effectiveness. Additionally, unmanaged excess heat from air conditioners can exacerbate outdoor heat stress, particularly during heat waves, reducing overall quality of life in urban areas.

Objectives

The project aims to increase and spread international knowledge about effective heat mitigation and sustainable cooling in cities. Emphasis is being placed on the interaction between heat mitigation in outdoor spaces and cooling of buildings. The aim of the project is to develop and support the application of measures that serve the health, safety and wellbeing of people and that push energy efficiency and support the way to carbon neutrality. To achieve this goal, the following four specific objectives have been identified:

- Fundamentals: The first specific objective is to establish a knowledge base on environmental quality criteria in indoor and outdoor spaces, as well as key performance indicators for urban cooling. This considers indoor and outdoor air quality and comfort, health, productivity, safety, energy efficiency, environmental impact, and cultural, social, and economic aspects. It also involves extracting and processing knowledge about human-centric indicators such as heat vulnerability indices.
- Methods: The second specific objective is to develop protocols for simulations and experimental methods to assess heat mitigation and cooling technologies. This includes evaluating simulation tools and the identification and development of experimental evaluation methods for urban heat and countermeasures.
- Solutions: The third specific objective is to identify and assess solutions to improve heat mitigation in urban outdoor areas and cooling in buildings, focusing on the interrelation of both measures. This involves measures such as urban design, airflow, shading, evaporation, cool materials, district cooling, and usage of natural heat sinks. The focus is on resilient, robust, and affordable technologies, considering technical-energetic and socio-economic aspects.
- Policy: The fourth specific objective is to transfer scientific research and results to real-world applications, identify best practices for policymaking, and strengthen existing networks to amplify global adoption of sustainable cooling practices and to maximise the project impact.

Progress

The project was accepted in November 2024. It is currently going through its one-year preparation phase and is engaging with potential participants.

Meetings

No project meeting were held in 2024.

Project duration
2025–2029

Co-Operating Agents
Peter Holzer, Philipp Stern,
Institute of Building Research & Innovation, Austria

Participating countries (provisional)
Australia, Austria, Belgium, Brazil, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Ireland, Spain, Sweden, Switzerland, Türkiye, UK, USA

Further information
www.iea-ebc.org

Grid Integrated Control of Buildings

EBC ANNEX 96

In addition to improving energy efficiency (reducing overall energy consumption), the International Energy Agency (IEA) has identified the need for demand-side action to improve 'system-wide efficiency'. This includes the emerging need for load shifting, which means managing the time of energy use. This is required to improve the security of energy systems, as part of the transition to variable renewable energy supplies. It also enables buildings to reduce emissions by using energy when grid carbon intensity is lower.

Load shifting in buildings can be achieved with various thermal and electrical energy storage assets that routinely occur in buildings (for instance hot water, HVAC, electrical batteries, and electric vehicles). These assets are known as 'flexible' loads and are capable of being dispatched using modern digital technologies.

In their 'Net Zero Emissions by 2050 Scenario', the IEA is calling for a tenfold increase in demand response availability from buildings between 2020 and 2030. Consistent with IEA recommendations, this new project aims to combine the learnings of EBC Annex 81 'Data-Driven Smart Buildings' and EBC Annex 82 'Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems', to unlock the availability of flexible loads in buildings. This is expected to be achieved by focusing on (i) the digitalisation framework necessary for automating asset dispatch and resource quantification, and (ii) by improving the technology readiness level (TRL)/ commercial readiness level (CRL) of flexible heating and cooling products and services.

Key research questions that this project is addressing include:

- What heating and cooling flexibility products and services are the most widely useable, predictable and cost-effective (with a target cost of <$200/kVA)?
- How can energy flexibility be digitally characterised and communicated in operational settings to continuously inform markets of forecast availability of the flexibility resource? How can this be automated and certified?
- How can flexibility resources be managed (in aggregate) to both improve the certainty that outcomes will be delivered, and avoid rebound effects when flexible resources return to service?

Grid Integrated Control of Buildings

A. Minimum Information Requirements	B. Flexible Demand Aggregation	C. Flexible Demand Product Packages	D. Case Studies and Implementation Models
A1: Reference scenarios and KPIs for market participation	B1: Stochastic forecasting and M&V methods	C1: Flexibility technologies review and evaluation	D1: Case studies and dissemination
A2: Device communication standards	B2: Building emulators and 'AI Gym' test environment	C2: Flexibility product guides and implementation tools	D2: Owner and occupant experience
A3: Ontology development and sufficiency methods	B3: Asset orchestration common exercises	C3: Product performance assessment	D3: Industry roadmap
A4: Platform Design and user pilots		C4: Time-of-use carbon assessment	

Structure of EBC Annex 96 'Grid Integrated Control of Buildings'
Source: EBC Annex 96

- What measurement and verification (M&V) methodologies and algorithms can account for uncertainty, to fairly and cost-effectively determine delivered flexibility after a demand response event?
- Can semantic web technologies enhance 'machine-readability' in a way that can automate flexibility services in buildings and/or energy trading processes, and support innovative business models?
- How can data-driven approaches be used to (i) reduce the various technical and commercial barriers to sourcing flexibility services from buildings, and (ii) package flexibility resources in a way that is attractive in various energy markets and regulatory environments?

Objectives

The vision of this project is to provide building owners and energy market participants with a framework of concepts, procedures, tools and evidence that can enable trustworthy, automated, cost-effective trading of flexibility resources from buildings at scale. To achieve this, the project objectives are to:

- advance the TRL/CRL of flexible load technologies available in buildings,
- develop the digital framework(s) for exposing flexible load resources to energy markets/schemes,
- demonstrate the potential for automating flexibility aggregation and orchestration processes through modern digitalisation technologies,
- assess the potential to use flexible loads to reduce emissions in building, by better matching demand with grid time-of-use emissions, and
- drive adoption of project results through case studies, business model innovation and results dissemination.

Deliverables

The planned deliverables from this project include:

- energy market reference scenarios describing how flexibility can participate in relevant jurisdictions, along with relevant digital platform requirements,
- a guide to M&V for flexible demand financial settlement,
- a report describing modelling analysis of the impact of coordinated management of fleets of flexible buildings,
- a state-of-the-art report, and assessment of technologies for delivering flexible demand from heating and cooling services,
- a report on the potential for flexibility to reduce time-of-use based greenhouse gas emissions,
- a repository of case studies of flexibility in real world applications, accessible through a web portal and
- an industry roadmap report explaining intervention opportunities to grow the flexible demand industry.

Progress

Initial discussions about the new project were held in various forums linked to EBC Annex 81 and EBC Annex 82. Based on these discussions, an initial project proposal was prepared, and approval was subsequently given to enter preparation phase at the June 2024 EBC Executive Committee meeting.

The first preparation meeting was held in October 2024. This meeting included a structured consultation process to identify the key industry challenges in some detail, solutions, research opportunities, available capability and processes for collaboration.

Significant effort has focused on recruitment of participants to the project collaboration. The project sub-task leadership and activity-level leadership has been largely recruited and is now working to prepare additional detailed work plans. A distribution list has been created with over 150 interested researchers representing over 70 organisations across 26 countries.

The project is supported and promoted by the Mission Innovation 'Affordable Heating and Cooling' Innovation Community.

Meetings

The following meetings were held in 2024:

- International workshop on Grid Integrated Control of Buildings, held in Prague, Czech Republic, in May 2024, and
- First preparation-phase expert meeting, held in Copenhagen, Denmark in October 2024.

Project duration
2024–2029

Co-Operating Agents
Stephen White, CSIRO, Australia
Rongling Li, Technical University of Denmark, Denmark

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

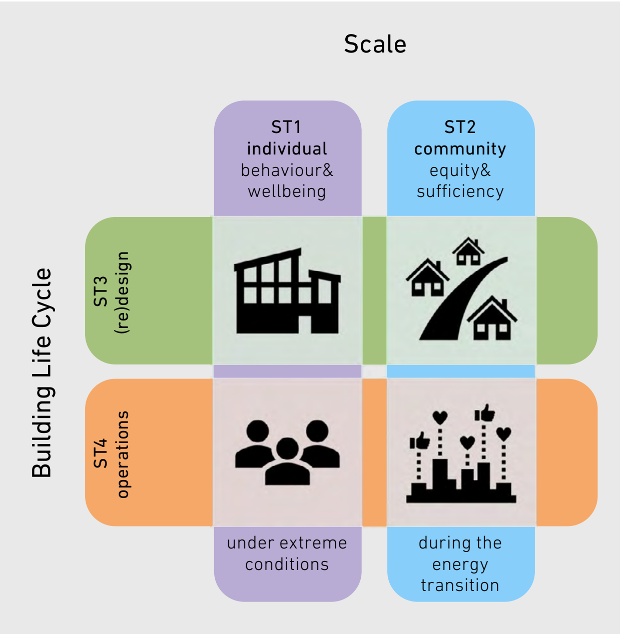
Further information
www.iea-ebc.org

Human-Centric Buildings for a Changing Climate

EBC ANNEX 95

People play an integral role in building performance and adaptation to climate change across both spatial and temporal scales. Considering the breadth of stakeholders in the built environment, they affect the market and design for new buildings, building construction, and the operation and management of buildings through their life cycle. In residential buildings, the owners or tenants are also the operators and make decisions about renovations and retrofits. In non-residential buildings, operators are usually distinct from the occupants and hold significant power over operating conditions and the resulting environmental performance. In a rapidly changing climate, these diverse stakeholders hold the key to achieving optimal levels of performance as defined by the following dimensions:

- resilience and adaptability to a changing climate, extreme events, and energy transitions,
- equitable allocation of building space and access to comfortable and healthy spaces, and
- mitigation of climate change.



To understand the role that occupants and building stakeholders must play in the energy transition while adapting to our changing climate, this new project has been established jointly as EBC Annex 95 with the IEA Technology Collaboration Programme on User-Centred Energy Systems (Users TCP). It is exploring the following questions to research the evolving role of humans in the energy transition to address climate change:

- How do people interact with their buildings (and why) under 'normal' conditions?
- How do these behaviours change under extreme conditions driven by climate change, and how do humans react under unprecedented conditions?
- Do these behaviours help or hinder their ability to survive and thrive?
- How will extreme events specifically impact building function (and indoor environmental quality and health)?
- What is the boundary or expectation, and/or the design and policy implications that might result from these conditions and behaviours (for example, at what point must comfort expectations shift due to a changing climate and the energy transition)?
- How do occupant expectations of buildings need to shift given the capabilities we have now? How do expectations need to shift for designers, building operators, communities, and so on?
- How do we design and redesign buildings to accommodate this 'new normal'?
- How do we design better buildings for people, especially under changing conditions and climate, while also promoting health and well-being?

EBC Annex 95 is organized in four interdependent and interacting subtasks under two management committees. The subtasks are illustrated as interconnected, recognizing the importance of integrated and interdisciplinary research
Source: EBC Annex 95

The in-person participants of the 1st Expert Meeting, held in Sevilla, Spain. in November 2024
Source: EBC Annex 95

Objectives

Determine the role that occupants and other building stakeholders must play to facilitate the energy transition while adapting to our changing climate. We also aim to develop, demonstrate, and deploy approaches to improve occupants' comfort, well-being, and health in buildings, using principles of sufficiency and equity. The specific objectives are listed below:

- Achieve a broader understanding of how the energy transition will impact various areas, people, and building types
- Create new definitions and frameworks on topics such as resilience and sufficiency that are specific to people
- Develop occupant-centric design strategies for new and existing buildings to adapt to climate change and the energy transition
- Create new controls technologies and operating strategies to simultaneously optimize occupant comfort and sustainability implications
- Develop new tools to support occupant-centric building policy, design, and operation
- Create guidance for integrating occupant considerations into codes and standards

Deliverables

The project is currently in its preparation phase, during which the specific deliverables will be determined.

Progress

In 2024, a planning workshop was held in Boston, USA, with around 30 international participants. The project officially kicked off with the first expert meeting in November in Sevilla, Spain, co-located with the Comfort at the Extremes (CATE) 2024 conference. During this first meeting participants worked on developing specific activities for the project.

Meetings

The following meetings were held in 2024:

- Planning workshop, held in Boston, USA, April 2024, and
- 1st Expert Meeting, held in Sevilla, Spain in November 2024.

Project duration
2024–2029

Co-Operating Agents
Liam O'Brien, Carleton University, Canada
Marianne Touchie, University of Toronto, Canada
Julia Day, Washington State University, USA
Zoltan Nagy, The University of Texas at Austin, USA

Participating countries
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Further information
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Validation and Verification of In-situ Building Energy Performance Measurement Techniques

EBC ANNEX 94

In recent years, there has been a rapid growth in the availability of cost-effective technologies that measure the energy performance of buildings in-situ. This growth has been driven by concerns over the performance gap between the real energy performance of buildings and that predicted by models, including those used for regulatory purposes. Innovation has been accelerated by the availability of smart meter data, weather data, and low-cost sensors that can measure the indoor environment. In fact, the building fabric thermal heat transfer coefficient (HTC) performance of more homes has likely been measured more often in the last few years than in all previous years combined.

