Energy in Buildings and Communities Programme

International Energy Agency

Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (Annex 58)

Project Summary Report









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Cover picture: EBC Annex 58 project test facilities
Source: EBC Annex 58

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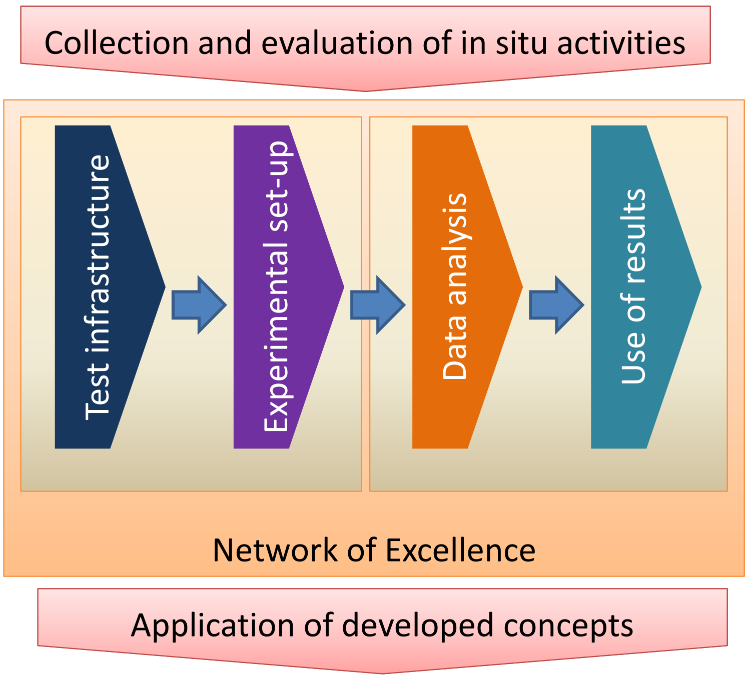
Project Summary

Quantifying the actual energy performance of buildings, verifying calculation models and integrating new advanced energy solutions for nearly zero or positive energy buildings can only be effectively realised by in situ testing and dynamic data analysis. But, practical experience has shown that the outcome of many on site activities can be questioned in terms of accuracy and reliability. Full scale testing requires high quality during all stages of research, starting with the test environment, such as test cells or real buildings, accuracy of sensors and correct installation, data acquisition software, and so on. It is crucial that the experimental setup (for example test layout or imposed boundary conditions for testing) is correctly designed, and produces reliable data. These outputs can then be used in dynamic data analysis based on advanced statistical methods to provide a characteristic with reliable accuracy intervals and final results that can be relied on. If the required quality is not achieved at any of the stages, the results become inconclusive, or even useless. The EBC project 'Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale



Schematic overview and organisation of the different project tasks.

Dynamic Measurements' has therefore developed the necessary knowledge, tools and networks to achieve reliable in situ dynamic testing and data analysis methods that can be used to characterise the actual energy performance of building components and whole buildings. The specific objectives of the project were to:

- develop common quality procedures for dynamic full scale testing to achieve better performance analysis, and
- develop models to characterise and predict the effective thermal performance of building components and whole buildings.

One of the project deliverables was completed in cooperation with the Dynastee-network (www.dynastee.info). This network of excellence on full scale testing and dynamic data analysis organizes events on a regular basis, such as international workshops, annual training courses and helps organisations interested in full scale testing campaigns. This has enhanced the network and continues the promotion of actual building performance characterization based on full scale measurements and the appropriate data analysis techniques.

The following reports have been published:

- Inventory of full scale test facilities for evaluation of building energy performances,
- Overview of methods to analyse dynamic data,
- Logic and use of the Decision Tree for optimizing full scale dynamic testing,
- Thermal performance characterization based on full scale testing - description of the common exercises and physical guidelines,
- Thermal performance characterisation using time series data – statistical guidelines,
- Empirical validation of common building energy simulation models based on in situ dynamic data, and
- Towards a characterisation of buildings based on in situ testing and smart meter readings and potential for applications in smart grids.

