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Energy in Buildings and Communities Programme

International Energy Agency

EBC Annex 75 Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables

Project Summary Report

Technology Collaboration Programme
by IEA

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Project Summary Report

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

This edition published in 2023 by the EBC Executive Committee Support and Services Unit.

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Cover picture: Example of cost-effective building renovation at district level
Source: University of Minho

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Project Summary

Urgent actions must be taken to decarbonise the building stock and meet the targets established in the Paris Agreement. Renovating the existing building stock to a zero-carbon level is a key priority to meet the decarbonisation goals. Apart from energy efficiency measures on the building envelopes, a switch to renewable energy-based building systems is urgently required. Furthermore, in addition to building renovation at the individual building level, building renovation at the district level offers a promising perspective as a strategy to promote the much-needed acceleration of the decarbonisation of the building sector.
However, as the renovation action level, the district can be associated with various challenges, mainly because of many architectural, technical, economic and regulatory hurdles and excessive reliance on fossil fuels. Furthermore, districts can also have complex stakeholder structures with different interests and tasks, making district approaches even more difficult.

With this background, this project aimed to clarify the cost-effectiveness of various building renovation approaches combining energy efficiency and renewable energy measures at the district level. The objective was to guide policy and other decision-makers on balancing and enabling an innovative and optimal mix of measures to decarbonise the existing residential buildings at the district level by taking advantage of the potential synergies between energy efficiency measures and the use of renewable energy. Possible combinations of technologies and the contexts in which they are most viable were investigated, as well as which business models, policies and process organisations could help modernise, support and accelerate building renovation processes.

This project showed through assessments in various countries that there is a significant potential for synergies between energy efficiency measures and renewable energy use in building renovation at the district level. Yet harnessing such synergies is a complex task requiring policy support to make it happen. It was also shown that new types of locally supported policy instruments, business models and advanced stakeholder dialogue are necessary to support this approach.

An overview of available and emerging technologies, a methodology to identify the best renovation solutions, a tool to support the application of the methodology and an overview of different renovation strategies in different contexts were developed and analysed in this project to facilitate the

development of related strategies for cost effectively transforming existing districts into low-energy and, more importantly, low-emission ones. Success stories and case studies were described and analysed, and barriers and drivers for building renovation at the district level were identified, characterised and analysed.

Several advantages of district projects were identified to accelerate the energy transition. In particular, it has been demonstrated that district projects can allow easier and more cost-effective access to renewable energy sources than building-by-building renovation approaches. Renovation at a district scale clearly increases flexibility in how and where energy is consumed.

However, it was also recognised that district projects often have no evident economic advantage compared to single-building projects. This project, therefore, emphasises that policy measures are necessary to leverage the potential of district projects for accelerating the decarbonisation of the building stock.

Available policy instruments were investigated, and specific recommendations were given to policymakers at the international, national and local levels. It is recommended that they provide clear and appropriate framework conditions to achieve the energy transition in the building sector at a pace compatible with the urgency needed to comply with the 1.5°C limit set by the Paris Agreement in the global decarbonisation plan and related remaining carbon budgets. Furthermore, this project also highlights the importance of policy action at the local level. Most of the concrete action to access the potential of building renovation projects at the district level combining energy efficiency measures and renewable energy use, can only happen at the local level. Policymakers at the local level are in the front row to enable such projects through regulations, economic incentives, and organisational and communication support. It is recommended that local authorities actively coordinate, organise and communicate on district renovation projects.

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

In short, building renovation at the district level combining energy efficiency measures with renewable energy use is a viable potential option to accelerate building renovation rates. However, success relies heavily on having a holistic approach that considers both cost-effectiveness and co-benefits, such as improving residents' overall

quality of life, improving the urban context and serving the public interest. For this to be possible, a framework that encompasses cooperation, information, capacity building, incentives and adapted regulations is urgently needed.

Detailed recommendations for policymakers at high and local levels can be found in the project report 'The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables: Making use of the Potentials – A Guide for Policy and Decision Makers' and in its two compact versions, divided according to their audience – policymakers and decision-makers (available in https://annex75.iea-ebc.org/publications).

