the INSTITUTE for
ENERGY EFFICIENCY

White Paper Summarizing Outcomes of a Two-Day Workshop

Systems-Level Approaches to Energy Efficiency in Buildings

June 2011

The Institute for Energy Efficiency
UC Santa Barbara

Acknowledgements

The Institute for Energy Efficiency would like to thank the sponsors of this workshop: United Technologies Corporation and Cisco Systems, Inc. Without their support, this workshop would not have been possible. We also wish to express thanks to the participants, listed below, who attended and contributed to the discussion and outputs.

Participants

Name	Organization
Ammi Amarnath	Electric Power Research Institute
Gregg Ander	Southern California Edison
Jeff Austin	Wells Fargo
John Beckinghausen	HSBC
Carl Blumstein	California Institute for Energy and Environment
Doug Brookman	Public Solutions (workshop facilitator)
Robert Cashner	Wells Fargo
Bryan Eisenhower	Center for Energy Efficient Design, UC Santa Barbara
Ryan Firestone	Navigant Consulting, Inc. (report author)
Anthony Florita	National Renewable Energy Laboratory
Jeff Harris	Alliance to Save Energy
Florence Hudson	IBM
Clas Jacobson	United Technologies Corporation
Azam Khan	Autodesk Research
Yoky Matsuoka	Nest Labs, Inc.
Igor Mezic	Institute for Energy Efficiency, UC Santa Barbara
Manish Modi	Oracle
Marti Ogram	Cisco Systems, Inc.
Edmund Richards	Cisco Systems, Inc.
Kurt Roth	Fraunhofer Center for Sustainable Energy Systems (remote presenter)
Melvin Schreiberg	Ecorithm, Inc.
Nancy Stein	Siemens Industry Inc.
Chris Tagge	Ecorithm, Inc.
Trae Vassallo	Kleiner Perkins Caulfield and Byers
Saul Zambrano	Pacific Gas and Electric Company

Sponsors

Executive Summary

On December 2 and 3, 2010, the Institute for Energy Efficiency at University of California Santa Barbara convened a two-day workshop that brought together stakeholders to develop recommendations for expediting the development and adoption of Systems Engineering for Energy Efficiency in Buildings (SEEEB). 25 industry leaders representing vendors, corporate-level consumers, research institutes, not-for-profits, utilities, government laboratories, and academics attended the workshop.

Building management systems can be used to coordinate and control lighting, mechanical, and other loads in buildings as well as to diagnose faults in equipment, controls, and user operation. Controls can minimize energy consumption and costs for given performance constraints; respond to demand response requests; and integrate on-site renewable energy into the building energy system. Fault diagnosis can identify energy-consuming problems early on to minimize energy and maintenance costs. Additional value streams include improvements in productivity and corporate image.

In light of these benefits, workshop participants discussed why customer adoption and system improvements have been slow to develop relative to other systems such as telecommunications and information technology. Barriers to customer adoption include the lack of demonstrations of applications that are replicable, scalable, persistent, cost effective, and certain. System improvements that would benefit customer adoption and effectiveness include industry-wide equipment communication standards and protocols, consistent metrics of performance, new software capabilities for data management and analysis, and more user-friendly building management systems. An additional barrier to widespread SEEEB adoption is the lack of an adequate skill set that spans building sciences, information technology, and social sciences.

Participants discussed improvements to SEEEB that would promote accelerated adoption and identified stakeholder entities that could carry out these improvements. Technical improvements span all areas of the system, from building equipment through middleware to normalize information and secure communications, and on to software to synthesize building information and provide controls and recommendations. Nontechnical improvements include education for building operators and occupants, the development of interdisciplinary academic curricula for the coming generation of system developers, and usability improvements achieved through behavioral research. Individual recommendations can be targeted to research institutes, universities, building owners and users, standards organizations, regulators, and utilities.

The group identified the need to pursue work on the value proposition by selecting proof points and implementing the existing integrative technologies for the purpose of performance evaluation, monitoring, and diagnostics development. In addition, the group suggested developing a framework within which to share best practices in SEEEB. The development of metrics within different building classes was deemed necessary in order to have the ability to effectively compare energy efficiency measures. Recent developments at research centers for integrated building systems in China reflect a need for development of similar centers in the U.S.

