National Institute of BUILDING SCIENCES

Moving Forward:

In-Depth Findings and Recommendations from the Consultative Council

An Authoritative Source of Innovative Solutions for the Built Environment

Introduction

The building community faced numerous challenges in 2011. Employment in the sector remained down; developers, designers and contractors had fewer projects; and homeowners and commercial building owners continued to face economic tests when selling or leasing their properties. While these challenges greatly impacted the building sector, the shared concerns across disciplines prompted a concerted effort to identify paths forward.

The National Institute of Building Sciences Consultative Council provides a forum to address the common desire to find solutions to these and other big-picture issues affecting the building industry and the nation. Initially established by the Institute's enabling legislation in 1974, the Council recently underwent a re-formation to its structure and mission. The updated Council includes representatives of leading organizations within the building community. Together, they are working to develop findings and recommendations to improve the built environment and the community that supports it.

In 2011, the Council focused in greater depth on four topic areas identified in last year's report:

- Defining High-Performance and Common Metrics,
- Codes and Standards Adoption and Enforcement,
- Energy and Water Efficiency, and
- Sustainability.

Members of the Consultative Council and other representatives from across the building community participated in Topical Committees to examine the previous findings and recommendations and offer additional insight into further opportunities in these areas. This report reflects their work.

Defining High-Performance and Common Metrics

Increasingly, the industry is seeing an evolution. High-performance building efforts are moving from voluntary systems, such as rating systems and guidelines intended to change the marketplace and create demand for green buildings, to the use of model "green" codes and standards adopted by jurisdictions.

High-performance buildings, in addition to ensuring a design meets a set of criteria "on paper," must be constructed to plans and specifications and then commissioned and operated as real buildings. To demonstrate performance, the building industry needs understandable criteria and metrics, along with innovative project delivery methodologies and strategies that support the goal of high-performance including the goal of zero net energy. Achieving high performance requires a focus on actual performance throughout a building's life cycle—from design and construction through operations and maintenance to deconstruction.

Making Progress

Several key recommendations identified in the 2010 report of the Consultative Council remain important and should receive continued attention by the building community.

The definition of high-performance building established by Congress in the Energy Independence and Security Act of 2007 (EISA)[1] still remains relevant. However, many of the attributes it includes require further definition, along with identifying and defining sub-attributes and metrics to demonstrate actual achievement.

Identified measures of building performance should include both quantitative and qualitative values; they should be measured and verified through the use of meters and occupant surveys. Qualitative measures get to *how* the building is really used. Establishing the best definitions for some attributes may require additional research. Such data should provide real information on measurement and verification and relate back to building use type and occupancy density. From the aggregation of both data types, a high-performance building system should derive an allowable measure for energy use, water use, etc., on a per person or unit output basis (e.g., kBTU/sq.ft./person/year or gallon/sq.ft./widget/year).

For clarification to building owners and the public, the building community should consider using the term "higher-performance" buildings, as it implies a measurable metric above a predetermined baseline. Use of this term infers the existence of a starting baseline for high performance.

The Institute (through its High-Performance Building Council) should identify the components and attributes that make up a high-performance building; the relevant standards and standards development organizations (SDOs) affected by each component; and the metrics involved. Information on existing SDOs with standards related to high-performance building attributes and metrics should accompany the expanded definition and identification of sub-attributes. After identifying the relevant SDOs, the High-Performance Building Council (HPBC) should work with the SDOs to classify or group standards by attributes

[1]The Energy Independence and Security Act (EISA) of 2007 (Title IV, Energy Savings in Buildings and Industry, Section 401, Definitions), definition of a "high performance building" is as follows: A building that integrates and optimizes on a life-cycle basis all major high-performance building attributes, including energy conservation, environment, safety, security, durability, cost-benefit, productivity, functionality and operational considerations.

or building systems. The Council should utilize a matrix of the 11 attributes identified by EISA to classify existing standards. In this process, it is important to recognize the unique expertise and outlook that led to the establishment of each SDO.

The Institute should form, with the engagement of the National Institute of Standards and Technology (NIST), a Standards Integration Group (SIG). The SIG would facilitate the use of common metrics or measurement protocols with the goal of advancing a holistic approach when demonstrating performance within and among high-performance building attributes. The SIG also should identify the current gaps in appropriate standards and work with existing SDOs to fill those gaps. Where attributes and existing standards appear to overlap, collaboration across SDOs would be encouraged. Ultimately, a common lexicon for high-performance building attributes and their metrics should develop.

The building industry requires consistency when setting the measurement and definition of minimum required performance levels. Existing programs and methods should form the basis for measurement and reporting. Such programs can include the U.S. Department of Energy's (DOE) pending Asset Rating Program, ASHRAE's Building Energy Quotient, the U.S. Environmental Protection Agency's (EPA) Portfolio Manager and Target Finder tools, the New Building Institute's (NBI) Post Occupancy Survey Template, and performance levels being adopted by the U.S. Department of Homeland Security (P+, P++, and HP).

Actual performance levels that will qualify as "baseline," "benchmark" and "high" performance should be defined, along with the applicable standards, test methods and order of testing during the project delivery process (such as ASTM E 2813). Where practical, standards should focus on measured results, such as energy use intensity (EUI), and then be tracked to a performance results index (PRI), with established goals by building type and location.

Upon establishment of a high-performance building system with underlying standards and metrics and the identification of required performance levels, owners and project delivery teams must become aware and knowledgeable of its benefits and applicability. The established system should include measurement, expression and reporting of both Owner Project Requirements (OPR) and Basis of Design (BOD) metrics.

The Institute's HPBC should provide continued leadership and a business plan to implement these recommendations.

Recommendations

- The building community should work to define sub-attributes and metrics to demonstrate the achievement of high-performance buildings—including both qualitative and quantitative measures.
- The Institute (through its High-Performance Building Council) should identify the components and attributes of high-performance buildings and develop a matrix of the standards affected by each component and the relevant metrics.
- The Institute, with the engagement of NIST, should form an SIG to encourage collaboration, facilitate use of common metrics and identify gaps in appropriate standards.

