Energy in Buildings and Communities Programme

Annual Report 2022

EBC

Energy in Buildings and Communities Programme

International Energy Agency

EBC Annual Report 2022

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Front cover image: The Solar Decathlon Europe held in June 2022 was the first edition of the competition profiting from the findings of the EBC Annex 74 outputs.
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www.iea-ebc.org
essu@iea-ebc.org

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EBC Executive Committee Chair's Statement

Before clinical investigations may begin, the design and manufacture of potential new medicines must be realized. Only then can their effects be understood through those investigations, and medicines without therapeutic effect are not permitted by regulators and governments. Ideally, there must be similar regulatory systems for energy-saving and renewable energy production technologies for buildings and communities. Technologies should be well-defined by their developers according to standardization frameworks and they should be checked for their efficiencies and effectiveness from neutral scientific standpoints.

However, there may be some key technologies already introduced to the market which lack appropriate standards, or that have not been sufficiently evaluated in-use to ascertain their operational performance and impacts. This is one cause of the so-called 'performance gap' between design assumptions and actual operation of buildings and community systems. This gap is drawing attention because expectations for all kinds of technologies for energy-saving and renewables have risen rapidly, especially during this decade after the invention and implementation of the technologies. While it is commonly believed that technologies that have already been implemented must surely save energy, in fact it is still necessary to review their real performance according to current standards for neutral scientific evaluation.

During the life of building fabric and services technologies, from their invention to full deployment, the standardization stage and evaluation methods (including testing methods) have become critical for full deployment. Before the current movement towards zero carbon, there were many research, development and demonstration (RD&D) projects that had been concluded only by showing the potential of the technologies, but before the standardization stage had been reached. Standardization for products, design and testing is essential for practitioners, who are required to deploy the technologies in their buildings and communities, and also for experts in charge of performance evaluation for building energy codes and regulations.

During discussions that took place at the IEA Future Building Forum Think Tank Workshop 2022 (see page 2), it emerged that the integration of technologies within building energy codes and regulations is vital for large scale deployment of technologies and to ensure their contribution to reducing energy use and decarbonization. This means that modern RD&D for energy-related technologies must include their standardization within the original plan and scope of the RD&D. Otherwise, the RD&D would be concluded leaving only optimistic expectations. This would give an adverse impression among practitioners, who could not judge whether or not they should adopt a novel technology. For instance, for the case of heat pump technologies (see EBC Annex 88 on page 8), their operational performance in buildings and community systems should be evaluated by using standards produced through RD&D, beyond the relative evaluation of products that is current common practice.

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

Existing Buildings: Pathways to Net Zero Carbon 2035

IEA FUTURE BUILDINGS FORUM THINK TANK WORKSHOP 2022 OUTCOMES

The latest Future Building Forum (FBF) Think Tank Workshop was convened in Gatineau, Canada, in October 2022, and was organised through the combined efforts of the IEA Buildings Co-ordination Group (BCG), its member TCPs, and Canada as the host country.

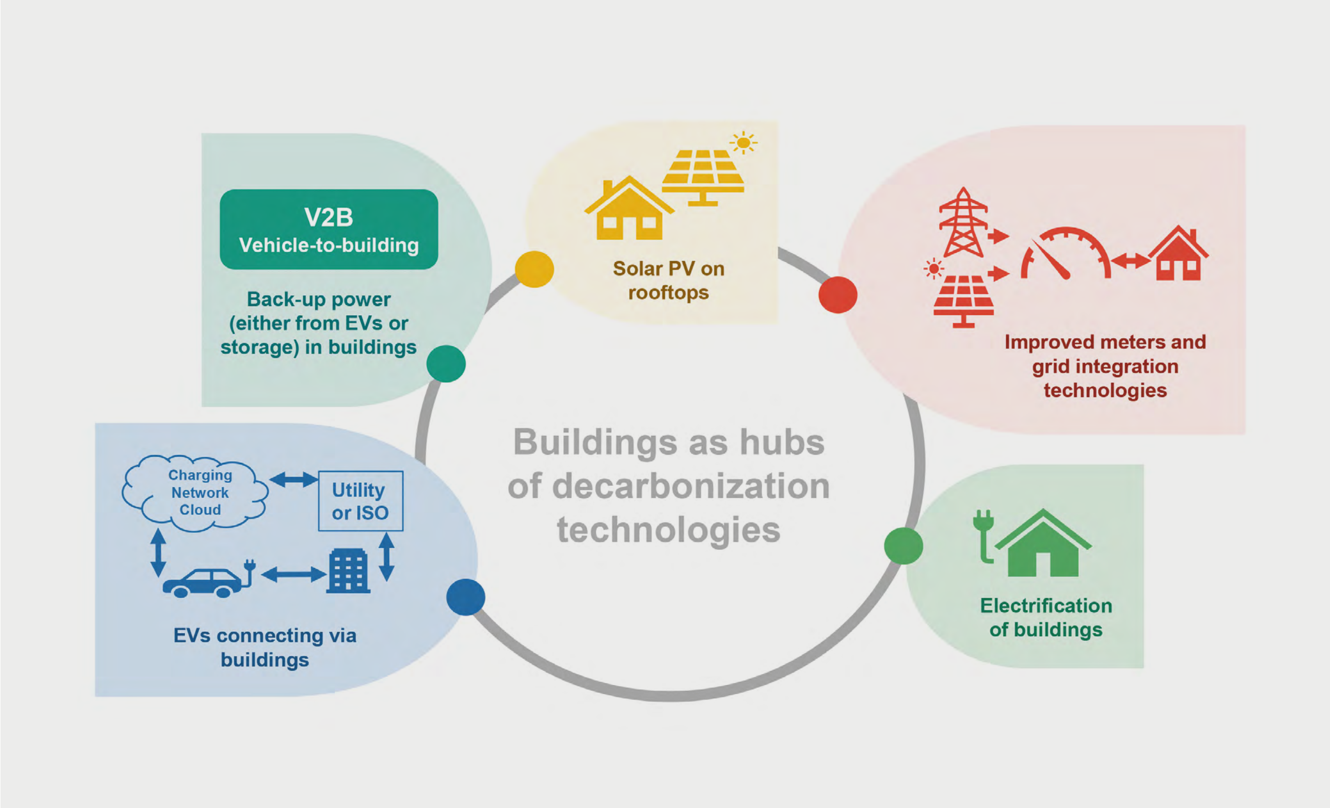
The purpose of the FBF Think Tank Workshops is to allow the International Energy Agency's (IEA) buildings-related Technology Collaboration Programmes (TCPs) to periodically discuss the research, development, and demonstration (RD&D) activities that will be needed over a five-year period, to achieve ambitious and disruptive deployment of technologies at scale by an agreed target date, typically 15 to 20 years ahead. This long-term series of workshops is convened through the combined efforts of the BCG member TCPs and the host countries.

The theme for the Workshop in 2022 was 'Existing Buildings: Pathways to Net Zero Carbon 2035'. Specifically, the purpose was to agree on the international collaborative RD&D activities needed to unlock deployment of low and zero carbon technologies in existing housing and buildings and to generate new ideas to identify:

- collaborative RD&D project concepts intended to be jointly carried out by the buildings-related TCPs that consider the information and data requirements of the receptors of the eventual outcomes of those projects;
- collaborative focus areas to include in the future Strategic Plans of the buildings-related TCPs.

Over the three days of the forum, participants representing nine TCPs, as well as representatives of Canadian industry, academia and government, discussed how to bring the existing building stock to performance levels that would meet the international greenhouse gas reduction targets. The discussions were structured around four dimensions, and for each of these the Workshop conclusions are summarised below.

The Final Report of the 2022 IEA Future Building Forum Think Tank Workshop contains the detailed outcomes agreed by the participants and the presentations made during the workshop.
Source: IEA Energy in Buildings and Communities (EBC) Technology Collaboration Programme



Expanding how we think about buildings of the future
Source: EBC Working Group on Building Energy Codes

Deep energy retrofit challenges and opportunities: This addresses approaches and activities around energy retrofits of buildings that achieve a minimum energy consumption reduction of 40%. On this theme, the Workshop participants concluded the following RD&D activities are required:

— create pathways to:
  - determine when it is better to do a complete demolition-reconstruction versus when to do a deep retrofit from the energy and carbon perspectives;
  - evaluate predefined solutions through modelling various pathways more efficiently to get to implementation faster;
  - explore how to address technologies as they approach the end of their service lives.

— determine data and metrics for how to best measure building performance, and to develop case studies to disseminate best practices and strategies in terms of recommissioning using digital tools and easily accessed information.

— pursue market development and engagement to determine how to improve the rate of retrofit through methods such as digitization, robotics, and so on, and to identify ways that homeowners can be enabled, empowered, and incentivized (other than through financing).

— streamline delivery particularly through industrialization and standardization to accelerate improvement of the building stock.

Systems as transformational processes: This deals with reducing operational carbon in buildings and the thermal and electrical grids that serve them. On this theme, the Workshop participants concluded the following RD&D activities are needed:

— develop visions and options for future energy systems at the building and district levels.

— model predictive controls to develop and apply effective and industry-acceptable control through artificial intelligence (AI) and machine learning for building energy systems.

— apply digitalization to better coordinate supply (spatial and temporal) through digitalization and 'smart' systems, and to manage generation diversity for renewable production options (photovoltaics, solar thermal, heat pumps, geothermal power, and so on) to match diverse load patterns.

— quantify benefits of district versus individual building solutions to develop aggregated datasets for cost, emissions, and energy for buildings at a regional level.

— concerning energy flexibility, define when storage is appropriate as a means of balancing impacts on the grid as a feasible economic option, examine the role of thermal grids in supporting the electricity grid, and develop scenarios for using interactive equipment.

Technological systems as catalysts for future proofing buildings: This addresses the operation and future proofing of retrofitted building systems. On this theme, the Workshop participants concluded it is necessary to carry out the following RD&D activities:

- for data and information systems, define minimum data management requirements, and develop and share global experiences on successful and unsuccessful initiatives.
- for the benefit of occupants, evaluate trust issues and opportunities for user-centric feedback, and keep them 'in the loop' by considering app design, plug and play, and users' perceptions.
- develop tools for educating and understanding the complexities concerning energy, carbon, and financial implications.
- develop materials for training building operators on operation, feedback, fault detection, and predictive controls.
- develop methodologies, and case studies for occupant-centric operation.
- concerning equipment and system optimization and control, develop key performance indicators, identify low-tech solutions to meet the needs of those less likely to adopt new technologies, develop advanced control of mechanical systems, evaluate appropriate level of digitalization, and investigate data issues across scales.
- redefine comfort considering climate, culture and building topology, and enable resilience and adaptability
- relating to measurement and verification, develop low cost and virtual sensors, provide guidance on sensor use and placement, and address uncertainty in building performance through measurement and collection.
- concerning user services and business models, compare different ways technology interacts with people to determine what works well, evaluate options to consider energy services as a business model, develop models for sustained engagement with communities, and develop guidelines to get buildings and utilities to work together optimally.

Building energy and carbon codes: This involves evaluating the applicability of metrics and the integration of new technologies in energy and carbon codes. On this theme, the Workshop participants concluded the following RD&D activities are required:

- concerning digital-first codes and artificial intelligence / machine learning, determine effectiveness of data collection and ownership, interoperability towards more advanced standards, and consider the barriers to digitization of code compliance.
- define machine readable metrics for buildings.
- understand what metrics are being used and whether they are effective.
- carry out user / stakeholder engagement, interactions / needs assessments.
- undertake interventions to evaluate the performance gap between designed / modelled performance and real monitored performance, and to develop case studies / review of current approaches on disclosure, and to understand the impact of mandatory disclosure versus requirement.
- propose incentives to facilitate market adoption by evaluating levels of subsidized improvements, determine the right incentives, evaluating financing options for retrofits, developing streamlined permitting processes, and evaluating options for voluntary disclosure.
- develop automation / digitalization of enforcement by determining what effective enforcement mechanisms look like, and consider affordability.

The FBF participants also identified some steps to strengthen the collaboration among the BCG TCPs:

- include 5-minute TCP presentations into the agenda of each TCP's Executive Committee meeting;
- create a database of experts accessible to all TCPs;
- require new TCPs' Annexes / Tasks to carry out an analysis of opportunities for inter-TCP activities;
- create a process to evaluate and progress the research ideas generated through the FBF Workshop to develop full cross-TCP collaborative projects;
- hold online meetings, led by the respective session coordinators to further develop the collaborative projects identified;
- develop coordinated collaborative project proposals for consideration by the relevant TCP Executive Committees.

Further information

www.iea-ebc.org/strategy/future-buildings-forum

Summarised by the EBC Executive Committee Support and Services Unit (ESSU)

New Research Projects

WAYS TO IMPLEMENT NET-ZERO WHOLE LIFE CARBON BUILDINGS

(EBC ANNEX 89)

EVALUATION AND DEMONSTRATION OF ACTUAL ENERGY EFFICIENCY OF HEAT PUMP SYSTEMS IN BUILDINGS

(EBC ANNEX 88)

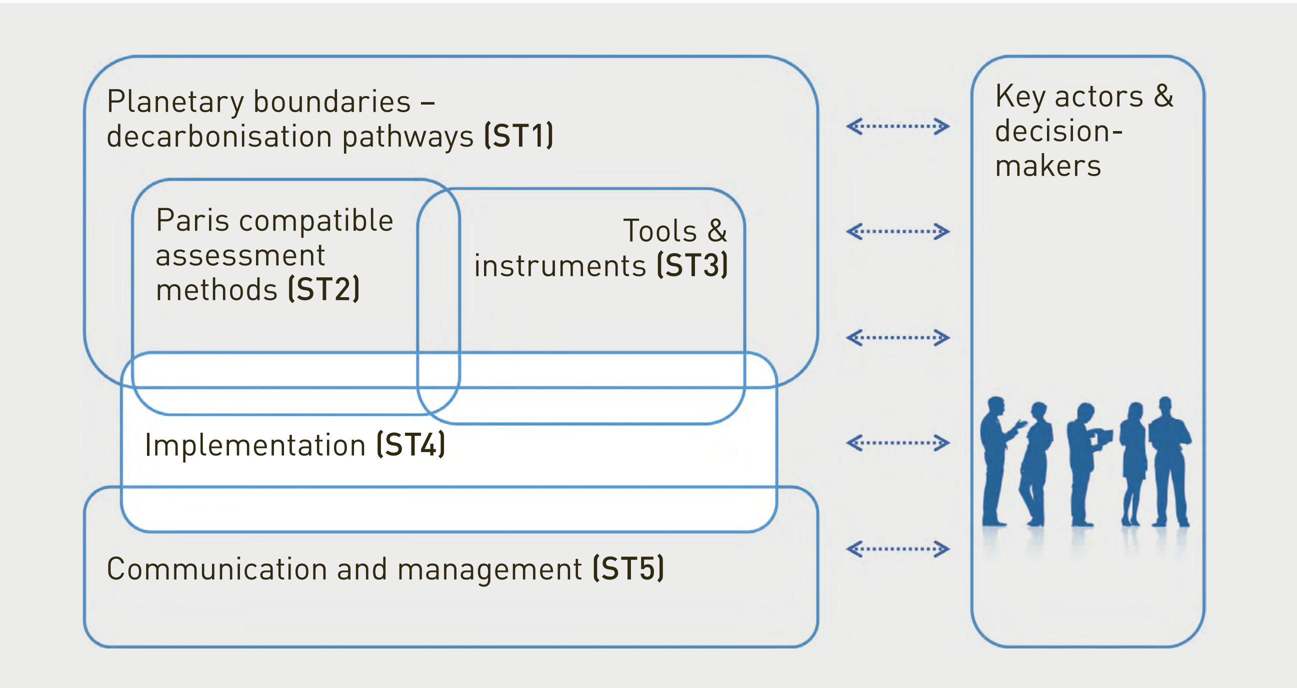
Ways to Implement Net-zero Whole Life Carbon Buildings

EBC ANNEX 89

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report states that to limit global warming to a temperature rise within 1.5°C, the remaining global greenhouse gas (GHG) budget stands at around 500 gigatonnes, and calls for rapid emissions reduction in all economic and industry sectors of the countries worldwide. With a share of 37% of the global energy related GHG emissions following a cross-sectoral approach, the construction and operation of buildings has a key role to help reaching this target. Several other documents, such as the EBC Annex 72 'Monte Verità Declaration', emphasize that legally binding requirements to limit the life cycle related GHG-emissions of new constructions and of refurbishments should be set and ambitious mitigation pathways should be established to support the transition to a net zero GHG emissions society.