This paper addresses some of the issues and outcomes that flowed from discussions at the workshop. Discussions centered on commercial buildings, and comparisons to and divergences from the residential sector were addressed more briefly.

The author of this paper is:
Ryan Firestone, Associate Director, Energy Practice, Navigant Consulting, Inc.

Table of Contents

1 Introduction

Commercial buildings waste approximately one-third of the energy they consume because of sub-optimal operating standards.[1] These buildings consume 18 percent of all energy produced in the United States.[2] This implies that improved building automation in commercial buildings could reduce United States energy consumption by 6 percent. This reduction represents significant energy and maintenance cost savings[3] and environmental benefits, as well as indirect benefits such as improved occupant health and productivity.

Current Building Management Systems (BMSs), however, are not designed to minimize system-level energy consumption. Instead, they operate on a component and subsystem basis to provide standard approaches to comfort, independent of the building operation or climate considerations. The realization of the potential energy savings from improved building operations will require building automation systems that take a whole-building, integrated system view and simultaneously optimize performance and energy consumption. The non-energy benefits of these improvements strengthen the business case for this shift to a systems-level approach to advanced energy efficiency in buildings.

Integrated building diagnostic and control systems have room to progress both in development and market adoption. Major technical issues arise in making this progress, due to the complexity of the dynamics of the underlying system and uncertainties in its operation. Even a medium-size BMS can produce millions of data points per day that need to be analyzed for faults and summarized for energy efficiency. Some of the analytical tools needed for such analyses are just being developed, riding on the wave of information and sensor technologies that enable data collection.

In light of these issues, on December 2 and 3, 2010, the Institute for Energy Efficiency at UC Santa Barbara convened a two-day workshop that brought together stakeholders to develop recommendations for expediting the development and adoption of systems engineering for energy efficiency in buildings. 25 industry leaders representing vendors, corporate-level consumers, research institutes, not-for-profits, utilities, government laboratories, and academics attended the workshop.

2 Overview of Technology

Building control and diagnostic systems are comprised of: hardware to provide services such as lighting and space conditioning; sensors to observe the parameters of conditioned spaces and the performance of equipment; software to collect setpoints and schedules, analyze sensed conditions, and make decisions and recommendations; user interfaces to inform and guide building operators and occupants; and middleware, a combination of hardware and software used as a gateway between the hardware and software. Combined, this system of hardware, middleware, and software can be used to operate and maintain building equipment reliably and efficiently. Meta-systems can aggregate information from multiple, distributed buildings in order to identify candidates for efficiency upgrades, exemplary high-performance buildings, and common performance issues across buildings.

2.1 Hardware

Building systems hardware can be further classified as equipment and sensors. Equipment provides building services such as lighting, space conditioning, and plug and process loads. Sensors, which

[1] McGraw Hill Construction, "Green Building SmartMarket Report," 2006.
[2] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "Buildings Energy Data Book 2010", Section 3.1. < http://buildingsdatabook.eren.doe.gov/default.aspx>, accessed online April 2011.
[3] Energy costs alone can account for as much as 30 percent of commercial building operating costs: Flex Your Power. Website "Best Practice Guide, Commercial Office Buildings." <http://www.fypower.org/bpg/index.html?b=offices>, last accessed March 2011.

observe climatic and occupancy conditions of building spaces and the surrounding environment, are essential in providing feedback in heating, ventilating, and air-conditioning (HVAC) controls and are also necessary for most intelligent lighting systems. Sensors also observe internal conditions of equipment such as temperatures and pressures in thermodynamics cycles and power consumption; this information can be used to characterize equipment performance and diagnose equipment faults. Traditionally, sensors have been hardwired; however, wireless, network-configurable sensors are now available that can greatly reduce the installation cost of systems in both existing and new buildings. Additional hardware provides communication paths such as those between equipment and controls, and between buildings and the grid.