Codes and Standards Adoption and Enforcement

When adopted by jurisdictions, codes and standards establish the community's expectations for protecting the health, safety and welfare of its citizens. Such codes and standards are developed and then adopted through a series of actions that assure engagement from all relevant stakeholders. This engagement, along with effective adoption and enforcement, ensures the industry follows codes and standards, thus meeting the community's expectations.

Codes and standards provide a common language and requirements for the design, construction and operations of buildings. This commonality provides many benefits for the public, the building industry and government. The public is assured that buildings provide a minimum level of protection from hazards, are accessible to users and maintain public health. Within the construction industry, manufacturers know they have the consistency in requirements necessary to invest in the production and development of products that meet these common needs; designers and contractors have consistent criteria to follow; and owners have buildings that possess a consistent baseline of attributes. Each industry segment can also develop the education and training activities it needs while being mindful of the overall codes and standards, and all industry members can work under these mutual requirements to achieve a common result. Governments can develop criteria with building expert input to assure technical feasibility and cost-effectiveness, access to an education and training infrastructure, and cost savings due to consistent methods for review and enforcement.

Examining Compliance

The compliance verification mechanisms for construction codes and standards drive how SDOs develop their codes and standards, set the level of stringency and whether the codes and standards are applicable across the building's lifespan. For instance, traditional plan review and construction inspection by state and local agencies (or their agents) cover up to, but not beyond, initial building occupancy. This limits the ability to confirm the building's actual performance as intended by the adopted codes or standards. A limited number of exceptions demonstrate how to verify ongoing post-occupancy compliance. These exceptions include health department rules associated with potable water purity and restaurant sanitary conditions or fire and life safety-related rules associated with fire alarms and fire suppression systems. Financial and human resources to implement post-occupancy compliance paths to address other requirements such as ventilation, energy use, water use and other building performance characteristics addressed by codes and standards may not be available, resulting in an inability to address such topics post-occupancy.

If the current compliance verification processes and/or resources cannot support verification of ongoing building performance, then a reexamination of the methods to validate compliance may be necessary. Such an approach could start with the desired performance results and criteria necessary to ensure achievement of the desired performance. Then, for each of those criteria, it could identify the degree to which compliance verification is needed and the methods for determining compliance.

For instance, energy codes generally are prescriptive with compliance being supported by a compliance verification process administered and enforced through building construction regulations. Submitted plans and specifications document whether the proposed project meets the criteria in all adopted codes, including energy. State and/or local government agencies (or federal or tribal agencies in the case of federal or tribal construction) review these construction documents and, if approved, construction is authorized.

During construction, the approving entity typically inspects construction to verify code compliance and to ensure that the provisions of the approved plans and specifications are followed. When construction is complete and that agency verifies compliance, a certificate of occupancy (CO) is granted. This approach is considered a traditional compliance verification path through enforcement of building construction regulations. While being responsive to many challenges in the built environment, such as structural integrity, many aspects of a building not considered in the initial verification process impact a building's post-occupancy performance. In the absence of market or other forces to ensure continued performance of the building and its systems, building officials need compliance verification processes and the available resources to ensure ongoing compliance.

One approach to compliance verification is to begin with a specific code format and adjust the remaining variables to achieve an expected level of compliance. The intent is to facilitate a results-driven approach, starting with a goal such as increased energy efficiency or improved indoor air quality (IAQ) and very high compliance rates and then working through the variables to assemble code adoption and compliance initiatives that support the goal. For instance, if actual building performance were to be assessed, the process would require a method for measuring and expressing performance, a required minimum level of performance (or graduated level if incentives are involved), someone assigned to document and review compliance and some method for levying penalties for non-compliance (or incentives for some above minimum performance level).

Using potable water as an example, rather than specify maximum fixture flow rates and similar prescriptive limits only verifiable at design and construction, an alternative approach could establish water use performance limits in terms of total gallons per specific unit of measure that vary by building type or use. Compliance would simply be based on a meter reading of actual use, with penalties or incentives tied to costs of water or property tax adjustments. Another example is mechanical ventilation of occupied spaces. Codes require certain system capabilities, but once occupancy occurs there is no way to ensure that actual operation and maintenance of the systems match those envisioned by the code.

Stretch Codes

Beyond the minimum codes and standards adopted and enforced as building regulations, stretch codes provide additional compliance options. "Stretch codes" commonly refer to "green" or energy codes that have more rigorous energy and/or environmental components than minimum codes or standards. Another term used to describe more rigorous codes is "overlay codes" because the minimum requirements established in the jurisdiction still must be followed (the more stringent requirements "overlay" on top of the minimum requirements).

Traditionally, zoning codes have had "historic overlay districts" that provide an additional layer of requirements for historic structures that lie within multiple zones. The overlay concept has been effective in the zoning arena because zoning in the United States is strictly a local matter and communities typically are aware of their appeals process through the local zoning board. For other codes, it is advisable to have clear procedures for the adoption and administration of overlay codes.

Stretch codes are optional because they typically are not administered and enforced in the traditional manner using the construction document review/permit/inspection/CO compliance path. The justification for adoption of "stretch" codes also varies. Sometimes, the minimum building and energy requirements adopted at the state level may not meet the desired levels of local municipalities who would like to reduce greenhouse gas emissions and energy consumption by making buildings within their jurisdiction more energy efficient. Owners, designers or builders also have adopted stretch codes as an option to guide their achievement of beyond minimum code compliance in communities where the basic building and energy codes have the force of law and the "code plus" stretch document is optional.

Stretch codes provide a regulatory option more rigorous than the checklists associated with Leadership in Energy and Environmental Design (LEED), Green Globes and other rating systems for those seeking to establish the credibility of construction projects that conserve natural resources, materials and energy and employ renewable energy technologies while maintaining healthy environmental air quality. Frequently, stretch codes include provisions that extend well beyond the scope of traditional codes and standards to include requirements for building commissioning and operations and maintenance. Like the checklists that precede them, stretch codes raise public awareness about the environment and allow communities or building owners and designers to select more rigorous criteria and/or delineate more project requirements that attempt to provide a more sustainable balance of potential impacts on the natural environment and building occupants. Stretch codes may be a vehicle to a more rigorous approach to energy and sustainability goals or they may provide a mechanism to avoid new or relatively untested energy efficiency and other construction practices at a time of economic downturn.

