National Institute of
BUILDING SCIENCES

Moving Forward

Findings and Recommendations from the Consultative Council

An Authoritative Source of Innovative Solutions for the Built Environment

Moving Forward
Findings and Recommendations from the Consultative Council

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Executive Summary

Buildings are complex systems embodying ideas, experiences, technologies and practices brought together by different disciplines, users and needs. In forming the National Institute of Building Sciences and its Consultative Council in 1974, the U.S. Congress recognized this complexity and the importance of bringing these diverse actors together to improve building sciences and policy.

Early in 2010, the Institute re-formed the Consultative Council to represent leading organizations within the building community. The Council was charged with identifying the high-level issues currently impacting the building community and offering findings and recommendations related to these issues.

The issues identified for 2010 include:

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

The Consultative Council established topical committees consisting of representatives from many organizations. Each committee prepared a report. With the exception of the Existing Buildings report (which will be produced at a later date), findings and recommendations from these reports are summarized below. The committees' full reports follow ths summary document.

Defining High Performance and Common Metrics

Findings & Recommendations

- Definition: Add the following sentence to the Energy Independence and Security Act (EISA) 2007 definition of high performance building: "A building will have achieved optimization on a life-cycle basis when its measured results meet or improve upon legitimate benchmark standards that define high performance."[1]
- The Institute's High Performance Building Council should form a Standards Integration Group (SIG) to perform necessary gap analysis (to identify gaps in information where additional work is needed) and coordinate consensus standards and measures development throughout the industry.
- Standards Development Organizations (SDOs) should develop standards that address attributes of a high-performance building as identified by the SIG's gap analysis. Where practical, SDOs are encouraged to engage in Attribute Groups to discuss the establishment and use of common metrics.
- Industry-wide performance-based standards should address the following four measures: Baseline, Benchmark, Measured Results and Performance Results Index (PRI).
- Owner and project delivery (production) teams should implement a high-performance building system that measures both the project and completed facility metrics according to the standards of accredited SDOs.
- The Institute's High Performance Building Council should provide the leadership and roadmap to implement these recommendations.

Attributes Development and Optimization

Although the building practices and structures of the past have tended to optimize the pieces and parts of the building process and product, the result has been a less-than-optimized whole building. Alternatively, the current high-performance building initiative looks, first, to optimize the whole building and then, to major systems on down to the parts and pieces. Whole building standards and measures are crucial to this initiative.

In order for standards and measures to be meaningful to anyone, they must be capable of being uniformly measured, expressed and understood by all users. The first step must be the establishment of consensus standards and measures for performance. The second step is the implementation of standards at the project-specific level.

Consensus Standards

In order to ensure standards uniformity and aggregated building optimization, the Institute's High Performance Building Council should convene an SIG to coordinate the work of attribute-focused SDOs. As such, when owners/developers choose to pursue high-performance goals, they should take the opportunity to adopt an SIG family of SDO standards.

SDOs should develop standards based on the identified attributes (energy, environment, safety, security, etc.) to achieve high-performance legitimacy. These standards can be used to help assess to what degree a building is considered a high-performance building.

[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.

Project Implementation

As the particular SDOs publish standards and processes for achieving high performance, owners and/or building teams will be equipped to implement a high-performance building system. In order for owners or building teams to make a legitimate claim of high performance, they need to successfully meet all of the requirements and validate the performance and cost-benefit measures.

Common Metrics

The following metrics can be used to help measure the actual performance of a building against the standards. Attribute Groups are encouraged to discuss how such measures can be defined for a particular attribute.

- **Baseline**–a measure of standard performance for specific whole building and major systems when the measure is cost, or for a particular unit of measure for critical components. Standard performance and productivity relates to the market or industry average, based on conventional or customary means and methods at a particular baseline year.
- **Benchmark**–a measure of in-progress high performance according to a viably optimized state. In many cases, this measure is derived as an interpolation between the baseline and an ends goal. Also, in most cases, a target performance value should be determined as well.
- **Measured Results**–a measure of actual results from the completed and operating building.
- **Performance Results Index (PRI)**–a ratio of component measures, where the numerator is the measured result and the denominator is the standard that it is measured against.

A high-performance building exists once the measured results meet or improve upon the benchmark measures, or when the Baseline PRI is 1.0 or less.

The complex nature of the building process and facility operations requires a hierarchical structure, starting with whole-building high performance; then drilling down from the whole building to major systems, sub-systems, components, materials, etc., as well as concepts; and concurrently drilling across to address each attribute. The intersection of each item and attribute would create a "destination" to define relative performance in terms of the metric used, how it is measured and how it is expressed.

Each intersection would be measured and expressed in two ways: (1) the Cost Benefit and (2) the High Performance (HP) Classification of: (a) Fails HP, (b) Meets HP, or (c) Exceeds HP. Individual building components and sub-components may include these cost and classification measures, but overall building performance would be evaluated according to units of measure relating to energy, carbon, light, sound, force, load, etc., as determined by the respective SDOs.

Implementation

In order to accomplish these recommendations, the Consultative Council proposes a four-step process:

1. The Institute's High Performance Building Council would form a Leadership Council representing all stakeholders (owners; building producers; codes, standards, measures and industry improvement organizations; and government agencies).
2. The Leadership Council would convene a brainstorming session with a broad base of stakeholder volunteers.
3. The Leadership Council would compile the brainstorming results, produce a roadmap for implementation and promote it throughout the marketplace and to policy-making groups. The outcome should address the formation of the various SDO Attribute Groups and SIG, as well as identification of needed research and development projects.
4. The building community would then implement the roadmap.

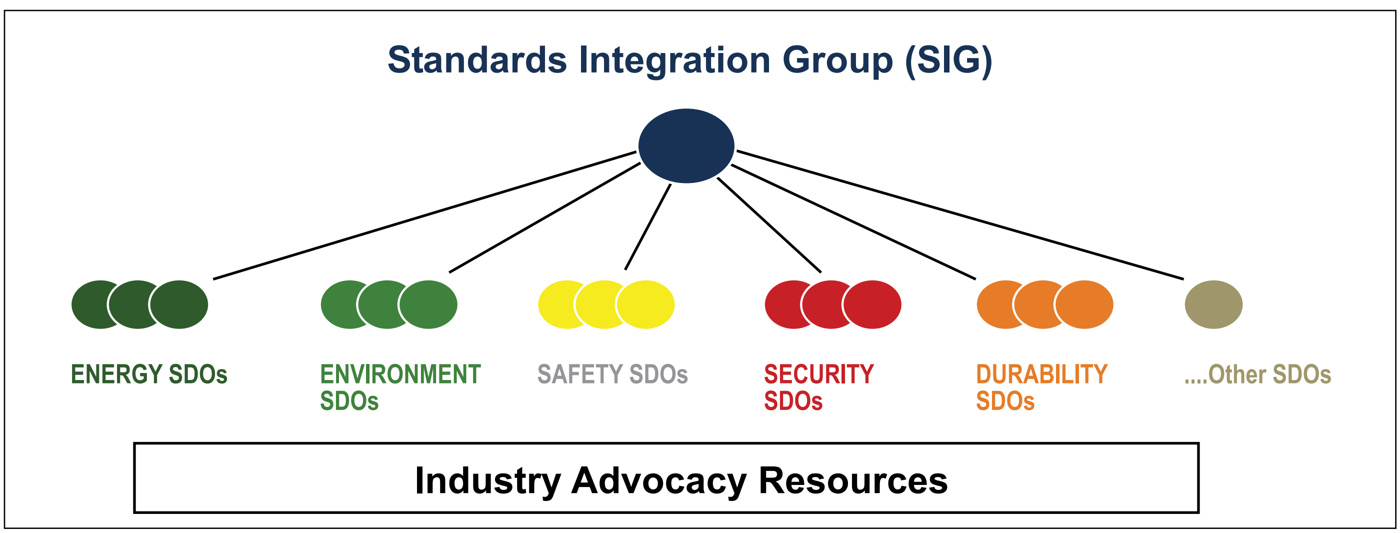

Figure 1—Relationship of the SIG to Standards Development Organizations (SDOs)

Energy and Water Efficiency

Findings & Recommendations

- The federal government should redouble its leadership efforts and urgently work with construction community stakeholders to develop widely acceptable energy and water efficiency metrics to be deployed in developing future codes, standards and efficiency programs.
- The federal government should provide monetary incentives in the form of funding and tax incentives for the adoption and enforcement of energy and water efficiency stretch/above baseline codes and standards.
- Investment in energy and water-related infrastructure is desperately needed. Programs aimed at repairing and replacing aging infrastructure would vastly improve efficiencies and create jobs.
- The building community and policymakers should shift towards performance-based code provisions that work towards net-zero energy buildings and away from prescriptive requirements.
- The President and Congress should prioritize, coordinate and support development of a national water strategy.
- The Environmental Protection Agency (EPA), working with other relevant agencies, should establish a plumbing research facility to support plumbing research programs that foster increased levels of water efficiency. Such a facility should be located within the National Institute of Standards and Technology (NIST) or another research institution charged with working with the private sector.
- Congress and the Administration should continue to fund successful labeling incentive programs like Energy Star™ and WaterSense™ and support retrofit incentive programs aimed at removing inefficient consumer appliances and plumbing fixtures from the marketplace.
- The building community and policymakers should support the development of codes and standards establishing requirements for the safe use of alternate water sources, such as reclaimed water, rainwater and gray water, and efficient outdoor irrigation practices.
- The U.S. Department of Energy (DOE) should work with codes and standards developers to provide energy savings analysis on change proposals, utilizing the same tools DOE uses to determine the efficiency of a new edition of a code or standard over a prior edition.

Introduction

Numerous efforts are underway, both in the United States and internationally, to develop comprehensive, performance-based energy metrics. Achieving net-zero energy performing buildings will require a greater understanding of the cost/benefit variables, thus allowing the building community to make informed decisions regarding which technologies to prioritize, develop and implement. The transition away from prescriptive-based specifications towards performance-based metrics also should include goals for the incorporation of systems that allow real-time user monitoring of building energy and water use to facilitate ongoing performance. Such systems will provide a built-in feedback system for continuously improving actual performance and informing the underlying metrics.

Conveying water consumes energy—from the source to the point of treatment, through the treatment process, while distributing water to the point of use, heating water during use and going through the wastewater treatment process. Plumbing distribution systems within buildings need to be designed with a greater focus on water and energy efficiency in residential, commercial and industrial sectors. During the design phase, designers should minimize the distance between the sources of hot water (generally the water heater) and the various points of use within a building.

Efficiency and conservation methods within buildings should continue to be employed in construction designs. However, the backbone of the nation's electrical and water delivery systems also needs significant repair and improvement. With nearly 60 percent of electricity and 20 percent of water being lost before it ever enters service, significant savings will not be realized until the delivery systems become more efficient and waste is reduced. The American Society of Civil Engineers, in a 2009 report, gave the U.S. drinking water and wastewater system a D-. The electrical infrastructure faired only slightly better by earning a D+. Both systems require significant investments in technology and distribution systems simply to maintain their current service, let alone to keep up with growing demands.

The assessments of technology performance will continue to benefit the building community as it strives to increase building energy efficiency and, as a result, drive development of new technology applications and design concepts. As technology is assembled into new building designs or renovations to existing buildings, the building community needs a better baseline of actual building performance against which to measure progress. More importantly, the application and use of prescriptive criteria must be eliminated in favor of stated performance goals or expected outcomes (although, after setting those goals or outcomes, prescriptive guidance to achieve them can be developed).

The United States has a profound need to improve the indoor and outdoor use of water in buildings. The EPA reports that 36 states expect to experience local, regional or statewide water shortages by 2013[2]. The nation employs a very conservative approach of utilizing potable water for nearly all applications, which may not be sustainable in an era of constrained supplies. Before additional improvements in indoor water efficiency can be confidently utilized, research on plumbing-related issues is required to better understand the implications of reduced flows in building supply and drainage pipes.

Codes and Standards Adoption and Enforcement

Findings and Recommendations

- At the state and local level, where code adoption and enforcement is largely conducted, the lack of resources, both financial and technical, significantly affects the ability of state and local officials to ensure that new buildings are satisfying the requirements provided by codes and standards and achieving the inherent benefits.
- Policymakers and the general public often misunderstand the codes and standards development, adoption and compliance process due to its complexities. There needs to be education initiatives to improve understanding.
- Increasing the participation of federal, state and local government agencies in the development of codes and standards would yield more uniformity and more consistently adopted and understood codes, thereby increasing the effectiveness of model building codes.

Introduction

Building codes cover the multidimensional aspects of the design and construction of new and existing buildings. Such codes represent baseline or minimum requirements. They can cover issues such as energy efficiency, life safety, accessibility, indoor air quality and many others.

Buildings last a long time, and codes and standards allow the benefits of improved construction today to be enjoyed for many decades. Continual improvements to codes, when adopted and enforced by jurisdictions, can result in consistent and long-lasting increases in energy efficiency, health, safety and accessibility.

Most model codes and standards are developed according to rigorous principles based on consensus, openness, balance, transparency and due process. In the United States, codes and standards are developed in the private sector, with the input of government agencies, consumer groups and other entities, to meet the changing demands of society. As technology, building science knowledge and understanding of risk improves, codes and standards evolve to incorporate such improvements. The typical code cycle lasts 3 to 5 years. The U.S. approach to code development allows plenty of time for input and transparency, but many challenges (as well as opportunities) remain on the path to achieving safer buildings that are more accessible and energy efficient.

Standard & Code Adoption: Implementing Best Baseline Practice

Building code requirements most often are established through adoption by state or local governments and by some federal agencies, such as the Department of Justice's Bureau of Prisons (although private developers also may impose these or more stringent requirements as a condition of a construction contract). Increasing code stringency provides new challenges to the building industry at large and to state and local agencies that are charged with administering and enforcing the codes.