EBC Annex 89 is focused on the mitigation pathways and actions required to implement whole life cycle-based net-zero GHG emissions from buildings in policy and practice. This means explicitly considering both embodied and operational emissions across all stages of the entire life cycle, also referred to as whole-life carbon (WLC). In other words, the project aims to contribute to global efforts to accelerate and scale-up the transition towards net-zero whole-life carbon (NetZ-WLC) buildings.

Implementing harmonised approaches in combination with practical strategies to rapidly decarbonise the building and real estate sector should be a priority. Therefore, this new project has been established to build upon the harmonised methodology developed by the completed EBC project, 'Annex 72: Assessing Life Cycle Related Environmental Impacts Caused by Buildings'.



Structure of the five synergistic project subtasks
Source: EBC Annex 89

This project aims to support key decision makers in developing and implementing whole life cycle-based decarbonisation roadmaps for single buildings and whole building stocks.

Objectives

The project scope of work to support the implementation of NetZ-WLC buildings aligned with the Paris Agreement encompasses:

- developing recommendations on setting life cycle based carbon targets and budgets as well as identifying carbon reduction pathways;
- addressing compatibility of assessment methodologies with the Paris 1.5°C target;
- mapping and assessing the relevance and effectiveness of tools and instruments to meet the Paris 1.5°C target;
- supporting implementation of context-based decisions and actions by key stakeholders;
- ensuring efficient and effective engagement with the stakeholders and dissemination of outcomes.

The project comprises the following five synergetic Subtasks:

- Subtask 1: Planetary boundaries and decarbonisation pathways
- Subtask 2: Paris compatible assessment methods
- Subtask 3: Enabling tools and instruments
- Subtask 4: Implementation and stakeholder actions
- Subtask 5: Communication and management

Deliverables

Among other formats, the deliverables are being formed as guidelines on how to support the implementation process, and consider the different situations of individual countries. To this end, the following reports are planned:

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

Progress

The project preparation phase was approved at the EBC Executive Committe meeting held in November 2022.

Meetings

No full project meetings were held during 2022, although a number of initial preparatory project meetings took place in December 2022.

Project duration
2022–2027

Operating Agent
Alexander Passer, TU Graz, Austria

Participating countries (provisional)
Austria, Australia, Belgium, Brazil, Canada, Czech Republic, Denmark, France, Germany, Greece, New Zealand, Norway, Spain, Sweden, Switzerland, Türkiye, USA, UK

Further information
www.iea-ebc.org

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

EBC ANNEX 88

Heat pumps are regarded as a very promising form of energy-efficient heat generator. However, publicly available information on the actual characteristics of heat pump systems in buildings is still insufficient to meet the needs of both system designers and product manufacturing engineers. In fact, there seems to be a huge potential to improve design practices and accuracy of energy calculation methods, which can be applied to strengthen building energy codes and regulations.

Objectives

The overall objective of EBC Annex 88 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. To meet this objective, the following project objectives have been set:

- Literature survey of test methods, monitoring methods and methods for energy calculations for heat pump systems, as well as existing design guidelines.
- Analysis and comparison of existing proposals on testing methods of heat pump systems, and development of recommendations for testing actual energy efficiency.
- Development of a manual on monitoring methods for energy efficiency and other characteristics of heat pump systems in buildings, and new data acquisition techniques on which to develop a database.
- Development and validation of alternative methods for predicting energy efficiency and energy use of heat pump systems in buildings under different conditions including partial load ratios, by utilizing product information based on existing test standards and protocols.
- Development of design guidelines for more energy efficient heat pump systems with demonstration data from applications in buildings.

Deliverables

The project deliverables are expected to be as follows:

- State-of-the-art report on existing testing methods and monitoring methods, on methods and product parameters for estimating energy use by heat pump systems, and on existing design guidelines for heat pump systems
- Recommendations of protocols to monitor actual characteristics and behaviour of heat pump systems
- Recommendation of test methods and monitoring methods of heat pump systems
- Database of monitoring results on heat pump systems in buildings
- Design guidelines of heat pump systems in buildings based on the evaluation of energy use and efficiency

Progress

Through two workshops convened for the preparation of the project proposal and the first project meeting, a consensus has been reached among participants on the major factors behind the discrepancies between actual energy efficiency of heat pump systems in buildings and the expectation of the energy efficiency based on existing testing standards. It has also been confirmed there are several organizations that have published proofs of such discrepancies. The major factor is the condition of the machines being tested, especially fixing the compressor speed to make a stable situation (i.e. not on-off, nor cyclic). The control of the machines especially for testing contributes to reproducibility and accuracy of the tests, but may change the energy efficiency of the machines when compared with actual levels observed in buildings.

Taking this disadvantage of current test methods and standards into consideration, new type test standards are under development, and one of them has already been published (CSA SPE-07:23 Load-based and climate-specific testing and rating procedures for heat pumps and air conditioners). Among the project participants, there are representatives of four teams, which are developing the load-based testing standards, including experts

Outdoor unit of a variable refrigerant system during the load-based test without fixing compressor speed
Source: EBC Annex 88

engaged in the CSA SPE-07:23. In the project, ideas for new types of test standards are being generated and their advantages and disadvantages compared. By refining these ideas, proposals for the development of standards are being created. Both previously published new load-based test standards and those under development require further validation and understanding by relevant industries to establish their positions in practice, especially design practices for HVAC systems.

In parallel with the work on test standards, field monitoring methods and the development of a database are being carried out in the project. A standard for field monitoring has been published as 'T/CAS 305-2018 Specification for measuring field performance of room air conditioners'. An instrument to make field monitoring of variable refrigerant flow systems has been developed and used to collect data. These methods provide actual energy performance of heat pump systems in buildings.

Load-based tests can be used to obtain energy efficiencies, which can be integrated into so-called seasonal average energy efficiencies. Another important application of the test results is energy calculations for HVAC systems on a building level. Calculated energy use by heat pump systems and energy efficiencies under partial load conditions are influential on calculated energy use. Therefore, energy calculation methods for heat pump systems are also being studied in the project.

Meetings

The following meetings were held during 2022:

— The 2nd Workshop in the preparation phase was held online in March 2022.

— The 1st Working meeting was held online in September and October 2022.

Project duration
2022–2027

Operating Agents
Takao Sawachi, Building Research Institute, Japan

Participating countries (provisional)
Australia, Brazil, Canada, China, Germany, Italy, Japan, the Netherlands, Switzerland

Further information
www.iea-ebc.org

Ongoing Research Projects

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)

DATA-DRIVEN SMART BUILDINGS

(EBC ANNEX 81) RESILIENT COOLING OF BUILDINGS

(EBC ANNEX 80)

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

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

(EBC ANNEX 78)

COST-EFFECTIVE BUILDING RENOVATION AT DISTRICT LEVEL COMBINING ENERGY EFFICIENCY AND RENEWABLES

(EBC ANNEX 75)

ASSESSING LIFE CYCLE RELATED ENVIRONMENTAL IMPACTS CAUSED BY BUILDINGS

(EBC ANNEX 72)

BUILDING ENERGY EPIDEMIOLOGY:
ANALYSIS OF REAL BUILDING ENERGY USE AT SCALE

(EBC ANNEX 70)

AIR INFILTRATION AND VENTILATION CENTRE – AIVC

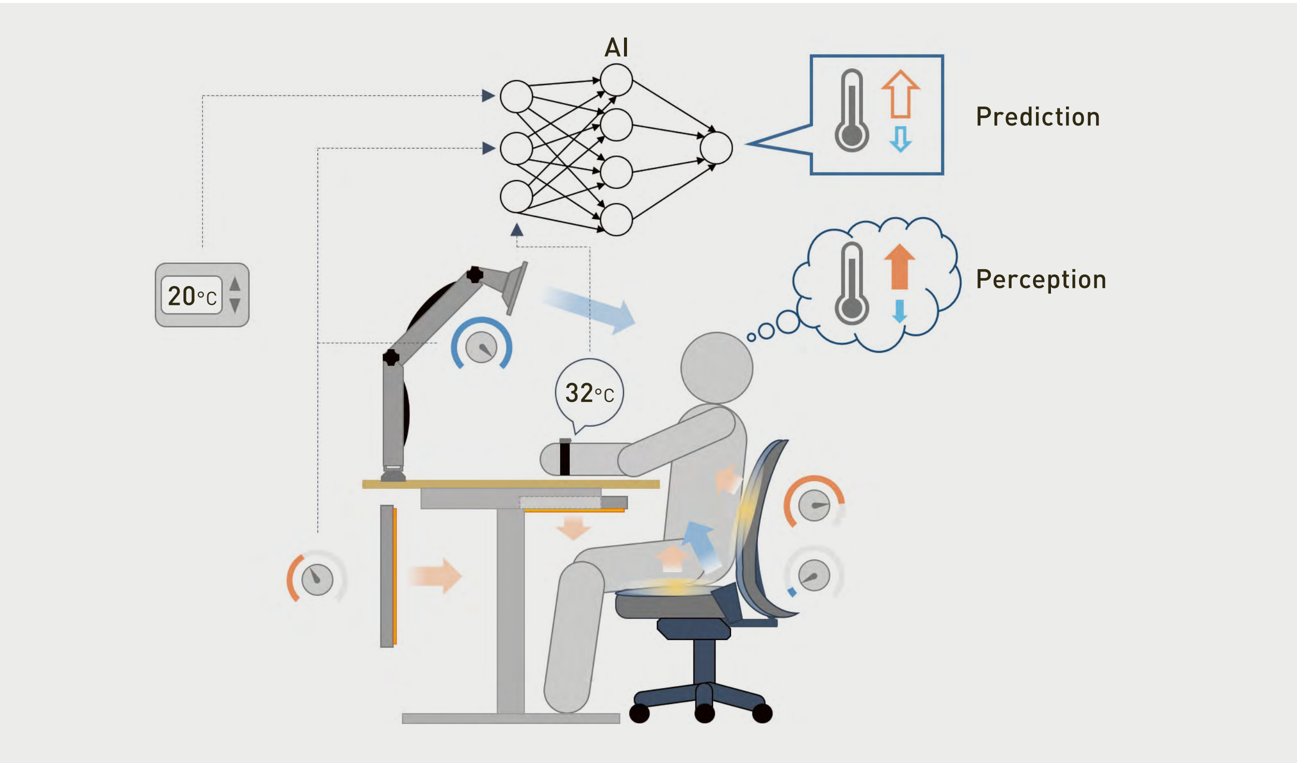
(EBC ANNEX 5)

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 acoustic have advantages of controlling the localized environment at occupants' workstations by their preference instead of conditioning an entire room to uniform conditions. This improves comfort, satisfaction, health of the occupants, and energy e iciency of the entire heating, ventilation and air-conditioning (HVAC) system substantially. Personalised Ventilation (PV) can also protect against cross contaminations, which are critical in open-plan offices and work places with close distance between occupants. It is foreseen that there will be an increasing interest and market for PECS in the future, as buildings will need to be future-proofed (e.g., against pandemics, heat waves, power outages). The application of PECS is for workplaces with mainly sedentary activity such as offices (such as open-plan, banks, control centers). Due to the COVID-19 pandemic, where many people have worked at home, there may also be an increase in home working places where PECS may be a solution.

EBC Annex 87 has now entered its working phase and has the overall objective to establish design criteria and operation guidelines for PECS and to quantify the benefits of PECS regarding health, comfort, energy, and costs. This includes control concepts and guidelines for operating PECS in spaces with general ambient systems for heating, cooling, ventilation and lighting. The scope includes all types of PECS for local heating, cooling, ventilation, air cleaning, lighting and acoustic. It includes desktop systems, which are mounted on desks or



A generic example of a Personalized Environmental Control System (PECS) and its control methods
Source: EBC Annex 87

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' body.

Objectives

The project objectives are to:

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

Deliverables

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

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

Progress

The project has successfully completed its preparation phase in 2022, and was approved to move on to its working phase at the end of 2022. The working phase is expected to run for three years.

The work in the Subtasks is ongoing and more specific activities within the Subtasks are being defined. Synergies between the Subtasks are being identified, and the first publications are already being planned.

The project has also been very active in dissemination and already held two workshops in international conferences and a webinar, which were all well-attended. There are already several dissemination activities planned in 2023.

Meetings

In 2022, two expert meetings were held to kick-off the project and to conclude its preparation phase. A large number of experts and interested parties joined these meetings. The first meeting was held in May 2022 (in-person) and an online preparatory meeting was held prior to the in-person kick-off meeting. The second meeting was held in October 2022 (hybrid meeting).

Project duration
2021–2026

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

Participating countries
Australia, Belgium, Brazil, P.R. China, Denmark, Finland, France, Germany, Italy, Singapore, Türkiye

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 climate change goals while maintaining a healthy, acceptable and desirable indoor environment. While ventilation is the main strategy that is adopted for indoor air quality (IAQ) management, other technologies influencing IAQ (e.g. air filtration) are available as well. However, there is no 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 the optimal solutions for maximizing energy savings while guaranteeing a high level of indoor air quality in new, renovated and existing residential buildings.

To achieve this, the aim of this project is to gather existing scientific knowledge and data on pollution sources in buildings, investigate opportunities of applying 'Internet of Things' (IoT) -connected sensors; to study current and innovative case studies of IAQ management strategies and develop road maps to ensure the continuous performance of the proposed solutions over their lifetime. The project is focused on residential buildings, because they 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 already studied in a separate EBC Annex 78 and are therefore not studied in detail in this project.

The project is bringing experts from mechanical engineering, building science, chemistry, data science and environmental health together with other stakeholders to work towards consensus on the basic assumptions that underlie such a performance assessment and practical guidelines and tools to bring the results to practice.

