Development of a New ASHRAE Protocol for Measuring and Reporting the On-Site Performance of Buildings Except Low-Rise Residential Buildings

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ABSTRACT

ASHRAE is developing guidance regarding the measurement and reporting of the performance of new and existing buildings except low-rise residential buildings. In the short-term, a consensus ASHRAE Protocol is being developed for rapid dissemination in a Special Publication within 12 to 18 months of the initiation of the project. Then, in the long-term, an ASHRAE Standard or Guideline would be developed, which would be a combination of existing ASHRAE Standards, Guidelines and other documents, that provides a consistent method of measuring, expressing and comparing the energy use, water use, and indoor environment of buildings, including the establishment of baseline criteria in each of these areas in order to facilitate comparison, design and operation improvements, and to further the development of building energy performance standards.

Such a protocol would be used to evaluate not only the as-built energy performance and water performance, but also the IEQ and comfort level being achieved in a building (e.g., Standard 90.1-2004, Standard 62.1-2004, Standard 55-2004, LEED, U.S. Army, etc.). These protocols will be a valuable tool that establishes a consistent, repeatable basis that shows that a building that is constructed by a particular design guideline is meeting some minimum level of all aspects of design expectations. Validation of the attainment of sustainable, green, or high-performance buildings could be established through these protocols. These documents would be immediately useful to other organizations, including AIA, IES, EPA, DOE, GSA, the US Military, US GBC, CIBSE, IEA, the European Union, and other organizations interested in sustainable design. Therefore, this paper reports on efforts to develop this protocol, including a valuable survey and ranking of existing efforts, and framework for the eventual protocol.

Introduction

ASHRAE is developing guidance regarding the measurement and reporting of the performance of new and existing buildings except low-rise residential buildings. These include a short-term ASHRAE Protocol, and a long-term ASHRAE Standard or Guideline that would combine existing ASHRAE Standards, Guidelines and other documents that provide a consistent method of measuring, expressing and comparing the energy use, water use, and indoor environment of buildings, including the establishment of baseline criteria in each of these areas, in order to facilitate comparison, design and operation improvements and to further the development of building energy performance standards.

The purpose of this effort is to develop consensus, peer-reviewed, ASHRAE protocols for "Measuring and Reporting the On-site Performance of Buildings Except Low-Rise Residential

Buildings." Validation of the attainment of sustainable, green, or high-performance buildings could be established through these protocols. To initiate the effort, ASHRAE authorized a Scoping Study (ASHRAE 2006) which was to provide advice to ASHRAE Technology Council regarding what work has been done to date, what is missing in the effort to develop such protocols, and to provide recommendations as to how to proceed. The following tasks were identified to be accomplished by the Scoping Study:

- Develop a preliminary review and brief synopsis of what's been done before in these fields of study.
- Determine what's missing to establish performance measurement and reporting protocols.
- Make recommendations to Technology Council about how to proceed, including the development of an analysis matrix of selected documents to help form the basis for the follow-on effort. Recommendations also address how ASHRAE should approach the development of a Special Publication, guideline or standard.

Ranking What's Been Done Before?

Past attempts to measure various aspects of building performance have resulted in individual guidelines that cover a specific purpose and many research papers, mostly of a narrow scope. Since building systems are interrelated, a comprehensive protocol is now needed that recognizes these relationships and quantifies, where possible, the total building performance results. Therefore, in order to assess the previous work that measures and reports the performance of buildings, an informal survey of over 44 documents was performed, and an evaluation matrix developed (Figure 1). The results of the survey were divided into three primary groups: 1) energy performance, 2) indoor environmental performance, and 3) water performance.

A brief synopsis of the indices that were used to rank the entries in the three primary groups is provided in the following section. As shown in Figure 1, performance within these groups in buildings as it relates to ASHRAE and other publications can generally be thought of in terms of:: 1) Measurement methods; 2) Sensors, instruments and calibration; 3) Data Analysis methods; 4) Baseline Information; and 5) Analysis approach. Within each of these categories, Low (L), Medium (M) and High (H) rankings were assigned to qualify each of the references reviewed.