The success of the building and construction market to meet code requirements relies on the availability and pricing of products and equipment. Equally important are the appropriate knowledge and skills of designers and contractors. Yet product development and workforce training takes time, which may not be considered when adopting updated codes and standards. Although many in the construction community are aware when code changes are going into effect, they often are reluctant to support code compliance or embrace the changes.

The recent increase in development of stretch/above baseline codes provides a straightforward potential solution. If these codes were to automatically become the next minimum code, they would provide the predictability and experience needed to support significant code compliance. Once established, incentive programs also could be used to promote the stretch code as a voluntary performance level for construction. Training, resources and financial incentives would work to fuel product development, skills and experience that would carry over to the broader market once the requirements became mandatory.

Resource constraints also tend to dampen the adoption of new codes. Some state policymakers are averse to adopting a code that will require significant and costly support. As codes advance further and faster, more resources will need to be invested to help the industry keep up. If resources are not available, code adoptions may stall.

An outcome-based objective that can be readily verified can assist jurisdictions in solving this problem. For instance, where code compliance is not achieved on an annual basis, penalties in the form of utility surcharges or property tax fines can be imposed. These outcome-based objectives may be more effective in the long run than the present situation, where buildings receive a certificate of occupancy upon completion, with limited or no inspections thereafter (depending upon the occupancy).

Code Compliance

As with code adoption, strengthening energy efficiency, health, safety and accessibility requirements over time presents several challenges to code compliance mechanisms. However, there is potential to significantly improve overall compliance through changes to the process and scope of enforcement, and as noted above, the format of codes.

Administration and enforcement of codes and standards is crucial to realizing safe, healthy, energy efficient and accessible buildings. The responsibility to administer and enforce the building code typically falls upon states or local jurisdictions, and the responsibility to submit compliant design documents for

[2] U.S. EPA, Water Supply and Use in the United States (2008).

a building permit falls on developers, designers and contractors. Education and communication regarding codes and standards is vital to the effective delivery of both enforcement and compliance.

The process by which code compliance is verified is typically local, with the state having oversight and/or enforcement responsibility for some types of buildings. Local agencies that are authorized and have the proper training and resources will typically enforce the adopted codes. Although empowered by statute and regulations to set forth the local code administration processes, the availability of resources determines the quality and extent to which jurisdictions perform plan reviews and construction inspections. When a state code agency actively supports local governments with the education, training and technical information services necessary to administer and enforce the code, compliance improves.

It is important for all stakeholders to know when a new code is expected to be implemented and to understand its requirements. Many states or jurisdictions start this education process months in advance of the code change and/or allow a window of compliance (e.g. permits can be issued for two different editions of the code during a specified grace period). Effective outreach, education and training greatly enhance acceptance and use of the new code.

Sustainability

Sustainable buildings and related infrastructure advance economic growth, environmental stewardship and social progress. They also are resilient to the effects of natural, accidental and willful hazards. Achieving a sustainable built environment requires numerous approaches, as indicated in the findings and recommendations below.

Findings & Recommendations

- Economic growth, environmental stewardship and social progress form the “triple bottom line” for sustainability that should be addressed in all building and infrastructure projects. Project goals and processes through the whole life cycle, from planning to renovation or removal, should demonstrate explicitly the economic, environmental and social benefits to the communities affected.
- Assuring that concerted actions are taken to achieve sustainability in buildings and communities requires credible, knowledgeable, patient and charismatic leaders (“champions”) for each group of stakeholders (at the national, state, local, industry and project levels). The building community (through the National Institute of Building Sciences and other organizations) should give substantial attention to identifying, informing and empowering potential champions.
- Providing the body of knowledge and tools for sustainable building and infrastructure practices requires substantial, comprehensive and sustained programs of research, development and demonstration (RDD). Policymakers and the building community need mechanisms to coordinate and advance the programs of the numerous public agencies, private foundations and private industries that fund RDD for sustainable buildings and infrastructure. Agencies should consider what interdisciplinary, multi-sponsored research is needed and stimulate the necessary funding, with clear indications of what benefits are to be achieved.
- To achieve true long-term sustainability of buildings and related infrastructure, designers, constructors, operators and owners must incorporate such concepts into the practices, standards and codes used throughout the life cycles of constructed facilities. The multi-faceted nature of sustainability requires that standards and practices state explicit performance requirements and have conformance assessment systems capable of accepting innovations. Building codes and infrastructure regulations should cite up-to-date, performance-based standards to assure acceptability of designs that provide better than minimal performance. As indicated above, the building community should undertake efforts to coordinate the establishment and use of consistent metrics.
- Formal and continuing education programs should provide future and present generations of professionals and technicians with the multi-disciplinary body of knowledge required to achieve sustainability in buildings. Each discipline or specialty involved in construction needs to understand the economic, environmental and social implications of its work, as well as its own special body of knowledge. Education and training curricula and programs require a well-rounded course of work providing knowledge in a breadth of subject areas with sufficient depth in focused technical areas. Collaborations across all disciplines can assist in defining the background education desired in social, life and physical sciences.
- Nationally recognized professional and technician licensure and certification programs should demonstrate how sustainability can be implemented in regular practice to address the needs of clients, employers and the public. Licensure boards should examine building and infrastructure professionals and technicians for needed knowledge of sustainability. Authoritatively accredited certification programs should be developed to recognize needed professional and technical expertise in sustainability.
- K-12, post-secondary and informal educational programs should teach students about the importance of a sustainable built environment, and should attract capable people to careers in building and infrastructure. All Americans are building occupants and beneficiaries of civil infrastructure. Their involvement is crucial to achieving sustainability goals. The building and infrastructure community should become involved in ongoing governmental and private efforts to address sustainability in K-12, post-secondary and informal education, and assure that appropriate recognition is provid-

ed to the importance of the built environment and building community.

- The economy must have a strong financial and insurance capacity to provide society with the benefits of a sustainable built environment. Society needs to understand and fund the potentially higher first costs associated with better economic, environmental and social performance over the project life cycle. To attract the financing required to produce sustainable buildings and infrastructure, investors need studies demonstrating increased public and private returns on investments. Appropriations for public construction should address life-cycle costs and benefits, and policies for accounting, financing, insurance and taxes should facilitate and promote private investment in sustainable buildings and related infrastructure. Budgeting and organizational practices, in both the public and private sectors, also should facilitate achievement of lower life-cycle costs.
- Public involvement in decisions made throughout the life cycle of a building or infrastructure system is needed to assure that the facility contributes to, and is perceived by stakeholders to contribute to, the sustainability of the affected communities. Model practices for public involvement should be developed and disseminated for appropriate types of building and infrastructure projects. These practices should involve interdisciplinary efforts representing typical proponents, participants and stakeholders.
- Buildings are subject to many regulations administered by many different authorities aimed at protecting the public health, safety, welfare and environmental quality. Attempts to improve sustainability in buildings often fall under the jurisdiction of several governmental entities, such as the building department, public health agency, utility commission and architectural review board. While validation and approval of these innovations are necessary, such projects often encounter prohibitively expensive delays in obtaining regulatory permits. Governance-focused organizations should develop and demonstrate model processes for improving the efficiency of the regulatory process for important classes of building and infrastructure projects. Where needed, the statutory authorities of regulatory agencies should be modified to enable participation in a streamlined process.

Education and Training

Buildings have a complex life cycle, from concept, design and construction to commissioning, occupancy, modification/renovation and deconstruction. Education and training within the building professions must reflect this complexity and the specific skill needs at each point in the building's life cycle. These life-cycle considerations include efficient use of energy and water through reduced waste and demand management, improved occupant comfort and health, and upgrading the human-building system interface. In each time period within the building's life cycle, particular segments of the building community must be engaged and have the requisite knowledge to adequately address the unique needs within that time period. (See Figure 2 for an example.)

Essential audiences for education and training include all people who impact the performance of the building during its life cycle. Such audiences include:

- The Owner,
- Commissioning Agent/Authority,
- General Contractor,
- Engineer,
- Architect,
- Installation Contractor,
- Service Contractor,
- Facilities Manager,
- Operations and Management,
- Users/Occupants,
- Support Contractors (including support contractors not directly related to systems maintenance, i.e., the cleaning service, replenishment services, etc.), and
- Inspectors and Enforcement Personnel.

Structure Life Cycle	Concept	Design	Construction	Commissioning	Occupancy	Modification of Use / System Upgrade	Deconstruction
PEOPLE INVOLVED							
Owner	X	X	X	X	X	X	X
Commissioning Agent	X	X	X	X	X	X	
General Contractor	X	X	X			X	X
Engineer		X		X	X	X	
Architect		X				X	
Installation Contractor	D	D	X		X		
Service Contractor				X	X		
Facilities Manager				X	X		
Operations & Maintenance				X	X		
User/Occupants					X		
Support Contractors				X	X		
Inspectors - Enforcement		X	X	X	X	X	X

D - Design/Build Scenario

Figure 2 – People Involved in the Structure Life Cycle

Requirements may be different across residential, commercial, industrial and specialized buildings (specialized buildings include hospitals, laboratories, schools), so training should specifically relate to the building types for which personnel are responsible.

While it is essential that people who enter a particular career get education and training initially, training must continue throughout their careers. Best practices go stale, equipment and processes change, and new regulatory requirements go into effect. To assure professionals seek out and retain it once received, such education and training must be dynamic and engaging.

Communication across all disciplines engaged in the building process is critical to achieving high-performance requirements. However, changes in current communication channels are needed because buildings are becoming more automated, and the technologies and management processes to operate, maintain and minimize energy consumption are requiring increasing levels of integration.

Incentives are needed to motivate businesses and organizations to see beyond short-term, financially driven bottom lines and look to the future in preparing the U.S. workforce for the challenges, complexities, technologies and competitive demands of the global economy. Without an increased emphasis on education and training of the workforce, industry may not be ready for the economy of tomorrow. Industry is committed, but without incentives, it will be difficult to move forward with decisive and accelerated programs.

Education and training incentive programs should be available to cover all levels and types of businesses and organizations, and should encompass all construction, maintenance and operational core competencies in the three primary building sectors: residential, commercial and industrial. Incentive programs should extend from apprenticeship programs and specific task training to professional development. Programs should include continuing education to achieve or maintain levels of recognized third-party certification or similar levels of accreditation. They also should be available to all Americans, especially veterans and minorities.

Introduction

Buildings are complex systems embodying ideas, experiences, technologies and practices brought together by different disciplines, users and needs. In forming the National Institute of Building Sciences and its Consultative Council in 1974, the U.S. Congress recognized this complexity and the importance of bringing these diverse actors together to improve building sciences and policy.

Early in 2010, the Institute re-formed the Consultative Council to represent leading organizations within the building community. The Council was charged with identifying the high-level issues currently impacting the building community and offering findings and recommendations related to these issues.

The issues identified for 2010 include:

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

The Consultative Council established topical committees consisting of representatives from many organizations. Each committee prepared a report. With the exception of the Existing Buildings report (which will be produced at a later date), in-depth findings and recommendations from these reports appear below.

Defining High Performance and Common Metrics

The Defining High Performance and Common Metrics Topical Committee offers the following framework driven by common metrics and ends with the intent to positively measure and affect high performance.

The Consultative Council provided the following charge to the Defining High-Performance and Common Metrics Topical Committee:

Before owners and design teams can produce high-performance buildings, there must be agreement on what attributes are included in such performance and how they are to be measured.[1] *Fundamental to the development of high-performance buildings is agreement on a common definition that structures can be measured against. This topical committee will examine the steps necessary to define high performance and make recommendations on how such a definition and its supporting metrics can be developed.*

Agreement on What Attributes Are Included (relevant to high performance)

The Energy Independence and Security Act (EISA) of 2007 (Title IV, Energy Savings in Buildings and Industry, Section 401, Definitions), defines a "high performance building" as:
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.

The list of attributes may be subject to enhancement, but the Committee sees no compelling reason to change these at this time. Each of these attributes needs a definition along with a list of sub-attributes and components. Standards Development Organizations (SDOs), as identified below, should collaborate to establish the hierarchy structure and definitions for attributes, sub-attributes and components.

How the Attributes Are to be Measured (and expressed)

The Committee recommends that the Institute's High Performance Building Council establish a hierarchical structure starting with whole-building high performance, then drilling down (vertically) from the whole building to systems, sub-systems, components and materials. Likewise, a drilling across (horizontally) also will address each performance attribute. The intersection of each system and attribute would create a "destination" in defining relative performance in terms of the metric used and how it is measured and expressed. Therefore, two tracks are identified: the first (the systems track) would follow the Uniformat[2] hierarchy starting with site, shell, interiors, services and then lower tiers, including things like lighting and carpet.

The second track (the attribute track) would address the attributes defined in EISA. Within those attributes would be sub-attributes such as blast resistance, air quality and noise.

The systems track would be integrated with the attribute track such that the intersections would identify a possible measurement issue (i.e. first cost of carpet + carpet life/durability and replacement cost). Each intersection could be measured and expressed in two ways:

1. Cost and Benefit: Wherever possible, the capital investment cost, life-cycle cost and return on investment should be determined. Where life-cycle cost and return on investment are not possible, other qualitative benefits should be defined.
2. High Performance (HP) Classification: Subject to the work of the SDOs, the Committee suggests classifications for each attribute: (1) Fails HP: Fails to satisfy the High Performance Standard, (2) Meets HP: Falls within the Mean Variance for the High Performance Standard; and (3) Exceeds HP: Exceeds the Mean Variance for the High Performance Standard. Given the availability of appropriate standards, the performances of lower tier intersection assessments are aggregated to assemble a whole-building performance assessment.[3]

Critical components and sub-components may include cost and classification measures, but ultimately will be evaluated according to units of measure relating to energy, carbon, light, sound, force and load as determined by the SDOs.