Project duration
2017 - 2023 (completed)

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Project Outcomes

1. Background

It is consensual that urgent actions must be taken to decarbonise the building stock and meet the targets established in the Paris Agreement. Buildings are a major source of carbon emissions, and cost-effectively reducing their energy use and associated emissions are particularly challenging for the existing building stock, mainly because of many architectural, technical and economic hurdles and the excessive reliance on fossil fuels. Apart from energy efficiency measures on the building envelopes, a switch to renewable energy-based building systems is urgently required to comply with the agreed climate targets.

Furthermore, in addition to building renovation at the individual building level, building renovation at the district level combining energy efficiency measures with renewable energy use offers a promising perspective as a strategy to promote the much-needed acceleration of the decarbonisation of the building sector. There are specific opportunities to develop and take advantage of district-level solutions at the urban scale.

In this context, this project aimed to clarify the cost-effectiveness of various building renovation approaches combining energy efficiency and renewable energy use at the district level, as well as discuss other crucial factors for creating the necessary framework to promote building renovation at the district level to accelerate building renovation and meet the decarbonisation targets compatible with the Paris Agreement.

2. Objectives

Identifying cost-effective strategies for achieving far-reaching reductions of carbon emissions and energy use in city buildings at the district level, combining energy efficiency and renewable energy measures, is a complex task. A large number of investments, enormous financial and human resources and tight coordination of several stakeholders are needed to transform the city's energy use in the existing building stock into low-emission and low-energy solutions.

In this context, the project had the following general goals:

– Investigate cost-effective strategies for reducing carbon emissions and energy use in buildings at the district level, in an urban context, combining energy efficiency and renewable energy measures;

– Guide policymakers, companies working in energy transition, and building owners on cost-effectively transforming existing urban districts into low-energy and low-emission districts.

With a focus on the following specific objectives:

– Give an overview of various existing and emerging technology options with the potential to be successfully applied and how challenges in an urban context can be overcome;
– Develop a methodology to identify cost-effective strategies for renovating urban districts, supporting decision-makers in evaluating the efficiency, impacts, cost-effectiveness, and acceptance of various solutions;
– Illustrate such strategies in selected case studies and gather best-practice examples;
– Give recommendations to policymakers and energy-related companies on how they can influence the uptake of cost-effective combinations of energy efficiency and renewable energy measures in building renovation at the district level and guide building owners/ investors on related cost-effective renovation strategies.

3. Methodology and scope

This project focused mainly on single and multifamily residential buildings. Districts with other buildings with similar characteristics, such as schools or simple office buildings without complex Heating, Ventilation and Air Conditioning (HVAC) systems, are also covered by considering parameters specific to their building type. The districts analysed in the project were carried out mainly in heating-dominated climate zones. Cooling was considered where appropriate, and the developed methodology is valid for both district heating and district cooling situations.

The identification of cost-effective strategies to transform existing districts into low-emission and low-energy ones is challenging. At this level, finding the balance between energy efficiency and renewable energy measures for the existing building stock is complex, and many research questions still need to be answered related to the strategies to be adopted. This project aimed to find the answer to the following questions:

– What are cost-effective combinations between renewable energy and energy efficiency measures to achieve far-reaching reductions in carbon emissions and primary energy use in urban districts?
– In particular, what are cost-effective strategies to combine district-level heating or cooling based on available environmental heat, solar energy, waste heat or natural heat sinks with energy efficiency measures applied to building envelopes?
– How do related strategies compare in terms of cost-effectiveness and impact with strategies that combine a decentralised switching of energy carriers to renewable energy sources

with energy efficiency measures applied to building envelopes?
- In particular, under which circumstances is it more appropriate to use available renewable energy potentials in cities at a district level, and under which circumstances are decentralised renewable energy solutions more advantageous, combined with energy efficiency measures applied to building envelopes?

