How to Bring Tomorrow Here, Sooner: Accelerating the Deployment of Intelligent Efficiency in Commercial Buildings

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ABSTRACT

Equipment and systems used in buildings are becoming adaptive to environmental inputs, anticipatory in their performance, and networked to one another within a facility as well as externally to other buildings. Based on the findings of a two-phase study by the American Council for an Energy-Efficient Economy (ACEEE), this paper summarizes enabling policies, program strategies, and the organizational approach required to accelerate the deployment of these phenomena, termed intelligent efficiency (IE), in the commercial buildings sector. Integration of information technology (IT) and building energy management is on the rise and the symbiotic benefits in annual energy cost savings are huge. However, to realize these savings, a number of factors have to fall into place—presence of building automation systems, availability of appropriate software solutions, financial incentives, and proven energy savings being some of them.

Cases of successful IE projects indicate that most of these have evolved through serendipity rather than a deliberate approach. We examine these early successes for critical success factors and tipping points and based on our analysis, we suggest necessary and sufficient conditions that catalyze an accelerated adoption of IE in the commercial buildings sector. We review key enabling technologies that constitute intelligent efficiency, take stock of new capabilities to analyze big data sets, and summarize industry-led efforts to develop standards for interoperability of network protocols. Our findings suggest that the government, utility program managers, and suppliers of IT and automation products have important roles to play in creating a macro environment conducive to adopting IE.

Introduction

Since the advent of the millennium, there has been a remarkable growth in the reach and capability of information and communication technology, or ICT, as the sector is collectively called. More and more aspects of our lives are now digitized, connected, and shared. New phrases like “big data,” “the Internet of things,” and “smart” everything are added to the lexicon every year. Considering that we spend 90% or more of our lives inside buildings (EPA 2009), it is inevitable that buildings, and devices within them, are also being swept away by the ICT wave. Big data though, is subject to big debate. The ability to monitor and control every device, every movement, every moment, raises concerns about privacy and freedom. The key, like always, is to harness technology “intelligently” so that the net effect is beneficial. The power of ICT when applied to energy use in buildings presents an enormous opportunity to save energy. The energy efficiency community has recognized this and there has been significant work over the last two years to define, demonstrate, and scale up what we call “intelligent efficiency” (IE).

“Smart” vs. “Intelligent”

A framework report by the American Council for an Energy-Efficient Economy (ACEEE) in 2012 (Elliott, Molina, and Trombley 2012) defines intelligent efficiency as “a systems-based, holistic approach to energy savings, enabled by information and communication technology and user access to real-time information. Intelligent efficiency differs from component energy efficiency in that it is adaptive, anticipatory, and networked.” Generally the word “smart” is used for equipment, appliances, or networks that have the ability to communicate digitally—send and receive information, and in most cases modify their behavior based on this communication. Smart electric meters, for instance, record and transmit near-real-time energy use data to the electric grid and can transfer demand response signals back to the building. The smart grid consists of smart meters and other components such as substations, transformers, switches, and more that have the capability to “talk” to each other. Smart buildings have sensors and controls that communicate with a central building automation system. When referring to intelligent efficiency, we do not mean any one of these on their own; rather, we imply an approach by which such interconnected devices can be used to harmonize their operations to achieve systemwide energy savings. Figure 1 shows how various smart technologies work together to create an intelligent system. The system boundaries can be extended in either direction—smart grid on the supply side and intelligent communities (and even cities) on the demand side.