Project duration
2011 - 2016 (completed)

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Observer: Finland

Further information
www.iea-ebc.org

Project Outcomes

1. Background

The rise of living standards, the scarcity of natural resources and the awareness of climate change has resulted in international pressure to significantly reduce the energy consumption of buildings and communities. In certain industrialised countries, more stringent requirements have been imposed by energy performance legislation and also an increased awareness of environmental issues in building codes can be noticed. Mostly, requirements and labelling of the energy performance of buildings is done during the design phase by calculating the theoretical energy use. Several previous studies showed however that the actual performance after construction of the building may deviate significantly from this theoretically designed performance. Sources of deviations between the actual and expected performance can be attributed to the occupants and operators, the systems and the building fabric. For the building fabric, building performance characterisation based on full scale testing – testing of building components or whole buildings under realistic dynamic conditions – could help to bridge the gap between theoretically predicted and real life performance of buildings. Full scale dynamic measurements are helpful to investigate the performance of building components and whole buildings as built in reality, including the influence of workmanship. As an example, Figure 1 compares the designed and realised overall heat loss (W/K) of 18 dwellings in the UK. The overall heat losses are obtained with in situ co-heating tests [Wingfield et al., 2011]. As can be seen, none of the houses realises its intended performance and their measured heat losses may be up to 200% of the designed value.

Examples such as the one mentioned above, explain why at present several in situ research testing activities are ongoing. In fact, an international preparatory workshop for the project showed interest in full scale testing from all over the world [Janssens et al., 2011]. Increasing research has been taking place in both full scale testing on building components (for instance in Paslink-cells, or in situ on components of real buildings) and on whole buildings (to characterise thermal performance and energy efficiency of either test buildings or real buildings). So it is clear that contrary to what may have been expected, numerical building component and building energy simulation models did not make full scale testing of building (components) redundant. To the contrary, together with increased application of numerical simulations, a renewed interest in full scale testing can be observed. This is to be expected, because

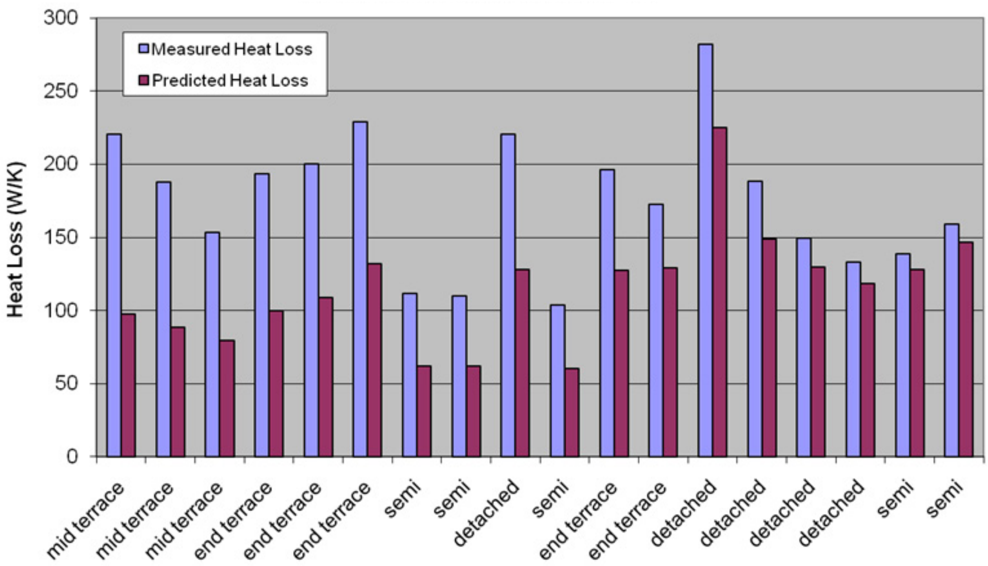

Figure 1. Measured versus predicted whole house heat loss (W/K) for 18 new build dwellings in the UK. None of the houses reached its as-designed predicted value, with deviations up to +100%.