Primary Groups

Energy performance. Energy performance relates to the usage of electricity, natural gas, diesel, and other sources of energy by building systems by whatever means that it is generated and used. Energy use efficiencies are most often determined by measuring the performance and comparing it to a baseline or allowance requirement.

Indoor environmental performance. Indoor environmental performance relates to the acceptability of conditions by the occupants of the building. At times it could also relate to the performance of the equipment in the building. These conditions, their consistency and controllability will ultimately determine the efficiency and productivity of both human efforts and equipment performance. To quantify the performance in this area, both baselines and measurement methodologies must be developed.

The indoor environmental performance category was subdivided into four areas: 1) Indoor air quality; 2) Thermal comfort; 3) Acoustics or vibration; and 4) Lighting and daylighting. These categories all relate to energy usage in some aspect to determine the quality of environment being produced by the energy-consuming systems. Therefore, protocols are needed to measure acceptability and the relationship to energy and water usage. Although buildings can be built with low energy and low water use, in certain instances, some are totally unacceptable to the occupants because of poor air quality, uncomfortable conditions, noise, and dimly lit spaces.

Water performance. The usage of potable water in buildings is becoming an important factor in choosing whether or not to build the facility in the selected area, and can have a significant impact on the cost of operating the building. Many technologies and equipment systems exist for lowering water usage without compromising performance. The acceptability and measurement of the water use of these systems must therefore be determined along with the development of baselines to calculate the efficiency of normalized water use on a uniform basis.

Other information. As shown in Figure 1, the other information category is defined in terms of: 1) Applicable building (S = single buildings, M = multiple buildings), and 2) Cost information (L = general information, M = detailed cost information, H = detailed regional costs). Using each of these categories, rankings were assigned to qualify each of the references reviewed.

Comments. Finally, a comments column has been provided for a brief synopsis of each of the references.

Secondary Groups

In each of the primary groups five secondary groupings are proposed to further facilitate the categorization of information. These secondary groupings include: 1) Measurement Methods, 2) Sensors, instruments and calibration, 3) Data analysis methods, 4) Baseline information, and 5) Analysis approach. Within each of these secondary groupings are additional levels (i.e., Low (L), Medium (M) and High (H)) that seek to answer specific questions about the reference in the context of the secondary grouping.

Preliminary Summary of the Review of Selected References

Energy Performance

In the area of design, ASHRAE Standard 90.1-2004, *Energy Standard for Buildings Except Low-rise Residential*, is regarded as the standard for most of the United States. This standard relies on a number of other standards to define the design and delivery process, such as:

- Standard 140 - Standard Method of Test for Evaluation of Building Energy Analysis Computer Programs
- Guideline 0 - The Commissioning Process
- Guideline 4 - Preparation of Operating and Maintenance Documentation for Building Systems

Together, these ASHRAE Standards and Guidelines form the basis for the design and delivery of building systems. ASHRAE Standard 90.1 provides the overall design standard, and is supported by Standard 140, which provides standard methods for testing building simulation programs used in the design evaluation of buildings. Guideline 0 and Guideline 4 provide advice regarding the delivery of systems and their proper operation and maintenance.

In the area of building energy performance measurement, ASHRAE has a number of Standards and Guidelines, which are supported by ASHRAE Research projects to form the consensus methods to be used to measure building energy performance. These include:

- Guideline 14 – Measurement of Energy and Demand Savings
- Standard 105 – Standard Method of Measuring and Expressing Building Energy Performance
- 827-RP – In-situ Tests for Blowers, Pumps and Chillers
- 1050-RP – Inverse Model Toolkit
- 1093-RP – Development of Diversity Factors
- 1004-RP – In-situ Tests for Cool Storage Systems
- 1092-RP – In-situ Tests for Air Handling Units
- 1286-RP – Evaluation of Building Performance Protocols

Guideline 14 provides procedures for the minimum acceptable level of performance in the measurement of energy and demand savings from energy management projects applied to residential, commercial or industrial buildings. Such measurements can serve as the basis for commercial transactions between Energy Service Companies (ESCOs) and their customers, or other energy conservation providers that rely on energy savings as the basis for repayment of the costs of the retrofit. Many of these methods may also prove useful for measuring the performance of a building.

