

# **Cost-Effective Commissioning for Existing and Low Energy Buildings – A New IEA ECBCS Research Project**

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## **Synopsis**

The benefits of commissioning are increasingly being recognized internationally. In 2004 and 2005, over 40 experts from 12 countries participated in two workshops to identify barriers to cost-effective building commissioning. These countries have adopted the commissioning practice to various extents. The results of these workshops became the basis for a new research project, Annex 47, on “Cost-Effective Commissioning for Existing and Low Energy Buildings.” Annex 47 was approved at the 56<sup>th</sup> Energy Conservation in Buildings and Community Systems (ECBCS) Executive Committee meeting in June 2005. At present, 13 countries are involved in this international research project.

The Annex research project is nearing the end of the one-year planning phase. This paper presents an overview of the international research plan for 2006-2008 based on the participant work plan and gives insight to the state of commissioning in several of the participant countries.

## ***About the Authors***

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## Background

Approximately one-third of end-use energy consumption in the International Energy Agency's (IEA) member countries occurs in residential, commercial, and public buildings<sup>1</sup>. In the United States, buildings represent 70 % ( $27.9 \times 10^{12}$  MJ, 26.45 Quadrillion Btu or  $7.8 \times 10^6$  GW h) of peak electricity use and account for 38 % of the U.S. carbon emissions, 52 % of sulfur dioxide (SO<sub>2</sub>) emissions, and 20 % of nitrous oxide (NO<sub>x</sub>) emissions [1]. This presents a major demand on energy resources, creates congestion on distribution systems, and represents a significant component of total emissions.

In response, the Energy Conservation in Buildings and Community Systems (ECBCS) program of the IEA has supported projects to enhance the operation of buildings to improve energy performance. In the 1990s, two successive projects were set up to develop fault detection and diagnosis tools and to implement them in real buildings. The implementation of these tools revealed that most of the buildings never worked as intended. These projects highlighted the need for and importance of commissioning buildings to avoid faults that can be attributed to the design and construction stages [2,3].

In 2001, the first IEA project on commissioning was started to develop commissioning methods and tools to ensure that HVAC components and systems reach their design potential and operate energy-efficiently. ECBCS Annex 40, "Commissioning of Building HVAC Systems for Improved Energy Performance," clarified the commissioning process on an international basis and developed tools for its implementation in conventional HVAC systems with a focus on functional testing and end use [4]. This international effort removed several barriers to commissioning. However, documented commissioning methods are currently only available for conventional HVAC systems and do not address the advanced systems and system combinations that are important for low energy buildings (LEB), such as building scale combined heat and power, integrated control of lighting, blinds and HVAC, and cooling techniques such as evaporative cooling and natural ventilation. Without suitable methods and tools to ensure the correct interaction between components and systems, their performance in the field can be expected to fall significantly short of what is intended.

In October 2004 and March 2005, over 40 experts participated in workshops to identify barriers to cost-effective building commissioning. The results of these workshops, presented in the next section, became the basis for a new annex proposal on "Cost-Effective Commissioning for Existing and Low Energy Buildings"—Annex 47 [5].

## Commissioning Benefits and Barriers

The current approach for new construction commissioning is to focus on achieving design intent. However, new buildings can often operate using less energy if they are optimized based on

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<sup>1</sup> IEA member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, and the United States.

actual use and occupancy rather than using only the information available to the designer. Similarly, retrocommissioning may not have an energy focus if the commissioning provider is called in mainly to solve nagging comfort problems. In the case of existing buildings, the usual practice is to attempt to make the building work as designed. However, the "as-built" and "as-used" building virtually always differs from the original design.

Economic benefits of commissioning beyond the energy savings include fewer change orders and call-backs for installers, fewer service calls and fewer complaints from occupants. These benefits often exceed \$10 per square meter (\$1 per square foot) in new buildings that are commissioned [6]. Evidence emerging from a study of Leadership in Energy and Environmental Design (LEED) certified buildings performed by the U.S. National Renewable Energy Laboratory and from a number of European studies strongly suggests that commissioning to optimize operation based on actual occupancy and use is even more critical for low energy buildings than for conventional buildings [7,8].

There are also a number of environmental benefits associated with reduced energy consumption, including the reduced global warming potential associated with a reduction of carbon emissions, reduced emissions of nitrogen oxides from power plants, and improved comfort and indoor air quality from remedying faults in HVAC systems, although the latter are difficult to quantify.