This new capability to measure millions of buildings in-situ has the potential to transform the energy performance of building stocks globally, for example by enabling the following:

- Quality assurance of new buildings and the retrofit of existing buildings to eradicate the performance gap
- Correct sizing of heating and cooling systems to improve their energy efficiency and reduce costs
- Quantification of building energy flexibility for demand response to support the electrification of heat
- Reliable Energy Performance Certificates that drive the sale and rental value of buildings
- Accurate energy demand predictions from improved models that help to engage households and de-risk heat-as-a-service solutions

This new project aims to increase confidence in the use of in-situ building energy performance measurement techniques, bringing together an international network of experts and facilities. Their activities are providing datasets and research insights to accelerate the development of methods to measure the thermal performance of buildings, propose a methodology by which these methods are deemed to be valid, build consensus on the best approaches for calculating uncertainty, and diagnose the causes of performance issues. The project is generating a database of real measured buildings and calibrated energy models, using which new and improved methods of thermal performance measurement can be developed.

Through this research, the project aims to accelerate the development and deployment of in-situ measurement methods to help to characterise and close the performance gap between the expected and actual energy use of dwellings. A key focus of the work is to bridge the gap between method development and end use to better understand the needs of potential applications and the differing requirements of different users. Translating building thermal performance measurements to actionable insights is also being investigated through the study of investigative techniques to disaggregate any underlying problems with thermal performance.

The project is spanning research at a range of technology readiness levels by both addressing the validation and verification of existing in-situ building energy performance measurement techniques and aiming to extend the applicability of methods to new climates and building typographies. The typographies to be studied include flats and high-performing homes, for which current methods have not been tested or refined. A key challenge of the work is to extend the seasons and climates in which the thermal performance of buildings may be accurately measured, requiring the collection of a large dataset from across the globe of dwellings in differing climates. This enables the development of measurement techniques for cooling dominated climates; currently research is concentrated primarily on heating dominated climates.

Forty-four participants attended the 1st Working Meeting of EBC Annex 94 in Leuven, Belgium, at which 14 participants presented some of their earlier related work. Source: University of Salford, UK

Objectives

The project aims to advance the adoption of in-situ building energy performance measurement techniques through the following objectives:

- Develop new knowledge and understanding of the breadth of real-world applications for in-situ building energy performance measurement techniques and the technical requirements of those applications across different sectors.
- Extend fabric thermal performance estimation methods to new building typologies and climates, improving accuracy, repeatability, and robustness.
- Co-create a new framework for the verification and validation of in-situ building energy performance measurement techniques. This will reconcile the current disparate approaches and provide the playbook for methods required for estimating uncertainty and evaluating accuracy and repeatability in the field.
- Develop building performance diagnostics to diagnose the reasons for HTC performance gaps. These are intended to disaggregate HTC estimates to identify the cause of observed underperformance and avoid expensive forensic studies.
- Collect and curate data sets to support the project work and create a legacy resource. These include new and existing simulated data, data from field trials in occupied homes and data from test houses.

Deliverables

The project has a range of deliverables planned as listed below:

- Applications and their requirements: report listing stakeholders, applications and requirements of in-situ building energy performance measurement techniques.
- Extend thermal performance methods:State of the art review and catalogue of methods; Development and evaluation of methods for new building typologies and for cooling dominated climates.
- Verification and validation: Play book of methods for estimating the uncertainty of different methods; Blind trial of methods to evaluate their accuracy.
- Performance diagnostics: State of the art review and catalogue of methods; Development and evaluation of new diagnostic methods.
- Data collection and curation: catalogue of data sets for the development and validation of methods, including new data collected during the project.

Progress

The project preparation phase was approved at the EBC Executive Committee meeting held in June 2024.

Meetings

The 1st Working Meeting was held at KU Leuven, Belgium, in November 2024.

Project duration
2024–2028

Co-Operating Agents
Prof David Allinson, Loughborough University, UK
Prof Cliff Elwell, University College London, UK
Prof Richard Fitton, University of Salford, UK

Participating countries
Belgium, Denmark, France, Germany, Ireland, the Netherlands, Spain, Sweden, UK, USA

Further information
www.iea-ebc.org

Energy Resilience of the Buildings in Remote Cold Regions

EBC ANNEX 93

Energy resilience of buildings is a topic that has been generally overlooked in building codes and regulations, and often in building design in general. However, energy resilience is especially relevant in cold, very cold and sub-arctic remote locations where loss of energy supply can be difficult to restore within a short timescale. Such cold regions cover almost one fifth of the Earth's total land area (excluding Antarctica and Greenland). The main communities in these regions include dwellings for indigenous and local people, military installations, customs and border protection stations, construction sites, mining camps, scientific research centres, government and community services, and so on. Except for Antarctica, the cold climate zones are mostly situated in the northern hemisphere due to the distribution of landmass. The logistics of construction, maintenance, and repair in such remote locations are unique and challenging.

For people to survive in the cold, buildings must be warm and comfortable in normal operations and habitable during crises caused by blackouts and energy shortages. Due to the current climate warming trends, energy crises, and critical political situations, these buildings are at risk of blackouts and energy shortages. Therefore, the study and enhancement of the resilience of buildings, heating, ventilating, and air-conditioning (HVAC), and energy supply systems in cold climates is especially important. The resilience of thermal energy systems in extreme climates is also important. While metrics and requirements for availability, reliability, and quality of power systems have been established, similar metrics and requirements for thermal energy systems are not well understood despite the clear need for such metrics in the Earth's cold regions. Several research projects have previously been conducted to address the resilience of buildings in warm, hot, and humid climatic conditions due to the higher population, and local economic challenges for example. However, in cold climate conditions, the resilience issue has not been extensively addressed. In these conditions, building resilience is essential to ensure habitability and survivability for the occupants; such infrastructure must be planned for, and designed, constructed, operated, and maintained to withstand disruptive events.

This new project has been approved within the EBC TCP, because good energy resilience needs to be ensured alongside low energy use. The development of methods to increase the overall energy resilience of buildings and building communities is critical for many stakeholders. Therefore, this project is intended to support a broad audience including public policy and decision makers, researchers, planners, architects, and engineers. To enhance the long-term impact of its results and findings, all results and guidelines will be published through channels tailored to each target audience.

Objectives

The objectives of the project are as follows:

- Identify major threats specific to cold regions that hinder the normal operation of buildings and energy systems; develop definitions, frameworks, and key performance indicators for energy-resilient buildings, communities, and energy supply systems; establish requirements for habitability, survivability, indoor air quality, and buildings sustainability levels in cold regions for 'black sky' operations.
- Document and assess existing practices through case studies across cold regions with different local conditions.
- Develop guidelines for energy-resilient and efficient buildings and energy systems for different cold regions, with these addressing technical, social, and economic aspects.
- Disseminate best practices for planning and construction of energy-resilient buildings and communities in cold regions through technical papers, conference presentations, and training.

Buildings in a typical remote cold region, Iceland
Source: Rakesh Ramesh

Deliverables

The deliverables from the project are expected to be as follows:

- A Guidebook that provides:
- a map of the threats, challenges, and energy security risks to building clusters in cold regions
- the basic definition and framework for the energy resilience concept
- physiological/psychological research on the gaps in our understanding of human resilience
- a building cluster map, and energy efficiency and resilience regulations for energy-efficient and resilient buildings
- guidelines on updating building codes for cold regions
- the identification of new methodologies to be adopted in building design for resilience in cold regions
- a description of electricity and heat production, and cooling
- a description of common obstacles, such as availability of building-related products, costs, supply chain challenges, and skilled labor
- recommendations for new solutions in energy system design
- a description and discussion of case studies
- A project summary report covering outcomes, guidelines, and best practices
- Scientific publications, conferences, webinars, workshops and summer schools, newsletters, website and social media dissemination

Progress

Three preparatory meetings were held during 2024 to fully develop the project approach. The project was approved at the EBC Executive Committee meeting held in June 2024.

Meetings

The following preparatory meetings before the project working phase were held in 2024:

- the first meeting in Chicago, Illinois, USA, in January 2024,
- the second meeting in Stockholm, Sweden, and Helsinki, Finland, in April 2024, and
- the third meeting in Akureyri, Iceland, in October 2024.

Project duration
2025–2028

Co-Operating Agents
Dr Hassam ur Rehman, VTT Technical Research Centre of Finland, Finland
Dr Alexander Zhivov, US Army Engineer Research and Development Center, USA

Participating countries (provisional)
Finland, Canada, P.R. China, Denmark, Japan, Norway, Sweden, UK, USA

Further information
www.iea-ebc.org

Ongoing Research Projects

SMART MATERIALS FOR ENERGY-EFFICIENT HEATING, COOLING AND IAQ CONTROL IN RESIDENTIAL BUILDINGS

(EBC ANNEX 92)

OPEN BIM FOR ENERGY EFFICIENT BUILDINGS

(EBC ANNEX 91)

LOW CARBON, HIGH COMFORT INTEGRATED LIGHTING

(EBC ANNEX 90)

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)

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)

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

EBC ANNEX 92

The rapid increase in the use of heating, ventilation, and air-conditioning (HVAC) systems in buildings worldwide has become a major driver of global energy demand. Heating alone accounts for approximately 45% of buildings-related emissions, with more than 55% of its final energy consumption still reliant on fossil fuels. Meanwhile, cooling primarily relies on the compression of volatile fluorinated gases. The core technology of such mechanical cooling has seen little change since its invention over a century ago. However, these traditional systems are neither energy-efficient nor environmentally friendly. Combined, space and process heating and cooling constitute the largest contributors to global energy use and greenhouse gas emissions. Transforming heating and cooling technologies through the use of innovative functional materials and advanced physical-chemical processes offers a significant opportunity to reduce HVAC energy demand, enhance indoor air quality (IAQ), and mitigate negative environmental and climate impacts.

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.

The kick-off event of EBC Annex 92, held in Syracuse, USA, in May 2024.
Source: Menghao Qin

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 specific 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, with selection criteria to be set up for different applications;
- develop further and 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 vapour compression refrigeration;
- develop innovative air purification systems using new sorbent materials. Both the active system and passive approaches are being 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 modelling and optimization is also being 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:

- Project summary report targeting researchers and professionals, HVAC and materials manufacturers, building designers and consultants, policy, regulatory and standards bodies.
- An overview report on methods and tools for selecting smart materials for energy-efficient heating, cooling, IAQ control, and thermal energy storage strategies.
- A collection of case studies and demonstrations of energy-efficient heating, cooling air cleaning, and thermal energy storage using smart materials.
- A collection of scientific publications in high-level journals.

Progress

The experts from the project have developed a new kind of adsorbent based on MOFs for the selective and efficient capture of formaldehyde in indoor environments. These new MOF sorbents exhibit an exceptionally high adsorption capacity, even in high humidity, and can be easily regenerated in a very energy-efficient manner, i.e. water soaking at room temperature. The study confirms that the newly developed MOF (Al-3.5-PDA) is among the best sorbents for energy-efficient control of indoor air pollutants. The results were published in Nature Communications in November 2024 (article number: 9456).

Meetings

The kick-off event of EBC Annex 92 was held at Syracuse University, USA, in May 2024.

Project duration
2024–2028

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

Participating countries
Belgium, Canada, P.R. China, Denmark, France, Germany, Republic of Korea, Portugal, Spain, Sweden, UK, 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.