A New Economic Paradigm

For decades, the United States has led the development and implementation of compliance verification with construction-based standards and codes (e.g. building construction regulations). In the past, strong consensus-based standards development programs have encouraged growth in the industrial segments by ensuring that American businesses understand the health, safety and performance-based requirements for their products, systems and services. This created a level playing field where manufacturers could successfully compete. Compliance with building construction regulations through activities such as traditional code enforcement, which references thousands of consensus based standards, has provided for an increasingly safe and efficient built environment for homes, commercial buildings and places of assembly. However, the current economic downturn is creating new and significant challenges for the code enforcement community.

Municipalities are delaying the adoption of updated model codes due to the perception that updated codes increase construction costs while providing an uncertain return on investment. Countering this perception requires the development of more widely accepted metrics to demonstrate payback periods for energy and water-efficiency provisions, as well as better methods to present how code updates are based on the latest knowledge and experience to protect public safety. Faced with the prospect of enforcing more codes of increasing complexity with fewer people, many municipalities resort to concentrating on enforcing only the basic life safety requirements of the construction codes. With these constraints, building officials are less likely to enforce energy and water efficiency provisions, which in turn means the energy and water efficiency gains expected from updated codes are not being fully realized.

To improve the built environment while dealing with ongoing economic stresses associated with compliance verification, new compliance paths must be identified that then can open opportunities for codes and standards developers to explore new formats, criteria, adoption mechanisms and/or timelines for compliance verification resulting in increased compliance rates and/or reduced costs associated with compliance verification. Meeting this challenge is important to public and private-sector agencies or entities that want to increase levels of compliance with current and future codes and standards. The information is even more important to those who purchase or lease buildings and pay expenses to operate them, but cannot ensure compliance with codes or standards due to a lack of training or resources. As codes and standards require higher levels of building performance; different formats to present the criteria, increase their scope, or extend beyond issuance of the initial CO, new approaches in code criteria, format and adoption, and new methods to assess compliance will need to be considered to ensure effective implementation and conformance with the code requirements.

New technological advancements, such as building information modeling (BIM), can play a role in relieving these constraints. They can help by improving the quality of code compliance verification. They also can improve the municipality's ability to cope with the burden of enforcing more complex energy and water efficiency-related provisions because jurisdictions can evaluate the data contained within the model codes and other requirements electronically. However, work still remains before BIM accomplishes the levels of interoperability needed to be deployed as a code-checking tool. Further, jurisdictions also need the training and tools to utilize BIM. Work to incorporate compliance checks with BIM is progressing and BIM may ultimately be an excellent tool for improved levels of code compliance, eventually streamlining code approvals by allowing plans and submittals to be code checked automatically and with fewer errors. Significant triple bottom line savings for building owners and developers are foreseen. Additional benefits to the widespread use of BIM include providing first responders digital access to building layouts and other important information.

Likewise, technology already plays a significant role in allowing standards developers to maintain high levels of participation from both private and public sector stakeholders towards the development of standards for construction-related products and services. The use of web-based programs that foster the ability to participate remotely are being widely employed by standards developers across the country and are resulting in achieving higher levels of participation.

A strong codes and standards development community supports a strong and robust economy. Government at all levels must work together with standards and codes developers to address the challenges of better articulating the benefits of participation in their various development processes. They need to encourage more widespread verification of compliance with construction codes and support the development of BIM and other technology-based initiatives that help streamline approvals and improve the quality and consistency of enforcement.

Recommendations

- Both regulators and the building industry should support efforts by codes and standards developers and adopting jurisdictions to explore alternative ways to format criteria to simplify and enhance compliance verification.

- Members of the building community should investigate energy-based metrics as alternatives to the prescriptive approach in model codes and standards.
- NIST, the U.S. Department of Energy, the Institute and others should encourage cities and smaller communities to adopt and enforce updated model codes.
- Software developers, regulators and building professionals should support the ongoing development of BIM for ultimate use as an automated code-checking tool that can improve compliance and streamline the approval process.

Energy and Water Efficiency

Achieving real-world energy and water use efficiencies in buildings requires decisions based on good science. Recently, a number of buildings constructed to meet the requirements of various green rating system programs have not achieved the anticipated efficiencies. These highly publicized failures have received a great deal of attention and are being used to call into question the cost effectiveness of green building design. However, the root cause surrounding these results resides not with a failure of the program itself or with a failure of the installed technologies, but rather with an inability for the building community, including the developers of green building codes, standards and rating systems, to access accurate data to better understand current energy and water use in buildings.

A consensus-based, national strategic action plan must provide resources and direction to facilitate location-specific efforts by individual authorities having jurisdiction. A "one size fits all" approach is not practical because of regional variations in climate, growth projections and water scarcity needs.

However, local authorities should identify and address location-specific challenges, such as installing more efficient equipment, adopting water conservation measures and upgrading infrastructure. Global water demand per capita is increasing just as global population is increasing at exponential rates. Increasing demands for energy (as much as 50 percent by 2030) are due to quality of life advances in developing countries and population growth, but electricity also is being considered (e.g. plug-in hybrid and all-electric cars) as an alternative to dwindling and unpopular fossil fuels.

It is impossible to accurately measure and express the effectiveness of green building design technologies without science-based performance benchmarks to measure against. There is an urgent need to conduct research and begin gathering, collating and understanding current energy and water use in buildings. This information would foster better decision making regarding the most cost-effective technologies to deploy in various building types and in different regions of the country.

Need for Baseline Energy and Water Use Data

Buildings use energy, water and other resources. Water use intensity data can be used within codes and standards to develop performance-based standards; by water utilities to identify large and inefficient users; by water auditors to develop water management strategies; and by federal and local governments to craft water use policies.

Generally, there is a lack of information on commercial end-use water use and very little research has been conducted on the topic. The need for more comprehensive building water use data is vital to the continued improvement of water management in buildings across the country. The construction community continues to call for the U.S. Government to provide leadership and direction towards the development and support of research programs that will advance the establishment of accepted science-based metrics and allow better understanding of how to best achieve energy and water use efficiencies in buildings.