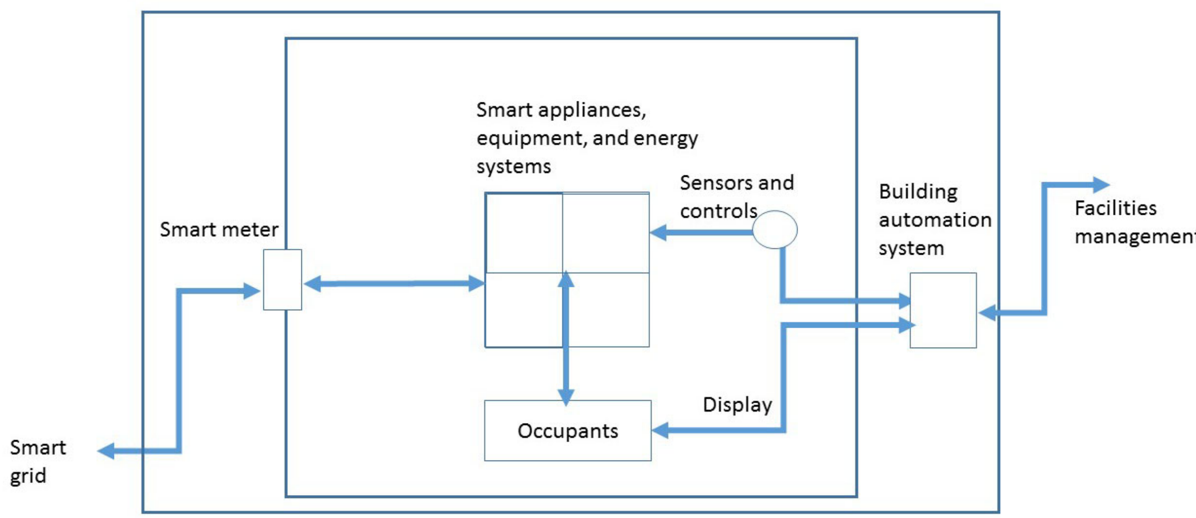

Figure 1. Using smart components to build an intelligent system.

In the second phase of ACEEE’s work on IE (Rogers et al. 2013), we estimated the long-term potential for energy savings from the implementation of IE in the commercial and industrial sector. Continuing this narrative, we now present a list of critical factors and enabling policies to expedite realization of the potential of intelligent buildings. We retain our focus on the commercial sector, as we believe commercial buildings are more ready for implementation of IE projects because they tend to be large energy consumers, have high levels of broadband communications interconnection, and have relatively wide implementation of sensors and controls, which represent important enabling infrastructure within which IE projects can successfully be integrated. We begin with a critical evaluation of barriers and challenges identified in the 2013 report and supplement our earlier recommendations through the evaluation of successful case studies of intelligent commercial buildings.

Methodology

Over the course of the last two years, our deliberations have been guided by a team of advisors[1] consisting of IT representatives, efficiency program administrators, manufacturers of building automation systems, and leading researchers in this space. Additionally, we interviewed building managers and analyzed case studies of buildings that have benefited from deploying intelligent systems. A more detailed discussion of our findings, including the economic potential for savings from IE, has been published in two previous reports by Elliott, Molina, and Trombley (2012) and Rogers et al. (2013). In this paper, we summarize key concepts from those and, based on updated information from our continuous engagement with stakeholders, try to answer the questions of what is required and what has worked so far in implementing an intelligent approach to energy efficiency. Our analysis is bifurcated into two parts: key enabling technologies, which provide the foundation for systems and processes to work intelligently; and key success factors that facilitate the adoption of intelligent efficiency.

To delineate the boundaries of IE and to distinguish it from other energy efficiency measures, we developed a heuristic, shown in Table 1, for determining when a technology reached the level of IE. To aid in this determination and to help the reader categorize and compare technologies along this evolutionary scale, we devised a simple hierarchy.

Table 1. A hierarchy of technological intelligence

Level	Attributes	Example
Level 0	Manual on/off	Simple on/off light switch
Level 1	Reactive on/off	Occupancy sensor for lighting
Level 2	Programmable on/off	Programmable thermostat
Level 3	Variable response	Dimmable lights with daylight sensors
Level 4	Self-learning, adaptive system with variable response	An HVAC system that receives inputs from sensors, weather data, occupancy schedule; remembers users' preferences and has the ability to ramp up and down as required

Source: Adapted from Rogers et al. 2013

The higher levels do not automatically translate into greater energy savings; for example, a reactive control for lighting in some applications will save as much or even more energy than a programmable system. Rather, the level speaks to the complexity of the system. In our selection of technologies, when the line between levels was blurred or the incremental savings between levels was hard to discern, we grouped the levels together. An example of this is our treatment of lighting at Levels 3 and 4: A system organized around intelligent efficiency would provide only as much light as needed in the locations needed and only at the times needed by workers to accomplish the required tasks.