dynamic full scale testing showed not only to be of interest to study building (component) performance under different real conditions, and as illustrated, quite often an important difference is observed between predicted and realised performance. It is also a valuable and necessary tool to integrate advanced components and systems into simulation models. As an example, Figure 2 shows full scale testing of building integrated photovoltaic cells (BIPV). Based on analysis of the measured dynamic data, a so-called grey box-model has been deduced [Jiménez et al., 2008; Lodi et al., 2011]. A grey box model is based on a combination of prior physical knowledge and statistics by identifying the unknown parameters of the system with dynamic data analysis. Once identified, the grey box model is able to predict the thermal dynamic response of ventilated photovoltaic double skin facades under different climatic conditions. In this way, it can be ensured that the behaviour of new advanced building components is integrated correctly in building energy simulation (BES) models.

A similar approach of parameter identification based on dynamic measurements can be used to identify suitable models to describe the thermal dynamics of whole buildings including building systems [Bacher and Madsen, 2011]. Characterising the dynamic behaviour of buildings is an essential and very valuable input, for example when optimising energy grids for building communities.

2. Objectives

The previous section explained that better characterisation and prediction of actual building performance are essential to realise energy reductions in buildings and community systems. Quantifying the actual performance of buildings, verifying calculation models and integrating new advanced energy solutions for nearly zero energy or positive energy buildings can only be effectively realised by in situ testing and dynamic data analysis. But, notwithstanding the renewed interest in full scale testing, practice shows that the outcome of many on site activities can be questioned in terms of accuracy and reliability. The focus of nearly all full scale testing activities is on the assessment of the components and buildings, often neglecting the necessity of reliable assessment methods and quality assurance issues. Full scale testing however, requires quality on all aspects of the process chain [Strachan and Baker, 2008], starting with a good test environment (test cells or real buildings, accurate sensors and correct installation, data acquisition software, …). Only when this is present, can a good experimental set-up be designed (for example test lay-out, imposed boundary conditions for testing, …), which produces reliable data that can be used for dynamic data analysis based on physical principles and advanced statistical methods. A characterisation with reliable accuracy intervals can then be achieved and final results relied on. As soon as the required quality fails in one area, the results become inconclusive or may even be wrong. Therefore, through international collaboration the objective of the project was