It is important to note that one project's high-performance end goals and benchmark(s) will be different from other projects. Therefore, any given project will pursue high performance according to that project's particular benchmark(s) and then measure accordingly.

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[1] The Defining High-Performance and Common Metrics Topical Committee suggested restating the charge: Before owners, developers, occupants and facility managers can demand, and building teams produce, high-performance buildings there must be agreement on what attributes are included in such performance and how they are to be measured and expressed.

[2] As a particular project advances in its design, and as materials and systems are selected, the Uniformat codes will map to Construction Specification Institute (CSI) codes for project documentation and production.

[3] In considering the issue of high performance classification, two distinct items must be considered. The performance of many attributes can be readily assessed through distinct testing and evaluation (e.g. testing windows for thermal performance or air leakage). When measuring and expressing the degree to which a building may be high performance, these attributes can and should be included. Other attributes associated with buildings only can be assessed on a subjective basis because standards or the possibility of standards do not exist (e.g. quality of infiltration control, manner in which different materials are assembled). These should be considered in determining the degree to which a building may be high performance, noting that measuring performance at broader levels (e.g. whole building as opposed to individual components and systems) will eliminate such concerns.

Agreement on Common Definitions to Measure Structures Against

A series of definitions must be established to guide the measurement[4] and expression of actual performance measured against the standard. These definitions are:

- **Baseline**–a measure of standard performance for specific whole building and major systems when the measure is cost, or for a particular unit of measure for critical components. Standard performance and productivity relates to the market or industry average, based on conventional or customary means and methods at a particular baseline year.[5]
- **Ends Goal**–a measure of "high performance" at some future attainable date. This goal will be valid if it is published by a valid SDO.
- **Benchmark**–a measure of in-progress high performance according to a viably optimized state. In many cases, this measure is derived as an interpolation between the baseline and an ends goal.
- **Target Value**–a measure set by the building production team and/or building owner above or below the benchmark value. This is based on the combination of things, including the high-performance processes and solutions the owner/developer and design/production team have at their disposal.
- **Measured Results**–a measure of actual results from the completed and operating building.
- **Performance Results Index (PRI)**–a ratio of component measures, where the numerator is the measured result and the denominator is the standard that it is measured against.

A high-performance building exists once the measured results meet or improve upon the *benchmark* measures, or when the Baseline PRI is 1.0 or less.[6]

Therefore, we propose the addition to the above EISA definition of a high-performance building: *"A building will have achieved optimization on a life-cycle basis when its measured results meet or improve upon legitimate benchmark standards that define high performance."*

Steps Necessary to Define High Performance

There are two major steps toward defining high performance. In order for standards and metrics to be meaningful to anyone, they must be capable of being uniformly measured, expressed and understood by all users. Given the fragmentation and diversity of the construction industry, the first step must be the establishment of consensus standards and measures for performance. The second step is the implementation of standards at the project-specific level that the actual results can be measured against.

Consensus Standards

For any particular attribute (energy, environment, safety, security, etc.) to be legitimately included within the high-performance definition, Standards Development Organizations (SDO) must develop the standards that such attributes can be measured against. Where practical, the Committee encourages SDOs to discuss the establishment and use of common metrics through Attribute Groups.

To ensure standards uniformity and aggregated building optimization, the Institute's High Performance Building Council should convene a Standards Integration Group (SIG) to coordinate the work of attribute-focused Standards Development Organizations (SDOs). The SIG also can lead the necessary gap analysis to identify where additional standards development is needed. When owners or developers chose to pursue a high-performance building, they should use an SIG family of SDO standards. Alternatively, the owners or developers could establish their own high-performance goals and implementation system, but then use the SIG/SDO standards and measures for comparative analysis and/or validation.

In developing the standards included in high performance, a qualifying SDO should engage a representative cross section of key stakeholders, including[7]:

- **Owners**–General Services Administration (GSA), U.S. Army Corp of Engineers, Building Owners and Managers Association (BOMA), Construction Users Roundtable, and developers and large owners.
  - **Building users**–facility manager organizations (International Facility Management Association (IFMA), APPA).
- **Building producers**–architects [American Institute of Architects (AIA)], engineers [National Society of Professional Engineers; American Society of Civil Engineers (ASCE); American Society of Mechanical Engineers (ASME); American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE)], constructors [(Associated General Contractors of America (AGC), Associated Builders and Contractors (ABC)] and manufacturers.
- **Standards, codes, measures and industry improvement organizations**–ASHRAE, ASTM International, National Institute

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[4] Note that each standard of measure will be normalized according to market location, building activity, date, climate, occupancy and other key building and use characteristics.

[5] The Committee suggests that a uniform date (somewhere between 2000 and 2008 occupancy) be established as the baseline for conventional (non-optimized) industry performance and productivity.

[6] EXAMPLE: For a particular project, the On-Site Energy Consumption (critical component) in kBtu/SF was: Baseline (120), End Goal [25% of Baseline in 2030] (30), Benchmark [Placed into operation in 2012] (100), Target Value (95), and Measured Result (90).

Baseline PRI – .75 (90/120)	End Goal PRI – 3.0 (90/30)
Benchmark PRI – .90 (90/100)	Target Value PRI – .95 (90/95)

In this case, the Benchmark PRI is less than 1.0, and so the On-Site Energy Consumption for this project would be deemed to have achieved *high performance.*

[7] Identified organizations are illustrative and do not necessarily encompass all the necessary interests and stakeholders.

of Standards and Technology (NIST), U.S. Green Building Council (USGBC), NIBS, Lean Construction Institute (LCI), American National Standards Institute (ANSI), Illuminating Engineering Society (IES), International Association of Plumbing and Mechanical Officials (IAPMO), National Fire Protection Association (NFPA), International Code Council (ICC).

- **Government.**
  - **Attribute agencies**–Department of Energy (DOE) for Energy, Environmental Protection Agency (EPA) for Environmental, Department of Homeland Security (DHS) for Security.
  - **Code enforcement agencies.**

The standards that these SDOs establish may be based on existing standards or start from existing research and related information and data sources. Baseline standards can be derived from survey data already compiled from well-known sources, such as the Commercial Buildings Energy Consumption Survey (CBECS) for energy. For Benchmark standards, the EPA Energy Star™ program, and Net Zero Energy Challenge programs could be candidates for identifying high-performance classifications. These could be further developed and submitted to the Energy SDO Attribute Group, which would assess and most likely validate and affirm that program as defining the high-performance energy attribute. Similarly, green building rating systems may be submitted to the Environmental SDO Attribute Group.

Project Implementation

As SDOs publish the standards and processes for achieving high performance[8], owners and building teams will be equipped to implement a high-performance building system. Once its measures of performance and cost-benefit have been validated empirically, an owner or developer may claim achievement of a high-performance building. To validate and legitimize claims of high performance, a recognized building system should be successfully applied by the entire building team. A high-performance building system for key attributes and the whole-building exists when:

- The Consensus Baseline Standards have been established and the Applied Project Baseline Standards have been computed for the project.
- The Consensus End Goal and/or Benchmark Standards have been established and the Applied Benchmark Standards have been computed.
- A Performance Assurance System and Target Values have been established, as informed by the Benchmark Standards.
- The project is completed, placed into operation, and its Measured Results meet or improve upon the Applied Benchmark Standards.

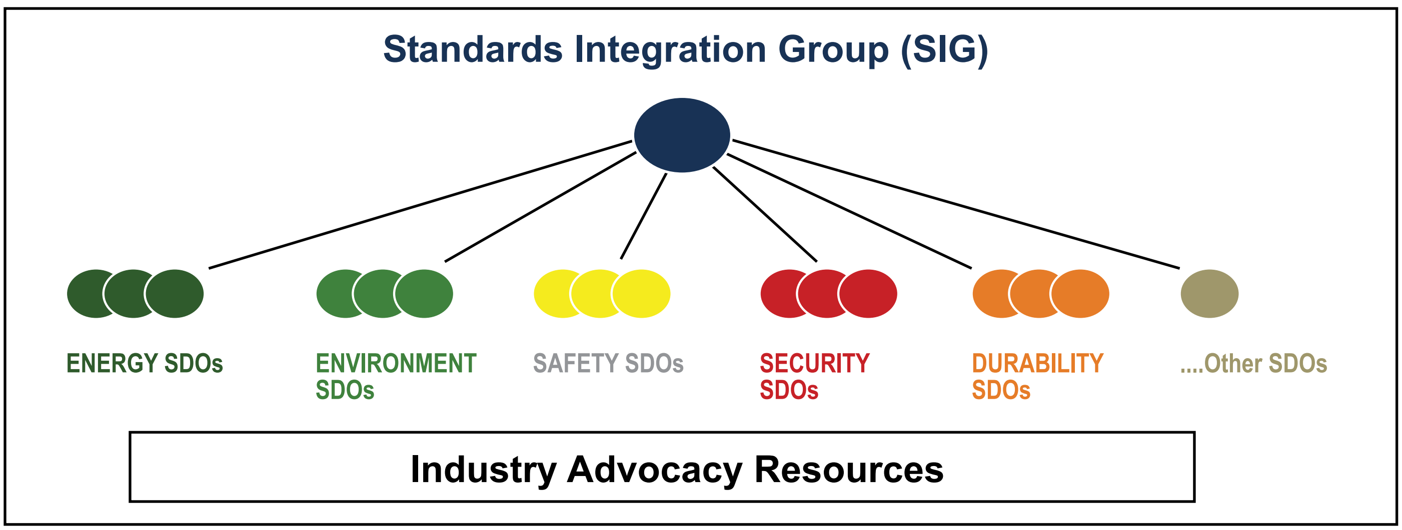

Figure 1—Relationship of the SIG to Standards Development Organizations (SDOs)

[8] After publication, designers and others can reference those standards in the design and construction of high-performance buildings. However, systems, components and products satisfying those standards may not be available. There can be a time lag between issuance of a standard and the availability of real data upon which to determine performance. This is much more acute at the component and product level than at the whole building level where performance can be measured on-site. However, in order to design a high-performance building, designers and specifiers, as well as contractors, need to have data on individual "pieces" of the building in order to make informed design and construction decisions.

Recommendations on How Such a Definition and its Supporting Metrics Can Be Developed

In order to accomplish these recommendations, the Consultative Council proposes a four-step process:

1. The Institute's High Performance Building Council would form a Leadership Council representing all stakeholders (owners; building producers; standards, measures and industry improvement organizations; and government agencies). This Leadership Council would:
   a. Develop and publish a consensus document on how to define high-performance and develop the supporting metrics.
   b. Prepare a draft roadmap for organizing and funding the development of the various SDO Attribute Groups.
2. The Leadership Council would convene a brainstorming session with a broad base of stakeholder volunteers. The agenda may include:
   a. Presentation of the Leadership Council's preliminary results,
   b. Breakout brainstorming sessions organized by high performance attribute,
   c. Breakout sessions to analyze and produce draft recommendations relating to the specific attribute(s):
      i. Definitions: attributes, sub-attributes, components,
      ii. Metrics: units of measure, variables impacting performance of critical components, and
      iii. Recommendations on how to establish each of the following standards for critical components, together with viable starting point standards (where possible): (1) Baseline, (2) End Goals and (3) Benchmark.
   d. Reports and recommendations by selected representatives from each breakout session.
3. The Leadership Council would compile the brainstorming results, produce a roadmap for implementation and promote it throughout the marketplace and to policy making groups. The outcome should address the formation of the various SDO Attribute Groups and SIG, as well as identification of needed research and development projects.
4. The building community would then implement the roadmap.

Energy and Water Efficiency

The Consultative Council established the following charge for the Energy and Water Efficiency Topical Committee:
Energy and water use within buildings have been identified as areas where concerted efforts could result in greater efficiency and less waste. This topical committee will identify the needs to achieve efficient energy and water use and offer recommendations to achieve these efficiencies.

This chapter addresses the primary aspects of energy and water efficiency in commercial, institutional and residential building structures. This includes the related infrastructure that supplies energy and water to buildings and removes wastewater from buildings, as well as the equipment and systems that provide, treat or otherwise reclaim water or treat waste on site and systems that create energy or reclaim waste energy on site. While industrial processes are not specifically addressed, such processes do offer a large opportunity for energy and water savings. Nevertheless, many of the energy and water savings opportunities included here can be applied to industrial buildings.

Numerous efforts are underway, both in the United States and internationally, to develop comprehensive, performance-based energy metrics. Achieving net-zero energy performing buildings will require a greater understanding of the cost/benefit variables, thus allowing the building community to make informed decisions regarding which technologies to prioritize, develop and implement. The transition away from prescriptive-based specifications towards performance-based metrics also should include goals for the incorporation of systems that allow real-time user monitoring of building energy and water use to facilitate ongoing performance. Such systems will provide a built-in feedback system for continuously improving actual performance and informing the underlying metrics.

However, the process of moving towards performance-based measurements must be achieved incrementally. Such incremental progress depends on development of specific measurement standards that more accurately estimate and predict the performance of energy and water saving technologies.

The development of these performance-based efficiency metrics will lead to knowledge about true current energy efficiency levels in the United States. This information also will be important in establishing a realistic energy efficiency baseline that we can more accurately measure our future efficiency initiatives against.

Improved use and enforcement of construction codes plays a vital role in improving water and energy efficiency in the nation's buildings. The code development community is actively working with construction industry stakeholders to develop energy and water efficiency stretch or above baseline codes. The federal government should enact legislation that provides incentives towards the adoption and enforcement of these codes at the municipal, county and state levels.

It is well documented that employing currently available technologies can reduce energy consumption in buildings by an estimated 30 to 50 percent when compared to traditional building design and construction practices.[9] Intelligently integrating these within a building can result in even higher levels of efficiency. However, such efforts may not guarantee actual savings because traditional building design baseline metrics are not well understood nor have they achieved consensus among construction industry experts.