Standard 105 provides a consistent method of measuring, expressing and comparing the energy performance of buildings to facilitate comparison, design and operation improvements, and development of building energy performance standards. The standard requires the measurement or estimation of energy use for existing buildings and allows for the prediction of energy use for proposed buildings. It specifies techniques for measuring, expressing, and comparing the energy performance of buildings and includes minimum requirements for reporting the performance and the comparison method. It doesn't establish building energy goals or limits and doesn't provide a method for certification of prediction methodology, such as computer programs. It does address all forms of purchased or external energy including active solar, wind geothermal, etc. Passively collected forms of energy (e.g., solar, natural ventilation) are excluded. In Standard 105 there are three levels of compliance to be selected by the user: Basic, Additional and Comparison. These levels are hierarchical so that each level builds on compliance with the previous level. Compliance with each level is demonstrated by completion of specific forms that are provided in the Standard.

Research Projects 827, 1050, 1093, 1004, 1092 and 1286, and others provide a solid basis for several ASHRAE guidelines and standards.

- Research Project 827 provides methods for testing the in-situ (i.e., on-site) performance of blowers, pumps and chillers used in a building's HVAC system.

- Research Project 1050 provides public domain regression tools for developing weather-normalized energy signatures for a building from monthly, daily or hourly data.
- Research Project 1093 provides a toolkit for developing diversity factors (i.e., 24-hour profiles) from hourly demand data, which are useful in building simulation programs for representing the hourly internal electrical loads in a building analysis, and in calculating normalized, monthly demand savings.
- Research Project 1004 provides for in-situ test procedures for cool storage systems, with the results from the application to three facilities.
- Research Project 1092 provides in-situ test procedures for measuring the performance of a building's air-handling units, with results from several facilities.
- Research Project 1286 provides an evaluation of building performance protocols, including: the US EPA's ENERGY STAR® program, the US GBC's LEED rating procedures, the CAL-ARCH and ARCH rating protocols by LBNL, the United Kingdom's British Research Establishment Environmental Assessment (BREEAM) protocol, and EnergyPrism Benchmarking Module by Nexus Energy Software.

Significant work has also been performed outside of ASHRAE in regards to the development of methods for measuring and reporting building energy use, for example:

- LoanSTAR Monitoring and Analysis Program: Building Energy Monitoring Workbook (1992). This a complete workbook that includes descriptions and installation instructions for sensors needed for measuring, procedures for retrieving data from remote buildings, and an overview of analysis methods in the Texas LoanSTAR program.
- ORNL Report "Measuring Energy-Saving Retrofits: Experiences from the Texas LoanSTAR Program" (1996). This ORNL Report contains a complete description of the measurement and verification methods developed for the Texas LoanSTAR program.
- Sustainability Assessment of the Robert E. Johnson State Office Building (2002). This report describes how the performance of the new REJ building was evaluated with measured hourly data and a calibrated simulation.
- NREL Report on energy performance analysis of six high-performance buildings (2005). This report provides an analysis, performed by NREL, of the performance assessment of six high-performance buildings.
- NREL's Draft "Procedure for Measuring and Reporting Commercial Building Energy Performance" (2005). This draft report summarizes the procedures developed in the previous report for general use in commercial buildings.
- CEC/LBNL's Draft document "Performance Monitoring System Specifications" (2005). The California Energy Commission (CEC) and Lawrence Berkeley National Laboratory's draft document provides advice regarding the specification of a performance monitoring system.
- NEMVP, IPMVP (1996 – 2003). The US DOE has developed the International Performance Measurement and Verification Protocols (IPMVP), beginning in 1996 and revised up through 2003. These protocols include procedures for the M&V of energy, indoor environmental quality, and new construction, including:
    - North American Energy Measurement and Verification Protocols (NEMVP), 1996. This was the first protocol to be published by the US DOE. It included a

purpose/scope, an overview, three M&V options, a section of other issues and references.