Thus, while the aggregate usage data that can be obtained by traditional metering of various building types is important and will result in significant water savings, the proper sizing of plumbing systems and the implementation of other water efficiency strategies requires a greater understanding of the use patterns associated with discrete fixtures, appliances and equipment. To advance plumbing codes, researchers, manufacturers and utilities should research and implement advanced metering and sub-metering technologies that can provide greater insight into how water is used in various building types to inform development of proper pipe sizing methodologies based on these use patterns.

While many water purveyors have fully metered systems, many water agencies surprisingly still charge customers flat rates, even in water-scarce regions of the United States. State and local governments must immediately begin to require that all buildings be metered for water use, at the gross building level at a minimum, but, ideally, sub-metered for all significant water uses within the building. Installing meters and billing according to usage is the single most effective water conservation measure a water utility can initiate. As recently measured by utilities, unmetered water consumption is reduced 15% to 30% when utilities implement metering and commodity rates.[2]

At a minimum, building owners should know, through metering by utilities and/or measuring of delivered energy forms, the aggregate energy use of a building, or group of proximate buildings under common ownership. With such information, it is possible to explore how different buildings of the same type and use, subject to the same or similar variables,

[2]The Alliance for Water Efficiency - 2011

perform in comparison to one another. Based on those comparisons, building owners can decide if action is necessary. Ideally, energy use data for various functions (e.g. lighting, heating, major plug loads, etc.) also should be available to assist in identifying ways to reduce energy use.

The ability to identify the greatest opportunities from energy-related technologies depends on the availability of energy use information, as well as information about the quality of services provided (e.g. lighting, temperature, air quality, insulation, etc.) for the energy expended in the building. Having a more refined measurement and demonstration of energy use and delivered building services should serve to prioritize the need for new technology, as well as the need to use the current technology in the right places to achieve the most benefit.

The Commercial Buildings Energy Consumption Survey (CBECS) conducted by the DOE's Energy Information Administration (EIA) is a national sample of the U.S. commercial building stock and their energy-related building characteristics, energy consumption and expenditures. EIA released survey data from 2003, the most current available. The 2007 CBECS had statistical flaws and recent economic conditions have placed future surveys in jeopardy. Thus, energy use data available for comparative purposes for the foreseeable future will be at least 10 years old. Without up-to-date information, it is difficult to assess how different buildings perform relative to their peers and how the building stock overall improves. CBECS funding must remain consistent to support the conduction of future surveys.

In order to compare energy use across buildings or determine progress to an established goal, there needs to be a common baseline from which to measure. As evidenced above, this baseline can be based on the performance of the existing building stock (such as CBECS) or the expected building performance based on a particular version of an energy code or standard. The lack of a common baseline can hamper the assessment of building performance.

ASHRAE Standard 105-07, "Measuring and Expressing Building Energy Use," was initially published in 1984 to support the implementation of building energy performance standards and recently received renewed interest due to the increased focus on building energy performance. Efforts should continue to support the updating, enhancement and use of this standard; efforts which now include consideration of primary energy use, as well as CO_2 emissions associated with buildings.

Rather than a common baseline referencing past performance, a finite future goal can provide consistency in showing progress towards such a goal. For example, net-zero energy use may be an appropriate baseline. While not achievable in all buildings, net-zero energy use provides a consistent point of measurement toward which every building can aspire. This also would foster increased involvement by all building owners and operators because they have a clear target to compare against that more easily provides the ability to market their success towards achieving that goal. This would in turn likely entice more energy use reporting and, if done pursuant to ASHRAE Standard 105, the public and private sectors could provide data easily aggregated to assess the state of the building stock.

While net-zero energy use does not generally impact the safety inherent in existing delivery infrastructure, net-zero water efforts require careful consideration. Existing water infrastructure and plumbing is based on historic flow rates. Decisions to implement some water efficiency strategies that reduce water consumption levels without fully understanding the systemic implications of reducing flows in water supply pipes and sanitary systems can result in unintended consequences. For example, both water and energy efficiencies in buildings can be increased by reducing the diameter of the hot water pipes between the water heater or boiler and the point of use. Doing so would reduce the time that the user would need to wait for hot water to arrive at the outlet, saving water and reducing the amount of cold water entering the water heater or boiler, which then requires heating.

However, reducing the diameter of water pipes in a building without understanding how water will be used in that building can have dangerous implications. The simultaneous activation of too many plumbing fixtures, appliances or other water consuming equipment in an undersized plumbing system can result in a dangerous drop in residual pressure in water supply pipes, which can cause a hot water scalding of a user. Excessively high flow velocities in water pipes also can cause water hammer, unacceptable noise and premature leakage.

Continued flow reductions on both water supply and sanitary drain systems, without fully understanding the implications of these flow reductions, place the health and safety of occupants and the efficacy of plumbing systems at risk. Researchers need to better understand water use in buildings to properly size water pipes to balance the needs for energy and water efficiency with the need to maintain residual pressures for safety and other performance concerns.

Currently, no robust datasets provide water use benchmark data by distinct building types. Establishment of such a system could result in development of comprehensive benchmark data that supplies a general range of "water use intensity" values represented as gallons per square foot. Water use intensity values can be used within codes and standards to develop performance-based standards (see below for more information), by water utilities to identify large and inefficient users, by water auditors to develop water management strategies, and by federal and local governments to craft water use policies.

This data would provide great benefit in the promulgation of performance-based "green" codes, standards and rating systems. This benchmark data would provide a means to compare the water use of one building against another to determine a relative level of water efficiency. Without this information, building codes, standards and rating systems cannot successfully implement performance-based requirements. Presently, performance-based systems fall back to baseline model plumbing codes and related fixture standards as the benchmark. Therefore these rating systems only require efficient plumbing fixtures and do not consider all other indoor water consuming equipment in buildings, such as commercial kitchen equipment, cooling towers and water-consuming medical equipment, as well as non-critical functions, such as ornamental fountains. These partial requirements do not produce water-efficient buildings because no benchmark data exists upon which to generate accurate and defensible performance-based goals. However, model code developers have developed comprehensive "green" building or plumbing codes that, while prescriptive in nature, do address commercial and institutional applications.