2.2 Software

Software systems are used to analyze and respond to information from sensors, equipment, and outside sources. Functions include coordinating controls of HVAC systems, setting and administering set points and schedules, identifying equipment faults and unmet set points, and synthesizing building performance information for building operators. Contemporary systems are typically limited to aggregating and presenting building information for building operators and providing these operators a single point of control for many building equipment systems; building operators are left to interpret performance information and outside signals in order to make decisions about how to best meet the often conflicting objectives of building lighting and climatic control, energy consumption, and maintenance. Advanced systems may include artificial intelligence to balance trade-offs between conflicting objectives; identify faults in equipment, controls, and user operation; and provide operations and maintenance (O&M) recommendations to building operators. These systems may respond to external signals such as energy prices, demand response requests, equipment and material costs, and weather forecasts.

2.3 User Interface

The user interface links building operators—and sometimes occupants—to the building system. User interfaces can include applications on central building management system computers, applications on smart phones or similar devices for building operators, and displays and interactive displays in buildings for occupants. A successful user interface informs users by translating data-heavy statements of system state into intuitive text and images; it also provides an intuitive platform for users to instruct and query the system.

2.4 Middleware

Middleware is a separate component of integrated building systems that serves as a bridge between building systems hardware and software. Middleware can include a network security layer to guard against internal and cyber attacks that could otherwise compromise the performance of the building and the safety of its occupants. Middleware is itself comprised of hardware and software that translates signals from heterogeneous building equipment and sensors into a single language usable by enterprise software applications (such as XML). Traditionally, middleware has been focused on multi-protocol translation of disparate and proprietary languages. Proprietary protocols commonly lock building owners and operators into ongoing relationships with single manufacturers. More robust middleware could provide two-way communication from heterogeneous equipment operating on multiple proprietary and open-source communications protocols. It could also provide the security required to protect building operations from attack, thus enabling the integration of building systems into information technology (IT) infrastructure without compromising the security of the IT system. Lastly, middleware can perform the function of delivering services and negotiating commands between devices and software applications.

2.5 Meta-Building Systems

An additional component of building systems is the meta-building system, which is the review and coordination of the performance of multiple buildings across a campus, enterprise, or other aggregation provided by additional communications and software. Meta-building systems can be used to identify candidates for efficiency upgrades, exemplary high-performance buildings, and common performance issues across buildings. These systems can also aggregate some building operations across buildings in order to reduce distributed building operations costs through the use of more highly trained staff in a central location.

3 Value Streams

Integrated, intelligent building systems offer numerous value streams to building owners and their tenants. Direct value streams reduce the O&M costs of buildings. Indirect value streams provide non-energy benefits such as improved productivity and organizational image. A compelling business case for integrated building systems typically comprises several value streams. Measurable performance metrics can be associated with each value stream.

3.1 Direct Value Streams

Direct value streams reduce the costs of operation and maintenance of buildings. These costs include energy, water, materials, equipment, and staff labor. Energy efficiency is achieved when building systems identify or allow building operators to identify energy-minimizing deployment of equipment to meet space-conditioning and lighting requirements. Further energy efficiency—as well as lower maintenance costs—are achieved when building systems identify equipment faults that may be causing isolated equipment or the integrated system to operate in an inefficient manner. At the enterprise level, meta-building systems allow centrally located operators to review the performance of multiple buildings and identify the best candidates for building retro-commissioning and upgrades to equipment and the building shell.

3.2 Indirect Value Streams

Indirect value streams improve the productivity[4] and/or perception of an organization housed within the building. Additionally, building systems can engage occupants with rich user interfaces that enable observation and control of the environment. This engagement can provide valuable education on energy consumption and motivate occupant-driven reductions in consumption.

3.3 Building Systems as Enabling Technology

In addition to the value streams listed above, building systems can enable additional functionality in buildings, including: grid connectivity, building connectivity, demand response, integration of renewable energy resources, energy storage, plug-in electric vehicles, price and load optimization, zero net energy, and the real-time visibility of building functions and activities.