- International Performance Measurement and Verification Protocol (IPMVP), 1997. This was the second protocol to be published by the US DOE. It included a purpose/scope, an overview, four M&V options, a section of other issues, a section that discussed new buildings, references, and two appendices: emissions and material extracted from the FEMP Guidelines.
- International Performance Measurement and Verification Protocol (IPMVP): Volume I - Concepts and Options for Determining Energy and Water Savings, 2001. This was the first of three protocols to be published by the Energy Efficiency Organization (EVO), which was sponsored by the US DOE (www.ipmvp.org). It included a purpose/scope, an introduction, four M&V methods, two sections on related issues (common issues and measurement issues), references, and three appendices: examples, uncertainty, measurements techniques.
- International Performance Measurement and Verification Protocol (IPMVP): Volume II - Concepts and Practices for Improved Indoor Environmental Quality, 2002. This was the second of three protocols published by EVO, also sponsored by the US DOE. It included a purpose/scope, an introduction to IEQ, best practices for maintaining IEQ, five M&V methods, sections on related issues and references.
- International Performance Measurement and Verification Protocol (IPMVP): Volume III - Concepts and Options for Determining Energy Savings in New Construction, 2003. This was the third (part A) of three protocols be published by EVO, also sponsored by the US DOE. It included an introduction, Four M&V methods, references, and three appendices: definitions, resources and case studies.
- International Performance Measurement and Verification Protocol (IPMVP): Volume III - Concepts and Practices for Determining Energy Savings in Renewable Energy Technologies Applications, 2003. This was the third (part B) of three protocols be published by EVO, also sponsored by the US DOE. It included an introduction, Four M&V methods, a discussion of quality and cost, and three appendices: definitions, resources and references.

- The U.S. Army Measurement and Verification (M&V) Costing Toolkit: (December 2003). The U.S. Army Measurement and Verification (M&V) Costing Toolkit provides detailed costing information for over one dozen different M&V plans, including costing information for sensors, calibration, data retrieval, analysis, travel, instrument removal, etc.
- 1286-RP – Evaluation of Building Energy Performance Protocols Research Project 1286. ASHRAE has developed guidance regarding the baselining of building energy use. This document evaluates building performance protocols, which include methods for comparing or baselining a building's energy use.
- U.S.E.P.A. Target Finder/Portfolio Manager. Other significant baselining information includes the US EPA's "Target Finder and Portfolio Manager" web pages.

Indoor Environmental Quality Performance Measurements

The evaluation of all aspects of a building's indoor environmental quality includes: thermal comfort, ventilation rates, indoor air quality, indoor lighting conditions, and acoustics. ASHRAE has a number of Standards and Guidelines that are supported by ASHRAE Research projects to form the consensus methods to be used to define and evaluate indoor environmental quality. These include:

