

The International State of Building System Commissioning

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ABSTRACT

Buildings are a major source of energy consumption and are direct contributors to the significant problems associated with energy dependence and the growing environmental impact of fossil fuel use. Building system commissioning is a quality assurance process designed to improve the operations of existing buildings and the design, construction and operations of future buildings. This process is gaining support in many countries as building owners and other stakeholders see the benefits through real-world projects. Greater investment is needed to scale up the process implementation as a means to realize critical performance goals.

This paper presents an assessment of the international state of building system commissioning in the Asia Pacific, European and North American regions, based on national reports for fifteen countries. The review investigates current practices for both new building and existing building commissioning, highlights a variety of initiatives that are underway, and discusses the local and international mechanisms that are developing the market.

Introduction

Approximately one-third of the global energy use is attributed to buildings and, despite improvements in the thermal performance of buildings, is inefficiently used (IEA 2008). This inefficiency, coupled with concerns for energy availability and increased understanding of the environmental impact of the building sector, is raising interest in energy efficient technologies and delivery processes. However, because the buildings industry is strongly driven by first cost, investment decisions that are often made without considering payback over the building lifecycle present a barrier to improving the building stock and environmental stewardship.

Although many countries have their own established procedures for building design, construction, and operations, current approaches are frequently inadequate for ensuring that buildings perform as intended. The complex and often opaque definitions of roles and responsibilities for members of the building industry lead to inefficiencies and information gaps in the lifecycle, even for conventional building systems. As non-conventional systems are introduced, a lack of familiarity by the designers, installers, or end-users can lead to the misapplication of technologies and result in poor performance. This risk increases the need for independent quality assurance.

Building systems commissioning is increasingly recognized as a valuable mechanism for quality assurance for the design, construction, and operation of buildings. The process is aligned with industry best-practices, where the roles of the individual players and their interactions are defined and the impact of their decisions can be considered. Initial commissioning begins during design and continues through construction, and occupancy. It helps ensure that the performance of the new building or major retrofit meets owner expectations. Retrocommissioning applies the

same process to existing buildings with the goal of improving the integrated performance of the building systems. Recommissioning is another type of commissioning that occurs when a building that has already been commissioned undergoes another commissioning process. Most buildings experience degradation in performance that, if left untreated, will reduce occupant productivity and energy efficiency, often well before comfort complaints trigger a response. The process of lifetime commissioning or ongoing commissioning seeks to apply regular checks of the systems and their interactions to maintain a greater level of performance throughout the lifecycle of the building.¹

The global need for improved building performance has led to numerous international collaborations. Because technological and policy developments occur at different rates and in different regions, there is an opportunity for mutual benefit and rapid advancement through the exchange of information. Commissioning research projects under the International Energy Agency's (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) program, Annex 40 (2000-2005) and Annex 47 (2005-2009),² provide a forum for the exchange of knowledge and experience among participating countries. Common definitions of the commissioning process were established in Annex 40 (Visier et al. 2005) and the research initiated under each of these projects has become the basis for the development of national guidelines.

The State of Building Systems Commissioning

Regional partnerships and international collaborations to promote the commissioning process have accelerated awareness and adoption. The following sections on the Asia Pacific, Europe, and North America regions provide an overview of the state of building systems commissioning. Each national assessment aims to present the national drivers, leading efforts and an indication of their success (if known). Fifteen countries are represented in this review.³

Asia Pacific

In the Asia Pacific region, the construction industry is experiencing unparalleled growth. China alone reports the annual construction of two billion square meters (21.5 B ft²) of floor space, (Qiu, 2008). The environmental impact of this growth has global repercussions. It is therefore critical that the building industry adopt building commissioning as a standard practice to improve the quality and efficiency of design, construction, and operations.

Asia Pacific countries are leveraging national energy laws, institutional mandates, and non-profit organizations to foster development of building systems commissioning. For several countries in the region, recent exposure through international symposia and conferences sparked

¹ These definitions stem from commissioning guidelines in the USA. International definitions are varied in their scope though there are efforts to harmonize practices as will be discussed in this report.

² IEA ECBCS 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.

³ Ongoing research in Hong Kong, Czech Republic, Norway, and the Netherlands was presented in Castro and Choinière 2006.

interest that has developed into national research projects. This exchange of information is particularly useful for countries that have natural synergies, such as climate, that facilitate transfer of technologies or guidelines. Through these cooperative exchanges, countries are able to leapfrog technologies and accelerate adoption.