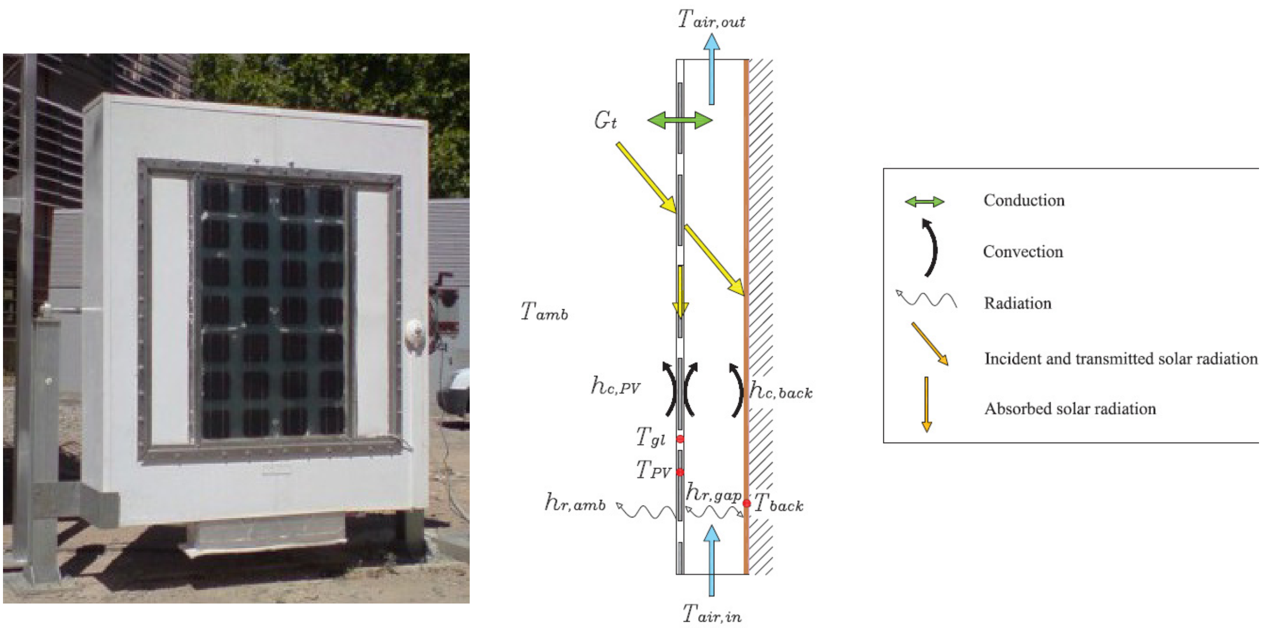

Figure 2. Left: test set-up to measure the thermal response of ventilated photovoltaic double skin facades under real climatic conditions. Right: schematic overview of the heat transfer processes taking place in the facade, which serves as the basis for a grey-box model [Lodi et al., 2011].

to develop common quality procedures for full scale testing and data analysis to achieve reliable performance characterisation and prediction of building components and whole buildings. To achieve this objective, the following tasks were carried out, which are described in more detail in the next section:

- inventory of the state of the art on full scale testing and dynamic data analysis
- development of a decision tree on how to measure the actual thermal performance of building components and whole buildings in-situ;
- analysis and development of dynamic data analysis tools that can be used to characterize building components and whole buildings starting from full scale dynamic data tests;
- undertake a detailed empirical validation exercise on a full-scale building to provide datasets suitable for assessing detailed simulation programs used in predicting building thermal performance;
- illustrate the applicability of full scale dynamic testing with respect to energy conservation in buildings and communities;
- set-up a network of excellence on full scale testing and dynamic data analysis for knowledge exchange and guidelines on testing.

3. Activities and Deliverables

3.1. Inventory of the state of the art

At the start of the project an overview was made of the full scale test facilities for the evaluation of energy performance of building components and whole buildings available at different institutes all over the world. Furthermore common methods were described to analyse the dynamic data obtained from full scale testing, with their advantages and drawbacks. This resulted in two reports.

The first report describes 25 existing test facilities or test sites according to their main functionalities: objectives, lay-out of the infrastructure, typical equipment and operation, examples of measuring campaigns and analysis methods. The descriptions were provided by the participants in EBC Annex 58, and are complemented by descriptions that were previously published in the book, 'Full Scale Test Facilities' (Janssens et al., 2011). The report is subdivided into two parts, related to the scale at which building energy performance is analysed: test facilities for outdoor testing of full scale building components, and test buildings for energy use analysis at building level. The inventory provides examples and background for building researchers responsible for the design and construction of new test facilities, or for the management of existing ones.

The second report gives an overview of existing data analysis methods, ranging from averaging and regression methods to dynamic approaches based on system identification techniques. These methods are discussed in relation to their application to the following in-situ measurement techniques:

Figure 3. Examples of different types of full scale test facilities (clockwise from top right): facility for façade field testing / outdoor test cell / test buildings for energy use analysis / facility for in-use testing.

- measurement of thermal transmittance of building components based on heat flux meters;
- measurement of thermal and solar transmittance of building components tested in outdoor calorimetric test cells;
- measurement of heat loss coefficient and solar aperture of whole buildings based on co-heating or transient heating tests;
- characterization of the energy performance of whole buildings based on energy use monitoring.