Given the balance between energy efficiency measures and renewable energy, specific importance was given to the following question in this context:
- To what extent does the cost-effectiveness of renovation measures on the building envelopes in the case of a local district heating system based on renewable energy differ from the cost-effectiveness of such measures in the case of decentralised use of renewable energy sources for heating in each building?
- The cost-effectiveness of various approaches was assessed against a starting situation in a specific city district. The scope of the project was based on the following three starting situations:
- Urban districts previously heated non-centrally by natural gas, oil or electricity, or cooled non-centrally through individual cooling devices;
- Urban districts previously connected to district heating systems with a high share of fossil fuel;
- Urban districts previously connected to district heating systems with a substantial share of renewable energy carriers.

According to this project's methodology, the assessments are carried out based on matching the energy needs of buildings with the energy supply. Each assessment compares various combinations of renovation measures (renovation packages) with a reference case. Renovation measures comprise both energy efficiency measures on building envelopes and renewable energy measures. The reference case (anyway measures) includes the renovation activities that would have been carried out anyway, just to restore the building's functionality.

A life cycle approach is chosen to indicate the costs for energy measures and anyway measures. Initial investment costs/ replacement costs, energy costs, including existing energy taxes and CO_2 taxes, as well as maintenance and operational costs, are included.

Participants used their own tools to apply the methodology, yet a common online tool was also developed to help illustrate the methodology and assess and compare renovation packages . The methodology was applied and tested in generic districts and case studies chosen among the participating countries of the research project. Based on the assessments, strategies were proposed to transform districts into low-energy and low-emission ones.

Besides the assessment of the generic districts and the case studies, successful examples of building renovation at the district level were studied and compiled to understand the factors that contributed to their completion, the obstacles and the lessons learned from each one.

Along with the technical evaluation of cost-effective renovation packages combining energy efficiency with renewable energy, other factors necessary to encourage and scale up district renovation initiatives were assessed, such as social, financial and policy-related factors. Qualitative interviews were held with various types of actors in participating countries, and their detailed analysis led to an appraisal of barriers and opportunities, policy instruments, business models and stakeholder collaborations. They were as important as the technical solutions to promote building renovation at the district level and the necessary acceleration of the building renovation rates.

The joint analysis of the success stories and the stakeholder interviews formed the basis for compiling barriers and drivers in a specific report. Ultimately, all of the project findings were included in the development of guidelines for investors and policymakers.

In this project, the collaboration between the academy and industry was constant through the analysis of success stories and interviews and the holding of a series of workshops throughout the project's development, where stakeholders from different countries and segments were heard, and the findings from this project were discussed.

4. Main findings and recommendations

As an action level for building renovation, the district allows for synergies through combinations of energy efficiency measures and the use of renewable energy, and it also offers opportunities for stakeholders to cooperate more strongly compared to an individual building approach. But building renovation at the district level also presents challenges such as high upfront costs, long payback time, and risks of not being implemented due to a potential withdrawal of some building owners at different stages.

Nevertheless, despite such challenges, there are also good reasons that might favour choosing district approaches rather than decentralised approaches. These can be the potential use of large renewable energy sources or storage systems that may not be accessed or available through decentralised systems. Others can be the chance of overcoming space or noise restrictions related to decentralised systems, the increased flexibility, the opportunity to apply innovative systems associated with fewer carbon emissions, the possibility to increase resilience through multiple energy systems, and the possibility of having a greater engagement of building owners when acting collectively.

The research within project shows that the best renovation solutions for a district-level

renovation depends on the starting situation of the district. The building insulation level, the installed heating/cooling systems, the availability of renewable energy sources and the possibility of integrating renewable energy are determining factors. Energy efficiency measures are relevant, especially if the initial conditions of the building envelopes have poor thermal performance.

The calculations carried out in this project also show that the same package of energy efficiency measures applied to a building envelope is usually the most cost-effective regardless of the heating system used, particularly whether a centralised or decentralised renewable energy-based system is chosen.

There are also indications that the synergies between energy efficiency measures and the use of renewable energy are even greater for district systems than for decentralised systems when environmental heat is used through heat pumps. This could occur because energy efficiency measures would reduce the temperature in the grid and, thus, the related heat losses, and increase the overall efficiency of the systems.