Objectives

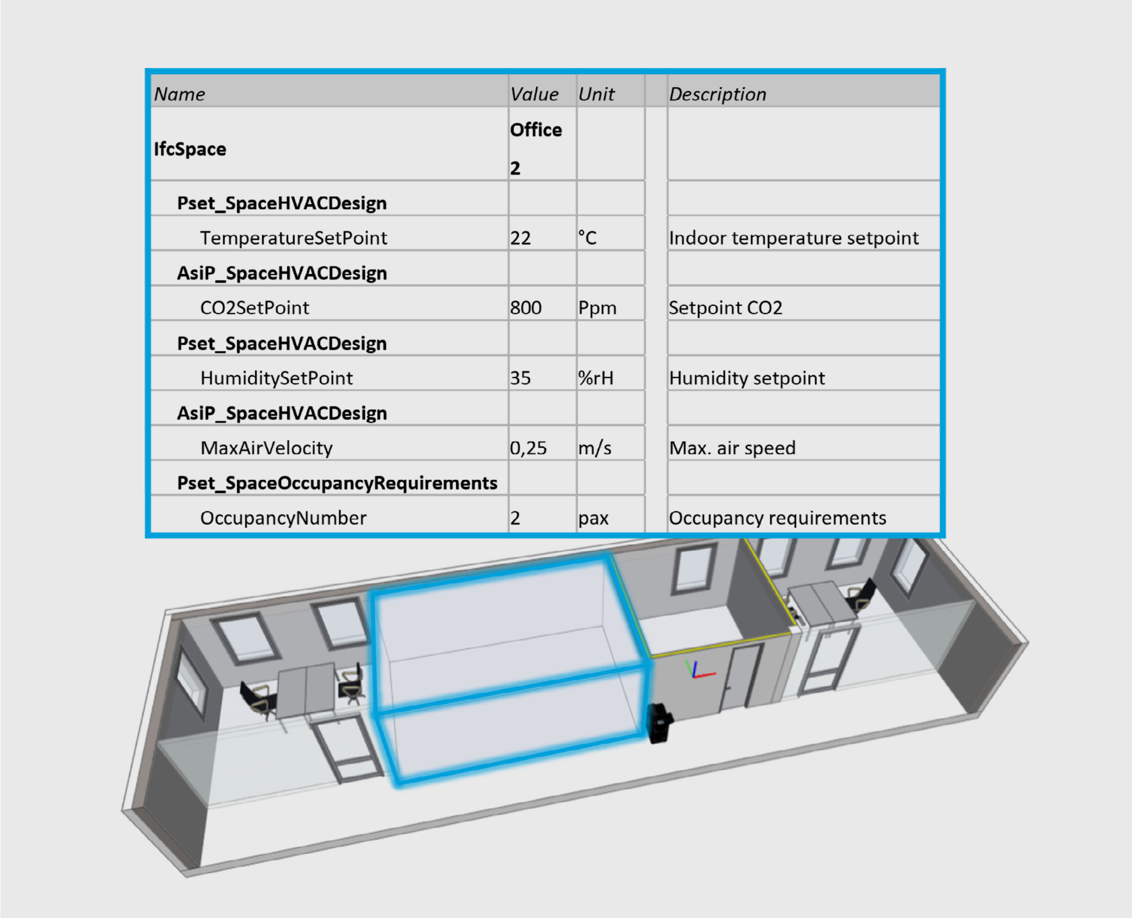
The primary objective of the project is to advance the integration of energy efficiency within Open BIM processes by fostering collaboration among stakeholders, enhancing interoperability, and addressing existing technological barriers. By leveraging standardized formats like IFC and innovative workflows, the project aims to enable seamless collaboration and improve energy-efficient building design and operations across diverse scales and stakeholders. The project objectives are as follows:

- integrating energy efficiency into open BIM by making energy efficiency assessment and optimization become an integral feature of open BIM;
- developing interoperable Open BIM processes: enable seamless stakeholder collaboration and data models while promoting seamless cooperation among all project stakeholders;
- advancing the interoperability and harmonization of open BIM processes and data models both on national and international level.

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.



Name	Value	Unit	Description
IfcSpace	**Office 2**		
Pset_SpaceHVACDesign			
TemperatureSetPoint	22	°C	Indoor temperature setpoint
AsiP_SpaceHVACDesign			
CO2SetPoint	800	Ppm	Setpoint CO2
Pset_SpaceHVACDesign			
HumiditySetPoint	35	%rH	Humidity setpoint
AsiP_SpaceHVACDesign			
MaxAirVelocity	0,25	m/s	Max. air speed
Pset_SpaceOccupancyRequirements			
OccupancyNumber	2	pax	Occupancy requirements

BIM Property definitions for energy efficient HVAC operation
Source: Austrian Institute of Technology GmbH

Progress

The project working phase started in January 2024. The project website was created as the primary portal for information sharing and collaboration among participants, and this has been populated with updates and research results. The project research topics are grouped in four categories:

- Data and ontologies
- Processes in design and operation
- Processes in operation and control
- Tools and algorithms – design + operations and control

Within these categories, research groups have formed to identify common collaboration goals. This process took place in the first half of 2024.

The libraries for BIM data (e.g. IFC Properties) have been identified in multiple research activities, and it was decided to take a broader look outside of Open BIM towards other ontologies, including historic buildings, smart homes and circular construction. The goal of establishing common data exchange formats and common data models is now underway.

The project partner, buildingSMART, has set up a Use Case Management Platform, which is capable of maintaining data models and especially IFC Property definitions, which can then be shared globally. This platform is used by various projects, since it provides machine readable interfaces (APIs) for using the definitions in projects.

Meetings

The following meetings were held in 2024:

- The Open BIM Kick-Off in Vienna, Austria, in January 2024,
- The Plenary Meeting in Cardiff, UK, in August 2024.

Project duration
2024–2026

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

Participating countries
Australia, Austria, Brazil, Canada, Denmark, Germany, Ireland, Italy, Sweden, UK

Further information
www.iea-ebc.org

Low Carbon, High Comfort Integrated Lighting

EBC ANNEX 90 – SHC TASK 70

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, lighting is of comparable magnitude at about 15% of electrical energy use to other existing or new end uses, for example electric vehicles and heat pumps. With rising electricity prices and increasingly directly-taxed GHG emissions, lighting also contributes to 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

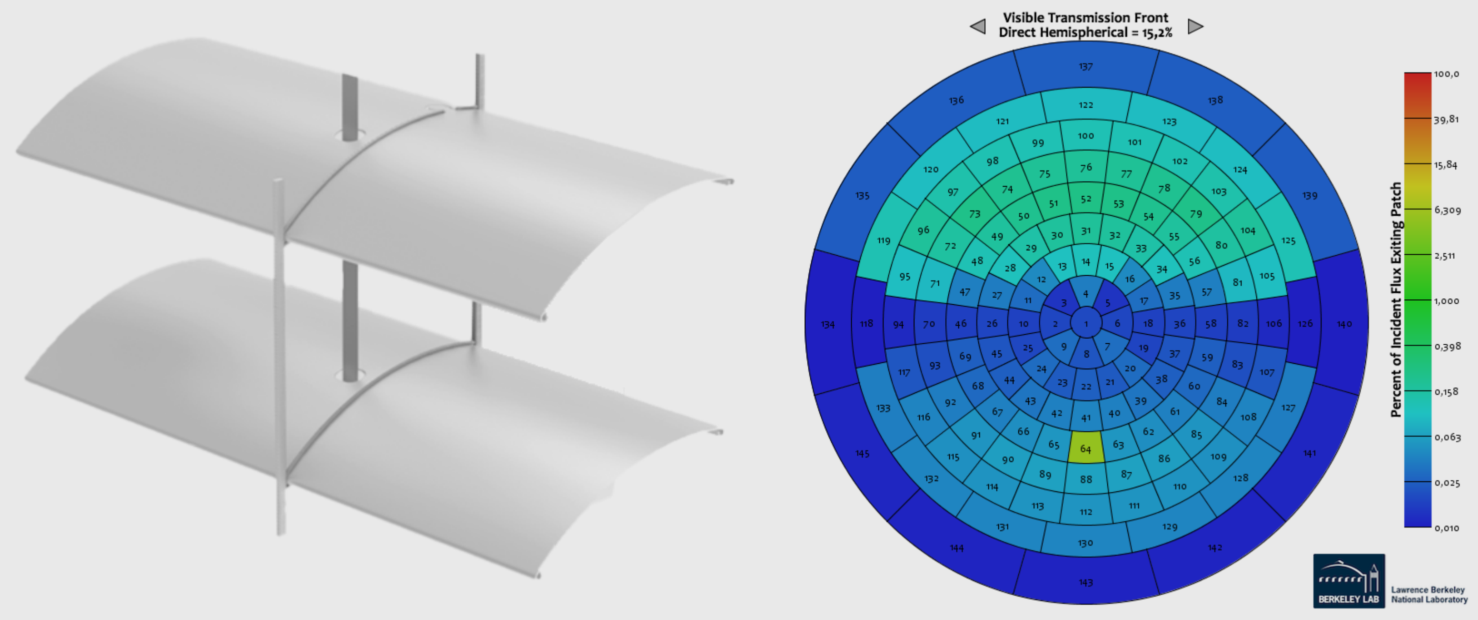
This international research project is a collaborative research activity with the IEA Solar Heating and Cooling (SHC) Programme: The aim of EBC Annex 90/SHC Task 70 is to identify and support implementing the potentials of lighting (electric lighting, and daylighting and passive solar through façades) 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 specific 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.

Deliverables

The following documents are planned to be published, supported by 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.



An example of complex fenestration systems (left, exterior venetian blinds, image © HELLA Sonnen- und Wetterschutztechnik GmbH) and false colour representation of BSDF in Klems discretization (right).
Source: EBC Annex 90/SHC Task 70

Progress

Link into building design processes via standardization: The revision of 'ISO/CIE 10916 Calculation of the impact of daylight utilization' has concluded, and was published in October 2024. This standard introduces a simple, hourly energy calculation and rating method for lighting, applying IEA TCP research outcomes. Additionally, the project experts have launched a standardization effort on BSDF Generation for complex fenestration systems. With shading and daylighting devices becoming crucial for managing overheating while ensuring occupant comfort, their representation is often unspecified. BSDFs provide an efficient solution, but current standardized methods for these complex systems are lacking, hindering objective evaluation of energy performance. The ISO/CIE AWI 25176 project aims to specify procedures for BSDF characterization of complex fenestration systems and generate tabular BSDF data sets for use in ISO 10916 and simulation tools, building strongly upon SHC/EBC TCP work as well.

Better (day)lighting with lower environmental impact – first case studies: Daylighting and lighting systems in buildings are being evaluated for quality and environmental impact. These assessments often reveal the need to balance quality with sustainability. In Turin, Italy, four offices were analyzed for supporting circadian rhythms through daylighting and electric lighting. While good daylighting design met circadian needs near windows, full circadian performance with electric lighting doubled energy use, raising environmental concerns. In Eslöv, Sweden, a sports hall renovation examined three daylighting retrofits: sidelight windows, skylights, and tubular daylight devices. Skylights performed best, but were more expensive, while tubular devices were more cost-effective due to lower maintenance. Over 30 years, all retrofits proved more sustainable than the current setup, with better lighting quality and financial payback within 24 to 28 years. These studies highlight the potential of thoughtful daylighting design to enhance quality and sustainability. More case studies will follow.

Meetings

The following meetings were held in 2024:
- 3rd Task Meeting was held in Berkeley, USA, in April 2024, and
- 4th Task Meeting was held in Lyngby, Denmark, in October 2024.

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

Further information
www.iea-ebc.org

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 buildings and real estate sector at various scales and perspectives and identifying critical GHG reduction pathways and actions;
- establish Paris-goal compatible assessment frameworks and evaluate 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;
- 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

Over the past year, the project has significantly advanced its collaborative research programme by engaging a diverse network of international experts and stakeholders. The project progressed through structured bi-weekly coordination meetings that emphasized reporting progress, addressing challenges, and planning future activities. Continuous interaction across project subtasks ensured enhanced synergy within the project.

The project focused on developing comprehensive guidelines and frameworks to facilitate the implementation of NetZ-WLC strategies. This effort included extensive literature reviews and policy analyses to align with global net-zero targets and GHG reduction

EBC Annex 89 in-person 3rd Expert Meeting, held in Melbourne, Australia, in November 2024. Source: DBI24

strategies. Rich discussions during expert meetings and workshops helped refine methodologies and share best practices for lifecycle assessments, aiming to standardize approaches across different regulatory environments.

The project also dedicated significant efforts to identifying and refining tools that enable the practical implementation of NetZ-WLC strategies. This included categorizing existing tools and developing new ones, supported by surveys and discussions to ensure their effectiveness and broader application.

In addition to technical advancements, the project emphasized dissemination and stakeholder engagement. It hosted international conferences and workshops, including significant events in Berlin, Germany, and Melbourne, Australia, to discuss ongoing challenges and to adjust its strategies. These forums, such as WSBE 24 and DBI24, were instrumental in facilitating knowledge exchange among policymakers, industry leaders, and researchers, shaping the project's direction and enhancing its policy relevance.
Furthermore, the project strengthened its digital presence to reach a broader audience and maintain engagement with global stakeholders through a public website and a LinkedIn group. A highlight of the year was co-hosting a COP29 event in Baku, Azerbaijan, during which the project leaders launched a global call to action to commit the built environment sector to NetZ-WLC. This initiative underscored the critical role of the buildings sector in meeting the Paris Agreement's climate targets, attracting support from over 106 researchers and 25 stakeholders.

Overall, the project activities have significantly contributed to the global dialogue and action towards achieving a sustainable and resilient built environment. The ongoing research and collaborative efforts were expected to pave the way for innovative strategies that others can adopt towards sustainability.

Meetings

The following meetings were held in 2024:

- 2nd Expert Meeting in Berlin, Germany in June 2024, and
- 3rd Expert Meeting in Melbourne, Australia in November 2024.

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, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Türkiye, UK, USA
Observers: Egypt, Greece, Hungary, Slovenia

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 reduce energy use for space heating/cooling and domestic hot water and efficiently utilising renewable energies. However, inappropriate design and the installation of heat pumps (for instance, capacity determined without following a sizing procedure, inappropriate operating temperatures, and so on) might negatively affect the energy use of this technology and the system payback period might become longer than its lifetime.