Australia. Indoor environmental quality assessments, rising energy costs, and a greater understanding of the link between comfort and productivity are driving the demand for improved energy efficiency of buildings in Australia. At present, most of the commissioning projects are associated with major contracts and do not address smaller projects. Furthermore, the fully integrated approaches to project commissioning, promoted by the Chartered Institution of Building Services Engineers (CIBSE) and American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) commissioning guidelines, are not well understood by the commercial sector, and this educational need is yet to be addressed (EcoLibrium 2006).

Awareness of the importance of the commissioning process is increasing, largely due to the market influence of voluntary, performance-based rating schemes such as the National Australian Built Environment Rating System and the Green Building Council's Green Star program. Through this mechanism, several large commercial real estate owners and governmental agencies have made commitments to achieve a certain rating in their building stock. The implementation and promotion of these rating schemes have the potential to trigger the demand for energy audits and commissioning in the existing building stock. Deakin University is developing rapid reporting techniques to facilitate building performance improvement in the commissioning process (Nakahara et al. 2007).

China. Mainland China has seen several construction booms. In the 1980's the rapid growth of residential construction prompted the Ministry of Construction to develop energy-efficient building codes. These codes did not include commissioning and quality, in general, was considered poor. In the 1990s, testing and commissioning concepts diffused into the Chinese buildings industry as part of the western management techniques from numerous overseas, joint venture construction projects (Chow et al. 2006). International partnerships now also extend to academic research. Chinese universities, including Tsinghua University, are conducting research on building optimization, building commissioning and other related work. In 2008, China's Ministry for Construction released acceptance codes for building services equipment and building systems, though no information could be obtained regarding the administration and enforcement of these requirements.

Hong Kong was one of the first adopters and developers of the building commissioning process due to early exposure to the United Kingdom's commissioning model. As early as 1990, the Hong Kong Government published twelve booklets based on the CIBSE Commissioning Codes. The documents were developed into commissioning specifications released in 2002 and are intended to be incorporated into government building project contracts (Chow et al. 2006). Furthermore, in 2004, Hong Kong introduced a new voluntary scheme, termed the Consolidated Environmental Performance Assessment Scheme (CEPAS), to promote the design of environmentally-friendly buildings. CEPAS incorporates building commissioning as a major element for performance assessment.

The Hong Kong Building Commissioning Centre (HKBCxC) was established in December 2004 as a non-profit organization whose mission is to promote the establishment of a

standardized approach to building commissioning in Hong Kong. The HKBCxC organizes programs for continuing professional development, certification services and publishes guidebooks on the management of building commissioning, field measurements, and system tuning. In the “Practical Guide to Building Commissioning Management” Chow et al (2006) report that independent contracts for commissioning and retro-commissioning are soaring in Hong Kong.

Japan. In 2006, building energy performance reporting became mandatory under the Energy Conservation Law. The reports are based on simple performance tests of the components and systems that have the largest impact on the energy consumption of heating, ventilation, and air-conditioning systems. In practice, there is significant variation in the implementation approach because no standard test procedures are specified and it is unclear whether relevant problems could be investigated adequately through the data contained in the reports. Hence, aspects of the commissioning process are drawing more attention in Japan’s building sector. In existing buildings, various approaches for retro-commissioning are commonly implemented, but initial commissioning for new construction is not common.

In 2005 the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (SHASE) technical committee on commissioning issued a guideline on the building services commissioning process. The Building Services Commissioning Association (BSCA), a non-profit organization launched in 2004, provides seminars about commissioning technologies in major cities and has undertaken cooperative activities with Asian countries such as China (including Hong Kong), Taiwan, and Korea. It also continues to compile commissioning documentation and tools through actual commissioning projects and research. BSCA’s strategy is to establish a certification program for commissioning engineers, including the Commissioning Authority, and to educate the construction industry and related government sectors.

Energy policy is playing an important role. The Ministry of Economy, Trade and Industries is interested in a new business model, based on building commissioning, to enhance energy efficiency of new and existing buildings and The Ministry of Land, Infrastructure and Transportation is promoting use of lifecycle energy management with a newly developed simulation tool. Market demand for commissioning is believed to be strong but mandates, based on energy and environmental policy, are needed for building owners to apply building commissioning to new construction.