3.2. Actual thermal performance of building components and whole buildings

To assist readers with various backgrounds in the design, set-up and execution of in-situ building performance testing, the project developed a roadmap for achieving reliable methods to measure the actual thermal performance of building components and whole buildings. Since there are many different objectives when measuring thermal performance, the approach considered most appropriate to present the options was to map out a decision tree to guide the user through defined options. The main question to be followed by the decision tree user is "What do you want to characterize?" Although a simple question, it is a very precise way to reach to the optimal test procedure. To guide the user, three main branches follow this question, as shown in Figure 4. These are then expanded on by presenting the user with subsequent questions to determine the nature of their research. At the end this filtering process results in a relevant reference document that

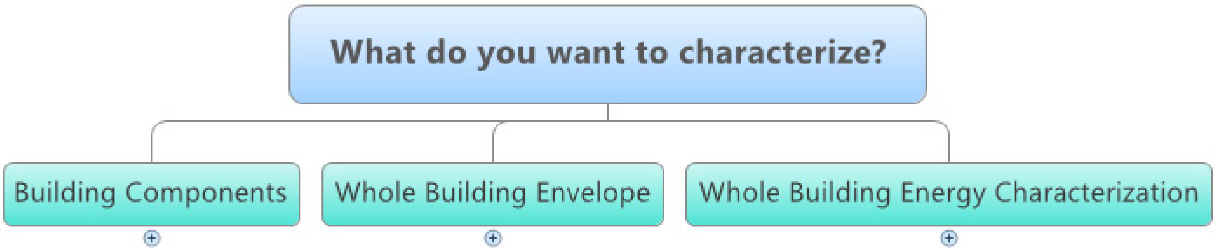

Figure 4. The main question and branches of the decision tree for identifying research support guidance.

the user can access for detailed guidance to support their specific research.

The decision tree is intended to be accessible to a broad audience from both academic and industry backgrounds, and efforts have been made to ensure the language used is as non-technical as possible.

The decision tree is intended to provide a valuable source of information for a range of potential users from both industry and academic backgrounds. By following the guidance contained in the reference documents, it will assist in the capture of robust data sets. It is important to note that the decision tree is intended to be a 'live' document, requiring periodic updating to reflect changes in the state of the art and to ensure the most recent versions of standards and reports are provided. The most recent version of the decision tree and the accompanying 'ReadMe' companion document is hosted at http://dynastee.info/ .

3.3. Analysis and development of dynamic data analysis tools

To analyse measured data from in-situ testing, a wide range of methodologies exist, and it is often not straightforward to choose the most appropriate approach for each particular application. To determine which methodology to use for dynamic data analysis, taking into account the purpose of the in-situ testing, the existence of prior physical knowledge, the available data and the statistical tools, the methodologies have been tested and validated on data collected from different case studies. The cases studied start with quite simple systems (opaque walls), progressively approaching to reality, and end with full-size buildings. Figure 5 shows one particular case study: the 'round robin test box'. This can be seen as a scale model of a building and has been built by one project participant, who was the only partner within the project aware of the exact composition of the box. After construction the box was shipped to several participatig organisations (different climatic conditions and different measurement data acquisition equipment) with the aim of performing a full scale measurement of the test box under real climatic conditions. At all test sites, different experiments have been performed, ranging from co-heating tests with constant indoor temperature, over free floating temperature runs, to imposed dynamic heating sequences ('ROLBS-signals'). The dynamic data obtained was distributed to other participating organisations, who had to try to characterize the test box based on the experimental data provided. Different analysis methods were used to characterise the thermal performance of the test box, varying from simple stationary methods (averaging method, simple and multiple linear regression) to advanced dynamic data analysis methods, such as ARX-, ARMAX and state space models.

An overview of all case studies and the lessons learned from them are compiled in a single report. This also presents guidelines concerning the physical aspects to be taken into account when performing dynamic data analysis. In addition, a second report focuses on guidelines about the statistical aspects of the methods. Following both sets of guidelines should result in reliable data analysis.