So, transparent technological information on heat pumps should be exchanged between HVAC designers/ building owners and heat pump manufacturers. However, different viewpoints and technical approaches have resulted in inconsistencies that represent an unresolved gap in product and building performance analyses that has limited the potential of the heat pump technology as an integrated part of efficient buildings. It can be said the problem may not be purely technological, but a sort of blind spot in existing standards and regulations. Heat pump performance depends highly on several parameters that define operating conditions. However, it is difficult to identify and foresee their influences with simple tests and calculation methods. For example, energy efficiency of heat pumps under low partial load conditions (i.e., heat pumps operated inevitably much below their maximum capacity) is not appropriately represented by existing testing standards and calculation methods for building energy codes. In response, this project has been established and comprises the following five subtasks:

- State-of-the-art for testing methods, monitoring methods and database, energy calculation methods and design guidelines
- Testing methods for heat pump products
- Monitoring methods and database
- Calculation methods of energy use by heat pump systems
- Design guidelines for HVAC system designers

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 planned 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

In 2024, the 'state of the art' report was published on the project website. This report contains four chapters on:

- testing methods (load-based test methods and current test methods). A representative result to clearly characterize the load-base test methods considered within the project when compared with current testing methods is shown in the figure opposite.
- monitoring methods and database on actual behaviour of heat pump systems
- energy calculation methods
- design guidelines for HVAC designers.

A two-day webinar on the outcomes from 'State of the Art' project task was held in October and November 2024. The webinar was delivered in collaboration with the IEA Heat Pumping Technologies Technology Collaboration Programme (HPT TCP).

Meetings

The following meetings were held during 2024:

- The 4th Series of Meetings in May and June 2024, and
- The 5th Series of Meetings in August and October 2024.

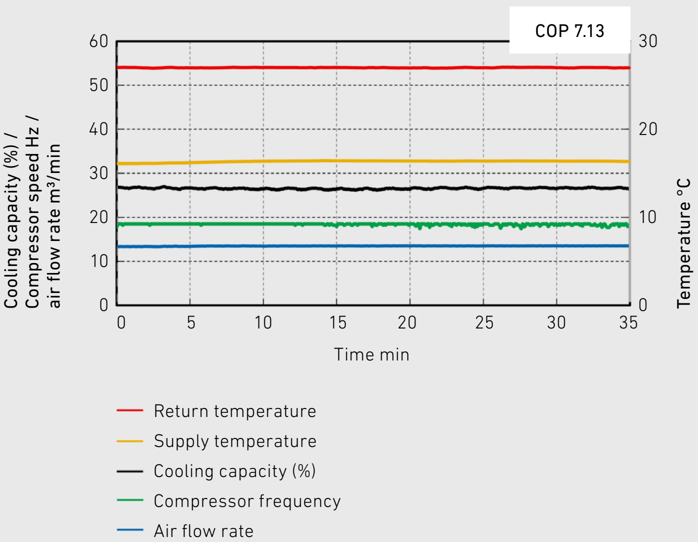
Project duration
2022–2027

Operating Agent
Takao Sawachi, Building Research Institute, Japan

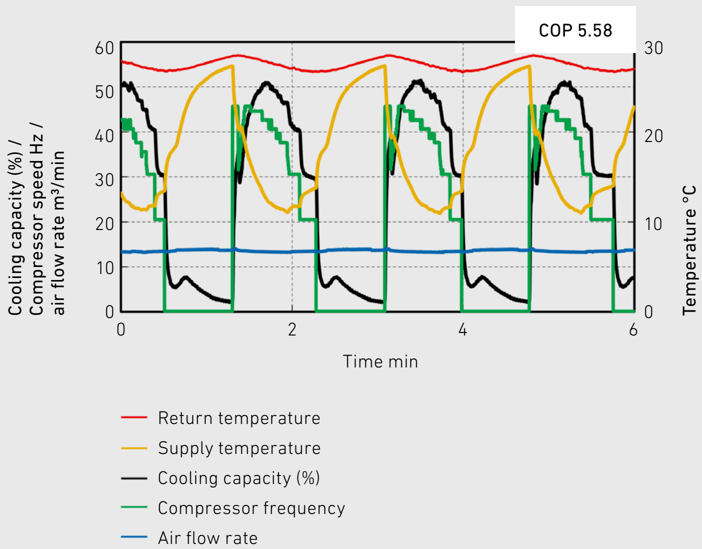
Participating countries
Australia, Brazil, Canada, P. R. China, Germany, Italy, Japan, the Netherlands
Observers: Philippines

Further information
www.iea-ebc.org

1)
Condition of tested room air conditioners and COP by a curret test method



2)
Condition of tested room air conditioners and COP by a new load-based test method



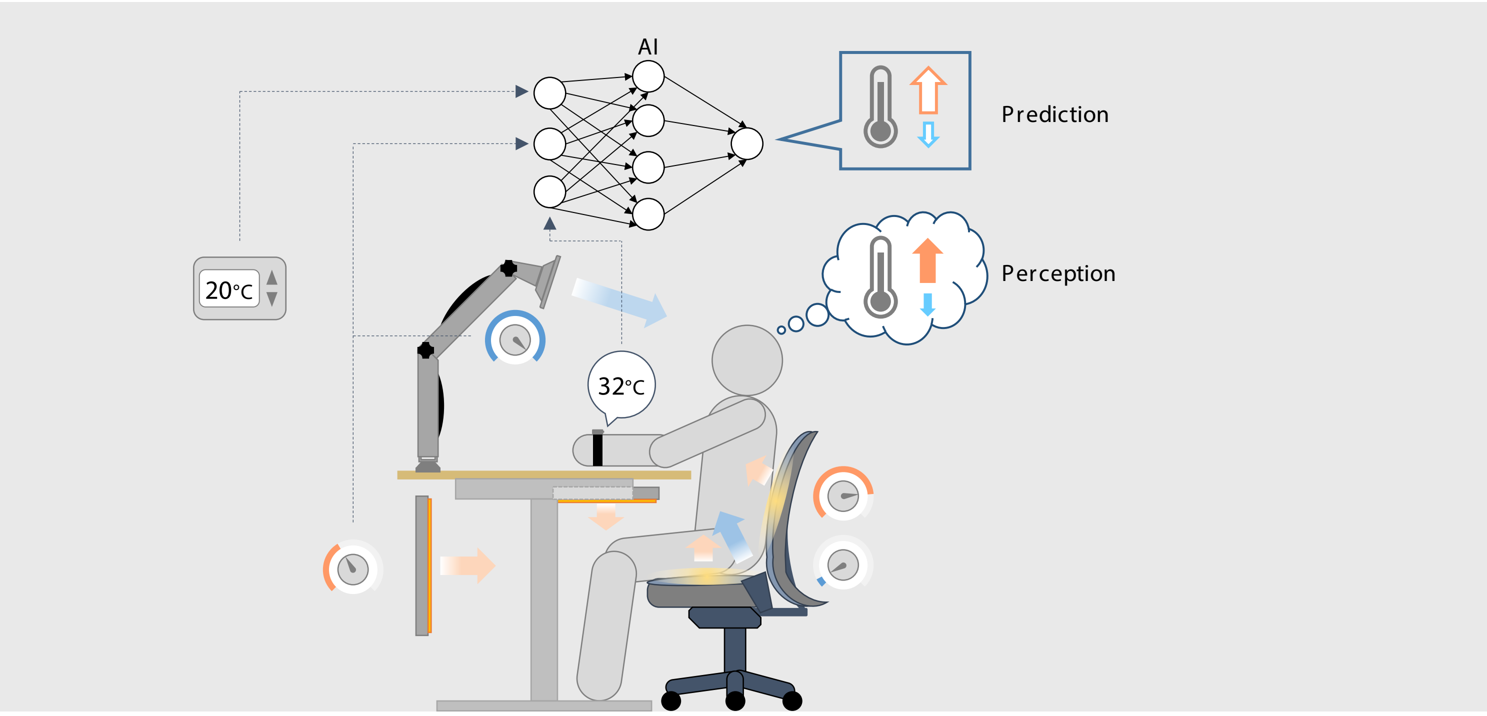
Comparison of coefficient of performance (COP) and status of equipment (room air conditioner) during a current test method and a newly developed load-based test method (Giannetti et al.)
Source: EBC Annex 88

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 preferences 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 including 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 is in 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 personalised environmental control system (PECS) and its control
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 planned 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 second year of its three-year working phase in 2024, which will be followed by a one-year reporting phase. The definition of PECS was developed by the project as 'a system that can provide individually controlled thermal, air quality, acoustic or luminous environments in the immediate surroundings of an occupant, without affecting directly the entire space and other occupants' environment'.

In the past year, the project participants were working on a very comprehensive and thorough review activity to collect the existing knowledge related to almost all aspects of PECS. This activity is formulated in a such a way that all subtasks of the project benefit from it. This allows the project team to identify the state-of-the-art in detail and to guide the rest of the work during the project to fulfil its objectives. Initial results from the created review tables are available, providing an overview of the previous studies that used PECS. Seven review articles are in preparation based on these review tables.

There has been ongoing work to develop a uniform terminology to be used in the project and on developing an updated version of the Technology Readiness Level assessment collection to better capture the current market status and status regarding the standards. Further, two web domains related to PECS were acquired for dissemination of the project results after its completion. These domains are 'personalizedenvironmentalcontrolsystems.org', and 'thepecs.org'. The project was active in dissemination and held several workshops, webinars, and seminars in international conferences that were all well-attended.

Meetings

The following meetings were held during 2024:

- The third meeting of the working phase was held in Singapore in a hybrid format in April 2024.
- The fourth meeting of the working phase was held in Torino, Italy in a hybrid format in September 2024.

Project duration
2022–2026

Operating Agent
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, Republic of Korea, Singapore, Sweden, Switzerland, Türkiye, UK, 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.

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;
- 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.

In-person participants at the 7th Working meeting, held in Dublin, Ireland, in October 2024.
Source: EBC Annex 86

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

In 2024, the working phase of this project was finished. The project hosted two in-person working phase expert meetings with hybrid facilities in Singapore and Dublin, Ireland, connected to the AIVC 2024 workshop and the AIVC 2024 conference. The focus of all subtasks teams was on finishing the work programme and preparing for reporting.

Notably, the 'Harm Intensity' metric was applied to existing guideline values to establish and discuss existing harm budgets. Statistical analysis of the data included in the IAQ database was carried out providing typical input values for design and simulation. The common exercises testing the implications of their work were wrapped up. This experience was also translated into potential real-world applications and products. A systematic literature review on smart ventilation was being prepared for publication. The intermediate results and activities in the project were reported in a series of sessions at the AIVC conferences and are being disseminated through collaboration with AIVC.

Meetings

The following hybrid expert meetings were held during 2024:

- 6th Working meeting, Singapore, in April 2024, and
- 7th Working meeting, Dublin, Ireland, in October 2024.

Project duration
2020–2025

Operating Agent
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, Switzerland, Türkiye, UK, USA
Observers: Chile, Greece

Further information
www.iea-ebc.org

Indirect Evaporative Cooling

EBC ANNEX 85

Buildings account for almost one-third of total energy use, and over 10% of building energy use 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 demands and greenhouse gas emissions. Although over 85% of cooling worldwide is achieved by mechanical vapour compression refrigeration, more than 40% of cooling could be provided by evaporative cooling, especially in dry climate zones.

Thus, this project is studying the feasibility of indirect evaporative cooling (IEC) technologies and is providing a roadmap about how to use evaporative cooling technologies in various dry climate zones. The target audiences include 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.

Objectives

The project objectives are as follows:

- Investigate IEC systems, as well as cooling towers, including cost, space, maintaining, and environment impacts, to find out the limitations of using IEC worldwide.
- Conduct field studies of existing IEC systems applied in different climates to build a field-testing database.
- Develop a general theoretical analysis method for IEC processes, to guide the design of different IEC systems.
- Evaluate the water and electricity use of IEC processes.
- 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 for different types of buildings under different dry climates and water resource conditions.

Deliverables

- The planned main deliverables of the project include:
- a book, provisionally entitled 'The Indirect Evaporative Cooling Source Book', including all of the outputs of the project including investigation and analysis of real cases, feasibility analysis, guidance and modelling;
- a simulation tool for various types of IEC technologies for different types of buildings and dry climate zones including the basic modelling of different IEC/direct evaporative cooling (DEC), from basic understanding and formulae used for heat and mass transfer processes inside, and a unified nomenclature.