In order to achieve these benefits, technological and process barriers to greater market penetration must be addressed. It is generally recognized that demonstrating cost-effectiveness, including the persistence of commissioning measures will remove a major barrier to the wider market acceptance of commissioning. Market penetration could be increased through comprehensive development and aggressive deployment of methods and tools that decrease the cost and allow the scaling up of the delivery of commissioning. Additionally, the continuing increase in the fraction of buildings with an energy management and control system (EMCS) can also be expected to facilitate market penetration because most of the commissioning methods in use today and most of the automated methods currently under development make use of EMCS.

## **The Annex 47 Project**

The Executive Committee of the Energy Conservation in Buildings and Community Systems (ECBCS) program established a new research project (Annex) in June 2005 called "Cost-Effective Commissioning for Existing and Low Energy Buildings."

The goal of Annex 47 is to enable the effective commissioning of existing and future buildings in order to improve their operating performance. The commissioning techniques developed through this research will help transition the industry from the intuitive approach that is currently employed in the operation of buildings to more systematic operation that focuses on achieving significant energy savings. The Annex will also exchange information on commissioning practices in different countries and disseminate relevant information to national practitioners. Details can be found at the Annex 47 website: <http://www.iea-annex47.org/>

Thirteen countries with the common goal of advancing building commissioning participated in the first meeting of Annex 47:

- Belgium
- Canada
- Czech Republic
- Finland
- France
- Germany
- Hungary
- Japan
- Korea
- The Netherlands
- Norway
- Sweden
- USA

Participants include research institutions, universities, control system manufacturers, equipment manufacturers, design and construction firms, and energy service companies.

Annex 47 will address the following objectives:

- To extend previously developed methods and tools to address advanced systems and low energy buildings, utilizing design data and the buildings' own systems in commissioning,
- To automate the commissioning process to the extent practicable,
- To develop methodologies and tools to improve operation of buildings in use, including identifying the best energy saving opportunities in HVAC system retrofits and standard reporting methods for the energy performance of buildings in support of the "European Union Energy Performance of Buildings Directive", and
- To quantify and improve the costs and benefits of commissioning, including the persistence of benefits and the role of automated tools in improving persistence and reducing costs without sacrificing other important commissioning considerations.

This project began by identifying existing barriers to the acceptance of commissioning as standard practice and will develop enabling technologies; for example, methodologies and automated tools to support the "field optimization" approach to commissioning for low energy buildings. The use of automated tools that speed up the process and reduce dependence on scarce and relatively expensive skilled practitioners is expected to further broaden the market for commissioning. The aim is the application of engineering principles to the operation of buildings specifically to achieve energy savings, rather than as a possible side effect. Once developed and applied to low energy buildings, these procedures could have substantial impact if eventually applied as standard commissioning practice to all buildings, potentially doubling the energy impact of commissioning in new buildings.

The overall structure for the Annex 47 research project is presented in Table 1. It is divided into three main tasks to address the initial commissioning of advanced and low energy building systems, commissioning and optimization of existing buildings, and commissioning cost-benefits and persistence.

The deliverables of this research will be:

- Methods and tools for commissioning advanced systems and low energy buildings,
- Methods and tools for field application, and
- Information on the costs and benefits that can be used to promote the wider use of commissioning.

**Table 1: Annex 47 Structure**

Scope of Annex	Subtask
1) What can be done for future buildings to enable cost-effective commissioning?	<b>Initial Commissioning of Advanced and Low Energy Building Systems</b>
	<ul style="list-style-type: none"> <li>•Develop information flowchart and information model</li> <li>•Develop general commissioning methodology for advanced &amp; low energy buildings               <ul style="list-style-type: none"> <li>–Functional test procedures</li> <li>–Control strategies for advanced systems</li> <li>–Case studies</li> </ul> </li> </ul>
2) What can be done for existing buildings and systems to conduct commissioning cost-effectively?	<b>Commissioning and Optimization of Existing Buildings</b>
	<ul style="list-style-type: none"> <li>•Develop data visualization, field optimization, and commissioning tools</li> <li>•Perform and disseminate documented case studies</li> </ul>
3) How can the cost-benefit situation of commissioning be represented?	<b>Commissioning Cost-Benefits and Persistence</b>
	<ul style="list-style-type: none"> <li>•Develop cost-benefit methodology</li> <li>•Develop methodology &amp; tools to enhance persistence</li> <li>•Develop international databases               <ul style="list-style-type: none"> <li>–Commissioning cost-benefit</li> <li>–Persistence</li> </ul> </li> </ul>

## The International State of Commissioning

Within the IEA member countries, the state of commissioning is at different levels of development. Most countries have established mechanisms for quality control, but all participants recognize that current approaches are not adequate for ensuring that buildings operate as intended. For several countries, the Annex 40 project was the first exposure to the commissioning process. This process has since advanced among the member countries. The following section describes the state of commissioning in several of the Annex 47 participating countries and presents some of the related research underway.