The Water-Energy Nexus

The "water-energy nexus" indicates the relationship between water and energy due to how society uses water. Thermoelectric power generation, for example, accounts for 48% of our nation's total water withdrawals, according to the U.S. Geological Survey. Energy is consumed in the conveyance of water from the source to the point of treatment, the treatment process itself, the distribution of water to the point of use, the heating of water during use, and the wastewater treatment process. Of the energy consumed in the State of California, 19% is consumed in the movement, storage, treatment and heating of water. Water heating alone accounts for an average of 13% of the total energy consumed in U.S. residential buildings.[10] These values reveal the huge potential to achieve significant energy savings through improved water efficiency measures.

Designers of plumbing distribution systems in buildings need to focus on water and energy efficiency in the residential, commercial and industrial sectors. The distance between the sources of hot water, generally the water heater, and the various points of use within a building should be minimized in the design phase. Where this is not possible, the use of on-demand or timer-controlled hot water circulation systems and increased use of pipe insulation materials on hot water lines will greatly improve both water and energy efficiency levels within the building.

In residential buildings, water heating comprises, by far, the largest share of water-related carbon emissions. Expanded use of geothermal systems to temper water and solar thermal water heating systems to augment traditional gas and electric water heating systems, especially in the Southern regions of the country, have the potential to significantly reduce energy loads related to water heating.

Infrastructure Needs

Our energy and water infrastructure is an aging workhorse that has served us well, but has become fragile as the demands placed upon it increase. These increasing demands include expansion for new uses, expansion to service new energy sources and the need to reduce greenhouse gas emissions.

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[9] A National Green Building Research Agenda – USGBC (2007).
[10] U.S. EPA (2007).

These expansions have forced utilities to invest more in generation than in delivery. Infrastructure expansion coupled with the need for an expanded transmission system to serve alternative energy generation requirements in the Energy Policy Act of 1992 and its amendments, has stressed the grid extensively. Electricity demand has increased by about 25 percent since 1990 while construction of transmission facilities decreased by about 30 percent. Financial investment in infrastructure has increased, but remains well below the levels needed to maintain and keep pace with our aging and growing system.[11]

At the building level, efficiency and power use management can play a key role in lessening demand on the electrical grid. Compact fluorescent lights and variable frequency drive motors are just two technologies readily available for use in construction. Both devices can deliver the same amount of light or power using a fraction of the energy of their predecessors. Even with these technologies entering the mainstream, the 2006 total primary energy annual savings was only 2.4 percent system wide.[12]

Demand response and load management programs showed similar savings over the same time period.[13] A "smart" grid system gives energy producers and consumers greater control over the distribution and use of energy. When consumers have information about the impact of their choices on energy costs, they can choose to either not run their air conditioning or postpone doing the laundry in order to reduce the load on the generation equipment and make demand more even and reduce standby losses. To realize these savings, smart devices are needed to communicate between the utility and appliances. Consumer can enter the parameters that fit their lifestyle and the heating, ventilation and air-conditioning (HVAC) system; kitchen appliances and laundry facilities would follow such parameters.

For years, businesses and factories have had systems that would reduce the peak demand load due to starting large motors used for production or HVAC equipment. These systems have advanced in complexity and efficiency. Electrical generation must respond to ever-changing demands that are difficult to control and challenging to react to. Generation and line losses account for nearly two thirds of all electricity produced.[14] The faster utilities discover defects in a transmission system, the sooner the power can be rerouted, thus minimizing further damage and reducing the cost and extent of the repair.

The nation's water infrastructure also is under stress—it too is in need of repair and expansion. Aging supply lines need to be replaced to ensure proper delivery of both potable water and water for fire protection. Ten percent of the nation's water distribution system is over 80 years old and 30 percent is between 40 and 80 years old. Nearly 2 trillion gallons of water is lost annually through leaks in water pipes. This annual loss equates to an estimated $1 to $2 billion.

Aside from the cost implications, it is estimated that a five percent reduction in water distribution system leakage would save 313 million kWh of electricity and avoid approximately 225,000 metric tons of CO_2 emissions annually.[15]

Older water distribution systems also may contain unsafe elements and chemicals that leach into drinking water. A dangerous spike in lead levels in Washington, D.C. recently occurred due to a change in water treatment practices that changed water chemistry. It is critical that utilities and cities purge older water distribution systems of lead components and other materials now known to cause illness and disease.

Efficiency and conservation methods within buildings should continue to be employed in construction designs. However, the backbone of the nation's electrical and water delivery systems also needs significant repair and improvement. With nearly 60 percent of electricity and 20 percent of water being lost before it ever enters service, significant savings will not be realized until the delivery systems become more efficient and waste is reduced.

The American Society of Civil Engineers, in a 2009 report, gave the U.S. drinking water and wastewater system a D-. The electrical infrastructure faired only slightly better by earning a D+. Both systems require significant investments in technology and distribution systems simply to maintain their current service, let alone to keep up with growing demands.

Energy Efficiency

As noted above, a uniform and accurate baseline is needed to measure advances in energy efficiency and thus foster an environment supportive of the development, application and use of new technologies and practices. These baselines can include data associated with real building performance such as utility consumption. However, it is challenging to compare such data across buildings without including measurements of the factors that impact energy use such as climate, occupancy rates, operations and maintenance (O&M) practices and the indoor environment (temperature, humidity, lighting, ventilation, etc.). Studies focusing on the performance of a particular technology allow for strict control of factors that impact performance but do not necessarily address how various technologies and design practices interact with one another and are assembled together to create a real building. Data is needed on both the performance of individual technologies and design practices as well as the performance of buildings as an assembly of technologies and integrated systems within the building's design.

Energy use data for individual technologies and whole buildings, whether real utility data or results from energy performance simulations, can inform design and construction decisions on

[11] North American Electric Reliability Corp. 2008 Long term reliability assessment 2008- 2017.
[12] Electricity Advisory Committee, Jan 2009.
[13] American Council for an Energy Efficient Economy (ACEEE) Report on Energy Efficiency Program Savings.
[14] Lawrence Livermore National Laboratory.
[15] The Carbon Footprint of Water, Bevan Griffiths-Sattenspiel and Wendy Wilson (2009).

both new and existing buildings. As noted above, those decisions can be affected by codes and standards. In one respect, codes and standards provide health and life safety criteria to ensure the acceptability of technology and building design. In this situation, they can be "show stoppers" that need to be addressed early on in the development of the technology or design. In another respect, they can drive energy efficiency progress by establishing minimum performance requirements that must be satisfied. If codes and standards are only voluntary in a jurisdiction or have not been adopted, they can be used as a measurement device to facilitate comparison.

Currently, the majority of energy codes and standards are prescriptive and therefore do not establish a common basis for building performance. Instead, they prescribe specific performance levels for many components or subsystems in a building. This provides a disincentive for the design team to consider the whole building. Although many prescriptive codes allow compliance on a performance equivalency basis, such compliance is only considered in the context of how the proposed building compares to a clone of itself that is compliant with the prescriptive code. Since prescriptive provisions cannot and do not regulate issues such as building geometry or fenestration area, a number of building designs can provide the same functionalities (e.g. floor area, office space, lighting, HVAC, etc.) while meeting minimum codes but have widely different energy use.

The standards development community is well aware of the barrier posed to sustainable development by a business-as-usual approach to standards. The building community should work with codes and standards developers to move toward performance or outcome-based criteria that address these concerns. Code enforcement officials will require training on any new criteria and methods.

As the nation strives for increased building energy efficiency and drives development of new technology applications and design concepts, the building community will benefit from assessments of technology performance. As technologies are assembled into new building designs or renovations to existing buildings, a better baseline of actual building performance is needed to measure progress. More importantly, the application and use of prescriptive criteria must be eliminated in favor of stated performance goals or expected outcomes. After setting those goals or outcomes, prescriptive guidance to achieve them can be developed.

Progress on energy efficiency currently is measured as some percentage above a baseline. Where there is a means to accurately and uniformly measure and express performance (for example, HVAC equipment efficiency or light output as a function of wattage input) percent savings can readily be determined. However, to address a whole building, the building community must move from a prescriptive basis to one based on total building performance, both simulated and real, that goes beyond the design and construction phase to include commissioning and continued operation of the building throughout its life.

Performance can be measured (first through simulation and then through actual consumption) and compared against a statistically valid baseline number to determine how much better the building is than its counterparts. Consumption also can be compared against a forward looking "gold standard" like net-zero energy use. The former comparative basis presents a continuing dilemma in establishing a singular and defensible baseline, which is not fostered by prescriptive energy codes and standards. The latter comparative baseline eliminates such issues and allows all involved to see the goal and work together to apply any and all technology and design approaches to get as close to zero as possible. This approach not only becomes a catalyst for application and use of new technology, but presents a compelling reason for integrated design and the use of new and innovative approaches to design, construct and deliver buildings.

The actual energy used in buildings and the opportunities to reduce future energy use depend on a variety of different choices in the design and operation of buildings. Experts classify these choices as either a process or a technology. The following section outlines some of the decisions that should be part of design considerations. While this report is not advocating specific technology use in individual buildings, the building industry, researchers, and government should examine expanded research and development and utilization of these technologies.

Processes

- **Site selection**–Site selection is the determination of the place (not position) of a structure. Planners should be encouraged to use previously disturbed land, favoring brownfields, if possible. The owner and design team should give consideration to how site selection can help facilitate building use. For example, if sound is an issue, building next to an airport or an interstate highway might not be a logical first choice. Access to transportation, infrastructure, renewable energy sources, and stormwater management areas also are important. Societal issues should be considered including preservation of farmland, critical habitats, wetlands and watersheds.
- **Energy audits**–An energy audit identifies how much energy a building uses and the purposes for which it is used, and identifies efficiency and cost-reduction opportunities. The level of audit should be commensurate with the levels of information needed. Energy auditors require specific skills and certifications to deliver the greatest value.
- **Training**–Training on systems, equipment, operations, maintenance procedures and the interrelationship of building systems is critical to the efficiency of a building. The flip of one switch, the turn of a single dial, no matter how well intended, may defeat any cutting-edge high-performance system. Training develops awareness. If people understand how their actions affect the system as a whole, they are less likely to do it out of "innocent ignorance." Training should be provided in a manner and at a depth appropriate to the person's responsibilities. Such training should include facilities personnel, building occupants, external contractors and corporate staff. Training should be recurring and include new occupants, contractors and O&M staff. Code enforcement personnel require regular training to assure familiarity with the latest codes, techniques, and technologies.

- **Operations and maintenance**–O&M focuses on managing the processes of producing and distributing products and services. This includes the facilities, production equipment and processes, with particular emphasis on efficiency and effectiveness. The design team must consider the O&M of facilities in the design process, including the funding of such projects. Building owners and policymakers must review accounting practices to include a focus on life-cycle costs vs. first cost plus O&M costs. O&M personnel must receive training on specific equipment and the building as a system.
- **Commissioning**–Commissioning, a quality-focused process for enhancing project delivery, concentrates on verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated and maintained to meet the Owner's Project Requirements. Commissioning for Existing Buildings ('retro-commissioning') is a systematic process for investigating, analyzing and optimizing the performance of building systems by improving their operation and maintenance to ensure their continued efficient performance over time. This process helps make the building systems perform interactively to meet the owner's current facility requirements.
- **Market incentives**–Financial incentives for energy efficiency may come in the form of tax incentives, grants and rebates, and loan programs. These incentives are among the most common ways that states promote energy efficiency. The Database of State Incentives for Renewables and Efficiency (DSIRE) (www.dsireusa.org) provides information on the types of incentives available in communities across the country. The first costs for energy efficient buildings or appliances are sometimes greater than their non-efficient equivalents. Although purchasers will benefit over a period of several years due to the energy savings, the higher up-front costs of energy efficient equipment can make such a purchase unattractive to many consumers. Loans covering these upfront costs and allowing people to pay back principal and interest from the energy savings, rebates that cover incremental costs and tax incentives can overcome this first-cost hurdle. Since energy bills are lower for energy efficient buildings, net operating costs (mortgage plus utility bills) for such buildings are usually lower, making energy efficiency a smart economic decision if financing is available. Jurisdictions should explore innovative approaches to encourage energy efficiency including one-bill programs, tariff-based financing and property tax-based financing. Governments also should incentivize energy efficiency workforce development.
- **Building occupants**–Building occupants can have an impact on the true energy efficient operation of a building. Building owners should provide training to promote understanding of what occupants can control, how systems work and their complexities, and recognition of when things are wrong. Indoor air quality and building occupant comfort may have a tremendous impact on productivity, health, and well-being, as well as the cost of ownership.
- **Building information models (BIM) and integrated design**–Paired with BIM, integrated building design—where disciplines involved in the building design and construction (including the operations and maintenance staff and the building occupants) work as a team from the beginning—can help realize more energy efficiency potential. Going forward, encouraging this type of collaboration, and urging codes and standards to further take into account advances in, and the impact of, building information technologies will help decrease building energy use.