Progress

During 2024, work on the final reporting continued as follows:

- A report on feasibility analysis of IEC/DEC presents using the indicator methods to give a macro feasibility first for different regions of the world and then for different specific IEC/DEC processes, to give the performance analysis.
- A report on performance analysis of IEC/DEC includes detailed performance of equipment, the heat and mass transfer performance of paddings and heat exchangers, electricity cost, the real testing performance, optimization methods, and water use.
- A report on simulation analysis presents the simulation of different kinds of IEC/DEC processes, finally to form a group of simulation procedures, or further to form a simulation tool, with case studies for using the simulation tool or procedures for simulating an IEC/DEC system.
- A report on the collection of cases presents real cases from different countries to show the current applications of IEC/DEC technologies, giving the basic information of the projects described, as well

Some of the participants of the EBC Annex 85 workshop held at Université de Reims Champagne, Reims, France, in October 2024
Source: EBC Annex 85

as the real testing performance of the system and processes, including the electricity use performance, water use performance, and any existing problems.

Meetings

Meetings were held in 2024 as follows:

- 20th Meeting Online and workshop in person in May 2024, Liege, Belgium.
- 21st Meeting Online and workshop in person in September and October 2024, Reims, France.

Project duration
2020–2025

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

Participating countries
Belgium, P.R. China, Denmark, France, Italy, Spain, Türkiye, USA
Observers: Algeria, Egypt

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 considering them instead 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

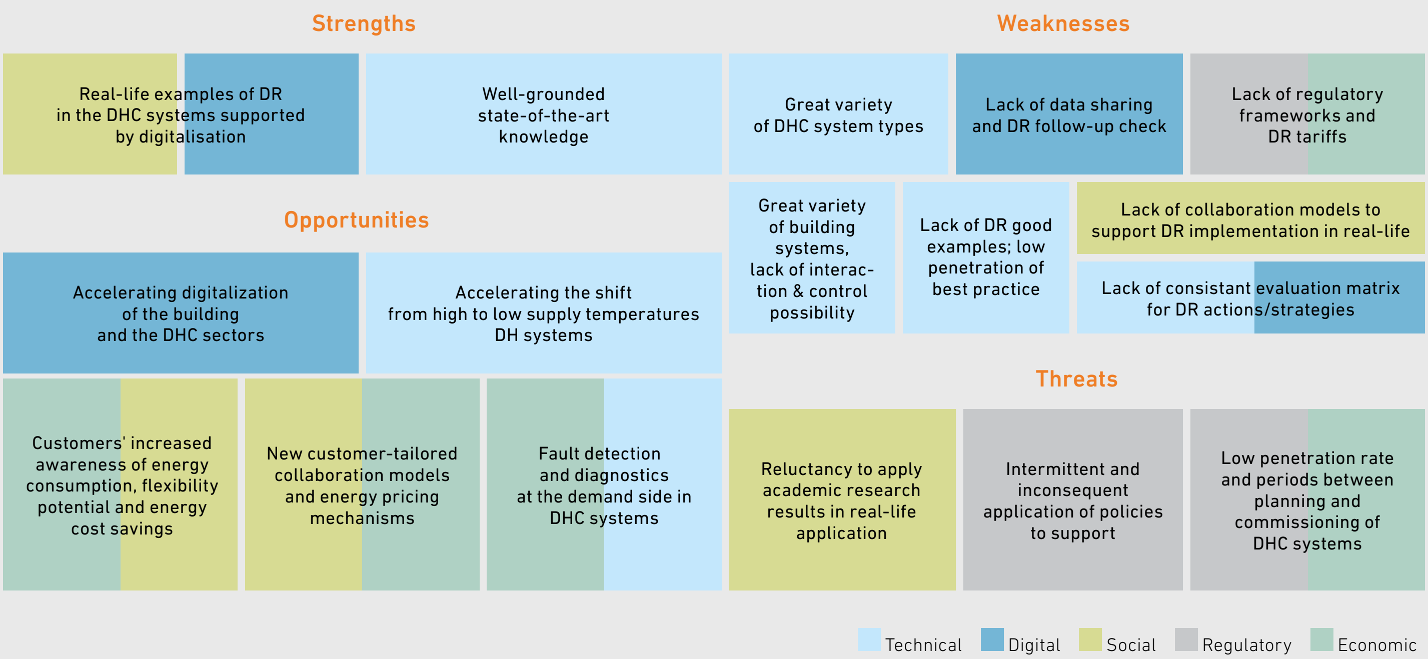
The planned project outcomes are as follows:

- 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 2024, the project published a valuable contribution in Energy Journal describing the 'strengths–weakness–opportunities–threats' (SWOT) analysis of demand-side management in DHC networks. The work concluded that the application of the demand response (DR) concept has progressed from theoretical exploration to real-world implementation. Although weaknesses still dominate—accounting for seven out of 17 identified

DEMAND RESPONSE IN DISTRICT HEATING AND COOLING SYSTEMS



The identified 'strengths–weakness–opportunities–threats' analysis elements
Source: 10.1016/j.segy.2024.100135

elements—they are no longer tied to technological limitations, but rather to social, economic, and regulatory challenges. The DR demonstrations revealed that while technological solutions are available, the diverse range of building installations and the varied configurations and generations of DHC systems complicate the replication of solutions across different systems. Interviews with DHC professionals, theoretical studies, and real-world demonstrations have confirmed that DR has the potential to address both current and future challenges in DHC operations. These include reducing supply temperatures today and phasing out fossil fuel peak boilers, while increasing the share of future renewable energy sources. However, most real-world demonstrations remain part of research initiatives, in which optimistic modeling is tested against practical, often unpredictable, conditions not always fully understood by academia. Implementing this concept demands more advanced control mechanisms, data exchange/storage, analytical solutions, engagement with multiple stakeholders, and competition with centralized thermal energy storage systems.

Furthermore, the SWOT analysis underscored the need to adjust the regulatory framework to enable DHC operators to develop new business models and DR tariffs. These adjustments would encourage customers to provide system flexibility without compromising their comfort, and daily routines, or exacerbating energy poverty. Finally, successfully implementing DR in DHC systems necessitates simultaneous top-down (from utilities to customers) and bottom-up (from customers to utilities) approaches for effective information management and knowledge/experience transfer.

Meetings

The following meetings were held in 2024:

- The 6th working meeting took place in Graz, Austria, in April 2024, and
- The 7th working meeting took place in Aalborg, Denmark, in September 2024.

Project duration
2020–2025

Operating Agent
Anna Marszal-Pomianowska, Aalborg University, Denmark

Participating countries
Austria, Belgium, Denmark, Germany, Italy, Netherlands, Singapore, Spain, Sweden, Switzerland, Türkiye, UK

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 centred 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

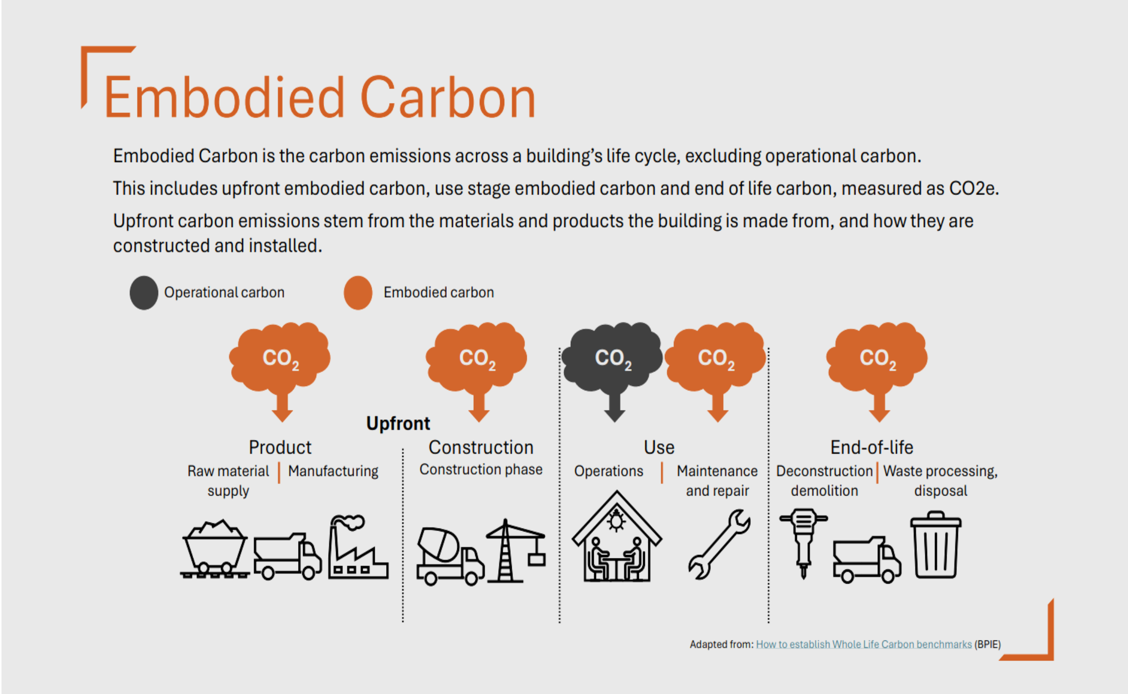
The project is undertaking three major activities to achieve these objectives, which are listed below:

- Analysis and technical reports: The project is conducting surveys on building energy 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 participants 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. It is disseminating its findings through the EBC website, conference papers, and newsletters.

Progress

The project released a report, 'Survey on New Technology Integration in Building Energy Codes,' in January 2024. This is a survey on how new energy efficiency technologies are integrated into building energy codes around the world. Also in January, the project published a Nature World View Article, titled 'Coping with climate change could be a matter of what building you're in,' which focuses on resilience in building energy codes. The article emphasizes the critical role of energy codes, particularly in promoting efficiency, and in increasing passive survivability during extreme weather events.

Over the past year, the project has been advancing four new topical reports. These reports cover a range of areas including embodied carbon in standards, resilience to overheating, a streamlined approach for building code development in emerging economies, and an in-depth impact assessment of building energy codes. This impact assessment utilizes the Global Change Assessment Model (GCAM) to evaluate how building energy efficiency policies affect energy consumption and emissions.



Embodied carbon impact
Source: EBC Working Group on Building Energy Codes

The project hosted a webinar titled 'A universal method of comparing building energy codes,' in June 2024. This webinar presented the IEA's new database on global building energy codes, allowing attendees to learn about the database and provide feedback on its methodology. It shared preliminary results and facilitated discussions on comparing and improving building energy codes internationally.

The project held its sixth Annual Symposium in November 2024, hosted in Melbourne, Australia. This was also a hybrid online event with two technical sessions focusing on energy and climate resilience, and embodied carbon in building energy codes. While in Melbourne in November, the project also participated in the Decarbonizing Building Industry (DBI) International Conference, giving a keynote presentation, as well as giving two additional presentations on the topics of flexible building energy codes for hot climates and future trends in building emissions.

Additionally, the project participated in the Buildings and Climate Global Forum, held in Paris, France, in March 2024. It also presented a poster titled, 'Building Energy Decarbonization: The Importance of Hot Climates', at the 2024 American Geophysical Union annual meeting held in Washington D.C., USA, in December 2024. Further, it was involved in the EBC Annex 89 Workshop on decarbonizing buildings. Finally, the group facilitated multiple discussions throughout the year with stakeholders and organizations related to building energy codes.

Meetings

In 2024, the project held or participated in the following meetings:

- Buildings and Climate Global Forum, held in Paris, France, in March 2024,
- Webinar titled 'A universal method of comparing building energy codes', in June 2024,
- Sixth Annual EBC Building Energy Codes Working Group Symposium, held in Melbourne, Australia, in November 2024,
- Decarbonizing Building Industry International Conference held in Melbourne, Australia, in November 2024,
- EBC Annex 89 Workshop on Decarbonizing Buildings, in November 2024, and
- American Geophysical Union Annual Meeting, held in Washington D.C., USA, in December 2024.

Project duration
2018–2026

Operating Agent
Meredydd Evans, Pacific Northwest National Laboratory, USA

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

Further information
www.iea-ebc.org

Positive Energy Districts

EBC ANNEX 83

The concept of a positive energy district (PED) describes an urban area within a city that is capable of generating more energy than is consumed, while being agile and flexible enough to respond to energy market price variations. While the definition of a PED must include an evaluation of an annual net energy balance, there are further requirements that need to be met: 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, and 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, as well as 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,
- case studies on PEDs and related technologies, and
- a book on "Positive Energy Districts: Fundamentals, Assessment Methodologies, Modeling and Research Gaps".

Progress

Significant advancement on different activities within the project took place in 2024 as described below, with the finalization of most research activities and the start of the reporting phase. Regarding the PED definition and assessment methods, various methodologies were tested to evaluate their benefits and limitations. Each method has its strengths and weaknesses, with a trade-off between simplicity and comprehensive assessment. A simple, universal method may not capture diverse local contexts, while a more detailed approach can increase complexity, limiting widespread application. The assessment was expanded to include hourly energy data, different weighting factors, and various computational methods.

Participants at the EBC Annex 83 meeting held in Pamplona, Spain, in April 2024
Source: EBC Annex 83

A data management and organization structure for modelling PEDs is also being finalized: Ontologies for simulated and monitored data are being developed for applications in PEDs. Datasets have a specific multidisciplinary nature, which makes it difficult 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 being tested and finalized following a state of the art technological and data assessment of more than 50 international case-studies.