Taiwan. In Taiwan, building commissioning for new construction is considered established practice. The Taiwanese government has issued a mandate requiring that all public projects with a budget over 15 million U.S. dollars acquire the Green Building Label before a construction permit can be granted. Testing, adjusting and balancing (TAB), commissioning, and the use of a building energy management system (BEMS) are prerequisites. However, the process implemented in Taiwan does not represent the full range of actions from design to operations. The commissioning role in Taiwan for existing buildings is typically similar to that served by energy service companies in Japan and the USA. Taiwan is involved in international activities to expand national practices as deemed necessary. For example, a review of the Green Building Label (similar to Leadership in Energy and Environmental Design (LEED) for new construction in the USA and CASBEE in Japan) suggested that a commissioning plan be added.

A national-scale project was launched in 2003, by the Architecture and Building Research Institute, Ministry of the Interior, to renovate all the central heating, ventilation, and air-conditioning (HVAC) systems in governmental buildings for energy conservation. The renovation process includes system diagnostics, remedial strategies, establishing engineering jobs, contracting, TAB, commissioning, and system performance validation through the BEMS. To date, 22 million USD have been spent with an overall energy-savings of 22 % and an average payback of five years. The success has since led to a series of demonstration projects for civil and governmental buildings. In 2008, Taiwan will launch another five-year program where the energy savings effort will be enhanced with greater system fine-tuning and commissioning as a means to support the Kyoto Protocol and global CO₂ emission reduction efforts.

Korea. The Korean Institute for Energy Research (KIER) is working to promote the commissioning process through energy conservation and quality assurance measures for new construction. Commissioning projects have been carried out by KIER as part of their research work, and have also been implemented in several buildings financed by foreigners. However, there is no recognized national standard and the Korean government has no intention to mandate the commissioning process.

Europe

The countries of the European region present significant differences in their building delivery processes as well as their emphasis on energy efficiency and measures for quality assurance. For most, with the exception of the UK, the commissioning process is quite new. However, the European Commission established the European Performance of Buildings Directive, EPBD (EC 2002), to promote the improvement of energy efficiency and building performance. Four requirements to be implemented by the Member States⁴ are to: 1) develop a framework for a methodology to calculate the integrated performance of buildings, 2) set minimum standards in new and existing buildings, 3) certify the energy performance of buildings, and 4) inspect and assess heating and cooling installations.

According to reports from the member states, the EPBD poses significant challenges in terms of its practical implementation, including difficulties associated with the transfer of requirements into existing building practices under a range of climates. However, because the commissioning process is well aligned with the goals of the EPBD, several national research programs are introducing commissioning tools as a means to address the requirements of the directive. In many countries, commissioning tasks are focused on the building handover, or performed as part of the facilities management. However, for commissioning to have a real impact on savings, the review must begin at the pre-design phase, where changes are easier and more cost-effective to make. It is anticipated that the increased attention to energy efficiency in

⁴ Member States for EPBD: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom of Great Britain and Northern Ireland. Norway and Croatia have also been involved in work to harmonize national procedures.

buildings will lead to greater application and consistency of commissioning through the building lifecycle.

Belgium. Commissioning research has been underway in Belgium for several years, and mainstream awareness of the importance of commissioning of low-energy buildings has increased due to the implementation of the EPBD and the introduction of the passive house concept for very low energy building. Energy performance laws, which set requirements for the energy performance and indoor climate for most buildings requiring a building permit, exist in the Flemish Region and are under development in the Brussels and Walloon regions.

Czech Republic. Building commissioning is a new concept in the Czech Republic. Only some aspects of building commissioning are implemented as a part of the facility management and energy auditing processes that are related to EPBD implementation. Under the IEA Annex 47 project, researchers have developed tools that support additional aspects of the broader commissioning process, including new control system energy services.

Finland. Historically, individual contractors and builders in Finland have managed commissioning-related activities as part of their quality assurance measures. More recently, emphasis has been placed on the development and implementation of "energy auditing" procedures. In 2002, a Finnish national research program called CUBE was launched to improve the performance of building services. This program includes a national R&D project to develop Finnish procedures for building commissioning, focusing on the indoor air quality and energy efficiency of buildings. The Finnish term and concept of "toimivuuden varmistaminen (ToVa)," an adaptation of building systems commissioning, is being promoted. Practical testing and further development of the guidebook and tools are underway. Methods and tools to support the commissioning of buildings and their subsystems throughout the phases of the building life-cycle are being developed.