Technologies

- **Renewable energy**–Once design teams, O&M staff, and building owners use technologies and processes to reduce the energy required to operate a building, renewable and low-carbon energy sources should provide the remaining energy needed. Such renewable energy can be provided through the existing infrastructure or generated on-site. Important technologies include photovoltaic, solar thermal, geothermal and wind systems.
- **Heat mass and energy storage**–Thermal energy storage systems reduce energy consumption during peak demand periods by shifting energy consumption to nighttime. Operation of the thermal energy storage compressor at night produces cooling energy that is stored as a cooled fluid or ice in tanks. During peak cooling hours, the thermal storage is used for cooling to prevent the need for chiller operation. The building structure itself also can be used to regulate internal temperatures.
- **Metering and real time feedback**–Energy monitoring is the consistent collection of data about energy use in buildings. This data is measured against benchmarks for building management, maintenance and efficiency optimization, and can be used to effect behavioral change to mitigate greenhouse gas emissions and reduce energy costs. The monitored data can be rendered automatically for reporting, measurement and verification, specifically to assist facility managers and building engineers in determining critical decisions to proactively manage their facilities.
- **Passive ventilation/shading/heating**–Passive ventilation uses the building layout, fabric and form to provide natural ventilation to a conditioned space using non-mechanical forms of heat transfer and air movement.
- **Building orientation**–How a building is positioned at a particular location can have significant impact on the building's performance related to daylighting and solar heat gain. Building occupants with access to outside views have been reported to have an increased sense of well-being, leading to higher productivity and increased job satisfaction. Important considerations for providing views include building orientation, window size and spacing, glass selection and locations of interior walls.
- **Green roofs and cool roofs**–Green roofs and cool roofs are designed to reduce the heat island effect and reduce the impact of outside forces on the building's heating and cooling needs. Green roofs also can serve as a means for mitigating stormwater runoff. When designing green roofs, select native or adapted plant species to reduce or eliminate the need for

irrigation. Building operators should obtain the necessary information to maintain any vegetated roofing system. If necessary, green roofs should be irrigated with non-potable water to the greatest extent possible.

- **Lower performing systems**–As a legacy of older technologies, an attempt to limit first costs and manufacturer protectionism, some systems and equipment types remain acceptable under energy codes despite lower performance levels relative to other systems and equipment that perform the same function. To reduce energy use, these poorer performing systems must be eliminated from the code. Such a requirement will encourage innovation and allow energy efficient technologies to compete on an even playing field. Further, this will provide increased focus on the use of life-cycle costing in decision making.
- **Building envelope**–The building envelope must be optimized to ensure maximized energy performance and indoor environmental quality. Attributes to be considered include air sealing, insulation, infiltration, durability and fenestration.
- **Mechanical systems (HVAC & Domestic Hot Water and other mechanical processes)**–Maintaining acceptable thermal comfort for building occupants should be considered a necessity for any building or space with regular occupancy. Studies have shown that comfortable people are more productive and generally happier. In a work environment, increased productivity can reduce the amount of time and energy required for an individual task. Over the course of a year, that can translate to fewer hours running equipment such as computers or task lighting, resulting in additional energy savings. Thermal comfort can be controlled through both active (HVAC) and passive systems (natural ventilation). Other mechanical systems include domestic hot and chilled water, steam, and similar systems or processes. Attributes to be included, among others, are mechanical insulation systems, controls, and leakage detection and repair.
- **Plug load controls**–Plug load controls manage electrical demand through plugs to reduce waste (also known as parasitic or vampire loads) during periods of non-use. Plug loads can be divided into several categories including:
  - **Design**–Specially marked outlets that power down during building non-use hours in addition to typical continuous service outlets.
  - **Uncontrolled**–Common outlets where designers or facility managers have no control. (Example: leased space in a commercial building.)
  - **Unforeseen**–Reconfiguration or change in use of portions of a building. (Example: a storage area becomes a cubicle office area with desk lamps, PCs, printers, etc.)
- **Lighting**–Government and researchers are making significant investments in the development of solid-state lighting (LEDs) as a method for reducing the energy needs associated with lighting. Use of daylighting and task lighting, and examination of lighting quality also should be explored.
- **Processes**–Process loads represent the energy used in business related activities—for example, cooking equipment in a restaurant, production equipment in a manufacturing facility and diagnostic machines in a hospital. As energy use of building systems becomes smaller, process loads can become a greater proportion of a building's energy use. These individual processes will require examination to achieve overall energy goals. Practices like mechanical insulation and energy recovery should be considered and can inform discussions moving forward.

Water Efficiency

The United States has a profound need to improve the indoor and outdoor use of water in buildings. The EPA reports that 36 states expect to experience local, regional or statewide water shortages by 2013.[16] However, policymakers continue to ignore the need to develop and implement a comprehensive national water strategy. Without addressing this need, the ongoing battle between states and among agriculture, commercial, industrial and residential users of water resources will continue. Without a holistic view of our nation's water needs, policymakers at all levels of government will have difficulty making appropriate and responsive decisions. The Council recommends that the federal government prioritize, coordinate and support development of a national water strategy prior to the emergence of inevitable water shortages.

Research Needs

Before additional improvements in indoor water efficiency can be used confidently, research is required to better understand the implications of reduced flows in building supply and drainage pipes. For example, as a result of the Energy Policy Act of 1992 (EPAct1992), toilet consumption was reduced from 3.5 gallons per flush (gpf) to 1.6 gpf. Further reductions in toilet consumption of another 20 percent to 1.28 gpf currently are underway. Experts worry that building drains and in sanitary sewage infrastructure will not adequately transport solid waste, resulting in blockages. Several plumbing and water efficiency related associations formed a coalition called the Plumbing Efficiency Research Coalition (PERC).[17] In addition to drain line transport, PERC has identified several research programs of importance to the plumbing and water efficiency industries. Unfortunately, funding for these research programs has proven difficult to secure. The Committee encourages the federal government to establish a national plumbing research facility charged with working with the private sector to support plumbing research programs fostering increased levels of water efficiency while ensuring plumbing systems remain safe and continue to perform.

[16] U.S. EPA, Water Supply and Use in the United States (2008).

[17] PERC is comprised of the 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).

Indoor Water Efficiency

In recent years, improving indoor water efficiency has seen considerable success. Both legislative mandates, such as the EPAct1992 requirements, and voluntary incentive programs, such as the EnergyStar™ and WaterSense™ labeling programs, have fostered market transitions toward use of increasingly efficient plumbing fixtures and appliances. The federal government should increase funding for these programs, especially for the highly effective EPA WaterSense™ program.

In residential buildings, continued improvement in water efficiency levels will be increasingly important. Americans use more water in the home than in any other country in the world, except Canada. Going forward, the U.S. Census Bureau expects the greatest percentage of regional population growth in areas of the country where water resources already are stressed.

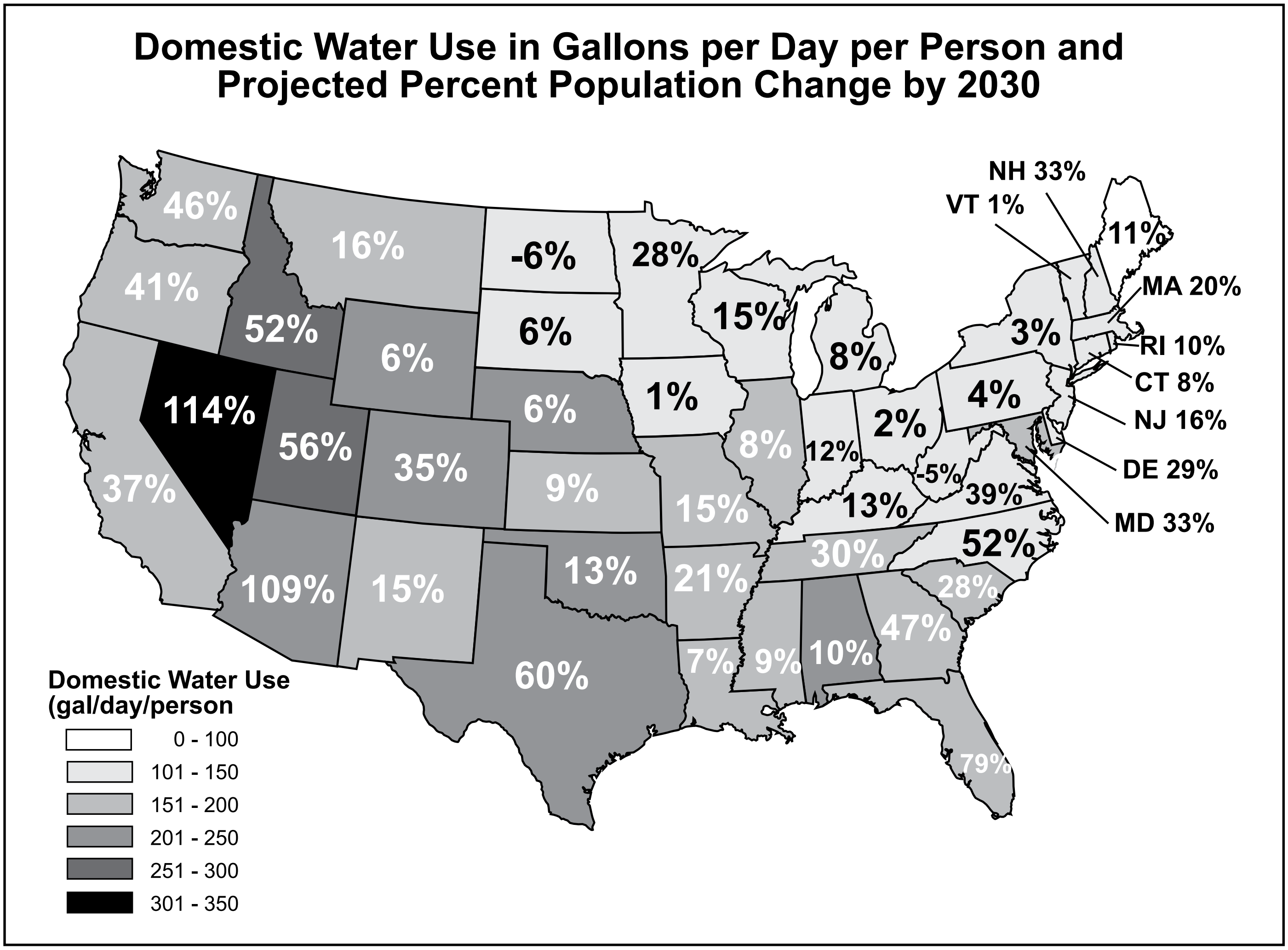

Figure 4: Water data from U.S. Geological Survey (USGS), Estimated Use of Water in the United States in 2000, County-level data for 2000; population data from U.S. Census Bureau, State Interim Population Projections by Age and Sex: 2004–2030

The implementation of incentive programs that foster installation of efficient plumbing fixtures and appliances, such as "high efficiency" toilets, bathroom faucets, showerheads and appliances, demonstrate effective programs for improving residential water efficiency levels. Los Angeles and Seattle have kept water use levels constant while their populations have grown significantly, partially through the use of effective incentive programs designed to replace older water guzzling plumbing fixtures and appliances (See Figure 5). Jurisdictions across the country should replicate the lessons learned from these progressive cities, with priority given to areas of water scarcity or infrastructure-related stress.

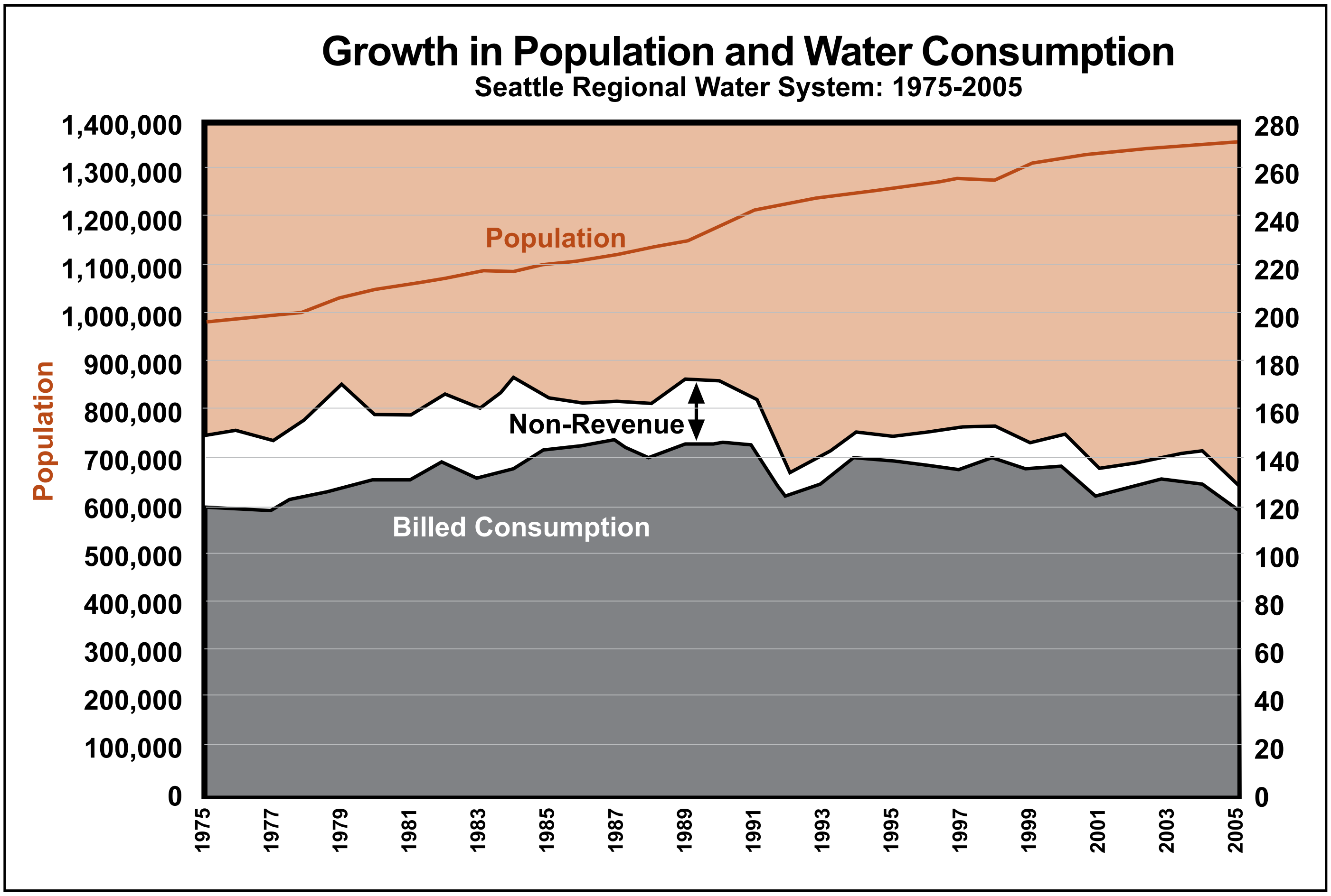

Figure 5

Likewise, there is great potential for improving water efficiency levels in commercial and institutional buildings. In recent years, researchers and manufacturers have developed vast efficiency improvements in ice makers, food steamers, pre-rinse spray valves and commercial dishwashers. In health care institutional buildings, steam sterilizers, X-ray film processing units and scrubber systems have seen efficiency improvements. The Committee recommends establishment of incentives for adoption of standards and codes that mandate use of these more-efficient devices.