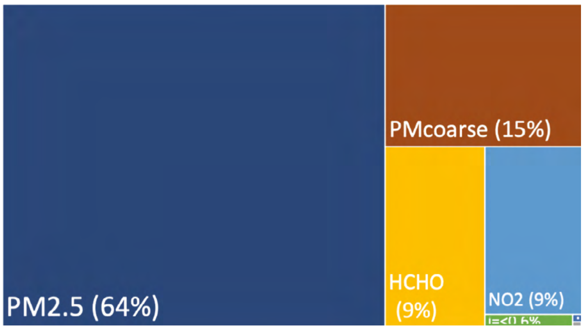
The project main goal is to accelerate the development of better and more energy efficient IAQ management strategies to address rapidly changing expectations of home environment due to the challenges of peak oil, climate change and pandemics.

This project is developing work carried out in the EBC Project, 'Annex 68: Indoor Air Quality Design and Control in Low Energy Residential Buildings' and is collaborating with the EBC Project, 'Annex 5: Air Infiltration and Ventilation Centre' in organizing of meetings and disseminating of project results.

Objectives

The main objectives and scope are as follows:

- develop a consistent set of metrics to assess energy performance and indoor environmental quality of an indoor air quality 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 the 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 buildings;



Breakdown of expected harm on population level due to exposure to indoor air pollutants
Source: Gioberttі Morantes, Delft, 2022

— improve the energy efficiency of the indoor air quality management strategies in operation and to improve their acceptability, control, installation quality and long-term reliability;
— disseminate the project findings.

Deliverables

The planned deliverables for the project include:

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

Progress

During 2022 the project convened two in-person working phase expert hybrid meetings in Athens and Delft connected to the ASHRAE / AIVC IAQ 2020 and the AIVC 2022 conferences. In between, the Subtasks had regular online meetings.

In Subtask 1, a new harm-based acceptable risk indicator and associated dynamic and monetized impact assessment for IAQ management strategies has been proposed. Subtask 2 has created data processing templates to feed the open IAQ database. Subtasks 3 and 4 are engaged in common exercises testing the implications of their work on real cases embedded in a local context. In Subtask 5, opportunities to derive real, time resolved air exchange rates from IAQ sensor data were discussed.

The intermediate results and activities in the project were reported in a series of sessions at the AIVC conferences and are disseminated through the collaboration with AIVC. The Danish participants held a very well attended national dissemination symposium.

Meetings

The following project meetings were held during 2022:

— a hybrid expert meeting in Athens, Greece, in May 2022, and
— An expert meeting in Delft, the Netherlands, in October 2022.

Project duration
2020–2025

Operating Agents
Jelle Laverge, Ghent University, Belgium

Participating countries
Australia, Austria, Belgium, Brazil, Canada, P.R. China, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Türkiye, UK, USA
Observers: Chile

Further information
www.iea-ebc.org

Indirect Evaporative Cooling

EBC ANNEX 85

Building energy consumption accounts for almost one-third of total energy consumption. Over 10% of building energy consumption is used for air conditioning and indoor thermal comfort in hot seasons. Changing the air conditioning mode is one essential solution to meet cooling demand without increasing power consumption and carbon emissions. Although over 85% of cooling worldwide is achieved by mechanical refrigeration, more than 40% of the cooling can be provided by evaporative cooling, especially in dry climate zones.

The main types of evaporative cooling technologies are:
— direct evaporative cooling (DEC) to produce cooling air or cooling water;
— indirect evaporative cooling (IEC) to produce cooling air or cooling water.

This project aims to study the feasibility of IEC technologies and provide the roadmap of using these technologies in various dry climate zones.

The following project tasks are planned:
— Definition and field study
— Feasibility study of IEC technologies
— Fundamental study
— Simulation tool and guidelines

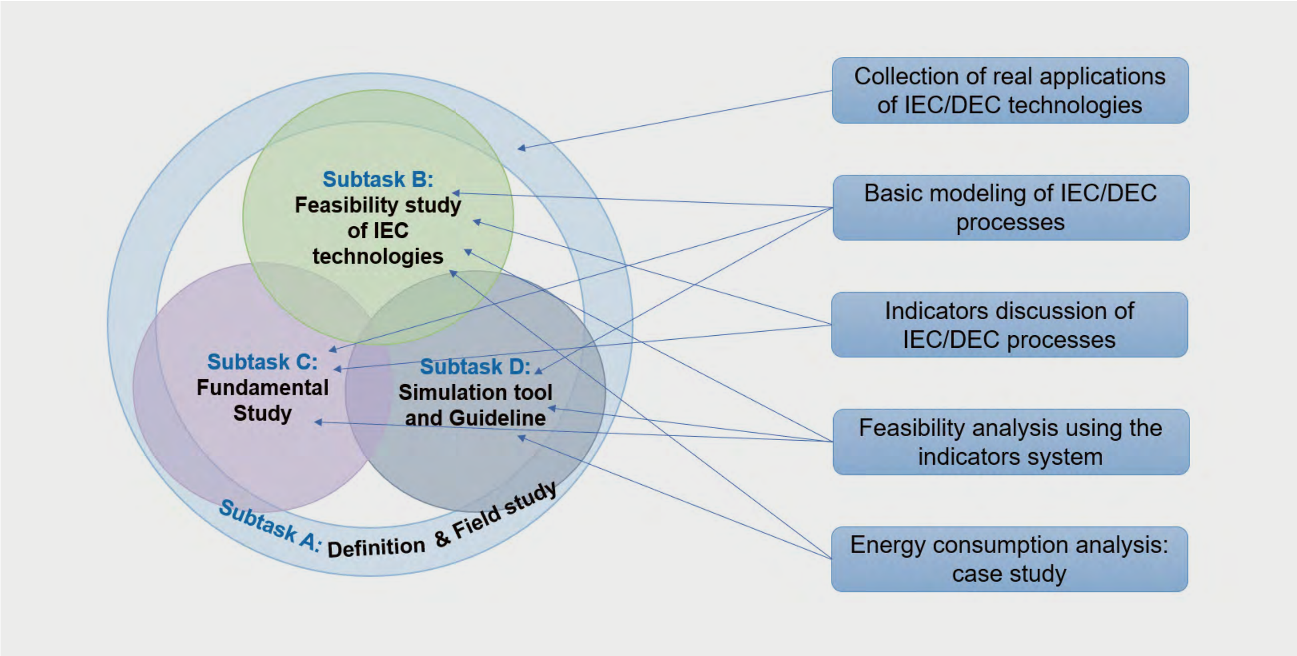
The targeted audience of the project includes design and planning practitioners, scientific communities, government officials and manufactures.

Objectives

The aim of the project is to develop international co-operation on IEC technology development. The project is focusing on discovering the current challenges of using IEC technology and reaching a scientific and applicable roadmap of applying IEC in various dry climate zones. The project objectives are to:
— investigate IEC and conventional cooling systems to gather the information on the equipment and maintenance cost, space requirements, environmental impacts and limitations of using IEC widely;
— carry out field testing of existing IEC systems in various climate zones to build a field test database;
— develop a general theoretical analysis method of IEC processes to guide the design of various IEC systems;
— evaluate water and electricity consumption of IEC processes;
— model the IEC systems and create a tool to simulate different types of buildings under various dry climate zones;
— develop a guide for designing the IEC systems for different types of buildings under various 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 theoretical analysis results for the general performance of indirect evaporative cooling technologies; fundamental analysis results through thermal analysis and optimisation; design guidelines for indirect evaporative cooling technologies and feasibility analysis of indirect evaporative cooling technologies);
— a simulation tool for various types of IEC technologies for different types of buildings and dry climate zones;
— a collection of case studies and feasibility analysis of indirect evaporative cooling technologies worldwide;
— reports of fundamental analysis result through thermal analysis and optimisation;
— design guidelines for indirect evaporative cooling technologies.



This schematic shows the relation of the four project Subtasks.
Source: EBC Annex 85

Progress

Researchers and institutions from China, Belgium, Denmark, France, Turkey, United States, Egypt, Algeria, Italy, and Spain have participated in the project, and Algeria which is not EBC member country, is voted to be observer in Annex 85.

Progresses of this project are as follows:

— Collection of real application projects of IEC technologies, by Subtask A. Projects include IEC applications in Data centers (China), IEC application used to humidify the inlet air (Denmark), IEC applications for building air conditioning (Belgium) .
— Research on performance indicators of IEC processes, by Subtask B and Subtask C. Indicators for IEC air coolers and IEC water chillers are analysed, and the performance of indicators according to outdoor air conditions are discussed.
— Modeling on DEC and IEC processes, by Subtask D and Subtask C: detailed modeling on IEC water chillers and cooling towers; internal heat and mass transfer coefficients, flow resistance of air were discussed for paddings. Developed an EES model for a dew point heat exchanger that have been validated experimentally and working on another prototype, by Subtask D.
— Different IEC cooling processes comparison and thermal analysis, by Subtask C. An equivalent thermal resistance is identified and used to compare different processes, to find the optimized process structure. Suitable climatic zones for different evaporative cooling technologies are obtained.
— Applications of IEC technologies, by all Subtasks. Several new IEC systems have been set up.

Meetings

The following online meetings were held in 2022:

— a workshop in April 2022,
— a workshop in July 2022,
— a workshop in October 2022, and
— a workshop in December 2022.

Project duration
2020 – 2025

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

Participating countries
Australia, Belgium, P.R. China, Denmark, France, Türkiye, USA
Observer: Egypt

Further information
www.iea-ebc.org

Demand Management of Buildings in Thermal Networks

EBC ANNEX 84

Today in traditional thermal networks, district heating and cooling (DHC) systems, buildings and end-users are just considered as a simple load point / demand-side variable and not as individuals and communities capable of enabling systemic interventions and delivering flexibility to the system, thus speeding up the process towards carbon-neutral societies. Demand management has the potential to facilitate the expansion of DHC networks without additional pipelines, the increased use of renewable energy sources and waste, and the reduction of peak periods and capacity challenges. These effects combined could increase the optimization opportunities considerably adding an untapped energy efficiency potential of more than 20%. Thus, integrating building and end-users is crucial for the smooth, cost and energy-efficient transition to generation DHC systems.

The work of the Annex investigates both the social and technical challenges and how these can be overcome for various building typologies, climate zones and local conditions as well as how digitalisation of heating / cooling demand facilitates demand management activation.

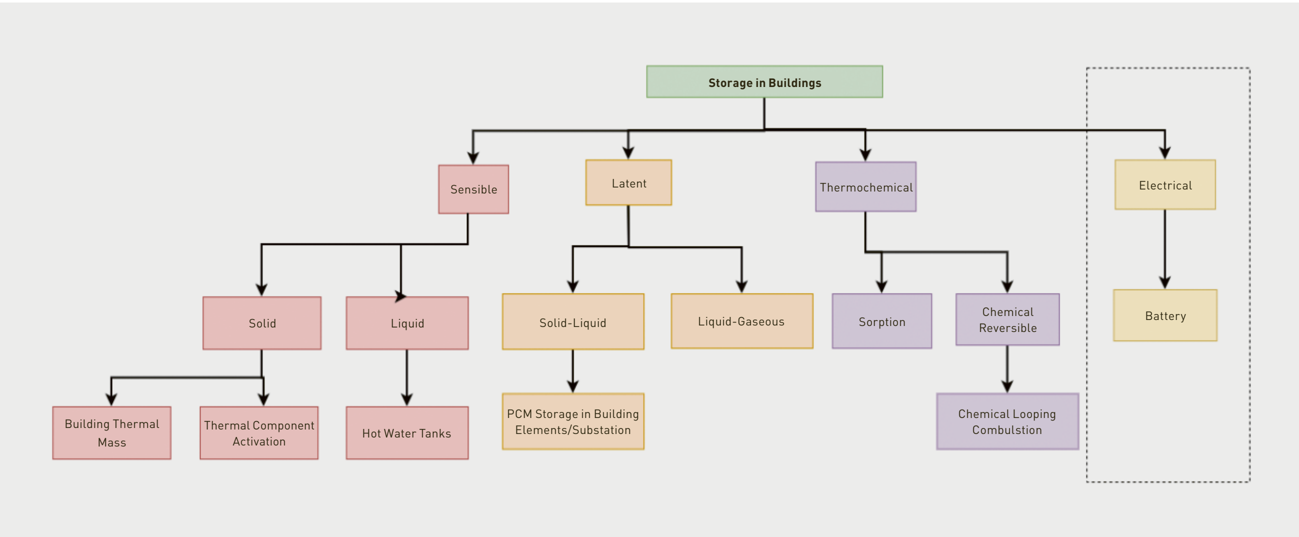
The work is divided into four tasks:

— Collaboration models – WHO
— Technology at building level – HOW hardware
— Methods and Tools – HOW software
— Case studies

Objectives

The Annex 84 work is divided into four following objectives representing the social, technological, methodological, and practical aspects of the demand response (DR) concept:

— Provide knowledge on partners / actors involved in the energy chain and on collaboration models / instruments for successful demand management.
— Classify, evaluate and provide design solutions for new and existing building heating and cooling installations for successful demand management in various DHC systems.
— Develop methods and tools to utilize data from energy and IEQ monitoring equipment for real-time data modelling of thermal demand response potential in buildings and urban districts.



An example of classification framework for storage options in the building
Source: AEE Intec, IEA EBC Annex 84

— Provide knowledge from and drive adaptation and visualization of project results through case studies and best practices.

Deliverables

The planned deliverables from this project include:

— comprehensive knowledge about the actors involved in the demand response of building in thermal networks;
— design guidelines for new and existing DHC substations and heating / cooling installations with specification of minimum technological requirements for enabling demand management beneficial for buildings and DHC Nets;
— method to derive new dynamic building characteristics from real-time data from smart heat meters used for DHC Nets real-time modelling;
— case studies of demand management at either single technology, building or DHC community level.

Progress

The demand response concept bridges the heating / cooling sector and the building sector, therefore the first working task focused on creating an overview of the existing situation in the field. This task included the survey directed to DHC professionals who daily struggle with the operation of DHC systems. The survey includes 17 questions, and it is available in English, German, French, Italian and Spanish.

The second work item was to create collect data on the production and demand side characteristics, the status of the existing legal framework for DR concept application together with the identification of national DR initiatives were investigated and are described in the soon-to-publish scientific publication in Energy.

Data from the existing building was collected for various European countries to group buildings based on publicly available information such as year of construction, specific heat / cold demand, building usage (e.g single family home, apartment block, office, factory. etc) as well as connection rates of each group type to DHC systems. In doing so, an overview of the most typically connected building typologies per country is being obtained, both in terms of total number of buildings connected as well as aggregated heated / cooled floor area.

A building's suitability to enable DR in DHC systems is highly dependent on its physical properties and operation (customer behaviour). Different technological options integrated at the building level enable DR. The preliminary task, the project work focused on development of the classification frameworks for various components of the building heating / cooling installations.