3.4 Benefit Metrics

Articulating the business case for integrated building systems requires metrics for quantifying value streams. For the most straightforward business cases, a favorable return on investment in capital expenditures for integrated building systems is provided by savings in energy and operations and maintenance. Indirect benefits metrics may be quantified using global organizational metrics such as productivity and market share. The value of additional building functionality enabled by building systems can be added to other benefits. Some indirect benefits may require qualitative evaluation.

Estimates of performance metrics for the business case are subject to uncertainty in magnitude and in persistence over time. How this translates into uncertainty in the business case will depend on the contractual vehicle by which system costs are incurred, and how the benefits of these systems are realized. Vendors can reduce risk to consumers by offering pay-for-performance or other shared-risk/shared-benefit types of contracts.

---

[4] For example, Singh, Syal, Grady, and Korkmaz, "Effects of Green Buildings on Employee Health and Productivity", American Journal of Public Health, September 2010, Vol. 100, No. 9. Preprint version available at http://news.msu.edu/media/documents/2010/08/840514e8-0b32-4aa4-9fc8-276b688dfed4.pdf
This research examined occupants who moved from conventional to Leadership in Energy and Environmental Design (LEED)-certified office buildings and found self-reported increases in productivity of 2.6 percent, with additional, smaller savings from reductions in time lost for asthma, respiratory allergies, depression, and stress.

4 Barriers to Adoption of Existing Systems

Despite their promise of energy and cost savings, there has not been widespread adoption of BMSs. Barriers to adoption include low energy costs, uncertainty in the business case, technical shortcomings of available systems, and the shortage of properly trained building and building management system operators.

4.1 Relative Costs of Energy and Systems

Current energy costs are often too low to justify the cost of integrated building systems based on energy savings alone and in light of investment risk and the hassle of installing complex systems. Systems costs are particularly high because systems design, installation, and configuration are all custom jobs tailored to individual sites. Often, this requires a series of contractors for distinct phases of the project: conceptualization and design, system build, and operation and maintenance. Each contractor must factor in the costs of a detailed hand-off of the project to the next phase contractor. The cost-effectiveness of systems increases when additional value streams (Section 3) and externalities (e.g., environmental benefits) are considered, although the quantification and valuation of these benefits can be highly uncertain (Section 4.2).

4.2 Uncertainty in the Business Case

In addition to the imbalance of cost and benefit described above, uncertainty in both the costs and benefits of integrated building systems makes the business case for BMSs difficult to specify. As is typical of projects with multiple stages and implementers, the cost of integrated energy systems is subject to uncertainty that is compounded at each stage of the project. Uncertain project costs can deter potential hosts from pursuing these projects.

Likewise, energy and other savings can be difficult to quantify. Benchmarking an existing building prior to system installation for comparison is difficult given annual variation in climate and the evolving usage of the building (occupancy, equipment usage, and building layout). For a new building, this is more difficult because even the building’s baseline performance is unknown. The persistence of savings from BMSs has not been well quantified but will affect the business case significantly. Ancillary benefits such as increased productivity are also difficult to quantify.

4.3 Usability

The usefulness of BMS is highly dependent on the staff available to use them. At a high level, contemporary systems are often criticized as being "data rich but information poor"; buildings are typically short on O&M staff and often no one is available to analyze the constant stream of data provided by the BMS. Building operators may not have the proper training to make use of the BMS, which can make their job more difficult rather than easier. Operators have been known to turn off or override BMS if it is too cumbersome.

4.4 Lack of Interoperability

Interoperability is the ability of system components to exchange information and use the exchanged information. This quality allows building systems to be developed modularly. Where open communication standards are provided, an open market for system components can develop and can fast-track innovation, as has been seen in the telecommunications and information technology industries. To date, there is not an open standard for building systems; consumers are typically locked into a particular vendor’s system and product line. This results in legacy systems that can be difficult or impossible to reconfigure as a building’s equipment, layout, and use evolve over time and as new building systems components become available.

Fortunately, many of the components necessary for integrated building systems are commercially available: controllable mechanical systems and lighting technologies, sensors, and information technology. What is missing is middleware—in either the form of translational equipment or in standards that remove the need for translational equipment—to allow configurable and reconfigurable systems.