However, cost-effectiveness is often not one of the advantages of district approaches. This implies that if policymakers want to implement district-level renovation projects to take advantage of the additional stated benefits, they will have to take appropriate policy action, as the market by itself is unlikely to deliver decarbonisation through district solutions to a large extent. It is a question, in particular, of taking advantage of the synergies between energy efficiency measures at the district level, which is not easy to achieve and, until now, also uncommon since district renovation projects are complex in themselves, and harnessing such synergies is associated with additional challenges.

One main conclusion from the studies is that no "ready-made" or "one size fits all" solutions exist. Still, several techno-economic potentials for district solutions are apparent.

Sometimes, specific measures will not be the most cost-effective, but this does not mean discarding them is necessary. On the contrary, there are situations when these measures offer co-benefits that will be the main reason to choose them. Therefore, a holistic approach must be taken when analysing different district renovation solutions, with the techno-economic viewpoint as one of the factors to be considered in the decision-making process. Looking also into public interests, social and urban aspects are essential, aiming at the general improvement of the indoor and outdoor spatial quality, comfort conditions and the residents' quality of life, which also contributes to a greater acceptance and participation of the residents in the process.

As the complexity grows with tailored strategies and upscaling to the district level, it is essential to consider and adequately

address several aspects. It is crucial that the points of view and objectives of the different stakeholders in the process converge towards a common agreement on the decarbonisation targets. However, in many cases, conditions are still lacking for this to be possible, and an entire framework needs to be created to make deep renovation the rule rather than the exception.

This starts with adapting regulations, building codes and energy certificates for building renovation, not just for new buildings, and for the district level as a complement to the single building level. It is recommended that regulations also facilitate and mandate the shift of building systems from fossil fuels to renewable energy sources and even ban fossil fuel systems at the international, national, regional and local levels to provide clear framework conditions towards decarbonisation.

Furthermore, overarching financial incentives, such as those provided through a carbon tax, to reflect more strongly the external costs of the consumption of fossil fuels or through emissions trading schemes are crucial. In addition, to advance building renovation at the district level, it is necessary that funding is provided to plan and implement the entire district renovation project rather than just individual measures. Depending on the country, additional incentives might also be needed on levels between the district and the individually owned building, like support for homeowner associations and integrated renovation services, instead of individual homeowners and single renovation measures.

It is also essential to address the lack of knowledge and achieve a sound understanding of deep renovations by offering training to the entire chain of professionals in the building sector, building owners, and local staff of city administrations.

Furthermore, new business models are needed to support district renovation, combining energy efficiency and renewable energy measures, ensuring that the related benefits can be harnessed despite different building ownerships and existing district heating/cooling systems. It is also recommended to test new financing models and tailor business and financing models to different target groups, paying particular attention to the most vulnerable groups, such as low-income groups and tenants.

Local authorities play a crucial role in these renovation processes. They can assume various functions, such as facilitators, mediators, coordinators, and motivators. First and foremost, they are well-positioned to establish co-creation trajectories with citizens in target areas and define specific local targets that motivate building owners to participate in the energy transition and related building renovation activities. They can also further encourage building renovation at the district scale through local energy planning, local regulations, and local financial incentives, promoting, in particular, the combination of energy efficiency measures

and renewable energy use. Depending on the country's context, they may introduce specific local regulations, such as making building envelope renovation, switching to renewable energy-based heating systems mandatory, or providing related regulatory incentives. However, many countries do not allow local authorities to set stricter requirements. They may also introduce local financial incentives or financing schemes to make building renovation attractive and promote appropriate business models.

Nevertheless, the key factor for successful building renovation at the district level is effective communication and coordination, without which the other aspects will not be applied to their full potential. The availability and easy access to transparent and clear information combined with stakeholder dialogue and knowledge exchange lead to greater adherence and participation. In particular, the involvement and collaboration of residents in the definition of the renovation proposal and throughout the entire process help with its acceptance and the understanding of the solutions. This approach can contribute to achieving more ambitious renovation levels and the expected operational performance due to behavioural use patterns.