Methodologies and frameworks for assessing PEDs from a sustainability perspective have been developed, covering environmental, economic, and social aspects. These frameworks aim to quantify PED sustainability performance and harmonize existing assessment methods. They were tested on various case studies to draw lessons and explore potential applications for scaling-up PEDs.

The PED database is growing as a joint activity of EBC Annex 83, and the European Union projects PEDEU NET and JPI Urban Europe to map currently existing PEDs, and as a cornerstone for both research and practitioners to learn more about PEDs. The inclusion of more PEDs in the database is continuing in a coordinated manner, by reporting information on the location, energy balance, publications, and further information on design methodologies and tools used for the design. Around 100 PEDs are currently mapped in the database.

PED guidelines were nearing completion in the past year with more than 80 documents analysed and deployed into brief design suggestions for practitioners, exploring all main topics in the project, including definitions, design, modelling and simulation, sustainability and governance. Among the dissemination activities, the Blended Intensive Programme (BIP) on PEDs, organized by Dalarna University and co-hosted by EBC Annex 83, took place in September 2024. Dalarna University offered this new BIP in PEDs for graduate exchange students, with around twenty participants.

The third 'IEA EBC Annex 83 Summer School for PhD students' was held in Graz, Austria, in July 2024. In partnership with the European Union EXCESS project, EBC Annex 83 developed the summer school titled 'Economics and Replication of PEDs'. The aim was to provide insights into the case study implementation of PEDs from an integrated technical-economic perspective.

Meetings

The following meetings were held in 2024:

- 8th Working Meeting, hosted by CENER, Pamplona, Spain, in April 2024.
- 9th Working Meeting, hosted by Concordia University, Montreal, Canada, in September 2024.

Project duration
2020–2025

Co-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, UK

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. Although the benefits of utilizing energy flexibility from the built environment are generally recognized, solutions that reflect diversity in building stocks, consumer behaviour, and market rules and regulations need to be developed for successful implementation.

The project work is 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

In 2024 the project was in the reporting phase.

The state-of-the-art methodologies and evaluations of energy flexibility at the building cluster level were summarized. Addressing energy flexibility at the building cluster level remained a challenge, with technical and non-technical barriers. Technical barriers for the early planning, design, and operation phases include the development of integrated modelling tools, control strategies addressing the building cluster or portfolio level, and developing quantitative methodologies and indicators. Dominant factors for energy flexibility are related to occupants, building characteristics, energy systems and storage, control systems, and external factors (e.g. weather and market).

The project teams investigated 'building-grid interaction signals', a generalization of 'price signals'. These signals must be aligned with the service objectives, e.g. load shifting versus load reduction. Characterizing energy flexibility involves characterizing and predicting the building load. In particular, the flexibility index and flexibility function were tested and improved.

The project highlighted the scarcity of field studies demonstrating energy flexibility at the building cluster or portfolio level. Two field implementations conducted within the project were described in the report: The use of a novel control algorithm (signal matrix model predictive control) to control space heating, domestic hot water heating, and a stationary battery, and the coordinated use of the different assets in a fully-equipped occupied building for flexibility. The project has advanced the state-of-the-art methods to characterize, model, and harness energy flexibility of building clusters and portfolios, enabling more demonstration projects to confirm the promising results of those two field studies.

The project also focused on policy and regulation, price-incentive structures, business models, and key factors influencing customers' willingness and possibilities to take part in energy demand flexibility. Countries with the most ambitious policies are the most advanced in deploying energy flexibility in commercial and residential buildings, which confirms that policies make a difference. However, the diffusion of energy flexibility for smaller consumers is still limited. Relatively few aggregators exist, which points to the need for more policies to create a market for flexibility. At the same time, there has been some diffusion of energy communities in a few countries, which points to the importance of considering alternative organizational approaches to activating the energy flexibility potential rather than only aggregators and market-based/commercial solutions. Finally, implicit demand response is relatively widespread in countries with dynamic pricing and time-of-use pricing for small consumers including households. This indicates that the potential of implicit demand response should not be ignored in policymaking. Price incentives for energy flexibility vary considerably between countries, with some having a considerable number of small customers using dynamic and/or time-of-use schemes and other countries with only a small number of customers using such schemes.

Many actors or stakeholders are involved in the energy system, and business models often include several stakeholders. Many value propositions were identified, including energy bill savings, new equipment/technology acquisition, financial incentives, and so on. Most of the stakeholder categories shared propositions related to societal or community contributions. This shows that not only financial benefits are in focus, but also broader societal gains. Dominating types of systems/equipment targeted by business models are HVAC (mainly heat pumps and air conditioners), followed by PV panels and electric batteries. The business models reviewed primarily focus on load shedding and load shifting. Regarding revenue sources, 30% of the cases involved a combination of subscription fees, equipment purchases, research funds, and professional service fees. This shows that revenues often depend on a multiplicity of sources.

The project site visit to the pit thermal energy storage in west Copenhagen, Denmark, in October 2024. Source: EBC Annex 82

Meetings

The following meetings were held in 2024:

- 6th working meeting in Prague, Czech Republic in May 2024,
- 7th working meeting in Copenhagen, Denmark in October 2024.

Project duration
2019–2025

Operating Agent
Rongling Li, Technical University of Denmark, Denmark

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 heating, ventilation and air-conditioning (HVAC) systems within buildings. 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 data capture, data management, data analysis, and data-driven decision implementation.

The project is accelerating 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 is also addressing 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 artificial intelligence (AI) themed competitions.

Objectives

The project objectives are to:

- provide knowledge, standards, protocols and procedures for low-cost high-quality data capture, sharing and use in buildings;
- develop a control-oriented building modelling framework for testing, development, and assessment of advanced HVAC control strategies;
- develop building energy efficiency software applications that can be used for reducing energy use in buildings;
- drive the adoption of 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

During 2024, the focus of the project was on consolidating research findings into the reports and a roadmap, and disseminating key findings through conferences and online resources.

An 'Open Data and Data Platforms' summary report was published and to inform readers about work relating to digital infrastructure and data management practices for modern commercial buildings. Its contents follow a guiding mnemonic: 'Making Data Shareable', 'Making Data Meaningful' and 'Making Data Accessible'. It provides a concise review of data infrastructure considerations, for anyone who is looking to implement a digitalisation uplift for their building.

A 'Model Predictive Control' summary report was nearing completion. This consolidates project work on both collecting data from real buildings that have deployed model predictive control (MPC), and benchmarking the performance of different MPC algorithms in virtual (digital twin) buildings. Different MPC modelling approaches are discussed, including analysis of the relative performance of MPC compared with reinforcement learning approaches.

A summary report on 'Applications and Services' was being prepared during 2024. It includes an extensive review and analysis of data-driven key performance indicators (KPIs) for building assessment. Survey research identified a degree of misalignment between available KPIs and stakeholder needs. Attempts to deploy various KPIs in case study buildings also identified difficulties obtaining relevant input data from building management systems (BMS).

The summary report also consolidates project work on fault detection and diagnosis (FDD) applications and building-to-grid (B2G) applications. Various market-available FDD software products were identified. Most of these are traditional rules-based services, not taking full advantage of emerging data-driven methods. Similarly, a review of KPIs for evaluating the performance of B2G services found a mismatch between available data and that needed for calculating KPIs. The project repository of case studies now reports on 18 buildings across 12 countries that have adopted some form of digital innovation.

Winners were announced for EBC Annex 81's ERA-net sponsored ADRENALIN (dAta-DRivEN smArt buiLdINgs) AI competitions. The two challenges were Building Energy Load Disaggregation and Smart Building HVAC Control.

Industry consultation was completed on the topic of barriers and solutions to the adoption of data-driven smart buildings. Consultation feedback, along with literature review findings, were compiled to identify policy options that government could employ to grow the industry for 'energy optimisation through digitalisation'. Recommendations, grouped under eight themes, are detailed in a report entitled 'Opportunities for Government Leadership on Data-Driven Smart Buildings'.

Dissemination activities of the project included:

- Joint webinar with the Netherlands Brains 4 Buildings project: The three-hour webinar included two expert panel discussion sessions and four industry case-study presentations on data-driven smart buildings. It was attended by 65 people including representatives from research and academia.
- International Conference on Building Data Acquisition, Ontology and Modelling (Hong Kong, April 2024): With expert speakers from EBC Annex 81, the conference attracted over 300 participants and over 10,000 views globally for the live broadcast.
- Policy Package presentations at IEA EBC Technical Morning (Utrecht, Netherlands) and AIRAH Big Data Forum (Brisbane, Australia).

Meetings

The following meetings were held in 2024:

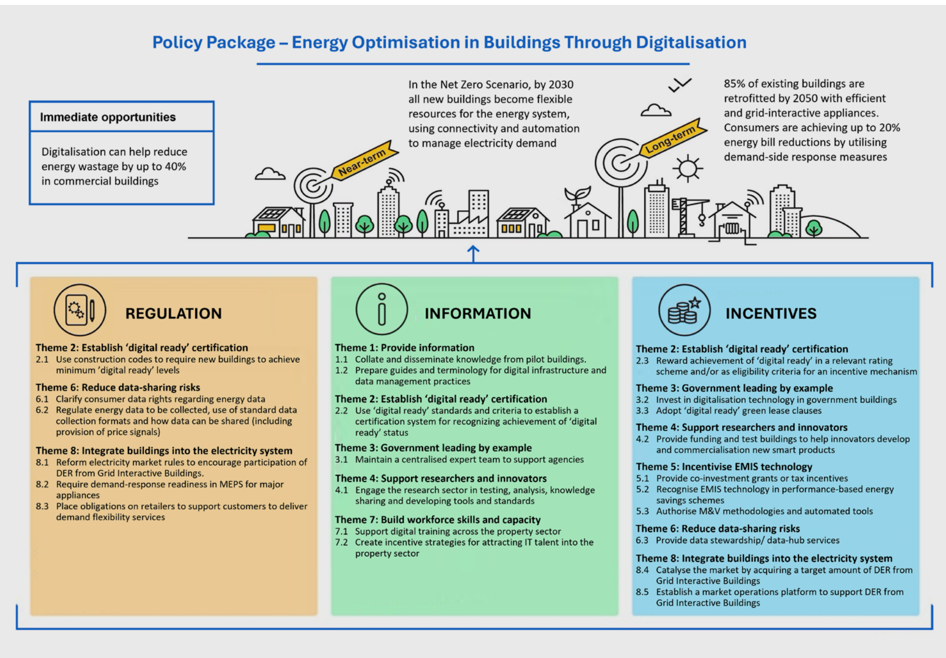
- Joint Research Webinar with the Netherlands Brains 4 Buildings project, in February 2024,
- International Conference on Building Data Acquisition, Ontology and Modelling, Hong Kong, in April 2024,
- Eighth (final) Expert Meeting in Prague, Czech Republic, in May 2024.

Project duration
2020–2024

Operating Agent
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, UK, USA

Further information
www.iea-ebc.org



EBC Annex 81 'Policy Package' for Increasing Adoption of Energy Optimisation in Buildings Through Digitalisation
Source: EBC Annex 81

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 outdoor air, which is often not the case.

There are increasing numbers of publications in many countries related to air cleaning and 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, well-being, and health. It is thus important to learn whether air cleaning can supplement ventilation by improving air quality, i.e. whether it can partly substitute the ventilation rates required by standards. Finally, the energy impact of using air cleaning as a supplement to ventilation needs to be estimated. This project focuses 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 EBC project has been established on the use of gas-phase air cleaning technologies.

Objectives

The project objectives are to:

- bring researchers and industry together to investigate the possible energy benefits of using gas phase air cleaners (partial substitution of ventilation with outdoor air);
- establish procedures for improving indoor air quality and reduced 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.