As a first step to development of a water use benchmark and resulting opportunities to reduce water use, it is essential that state and local governments immediately begin to require that all buildings be metered for water use at least at the gross building level, but, ideally, sub-metered for all significant water uses within the building.

Energy and Water Audits

An energy audit is simply an assessment of energy use within a building or relevant portion or subsystem of a building.[3] The more refined the audit of inputs and outputs, the more robust the available data, thus enhancing the ability to make more informed decisions concerning changes intended to reduce inputs and/or enhance outputs.

The objectives of an audit include (with possible areas of focus for improvement shown in parenthesis):

- The analysis of building and utility data, including a study of the installed equipment and analysis of energy bills (the availability of better and more refined utility/energy use data);
- The survey of the real operating conditions (better survey tools and systems that can monitor and record such conditions over time);
- The understanding of the building behavior and of the interactions with weather, occupancy and operating schedules (better monitoring systems and tools to record variables affecting energy use);
- The selection and the evaluation of energy conservation measures (facilitated to the degree that audit outputs can help select appropriate measures);
- The estimation of energy saving potential (facilitated to the degree that the audit yields relevant information and an appropriately refined level);
- The identification of customer concerns and needs (it might be presumed that as more refined and accurate methods of auditing and resultant use of data occurs, the satisfaction of customer needs would be enhanced while concurrently their concerns could increase commensurate with the number of available and more refined data points).

Considering the above, the following general improvements in energy audit methodologies could be considered:

- The availability of metering technology, building controls, and recording of building energy use and building attribute outputs (temperature, humidity, air quality, lighting quality, etc.) pursuant to such technology and controls can and should drive the information collected in audits and how that information is reported.
- Similarly, the information desired based on the intended purpose of using the information would drive the identification of needs associated with building data and, to the degree those are not being met, drive increased emphasis on development of technologies or approaches to gathering those data.

Almost 30 years ago, ASHRAE conducted a research project, "RP-351—Energy Audit Input Procedures and Forms," which catalogued all existing energy audit procedures (at the time), reviewed and assessed them, and offered recommendations for future use based on the findings of the research. It would seem timely to revisit this work and conduct an update, focusing first on the intended use of the information gathered by the audits. The intended use will dictate needs and allow one to assess and prioritize needs and determine if current audit methodologies meet those needs.

The ability to identify any 'sweet spots' for energy-related technologies depends on the availability of energy use

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[3]ASHRAE describes auditing as being comprised of four levels of audit:
- Level 0 – Benchmarking: This first analysis consists of a preliminary Whole Building Energy Use (WBEU) analysis based on historic utility use and costs and the comparison of the performance of the buildings to those of similar buildings. This benchmarking of the studied installation allows determination if further analysis is required;
- Level I – Walk-Through Audit: A preliminary analysis is made to assess building energy efficiency to identify not only simple and low-cost improvements but also a list of energy conservation measures (ECMs) or energy conservation opportunities (ECOs) to orient the future detailed audit. This inspection is based on visual verifications, study of installed equipment and operating data, and detailed analysis of recorded energy consumption collected during the benchmarking phase;
- Level II – Detailed/General Energy Audit: Based on the results of the walk through audit, this type of energy audit consists of an energy use survey in order to provide a comprehensive analysis of the studied installation, a more detailed analysis of the facility, a breakdown of the energy use and a first quantitative evaluation of the ECOs/ECMs selected to correct the defects or improve the existing installation. This level of analysis can involve advanced on-site measurements and sophisticated computer-based simulation tools to evaluate precisely the selected energy retrofits;
- Level III – Investment-Grade Audit: Detailed analysis of capital-intensive modifications focusing on potential costly ECOs requiring rigorous engineering study.

information as well as information about the quality of services provided in the building for the energy expended. If energy use is only measured at the total building level, without assessment of the quality of services provided through the expenditure of that energy, it is challenging to assess the degree to which any specific technology can or cannot play a role and, when technologies are aggregated, for determining which ones to prioritize. Facilitating an assessment of energy use and delivered building attributes to further a more refined measurement and expression of energy use and delivered building services should then effectively serve to prioritize the need for new technology, as well as the application of current technology in the right places to achieve the most benefit.

Water audits, similar to energy audits, provide a comprehensive understanding of how a building consumes water. If a building owner knows his/her biggest water user, investing in processes and technology can have a serious impact on water reduction and facilitate better management. Real-time data collected on building end-use equipment can help in accurately determining efficiency opportunities. A comprehensive water audit is a systematic process whereby all major water-consuming equipment and processes are evaluated to estimate the water consumption over a given period of time (typically annually).This can be developed in a multi-phase process that embodies the following elements:

- **Prepare for the assessment:** set goals for the assessment, gather historic water use data, collect building inventory data and prioritize buildings for surveys;
- **Conduct water walkthrough surveys and build a water balance:** analyze historic water use data, develop a baseline, perform walkthrough surveys of priority buildings and processes, meter key water uses and quantify water use at the process level;
- **Evaluate efficiency opportunities:** investigate operation and maintenance improvements and repairs and research available efficient technology options; and
- **Compile results and prioritize:** estimate water savings of water efficiency measures, develop economics of water efficiency measures and prioritize water efficiency opportunities based on results.

In addition to water audits in buildings, the nation's water distribution infrastructure, which continues to fail at alarming rates, urgently needs auditing. While the construction community struggles to reduce water consumption in buildings, water distribution infrastructure wastes up to 25% of treated water due to leakage between the point of treatment and the building. The vast majority of the country's water and wastewater systems are in urgent need of repair and replacement.

According to Congressional Budget Office estimates from 2002, it will take $335 billion over the next 20 years to repair and update water distribution systems and an additional $300 billion to do the same for sewer systems. The process of repairing the nation's crumbling infrastructure can create tens of thousands of long-term American jobs. The United States Conference of Mayors estimates that every job created through rebuilding water systems creates more than 3.6 jobs elsewhere and every dollar invested in water infrastructure adds $6.35 to the national economy.