Local authorities, in particular, can assume a key role in ensuring appropriate communication and advice to building owners and offering support for coordinating and organising processes for integrating building renovation at the district level, particularly when renewable energy systems are already being planned at the district scale. Local authorities can ensure that experts in various fields, such as energy, legal, and social, provide related knowledge and organisational support. Local authorities may also co-create local renovation hubs and demonstrate fossil-free pilot districts for this purpose.

Local authorities can promote the development of integrated district renovation plans that combine energy efficiency measures and renewable energy use to leverage related synergies. Beyond the scope of districts, there is also a need at the local level to develop coherent city-wide decarbonisation plans that provide a strategy to reduce carbon emissions from buildings in all districts of a region or city to zero.

In short, cost-effective technological combinations suitable and tailored to each local context are needed, aiming at the public interest and improving the citizens' quality of life. An integrated approach to district-specific building renovation is required to find a deep local renovation optimum, not only balancing energy efficiency measures and renewable energy use, yet beyond that, also balanced with other interests. It is recommended to base this approach on stakeholders' cooperation, the balance of needs, in-depth knowledge, information, appropriate incentives, and regulatory frameworks that enable building renovations at the district level, leveraging synergies

between energy efficiency measures and the use of renewable energy sources, as illustrated in the various reports.

5. Main recommendations for Policymakers

The work carried out in this project led to the elaboration of a large number of recommendations addressed to selected target groups in different levels of action.

Detailed recommendations for policy and decision-makers can be found in the the project report 'The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables: Making use of the Potentials – A Guide for Policy and Decision Makers' and in its two compact versions, divided according to their audience – policymakers and other decision-makers.

Here are only presented some general recommendations addressed to high-level policymakers who call for an enabling environment for an integrated approach, upscaling building renovation to the district level and combining energy efficiency measures with renewable energy sources.

OVERALL RECOMMENDATIONS FOR HIGH-LEVEL POLICYMAKERS	
REGULATIONS STANDARDS AND PLANNING	Provide a legal framework to foster target-orientated building renovations at the district level. Adapt laws and regulations to stimulate building renovation at both the building and the district levels
	Deploy building codes with clear goals and standards aiming at zero-carbon building renovation and an overarching goal of zero-carbon districts
	Guide the deployment of district solutions combining energy efficiency measures and renewables through energy planning covering the entire city
	Create a certification system to set standards also at the cluster and district levels while maintaining high ambitions at the building level
	Promote a holistic approach combining building renovation, urban planning, energy grid development and carbon reduction goals so that overall quality of life can be achieved and residents' acceptance increased
	Support and develop incentives and regulations, as well as coordination and planning at overarching policy levels, and enable local authorities to assume an active role
	Guide local actors and decision-makers by defining a clear and practice-oriented decarbonisation path, developing clear definitions of zero-carbon standards involving a broad spectrum of practitioners

	Take advantage of the time when regular maintenance of building elements or a district grid is required to improve their energy performance and synchronise related renovation activities within a district
	Tighten regulations requiring the use of renewable energy whenever a heating system is replaced or newly installed and ban, at some point, the use of fossil fuel-based heating and cooling systems at international, national, regional and local levels, while strongly supporting vulnerable groups during the transition periods/processes to maintain overall acceptance for decarbonisation
	Require the combination of energy efficiency measures and renewable energy measures in concessions for district heating systems or public tenders
	Ensure that also the peak capacity of large district heating systems is provided through renewable energy
ECONOMIC AND FINANCIAL INSTRUMENTS	Assure financial support to the energy transition to even out potential (initial) adverse socio-economic effects whenever necessary and prevent thereby that the technological district renovation solutions are being neglected due to high initial and coordination costs
	Ensure that financial support favours a combination of energy efficiency measures and renewable energy measures and that counter-productive incentives are avoided
	Provide financial support for the development of integrated district renovation plans that combine both energy efficiency measures and renewable energy measures
	Deploy financial measures and business models to promote ambitious building renovations, including funding for building renovations at the district level
	Provide incentives and subsidies for comprehensive and multi-measured building renovations that are not yet cost-effective
	Facilitate cross-sector business models and the cooperation of energy companies, renovation solution suppliers and housing companies by eliminating possible legal barriers
	Make financial guarantees and funds available not only for individual measures but for the entire process, ensuring the final performance of the renovation project at the building as well as the district level
	Deploy financial schemes for different target groups, especially low-income households, to unburden them from the upfront and following costs of the building renovation upscaling
	Offer integrated solutions and services by providing a single point of contact