Data on ten case studies have been collected. The KPIs to evaluate them have been developed as part of the activity the Subtask 'KPI working group'. Currently, a brochure describing the key characteristics of each case study is under development.

Meetings

In 2022, the project held two meetings as follows:

— The 2nd hybrid working meeting was held in March–April, 2022, hosted in Kassel, Germany.
— The 3rd working meeting took place in September 2022 in Aalborg, Denmark, together with IEA DHC TCP Annex TS4 'Digitalisation of District Heating and Cooling' to share experience and establish collaboration.

Project duration
2020–2025

Operating Agents
Anna Marszal-Pomianowska, Aalborg University, Denmark

Participating countries
Austria, Belgium, Denmark, Italy, the Netherlands, Singapore, 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. 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 time it takes for building codes to integrate research and technology breakthroughs, thus limiting the energy savings potential of building energy codes.

In 2018, the International Energy Agency's Energy in Buildings and Communities Program (EBC) launched the Building Energy Codes Working Group (BECWG) to address these challenges. The BECWG goals are centered around furthering building energy codes research and collaboration efforts to advance energy efficiency in buildings and communities. The BECWG is dedicated to the consideration of building energy codes in EBC Annexes, along with the integration of Annex 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:

— Activity 1: Analysis and technical reports. The project is conducting surveys on basic codes information to understand the range of practices across participating nations. Drawing on the results of these surveys, the project is developing reports around various topics of interest such as building energy codes for existing buildings and best practices for code compliance.
— Activity 2: 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. The project is also hosting an Annual Building Energy Code Symposium, which allows the project members to exchange ideas on relevant topics of interest.
— Activity 3: Dissemination. In addition to conducting analyses and facilitating webinars, the project is working towards disseminating their research findings to wide range of regional stakeholders and collaborate with them closely to promote code improvements and implementation of best practices. The project is disseminating their findings through the EBC website, conference papers, and quarterly newsletters.

Progress

Analysis and technical reports

— The BECWG released two reports titled 'All countries targeted for zero-carbon-ready codes for new buildings by 2030' (with IEA) and 'International review of energy efficiency in data centers' (led by Australia) in 2022.
— BECWG (led by USA) published a paper titled 'What, why and when to go virtual: An international analysis of early adopters of virtual building energy codes inspections' in the journal Energy Research & Social Science. The paper explored how remote inspections have impacted processes for building energy code compliance checks around the world.
— The BECWG is developing four topical reports in 2023–24. These topical reports include: 1) a report led by Australia on climate resilience in building energy

Construction of Energy Sciences Building at the Pacific Northwest National Laboratory, United States. While building energy codes have been a central tool for many jurisdictions to increase the energy performance of newly constructed buildings, contemporary codes are increasingly expanding to cover existing buildings at times of major renovations. Source: Pacific Northwest National Laboratory, 2021.

codes, 2) a report led by Japan on new technology integration in building energy codes, 3) a report led by Canada on embodied carbon in building energy codes, and 4) a report/paper led by US on global building energy codes impact analysis.

Webinars and other events

— The BECWG had hosted two webinars in 2022. The webinars were focused on: (1) embodied carbon in building energy codes, and (2) management of energy efficiency in data centers.
— The BECWG held its fourth Annual Symposium on 8 November 2022 and was hosted in Istanbul, Turkey. The symposium was a hybrid event and comprised of three technical sessions. The technical sessions focused on: (1) implementing building performance standards, (2) integrating new technologies in building energy codes, and (3) methods for assessing progress with the building energy code implementation.
— BECWG participated in the 2022 IEA Future Buildings Forum (hosted in Ottawa, Canada) and presented in a session on 'Building Energy and Carbon Codes: Considerations, Opportunities, and Challenges'. In addition, BECWG participated in a panel session on 'A New Era in Advancing Buildings Decarbonization' at the 2022 Global Clean Energy Forum (Pittsburg, US).

Dissemination

— The BECWG published newsletters, communicating the details of past/future webinars and topical reports to the regional stakeholders.

Meetings

— Fourth EBC Building Energy Codes Working Group Annual Symposium (8 November 2022).
— IEA Future Buildings Energy Forum (October 2022)
— Webinar on 'Embodied Carbon in Building Energy Codes' (October 2022)
— Global Clean Energy Forum (September 2022)
— Webinar on 'Management of Energy Efficiency in data centers' (April 2022)

Project duration
2019–2022

Operating Agents
David Nemtzow, Department of Energy, USA
Michael Donn, Victoria University of Wellington, New Zealand
Meredydd Evans, Pacific Northwest National Laboratory, USA

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

Further information
www.iea-ebc.org

Positive Energy Districts

EBC ANNEX 83

The expression 'positive energy district' (PED) describes an area within the city boundaries, capable of generating more energy than is consumed, while being agile / flexible enough to respond to energy market price variations. However, the formulation of PED definitions cannot be based merely on an annual mathematical net balance: PEDs should first be based on energy efficiency solutions, support the minimisation of impacts on the connected centralised energy networks by offering options for increasing onsite load-matching and self-use of energy, technologies for short- and long-term energy storage, and providing energy flexibility with smart controls and techniques. In this context, the concept of PED is aimed to facilitate the transition of the urban environment toward carbon neutral communities by including in the urban areas lighthouse innovating areas pushing towards synchronised and parallel development of energy efficient technologies, public perception of building energy systems, new sustainability paradigms and business models. However, as a novel research idea, the PED concept needs further refinement of definitions, improvement in energy and systems modelling for true holistic design of neighborhoods; development of new and integrated sustainability assessment approaches and testing of all aforementioned points within case-studies to establish bi-directional improvements between practice and methodological advances. The project aims at targeting these issues with an integrated approach.

Objectives

The main objectives and scope are as follows:

— Map the city, industry, research and government (local, regional, national) stakeholders and their needs and role with the specific PED project objectives to ensure principal stakeholders iare involved in the development of relevant definitions and recommendations.
— Create a shared in-depth definition of a positive energy district bthrough a multi-stakeholder governance model.
— Develop the required information and guidance for implementing the necessary technical solutions (at building, district and infrastructure levels) that can be replicated and ultimately scaled up to the city level, giving emphasis to the interaction of flexible assets at the district level and also economic and social issues such as acceptability.
— Explore novel technical and service opportunities related to monitoring solutions; big data; data management; smart control and digitalisation technologies as enablers of PEDs.
— Develop the required information and guidance for the planning and implementation of PEDs, including both technical and urban planning. This includes economic, social and environmental impact assessments for various alternative development paths.

Deliverables

The planned main project outcomes are as follows:

— definitions and key concepts for PEDs;
— methods, tools and technologies for realising PEDs;
— governance principles and impact assessment for PEDs, and case studies on PEDs and related technologies.

Progress

The project work in 2022 has seen the significant advancement on the development of a joint PED database together jointly with the Cost Action PED-EU-NET, JPI Urban Europe and EERA-Net, based on the data collection framework developed in the previous year. The database includes a wide range of case studies with specific information on the location, energy balance, publications and further information on design methodologies and tools used for the design.

A repository of PED guidelines for design is underway in order to investigate similarities and propose harmonized outputs: more than 40 guidelines to designing PEDs have been collected and systematically classified.

Positive energy district demonstrator in Sello, Finland.
Source: EBC Annex 83

Moreover, the analysis of the state of the art on sustainability assessment of PEDs was used as basis for the development of a framework for sustainability assessment of Positive Energy Districts: the approach is investigating the environmental, social and economic perspective, investigating and harmonizing different methodologies and ultimately proposing indicators and solutions to design sustainable PEDs.

A review of existing PED case studies is being developed with a specific focus on modelling choices and energy systems developed for different solutions and climates as well as within the framework of energy flexibility solutions for PEDs.

Among the dissemination and training activities the EBC Annex 83 PhD Summer school on 'Positive Energy Districts: Towards a holistic approach to modeling and performance assessment' was held in Canada in the first week of July. The school tackled issues such as plus energy design, urban energy modeling, energy systems modeling, energy flexibility, environmental analyses, data-driven modelling, business models. More than 40 students from different countries participated and worked.

In July 2022, the project organized a workshop titled 'Sharing the experiences on Positive Energy Districts: Lessons learned from Annex 83' as a parallel event to the SSPCR conference in Bozen. The event was meant to involve stakeholders and interact with the Annex 83 participants in order to create a forum for exchanging knowledge and know-how. More than forty people joined this event in person.

In 2022, the Subtasks have planned and implemented further different internal and open workshops on: PED definitions, energy systems design and district energy modelling and dissemination local workshops.

Several journal papers have been published and the project participants have been involved in the management of Journal special issues connected with the project work.

All outcomes of the open forums and workshop have been used in developing project deliverables and meeting the aforementioned project objectives.

Meetings

The following meetings were held in 2022:

— The 4th Working Meeting was held online in April 2022.
— The 5th Working Meeting was held in Espoo, Finland, in September 2022.

Project duration
2019 – 2024

Operating Agents
Pekka Tuominen and Francesco Reda, VTT Technical Research Centre of Finland Ltd., 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, Türkiye, 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 a low-carbon energy system that displaces conventional fossil fuels with renewable energy sources while maintaining, if not improving, the operation of the energy system. Building energy flexibility may address several challenges facing energy systems and electricity consumers as society transitions to a low-carbon energy system characterized by distributed and intermittent energy resources. For example, by changing the timing and amount of building energy consumption through advanced building technologies, electricity demand and supply balance can be improved to enable greater integration of variable renewable energy. Although the benefits of utilizing energy flexibility from the built environment are generally recognized, solutions that reflect diversity in building stocks, customer behavior, and market rules and regulations need to be developed for successful implementation.

In a paper to the journal Building and Environment, Annex 82 poses and answers ten questions covering technological, social, commercial, and regulatory aspects to enable the utilization of energy flexibility of buildings in practice. The paper provides a critical overview of techniques and methods for quantifying and harnessing energy flexibility. Concepts of resilience and multi-carrier energy systems and their relation to energy flexibility are discussed. The importance of balancing stakeholder engagement and technology deployment is highlighted. Finally, the crucial roles of standardization, regulation, and policy in advancing the deployment of energy flexible buildings is brought into focus. The ten questions are:

— How can building energy flexibility contribute to a low-carbon future energy system?
— How can energy flexibility be quantified?
— How can energy flexibility be harnessed?
— How do multicarrier energy systems contribute to energy flexibility?
— Can energy flexible buildings contribute to energy system resilience?
— Who are the stakeholders involved in energy flexibility?
— What new approaches to the design of energy flexibility solutions can increase user engagement?
— How should energy performance standards and requirements be adapted to support building energy flexibility?
— What business models can successfully develop and utilize energy flexibility?
— How can policy evolution support the future deployment of energy flexibility?

Objectives

The project objectives are to:

— demonstrate and further develop the project characterisation and labelling methods in order to make them commonly accepted;
— 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.

The Annex 82 participants – happy to finally meet in person after two years with online meetings due to corona.
EMPA, Zürich October 2022.
Source: Federica Bellizio, EMPA

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

There is on-going cooperation between EBC Annexes 82 and 81 with participants from the two projects jointly contributed to two review papers. A third literature review is initiated entitled: Flexibility and Resilience in buildings and communities: A review of the role of multicarrier energy systems.

Work on dominant factors and penalty signals is ongoing. The results are being utilized in a series of Common Exercises. A first common exercise has been conducted using own data sets utilizing common guidelines. The aim was to test the methodology developed in Annex 67 for obtaining Flexibility Functions. Ten Annex 82 teams have carried out this exercise, which lead to the refinement of the Annex 67 methodology. Following this more detailed research questions are being defined and some are being tested in the Common Exercise 2. These research questions are: boundary conditions, penalty signal amplitude, consecutive events, starting conditions, clusters vs. individual, multi-carrier, resilience, signals for business models, incorporating behaviour, multi-objective optimization.

The collection of case studies showing different business cases for utilization of energy flexibility from buildings is being carried out. The aim is to show energy flexibility created value from real life demonstrations.

A study has been initiated to review new strategies on how to design DR schemes and solutions based on active involvement of prospective stakeholders in the future design (co-creation and co-designing methods) – including barriers and motivations for energy technology providers to develop solutions in cooperation with the users.

Meetings

The following meetings were held in 2022:

— 2nd working meeting, online April 4–5, 2022,
— 3rd working meeting, Zürich 10–11 October 2022.

Project duration
2019–2025

Operating Agents
Søren Østergaard Jensen, Technical University of Denmark, Denmark
Rongling Li, Technical University of Denmark, Denmark

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

Further information
www.iea-ebc.org

Data-Driven Smart Buildings

EBC ANNEX 81

Digital technology has potential to save energy through advanced control and operation of building heating, ventilation and air-conditioning (HVAC) systems. Emerging digital technologies include:
— the 'Internet of Things';
— Artificial intelligence (AI), machine learning (ML) and related data analytics techniques;
— digital platforms and semantic web technologies.

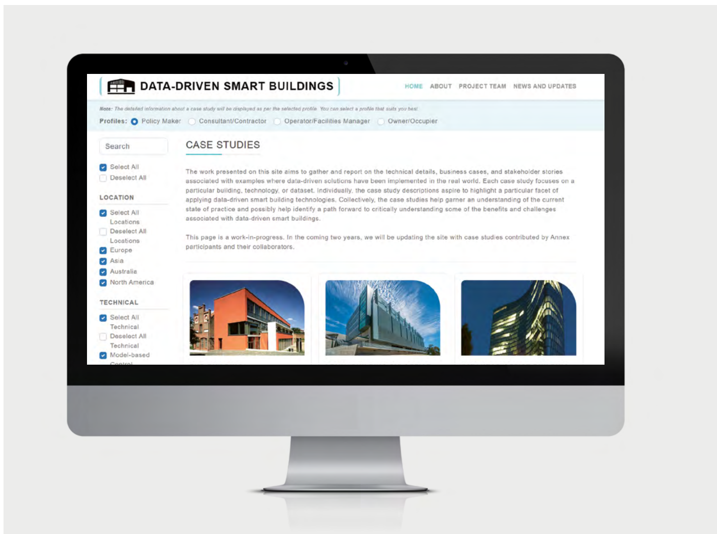
The project aim is to accelerate an adoption of digitalisation and energy saving data-driven services in non-residential buildings. It seeks to optimise energy consumption from HVAC equipment through data-driven control strategies and equipment fault diagnostics. It also aims to address interoperability and other data management barriers which prevent digital technologies from being adopted at scale.

In collaboration with the Mission Innovation Affordable Heating and Cooling Innovation Challenge, the project is supporting researchers and innovators through the hosting of AI competitions.

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

Deliverables
The planned deliverables from this project include:
— a proposal for governments to use of data-driven smart building solutions in their own buildings and, particularly, to adopt the HVAC data-sharing principles and processes developed in this project;
— a report on functional-requirements for a 'minimum viable product' (MVP) Open Data Platform that could support low transaction cost data-sharing amongst an ecosystem of building services innovators;
— an online repository of exemplar data sets for building analytics research;
— data-driven control-oriented building models suitable for model predictive control in different building typologies and scenarios;
— a software repository, containing prototype software implementations and Application descriptions for energy saving HVAC services;
— a 'grand challenge' / 'hackathon' style competition for incentivising innovators to develop data-driven applications.