3.4. Building energy simulation validation exercise

To check the reliability of detailed dynamic simulation programs, commonly used in practice and research for predicting the energy and environmental performance of buildings, an empirical validation experiment on a full scale building has been performed and the measured data compared with predictions. This is an essential addition to the existing BESTEST portfolio and several validation standards, which had previously only dealt with inter-model comparisons. An appraisal of available test facilities for empirical validation was undertaken at the start of the project. The Twin Houses, a Fraunhofer IBP experimental facility at Holzkirchen, Germany, were selected (see Figure 6). Two experiments were conducted:

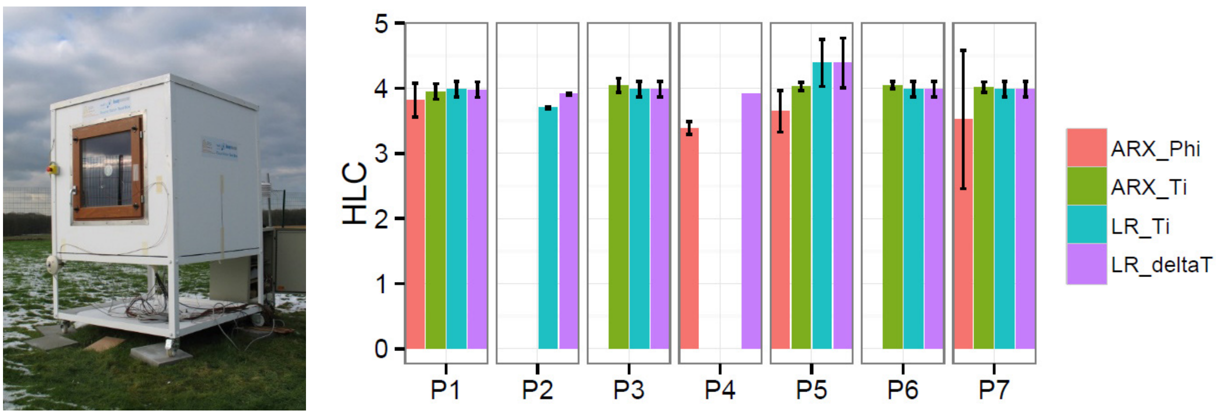

Figure 5. Left: the round robin test box as one of the case studies used to assess the reliability of different methodologies. Right: the overall heat loss coefficient (HLC) of the box (W/K) as determined by different participants (P1 to P7) and different analysis methods (ARX and regression LR).

Figure 6. External view (right) and internal view (left) of the test dwelling used for the building energy simulation validation exercise.

the first in summer 2013, the second in spring 2014. A comprehensive validation methodology was adopted. This comprised of experimental design, developing a detailed specification, undertaking blind validation, in which modelling teams were only given boundary conditions and asked to predict internal conditions, results analysis, a second phase of modelling after all measured data were released, and re-analysis. Over 20 modelling teams were involved in following the experimental specification and submitting predictions using a range of commercial and research programs.

The main outcome from the study is the set of detailed specifications, augmented by feedback from modelling teams, and the detailed experimental datasets, all available through Open Access arrangements. The resulting specification and datasets can be used by developers of new programs, or by those extending existing programs to test their predictions; they can help to identify program deficiencies; they can be used in training for program users; and they can be used as a dataset for testing system identification methods to identify key building performance characteristics such as overall heat loss and solar aperture. The experiments have already been used for these purposes. In addition, software vendors can use them to provide evidence of prediction reliability.

3.5. Applicability of full scale dynamic testing

The final stage of the project focused on the application of the developed concepts by showing the applicability and importance of full scale dynamic testing for different issues with respect to energy conservation in buildings and community systems. The first part of this stage explains how the developed methods can be used to characterise the thermal performance of buildings based on in situ testing and smart meter readings. Using the developed methods, these were improved by analysing the available measured data and identifying which additional data could improve the accuracy of the results, both with real and 'virtual' data.

The second part of this stage demonstrated that reliable dynamic characterization of the energy use in buildings is beneficial for modelling smart grid solutions – including demand side management, minimising import / export of energy, analysing energy supply and demand options – from the perspectives of the grid operator and the building owner. Examples from different countries have shown the benefits of this framework in the context of intelligent energy networks. With growing interest in building and home automation systems, the availability of valuable time series data is expected to increase. The application potential for online identification and characterisation of the dynamic thermal performance of buildings using the methods presented in this project is therefore expected to increase, enabling the harvesting of energy flexibility in buildings and promoting energy efficiency at a district level.