However, the federal government alone cannot bear the financial burden to address this critical need. Large and small water utilities alike must document the need and seek regulatory authority for the ability to appropriately price water to include provisions for required improvements to their local infrastructure. Properly addressing these needs will require a coordinated effort at the national level, but also must involve regional, local and private-sector concerns to assure efficiency and effectiveness.

The Water / Energy Nexus

The connection between water and energy is a significant policy issue in need of national attention. Electricity generation needs water; pumping and treating water requires electricity; and water heating uses natural gas and oil, as well as electricity.

Specifically, this relationship can be summarized as follows:

- Embedded Water in Energy:
  a. Energy production requires consistent and plentiful sources of water that do not compete with the potable water requirements of the affected human population and wildlife. Water is required for hydroelectric generation and power generation cooling methods. The U.S. Geological Survey (USGS) reported in its *Estimated Use of Water in the United States in 2005* that 49% of the nation's total water use and 53% of fresh surface-water withdrawals went into the production of thermoelectric power; on average that was 23 gallons per kilowatt-hour produced.
  b. The extraction, refining, processing and transportation of various energy sources also needs water.
- Embedded Energy in Water:
  a. **Drinking water process.** The process of extracting raw water from the source, conveying it to the treatment facility, treating it to required standards and distributing it to customers all requires energy.
  b. **Customer use.** Circulating, pressurizing and heating water for use inside households and businesses, as well as for outdoor water-related uses by customers, such as watering lawns, all requires energy.
  c. **Wastewater processes.** Conveying wastewater to treatment facilities, treating the wastewater to required standards, and discharging the treated effluent into a receiving body of water all requires energy.[4]

National research into the deep connection between water and energy has been insufficient. The California Energy Commission found that 19% of the state's electric energy load comes from the pumping and treatment of drinking water and wastewater, and 32% of its gas load is related to the heating of water by consumers. However, few other states have done this analysis, and there has been no national research into this important

[4]GAO Report, *Energy-Water Nexus,* March 2011

area. Further, the issuance of permits for new electric generating facilities has been inconsistent because of the perceived unavailability of needed cooling water resources. National research on this issue also has been missing.

There must be a national research program directed to understand the complex relationship between energy and water, including production, infrastructure, training and funding. Consistency of approach, consistency of appreciation of value and consistency of mandates are critical elements to ensuring the water / energy nexus is better understood and future decisions are made with an appreciation for the balance between energy and water considerations.

Plumbing Research Needs

When considering the dire water scarcity and declining water quality issues the nation will face in the near future, the difficulty in obtaining funding on research for building plumbing systems is puzzling. Continuing to make flow reductions, on both the water supply side and on the sanitary drain side of the system, without fully understanding the implications of these reductions, places the health and safety of occupants and the efficacy of plumbing systems at risk.

On the water supply side, reduced velocity in water supply pipes has the potential to permit the growth of biofilm on interior water pipe walls. As discussed earlier, a better understanding of water use in buildings to properly size water pipes must inform efforts to balance the needs for energy and water efficiency with the need to maintain residual pressures for safety and other performance concerns. Conducting needed research on water use in buildings also will help ensure that water velocity in pipes can be maintained at levels that ensure adequate scouring action to minimize the potential for dangerous biofilm build up in pipes.

The need for research on sanitary drainlines in buildings is equally profound. Recently, the need to find additional efficiencies on water-consuming plumbing fixtures resulted in the creation of voluntary specifications that eliminate another 20% from the flush discharge volume of water closets, bringing consumption down to a maximum average of 1.28 gpf. These toilets are known as high efficiency toilets (HETs). Many plumbing experts are concerned that the water infrastructure is at or approaching a “tipping point” where a significant number of sanitary waste systems will be adversely affected by drainline transport problems, especially in larger commercial systems that have long horizontal runs to the sewer.

Looking forward, newer technologies, such as non-water consuming and high efficiency urinals (HEUs), lower flow rate faucets and increasingly efficient water consuming appliances will further reduce the amount of water discharged into sanitary waste systems. Equally significant are graywater reuse systems that collect discharged water from lavatory basins, clothes washers, bathtubs and shower fixtures in a residence for reuse, usually for irrigation purposes. This is another emerging technology that will significantly reduce wastewater in residential sanitary drainage systems.

In 2010, the Plumbing Efficiency Research Coalition (PERC)[5] developed a comprehensive designed experiment to begin the scientific study of reduced flows in building drains, which even includes evaluation of a potential low cost solution to deploy where drainline blockages occur. In spite of the meager budget associated with this work, PERC has had difficulty in obtaining funding to conduct this desperately needed research. The prospects for obtaining funding from the federal government for this work were ultimately considered impossible. Fortunately, due to hard won support from the private sector, PERC will commence this research in 2012.

Generally, there is a lack of information on commercial end-use water use and very little extensive research has yet to be conducted. Such research would monitor, in real-time, water consuming equipment and processes in commercial buildings, such as plumbing fixtures; commercial kitchen equipment; irrigation; laboratory/medical equipment; heating, ventilation and air conditioning (HVAC) systems; and ornamental fountains. This data could be examined to understand patterns in water use by end-use and to support development of metrics that provide benchmarks on water use by end-use for distinct building types. Building owners, designers, operations and maintenance staff, policymakers, and codes and standards developers could utilize the information to more accurately estimate water use by building type and the potential savings of efficiency opportunities.

Thermal insulation is routinely used to improve the thermal efficiency of hot water delivery systems. Although specific requirements vary, all major building energy codes currently require some pipe insulation on domestic hot water (DHW) piping. DHW piping insulation requirements have been based on the energy savings associated with reduced heat loss from piping systems. However, thermal insulation also helps conserve water by reducing the time it takes from the initial demand for water (turning on the tap) until the water is delivered to the demand point at the required temperature. A study is needed to quantify the potential energy and water savings associated with increasing the use of pipe insulation.