4.5 Lack of Expertise and Tools

In the United States, a lack of appropriately trained engineers and scientists has hampered progress in this field. Academic enrollment in technical fields concerning energy has been cyclical, with broad interest only during energy crises. Additionally, few academic programs have bridged the gap between thermal engineering and information technology, both of which are required for the design and control of integrated, low-energy systems. Likewise, software tools do not exist to enable firms to design systems rapidly and inexpensively. For example, dynamic building simulation models are needed to model building controls and occupant behavior; current building simulation models are predominantly steady-state models that cannot capture this detail.

5 Building Systems of the Future/Needed Improvements

Integrated building systems are complex systems comprised of diverse equipment; they also manage vast amounts of data. Improvements to the state of the art that improve the efficiency of developing and using systems could foster accelerated adoption. Experience with current building systems and other complex, information-based systems suggests several areas for improvement and innovation. Improvements can be broadly categorized as technical improvements to systems and system components directly, and nontechnical improvements to the process of developing systems, training users, and providing incentives. Additionally, research and demonstration projects are needed to develop proof points that support a certain, compelling, and generalizable business case for intelligent integrated building systems.

5.1 Technical Improvements

The advent of communication networks and improved computing power and data management have created opportunities for technical improvements to building systems. New, innovative layers of software can leverage these information improvements and existing components to improve the usefulness and versatility of building systems. This subsection describes technical improvements that could be accomplished with such software.

5.1.1 Component Interoperability

Integrated system progress has been stymied by a lack of interoperability among building and system equipment. Varied, proprietary communications standards across manufacturers limit building managers' options when replacing equipment or adding new equipment: the new equipment must work with the existing building management system. Even under these restrictions, configuration of the new equipment into the existing BMS can be complicated. An open-source, standardized communication protocol for building equipment and BMS would open the market for BMS-ready building equipment and avoid duplication of effort among BMS developers. Standardization of lexicon and naming conventions related to building equipment, sensors, locations, and information constructs would further simplify the market and allow manufacturers to develop discrete portions of the BMS independent of other system components. Industries such as telecommunications and information technology have gone through similar standardization processes, resulting in robust markets that can now respond quickly to bring consistent, rapid progress.

For existing equipment and systems, middleware can be used to translate numerous equipment and sensor communications into a common language. If this middleware also understands new open-source communication protocols, then it can accommodate new building equipment going forward as it is added to existing systems. Middleware can also provide the layer of IT security necessary to integrate BMSs with IT infrastructure while protecting both the building operations and IT systems from attack.

5.1.2 Usability

The software layer of BMSs could benefit from the improved intelligence of which modern computing is capable. BMSs typically continuously monitor thousands to millions of data points; this is simply too much information for a building operator to process, let alone utilize. Software intelligence could process this data in real time to optimize the deployment of building equipment, accurately identify faults, and provide actionable recommendations to building operators. At the enterprise level, software intelligence could be used to normalize performance data across a suite of buildings in order to track trends in performance and identify performance outliers.

Ultimately, the successful performance of a building is dependent on the building operator and building occupants. Building operators and users require a usable BMS to steer their buildings towards optimal efficiency. Usability of BMSs could be improved through improved intuition of user interfaces and a synthesis of information, as well as actionable intelligence that is clearly presented to users. Usability could be improved for all BMS users (i.e., building operators, occupants, and centralized enterprise-level building managers).

5.1.3 Fault Detection and Verification

Improvements to BMS fault detection and notification would allow early and targeted system maintenance, keeping building systems running at optimal levels (Section 5.1). Current systems tend to lack the sophistication to filter "false positives" out of fault detection reports. In fact, false positives can overwhelm the number of actual faults; the large number of maintenance checks required to investigate reported faults can actually increase maintenance costs. Worse, building operators may learn to ignore fault reports entirely. Fault detection software and communications with onboard fault detection systems should be dynamic to learn the patterns of each building's operation and adjust to changes in configuration and usage.