France. The commissioning process is just beginning to take hold in France and a national guideline on commissioning is under development. In practice, commissioning is implemented in the operations phase, though there is greater interest from large building owners for more complete commissioning plans as a result of ongoing national research and new requirements under the EPBD. Current research is focused on automating the commissioning process to improve performance, pushing for early implementation of the commissioning process from design through certification, and developing tools and procedures for specific building applications (e.g., schools).

Germany. Commissioning for new construction is not established or even required as a third party service in Germany. German law (HOAI) dictates that architects and design engineers perform the following tasks within the construction administration and construction supervision:

- supervising acceptance and performance tests and statement of deficiencies;
- collecting/compiling and delivering as-built documentation, operating manuals, and acceptance protocols; and

- supervising the rectification of deficiencies that fall under the two-year contractor's warranty period or the five-year design team warranty period from date of acceptance.

This approach, initiated in 1976, presents a model for internal commissioning during the construction phase and, in conjunction with energy conservation laws, has resulted in higher performing buildings. Efforts to implement the full commissioning process beginning in pre-design have been more recent. In one German national research program on energy optimization in buildings (ENOB), more than twenty demonstration buildings surpassed national energy consumption standards by 50 % without incurring additional building costs. The program has been extended and now supports 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. Energy agencies and utilities support energy efficiency through contracting and public private partnerships. Two other projects, ModBen and Building EQ, deal with performance evaluation of existing buildings.

The Netherlands. In the Netherlands, practitioners agree on the importance of building commissioning. However, it is currently only implemented in the installation and formal handover of selected buildings. A pilot project on functional performance tests conducted in forty buildings identified that 70 % of the systems tested were malfunctioning, leading to increased energy use and reduced comfort. To improve system operation, large-building owners are investigating performance contracting for operations and maintenance, based on well-defined criteria. The commissioning process plays an important role. The Netherlands Organization for Applied Scientific Research is involved in the development of national standards concerning the energy performance of new buildings to promote the implementation of the whole commissioning process.

Norway. Building commissioning is not established practice in Norway. A draft national commissioning guideline was developed in 2007 to promote the life-long commissioning of building HVAC systems. The guideline is currently under review and several large governmental and private building owners are involved in the effort to verify, document and implement suitable tools to provide continuous control of energy and indoor environment during the life of the building.

United Kingdom. The UK developed the earliest commissioning codes and provided the basis for similar work in many other countries. CIBSE published the first commissioning code on air-distribution systems in 1960 and subsequently released codes for other types of equipment. The emphasis of the commissioning codes was originally post-construction commissioning. Bordass (2008) reports that independent commissioning engineers were usually appointed as part of the design and build team in the late 1970's and early 1980's. However, as markets became more competitive, in the late 1980's and 1990's, commissioning was less commonly sold as a separate service and eventually became a subcontractor role, which had a negative impact on quality due to cost-cutting pressures. Today, initial commissioning has become routine for large projects and quality has once again improved but there are still major challenges in that the commissioning period is often squeezed when other delays impact the delivery date.

The current set of CIBSE commissioning codes includes: air distribution systems, boilers, automatic controls, lighting, management (Code M), refrigeration, and water distribution systems. Code M shows an important change in the approach to the initial commissioning process by stating that the commissioning manager should be appointed early in the design phase in order for the system to be designed as commissionable.

Other organizations have also been directly involved in improving the commissioning industry. The Building Services Research and Information Association (BSRIA), a non-profit consulting design, construction, and operations organization is leading the “Soft landings” development with support from the Usable Buildings Trust, a non-profit organization dedicated to improving building performance through the better use of feedback. The Soft landings procedure aims to reduce the loss of information by extending the service of the design and building (and commissioning) team to facilitate fine-tuning and debugging at building handover in order to achieve a closer match between design targets and building operation, and to allow individuals to learn from the experience (BSRIA 2008). The Commissioning Specialists Association (CSA) is focused on career development, including training and certification of individuals.