It is essential that the federal government immediately begins to take water and plumbing-related issues more seriously, invest in updating water infrastructure and support needed research on how buildings can become more water-efficient without compromising health and safety or system performance.

[5]PERC is comprised of the American Society of Plumbing Engineers (ASPE), Alliance for Water Efficiency (AWE), the International Association of Plumbing and Mechanical Officials (IAPMO), the International Code Council (ICC), the Plumbing–Heating–Cooling Contractors National Association (PHCC) and the Plumbing Manufacturers International (PMI).

Federal preemption for certain plumbing products and impacts on manufacturers

For more than 15 years, a preemption clause in the Energy Policy Act of 1992 (EPACT 92) (42 U.S.C. 6297(c)) has prevented states from establishing more stringent water efficiency requirements for products covered in EPACT 92, the Energy Policy Act of 2005 (EPAct05) and contained within 42 U.S.C. 6295 (j) and (k) without first obtaining a waiver from DOE. The limits governed the permissible water consumption of lavatory faucets, kitchen faucets, showerheads, water closets and urinals. Pre-rinse spray valve limitations were added in the Energy Policy Act of 2005 (EPAct05). The regulations are linked to a referenced industry standard, ANSI/ASME Standard A112.18.1, requiring a review of the water-efficiency limits in the event that the ASME standard is amended to increase the water efficiency requirements for showerheads or faucets.

However, some jurisdictions, believing the preemption clause to have expired, have enacted water efficiency requirements more stringent than allowed. In most cases, they require the use of WaterSense labeled products, which nominally consume 20% less than that prescribed in EPACT 92. DOE did not enforce preemption in these cases, thus perpetuating the view that the preemption clause had expired. The fact that the referenced standard, ANSI/ASME Standard A112.18.1, has not been revised, even while many more water-efficient devices have become available, is complicating the situation. DOE finally moved to formally waive preemption for faucets, showerheads, water closets and urinals in a rule issued and effective on December 22, 2010.

Lack of enforced preemption has the effect of allowing states to adopt more stringent water consumption requirements and removes perceived impediments to the adoption of green building codes and regulations. However, it may also produce a high degree of variation in state regulations around the country, a source of concern for the manufacturers of water-efficient products. A high degree of variation in the regulations between states may require manufacturers to develop different products for different states, pushing up distribution, marketing and development costs. Further, poorly chosen maximum use limitations could negatively impact the performance and effectiveness of these products.

Federal guidelines pertaining to the use of non-potable water

Even though appliances and fixtures are becoming increasingly more efficient and consuming less water, they still discharge water into sanitary waste systems. In the near future, graywater reuse systems will be able to significantly reduce the amount of wastewater going into residential sanitary drainage systems. These reuse systems collect discharged water from lavatory basins, clothes washers, bathtubs and shower fixtures in a residence for reuse (usually for irrigation purposes).

Such interest in the use of non-potable water for various applications has surged in recent years, driven in part by the emergence of new stretch codes and standards, as well as the recognition that water is a finite resource. Non-potable water provides a viable means of reducing the need for potable water by reusing and recycling water. Treatment of non-potable water also is less energy-intensive than treatment to potable water standards. Numerous applications are available, including water closet and urinal flushing, cooling tower makeup, automatic fire suppression systems, landscape irrigation and fountains. Non-potable water may include rainwater, graywater, reclaimed water and non-potable water from various other alternative sources.

Currently, however, there are no federal regulations governing water quality or permissible utilizations for non-potable water. In 2004, the Environmental Protection Agency released EPA/625/R-04/108, *Guidelines for Water Reuse*. While that document is instructive, it is not binding. The *Guidelines for Water Reuse* is currently undergoing an update intended to further streamline it and incorporate the latest findings. The update is slated for completion by October 2012.

The regulations on how non-potable water can be used in applications inside and outside of buildings are highly variable throughout the nation. Many states do not even have such regulations. The lack of uniform regulations is currently the greatest impediment to more wide-spread use of non-potable water in buildings and on building sites.

Recommendations

- SDOs should update or develop new consensus standards designed explicitly for benchmarking a building's energy usage, and consider "net-zero energy" as the goal.
- The U.S. Government should develop incentives for state and local governments to immediately require water metering of all buildings and to adopt and properly enforce comprehensive "green" building or plumbing codes.
- The U.S. Government should support the research and development of less invasive water sub-metering technologies and employ these technologies to better understand complex water use patterns associated with various building types.
- The U.S. Government should encourage and provide a tax incentive to building owners that voluntarily get their buildings audited and implement the recommendations from the audits to reduce their energy and water use; the degree of incentive should increase in relation to the reduction in energy and water use. Widespread energy and water auditing will provide the data and information required to establish more accurate baseline metrics, prioritize installation of energy and water-efficient technologies that offer the best return on investment, and provide real-time or near real-time feedback to building owners.
- State and local governments should require water utilities to conduct independent leakage audits and report the percentage of water leaking from their distribution systems, along

with a plan for the repair and update of systems that demonstrate excessive leakage.
- The U.S. Government should become more actively engaged in the development of research programs and provide financial support for scientific study to ensure that increasingly taxed water supplies are used as efficiently as possible while still maintaining health and safety.
- The U.S. Government and the building community should support research to quantify the long-term costs and benefits associated with increasing the use of pipe insulation on hot water pipes.
- DOE should undertake a review of the current water efficiency standards and test procedures contained within 42 U.S.C. 6295 (j) and (k) to determine whether improving the water efficiency requirements for any or all named products is technologically feasible, economically justified and consistent with the maintenance of public health and safety. If the permissible water consumption standards are reduced, DOE should reinstate the preemption of state restrictions contained within 42 U.S.C. 6297(c) in the interest of promoting uniform standards, interstate commerce, and public health and safety.
- The Environmental Protection Agency should set uniform national non-potable water quality standards, along with permissible utilizations of non-potable water. Water quality standards should reflect the minimum and maximum water quality parameters required to protect public health and safety, as well as the integrity and function of plumbing systems and devices. Where scientifically sound information is unavailable to establish standards, research should be undertaken to fill knowledge gaps.