Construction codes and standards also must require increased use of water meters in all building types. This is especially true for multi-family residential buildings where residents currently lack financial incentive to repair or replace leaky pipes, plumbing fixtures and appliances. In addition, requiring water meters for specific use applications within a building will provide building facility managers with an effective water efficiency feedback mechanism. These include: makeup water to cooling towers, evaporative condensers, larger evaporative coolers, fluid coolers, large boilers and makeup water supplies to swimming pools.

In HVAC applications, codes and standards should prohibit once-through cooling practices using potable water. Cooling towers and evaporative coolers should include makeup water and blow down meters, conductivity controllers and overflow alarms. Wherever possible, commercial and industrial cooling or air-conditioning applications should use reclaimed (recycled) water or on-site treated non-potable water.

Alternate Water Sources

In an era of constrained water supplies, the very conservative approach in the United States of using potable water for nearly all applications may not be sustainable. Reusing lightly contaminated graywater collected onsite reduces the quantity of potable water consumed by the facility as nonpotable supplies replace potable supplies. Additionally, sewer systems receive less water. The same occurs for reclaimed/recycled water, where a portion of the wastewater generated by entire communities is collected, treated and returned to facilities for nonpotable reuse. This reduces the influent collected for treatment to potable water standards and also reduces the effluent discharged to the environment. Rainwater harvesting also offsets potable water consumption and has the added benefit of reducing the quantity of stormwater needing onsite management.

If entire communities embrace alternate source use, they may reduce the required size of water mains. Such reductions can allow the lining of aging infrastructure (often reducing internal diameter and capacity) rather than requiring a wholesale replacement. This dramatically reduces costs and the surface disruptions associated with upgrades. Reduced potable water delivery also cuts the costs and energy associated with treatment and conveyance (pumping).

The federal government can encourage the widespread collection and use of alternate water sources through a variety of activities.

- **Support the development of a standard nonpotable water quality definition**–The water quality required for various indoor applications varies widely by state. Many states and jurisdictions allow few or no indoor utilizations of nonpotable water. This wide variation makes it extremely difficult for system producers to create equipment usable in a wide variety of applications and locations. The U.S. EPA has released Guidelines for Water Reuse, which offers guidelines to states and jurisdictions seeking to reuse water, but federal regulations for nonpotable water do not exist. Also, the document does not address rainwater harvesting. A comprehensive update to the federal guidelines to include all sources of alternate water, and federal regulations to establish uniform nonpotable water requirements, could dramatically escalate the implementation of nonpotable water use.
- **Conduct cooperative research with the private sector on appropriate water quality**–For many applications, insufficient high-quality technical data exists on acceptable water quality to protect public health. As a result, states either impose conservatively stringent requirements for nonpotable water use or disallow it entirely. In order to appropriately identify information gaps and prioritize them for future research, a full review and compendium of available research is vitally important. Additionally, due to the lack of a standard water quality definition, researchers have performed very little research on the impact of nonpotable water on water consuming devices such as toilets, urinals, cooling towers, and sprinklers. This research also is vital to ensure that the use of nonpotable water does not create unintended consequences by reducing effectiveness, durability or water efficiency. Other research needs include examination of the impact of graywater and reclaimed water on soils, water transport, microorganisms in soils and long-term plant health.
- **Encourage the revision of state water rights laws**–Some states, predominantly those in the West, retain water rights laws that make rainwater harvesting illegal.
- **Support the development of new sewer billing approaches and technologies**–In many locations, sewer fee billing reflects the consumption of water recorded on water meters. Jurisdictions assume that the water flowing to water treatment facilities will roughly equal the water flowing in through the water service. With the use of alternate water sources, this is no longer the case, and has impeded the implementation of water reuse in some locations. Development of new sewer billing technologies and systems could decouple those systems, opening the door for more alternate water installations.
- **Conduct cooperative research with the private sector on decentralized water quality management procedures**–The use of decentralized systems places treatment in multiple locations, dramatically complicating efforts to both regulate it and ensure its proper operation to protect public health. Obtaining vital information on the best system or systems that states and jurisdictions may employ to monitor and permit these systems requires research into and testing of various management approaches. The federal government could bring together all stakeholders (public health, water utility, state and local government, building officials, construction) to investigate and refine models and technologies.
- **Utilize alternate water sources at federal facilities**–Federal facilities can and should upgrade to take advantage of alternate water sources. This would save significant quantities of water, while building awareness and confidence among public health officials, construction firms, building officials and others regarding this practice.
- **Work with code and standard development organizations to adopt alternate water source methods such as rainwater harvesting.**

Outdoor Turfgrass and Landscape Irrigation

The use of potable water for irrigation of vegetation has proven extremely complex and controversial, particularly in water-limited regions in the Western United States. Research by the Water Research Foundation (WRF) concluded that outdoor water use accounted for approximately 58% of domestic water consumption, averaged over 12 cities. The need for water conservation efforts addressing outdoor water use is clear despite the limited data and small number of locations surveyed. To date, federal efforts have largely focused on indoor water consumption (EPAct1992, 2005), but increased emphasis on the very large amount of water used outdoors, primarily in irrigation systems, is vitally important.

- **Support research efforts to quantify water use.** Water efficiency efforts, particularly outdoors, depend heavily on information about water use patterns and distribution. Despite its limited scope, data gleaned from the WRF Residential End Use Survey provide trend type information. Researchers and policymakers need more geographically diverse information to understand the scope of domestic outdoor (and irrigation) water use. Federal support and participation would help development and deployment of a new WRF study.
- **Continue development of WaterSense™ product specifications for irrigation.** The EPA WaterSense™ program is developing specifications for smart irrigation controllers, an effort of significant importance. The lack of authorization and very weak funding limits the WaterSense™ program's ability to expand those efforts.
- **Conduct research on the health and environmental impacts of nonpotable water use for irrigation.** Insufficient information exists on the public health impacts of the use of non-potable water above ground for irrigation. This lack of information impedes the acceptance of the practice by public health officials. Information needs also include the impact of non-potable water on soil hydrology, long-term plant health and microbiological constituents.

- **Support for consensus standard development.** To date, the landscape irrigation industry functions without consensus standards, limiting the ability to develop water efficiency specifications. Standard Development Organizations are now pursuing such standards for some irrigation products. The support and participation of federal agencies such as EPA could help to ensure the success of these efforts.
- **In arid regions of the country, support incentives for applying Xeriscaping landscape techniques in residential and commercial applications.** Xeriscaping uses native and drought tolerant plants and other techniques to limit the amount of irrigation required.

Findings & Recommendations

- The federal government should redouble its leadership efforts and urgently work with construction community stakeholders to develop widely acceptable energy and water efficiency metrics to be deployed in developing future codes, standards and efficiency programs.
- The federal government should provide monetary incentives in the form of funding and tax incentives for the adoption and enforcement of energy and water efficiency stretch/above-baseline codes and standards.
- Investment in energy and water-related infrastructure is desperately needed. Programs aimed at repairing and replacing aging infrastructure would vastly improve efficiencies and create jobs.
- The building community and policymakers should shift towards performance-based code provisions that work towards net-zero energy buildings and away from prescriptive requirements.
- The President and Congress should prioritize, coordinate and support development of a national water strategy.
- The U.S. EPA, working with other relevant agencies, should establish a plumbing research facility to support plumbing research programs that foster increased levels of water efficiency. Such a facility should be located within the National Institute of Standards and Technology (NIST) or another research institution charged with working with the private sector.
- Congress and the Administration should continue to fund successful labeling incentive programs, like Energy Star™ and WaterSense™, and support retrofit incentive programs aimed at removing inefficient consumer appliances and plumbing fixtures from the marketplace.
- The building community and policymakers should support the development of codes and standards establishing requirements for the safe use of alternate water sources, such as reclaimed water, rainwater and gray water, and efficient outdoor irrigation practices.
- The U.S. DOE should work with codes and standards developers to provide energy savings analysis on change proposals, utilizing the same tools DOE uses to determine the efficiency of a new edition of a code or standard over a prior edition.

Codes and Standards Adoption and Enforcement

Buildings and their surrounding communities dominate the landscape of people's lives and livelihoods in the United States in ways that are both subtle and profound. Human behavior also significantly impacts how buildings perform.

Building Codes: Bringing Best Practice to Scale

Building codes cover the multidimensional aspects of the design and construction of new and existing buildings. Building codes set baseline minimum requirements and represent an attempt to bring best practices to scale for the benefit of society. Such codes represent baseline or minimum requirements. They can cover issues such as energy efficiency, life safety, accessibility, indoor air quality and many others.

Buildings last a long time, and codes and standards allow the benefits of improved construction today to be enjoyed for many decades. Continual improvements to codes, when adopted and enforced by jurisdictions, can result in consistent and long-lasting increases in energy efficiency, health, safety and accessibility.

In America, codes and standards are developed in the private sector with the input of government agencies, consumer groups, and other entities to meet the changing demands of society. Most model codes and standards are developed according to rigorous principles based on consensus, openness, balance, transparency and due process. As technology, building science knowledge and understanding of risk improves, codes and standards evolve to incorporate such improvements. The typical code cycle lasts 3 to 5 years. The U.S. approach to code development allows plenty of time for input and transparency, but many challenges (as well as opportunities) remain on the path to achieving safer buildings that are more accessible and energy efficient.

Standard & Code Adoption: Implementing Best Baseline Practice

Building code requirements most often are established through adoption by state or local governments and by some federal agencies, such as the Department of Justice's Bureau of Prisons (although private developers also may impose these or more stringent requirements as a condition of a construction contract). Ideally, jurisdictions adopt new codes immediately following the release of updated national model codes—approximately every three years. Increasing code stringency provides new challenges to the building industry at large and to state and local agencies that are charged with administering and enforcing the codes.

The success of the building and construction market to meet code requirements relies on the availability and pricing of products and equipment. Equally important are the appropriate knowledge and skills of designers and contractors. Yet product development and workforce training takes time, which may not be considered when adopting updated codes and standards. Once modified and adopted, states typically provide a window of time to phase in newly adopted codes. Although many in the construction community are aware when code changes are going into effect, they often are reluctant to support code compliance or embrace the changes.

The recent increase in development of stretch/above-baseline code criteria provides a straightforward potential solution. Several states have established such codes so that higher standards can be adopted in a consistent manner. If these codes were to automatically become the next minimum code, they would provide the predictability and experience needed to support significant code compliance. Once established, incentive programs also could be used to promote the stretch code as a voluntary performance level for construction. Training, resources and financial incentives would work to fuel product development, skills and experience that would carry over to the broader market once the requirements became mandatory.

Resource constraints also tend to dampen the adoption of new codes. Some state policymakers are averse to adopting a code that will require significant and costly support. As codes advance further and faster, more resources will need to be invested to help the industry keep up. If resources are not available, code adoptions may stall.

An outcome-based objective that can be readily verified can assist jurisdictions in solving this problem. For instance, where code compliance is not achieved on an annual basis, penalties in the form of utility surcharges or property tax fines can be imposed. These outcome-based objectives may be more effective in the long run than the present situation, where buildings receive a certificate of occupancy upon completion, with limited or no inspections thereafter (depending upon the occupancy).

Adoption of codes can occur directly through legislative or regulatory action. Such processes vary by state and within states but typically require public participation at some point in the process. Often starting with a model code or standard as a baseline, implementing bodies consider modifications to account for local preferences and construction practices. Compliance with regulations or legislative requirements may require additional procedures depending on the mechanism for final adoption.

Some states adopt or revise codes in concert with the publication of a new edition of a code. This may occur either through a legislative or regulatory process, or when the state regulation or legislation refers to "the most recent edition," in which case the adoption occurs after the model document has been reviewed for consistency with the empowering legislation. Other states review the new editions on a case-by-case basis to consider adoption, without a designated time line for adoption.

Code Compliance

The gap between current practice and code requirements is unknown. The lack of understanding of requirements by designers, contractors and building code officials clearly indicates a significant shortfall in the building sector when it comes to building codes. As with adoption, strengthening energy efficiency, health, safety and accessibility over time presents several challenges to code compliance mechanisms. However, improvements in overall compliance and advances in efficiency, health and safety through changes to the process and scope of enforcement, and as noted above, format changes can significantly impact the potential to ensure compliance.

Ensuring that a building complies with codes and standards is an important step in the building process. Realization of safe, healthy, energy efficient and accessible buildings depends on codes and standards administration and enforcement. The responsibility to administer and enforce the building code typically falls upon states or local jurisdictions, and the responsibility to submit compliant design documents for a building permit falls on developers, designers and contractors. Education and communication regarding codes and standards forms the basis of effective enforcement and compliance. Enforcement strategies vary according to a state or local government's regulatory authority, resources and staffing; programs may include all or some of the following activities:

- Review of plans,
- Review of products, materials and equipment specifications,
- Review of tests, certification reports and product listings,
- Review of supporting calculations,
- Inspection of the building and its systems during construction,
- Evaluation of materials substituted in the field,
- Inspection immediately prior to occupancy,
- Issuance of building permit, certificate of occupancy and/or other administrative documents, and/or
- Processing of variance/appeal requests to the building code.