- Standard 55 – Thermal Environmental Conditions for Human Occupancy. ASHRAE Standard 55 provides advice to designers regarding the proper thermal comfort conditions for human occupancy.
- Standard 62.1 – Ventilation and Acceptable Indoor Air Quality. ASHRAE Standard 62.1 provides design guidance regarding ventilation rates that will provide a building's occupants with acceptable indoor air quality.
- Guideline 10P – Criteria for Achieving Acceptable Indoor Environment. ASHRAE usually refers to the Illumination Engineering Society of North America (IESNA) for acceptable lighting levels, and will be providing guidance in Guideline 10P, including:
  - Acceptable lighting levels (lighting/daylighting).
  - Acceptable noise levels (Acoustics).
- Research Project 1286-RP – Evaluation of Building Energy Performance Protocols. International Performance Measurement and Verification Protocol (IPMVP): Volume II - Concepts and Practices for Improved Indoor Environmental Quality, 2002. This report includes five options for measuring IEQ based on modeling; Option 1 - no measurement, Option 2 - Model-based measurement, Option 3 – Short-term measurements of selected IEQ parameters; Option 4 – Long-term continuous measurement of selected IEQ parameters; Option 5 – Surveys to assess occupant perceptions and ratings or IEQ. Volume II also contains an extensive list of IEQ literature from which these methods are based, and cost information.

Water Performance

Surprisingly, significant information was found that covers M&V methods for water performance, in references that either directly discussed this or indirectly discussed metering technology that could be applied to water performance, for example:

- ASHRAE Guideline 14 has information about metering of chilled water and hot water use that is applicable to potable water systems.
- The American Society of Plumbing Engineers has numerous publications in this area.
- The CEC/LBNL report contained information that indirectly related to water performance M&V methods.
- ASHRAE Research Projects 1004RP contains information about flow measurements.
- The IPMVP contains information about M&V for potable water use, landscape watering, etc.
- The previously mentioned NREL reports (2005) contained assessments of how well the case study buildings performed regarding water performance.

- The US GBC LEED program has information about water performance LEED credits.
- The US Army has costing information about different water meters, data loggers, etc.

What's Missing to Establish Performance Measurement and Reporting Methods?

From the results of the ASHRAE Scoping Study, it became clear that extensive work had already been performed that provides a solid basis for developing selected performance measurement and reporting methods. However, to date, no previous ASHRAE document exists that provides coordinated performance measurement and reporting methods for energy use, water use, and indoor environmental conditions. Therefore, there is a need to complete the preliminary survey of documents initiated in the Scoping Study, both within ASHRAE and outside ASHRAE.

Such a survey would then need to classify documents using a proper framework (i.e., Standard, Guideline, Research Report, Peer-reviewed Paper, etc.) and include important information about how the different documents relate to each other, or whether there are areas where there is conflicting advice from the different reports. Such a survey also needs to note what can't be done today, being mindful of what research needs to be done to develop badly needed measurement and reporting methods.

Need to have Extensive Survey of Existing Research

In the next phase of the project ASHRAE will be performing an exhaustive, accurate, annotated bibliography, which includes a complete citation of the work, description of what was done, why it is important, and how it contains information or methods that are useful to the measurement and reporting of energy use and environmental conditions in a building. This survey will encompass ASHRAE Standards, Guidelines, Research Projects, and peer-reviewed literature, and research and literature published and performed outside of ASHRAE. This survey will have a classification procedure and should include a keyword index to allow for rapid searching and classifying.

The preliminary survey performed for the Scoping Study included over forty references from sources known to the committee. Although the survey includes substantial information on the M&V of building energy use, it has few references on IEQ, acoustics and water M&V. Furthermore, since the references in this preliminary survey were assembled from those known by the authors, it is in no way representative of an exhaustive search; hence, the need for such a search.

Tying Together and Classifying the Documents

The results of this survey are expected to become the nucleus for developing Protocols for Measurement and Verification of building performance, since the survey would utilize a classification scheme for tying together the different information sources. This classification scheme should also include a quality index to rank the reliability of the different information, should there be conflicting procedures, or different procedures for performing the same function.