Sustainability

Improve the Efficiency of (Streamline) the Regulatory Process

Federal, state and local governments have established a variety of regulations to promote public health, safety and welfare and to protect the environment. Most of these are consistent in intent with sustainability, but many are prescriptive in nature and unsupportive of sustainability in specific situations. Many different regulatory agencies, each with its own procedures, have jurisdiction over different aspects of building and infrastructure projects.

Regulatory streamlining is a process, involving project proponents and all cognizant regulatory jurisdictions and stakeholders, to give simultaneous and coordinated attention to meeting the intents (performance requirements) of all regulatory requirements. Long, expensive delays often are imposed on building and infrastructure projects before approvals can be obtained from all regulators. Innovations for sustainability can exacerbate such delays. Modern information technologies, such as BIM, permit efficient sharing of pertinent information and can facilitate streamlining.

Recommended Triple-Bottom-Line Definition of Sustainability

The Institute and all other stakeholders concerned with sustainability need to be clear that a sustainable society and built environment meet the triple bottom line: human needs for economic growth, environmental stewardship and social progress. The stakeholders that must act in concert to achieve sustainability in buildings and communities are numerous and diverse: citizens, constructors, designers, educators, environmentalists, financers, insurers, manufacturers, occupants, operators, owners, policymakers and regulators. Therefore, the definition of sustainability should address the economic, environmental and social concerns of all stakeholders. Policymakers and members of the building community are encouraged to utilize a common definition for sustainability. A potential starting point is identified below.

> *Sustainability is a set of environmental, economic and social conditions in which all of society has the resilience, capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality or availability of natural, economic and social resources.*

Education/Training in Sustainability for Professionals and Technicians

Knowledge and practice for sustainability are evolving rapidly; their successful application requires strong educational programs for the building community workforce (including programs for professionals, technicians and trades, and pre-career and continuing education). Educational needs go beyond designers, constructors, operators, maintainers and regulators to include owners; real estate, finance and insurance industries; policymakers; and the general public. Sustained educational efforts are needed for building occupants and operators as building systems are upgraded and occupants and operators change.

The Consultative Council member organizations have the following links to educational activities on their websites:

AGC: Green Construction Education Program: www.agc.org/cs/gcep
AIA: Continuing Education System: Sustainable Design: www.aia.org/education/ces/AIAB089084?dvid=&recspec=AIAB089084
ASCE: www.asce.org/knowledge-learning/continuing-education
ASTM: www.astm.org/COMMIT/sustain.html
BOMA: 360 Performance Program: www.boma.org/GETINVOLVED/BOMA360/Pages/default2.aspx BOMA: Sustainable Operations Series: live.blueskybroadcast.com/bsb/client/CL_DEFAULT.asp?Client=239614&PCAT=1765&CAT=2587
HVAC Excellence: www.hvacexcellence.org
IAPMO: www.iapmo.org/pages/educationandtraining.aspx
ICC: www.iccsafe.org/Education/Pages
IES: www.ies.org/education
NIA: www.insulation.org/midg/

Recognition of Life-Cycle Performance by the Financial and Insurance Communities

Currently, in common budgeting practices there is an organizational disconnect between construction (capital) and operations. This disconnect decreases the ability to realize savings based on life-cycle costing. Sustainability requires achievement of economic, environmental and social benefits over the lifetime of a building or infrastructure project. Because people tend to focus on minimizing first costs and ignore externalities, they often perceive sustainability to seem uneconomical. Thus, mechanisms (e.g., budgets, insurance and tax incentives) are needed to facilitate the financing of sustainable life-cycle performance for buildings and related infrastructure. Life-cycle costs and the productivity and well-being of those served or affected by the project also need to be taken into consideration. The Sustainability Topical Committee will work with the Institute's Council on Finance, Insurance and Real Estate (CFIRE) to promote recognition of life cycle economic, environmental and social performance when making finance and insurance decisions.

Champions of Sustainability in the Public and Private Sectors

Each group of stakeholders (at the national, state and local, industry and project levels) needs credible, knowledgeable, patient and charismatic leaders ("champions"). Potential champions of sustainability in buildings and communities are numerous and diverse: citizens, constructors, designers, educators, environmentalists, financers, insurers, manufacturers, occupants, operators, owners, policymakers and regulators. Substantial attention should be given to identifying, informing and empowering potential champions.

Recommendations

- The Institute should work with existing organizations that support development of more efficient regulatory processes that take advantage of digital technology. Organizations participating in the Consultative Council and other building community stakeholders (including regulators) should participate in such a process to assure inclusion of all important considerations.
- The Institute should produce a 30-minute audio-visual module for educators to address sustainability and building sciences. The Sustainability Topical Committee will collaborate with the Education and Training Topical Committee and the Sustainable Building Industry Council (SBIC) in this effort.
- The Topical Committee will work with the Institute's Council on Finance, Insurance and Real Estate (CFIRE) to promote recognition of life-cycle economic, environmental and social performance when making finance and insurance decisions.
- Potential champions of sustainability should be identified in the High Performance Building Congressional Caucus; state and local government associations; the Institute's Board of Directors and Consultative Council; professional societies and trade associations; and advocacy groups.

Participants

2011 Consultative Council Member Organizations

ASTM International
American Institute of Architects
American Society of Civil Engineers
ASHRAE
Associated General Contractors of America
Building Owners and Managers Association International
Construction Specifications Institute
ESCO Institute
Extruded Polystyrene Foam Association
Glass Association of North America
Green Mechanical Council
HOK
Illuminating Engineering Society
International Association of Lighting Designers
International Association of Plumbing and Mechanical Officials
International Code Council
Laborers' International Union of North America
National Insulation Association
NORC at the University of Chicago
United Association of Journeymen and Apprentices of the Plumbing and Pipefitting Industry

Consultative Council 2011 Leadership

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Vice-Chair: Ron King, National Insulation Association
Secretary: Tom Meyer, ESCO Group

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Energy and Water Efficiency: Peter DeMarco, International Association of Plumbing and Mechanical Officials
Education and Training: Larry Bulman, United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry
Codes and Standards Adoption and Enforcement: Nancy McNabb, National Institute of Standards and Technology
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