[1] Please refer to Rogers et al. 2013 for constituents of our advisory team.

Key Enabling Technologies for IE

We placed IE elements into the following categories: smart building components, smart lighting, smart HVAC components, advanced building automation systems (BASs), and smart power grids. Buildings conforming to our definition of IE have most if not all of these components. Although there are benefits from each of these on their own, for true systems-level benefits, these technologies have to work together. We list these in an ascending order of scale of impact here.

Smart Building Components

New developments in materials science are giving us materials that are reactive to environmental conditions and can be designed to make a building more energy efficient. For example, it is now possible for windows to lighten and darken depending upon the intensity of sunlight. This reduces the air-conditioning load in the summer and the heating load in the winter. It also can improve the work environment by reducing glare. A recent study by the Lawrence Berkeley National Laboratory found that smart windows alone have the potential to reduce energy use for cooling by 19 to 26% and lighting by 48 to 67% (Lee 2007). Other products, such as grid-responsive refrigerators and dishwashers have been commercially available for some time. Ceiling fans that inform and regulate the thermostat are in development. Much other smart equipment makes it to Level 1 or Level 2 of our hierarchy defined above. Some examples are advanced power strips, computer power management systems, and smart elevators and escalators.

There continue to be incremental gains in the area of lighting. When a BAS has information related to current and future occupancy, it can not only bring lights on and off at optimal times and luminosities, but also do a comparative analysis of whether the impact on HVAC energy use that results from lightening smart windows and letting in sunlight will be less or more than darkening the windows and turning the lights up. A report by the Northwest Energy Efficiency Alliance (NEEA 2013a) and claims by Osram Sylvania (Osram Sylvania 2013) indicate potential savings of 40 to 75% beyond what is possible with standard occupancy-based lighting controls.

Technologies now coming on the market enable each subset of a BAS to self-optimize. For example, advanced control strategies for packaged HVAC systems that customize the air conditioning to the needs of the occupants using technologies such as multi-speed fans and demand control ventilation, result in cost savings ranging from 24% to 32% depending on the building type (Wang 2011).

Advanced Building Automation Systems (advanced BASs)

New-generation BASs have the capability to provide performance monitoring and analyses at both the system and whole-building levels. Facility managers no longer need to walk around their buildings looking for problems; instead the system identifies a fault and either self-corrects or directs the manager to the problem. The difference between a Level 3 BAS and a Level 4 BAS is the ability of the latter to perform continual optimization. The energy savings due to intelligent efficiency is the difference between a system that is occasionally optimized and one that is always optimized and continuously improving. Research done by the Pacific Northwest National Laboratory (PNNL), the National Institute of Standards and Technology, the

Natural Resources Defense Council, and Energy Design Resources found savings ranging from 24–46% for enabling Level 3 BAS and an additional 10–30% with intelligent Level 4 systems that have automated fault detection and diagnostics, historical analysis, and predictive capabilities (Wang et al. 2011; Sinopoli 2010; Henderson and Waltner 2013).

Smart Grid

Still in its infancy, the smart grid is an interactive electricity grid that will be able to communicate information between the utility and individual buildings, and possibly even systems within buildings and facilities, in real time. This information, likely a locational and time-of-day price signal, can be used by the BAS to determine how to run the building to minimize energy costs by optimizing demand and minimizing use of energy. A study by PNNL indicated that electric utility customers could realize 10% energy savings through transactive controls[2] (Katipamula et al. 2006).

In addition to utility build-out of transmission and distribution smart grids, large commercial and industrial customers are building their own smart grids within their facilities. To do so, they install smart meters that make their energy consumption visible at a system level. The cost of such meters has fallen 30% in the last two years (SmartGridNews.com 2013). Energy service companies such as BuildingIQ, Ecova, EnerNOC, Schneider Electric, and Siemens are expanding into this market, currently estimated to be $6.2 billion in sales (SmartGridNews.com 2013), with services that can leverage these smart meters into energy management systems that provide clients with real-time energy management capabilities.