The Preliminary Matrix (Figure 1) was intended to be a preliminary, strawman classification scheme that will need to be refined and re-examined by the follow-on effort. This

Preliminary Matrix was divided into three primary areas: energy, IEQ, and water performance, and includes a catch-all category that has items common to all three. This choice of three categories will need to be re-examined by the follow-on committee to ascertain whether or not it is appropriate for an ASHRAE protocol on measured performance. In addition, the sub-categories in the Preliminary Matrix will need to be reviewed for appropriateness, as well as the classification labels (i.e., L, M, H, etc.). Finally, all references in this Preliminary Matrix will need to be re-examined to assure that the preliminary assessment was accurate and can be carried forward.

How Do Documents Relate to Each Other?

One important result of the preliminary classification scheme was the identification of the need for a sketch of the inter-relationship of the different works, beginning with the importance of the work (i.e., Standard, Guideline, Research Report, Tech Paper, etc.), and how the work references, or relates to other works. This would include the placement of the work in an historical context, and whether or not the work depends on other works.

What Can't Be Done Today?

The Preliminary Matrix uncovered several aspects of the literature that are worth noting. First, in the area of M&V for energy performance, there appears to be a wealth of information in the ASHRAE literature and in other literature. Therefore, any follow-on effort will be faced with the task of sorting through a multitude of references to determine which are more or less relevant to a protocol. Second, in the area of IEQ and water performance, although the Scoping Study identified several sources in the literature, it did not have the time or resources to extensively analyze these sources for the necessary details, as was the case for the M&V for energy. Therefore, any follow-on effort will need to dig further into the references in this Preliminary Matrix, and in other references to ascertain the important references in these areas.

In the follow-on effort, it will be important to determine what aspects of performance measurement cannot adequately be accomplished today. The sketch outlining the relationship of the previous works to one another should help identify shortcomings and holes, or gaps of knowledge that need to be addressed. Examples include: procedures for measuring productivity, measuring on-site natural ventilation, measuring rainwater collection, and building-level, sanitary sewer measurements.

Synthesizing Protocols from the Previous Work

Once the previous work has been categorized and analyzed, specific methods will be identified and protocols developed from individual and combined methods. These protocols will satisfy specific M&V criteria to be developed by ASHRAE and other organizations, such as the US GBC. For example, the need for "low, medium, high" accuracy methods would also have "low, medium, high" costs associated with the methods. It is the intention that these consensus ASHRAE Protocols would be developed for rapid dissemination in a Special Publication.

Such protocols would be used to evaluate not only the as-built energy and water performance, but also the IEQ and comfort being achieved in a the building (utilizing some design criteria, e.g., Standard 90.1, Standard 62, Standard 55, LEED, etc.). These protocols would be a valuable tool that establishes a consistent, repeatable basis that show that a building

is meeting some minimum level of all aspects of the design expectations. Validation of the attainment of sustainable, green, or high-performance buildings could be established through these protocols. These documents would be immediately useful to other organizations, including AIA, IES, EPA, DOE, GSA, the US Military, US GBC, CIBSE, IEA, the European Union, and others interested in achieving sustainable design.

In the long term, an ASHRAE Standard or Guideline will most likely be developed that provides a consistent method of measuring, expressing and comparing the energy use, water use, and indoor environment of buildings. The guideline or standard would be a combination of existing ASHRAE Standards, Guidelines and other documents including results of new research identified during the survey, classification and protocol development activities. A new Standard or guideline would include the establishment of baseline criteria in each performance area in order to facilitate comparison, design and operation improvements, and to further the development of building performance standards.

Summary

ASHRAE is developing guidance regarding the measurement and reporting of the performance of new and existing buildings except low-rise residential buildings. These include a short-term ASHRAE Protocol, and a long-term ASHRAE Standard or Guideline that would combine existing ASHRAE Standards, Guidelines and other documents that provides a consistent method of measuring, expressing and comparing the energy use, water use, and indoor environment of buildings, including the establishment of baseline criteria in each of these areas.