The verification process for code compliance typically occurs locally, with the state having oversight and/or enforcement responsibility for some types of buildings. Local agencies, authorized and with the proper training and resources, typically will enforce the adopted codes. The proximity of local agencies to the construction site and construction community offers the potential for more regular enforcement, but occasionally the state must supply expertise not available at the local level. Although empowered by statute and regulations to set forth the local code administration processes, the availability of resources determines the quality and extent to which jurisdictions perform plan reviews and construction inspections. Jurisdictions vary, and their political leadership plays a role in determining the emphasis placed on local development, construction and enforcement. These differences often lead to differences in the rate of code compliance across a state. When a state code agency actively supports local governments with the education, training and technical information services necessary to administer and enforce the code, compliance improves.

Some states allow local jurisdictions to conduct enforcement activities that usually fall under the state's responsibility. This strategy offers the advantages associated with state enforcement, recognizes those local governments with equivalent enforcement capabilities and helps ensure comparable levels of compliance. Continued state assistance helps to ensure a consistent level of enforcement by local jurisdictions. A hybrid approach involves the state conducting the plan review and the local authority conducting the construction inspection.

It is important for all stakeholders to know when a new code is expected to be implemented and to understand its requirements. Many states or jurisdictions start this education process months in advance of the code change and/or allow a window of compliance (e.g. permits can be issued for two different editions of the code during a specified grace period). Effective outreach, education and training greatly enhance acceptance and use of the new code.

Prescriptive forms, software-generated forms, and modeling runs represent several common methods to document compliance. Local jurisdictions can generate simplified prescriptive forms, typically for residential construction. Also, jurisdictions may allow the use of software programs to demonstrate compliance. Software checklists, and tools such as these, encourage code officials to become more productive and comfortable with performance-based codes.

Findings and Recommendations

- At the state and local level, where code adoption and enforcement is largely conducted, the lack of resources, both financial and technical, significantly affects the ability of state and local officials to ensure that new buildings are satisfying the requirements provided by codes and standards and achieving the inherent benefits.
- Policymakers and the general public often misunderstand the codes and standards development, adoption and compliance process due to its complexities. There needs to be education initiatives to improve understanding.
- Increasing the participation of federal, state and local government agencies in the development of codes and standards would yield more uniformity and more consistently adopted and understood codes, thereby increasing the effectiveness of model building codes.

Sustainability

The Consultative Council provided the Sustainability Committee with the following charge:
Considerable attention has been given to the need for buildings and related infrastructure to be sustainable over their life cycle. In achieving sustainability, everything from individual building materials to completed structures must be examined and understood. This topical committee will explore the needs to achieve sustainable buildings and recommendations on how to integrate their findings into the building professions' standard practices.

The committee's scope explicitly addresses buildings and related infrastructure over their full life cycles. Herein the terms building and buildings signify buildings and related infrastructure.

In developing this report, the committee uses the definition of sustainability formulated by the Sustainability Committee of the Institute's Whole Building Design Guide[18]:

> This approach, often called "sustainable design," supports an increased commitment to environmental stewardship and conservation, and results in an optimal balance of cost, environmental, societal and human benefits while meeting the mission and function of the intended facility or infrastructure.

Thus, sustainability addresses the triple bottom line supporting: (1) economic growth, (2) environmental stewardship and (3) social progress. For sustainability, buildings (and related infrastructure) must be safe, healthy, functional and durable for their long service lives and resilient to effects of natural, accidental and willful hazards. Therefore, the scope of this committee's work will complement the scopes of the other Council committees (Defining High Performance/Common Metrics, Energy and Water Efficiency, Education and Training, Codes and Standards, and Existing Buildings).

In dealing with infrastructure related to buildings, the committee addresses infrastructures for communications, energy, transportation, waste and water, and considers buildings in the context of urban systems including commercial, educational, industrial, institutional, natural, recreational and residential facilities. True sustainability requires achievement in both the context of communities and at the individual building or infrastructure level. Sustainability should be part of everyday practice, not a separate requirement.

Issues for Sustainability

Leadership

Numerous and diverse stakeholders must act in concert to achieve sustainability in buildings and communities including: citizens, constructors, designers, educators, environmentalists, financers, insurers, manufacturers, occupants, operators, owners, policy makers and regulators. Each group of stakeholders (at national, state and local, industry, and project levels) needs credible, knowledgeable, patient and charismatic leaders ("champions"). Identifying, informing and empowering potential champions should receive substantial attention.

Knowledge Base

The building community needs the ability to predict economic, environmental and social consequences of particular actions or alternatives over a building's life cycle. For instance, what are the economic costs and benefits of a building on a specific site? Sometimes, the community may find a simpler analysis adequate, such as the differences in costs and benefits between alternative sites. Environmental and social consequences require similar knowledge. The building community can ask related questions about the consequences of introducing products or practices to the marketplace.

A whole building approach relies on understanding the relationship between sustainability and other building attributes, including safety, security, historic preservation and functionality. Modern techniques, such as building information modeling (BIM) and geographical information systems (GIS), greatly facilitate these efforts. These techniques and tools deserve greater adoption and development.

Rehabilitation and adaptive reuse of buildings and infrastructure can contribute greatly to sustainability by preserving and using existing constructed, environmental and social capitals. Rehabilitation and adaptive reuse require improved evaluation technologies to assure sustainability and resilience.

Decisions related to sustainability, occupant well being and productivity for buildings and the social and economic values for infrastructure and communities requires predictability. Substantial research efforts have been conducted, but additional efforts are needed to provide this predictability.

The missions of many federal agencies, private foundations and associations support research, development and demonstration (RDD) for sustainable buildings and infrastructure, but such programs often are fragmented making it difficult to find support for comprehensive and efficient research programs. Researchers need the mechanisms to formulate effective RDD agendas (that may cut across sponsors' missions), and agencies, foundations and associations should provide for their funding. Achieving desired results requires looking at systems and practices and how they interact in the context of a whole building and even a whole community.

Practices, Standards and Codes

Practices, such as guidelines, specifications, standards and codes, put the knowledge base into forms that facilitate decisions in planning, design, construction, operation, maintenance, renovation and deconstruction—essentially the whole life cycle of the built environment. Governments, building owners and practitioners must understand when the appropriate use of practices,

[18] www.wbdg.org/design/sustainable.php.

standards and codes can achieve results. SDOs and professional organizations must review and revise practices at all levels, from materials standards to those for building systems, and from those for planning to those for maintenance, at frequent intervals to promote sustainability. For example, materials standards should facilitate recycling without degrading performance. All standards and codes should explicitly state performance requirements to facilitate beneficial innovations.

Sustainability rating systems, such as EnergyStar™, LEED and Green Globes, and CEEQUAL in the United Kingdom for civil infrastructure have resulted in gaining recognition and support for sustainability among policy makers and owners, and in promoting products and practices contributing to sustainability. Continued development can make these systems more rational and quantitative to appreciate beneficial innovations and improve economic, environmental and social aspects of performance.

Building codes and infrastructure regulations should support sustainability by appropriate references to up-to-date standards addressing sustainability. Assuring that well-intended regulations do not inhibit or forbid sustainability by requiring adherence to less sustainable or outdated standards requires careful examination and review. Regulations citing performance-based standards can systematically address this concern. With explicit required minimum performance, owners, designers and contractors can satisfy regulatory requirements through alternatives that provide better than minimal performance. Greater participation in the code development process by a wide variety of stakeholders also will aid in this process.

Evaluation and accreditation of building product claims for sustainability should accompany the development of necessary underlying standards. Currently, many sustainability claims by building product manufacturers have few verification requirements. To ensure the veracity of the manufacturers' claims, accredited evaluators should perform product evaluations.

From the earliest planning stages of a project, through its design, construction, commissioning, operation, maintenance and rehabilitation or removal, design and construction requires teamwork, including owners, designers, constructors, occupants/users, operators/maintainers, financers, insurers and regulators. Some sectors may call this integrated design or "integrated project delivery" (IPD). The building community must develop and implement practices and standards supporting non-adversarial integrated design. These include contract documents, zoning supporting net-zero energy building at the community scale, life-cycle assessment techniques supporting decisions, and financing and insurance recognizing advantages of life-cycle performance over lowest first cost. Capital and operating budgeting practices need revisions supporting decisions for better life-cycle performance.

The standards and practices developed and maintained by leading professional societies and associations of the building community should incorporate provisions providing for sustainability. Moreover, they should address sustainability consistently since, during the development of each and every building or infrastructure project, practitioners use many such standards and practices. Common metrics and levels of performance should be used for sustainability. Timely and effective updating of standards and codes require effective mechanisms for feedback from leading practitioners to standards developing organizations and code authorities. The building community should establish a voluntary coordination effort, such as a sustainable construction standards management board. In addition, SDOs, testing and certification facilities should extend existing conformance assessment mechanisms to address sustainability requirements.

Education and Certification

Sustainable buildings and related infrastructure represent important sectors for green job development (both in national and international commerce) for more sustainable products and services, as well as for improving the economic, environmental and social conditions of the communities directly served.

The knowledge and practices for sustainability are evolving rapidly; their successful application requires strong educational programs for the workforce of the building community, including professionals, technicians and trades, pre-career and continuing education. Educational needs go beyond the workforce of the building community (designers, constructors, operators, maintainers, and regulators) to include owners, real estate, finance and insurance industries, policy makers and the general public. As building systems or the occupants and operators change, building occupants and operators need sustained educational opportunities.

Certifications include professional licensure, technicians and trades qualifications, and certifications of special expertise. Generally, licensure evolved to assure the public health, safety and welfare, but has not yet addressed many of the economic, environmental and social aspects of sustainability. Including sustainability in the bodies of knowledge for licensure, and providing authoritative certifications of greater expertise in sustainability, appropriate for the various professions and trades, require parallel efforts.

Institutions of higher education actively pursue development of courses and curricula for sustainability. However, the committee wonders how consistency and the relevance to integrated design is addressed across institutions and the many disciplines educating future building professionals, technicians, financers and insurers.

Professional societies, trade associations and craft unions currently develop continuing education programs in sustainability for their members for both new construction and rehabilitation. How can they assure synergy and consistency across these programs?

Professional licensure and post licensure specialty certifications protect the public and demonstrate competence. Methods for incorporating sustainability competence into existing programs and the authoritative accreditation of additional sustainability certification programs remain a question.

The building and infrastructure community should work closely with the U.S. Departments of Education and Labor, and their state and local counterparts to develop cooperative programs for professional and technician education and training.

Financial Resources and Incentives

Sustainability requires life-cycle analyses of economic, environmental and social costs and benefits. A focus on minimal first costs and ignoring externalities causes sustainability to seem uneconomical. Thus, policymakers must identify and implement mechanisms (budgets, insurance, tax incentives, etc.) to facilitate the financing of sustainable life-cycle performance for buildings and related infrastructure with consideration of real energy and water costs, and recognition of occupant productivity and well being, and community values. Current common budgeting and organizational disconnects between construction (capital) and operations lead to decreased abilities to realize savings based on life-cycle costing.

A number of local, national and international innovative practices show promise for incentivizing sustainability. These include energy labeling, environmental and carbon footprinting, and developers providing assurance of predicted performance (as is a practice in France).

Eventually, clarity and transparency in the economic, environmental and social benefits of sustainability will provide justification for the needed financial resources. Greater productivity from greater functionality and better environmental quality, energy and water efficiency, and lesser risks of accidents and failures can increase property values more than costs. In the interim, communities can justify subsidies such as tax incentives in cases where taxpayers would not see changes in their tax liability due to such investments.

Federal, state and local governments have supported sustainable building and infrastructure projects with a variety of public projects, grants, tax incentives and priorities. How can legislatures and agencies learn about the most effective approaches from research and experience?

Public Involvement, Understanding and Support

Social sustainability implies that the project strengthens the community affected by the building and infrastructure projects, whether as neighbors or as suppliers and recipients of its products/services. To communities, both the perception and reality of costs and benefits matter.

Evidence of sustainability includes strong and enduring public support for a project. Involving stakeholders in the development of the project, providing reliable information on the alternatives under consideration and their effects, and showing the project's benefits to the affected community can lead to securing such support. Advanced visualization techniques can assist in achieving understanding of disruptions during construction and of long-term benefits of projects.

Public recognition of a project's economic, environmental and social sustainability and benefits to those affected directly and indirectly requires effective public involvement. Governance-focused organizations should develop and disseminate guidelines and recommended practices for public involvement. Also, gaining understanding and support of sustainable building and infrastructure projects requires public education (K-12 and adult education).

Legal and Regulatory

Private policies, such as those for profitable and secure investments, can be consistent with sustainability when explicit and clear economic, environmental and social benefits exist. Appraisals and insurance premiums should reflect life-cycle economic performance.

Public policies, such as public investments and tax incentives, also can support sustainability when informed by better measures for sustainability.

Federal, state and local governments have established a variety of regulations to promote public health, safety and welfare and 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. Also, many different regulatory jurisdictions, each with its own procedures, have jurisdiction over each building and infrastructure project. Building and infrastructure projects often suffer long, expensive delays before all regulators can issue approvals. Innovations for sustainability can exacerbate such delays.

The regulatory streamlining involves project proponents and all cognizant regulatory jurisdictions and stakeholders in which simultaneous and coordinated attention focuses on meeting the intents (performance requirements) of all regulatory requirements. Modern information technologies, such as BIM, permit efficient sharing of pertinent information facilitate streamlining.

A variety of laws and regulations provide for equity and protection of the public health, safety and welfare and environmental quality. Policymakers should assure that laws and regulations include intents (performance requirements) explicit and permissive to beneficial innovations. To allow timely review and permitting of sustainable building and infrastructure projects, regulatory implementation procedures should be streamlined (coordinated).