Case Studies of Data-Driven Smart Buildings
Source: EBC Annex 81



Progress

Several publications were produced reviewing specific aspects of Data-Driven Smart Buildings, including (i) guidelines for managing data governance issues and maxmising the availability and value of data, (ii) a review of building information management using meta-data schemas (iii) a review of data-driven fault detection and diagnostics for building HVAC systems, and (iv) a review of data-driven key performance indicators and datasets for building energy flexibility. This work has been further aggregated into a major review report on the state of the art of data-driven smart buildings.

The Annex defined its own version of what a 'data-driven smart building' is, incorporating statements of (i) the purpose for embedding intelligence and (ii) how intelligence is achieved.

A review of available schemas for structuring and sharing data, during the operational phase of building life, considered seven meta-data schemas. It classified the usefulness of these schemas across a range of qualitative dimensions, to help users to understand the benefits and limitations of schemas in different scenarios.

Research showed that most data platforms use some form of structured data-schema for managing data and use APIs for sharing data. However, most providers are still working in siloes and so there is a need to both standardise on software tooling and support semantic interoperability.

Nineteen model predictive control (MPC) test cases were reviewed, and high-quality, high-resolution datasets were published for six of the test cases; being representative of different building typologies, countries and climates. These datasets can be used to develop, test and benchmark advanced control applications. The BOPTest Framework, for benchmarking MPC algorithms, has been expanded to include seven emulated buildings with a further five emulators under development. Four organisations are using BOPTest to evaluate the performance of their data-driven control algorithms.

A special issue, 'AI in Smart Buildings', was published in ASHRAE's research journal - Science and Technology for the Built Environment. An editorial and four papers from the project were published. Lawrence Berkeley National Lab work, collecting AFDD uses case data, and software/strategy data, has been shared with participants to develop and test AFDD algorithms. The difficulty with characterizing electricity demand flexibility in buildings was illustrated when 330 building-to-grid (B2G) data sets were reviewed - of which 16 were considered adequate for analysis. Research is required to better understand data sufficiency for calculating B2G KPIs and drive data quality / consistency. The activity aims to develop a Python package to calculate data driven B2G KPIs. Nine case studies of digital innovation in real-world buildings were published under creative commons at a dedicated project website (datasmartbuildings.org).

The ERA-Net sponsored ADRENALIN (dAta-DRivEN smArt buiLdINgs) project with 10 Partners (4 academics, 6 industrial) and 3 non-EU Observers commenced in May 2022. A tutorial of the Data Clearing House hosting platform was given to the ADRENALIN consortium. New data sets are being collected in preparation for the first data-driven smart buildings competition in 2023. Results of the Hong Kong EMSD Global AI Challenge were presented in an EBC Annex 81 webinar. This is enabling the project to deliver the anticipated competitions.

Meetings

The following meetings were held in 2022:

— Fifth Research Results Webinar, in March 2022
— Fourth Expert Meeting, Online, in May 2022
— Fifth Expert Meeting, Gothenburg, October in 2022
— Sixth Research Results Webinar November in 2022

Project duration
2020–2024

Operating Agents
Stephen White, CSIRO, Australia

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

Further information
www.iea-ebc.org

Resilient Cooling of Buildings

EBC ANNEX 80

The use of energy for space cooling is growing faster than for any other end use in buildings. Rising demand for space cooling is already putting enormous strain on electricity systems in many countries, as well as driving up greenhouse gas emissions. There is no doubt that the global demand for space cooling will continue to grow for decades to come. Meeting peak electricity demand would become a major challenge. It is therefore vital to curb the rapid growth in demand for air conditioning and achieve sustainable development of the sector of cooling.

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

Objectives

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

— quantify the potential benefits of resilient cooling for a wide range of building typologies, climate zones, functional specifications and other boundary conditions;
— systematically assess benefits, limitations and performance indicators of resilient cooling;
— identify barriers to implementation and conduct research to overcome such barriers and facilitate implementation on a large scale;
— provide guidelines for the integration of resilient cooling systems in energy performance calculation methods and regulations. This includes specification and verification of key performance indicators;
— extend the boundaries of existing low energy and low carbon cooling solutions and their control strategies, and develop recommendations for flexible and reliable resilient cooling solutions that can create comfortable conditions under a wide range of climatic conditions;
— investigate the real performance of resilient cooling solutions through field studies, and analyse performance gaps and develop solutions to overcome them;
— analyse, exchange and encourage policy actions, including minimum energy performance standards, building codes, financial incentives and product labelling programmes, educational initiatives, as well as others;
— establish links with other international programmes, such as KIGALI – Cooling Efficiency Programme, Mission Innovation Challenge #7 and other related IEA Technology Collaboration Programmes.

Deliverables

The project is producing the following deliverables:

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

Progress

In 2022, the project reached the fourth year of its working phase, and published the following conference and journal papers:

— Interaction of urban heat island and heatwave: comparison of the days with heatwave and without heatwaves
— Evaluating future projected building energy performance using a synthesized representative urban effect preserved (SYRUP) climate dataset
— A data schema for exchanging information between urban building energy models and urban microclimate model for coupled simulations
— Evaluation and mapping the indoor thermal risk of older people in long-term care (LTC) buildings with their local weather conditions
— Identification of heat vulnerable buildings and communities through global environmental multiscale and city building energy modeling of heatwaves

- A new method of selecting future reference years for indoor overheating assessment during heatwaves
- Resilient Cooling in Buildings – A Review of definitions and evaluation methodologies
- Analyzing the climate-driven energy demand and carbon emission for a prototype residential nZEB in central Sweden
- Using machine learning algorithms to multidimensional analysis of subjective thermal comfort in a library
- Development of a bioheat model for older people under hot and cold exposures
- Investigation of Human Thermal Comfort and Physiological Response in Bed with Personalized Climate System
- Development of criteria for limiting overheating in buildings having long-term care and senior occupants in respect to heat-related health of building occupants
- Interaction of urban heat island and heatwave – Comparison of the days with heatwave and without heatwaves
- Evaluating future projected building energy performance using a synthesized representative urban effect preserved (SYRUP) climate dataset
- Added value of convection permitting climate modelling in urban overheating assessments
- Simulation-based framework to evaluate resistivity of cooling strategies in buildings against overheating impact of climate change
- Evaluating approaches of selecting extreme hot years for assessing building overheating conditions during heatwaves
- Impact of reflective materials on urban canyon albedo, outdoor and indoor microclimates
- CityFFD city fast fluid dynamics for urban micro-climate simulations on graphics processing units
- Estimating urban wind speeds and wind power potentials based on machine learning with City Fast Fluid Dynamics training data
- Calibration of building model based on indoor temperature for overheating assessment using Genetic Algorithm

Meetings

The following meetings were held in 2022:

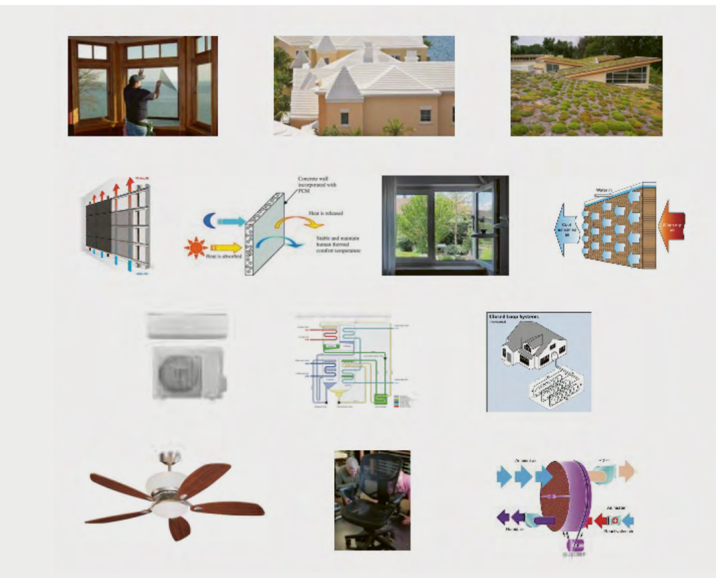
- The 6th Expert Meeting was held in Aalborg, Denmark in April 2022.
- The 7th Expert Meeting was held in Florianópolis, Santa Catarina, Brazil in October 2022.

Project duration
2019–2023

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

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

Further information
www.iea-ebc.org



To assist with making recommendations for policy makers, the project has documented existing policies for cooling strategies that reduce heat gain, remove sensible heat, enhance personal comfort, or remove latent heat, and has also reviewed whole-building performance policies.
Source: EBC Annex 80

Occupant-centric Building Design and Operation

EBC ANNEX 79

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

Despite progress in experimental research and occupant behaviour modelling, design and building operation practice shows that many models do not represent the manifold human interactions with a building appropriately enough, and that there is no guidance for designers and building managers on how to apply occupant behaviour models in standard practice. This project seeks to bridge this gap between science and building practice, to provide new insight into comfort-related occupant behaviour and interactions in buildings, and to exploit new data mining techniques to enhance occupant modelling.

Objectives

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

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

Deliverables

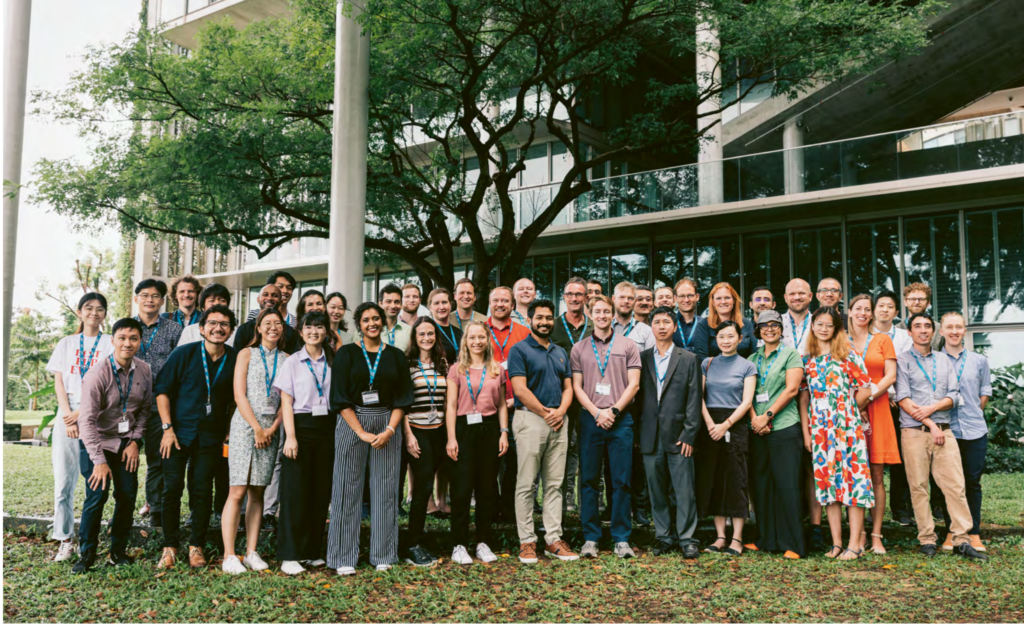
The main planned project outcomes are as follows:

- a overview report giving of the most significant activities and contributions of the project to different audiences;
- a book of the 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 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 or spaces that demonstrate occupant-centric controls.

Progress

In 2022, the Annex wrapped up existing activities and dissemination. A international survey was conducted to understand occupants' willingness to share information needed in research studies and for improving design and operation. Further, a review paper was published which critically investigated multi-domain comfort studies to develop guidelines for such studies. An international round-robin test in multiple similar climate chambers aims at investigating physiological responses of occupants exposed to multi-domain environmental stimuli. Finally, an IEQ work-from-home survey has been developed and is collecting data, given the widespread global transition to telework.

Platforms were developed for sharing both occupant behaviour data (ASHRAE Global Occupant Behavior Database) and data-driven models. Moreover, a method and tool were developed to anonymize occupant data such that the occupant behavior data cannot be used to identify the original occupants. A literature review on synthetic population models was performed to develop methods and recommendations for occupant modeling and design applications.



In-person participants of the Singapore meeting in Sept. 2022
Source: National University of Singapore

The manuscript for a open-source book titled Occupant-centric simulation-aided building design was completed in 2022 (publication date mid-2023). The book is the major outcome of the Annex's occupant-centric design efforts and includes occupant-centric design procedures; methods to collect information about occupants during the design process; development and application of occupant-centric methods, fit-for-purpose occupant modeling approaches; simulation-aided design methods; best practices for building interface design for usability; simulation of occupant-centric controls; and finally case studies. The case studies demonstrate how occupant-centric methods can be applied to a diverse assortment of buildings at various life cycle stages and in different locations.

In order to advance building operations and controls researchers have largely focused on simulation-based occupant-centric controls (OCC) research and OCC in both non-residential (commercial and institutional) and residential buildings. An ontology for OCC case studies was developed with case study collection underway. In 2022, the researchers developed standardized methods to evaluate the benefits of OCC in the case study buildings. Finally, a methodology to longitudinally collect occupant data was developed to help inform occupant-centric controls.

Several cross-task activities have advanced, with significant progress on the following activities: investigation of the availability and quality of occupant data in the early design advancing agent-based modelling of occupant behaviour, a framework for occupant behaviour models documentation, the ASHRAE Global OB Database, and the characterization of human factors and ergonomics for the built environment.

In 2022, Annex 79 was present at the ASHRAE Annual Conference in June 2022 in Toronto, where two seminars were led including one on the Global OB Database. Additional seminars were led at CLIMA conference in Rotterdam (May 2022), Indoor Air conference in Finland (June 2022), and COBEE conference in Canada (July 2022). Annex 79 also presented on occupant aspects of building energy codes at the IEA Future Buildings Forum in Canada (October 2022). The Annex has published widely in leading international journals, including a special issue on occupant-centric controls in the Journal of Building Performance Simulation. Annex 79 continued its close cooperation with ASHRAE by leading a set of chapters on measuring occupancy and occupant behaviour in buildings in the ASHRAE Performance Measurement Protocol.

Meetings

The following meetings were held in 2022:

— The 8th Expert Meeting was online and hosted by London, UK in March 2022
— The 9th Expert Meeting took place in Singapore and online in September 2022

Project duration
2018 – 2023

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

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

Further information
www.iea-ebc.org

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

EBC ANNEX 78

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

There are an increasing number of publications in many countries related to air cleaning and there are also increasing sales of gas-phase air cleaning products. This introduces a demand for verifying the efficacy of air cleaning on indoor air quality for comfort, wellbeing and health. It is thus important to learn whether air cleaning can supplement ventilation with respect to improving air quality, i.e. whether it can partly substitute the ventilation rates required by standards. Finally, the energy impact of using air cleaning as a supplement to ventilation needs to be estimated. This project is focusing on gas-phase air cleaning, but does not include filtration.

In some locations in the world, the outdoor air quality is so bad that 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;
— models for predicting the performance of gas phase air cleaning equipment.