5.1.4 Automated Tools for Commissioning and Recommissioning

In addition to ongoing fault detection, integrated building systems would also benefit from automated commissioning and recommissioning tools. Commissioning and recommisioning are the systematic process of ensuring that a building is operating as intended and with optimal efficiency. This process must typically be customized to each building. Although commissioning has become common, recommissioning occurs infrequently (if at all), allowing time for building performance to stray significantly from intended performance. Tools that could provide some of this customization automatically, and could be executed frequently, would keep buildings running optimally while reducing the need for time-consuming and expensive customized commissioning efforts.

5.1.5 Building Simulation for Controls and Behavior

Building and BMS design could both benefit from improved simulation capabilities to account for building controls, the behavior of occupants (Section 4.5), and passive thermal designs. Whereas traditional building system design tries to minimize the effects of thermal system dynamics, low-energy systems harness these effects and minimize HVAC needs while staying within performance parameters. Predictable performance of low-energy systems and control strategies is dependent on the development of building simulation tools that can capture thermal system dynamics. Tools should also address uncertainty of performance estimates.

5.1.6 Scalable Deployment of Systems

Significant customization is required to configure BMSs and to design their controls. Scalable approaches to BMS deployment would bring BMS costs down, thereby improving the business case. As discussed earlier in this section, this could be achieved by developing BMSs, control strategies, and diagnostics that work for a diversity of building types and locations. Additional improvements could be made by developing artificial intelligence to reduce the amount of human capital required to interpret BMS data at the building and enterprise levels.

5.2 Nontechnical Improvements

Additional improvements could be made to the process through which systems are inspired, developed, deployed, and maintained. Properly constructed energy efficiency incentives would encourage BMS adoption. Academic programs are necessary to provide the skilled workforce required to develop the BMSs of the future. Education is also required for building operators to fully utilize BMSs.

5.2.1 Energy Efficiency Incentives

Energy efficiency incentives are typically offered for the installation, replacement, or removal of equipment, rather than the top-down approach of incenting overall reductions in consumption achieved through the optimal use of equipment. Incentives from utilities and regulatory agencies for BMSs and the savings they achieved would help improve the business case for BMS while expanding the opportunities that these agencies have to meet their energy efficiency targets. At the enterprise level, incentives that span the geographic jurisdictions of regulatory agencies and utilities would help simplify the analysis required to justify BMS adoption.

5.2.2 Ongoing Performance Criteria

Current incentive, certification, and compliance programs address the design and installation of low-energy systems. However, the performance of low-energy buildings may not meet design expectations and commonly degrade over time as systems get out of tune. To address this, ongoing performance criteria can encourage continuous monitoring and frequent, automated re-commissioning; LEED becomes Leadership in Energy and Environmental *Performance*.

5.2.3 Building Codes and Labeling Standards

Building codes and appliance standards are proven routes to energy savings. As the benefits of integrated energy systems are demonstrated, some elements of these systems may be successfully introduced into state building codes. Likewise, appliance *labeling* standards give system designers assurance that the various components of the designed system will work together as expected. Of course, the success of codes and standards depends on thorough enforcement of compliance.

5.2.4 Interdisciplinary Academic Programs

Interdisciplinary academic programs are necessary to train the labor force required to develop the BMSs of the future. These programs would integrate systems engineering, building sciences, and physics. Current rise of interest in this field justifies the development of an interdisciplinary curriculum and associated research centers. One exemplary program is the recently established Tsinghua University's United Technologies Corporation Research Institute for Integrated Building Energy, Safety and Control Systems in Beijing, China. In order to maintain the national competitiveness in this field, similar efforts should be pursued in the U.S.

5.2.5 Building Operator Education

Building operator education is also necessary to understand the benefits of controls and diagnostics and to understand and fully utilize BMSs. Building operators are typically extremely time-constrained; utilizing BMS needs to be presented as a time-saving technique rather than something that adds additional requirements. BMSs can save time by centralizing the specification of set points and schedules; automating routine control decisions; and minimizing maintenance requirements through automated fault detection, reduced need for routine maintenance, and a reduction in labor required for major repairs due to early fault detection.