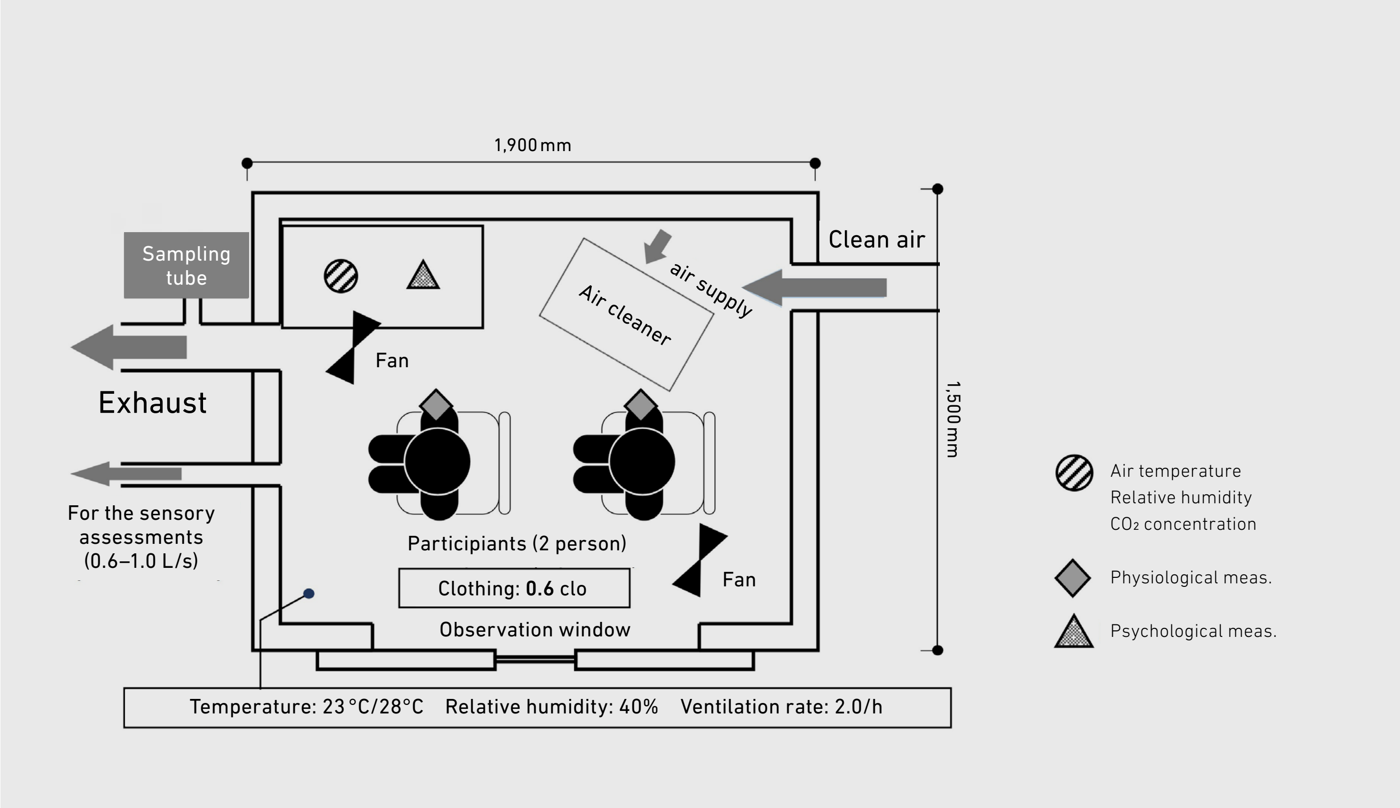
Deliverables

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 (partly substituting) required ventilation rates with gas-phase air cleaning,
- a test method for air cleaning technologies that includes chemical measurements and perceived air quality as measures of performance,
- a report on the long-term performance of air cleaning,
- a report on gas phase air cleaning technologies.

Progress

During 2024, a concept for partly substituting ventilation with gas-phase air cleaning technology has been established and published. The energy performance of gas-phase air cleaning technologies has been studied by three of the participating universities. These studies are mainly based on computer simulations, but without any data for systems in operation. For absorption air cleaning technologies, the pressure loss in the ventilation system will increase with an increase in fan energy. However, an air cleaner may partly substitute for outside air and reduce the energy for pre-heating/cooling and fan



Chamber plan and the measurement locations for the test by Akamatsu et. Al.
Source: N. Akamatsu et al., "Effects of a gas-phase air cleaner in removing human bioeffluents and improving perceived air quality," Build Environ, vol. 257, Jun. 2024, doi: 10.1016/j.buildenv.2024.111540.

energy. The energy performance was investigated further during 2024. A new metric has been established, clean air delivery rate divided by the energy used for heating, cooling and ventilation, i.e. CADR per kWh. This metric can also be calculated for a reference ventilation system, so it is possible to compare the energy performance of using an air cleaner compared to the energy used for increasing the airflow of a ventilation system with and/or without an energy recovery unit. The project is now analysing if using an air cleaner or increasing the amount of outside air is more energy efficient.

Several papers on the experimental studies of the test procedure were published in 2024. This included tests involving 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 now the basis for the work on a new test standard under ISO TC142. (The inquiry for a new work item, WI_TS23743, was issued by TC142 in 2024.) The plan is to develop an ISO Technical Specification, which is an official ISO document, that could later be developed into a standard; other organisations would use the test method before a standard is developed.

Drafting of the reports for the official project deliverables was completed ready for approval during 2024. Some of the reports are being jointly published with EBC Annex 5 'Air Infiltration and Ventilation Centre'. Several presentations about the project were also made at conferences and webinars.

Meeting

– The 12th Expert meeting was held in Singapore, Singapore in April 2024.

Project duration
2018–2025

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 45 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 occupant health in buildings is pivotal and emphasizes the significance for the AIVC's continuing 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 strategic advice and design guidance 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, through conferences and workshops, webinars, databases, social media, and a high visibility web presence.

Deliverables

- Events: the AIVC 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 2024, the AIVC focused its work mainly on 13 projects, the AIVC Industry Advisory Committee, the 44th AIVC Annual Conference, 'Retrofitting the Building Stock: Challenges and Opportunities for Indoor Environmental Quality', a workshop held in Singapore, 'Ventilation, IEQ and Sustainability', and eight 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', and EBC Annex 87 'Personalized Environmental Control Systems'.

The latest AIVC projects launched include the following:

- Definition on indoor environmental health, and
- Ventilative cooling and thermal comfort in national energy performance of buildings regulations.

The following previously launched projects continued during 2024:

- Measurement for exterior wall airtightness of high-rise buildings using stack effect/individual air conditioning and outdoor air entering through entrance doors,
- Designing building ventilation for epidemic and disaster preparedness,
- The European Union Energy Performance of Buildings Directive (EPBD) revision and ventilation,
- Energy recovery ventilation,
- Personalized environmental control systems (PECS),
- Building and ductwork airtightness regulations in various countries,
- Building ventilation regulations in various countries,
- Temperature take-back effect in the context of energy efficient ventilation strategies,
- Indoor air quality metrics,
- Supplementing ventilation with gas-phase air cleaning, and
- Competent tester schemes for building airtightness testing.

In 2024, the AIVC released several key publications:

- Technical Note TN 73: Overview of the trends in building and ductwork airtightness in 16 countries.

AIVC Board meeting held in Dublin, Ireland, in October, 2024
Source: EBC Annex 5 AIVC

www.aivc.org

- Five Ventilation Information Papers (VIPs) focusing on trends in building and ductwork airtightness in Japan, Republic of Korea, New Zealand, USA and Germany.
- Two VIPs on trends in building ventilation requirements and inspection in Spain and France.
- VIP 49: Resilient Cooling of Buildings.

Also in 2024, the AIVC hosted a series of eight webinars covering a variety of topics as listed below:
- AIVC and TightVent organized a webinar on airtightness tests for high-rise buildings,
- A webinar on new standards, guidelines and regulations for ventilation due to COVID-19,
- Two webinars co-organized by AIVC and Venticool were focused on ventilative cooling and thermal comfort (design and performance assessment of ventilative cooling, exploring window opening behaviour for optimal cooling and thermal comfort),
- A webinar looking into new developments in design and characterisation of energy-efficient ventilation systems,
- A webinar exploring the topic of personalized environmental control system (PECS) in action with insights from case studies, and
- Two webinars by AIVC and TightVent addressing building airtightness impact on energy performance calculations, and building and ductwork airtightness trends and regulations in China, Japan and New Zealand.

To further develop the aims of the AIVC and to keep a broad perspective on the fields of ventilation, infiltration, and IEQ, the AIVC Board established an Industry Advisory Committee in 2023. This is a group of voluntary 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 for AIVC activities. Its mission is to serve as a voice for the industry in AIVC activities, providing feedback on Board proposals and decisions; formulate suggestions for future work and provide advisory feedback on publications and other AIVC products; help to disseminate AIVC deliverables to industry and practitioners and amplify outreach. The advisory committee meets remotely twice a year to give timely feedback in advance of AIVC board meetings.

AIVC maintains a strong and close collaboration with the TightVent and venticool platforms. To foster greater interaction with related organizations and enhance its societal impact, AIVC is also a founding member of the Indoor Environmental Global Alliance and has collaboration agreements with ASHRAE, REHVA, ABAA and ISIAQ.

AIVC continues to facilitate collaboration between various initiatives. For example, the Advisory Board of Practitioners (ABoP), an initiative launched in 2021 by EBC Annex 80, AIVC and venticool, facilitates regular exchange between Annex 80 scientists, practitioners, planners and representatives from relevant industries. As of 2024, following the completion of EBC Annex 80, the ABoP operates under the joint umbrella of AIVC and venticool.

Meetings
The AIVC Board organized two board meetings in 2024, which were held in:
- Singapore in April, 2024, and
- Dublin, Ireland in October, 2024

Project duration
1979–2026

Co-Operating Agents
Peter Wouters, INIVE vzw, Belgium
Arnold Janssens, INIVE vzw/UGent, Belgium

Participating countries
Australia, Belgium, Canada, Denmark, France, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Republic of Korea, Spain, Sweden, United Kingdom, USA

Further information
www.iea-ebc.org

Completed Research Projects

OCCUPANT-CENTRIC BUILDING DESIGN AND OPERATION

(EBC ANNEX 80)

RESILIENT COOLING OF BUILDINGS

(EBC ANNEX 79)

Occupant-centric Building Design and Operation

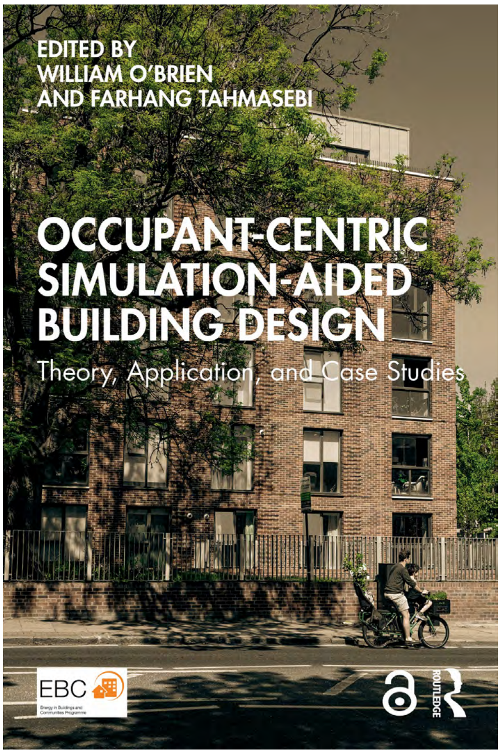
EBC ANNEX 79

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 overall goal of this project was to integrate and implement knowledge and models of occupancy and occupant behaviour into the design process and building operation to simultaneously improve energy performance and occupant comfort. The project key areas of focus included:

- 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.



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

Achievements

The completed deliverables from the project include guidelines, databases, and global case studies to support the design and operation of buildings that incorporate better knowledge about occupants to achieve both improved energy performance and occupant comfort. A key achievement is the publication of an open-access book on occupant-centric building design, which spans the fundamentals of occupant needs and their incorporation into the design process, to simulation-based workflows,

The Final EBC Annex 79 meeting, held in Aachen, Germany, in June 2023. Source: EBC Annex 79

supported by global case studies. Another highlight of the project is the creation of the ASHRAE Global occupant behaviour database, which includes a very large collection of longitudinal occupant data, covering many domains such as occupancy and window operations. Finally, the large critical mass of multidisciplinary researchers from EBC Annex 79 have reconnected to contribute to this field via the ongoing EBC Annex 95 'Human-centric Building Design and Operation for a Changing Climate', which is a joint project with the IEA User-Centred Energy Systems Technology Collaboration Programme.

Publications

The main project deliverables are as follows:

- 'A Comprehensive Guideline for Documenting and Implementing Occupant Behavior Models in Building Performance Simulation and Advanced Building Controls', a report giving an overview of the most significant activities and contributions of the project for different audiences;
- an open-access book 'Occupant-Centric Simulation-Aided Building Design' that 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 ('ASHRAE Global OB Database', www.ashraeobdatabase.com);
- a database with occupant behaviour models that is based partially on the ASHRAE Global OB Database;
- a collection of documented case studies of buildings and spaces that demonstrate occupant-centric controls.

Meetings

No meetings were held in 2024.

Project duration
2018–2024

Co-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, UK, USA
Observers: Hungary, Poland, UAE

Further information
www.iea-ebc.org

Resilient Cooling of Buildings

EBC ANNEX 80

Cooling of buildings is a global trend, driven by factors such as urbanization, climate change, economic growth in densely populated hot regions, and rising comfort expectations. This increasing reliance on room cooling necessitates the development of sustainable solutions to mitigate its environmental and economic impacts.