Progress

The project started its working phase in July 2019. Due to the pandemic, it was not possible to organize any face-to-face meetings during 2020 and 2021. Several online meetings and presentations at conferences and seminars were made.

A concept for partly substituting ventilation with gas phase air cleaning technology has been established and published. Energy performance of gas phase air cleaning technologies has been studied by three of the participating universities. These studies are mainly based on computer simulations, but without any data for the systems in operation. For absorption air cleaning technologies the pressure loss in the ventilation system increases 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 energy. It is now being analysed if it is more energy efficient to use an air cleaner, or to increase the quantity of outside air.

Experimental studies on a test procedure were conducted at the Technical University of Denmark during 2022, in which more than 30 subjects participated. Three different air cleaning technologies were used. Perceived air quality was measured both by whole body exposure and through air funnels according to ISO16000-44. However, not all technologies improved the perceived air quality. The whole body testing gave stronger responses from the subjects than the facial exposure, but both methods gave the same trends. The test procedure is planned to be the basis for a new test standard under ISOTC142.

Meetings

In 2022, the following meetings were held:

— Online expert meeting in June 2022, and
— Online expert meeting in October 2022.

Project duration
2018–2024

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

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

Further information
www.iea-ebc.org

Testing of perceived air quality with whole body exposure (left) and use of funnels (right).
Source: International Centre for Indoor. Environment and Energy, Technical University of Denmark

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

EBC ANNEX 75

Buildings are a major source of carbon emissions. Reducing energy use and carbon is challenging for the existing building stock. There are often architectural and technical hurdles to achieving low emissions and low energy use in the existing ones unlike new contruction. Also, the cost-effectiveness of a high energy performance in existing buildings is often lower than in constructing new buildings. However, specific opportunities for district-level solutions in cities must be explored. This project aims to clarify the cost-effectiveness of various approaches combining energy efficiency and renewable energy measures at the district level. At this level, finding the balance between these two types of measures for the existing building stock is a complex task.

Objectives

The project's general objectives are to:

— investigate cost-effective strategies for reducing GHG emissions and energy use in buildings at district level, in an urban context, combining both energy efficiency measures and renewable energy measures;

— provide guidance to policymakers, companies working in the energy transition field, as well as building owners, on how to cost-effectively transform existing urban districts into low-energy and low-emission districts.

Its focused objectives are to:

— give an overview of various existing and emerging technology options and how challenges occurring in an urban context can be overcome;

— develop a methodology to identify cost-effective strategies for renovating urban districts, supporting decision-makers in the evaluation of the efficiency, impacts, cost-effectiveness, and various solutions;

— illustrate such strategies in selected case studies and gather best-practice examples;

— give recommendations to policymakers and energy-related companies on how they can influence the uptake of cost-effective combinations of energy efficiency measures and renewable energy measures in building renovation at district level.

Deliverables

The following project deliverables were planned:

— an overview of available and emerging technology for cost-effective building renovation at district level;

— a methodology for investigating cost-effective building renovation at district level;

— an online supporting tool for decision-makers to support the application of the project methodology;

— lessons learned from the application of the methodology into generic districts and case studies;

— success stories of cost-effective building renovation at district level;

— strategies to transform existing districts into low-energy and low-emission districts;

— good practices and lessons learned from transforming existing districts into low-energy and low-emission districts;

— barriers and drivers for energy-efficient renovation at district level;

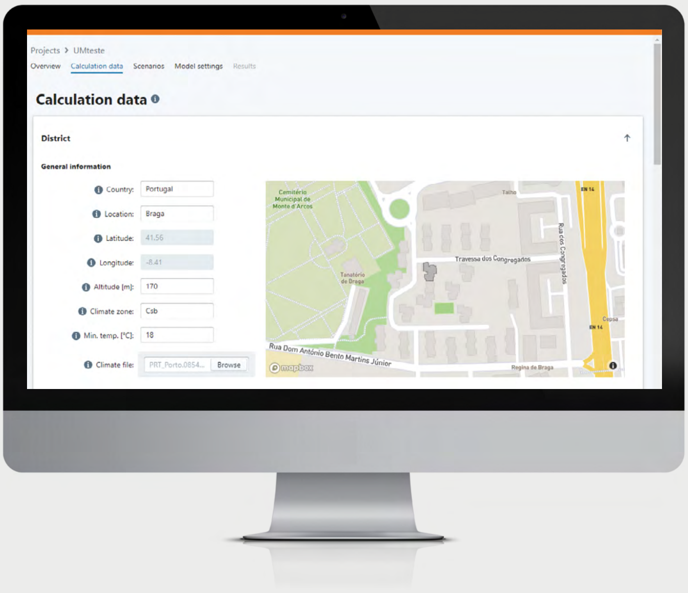
— policy instruments and new business models for encouraging market take-up and transforming existing districts into low-energy and low-emission districts;

— guidebooks for policymakers, energy-related industry, building owners and investors on encouraging the market uptake of cost-effective strategies combining energy efficiency and renewable energy measures, including district-based solutions.

Progress

The project was in its final phase during 2022, mainly finishing the planned reports and promoting dissemination actions. In 2022, the application of the Annex 75 methodology was concluded with the assessment of eight case studies and six generic districts, which also served to test the first version of the online Annex 75 Calculation Tool: https://annex75.bim.energy/.

Lessons learned from the simulation of generic districts and case studies, combined with the assessment of successful examples of district renovation and the



Screenshot of the EBC Annex 75 calculation tool, which helps make project decisions on the cost-effectiveness of renovation solutions at the district level.
Source: EBC Annex 75.

stakeholder interviews, provided content for several of the project reports, which contributed to the dissemination of good practices on cost-effective renovations at the district level. The resulting reports include topics related to international and local level policy instruments, business models and technical solutions according to the initial conditions of the district. Furthermore, they confirm how the active role of the different actors in the renovation process benefits the project and is crucial for its success and effective communication at all levels.

Additionally, after nearly three years of regular remote-only meetings, an in-person meeting took place in Vienna, Austria in June 2022 alongside a workshop to discuss with local stakeholders the main findings and recommendations under preparation in this project. Local and international experiences were shared, resulting in a fruitful contribution to preparing the Guidebook.

In October 2022, the preliminary results of the project were in the IEA Future Buildings Forum Think Tank Workshop. Also in October 2022, a special workshop was organised that was integrated into the SBE22 Delft Conference to give an overview of the work carried out in the project.

In November 2022, the findings of the project were presented at the 23rd EFRIARC Autumn Seminar, in Lisbon, Portugal, as a discussion on the challenges and opportunities of decarbonising the building sector through its renovation at the district level.

In 2022 two papers related to the research from the project were published in the peer-reviewed scientific journal Sustainability, as part of the Special Issue 'Building Renovation—Towards a Decarbonized Building Stock 2050'.

Meetings

In 2022, two meetings were convened:

— An online meeting was held in March 2022.
— A project meeting was held in Vienna, Austria, in June 2022.

Project duration
2017–2023

Operating Agent
Manuela Almeida, University of Minho, Portugal

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

Further information
www.iea-ebc.org

Assessing Life Cycle Related Environmental Impacts Caused by Buildings

EBC ANNEX 72

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

Objectives

The project objectives are to:

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

Deliverables

The following deliverables are planned:

- a report on harmonised guidelines on the environmental LCA of buildings;
- a report on establishing environmental benchmarks for buildings, including case study examples;
- a report on national LCA databases used in the construction sector;
- a report on guidelines for design decision makers on optimization using building assessment workflows and tools;
- a report on building case studies on the application of LCA in different stages of the design process;
- a report on how to establish national / regional LCA databases targeted to the construction sector;
- Report on Optimisation strategies to reduce the life cycle related environmental impacts of new buildings and refurbishments;
- Report on the impact of individual, industry and political decisions on transitions towards environmental sustainability;
- Summary Project Report.

Progress

The focus in 2022 was on editing and finalising the official deliverables and background reports.

A strategy for design decision makers was defined to handle and analyse uncertainty in different design phases. A categorisation for building LCA tools for design decision makers is being proposed. A survey was sent to

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

Source: Raquel Gomez

tool providers and users to obtain necessary information for the assessment of available tools. The goal is to support designers and architects in the choice of a tool to assess the environmental impacts of a building. Experts from seven countries participate on a round robin test of different typical BIM-LCA workflows based on the same BIM model. This activity allows the assessment of differences in extracted bills of quantities and LCA results.

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

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

The "Monte Verità Declaration on a built environment within planetary boundaries", signed by more than 40 scientists from 20 countries was handed over to Philippe Moseley, Policy Officer at the European Commission (see Figure 1) during the final event at the SBE'22, Berlin.

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

The final deliverables are currently being revised based on the review feedback by Executive Committee members. The Annex 72 is expected to be closed during the June 2023 meeting of the Executive Committee in Copenhagen, Denmark.

Meetings

In 2022, the following meetings of the editorial group were held:

— The 1st Editorial Meeting was held online on 17 and 18 March 2022.
— The 2nd Editorial Meeting was organised by Dr Thomas Lützkendorf and Dr Maria Balouktsi and held on 23 and 24 May 2022 in Weimar, Germany.
— Final event (special session) was held on 21 September 2022 at the Sustainable Built Environment Conference SBE'22, in Berlin, Germany

Project duration
2016–2023

Operating Agent
Rolf Frischknecht, treeze Ltd., Switzerland

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

Further information
www.iea-ebc.org

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

EBC ANNEX 70

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

An energy epidemiology approach is well-suited to dealing with uncertainty using methodological tools and analysis techniques. These include: common definitions and metrics; population selection techniques; study designs for data collection, comparison and analysis; approaches to dealing with bias; guidelines for working towards identifying causal relationships, and systematic approaches to reviewing evidence.

The project is focused on identifying, reviewing, evaluating and producing leading edge methods for studying and modelling the building stock, including data collection techniques on energy use, building features and occupant features; building morphology; analysis of smart meter energy data, building systems and occupant behaviour; modelling energy demand among sub-national and national building stocks.

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

Objectives

The project objectives are to:

— support countries in developing realistic decarbonisation transitions and pathways by facilitating better available empirically derived energy and buildings data;

— inform and support policymakers and industry in the development of low energy and low carbon solutions by evaluating the scope for using empirical building stock and energy use data;

— develop best practice in the methods used to collect and analyse data related to real building energy use, including building and occupant data;

— support the development of robust building stock data sets and building stock models through better analysis and data collection.

Deliverables

The following project deliverables are being created:

— a register of energy and building stock data among participating countries and more widely;

— a register of energy and building stock models;

— a data schema for energy and building stock data for developing countries and emerging economies;

— guidelines for energy and building stock model reporting and metrics for stock model comparisons;

— a series of reports on: stakeholder key issues on needs and uses of data; best practice use cases for energy and buildings data; classification for energy and buildings stock data; classification of energy and buildings stock models; stock model uncertainty and sensitivity tests.

Progress

The project is in its reporting phase. Each Subtask has finalised each of its activities and is editing the final report covering the efforts focused on: A) user's needs, B) energy and building stock data, and C) energy and building stock models.

In Subtask A, an Energy and Buildings Stock Data Users & Needs survey was completed with over 800 responses from across the Annex 70 member countries. The survey provides information on what energy and building data a range of stakeholders need and use to support their energy and buildings analysis and modelling, and

Building Market Brief for United Kingdom
Source: Nägeli, C., Camarasa, C., Delghust, M., Fennell, P., Hamilton, I., Jakob, M., Langevin, J., Laverge, J., Reyna, J. L., Sandberg, N. H., & Webster, J. (2022). Best practice reporting guideline for building stock energy models. Energy and Buildings, 260, 111904. https://doi.org/https://doi.org/10.1016/j.enbuild.2022.111904

decision-making to address carbon emissions and improve building energy performance. A systematic literature review described the ways in which published literature describes data use and how these efforts have changed over time. Lastly, case studies describing the use of energy and buildings data from across members illustrate the latest approaches to using, analysing, and modelling with energy and buildings stock data. These activities were used in the Annex 70 energy and building stock data and model registry.

Subtask B built an Energy and Building Stock Data Registry, under the guidance of the International Energy Research Centre in Cork, Ireland. The registry provides an online platform for identifying, describing and sharing energy and building stock data. In 2021 the Registry contains information on over 1000 datasets across the themes of energy, buildings, people, environment, and other important data for energy and buildings analysis. The Registry provides a resource that is intended to continue to be updated with key data attributes and information resources for the research and policymaking community. In addition, a set of best practice guides focused on remote sensing, user surveys, energy metering data, and geospatial energy and buildings data are provided.

Finally, Subtask C developed a model classification that forms the basis of the online Energy and Building Stock Model Registry, which enables researchers to describe building energy stock models. The Subtask has published guidelines for reporting energy and building stock models led by Chalmers and Annex 70 members and offers a framework for reporting models in peer-reviewed journal articles. Finally, the modelling team of Subtask C produced a set of common exercises and guidance for undertaking model uncertainty and sensitivity tests.
Annex 70 partners have been engaged in disseminating the outputs of the Subtasks efforts and the concept of energy epidemiology.

Meetings

The following meetings took place in 2022:

— December 2022 – Annex 70 Subtask leads meeting.
— January 2023 – Annex 70 Subtask leads meeting

Project duration
2016–2022

Operating Agent
Ian Hamilton, University College London, UK

Participating countries
Australia, Austria, Belgium, Canada, P.R. China, Denmark, Germany, Ireland, Japan, the Netherlands, Portugal, Norway, Sweden, Switzerland, UK, 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 43 years since its inauguration in 1979. During this extended operational period, the Centre has been continuously reshaping to reflect emerging concerns and answer to 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 the midst of another 'energy shock', adequate ventilation provision may be put at risk, with the spotlight on the AIVC. The Centre sees this global energy crisis as an opportunity to enhance its networking and dissemination activities and emphasize the significance of ventilation in providing acceptable indoor air quality (IAQ).

Objectives

The objectives of the AIVC are to:

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

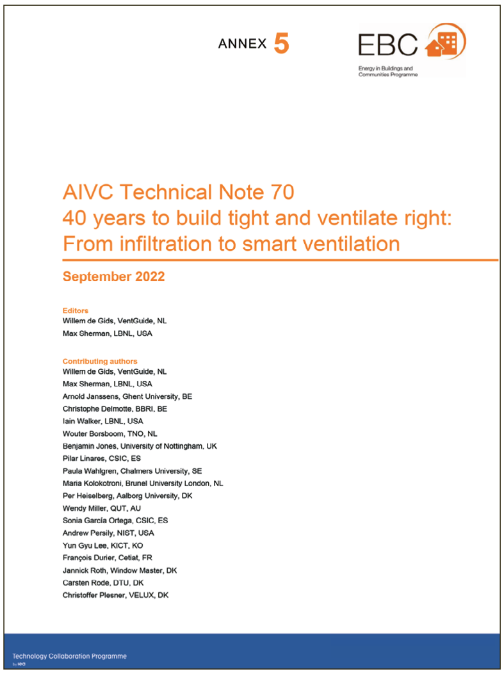
Deliverables

— Events: annual conference, one to two workshops per year on specific topics, and one to two webinars per year;
— Publications: conference and workshop proceedings, technical notes and contributed reports [one per year], and a biannual newsletter

Progress

In 2022, the AIVC focused its work mainly on thirteen projects, the 41st and 42nd AIVC Annual Conferences (due to the COVID-19 pandemic it was not possible to organize physical events in 2020 and 2021), 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', EBC Annex 80 'Resilient Cooling of Buildings', EBC Annex 86 'Energy Efficient Indoor Air Quality Management in Residential Buildings', and EBC Annex 87 'Personalized Environmental Control Systems'.