5.2.6 Building Occupant Education

It is also important to pursue efforts in occupant education. In modern naturally convected buildings, a number of which exist on the UC Santa Barbara campus, the site of the workshop, occupants are not sufficiently informed about the need for opening windows and other operational aspects of living in such a "green" building. This can be achieved by using the existing IT infrastructure and developing educational applications on top of it.

5.3 Proof Point Development

Given the uncertainty in the business case for integrated energy systems (Section 4.2), wider adoption will require demonstrated value and performance. Proof points of value and performance must quantify benefits from numerous value streams in terms applicable to broad classes of potential host sites. Different classes of building will require different metrics; within each class, however, buildings can be assessed for savings potential and can be benchmarked to their peers.

Office buildings and university campuses would be ideal candidates for proof point development. Office buildings are ubiquitous, allowing for replicable projects. They are also well represented in trade associations such as the Building Owners and Managers Association International, which would be good platforms for disseminating proof points. University campuses typically contain a diversity of mixed-use buildings, with combinations of classroom, office, laboratory, food service, dormitory, and recreation spaces in each building, calling for sophisticated and versatile system designs and controls to achieve low-energy performance. The researchers and students from a variety of disciples provide the research capabilities necessary to improve systems and develop proof points. Universities typically have minimal concern over the privacy of energy consumption and equipment performance data.

6 Recommendations

Several distinct actors are necessary to bring about the previously described improvements. All of these actors must recognize the importance of integrated building systems and act accordingly to bring about the BMSs of the future that will be required for wider system adoption.

6.1 Research Organizations

Research organizations can advance the field by conducting research on topics such as the following:

- Quantifying efficiency gains from BMSs, and characterizing and reducing the amount of uncertainty in these estimates
- Developing data analysis and visualization tools that convert vast amounts of data into informative, useful, and actionable information for building operators and occupants
- Characterizing the supporting role that building occupants can serve in achieving energy efficiency through the use of BMSs (e.g., specifying schedules through in-room displays)
- Developing building simulation tools that account for building controls and occupant behavior
- Developing tools for continuous commissioning
- Developing building simulation tools to support systems engineering approaches to low-energy building operations.
- Fault detection to identify faults in equipment and operations early on, with minimal false positives

Another role for these organizations is to provide a forum for manufacturers, building owners, and other stakeholders to discuss the needs of the industry and to organize collaboratives to conduct research, implement demonstration projects, and develop standards for interoperability and cyber security. An important role for these organizations is to develop proof points on which emerging technologies can be tested and their performance compared. In such a rapidly changing field, the existence of benchmarks is a necessity.

Research organizations include universities, publicly funded organizations, not-for-profits, and privately funded organizations.

6.2 Universities

In addition to their role as a research organization, universities can also provide the interdisciplinary education required to develop the workforce necessary to build the BMSs of the future. As described earlier, disciplines would include systems engineering, building sciences, physics, and sociology. University campuses can provide a "living laboratory" for researching buildings, implementing BMSs, monitoring building performance, and providing hands-on experience for students. The development of an interdisciplinary curriculum would facilitate the creation of new programs on campuses that already house many of the component disciplines.

6.3 Building Operators and Users

In order for effective BMSs to be developed, building users will be needed to articulate needs and to host demonstration projects. Building users will need to articulate their priorities including energy efficiency, adherence to building climate set points, and participation in demand response activities; buildings will be required for in situ testing of new algorithms and equipment. Building operators will be needed to understand their capabilities and behavior in order to identify practical BMS solutions and potential areas for building operator education and reeducation.

As consumers, building users can apply pressure to manufacturers by insisting on features such as interoperability of components, usability of systems, and shared-risk contractual vehicles.

6.4 Standards Organizations

Developing standards for interoperability, cyber security, and lexicon will require the participation of standards organizations. Current building automation equipment use a diversity of building automation protocols, such as the data communication protocol for Building Automation and Control Networks (BACnet)[5] and the computer network protocol TCP/IP.[6] This diversity of standards results in products that are not interoperable and limits automation systems to equipment using the same standards protocols.

Other industries such as telecommunications and information technology have gone through this process; understanding the success of the standardization efforts in these fields and even employing some of the same personnel would provide a starting point for BMS standardization.