- **Canada:** A national program on continuous building optimization (retrocommissioning) is underway with the participation of government agencies and national energy utilities. The program includes the development of guides and tools that facilitate the implementation of the optimization process, as well as the delivery of training and awareness programs aimed at addressing the needs of building owners, commissioning providers and building operators. The optimization process and a tool developed in Canada are being promoted in more than 20 demonstration projects. Demonstration projects include some of the first Canadian LEED buildings and the participation of major Canadian facility management firms and commissioning providers.
  
- **Czech Republic:** The Czech team from Czech Technical University (CTU) in Prague is focused on the implementation of modern control systems in building performance

optimization, including intelligent control of HVAC in low-energy buildings. Activities are supported by CTU and the National Ministry of Industry.

- **Finland:** In Finland the term "commissioning" is quite new. As a part of Annex 40, Finnish translations of the international glossary were made. The English term commissioning was translated into the Finnish term "toimivuuden varmistaminen (ToVa)" and is being promoted as a process. Until recently commissioning-type activities have been developed mainly just by individual contractors and builders as part of their quality assurance processes. Since 1993 similar types of activities especially from the point of view of energy efficiency of buildings have been carried out as a part of "Energy Auditing," where standard procedures and tools have been developed and implemented<sup>2</sup>.

In early 2002, a building services technology program called CUBE was launched to improve the performance of the service content of building services<sup>3</sup>. This program includes a national R&D project to develop Finnish procedures for building commissioning with a special focus on the indoor air quality and energy efficiency of buildings. The aim of the project is to develop "systematics," methods and tools to be used in a commissioning process during the different building life-cycle phases (planning, design, commissioning, acceptance, operation & maintenance, and reporting). The developed methods will be tested and validated in the commissioning of real buildings such as schools, residential buildings and offices. The results of the project will be published in a commissioning guidebook, presented at the national CUBE conference in March 2006. Practical testing and further development of the guidebook and tools will be done in a new project that is under preparation.

- **France:** There is a new certification program (HQE-idem) that has been established. In practice, commissioning is being implemented in the operation phase and a national guideline on commissioning is under development.
- **Germany:** The national guideline EnEV 2006 will be enforced beginning this year. Mandatory for all new buildings and major retrofits, this guideline defines permissible values for energy consumption for heating, cooling, ventilation and lighting and uses the DIN V 18599 as the standard calculation method. Furthermore, it also mandates that all public buildings display their energy consumption to the public with an energy certificate.

Within the national research program (ENOB) more than 20 demonstration buildings have already been built with great success, outperforming national energy consumption standards by 50 % without additional building costs. The program will be continued, supporting the design process, commissioning, and monitoring of the first two years of operation. ENOB also supports several projects focusing on improved commissioning and operation of innovative buildings.

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<sup>2</sup> [www.motiva.fi/en/areas/energyaudits/](http://www.motiva.fi/en/areas/energyaudits/)

<sup>3</sup> [www.tekes.fi/cube](http://www.tekes.fi/cube)

Energy agencies and utilities support energy efficiency by means of contracting and public private partnerships.

- **Hong Kong/China:** The Hong Kong team is mainly involved in energy management and control systems (EMCS)-assisted commissioning of HVAC systems for both chiller plants and air-side systems and for both existing and new buildings. The R&D efforts include the methodology and application development, validation and site application case studies. The main application-site study is being conducted in cooperation with a major property developer in Hong Kong. The site is a very large-scale building development, the International Commerce Centre, which is over 100 stories high. The involvement of the R&D team starts from the HVAC design stage and continues through the operation stage of the building.
- **Japan:** The Building Services Commissioning Association, a non-profit organization, was launched in 2004. The organization continues to provide seminars for commissioning technologies and schemes in major cities and started to contact Asian countries such as China including Hong-Kong, Korea and Taiwan in order to undertake cooperative activities in building performance assurance. A technical committee on commissioning was set up in the scientific organization SHASE, the equivalent of ASHRAE in the United States, and a first version of the guideline on commissioning of HVAC systems was published. In Japan, aspects of the commissioning process are becoming more common in building projects and the number of real building projects that implement commissioning as a separate task is increasing. Furthermore, as of April 2006, performance testing of major components, such as air-handling units, chillers, heat pumps, etc., which consume the most energy, will become mandatory under the Energy Conservation Law.
- **Korea:** A research project is underway to develop analytical methods and experimental verification of optimal control for intelligent building HVAC systems. Following verification of the energy performance in a simulated facility, selected tools will be applied to demonstration buildings in the New Administration Complex City.
- **The Netherlands:** The Netherlands Organization for Applied Scientific Research (TNO) is involved in the development of national standards concerning the energy performance of new buildings. At the EU level, TNO is one of the key players in the knowledge transfer to all EU-members of the Energy Performance Building Directive (EPBD).