The latest AIVC project launched is entitled 'Ventilation and IAQ guidelines in context of high energy prices'. Previously launched projects which were still running in 2022 include: 'Energy Recovery Ventilation', 'Personalized Environmental Control Systems (PECs)', 'Airtightness status at country level', 'Ventilation status



TN 70: 40 years to build tight and ventilate right: From infiltration to smart ventilation
Source: EBC Annex 5

at country level', 'Ventilation, airtightness and COVID-19', 'Temperature take-back effect in the context of energy efficient ventilation strategies', 'Rationale Behind Ventilation Requirements and Regulations', 'Indoor Air Quality Metrics', 'Competent Tester Schemes for Building Airtightness Testing', 'Air cleaning as alternative for ventilation', 'IAQ and ventilation specifications in garages', and '40 Years of AIVC'.

In 2022, the AIVC released three Technical Notes (TNs): TN 69: 40 years to build tight and ventilate right: History of the AIVC in February; TN 70: 40 years to build tight and ventilate right: From infiltration to smart ventilation and TN 71: Durability of building airtightness in September. Furthermore 3 Ventilation Information Papers (VIPs) were also published: VIP 45.1: Trends in building and ductwork airtightness in Estonia in July; VIP 45.2: Trends in building and ductwork airtightness in Spain in September; and VIP 45.3: Trends in building and ductwork airtightness in the Czech Republic in December. The project 'Rationale Behind Ventilation Requirements and Regulations' is coming to an end, with a Technical Note as the intended outcome.

TN 70: 40 years to build tight and ventilate right: From infiltration to smart ventilation

The AIVC organized 8 webinars over the course of 2022. Four webinars on resilient cooling of buildings (Indicators to Assess Resilience of Cooling in Buildings, Future weather data and heatwaves, Examples of resilient cooling solutions, and Case studies and policy recommendations) in May and September 2022; an industry oriented webinar on EBC Annex 78 'Substituting Ventilation by Gas Phase Air Cleaning', a webinar on 'Dumb buildings with smart users? Linking building performance and human well being', and a webinar on the 'Use of Super Cool Materials for Efficient Building Ventilation and Heat Mitigation' in November 2022; a webinar on 'IEA EBC Annex 87: Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems (PECs)' was also held in December 2022.

To have more interaction with related organizations and a stronger societal impact, AIVC is a founding member of the Indoor Environmental Global Alliance (www.ieq-ga.net). There is also a close collaboration with the TightVent platform (www.tightvent.eu) and the venticool platform (www.venticool.eu).

AIVC is facilitating collaboration between various initiatives. As an example, the Advisory Board of Practitioners, an initiative from EBC Annex 80, AIVC and venticool, launched in March 2021 seeks to establish a format for regular exchange between Annex 80 scientists and practitioners and planners, as well as representatives from relevant industries.

March and September editions of the AIVC newsletter were published in 2022.

Meetings

The AIVC Board organized two board meetings in 2022:

— Athens, Greece in May, 2022
— Rotterdam, Netherlands in October, 2022

Project duration
1979–2026

Operating Agent
Peter Wouters, INIVE EEIG, Belgium

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

Further information and reports
www.iea-ebc.org

AIVC

www.aivc.org

Completed Research Projects

COMPETITION AND LIVING LAB PLATFORM
(EBC ANNEX 74)

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

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

Competition and Living Lab Platform

EBC ANNEX 74

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

Twenty-one competitions have been conducted up to the end of 2021 of which nine took place in the US, four in Europe, three in China, two in Columbia, two in Middle East (UAE) and one in Africa (Morocco). Due to the worldwide pandemic, the 2020 editions in the US and Middle East have been performed in 2021, the 2021 European edition was postponed to June 2022. With the United Arab Emirates and Morocco – two countries with hot climates – recently held competitions. Many of the experimental houses are used for education or research when transferred back and reassembled in their home countries. The European event in Germany 2022 was the 20th anniversary of the SDE movement.

The project forms the EBC-based platform for mapping and linking the competition and living lab experiences worldwide and working towards improving competition formats. It intends to stimulate technological knowledge, scientific and architectural quality within future competitions and living labs based on the development of a systematic knowledge platform, and to link to knowledge from previous and current IEA TCP activities. The project aspires to increase the impact of competitions and living lab worldwide by means of communication and development of educational material.

Main parts of the project have been linked to an EC project running parallel to document the results and lessons learned, especially from the European Solar Decathlon edition and communicate these within the Smart City Information System. The project was finished by the end of 2020 under the service contract ENER/C2/2016-502/SER/SI2.763962. The final report is made available by the project coordinator: https://www.egen.green/news/solar-decathlon-europe/

Achievements

The EBC Annex 74 online knowledge platform was continuously improved and material added: www.building-competition.org.

Four documents were produced as a result of Subtask A. Its main report includes a review of the European editions of the Solar Decathlon between 2010 and 2019. 65 solar-powered competition buildings with numerous innovations were analysed regarding the building design and construction as well as the energy engineering. The presentation provides the background knowledge for the future development of the competition format. At the same time, it already shows which impulses have been introduced for the edition in 2022 in Germany as a result of the analyses carried out.

The main report supplemented by three so-called focus reports:

- The focus report 'Monitoring Data Visualization' contains for an overview of the graphical processing of the measurement data collected within past Solar Decathlon competitions.
- The report under the title 'Topical Papers' contains a set of thematic in-depth papers that link typical topics of the Solar Decathlon with research and practice issues, pointing out connections to IEA research networks.
- The documentation 'Project Facts Template' presents a newly developed data collection structure for the quantitative data of buildings in a competition.

The Solar Decathlon Europe held in June 2022 was the first edition of the competition profiting from the findings of the EBC Annex 74 outputs.
Source: Steinprinz, University Wuppertal

The main report of Subtask B 'Solar Decathlon Competitions – Impacts and Performance' focuses around a systematic worldwide survey to measure the impact and performance of the various competition editions. Dozens of semi-structured interviews were conducted to complement the raw data of the surveys and to enrich the analysis. More than 70 interviews were conducted with students, professors and researchers, professionals, companies, and the various organizing teams and key people involved in the development of the competition since its origins. These interviews helped to understand the relationship between objectives – strategies – achieved performance, key drivers, lessons learned, and suggestions for future improvement. The intense experience accumulated in all editions is rich and varied. A systematic analysis has been carried out throughout this project that allows for a critical balance, to recognize the great potential of the competition, and to draw many lessons learned not only regarding the competition itself, but also on how to give continuity by taking advantage of previous experience, maximizing the outreach performance.

The purpose of the focus report 'After Competition and Living Lab Scenarios' is to make knowledge available about the after-competition use of Solar Decathlon projects as living labs to those who are intending to participate in a living lab competition and those who are on the way to set up their own living lab. The report allows a compact overview for future organizers and teams about successfully implemented living labs.
All reports are available on the Annex 74 web portal.

Publications

The project deliverables were Competition and Living Lab Platform Science and Technology reports:

— Main Report
— Monitoring Data Visualization
— Topical Papers
— Project Facts Template
— Impacts and Performance.
— After Competition and Living Lab Scenarios

Meetings

No meetings were held in 2022.

Project duration
2018 – 2022

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

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

Further information
www.iea-ebc.org

Towards Net Zero Energy Resilient Public Communities

EBC ANNEX 73

Previously, most planners of public communities addressed energy systems for new facilities on an individual facility basis without consideration of community-wide goals relevant to energy sources, renewables, storage, future energy generation needs and resiliency aspects. Moreover, building-centric planning falls short of delivering community-level solutions for energy efficiency and energy resilience. For example, many building code requirements focus on hardening to specific threats for the 'mission-critical' buildings in a multi-building community. Disruptions of electrical and thermal energy supplies may degrade critical mission capabilities and cause significant economic impacts at military and civilian installations. Thus, sustainable community projects should consider and combine efficiency and resiliency targets. Significant energy savings would reduce heating, cooling and power needs, and thus contribute to increased energy security.

The EBC Annex 73 project scope included the decision-making process and computer-based modelling tools for achieving net zero energy resilient public-owned communities. The goal is to develop guidelines and tools that support the planning of net zero energy resilient public communities and that are easy to understand and execute. Specific objectives are to:

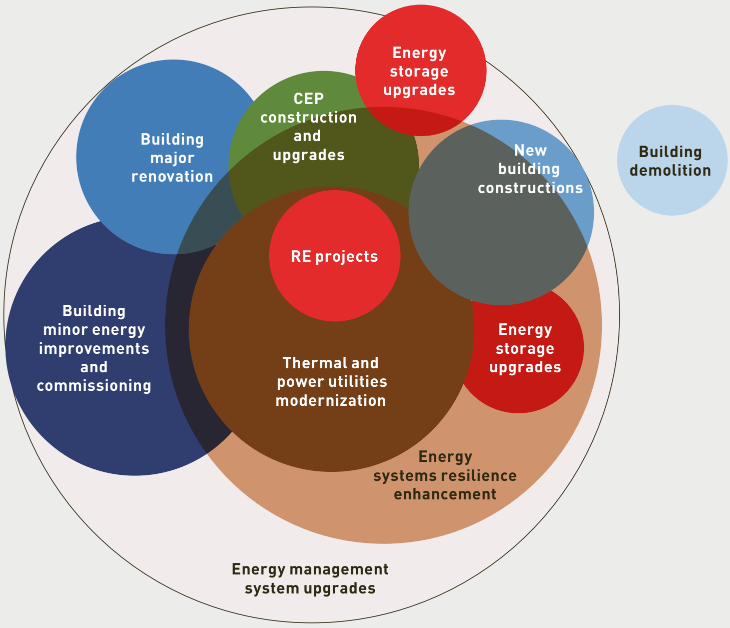
- collect, analyse, and document information about best practice community-wide energy master planning processes and find out how they can be improved;
- develop energy, cost, and resilience targets and constraints;
- develop a database of power and thermal energy generation, distribution and storage technologies, and system architectures;
- develop guidance for 'Energy Master Planning for Net Zero Energy Resilient Public Communities';
- collect and describe the business and financial aspects and legal requirements and constraints that can be used for implementation of energy master plans for public communities in participating countries;
- integrate the targets, constraints, enhanced system architectures, the technology database, and resilience analysis into an interactive modeling and optimization tool.

Achievements

One part of the project was to collect and investigate case studies of community energy master planning. The goal of research was to investigate how energy master planning for entire communities is performed, and to find out how it can be improved. Thirty-two case studies of community master planning for military camps, universities, research institutes, hospitals, small communities, towns, and large cities have been chosen in participating countries, studied, and analyzed. The project has also investigated and analyzed framing goals and constraints for building and community energy projects that must be considered when energy master planning is conducted.

The quantitative approach to resilience established in the project and described in the Energy Master Planning toward Net-Zero Energy Resilient Public Communities Guide allows for evaluation of both the ability of a system to absorb the impact of a disruption (robustness), and its ability to recover. A list of power and thermal energy system architectures technologies and technologies they employ was generated by the project team from case studies, best practices collected using surveys conducted in the USA and in Europe from district energy associations, discussions at the ASHRAE Technical Committee 7.6 'Public Buildings' working group meetings in 2018 and 2019, and from previous experience and research conducted by the project team members.

The scope of the Energy Master Plan (EMP) can be broad; it may include new construction, demolition, and consolidation projects; energy supply; and energy distribution and energy storage components, including creative methods to build innovative site-to-grid arrangements that may provide grid stability or site resilience. The Guide offers variety of implementation



Interrelation of projects under energy masterplanning
Source: EBC Annex 73

strategies and introduces a methodology for life cycle cost analysis (LCCA) of different EMP alternatives. The Energy Resilience of Interacting Networks (ERIN) tool has been developed to support an energy master planning process that allows for the assessment of the resilience of energy supply systems to various DesignBasis Threats. The tool operates over networks that supply both individual buildings and districts.

The Energy Master Planning concept developed in the project and described in the Guide differs from previously developed concepts in such a way that in addition to meeting community's framing energy goals, it integrates development of a highly resilient 'backbone' of energy systems. This allows critical missions and service operations to be maintained effectively during extended outages over a range of emergency scenarios, whether caused by weather, manmade events, or aging infrastructure. The methodology and tools developed in the project have been tested in six pilot projects by teams from Austria, Germany, Denmark, and the USA. The book of pilot projects provides an overview of the pilot studies, lists the tools developed and available to Resilience Energy Master Planning, and describes the Resilience inclusive master planning process.

Finally, two further guides have been developed on resilient thermal energy systems design, one for cold and arctic climates, and the other for hot and humid climates. These address specifics of design in these conditions, including requirements for the building envelope, heating, ventilating, and air conditioning (HVAC) and energy supply systems.

Publications

The project deliverables are as follows:

— Energy Master Planning for Resilient Public Communities – Pilot Studies
— Energy Master Planning for Net-Zero Energy Resilient Public Communities – Project Summary Report
— Energy Master Planning toward Net Zero Energy Resilient Public Communities Guide
— Energy Resilience of Interacting Networks (ERIN) Tool User Guide
— Technologies Database
— Energy Master Planning for Resilient Public Communities – Case Studies
— Guide for Resilient Thermal Energy Systems Design in Cold and Arctic Climates
— Guide for Resilient Energy Systems Design in Hot and Humid Climates

Meetings

No meetings were held in 2022.

Project duration
2018–2022

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

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

Further information
www.iea-ebc.org

Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings

EBC ANNEX 69

Adaptive thermal comfort has been identified as a key point to balance reducing building energy use and providing a comfortable indoor environment for occupants. Widespread evidence has shown that strict indoor temperature control can result in high energy costs and greenhouse gas emissions and may not always be beneficial to the comfort and health of the occupants. The development of adaptive thermal comfort provides criteria and inspiration for the design and operation of low energy buildings. It is indicated that people living in different climate zones share different acceptable ranges of indoor temperature and adaptive responses. The application of adaptive thermal comfort should take seasons and climates into consideration.

If indoor temperature is maintained within the acceptable range, people can achieve thermal comfort through three kinds of adaptive methods: physiological, psychological, and behavioral response mechanisms. A steady indoor thermal environment based on the predicted mean vote (PMV) approach is not always required and may not always accurately represent the true thermal demand of all inhabitants. The actual thermal demand of the inhabitants and thermal adaption mechanisms must be determined in order to overcome the challenges in building energy-saving technology. Additionally, adaptive thermal comfort gives users the chance to customise their environment, which can raise user satisfaction with the indoor thermal environment above what is typically possible with strict adherence to the PMV approach.