INFORMATION AND CAPACITY-BUILDING	Develop collaborative platforms for different target groups, learning networks, and reliable and easy-to-use tools for professionals and end-users, assuring quality in procurement, design, and execution
	Create transparent and accessible databases by enhancing the collection of energy performance information through building inspections, energy audits, smart meter promotion and big data analysis
	Develop online energy maps as an information resource on connection possibilities to renewable energy sources, energy grids and heating/ cooling networks
	Support and promote capacity-building for the whole chain of the renovation process actors
	Raise awareness and ensure effective communication among the district renovation stakeholders from the early stages and throughout the entire process, especially involving residents
	Help to spread information about local examples, inspiring action
RESEARCH	Support R&D to unravel the needed process innovations at local and regional scales, particularly for developing integrated building renovation services for different target groups and at the district scale
	Provide funding to develop and test innovations related to improved renovation measures for reaching decarbonisation
	Explore innovative solutions in research projects beyond the existing legal structure, granting exemptions through sandbox projects

Project Participants

Country	Organisation
Austria	AEE - Institute for Sustainable Technologies AIT - Austrian Institute of Technology Institute for spatial planning and housing, City of Salzburg
Belgium	KU Leuven - Faculty of Engineering Technology VITO - Flemish Institute for Technological Research, EnergyVille
China	Hunan University
Czech Republic	CVUT - Czech Technical University in Prague
Denmark	Aalborg University - Danish Building Research Institute Kuben Management
Germany	Beratungs und Service - Gesellschaft Umwelt mbH Germany Association of Housing, Urban and Spatial Planning
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Norway	SINTEF
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Sweden	Lund University StruSoft
Switzerland	INDP - Institute for Sustainability and Democracy Policy Basler & Hofmann Econcept ZHAW – Zurich University of Applied Sciences

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EBC and the IEA

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.
A basic aim of the IEA is to foster international co-operation among the 31 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes.
The mission of the IEA Energy in Buildings and Communities (IEA EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)
The R&D strategies of the IEA EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. These R&D strategies aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five areas of focus for R&D activities:

- Integrated planning and building design
- Building energy systems
- Building envelope
- Community scale methods
- Real building energy use

The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (*):

Annex 1:	Load Energy Determination of Buildings (*)
Annex 2:	Ekistics and Advanced Community Energy Systems (*)
Annex 3:	Energy Conservation in Residential Buildings (*)
Annex 4:	Glasgow Commercial Building Monitoring (*)
Annex 5:	Air Infiltration and Ventilation Centre
Annex 6:	Energy Systems and Design of Communities (*)
Annex 7:	Local Government Energy Planning (*)
Annex 8:	Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9:	Minimum Ventilation Rates (*)
Annex 10:	Building HVAC System Simulation (*)
Annex 11:	Energy Auditing (*)
Annex 12:	Windows and Fenestration (*)
Annex 13:	Energy Management in Hospitals (*)
Annex 14:	Condensation and Energy (*)
Annex 15:	Energy Efficiency in Schools (*)
Annex 16:	BEMS 1- User Interfaces and System Integration (*)
Annex 17:	BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18:	Demand Controlled Ventilation Systems (*)
Annex 19:	Low Slope Roof Systems (*)
Annex 20:	Air Flow Patterns within Buildings (*)
Annex 21:	Thermal Modelling (*)
Annex 22:	Energy Efficient Communities (*)
Annex 23:	Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24:	Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25:	Real time HVAC Simulation (*)
Annex 26:	Energy Efficient Ventilation of Large Enclosures (*)
Annex 27:	Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28:	Low Energy Cooling Systems (*)
Annex 29:	Daylight in Buildings (*)
Annex 30:	Bringing Simulation to Application (*)
Annex 31:	Energy-Related Environmental Impact of Buildings (*)