Although retrocommissioning is not widespread, there is expected to be a major increase in its implementation as demand for improved energy and carbon performance increases, driven by new requirements of the EPBD, occupants, and building owners.

North America

In North America, the concept of building commissioning began with the Code of Practice for Commissioning Mechanical Systems in Buildings that was developed in 1986 by the Standing Committee of Consulting Engineers and Mechanical Contractors of British Columbia. Today there are several, industry-recognized guidelines on the commissioning process: ASHRAE Guideline 1-1989 The HVAC Commissioning Process (revised in 1996), and ASHRAE Guideline 0-2005, The Commissioning Process. Although building systems commissioning is established practice in both Canada and the USA, the process is not widespread. Many of the existing resources are focused on conventional HVAC systems and there is need for information on other types of systems, particularly due to increased interest in non-conventional, low energy systems.

In Canada and the USA, awareness has increased through professional organizations, certification programs (e.g., LEED), large-owner mandates, and energy-efficiency initiatives. However, market barriers are significant. There is a need for greater awareness of the benefits and cost of commissioning to increase demand, and a need for more training and certification of commissioning providers to increase the supply. At present, building owners lack the access to experience and lessons learned in easily accessible, creditable and persuasive formats that would facilitate their investment decisions. Furthermore, tools and standardization are needed to reduce the cost of commissioning and improve the cost-benefit ratio for greater uptake. This includes automated tools, data on cost-benefits, and clear specifications for key building performance metrics, monitoring methods, and energy calculation methods.

Details of National Initiatives are Described Below

Canada. Commissioning in Canada is quite limited; generally implemented as a result of large owner mandates or as a part of a green building rating program. There is, however, growing interest in developing a non-profit commissioning organization as a means to accelerate training and certification of commissioning providers and to educate stakeholders.

Initiatives aimed at addressing the needs of building owners, commissioning providers and building operators include the development of guides, tools and incentives to facilitate the implementation of the optimization process, and the delivery of training and awareness program. There are two national-scale research programs which involve the participation of governmental departments and partnerships with national energy utilities. A program from the Office of Energy is focused on implementation and includes a project to promote the optimization process through more than twenty demonstration projects. These projects include some of Canada's first LEED buildings and involve the participation of major Canadian facility management firms and commissioning providers. In addition, several of the projects implement DABO, a continuous building commissioning and optimization tool developed in Canada.

USA. Rising energy costs and a shift in public policy that emphasizes the need for energy independence are driving energy conservation. In the absence of national commissioning requirements, individual state codes⁵ and institutional mandates have proven to be strong market drivers, though enforcement mechanisms have been problematic.

The buildings industry is working to address market barriers and improve the quality of its services. Non-profit organizations, including ASHRAE, Portland Energy Conservation, Inc. (PECI), the California Commissioning Collaborative and the Building Commissioning Association (BCA), provide access to industry resources for both providers and building owners, including:

- a library of published papers and commissioning guides for retro-, initial, and on-going commissioning;
- tools: design guides, operations and maintenance best practices, case studies database;
- sample documents: commissioning plans, specifications, functional tests, checklists; and
- training and certification programs, career and provider directories.

In recent years, market indicators show growth in the number of firms offering commissioning services. In 2008, 267 commissioning provider firms and 665 members registered with the BCA. There has also been a dramatic increase in commissioning certification and training provided by

⁵ California includes acceptance testing in the building energy code, Washington state building code includes requirements for lighting controls and mechanical systems and Massachusetts has approval and acceptance requirements in the energy conservation section of its building code.

professional organizations⁶, which indicate a demand by engineering professionals for more knowledge.

Utilities and government agencies have also invested resources on research and technology demonstration activities in an effort to stimulate the market for commissioning. More investment is needed to significantly improve the energy efficiency of the existing building stock, to meet the low energy targets for new construction, and to address the projected shortage of skilled and certified providers.

Summary and Conclusions

Commissioning is a promising quality assurance process and is gaining acceptance internationally as a means to improve building performance. The concept of commissioning originated in the UK in the 1960's and developed in Hong Kong and Canada in the 1980's. The process has been refined in individual countries and researchers are working with the building industry to merge the commissioning process with existing best practices to develop a more complete and streamlined approach to ensure that buildings operate as intended.