What is being developed is a short-term and long-term effort to accomplish this. In the short-term, a consensus ASHRAE Protocol is being developed for rapid dissemination in a Special Publication within 12 to 18 months from the initiation of the project. Then, in the long-term, an ASHRAE Standard or Guideline would be developed. To accomplish this effort, ASHRAE is developing a Special Project to complete the survey of the previous work and to develop the protocols. Once this work is complete, and public comments received, a Special Publications Committee will be formulated to publish the results of the survey of the previous work and the protocols. The results assembled in the Scoping Study (ASHRAE 2006) represent the first step in a multi-year project, which will develop and deliver protocols for the measurement and reporting of the performance of new and existing buildings except low-rise residential buildings.

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Figure 1: Evaluation Matrix of Existing Literature for Measurement and Verification of Building Performance

	I. Energy Performance					II. Indoor Environmental Performance														III. Water Performance					IV. Other	
						1. Indoor Air Quality (e.g.,CO2, CO, Particulates, VOCs, Mold, Mildew)				2.Thermal Comfort (e.g., MRT,humidity, air speed)				3. Acoustics or Vibration (e.g., Noise Criteria, Impact Isolation)				4. Lighting/Daylighting Quality (e.g., Light Levels, Glare, Color, Contrast)										
	1. Measurement Methods?	2. Sensors, Instruments,	3. Data Analysis Methods?	4. Baseline Information?	5. Analysis Methods?	A. Measurement Methods?	B. Sensors, Instruments,	C. Data Analysis	D. Baseline Information?	A. Measurement Methods?	B. Sensors, Instruments,	C. Data Analysis	D. Baseline Information?	A. Measurement Methods?	B. Sensors, Instruments,	C. Data Analysis	D. Baseline Information?	A. Measurement Methods?	B. Sensors, Instruments,	C. Data Analysis	D. Baseline Information?	1. Measurement Methods?	2. Sensors, Instruments,	3. Data Analysis	4. Baseline Information?	5. Analysis Methods?	Applicable Building	Cost Information?
Abushakra et al. (2004)			L,M,H	L,M,H	W,C																					M	
ASHRAE (1988)										L,M,H	L,M,H	L,M,H		L,M,H	L,M,H	L,M,H											
ASHRAE (1993)	L		L																								
ASHRAE (1996)	L,M,H		L,M,H		W,C																						
ASHRAE (2002)	L,M,H	L,M,H	L,M,H		W,C,S													L	L	L		L	L	L		W,C	M	M
ASHRAE (2004a)										L			L															
ASHRAE (2004b)						L		L	L																			
ASHRAE (2004c)	L,M,H		L,M,H																									
ASHRAE (2004d)	L,M,H		L,M,H	L, M, H	W,S																							
ASHRAE (2005a)														L,M,H	L,M,H	L,M,H	L,M,H											
ASHRAE (2005b)	L,M,H		L,M,H		W,C																							
ASPE (2006)																						L,M,H	L,M,H		L,M,H		M	
Beasley et al. (2002)			L,M,H	L,M	W,C																						M	
CEC/LBNL (2005)	L,M,H	L,M,H	L,M,H		W,C,S					H	H	L										L	L	L		W,C	M	M
Claridge et al. (2003)			L,M,H	L,M,H	W,C																						M	
Elleson et al. (2002)	L,M,H	L,M,H	L,M,H	L,M	W,C																	L	L	L		W,C	M	
Glazer (2005)	L	L	L	L	W				L				L					L			L						M	
Haberl et al. (1992)	L,M,H	L,M,H	L		W,C																	L	M	L		W,C	M	M
Haberl et al. (1996)	L,M,H	L,M,H	L,M,H		W,C,S																	L	L	L		W	M	L
Haberl and Bou-Saada (1998)			L,M,H	L,M	S																						S	
Haberl et al. (1998)	L,M	L,M	L,M,H	L,M,H	W,C,S																	L		L		W	M	M
Haberl et al. (2001)			L,M,H	L,M,H	W,C																						M	