6.5 Regulatory Agencies

Regulatory agencies are capable of providing "push" and/or "pull" factors for BMS adoption based on their energy savings potential.

- Incentives for installing and maintaining BMSs, provided through regulatory agencies or mandated by them, will improve the business case for the systems.
- Incentives and regulations should go beyond system design and installation and be based on ongoing, whole-building performance.
- Regulators could develop cross-jurisdiction incentives that could support the economies of scale that geographically distributed corporations could benefit from in implementing corporate-wide BMS practices.
- Regulators could also require BMSs in building codes, although this would not impact the majority of buildings for many years to come given current low rates of building stock turnover.

6.6 Utilities

Energy utilities can support BMS adoption and use through the development of BMSs and whole-building-level incentives, as discussed above. Utilities can also participate in research and demonstration projects in order to inform their customers and advocate for this technology. An example of this participation is the Office of the Future (OTF) consortium,[7] through which utilities and research institutes have developed prototype office buildings that are 25 percent more efficient than current building codes and are now developing prototypes that are 50 percent and 75 percent more efficient than codes.

6.7 Manufacturers and Vendors

Adoption of BMSs would be enhanced by the cooperation of manufacturers of BMS components and building equipment. Their cooperation would be needed to develop standards, develop products that adhere to these standards, and conduct research and demonstration projects.

---

[5] BACnet was developed under the auspices of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

[6] The Internet Protocol Suite (TCP/IP) was developed by the United States Defense Advanced Research Projects Agency

[7] The OTF program is managed by the New Buildings Institute. More information about OTF can be found at <http://newbuildings.org/advanced-design/advanced-energy-office>.

7 Conclusions

Inefficiencies in building controls and operations consume a significant portion of societal energy; commercial buildings alone waste six percent of all U.S. energy consumed. Improved integration and control of building systems would significantly reduce this waste while providing the same level of service and comfort. Systems engineering provides a framework for achieving these savings; the approach takes advantage of beneficial interactions between spaces and their surroundings, rather than the traditional approach of isolating spaces from their surroundings and then controlling them.

While the energy savings of improved controls and operations alone may not justify the cost of improved building systems operation, additional value streams strengthen the business case. Intelligent buildings systems can identify faults and inefficiencies early on, before these problems consume much energy or cause significant damage. Fault detection therefore reduces energy consumption from faults and also reduces maintenance costs. Indirect benefits of improved building systems include increased occupant productivity and improved corporate image.

Many of the technology components necessary for integrated building systems exist, however, the tools necessary to design and build integrated systems are lacking. Existing equipment for building systems include the hardware to provide HVAC, lighting, and safety services, software to monitor and control this hardware, and infrastructure for hardware and software to communicate. The missing components that are necessary for system integration are component interoperability (communication standards and/or middleware could achieve this) and the design tools and expertise necessary to develop and assemble these integrated systems.

Near-term improvements are necessary to move the SEEEB field forward.

Technical improvements include:

- building simulation tools capable of capturing the dynamic activity of thermal system in response to the natural environment, occupant activities, and system controls;
- tools for fault detection and continuous commissioning; and
- system interfaces for improved usability by occupants and building operators.

Non-technical improvements include:

- incentives for whole-building energy savings;
- performance-based criteria for incentives and green building certification;
- academic programs to train systems engineers and develop innovative methods and tools; and
- building operator education.

Finally, proof points must be developed to demonstrate integrated system value and performance.

A broad range of participants will be required to bring this field forward:

- Universities and other research organizations are needed to develop and test technologies.
- Building operators and users are needed to articulate needs and host demonstration projects.
- Stakeholder consortiums and standards organizations are needed to standardize communications protocols.
- Regulatory agencies are needed to provide both the push (building codes and appliance labeling standards) and pull (incentives) to accelerate the market for integrated building systems.
- Utilities are needed to support system development, pilot system demonstrations, and proper incentive structures.
- Manufacturers and vendors are needed to work with all of the other stakeholders to develop and market the interoperable components of integrated systems.

the **INSTITUTE** *for* **ENERGY EFFICIENCY**

UC SANTA BARBARA