In the Netherlands, practitioners in the field agree on the importance of real commissioning, but it is currently only implemented in the formal handover of building and installation. There is also strong interest from large-building owners for functional testing of the installations in the buildings, e.g. the (i) energy production (heating and cooling), (ii) energy transport (water and air), (iii) air treatment (Air Handling Unit), and (iv) energy transfer to the room (end units). Our mission is to promote the implementation of the whole commissioning process.

There is no national research program for developing functional test procedures. In order to develop such procedures, financial resources need to come from industry players. Currently a pilot on functional tests is being executed for 10 months in 40 existing buildings. Another project is underway to demonstrate the benefits of using fault detection and fault diagnosis (FDD) system for AHUs. The FDD is an expert rule based system based on the principles developed by the French Scientific Center for Building Physics (CSTB) and NIST. To test the FDD system, data is automatically collected from an AHU at a swimming pool complex.

The key areas of TNO's research are to develop:

- Suitable tools for functional testing of systems affecting the (i) the indoor environment, (ii) energy consumption, (iii) the circuit of energy -production, -transport, AHU, end units in the room;
  - Key performance indicators (KPI) to be used as the basis in new types of performance contracts between building owner and installer; and
  - An FDD expert rule based system with flexible input of the expert rules.
- **Norway:** A national research project on “Life-Time Commissioning for Energy Efficient Operation of Buildings” is in progress. The overall objective is to contribute to the implementation of life-long commissioning of building HVAC systems, so that this becomes a standardized way of constructing, operating and maintaining the HVAC systems. Several large governmental and private building owners are supporting the project.

The main goal is to develop, verify, document and implement suitable tools for functional control of energy and indoor environmental conditions in buildings under continuous operation during the entire life of the building. Three PhD projects at the Norwegian University of Science and Technology are currently underway:

- Modeling and simulation methods for lifetime supervision of energy and indoor environmental performance of buildings,
  - Real-time supervision of building HVAC system performance, and
  - Using building energy monitoring to verify building energy performance.
- **USA:** In a 1998 study, market penetration of commissioning was estimated to be less than 5 % for new buildings, and approximately 0.03% for existing buildings. Awareness has increased through certification programs (e.g., Leadership in Energy and Environmental Design (LEED)), large-owner mandates, State and local initiatives, and professional organizations. There is a high demand for tools to facilitate the commissioning process, including automated tools, and for data on cost-benefits. Methodologies for quantifying the benefits of commissioning are under development but no standards exist. At present, there are guidelines on the commissioning process, including a new document that is under public review “ASHRAE Guideline 30P: The Commissioning Process for Existing HVAC&R Systems.”



## Conclusions

Commissioning is internationally recognized as a valuable process for ensuring that buildings operate as intended. This is even more critical for advanced systems that rely on system interactions. At present, tools are emerging for conventional systems, but need to be extended to other types of systems. This research and development projects are underway internationally.

In June 2005, the ECBCS launched a new international research project in the area of commissioning. Annex 47: “Cost-Effective Commissioning of Existing and Low Energy Buildings” seeks to eliminate barriers to commissioning as standard practice by: extending previously developed methods and tools to address advanced systems and low energy buildings, automating the commissioning process, and developing methodologies to quantify and improve the costs and benefits of commissioning.

Thirteen countries are involved in this project. The state of commissioning is at various levels of implementation as are the technologies used in the participating countries. The strength of the annex project is in the exchange of information and collaboration in the development of tools. The deliverables of this research will be: 1) methods and tools for commissioning advanced systems and low energy buildings, 2) methods and tools for field application; and 3) information on the costs and benefits that can be used to promote the wider use of commissioning. It is intended that the results of this project be transferred to the buildings industry in each of the participating countries.

## Acknowledgement

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