Haberl et al. (2003)			L,M,H	L	W,C																						M	
Haberl and Cho (2004a)			L,M,H		W,C																						M	
Haberl and Cho (2004b)			L,M,H		S																						M	
IES (2006)																		L,M,H		L,M,H	L,M,H	L	L		L	W		
IPMVP (1997)	L,M	L,M	L,M		W,C,S							L						L	L	L	L						M	
IPMVP (2001)	L,M	L,M	L,M		W,C,S							L						L	L	L	L	L	L	L	L	W,C	M	
IPMVP (2002)						H	H	M	M	H	H	M	L					H	H	M	L						M	M
IPMVP (2003a)	L,M,H	L	L,M	L	W,C,S																						M	L
IPMVP (2003b)	L,M,H	L	L,M	L	W,C,S																						M	L
Kissock et al. (2003)			L,M,H	L	W,C																						M	
Landman and Haberl (1998)			L,M,H	L,M	W,C																						M	
NEMVP (1996)	L,M	L,M	L,M,H		W,C							L															M	M
NREL (2005)	L,M,H	L,M,H	L,M,H	L,M,H	S					L	L	L	L					L	L	L	L	L	L	L	L	W	M	
Reddy et al. (1997a)			L,M,H	L,M	W																						M	
Reddy et al. (1997b)			L,M,H		W																						M	
Reddy et al. (1999)			L,M,H		W,S																			H		W,C	M	
Reddy et al. (2002)			L,M,H	L,M	W,C																	L	L	L		W,C	M	
Sylvester et al. (2002)	L,M,H	L,M	L,M,H	L	S													M	M	H						S		
USGBC (2006)	L,M,H		L,M,H	L,M,H	W	L,M,H		L,M,H	L,M,H													L,M,H		L,M,H	L,M,H	W,C		
USEPA (2005a)				L,M,H	W																							
USEPA (2005b)				L,M,H	W																							
U.S. Army (2003)	L,M,H	L,M,H	L,M,H		W,C,S	L,M,H	L,M,H			L,M,H	L,M,H							L,M,H	L,M,H			L,M,H	L,M,H				M	L,M,H
	L = General Information	L = General Information	L = General Information	L = Has baseline references	W = Whole-building	L = General Information	L = General Information	L = General Information	L = Has baseline references	L = General Information	L = General Information	L = General Information	L = Has baseline references	L = General Information	L = General Information	L = General Information	L = Has baseline references	L = General Information (e.g., light level, glare, color rendition, contrast)	L = General Information	L = General Information	L = Has baseline references	L = General Information	L = General Information	L = General Information	L = Has baseline references	W = Whole-building	S = Single	L = Has general Cost information
	M = Specific equations	M = Equip. Specifics	M = Specific equations	M = Baseline methods	C = Component Isolation (e.g.,	M = Specific equations	M = Equip. Specifics	M = Specific methods	M = Baseline methods	M = Specific equations	M = Equip. Specifics	M = Specific methods	M = Baseline methods	M = Specific equations	M = Equip. Specifics	M = Specific methods	M = Baseline methods	M = Specific equations	M = Equip. Specifics	M = Specific methods	M = Baseline methods	M = Specific equations	M = Equip. Specifics	M = Specific equations	M = Baseline methods	C = Component Isolation	M = Multiple	M = Has detailed cost information
	H = Includes examples	H = Installation, calib., accuracy	H = Includes examples	H = Includes examples	S = Calibrated Simulation	H = Includes examples	H = Installation, calib., accuracy	H = Includes examples	H = Includes examples	H = Includes examples	H = Installation, calib., accuracy	H = Includes examples	H = Includes examples	H = Includes examples	H = Installation, calib., accuracy	H = Includes examples	H = Includes examples	H = Includes examples	H = Installation, calib., accuracy	H = Includes examples	H = Includes examples	H = Includes examples	H = Installation, calib., accuracy	H = Includes examples	H = Includes examples	S = Calibrated Simulation		H = Detailed regional costs