3.6. Network of excellence on full scale testing and dynamic data analysis

EBC Annex 58 has worked closely with the Dynastee network (www.dynastee.info). Enhancing this network, and using it to encourage actual building performance characterization based on full scale measurements and the appropriate data analyzing techniques were important aims of this project. The Dynastee network of excellence on full scale testing and dynamic data analysis organizes events on a regular basis, such as international workshops, annual training courses and will be of help for organisations interested in full scale testing campaigns.

4. Outcomes

The outcomes of this project and the parallel dissemination of the results via both the EBC Programme and the Dynastee network will certainly promote best practices with respect to dynamic data collection and analysis. The intensive international collaboration led to a major step forward in actual building performance assessment. The methods developed within the framework of this project are valuable to:

(1) develop real building quality assessment, bridging the gap between as-designed and performance obtained on site,

(2) organize the operation of energy systems by generating models that can be used to quantify the dynamic response and the flexibility available in different buildings, or groups of buildings, and

(3) develop models that are useful in simulation environments to assess different designs at increasing scale, i.e. from individual building to district level.

Project Participants

Country	Organisation
Austria	University of Innsbruck
Belgium	Belgium Building Research Institute KU Leuven Universiteit Gent Université de Liège Haute Ecole de la Province de Liège Cenaero Knauf Insulation
P.R. China	City University of Hong Kong The Hong Kong Polytechnic University
Czech Republic	Brno University of Technology Czech Technical University Prague
Denmark	Danish Technological Institute Technical University of Denmark
Finland	Tampere University of Technology
France	Institute for Solar Energy (INES) Ecole Nationale des Travaux Publics de l'Etat Isover Saint Gobain CSTB
Germany	Fraunhofer Institut für Bauphysik (IBP) Passive house Institute
Italy	Politecnico di Milano Universita degli Studi di Firenze European Commission – DG Joint Research Centre

Country	Organisation
The Netherlands	Eindhoven University of Technology
Norway	Norges Teknisk-naturvitenskapelige Universitet
Portugal	University of Porto Portuguese Energy Agency University of Coimbra
Spain	IIngenieria Energy Efficiency in Buildings R&D Unit of CIEMAT Engineering High School of Bilbao CIMNE Tecnalia Research & Innovation, Building, energy and environmental group
United Kingdom	University of Strathclyde Glasgow Caledonian University Leeds Metropolitan University University College London Timber Research and Development Association
USA	Lawrence Berkeley National Laboratory

Project Publications

Inventory of full scale test facilities for evaluation of building energy performance, Arnold Janssens, KU Leuven, Belgium 2016
available from www.iea-ebc.org

Overview of methods to analyse dynamic data, Arnold Janssens, KU Leuven, Belgium 2016
available from www.iea-ebc.org

Logic and use of the Decision Tree for optimizing full scale dynamic testing, Aitor Erkoreka, Chris Gorse, Martin Fletcher, Koldobika Martin, KU Leuven, Belgium 2016
available from www.iea-ebc.org

Thermal performance characterization based on full scale testing - description of the common exercises and physical guidelines, Maria Jose Jimenez, KU Leuven, Belgium 2016
available from www.iea-ebc.org

Thermal performance characterisation using time series data – statistical guidelines, Henrik Madsen, Peder Bacher, Geert Bauwens, An-Heleen Deconinck, Glenn Reynders, Staf Roels, Eline Himpe, Guillaume Lethé, KU Leuven, Belgium 2016
available from www.iea-ebc.org

Empirical validation of common building energy simulation models based on in situ dynamic data, Paul Strachan, Katalin Svehla, Matthias Kersken, Ingo Heusler, KU Leuven, Belgium 2016
available from www.iea-ebc.org

Towards a characterisation of buildings based on in situ testing and smart meter readings and potential for applications in smart grids, Dirk Saelens, Glenn Reynders, KU Leuven, Belgium 2016
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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 29 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 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

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

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