Therefore, it is essential to conduct systematic and profound research on adaptive thermal comfort. If the building's services systems could be running in a 'part-time and part-space' mode dependent on occupants' individual demand instead of the 'whole-time and whole-space' mode prevalent in many buildings today, energy use could also be reduced.

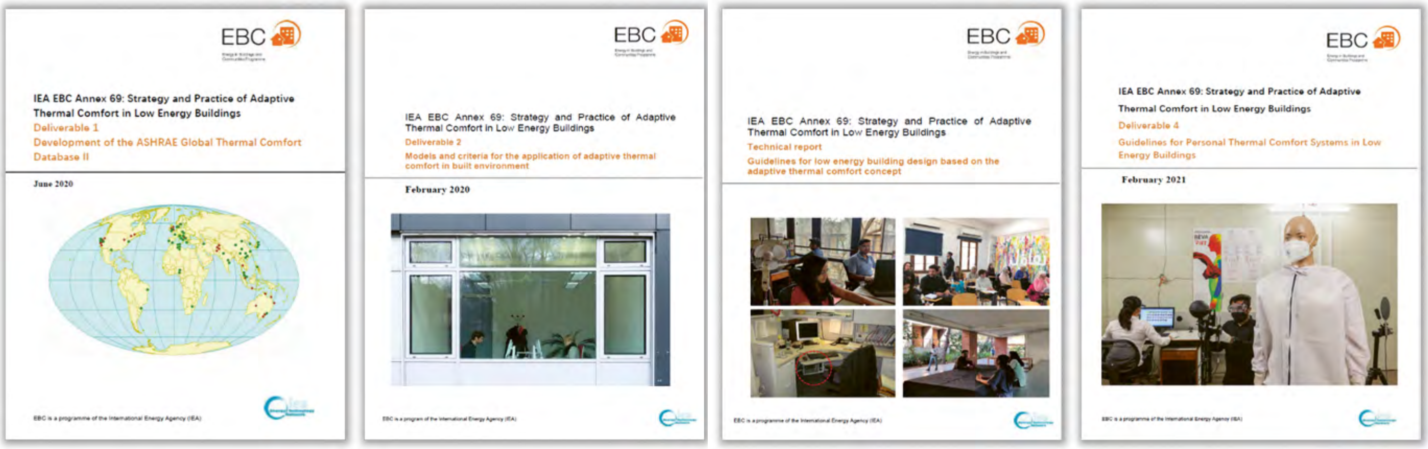
Achievements

EBC Annex 69 was an international collaborative project involving 48 participants from 12 countries. It has developed an analytical and quantitative description of occupants' adaptive thermal comfort in buildings. It has provided appropriate design strategies, comfort assessment methods, and control algorithms for indoor environments. The underlying rationale of the project was to balance comfortable indoor environments alongside building energy efficiency. The project comprised four key components:

— establish a global thermal comfort database with quantitative descriptions of occupant thermally adaptive responses;
— propose a revision of indoor environmental standards based on adaptive thermal comfort concepts;
— application of the adaptive thermal comfort concept to achieve low energy intensities in buildings;
— provide guidelines for developing personal thermal comfort systems.

The Global Thermal Comfort Database II comprises empirical data from five continents and 23 countries, contributed by 47 field research projects. It contains 82,000 sets of objective indoor climatic observations paired with 'right-here-right-now' subjective evaluations of thermal environment by the building occupants. Database II is online and open-source. Online data analytics and visualisation tools are provided for researchers and practitioners to explore and navigate their way around this large repository of comfort data.

Existing international standards were compared on the extent of their permissible thermal variability and compatibility with adaptive thermal comfort processes. New research into adaptive mechanisms was conducted, including methodological aspects such as linguistic differences in the subjective rating scales used to quantify thermal perception, and the speed of adaptive comfort responses to dynamics in outdoor climatic environments. Novel approaches to the modelling of individual adaptive



The project deliverables may widely benefit building planners (architects, engineers, sustainability certification consultants) and building operators (facility managers, operators, owners, and tenants), HVAC manufacturers, building science research and education communities, and end-users wishing to explore energy-efficient solutions without compromising occupant thermal comfort.
Source: EBC Annex 69

mechanisms within the context of the classic heat-balance thermal comfort models were also developed. Methods of quantifying the predictive accuracy of thermal comfort models are summarised.

A new framework was developed to embed adaptive comfort principles in the design and operation of buildings, structured around five elements: adaptive principles; building context; adaptive responses; design phase, and operation of the building. The framework and associated guidelines are generic, thereby facilitating their application across different building typologies, occupancy patterns, climate zones, and occupant groups. To derive practical insights and recommendations, 14 exemplar buildings were investigated.

Appliances enabling individual building occupants to manage their microclimate within a climate-responsive building are collectively referred to as Personal Comfort Systems (PCS). They come in a variety of types and can be used for heating, cooling, ventilation, or various combinations thereof. By focusing on the microclimate of individual occupants rather than the entire space inside a building, PCS offers significant potential to optimise occupant comfort while reducing overall energy demand of the building. The project established a guideline for PCS based on latest peer-reviewed research publications, which presents a classification scheme for PCS, defines important PCS characteristics device-by-device, and develops a protocol for assessing PCS comfort performance.

Publications

The project deliverables are as follows:

- Development of the ASHRAE Global Thermal Comfort Database II
- Models and criteria for the application of adaptive thermal comfort in built environment
- Guidelines for low energy building design based on the adaptive thermal comfort concept
- Guidelines for Personal Thermal Comfort Systems in Low Energy Buildings

Meetings

No meetings were held in 2022.

Project duration
2015–2022

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

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

Further information
www.iea-ebc.org

Background Information

EBC AND THE IEA

RECENT PUBLICATIONS

EBC EXECUTIVE COMMITTEE MEMBERS

EBC OPERATING AGENTS

PAST PROJECTS

EBC and the IEA

THE INTERNATIONAL ENERGY AGENCY

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

This framework provides uncomplicated, common rules for participation in RD&D programmes, known as Technology Collaboration Programmes (TCPs), and simplifies international cooperation between national entities, business and industry. The TCPs are established by legal agreements between countries that wish to pursue a common programme of research in a particular area. In fact, there are now over 40 such TCPs – for more information see: www.iea.org/tcp.

There are numerous advantages to international energy technology RD&D collaboration through the TCPs, including:

- reduced cost and avoiding duplication of work,
- greater project scale,
- information sharing and networking,
- linking IEA member countries and non-member countries,
- linking research, industry and policy,
- accelerated development and deployment,
- harmonised technical standards,
- strengthened national RD&D capabilities, and
- intellectual property rights protection.

ABOUT EBC

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

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

OBJECTIVES AND STRATEGY

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

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

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

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

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

MISSION STATEMENT

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

NATURE OF EBC ACTIVITIES

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

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

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

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

EBC PARTICIPATING COUNTRIES

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

COORDINATION WITH OTHER BODIES

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

COLLABORATION WITH IEA BUILDINGS-RELATED TECHNOLOGY COLLABORATION PROGRAMMES

The EBC TCP continues to coordinate its research activities, including Annexes and strategic planning, with all IEA buildings-related TCPs through collaborative projects and through the BCG (Buildings Coordination Group), constituted by the IEA Energy End Use Working Party (EUWP) Vice Chair for Buildings and the Executive Committee Chairs of the following IEA Technology Collaboration Programmes:
– District Heating And Cooling (DHC)
– User-Centred Energy Systems (Users)
– Energy in Buildings and Communities (EBC)
– Energy Conservation through Energy Storage (ECES)
– Heat Pumping Technologies (HPT)
– International Smart Grid Action Network (ISGAN)
– Photovoltaic Power Systems (PVPS)
– Solar Heating and Cooling (SHC)
– Energy Efficient Electrical Equipment (4E)

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

COLLABORATION WITH THE IEA SOLAR HEATING AND COOLING PROGRAMME

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

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

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

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

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

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

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

NON-IEA ACTIVITIES

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

- Mission Innovation (MI), and
- The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE).

Recent Publications

Air Infiltration and Ventilation Centre (AIVC) – EBC Annex 5

Databases

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

AIVC Conference Proceedings

- 41st AIVC – ASHRAE IAQ Joint Conference, held, Athens, Greece, May 2022
- 42nd AIVC Annual Conference, held Rotterdam, the Netherlands, October 2022

Ventilation Information Papers

- VIP 41: Impact of wind on the airtightness test results, 2021
- VIP 42: The Concept for Substituting Ventilation by Gas Phase Air Cleaning, 2021
- VIP 43: Residential ventilation and health, 2021
- VIP 44: Residential Cooker Hoods, 2021
- VIP 45.1: Trends in Building and Ductwork Airtightness in Estonia, 2022
- VIP 45.2: Trends in Building and Ductwork Airtightness in Spain, 2022
- VIP 45.3: Trends in Building and Ductwork Airtightness in the Czech Republic, 2022

Technical Notes

- TN69: 40 years to build tight and ventilate right – History of the AIVC, 2022
- TN70: 40 years to build tight and ventilate right – From infiltration to smart ventilation, 2022
- TN71: Durability of Building Airtightness, 2022

Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings (EBC Annex 69)

- ASHRAE Global Database of Thermal Comfort Field Measurements, 2022
- Development of the ASHRAE Global Thermal Comfort Database II, 2020
- Models and Criteria for the Application of Adaptive Thermal Comfort in Built Environment, 2020
- Guidelines for Low Energy Building Design Based on the Adaptive Thermal Comfort Concept, 2020
- Guidelines for Personal Comfort Systems in Low Energy Buildings, 2021

Building Energy Performance Assessment Based on In-situ Measurements (EBC Annex 71)

- Physical Parameter Identification, 2021
- Building Behaviour Identification, 2021
- Challenges and General Framework, 2021
- Description and Results of the Validation of Building Energy Simulation Programs, 2021

Towards Net Zero Energy Public Resilient Communities (EBC Annex 73)

- Energy Master Planning toward Net Zero Energy Resilient Public Communities Guide, 2021
- Energy Master Planning for Resilient Public Communities – Pilot Studies, 2022
- Energy Resilience of Interacting Networks (ERIN) Tool – User Guide, 2021
- Technologies Database, 2021
- Energy Master Planning for Resilient Public Communities – Case Studies, 2021
- Guide for Resilient Thermal Energy Systems Design in Cold and Arctic Climates, 2021
- Guide for Resilient Thermal Energy Systems Design in Hot and Humid Climates, 2022

Competition and Living Lab Platform (EBC Annex 74)

- Participatory Research for the Evaluation of Satisfaction with Solar Decathlon Competitions: A Survey Analysis, 2021
- Competition and Living Lab Platform Science & Technology (Subtask A) Focus Report 1: Monitoring Data Visualization, 2021
- Competition and Living Lab Platform Science & Technology (Subtask A) Focus Report 2: Topical Paper, 2021
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- The Solar Decathlon Knowledge Platform – Concept and Application, 2018

Working Group on Building Energy Codes

- Building Energy Codes and Other Mandatory Policies Applied to Existing Buildings, 2021
- Best Practices for Building Energy Codes Compliance, 2021
- International review of energy efficiency in Data Centres, 2022

EBC Executive Commitee Members

CHAIR
Dr Takao Sawachi (Japan)

VICE CHAIR
Prof Paul Ruyssevelt (United Kingdom)

AUSTRALIA
Stanford Harrison
Department of Climate Change, Energy, the Environment and Water
stanford.harrison@dcceew.gov.au

AUSTRIA
DI (FH) Isabella Warisch
Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology
Isabella.Warisch@bmk.gv.at

BELGIUM
Dr Peter Wouters
Buildwise
peter.wouters@buildwise.be

BRAZIL
Gustavo Santos Masili
Ministério de Minas e Energia
gustavo.masili@mme.gov.br

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

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

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

DENMARK
Søren Østergaard Jensen
The Danish Energy Agency
snjn@ens.dk

FINLAND
Dr Hassam ur Rehman
VTT Technical Research Centre of Finland
Hassam.Rehman@vtt.fi

FRANCE
Marjorie Musy
CEREMA
marjorie.musy@cerema.fr

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

IRELAND
Conor Hanniffy
Sustainable Energy Authority of Ireland
conor.hanniffy@seai.ie

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

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

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

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

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

NORWAY
Harald Rikheim
Norges Forskningsråd
hri@forskningsradet.no

PORTUGAL
João Mariz Graça
Direção-Geral de Energia e Geologia
Joao.Graca@dgeg.gov.pt

SINGAPORE
Noel Chin
Building and Construction Authority
Noel_CHIN@bca.gov.sg

SPAIN
María José Jiménez Taboada
CIEMAT – Plataforma Solar de Almería
mjose.jimenez@psa.es

SWEDEN
Dr Jörgen Sjödin
Swedish Energy Agency
jorgen.sjodin@energimyndigheten.se

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

TÜRKİYE
Assoc. Prof Dr Gülsu Ulukavak Harputlugil
Çankaya Üniversitesi
gharputlugil@cankaya.edu.tr

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

USA
Marc LaFrance
US Department of Energy
marc.lafrance@ee.doe.gov

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

IEA Secretariat
Ksenia Petichenko
Ksenia.Petichenko@iea.org

EBC Operating Agents

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

Prof Dr Arnold Janssens
University of Ghent, Belgium
Arnold.Janssens@UGent.be

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

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

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

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

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

Rüdiger Lohse
KEA – Climate protection and energy agency of Baden-Württemberg GmbH, Germany
ruediger.lohse@edlhub.org

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

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

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

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

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

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

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

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

Data-Driven Smart Buildings – EBC Annex 81
Dr Stephen White
CSIRO, Australia
Stephen.D.White@csiro.au

Energy Flexible Buildings towards Resilient Low Carbon Energy Systems – EBC Annex 82
Dr Rongling Li
Technical University of Denmark
liron@byg.dtu.dk

Søren Østergaard Jensen
Technical University of Denmark
sosje@dtu.dk

Positive Energy Districts – EBC Annex 83
Dr Francesco Reda
VTT Technical Research Centre, Finland
Francesco.Reda@vtt.fi

Dott. Ing. Francesco Guarino
Università di Palermo, Italy
francesco.guarino@unipa.it

Demand Management of Buildings in Thermal Networks – Annex 84
Dr Anna Marszal-Pomianowska
Aalborg University, Denmark
ajm@build.aau.dk

Indirect Evaporative Cooling – Annex 85
Dr Xiaoyun Xie
Tsinghua University, P.R. China
xiexiaoyun@tsinghua.edu.cn

Energy Efficient Indoor Air Quality Management in Residential Buildings – Annex 86
Prof Jelle Laverge
Ghent University, Belgium
jelle.laverge@ugent.be

Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems – Annex 87
Dr Ongun Berk Kazanci
Technical University of Denmark
onka@byg.dtu.dk

Prof Bjarne Olesen
Technical University of Denmark
bwo@byg.dtu.dk

Building Energy Codes
EBC Working Group
Michael Donn
Victoria University of Wellington
michael.donn@vuw.ac.nz

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

Meredydd Evans
Pacific Northwest National Laboratory , USA
m.evans@pnnl.gov

Past Projects

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