Findings & Recommendations

- Economic growth, environmental stewardship and social progress form the "triple bottom line" for sustainability that should be addressed in all building and infrastructure projects. Project goals and processes through the whole life cycle, from planning to renovation or removal, should demonstrate explicitly the economic, environmental and social benefits to the communities affected.
- Assuring that concerted actions are taken to achieve sustainability in buildings and communities requires credible, knowledgeable, patient and charismatic leaders ("champions") for each group of stakeholders (at the national, state, local, industry and project levels). The building community (through the National Institute of Building Sciences and other organizations) should give substantial attention to identifying, informing and empowering potential champions.
- Providing the body of knowledge and tools for sustainable building and infrastructure practices requires substantial, comprehensive and sustained programs of research, development and demonstration (RDD). Policymakers and the building community need mechanisms to coordinate and ad-

vance the programs of the numerous public agencies, private foundations and private industries that fund RDD for sustainable buildings and infrastructure. Agencies should consider what interdisciplinary, multi-sponsored research is needed and stimulate the necessary funding, with clear indications of what benefits are to be achieved.

- To achieve true long-term sustainability of buildings and related infrastructure, designers, constructors, operators and owners must incorporate such concepts into the practices, standards and codes used throughout the life cycles of constructed facilities. The multi-faceted nature of sustainability requires that standards and practices state explicit performance requirements and have conformance assessment systems capable of accepting innovations. Building codes and infrastructure regulations should cite up-to-date, performance-based standards to assure acceptability of designs that provide better than minimal performance. As indicated above, the building community should undertake efforts to coordinate the establishment and use of consistent metrics.
- Formal and continuing education programs should provide future and present generations of professionals and technicians with the multi-disciplinary body of knowledge required to achieve sustainability in buildings. Each discipline or specialty involved in construction needs to understand the economic, environmental and social implications of its work, as well as its own special body of knowledge. Education and training curricula and programs require a well-rounded course of work providing knowledge in a breadth of subject areas with sufficient depth in focused technical areas. Collaborations across all disciplines can assist in defining the background education desired in social, life and physical sciences.
- Nationally recognized professional and technician licensure and certification programs should demonstrate how sustainability can be implemented in regular practice to address the needs of clients, employers and the public. Licensure boards should examine building and infrastructure professionals and technicians for needed knowledge of sustainability. Authoritatively accredited certification programs should be developed to recognize needed professional and technical expertise in sustainability.
- K-12, post-secondary and informal educational programs should teach students about the importance of a sustainable built environment, and should attract capable people to careers in building and infrastructure. All Americans are building occupants and beneficiaries of civil infrastructure. Their involvement is crucial to achieving sustainability goals. The building and infrastructure community should become involved in ongoing governmental and private efforts to address sustainability in K-12, post-secondary and informal education, and assure that appropriate recognition is provided to the importance of the built environment and building community.
- The economy must have a strong financial and insurance capacity to provide society with the benefits of a sustainable built environment. Society needs to understand and fund the potentially higher first costs associated with better economic, environmental and social performance over the project life cycle. To attract the financing required to produce sustainable building and infrastructure, investors need studies demonstrating increased public and private returns on investments. Appropriations for public construction should address life-cycle costs and benefits, and policies for accounting, financing, insurance and taxes should facilitate and promote private investments in sustainable buildings and related infrastructure. Budgeting and organizational practices, in both the public and private sectors, also should facilitate achievement of lower life-cycle costs.
- Public involvement in decisions made throughout the life cycle of a building or infrastructure system is needed to assure that the facility contributes to, and is perceived by stakeholders to contribute to, the sustainability of the affected communities. Model practices for public involvement should be developed and disseminated for appropriate types of building and infrastructure projects. These practices should involve interdisciplinary efforts representing typical proponents, participants and stakeholders.
- Buildings are subject to many regulations administered by many different authorities aimed at protecting the public health, safety, welfare and environmental quality. Attempts to improve sustainability in buildings often fall under the jurisdiction of several governmental entities, such as the building department, public health agency, utility commission and architectural review board. While validation and approval of these innovations are necessary, such projects often encounter prohibitively expensive delays in obtaining regulatory permits. Governance-focused organizations should develop and demonstrate model processes for improving the efficiency of the regulatory process for important classes of building and infrastructure projects. Where needed, the statutory authorities of regulatory agencies should be modified to enable participation in a streamlined process.

Education and Training

Buildings have a complex life cycle, from concept, design and construction to commissioning, occupancy, modification/renovation and deconstruction. Education and training within the building professions must reflect this complexity and the specific skill needs at each point in the building's life cycle. These life-cycle considerations include efficient use of energy and water through reduced waste and demand management, improved occupant comfort and health, and upgrading the human-building system interface. In each time period within the building's life cycle, particular segments of the building community must be engaged and have the requisite knowledge to adequately address the unique needs within that time period. (See Figure 6 for an example.)

Essential audiences for education and training include all people who impact the performance of the building during its life cycle. Such audiences include:

- The Owner,
- Commissioning Agent/Authority,
- General Contractor,
- Engineer,
- Architect,
- Installation Contractor,
- Service Contractor,
- Facilities Manager,
- Operations and Management,
- Users/Occupants,
- Support Contractors (including support contractors not directly related to systems maintenance, i.e., the cleaning service, replenishment services, etc.), and
- Inspectors and Enforcement Personnel.

Requirements may be different across residential, commercial, industrial and specialized buildings (specialized buildings include hospitals, laboratories, schools, etc.), so training should specifically relate to the building types for which personnel are responsible.

While it is essential that people who enter a particular career get education and training initially, training must continue throughout their careers. Best practices go stale, equipment and processes change, and new regulatory requirements go into effect. To assure professionals seek out and retain it once received, such education and training must be dynamic and engaging.

Structure Life Cycle	**Concept**	**Design**	**Construction**	**Commissioning**	**Occupancy**	**Modification of Use / System Upgrade**	**Deconstruction**
PEOPLE INVOLVED							
Owner	X	X	X	X	X	X	X
Commissioning Agent	X	X	X	X	X	X	
General Contractor	X	X	X	X		X	X
Engineer		X		X	X	X	
Architect		X				X	
Installation Contractor	D	D	X		X		
Service Contractor				X	X		
Facilities Manager				X	X		
Operations & Maintenance				X	X		
User/Occupants					X		
Support Contractors				X	X		
Inspectors - Enforcement		X	X	X	X	X	X

D - Design/Build Scenario

Figure 6 – People Involved in the Structure Life Cycle

Communication Needs

As sustainable, high-performance building design, construction and operations continue to penetrate the market for both new and existing buildings, current communication channels need to change. In current practice, little communication generally occurs between the following pairs of building industry stakeholders:

- Design professionals (architects, designers and engineers) with operations and maintenance personnel (facility managers, technicians, operators and maintenance service providers),
- Operations and maintenance professionals and building occupants (users),
- Capital planning/finance departments and design professionals, and
- Capital planning/finance department and operations and maintenance personnel.

Within current academic settings (community colleges and university undergraduate and graduate programs) that prepare future professionals for careers in the building industry, little communication generally occurs between the following pairs of educational focus areas:

- Architecture and engineering (building systems: heating, cooling, lighting, controls, electrical),
- Community colleges and universities, and
- Pairs of engineering sub-disciplines, such as:
    - Mechanical (heating and cooling) systems and electrical systems,
    - Lighting and mechanical systems, and
    - Controls and electrical systems.

Communication channels need to changes because:
- Buildings are becoming more automated,
- Technologies and management processes used to operate, maintain and minimize energy consumption require increasing levels of integration, and
- Historically, the design, construction and operations and maintenance professionals and educators have worked in "silos," only communicating or coordinating as required to meet contractual and/or program requirements.

More specifically, sustainable, high-performance buildings often require use of new technologies and processes. Thus, architects, engineers and designers must have a practical, real-world understanding of buildings and how the systems within those buildings operate and can be maintained as designed. Under current design and construction contracts, architects, engineers and designers rarely have the opportunity to visit a facility they have designed to gain insight on building performance and to gather lessons learned. Without the opportunity to understand the real performance of the design, designers replicate some of the same faulty practices and techniques in multiple buildings. Some of these challenges include:
- Insufficient space to allow proper maintenance of systems and equipment, and
- Systems and equipment do not operate as efficiently as possible, resulting in increased energy consumption and decreased indoor environmental quality.

Decreased risk presents the best business case (benefits) to improve communication channels. Decreased risk can result in:
- Insurance companies having additional confidence that sustainable, high-performance building designs operate at the level expected for sustainable, high-performance buildings, and
- Actual energy consumption of buildings aligns with predicted energy consumption levels and costs from energy models, reducing the risk to building owners and building design professionals.

To achieve energy efficiency and sustainable building goals, communication channels require a large shift. The building community can implement many activities to help fulfill this need:
- Encourage professional associations to have shared regional meetings and conferences to foster collaboration and discussion,
- Encourage professors and instructors at academic institutions to have interdisciplinary projects. If possible, set interdisciplinary requirements within curricula,
- Encourage professional organizations and academic institutions to share resources (printed materials, courses and expertise) by establishing clear guidelines and boundaries for intellectual property and ownership of submarkets of the building industry,
- Establish both national and regional forums through the National Institute of Building Sciences and invite key individuals from professional associations and academic institutions, and
- Further develop and provide continual funding to support the Whole Building Design Guide (www.wbdg.org).

In addition to expanded communication skills to support interdisciplinary interaction, professional curricula should include business skills, including marketing and finance. This will assist in communications with owners and improve the ability for such professionals to develop and implement successful business models.

Identifying Effective and Responsive Education and Training

A variety of methods and sources for accreditation, certification and credentialing exist within the building professions. These include professional societies, trade organizations, individual manufacturers, post-secondary education institutions and specialized training companies. Assuring the efficient achievement of building owner and governmental requirements requires that education and training methods and sources produce knowledgeable personnel. Within the federal building sector, the recently adopted Federal Building Personnel Training Act of 2010 requires identification of core competencies and the methods for personnel to demonstrate achievement of these competencies. Outcomes under this Act will likely shape activities elsewhere within the building sector.

Determining the validity of the offerings may require third-party accreditation of training curricula and programs. However, a reputable and respected entity must provide such accreditation.

Incentives for Education & Training

As building design, new construction, renovation, maintenance and facility management become increasingly complex and subject to numerous codes, regulations, standards and compliance requirements, it has never been more important assure the readiness of our nation's workforce. All aspects of the building industry from field forces to professionals to facility owners and managers need to ensure they have the knowledge and requisite skill sets to respond and compete in today's global economy. Critical components to those collective efforts include education and training incentives.

Incentives, in any form, intend to enable or motivate a particular course of action. Incentives aim to provide value and to contribute to the success of an organization or company, and in this case, improve the nation's economy by creating jobs and preparing the workforce for long-term recovery and competitiveness. In times of recession, companies, organizations and individuals need help with incentives to prepare for tomorrow and the recovery of the economy. The need for those incentives is not exclusive to recessionary times; in boom times those same entities need incentives to look beyond current levels of activities.

Economic activity, both in terms of individual decision making and company or organizational strategic planning and operational performance, embody the needs for incentives. Generally all circles acknowledge the need for, and value of. education and training. However, in a slow economy it is historically one of the first areas where expense reductions are focused, and in recovery, it is one of the last areas addressed. Meaningful incentives provide a bridge during those economic cycles. As the nation strives for increased productivity and implementation of new technologies, incentives help strengthen core infrastructure.

Many types of incentives and approaches can motivate the desired outcome. One type or method will not fit all circumstances. For purposes of this report, the Committee has focused on remuneration or financial incentives, some of which appear below:

- Tax credits,
- Tax deductions or increased levels of tax deductions,
- Rebates,
- Grants,
- Loans (Low interest and/or extended payment periods), and
- Funded programs, in whole or in part.

Education and training incentive programs should be available to cover all levels and types of businesses and organizations, and should encompass all construction, maintenance and operational core competencies in the three primary building sectors: residential, commercial and industrial. Incentive programs should extend from apprenticeship programs and specific task training to professional development. Programs should include continuing education to achieve or maintain levels of recognized third-party certification or similar levels of accreditation. They also should be available to all Americans, especially veterans and minorities.

Industry looks to work in partnership with federal agencies charged with developing and administering education and training incentive programs. Industry commits to provide quality education and training programs on a continuous basis. Industry requests that core competency incentive programs develop jointly in a manner that supports and motivates educational and training programs with as minimal bureaucracy as possible without sacrificing timely reporting and performance verification processes.

Education and training of the nation's workforce does not happen overnight. Congress must act now to embark on aggressive education and training programs. Without meaningful incentives, industry will respond slowly due to the demands of the economy and shareholder-driven short-term financial models that seem the norm in our economy. Education and training represent a primary example of the need for different financial performance models. Education and training investment is not an expense; it is an investment that can provide substantial returns to the economy. Studies have shown that with increased education and training, productivity and quality improvements have returned $3 to $4 for every dollar invested.

Incentives are needed to motivate businesses and organizations to see beyond short-term, financially driven bottom lines and look to the future in preparing the U.S. workforce for the challenges, complexities, technologies and competitive demands of the global economy. Without an increased emphasis on education and training of the workforce, industry may not be ready for the economy of tomorrow. Industry is committed, but without incentives, it will be difficult to move forward with decisive and accelerated programs.

National Institute of Building Sciences Consultative Council

2010 Member Organizations

ASTM International
American Institute of Architects
American Society of Civil Engineers
American Society of Heating, Refrigerating and Air-Conditioning Engineers
Associated General Contractors of America
Building Owners and Managers Association International
Construction Specifications Institute
ESCO Institute
Extruded Polystyrene Foam Association
Illuminating Engineering Society
International Association of Plumbing and Mechanical Officials
International Code Council
National Insulation Association
National Opinion Research Center at the University of Chicago
United Association of Journeymen and Apprentices of the Plumbing and Pipefitting Industry

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