This project has addressed this challenge by devising, evaluating, and promoting innovative approaches to resilient cooling and mitigating the risk of overheating. It established a well based definition for resilient cooling, referring to energy-efficient and cost-effective cooling concepts with low greenhouse gas emissions that enhance thermal resilience, while addressing global and local climate change effects. It focused on four key technology groups:

1) reducing heat gains to the indoor environment and people,
2) removing sensible heat from the indoor environment,
3) increasing personal comfort apart from space cooling, and
4) removing latent heat from indoor environment.

The project has systematically assessed existing cooling technologies within these groups, identifying their capabilities, limitations, and resilience qualities. It further advanced these technologies to improve robustness, efficiency, carbon neutrality, and affordability, while evaluating their actual performance.

Achievements

The has project contributed to the professionalization and practical application of resilient cooling in a variety of climates and building types. Its outcomes encompass a broad spectrum of thematic areas. So far, the official deliverables have reached over 1500 downloads, and 60 publication citations and recommendations.

Publications

State-of-the-Art Review: The foundation for the subsequent efforts in the project was established by the State-of-the-Art Review. It provides a comprehensive overview of the current state of cooling technologies, encompassing their underlying physical principles, advantages, limitations, technological progress, practical availability, and applicability. This was based on an extensive and systematic review of current literature, complemented by the scientific and practical expertise of the authors.

Deliverable	Reads	Citations	Recommendations
State-of-the-art Review	869	8	13
Field Studies Report	138	1	6
Technology Profiles Report	211	0	12
Policy Recommendations	141	4	5
Key performance Indicators Report	178	5	6
Total	1537	18	42

Impact overview for selected EBC Annex 80 publications (as of January 2025).
Source: Research Gate, 2025

Resilient Cooling Technology Profiles: This catalogue provides a clear, practical guide to implementing resilient cooling solutions in buildings. This comprehensive resource offers detailed information for all stakeholders involved in the design and development of buildings and their technical systems, including refurbishment and new construction.

Field Studies Report: The application of resilient cooling technologies was empirically evaluated in 13 field studies across seven countries. Each field study comprises a detailed description of the cooling system, its performance, and associated simulation results. This report provides a comprehensive overview of the cooling solutions employed in various buildings across diverse climate zones, offering a comparative analysis of the available options.

Resilient Cooling Design Guideline (jointly with REHVA): A significant advance was achieved with the creation of this guideline aimed at planners, published in co-operation with the Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA). This provides a comprehensive description of the design process, the principles for assessing building resilience to heat waves and power outages, and the available software tools. The final chapters of the document present two case studies of the implementation of the guidelines illustrating the approach in a retrofit and a new construction building.

Policy Recommendations: In addition to the technical aspects of resilient cooling, extensive research was conducted into the development of regulatory recommendations. Existing regulatory measures were analyzed in detail, and gaps and opportunities for improvement were identified. The research resulted in the development of 37 regulatory recommendations to promote resilient cooling in buildings.

Midterm Report: This provides an interim summary of the work completed within the first two years of the project working phase.

Project Summary Report: This presents a comprehensive summary of the completed project.

Published Paper in Nature Data Descriptor 'Typical and extreme weather data for studying the resilience of buildings to climate change and heatwaves': This paper delivers a concise collection of current and future weather datasets for building simulations across 15 major cities representing 10 global climate zones. These datasets provide hourly data on key climate variables that are essential for accurate building performance modelling. The files include typical and extreme weather years and multi-year projections covering three time periods: historical (2001–2020), mid-term future (2041–2060), and long-term future (2081–2100). The methodology was developed using bias-corrected projections from a regional climate model and multi-year observational data, and uniquely accounts for future changes in the frequency, duration, and intensity of extreme temperatures. These datasets are among the first to incorporate such detailed projections, and are designed to support studies on building adaptation and resilience to climate change and heatwaves. (www.nature.com/articles/s41597-024-03319-8)

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, UK, USA

Further information
www.iea-ebc.org

Background Information

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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/about/technology-collaboration.

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

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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

– 43rd AIVC Annual Conference, help in Copenhagen, Denmark, October 2023

Ventilation Information Papers

– VIP 45.9: Trends in Building and Ductwork Airtightness in Japan, 2024
– VIP 45.10: Trends in Building and Ductwork Airtightness in Republic of Korea, 2024
– VIP 45.11: Trends in Building and Ductwork Airtightness in New Zealand, 2024
– VIP 45.12: Trends in Building and Ductwork Airtightness in USA, 2024
– VIP 48.1: Trends in building ventilation requirements and inspection in Spain, 2024
– VIP 49: Resilient Cooling of Buildings, 2024
– VIP 45.13: Trends in Building and Ductwork Airtighness in Germany, 2024
– VIP 48.2: Trends in building ventilation requirements and inspection in France, 2024

Technical Notes

– TN73: Overview of the trends in buildings and ductwork airtightness in 16 countries, 2024

Working Group on Building Energy Codes

– Survey on New Technology Integration in Building Energy Codes and Appendices 1 and 2, 2024

Occupant-Centric Building Design and Operation (EBC Annex 79)

– Occupant-Centric Building Design and Operation Final Report

Resilient Cooling of Buildings (EBC Annex 80)

– Resilient Cooling Design Guidelines
– Midterm Report
– Field Studies Report
– Technology Profiles Report
– Policy Recommendations
– Project Summary Report
– Key Performance Indicators Report
– Typical and extreme weather datasets for studying the resilience of buildings to climate change and heatwaves

Data-Driven Smart Buildings (EBC Annex 81)

– Subtask A Report, 2024
– Opportunities for Government Leadership on Data-Driven Smart Buildings, 2024

Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems (EBC Annex 82)

– Data-driven predictive control for demand side management: Theoretical and experimental results, 2024
– Stochastic occupancy modelling for spaces with irregular occupancy patterns using adaptive B-Spline-based inhomogeneous Markov Chains, 2024
– A study on price responsive energy flexibility of an office building under cooling dominated climatic conditions, 2024
– Experimental implementation of an emission-aware prosumer with online flexibility quantification and provision, 2024

Demand Management of Buildings in Thermal Networks (EBC Annex 84)

– Strengths, weaknesses, opportunities and threats of demand response in district heating and cooling systems. From passive customers to valuable assets, 2024
– Case Studies – Projects and Implementation of Demand-Side-Management in Thermal Networks, 2024
– Flexibility potential analysis with quantifiable KPI assessment for energy sector coupling leveraging advanced thermal storage solutions, 2024
– Critical Review of Digital Infrastructures on the Semantic Interoperability in Buildings and 4th Generation District Heating System, 2024
– Demand Response application – A survey with district heating professionals, 2024
– Exploring smart heat meter data: A co-clustering driven approach to analyse the energy use of single-family houses, 2024

Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings (EBC Annex 88)

– State of the Art (Subtask A Report), 2024

Energy Resilience of the Buildings in Remote Cold Regions (EBC Annex 93)

– Quantifying and Rating the Energy Resilience Performance of Buildings Integrated with Renewables in the Nordics under Typical and Extreme Climatic Conditions, 2024

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EBC Projects

Annex 1	Load Energy Determination ofBuildings
Annex 2	Ekistics and Advanced Community Energy Systems
Annex 3	Energy Conservation in Residential Buildings
Annex 4	Glasgow Commercial Building Monitoring
Annex 6	Energy Systems and Design of Communities
Annex 7	Local Government Energy Planning
Annex 8	Inhabitants Behaviour with Regard to Ventilation
Annex 9	Minimum Ventilation Rates
Annex 10	Building HVAC System Simulation
Annex 11	Energy Auditing
Annex 12	Windows and Fenestration
Annex 13	Energy Management in Hospitals
Annex 14	Condensation and Energy
Annex 15	Energy Efficiency in Schools
Annex 16	BEMS 1 – User Interfaces and System Integration
Annex 17	BEMS 2 – Evaluation and Emulation Techniques
Annex 18	Demand Controlled Ventilation Systems
Annex 19	Low Slope Roof Systems
Annex 20	Air Flow Patterns within Buildings
Annex 21	Thermal Modelling
Annex 22	Energy Efficient Communities
Annex 23	Multi Zone Air Flow Modelling (COMIS)
Annex 24	Heat, Air and Moisture Transfer in Envelopes
Annex 25	Real time HEVAC Simulation
Annex 26	Energy Efficient Ventilation of Large Enclosures
Annex 27	Evaluation and Demonstration of Domestic Ventilation Systems
Annex 28	Low Energy Cooling Systems
Annex 29	Daylight in Buildings
Annex 30	Bringing Simulation to Application
Annex 31	Energy-Related Environmental Impact of Buildings
Annex 32	Integral Building Envelope Performance Assessment
Annex 33	Advanced Local Energy Planning
Annex 34	Computer-Aided Evaluation of HVAC System Performance
Annex 35	Design of Energy Efficient Hybrid Ventilation (HYBVENT)
Annex 36	Retrofitting of Educational Buildings
Annex 37	Low Exergy Systems for Heating and Cooling of Buildings (LowEx)
Annex 38	Solar Sustainable Housing
Annex 39	High Performance Insulation Systems
Annex 40	Building Commissioning to Improve Energy Performance
Annex 41	Whole Building Heat, Air and Moisture Response (MOIST-ENG)
Annex 42	The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM)
Annex 43	Testing and Validation of Building Energy Simulation Tools
Annex 44	Integrating Environmentally Responsive Elements in Buildings
Annex 45	Energy Efficient Electric Lighting for Buildings
Annex 46	Holistic Assessment Toolkit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)
Annex 47	Cost-Effective Commissioning for Existing and Low Energy Buildings
Annex 48	Heat Pumping and Reversible Air Conditioning
Annex 49	Low Exergy Systems for High Performance Buildings and Communities
Annex 50	Prefabricated Systems for Low Energy Renovation of Residential Buildings
Annex 51	Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision Makers
Annex 52	Towards Net Zero Energy Solar Buildings (NZEBs)
Annex 53	Total Energy Use in Buildings – Analysis and Evaluation Methods
Annex 54	Integration of Microgeneration and Other Energy Technologies in Buildings
Annex 55	Reliability of Energy Efficient Building Retrofitting – Probability Assessment of Performance and Cost
Annex 56	Cost Effective Energy and CO_2 Emissions Optimization in Building Renovation
Annex 57	Evaluation of Embodied Energy and Carbon Dioxide Equivalent Emissions for Building Construction
Annex 58	Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurement
Annex 59	High Temperature Cooling and Low Temperature Heating in Buildings
Annex 60	New Generation Computational Tools for Building and Community Energy Systems
Annex 61	Business and Technical Concepts for Deep Energy Retrofit of Public Buildings
Annex 62	Ventilative Cooling
Annex 63	Implementation of Energy Strategies in Communities
Annex 64	LowEx Communities – Optimised Performance of Energy Supply Systems with Exergy Principles
Annex 65	Long-term Performance of Super-insulating Materials in Building Components and Systems
Annex 66	Definition and Simulation of Occupant Behavior in Buildings
Annex 67	Energy Flexible Buildings
Annex 68	Indoor Air Quality Design and Control in Low Energy Residential Building
Annex 69	Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings
Annex 71	Building Energy Performance Assessment Based on In situ Measurements

Annex 73	Towards Net Zero Energy Resilient Public Communities
Annex 74	Competition and Living Lab Platform
Annex 76	Deep Renovation of Historic Buildings towards Lowest Possible Energy Demand and CO_2 Emission
Annex 77	Integrated Solutions for Daylight and Electric Lighting
Annex 78	Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications
Annex 79	Occupant-centric Building Design and Operation
Annex 80	Resilient Cooling
Annex 81	Data-Driven Smart Buildings
Annex 82	Energy Flexible Buildings towards Resilient Low Carbon Energy Systems
Annex 83	Positive Energy Districts
Annex 84	Demand Management of Buildings in Thermal Networks
Annex 85	Indirect Evaporative Cooling
Annex 86	Energy Efficient Indoor Air Quality Management in Residential Buildings
Annex 87	Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems
Annex 88	Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings
Annex 89	Ways to Implement Net-zero Whole Life Carbon Buildings
Annex 90	Low Carbon, High Comfort Integrated Lighting
Annex 91	Open Building Information Modelling for Energy Efficient Buildings
Annex 92	Smart Materials for Energy-efficient Heating, Cooling and Indoor Air Quality Control in Residential Buildings
Annex 93	Energy Resilience of the Buildings in Remote Cold Regions
Annex 94	Validation and Verification of In-situ Building Energy Performance Measurement Techniques
Annex 95	Human-Centric Buildings for a Changing Climate
Annex 96	Grid Integrated Control of Buildings
Annex 97	Sustainable Cooling in Cities

Working Group – Energy Efficiency in Educational Buildings
Working Group – Indicators of Energy Efficiency in Cold Climate Buildings
Working Group – Annex 36 Extension: The Energy Concept Adviser
Working Group – HVAC Energy Calculation Methodologies for Non-residential Buildings
Working Group – Cities and Communities
Working Group – Building Energy Codes

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

Technology Collaboration Programme

by iea