Annex 32:	Integral Building Envelope Performance Assessment (*)
Annex 33:	Advanced Local Energy Planning (*)
Annex 34:	Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35:	Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36:	Retrofitting of Educational Buildings (*)
Annex 37:	Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38:	Solar Sustainable Housing (*)
Annex 39:	High Performance Insulation Systems (*)
Annex 40:	Building Commissioning to Improve Energy Performance (*)
Annex 41:	Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42:	The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43:	Testing and Validation of Building Energy Simulation Tools (*)
Annex 44:	Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45:	Energy Efficient Electric Lighting for Buildings (*)
Annex 46:	Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47:	Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48:	Heat Pumping and Reversible Air Conditioning (*)
Annex 49:	Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50:	Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51:	Energy Efficient Communities (*)
Annex 52:	Towards Net Zero Energy Solar Buildings (*)
Annex 53:	Total Energy Use in Buildings: Analysis and Evaluation Methods (*)
Annex 54:	Integration of Micro-Generation and Related Energy Technologies in Buildings (*)
Annex 55:	Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (*)
Annex 56:	Cost Effective Energy and CO_2 Emissions Optimization in Building Renovation (*)
Annex 57:	Evaluation of Embodied Energy and CO_2 Equivalent Emissions for Building Construction (*)
Annex 58:	Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
Annex 59:	High Temperature Cooling and Low Temperature Heating in Buildings (*)
Annex 60:	New Generation Computational Tools for Building and Community Energy Systems (*)
Annex 61:	Business and Technical Concepts for Deep Energy Retrofit of Public Buildings (*)
Annex 62:	Ventilative Cooling (*)
Annex 63:	Implementation of Energy Strategies in Communities
Annex 64:	LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles (*)
Annex 65:	Long-Term Performance of Super-Insulating Materials in Building Components and Systems (*)
Annex 66:	Definition and Simulation of Occupant Behavior in Buildings (*)
Annex 67:	Energy Flexible Buildings (*)
Annex 68:	Indoor Air Quality Design and Control in Low Energy Residential Buildings (*)
Annex 69:	Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings (*)
Annex 70:	Energy Epidemiology: Analysis of Real Building Energy Use at Scale
Annex 71:	Building Energy Performance Assessment Based on In-situ Measurements (*)
Annex 72:	Assessing Life Cycle Related Environmental Impacts Caused by Buildings (*)
Annex 73:	Towards Net Zero Resilient Energy Public Communities (*)
Annex 74:	Competition and Living Lab Platform (*)
Annex 75:	Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables (*)
Annex 76:	Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO_2 Emissions (*)
Annex 77:	Integrated Solutions for Daylight and Electric Lighting (*)
Annex 78:	Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications

Annex 79:	Occupant-centric Building Design and Operation
Annex 80:	Resilient Cooling
Annex 81:	Data-Driven Smart Buildings
Annex 82:	Energy Flexible Buildings towards Resilient Low Carbon Energy Systems
Annex 83:	Positive Energy Districts
Annex 84:	Demand Management of Buildings in Thermal Networks
Annex 85:	Indirect Evaporative Cooling
Annex 86:	Energy Efficient Indoor Air Quality Management in Residential Buildings
Annex 87:	Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems
Annex 88:	Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings
Annex 89:	Ways to Implement Net-zero Whole Life Carbon Buildings
Annex 90:	Low Carbon, High Comfort Integrated Lighting
Annex 91:	Open BIM for Energy Efficient Buildings
Working Group -	Energy Efficiency in Educational Buildings (*)
Working Group -	Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group -	Annex 36 Extension: The Energy Concept Adviser (*)
Working Group -	HVAC Energy Calculation Methodologies for Non-residential Buildings (*)
Working Group -	Cities and Communities (*)
Working Group -	Building Energy Codes

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