This paper reviewed the state of commissioning in fifteen countries within the Asia Pacific, European, and North American regions. Within the building industry, the need for improved energy efficiency and quality assurance has long been evident, but shortsighted investment criteria and decisions present a major barrier. In recent years, rising energy consumption in buildings and greater awareness of their energy impact has prompted both national and international concerns regarding energy security and environmental security. Furthermore, much of the information on potential energy savings or cost savings through commissioning is anecdotal. There is an immediate need for research to establish standard methodologies to document actual costs and benefits.

International programs provide the basis for technology transfer and policy adoption. In the area of commissioning, this includes the IEA ECBCS Annex 40 and Annex 47 research projects, the international dissemination of commissioning information lead by national commissioning non-profit organizations, and international commissioning projects. As a result of these interactions, individual countries have begun to adopt strategies to improve the performance of their existing building stock and improve the delivery process for new buildings.

Early investors in the commissioning process have attempted a number of different development paths including national research programs, industry guidelines, government mandates, training programs, demonstration projects, international collaborations, and the creation of non-profit organizations to gather resources and disseminate information. One of the most promising of these is the establishment of commissioning demonstration projects with detailed information about the associated costs and benefits of the process. The need for quantitative and qualitative information (beyond anecdotal reports) is universal. Demonstration projects can provide a foothold for the industry and justify the large owner mandates, national mandates, and additional measures that are needed to scale up the adoption of commissioning as standard practice.

⁶ Certification and Training Providers include: BCA / University of Wisconsin, National Environmental Balancing Bureau, Associate Air Balance Council, Association of Energy Engineers, Sheet Metal and Air Conditioning Contractors National Council, ASHRAE, and PECEI

The dissemination of information and education is also a critical component in establishing the commissioning process. Non-profit organizations including the BSCA, CIBSE, HCBCxC, and PECEI have each played a key role in fostering interest in commissioning research and commissioning projects and exchanging information, first on national levels, and increasingly at international levels.

Although the goals of reducing energy consumption and green house gases are gaining political support, investment still lags behind. There is a disparity between those who must invest in the development of commissioning technologies and those who would benefit. Because adoption has been slow, public and private partnerships are needed to grow both the supply side and the demand side of the commissioning market. On the supply side, there is a need for greater standardization of products and services. There is a dramatic shortage of skilled providers and a lack of resources to enable the industry to improve the building delivery process. On the demand side, resources are needed to make the business case for the long-term benefits of their investment. Owners lack the resources, such as contracting documents, and market information that is needed to facilitate the procurement of commissioning services. Harmonization is needed to assure that the process adequately spans the building lifecycle and to ensure that the benefits obtained in individual projects can be scaled up to meet national needs. Continued support for the development of the commissioning market is needed for a global increase in building performance.

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References

- Bordass, William (William Bordass Associates, Technical Director of Usable Buildings Trust). 2008. Personal communication. May 6.
- [BSRIA] Services Research and Information Association. 2008. "How to Glide a Building" Press release on Soft Landings. <http://www.bsria.co.uk/press/?press=472>. May.
- Castro, N. and D. Choinière. 2006. Cost-Effective Commissioning for Existing and Low Energy Buildings- A New IEA ECBCS Research Project. Proceedings of the National Conference on Building Commissioning.
- Chow, L. KH. et al. 2006. Practice Guide to Building Commissioning Management. Hong Kong Building Commissioning Centre.
- EcoLibrium, 2006. Commissioning: where to now? Australian Institute of Refrigeration, Air-conditioning and Heating, June edition.
- [EC] European Commission, 2002. *European Performance of Buildings Directive*. European Directive 2002/91/EC.
- [IEA] International Energy Agency. 2008. Energy Conservation in Building and Community Systems Work Program, www.iea.org <http://www.ecbcs.org/home.htm>
- Nakahara, N. et al. 2007. Proceedings of the Asia Pacific Conference on Building Commissioning (APCBC) Workshop in Kyoto, Japan.
- Qiu Baoxing, 2008. Press briefing on China's energy-efficient building and green building initiative. Feb. 26, 2008. http://english.gov.cn/2008-02/28/content_904034.htm
- Visier, J.C. et al. 2005. IEA Annex 40: Commissioning of Buildings and HVAC Systems for Improved Energy Performance. Final report, www.commissioning-hvac.org