Key Success Factors

IE is not any single technology, but rather an approach that leverages the power of IT to optimize the energy use of buildings. Adoption of IE is not straightforward since it embodies a number of different technologies and requires a strategic vision of building energy management. While a number of developments have come together in the last few years that promise a bright future for this approach, we explore factors that have the potential to act as catalysts to expedite first the adoption and ultimately the diffusion of intelligent efficiency. IE offers opportunities for new and significant energy savings. However, energy savings are not the dominant force driving its adoption. There are a number of other variables that have to fall into place before a building can become truly intelligent. Some of these are within the sphere of control of the building owners and managers and others are broader changes that can provide a conducive environment for IE. In the next sections, we zoom in from the macro level to the organizational level to classify these factors.

Big Data and Data Analytics

The increasing volume, velocity, and variety of information available in every sector of the economy have exploded in recent years. Advancements in sensors, smart meters, data collection, data storage, and computational capabilities have transformed the way we think about data and ushered in an era of very large data sets popularly known as "big data." Big data and

[2] The term "transactive" refers to managing the supply, distribution, and demand of energy (usually electricity) based on the value of a triggering transaction such as the time-of-day price. For a basic discussion of how this works, see here http://www.gridwiseac.org/about/transactive_energy.aspx.

data analytics are fundamental to IE, as they enable all of the computational and optimizing abilities described thus far in this report. However, before BASs can provide management with better information or improve the effectiveness and efficiency of devices and systems, they must be programmed to gather the most pertinent data and to use that massive amount of data to produce useful information. The sheer volume of data taxes the IT systems of many small and medium-size businesses. Larger operations may have the ability to store the data, but are often unable to turn it into useful information.

As the repository of some of the biggest nationwide data sets, the federal government can take the lead in demonstrating benefits from managing aggregated data. An example of large-scale data mining is the Open Data Format Initiative that makes available energy consumption and intensity data from all government buildings (Whitehouse.gov 2011). From these data, building energy consumption trends have been identified and new data mining efficiency products and services have been created (Whitehouse.gov 2013).

Utilities also have a role to play in demonstrating the power of big data to help customers reduce energy usage. Some utilities and the commissions that regulate them are already considering how this might evolve. The California Public Utilities Commission held an information exchange event in April of 2013 to educate commissioners and staff on how energy consumption data can be utilized to evaluate the effectiveness of policies and programs and the availability of such data (CPUC 2013).

Several utilities and grid operators have come together to form the Open Automated Demand Response Alliance and a new protocol for communicating demand response information. OpenADR is an open and standardized way for electricity providers and electricity system operators to communicate demand response signals with each other and with their customers using a common language over an existing network such as the Internet (OpenADR Alliance 2013). Before a request for demand reduction is sent, the need must first be identified. This requires analyzing large volumes of data and determining the optimum response. This collective effort and common protocol could be a foundation for utilities and their customers to analyze, manage, and communicate energy data.

Interoperability of Networks

Scores of manufacturers are involved in building and manufacturing automation, and many of them have their own software programs. These programs are often not consistent in how they communicate energy data (ODVA 2011). Process control and automation systems are often installed in piecemeal fashion, and since most facilities do not have the option to choose only one vendor for all of their automation needs, they are left with the choice of either having systems that cannot communicate with each other or having them do so through some type of translation process. (M. Burgoon, Rockwell Automation, pers. comm., August 9, 2013).

There are already several industry-led efforts to develop interconnection standards for industrial equipment and systems, three of which are focused on the problem of communicating energy data. Cisco Systems, Rockwell Automation, and Schneider Electric are working with ODVA, a global association of leading automation companies, to develop an international energy communication protocol, CIP Energy, based on the Common Industrial Protocol (CIP™) architecture, that is designed to transform the way manufacturers monitor and control energy usage by providing a common-command interface and network-visible data structure (Lydon 2011; Rockwell 2011). It is an extension of the popular protocol at the heart of EtherNet/IP™ (ODVA 2011). The specification for CIP Energy includes attributes and services that help system designers reduce the cost and time to implement energy-improvement projects. CIP Energy makes operational energy consumption data available at the network level, enabling manufacturers to optimize energy usage during production and diagnose potential problems at the process or even machine level (Rockwell Automation 2011).

The Information Technology Industry Council is working with National Institute of Standards and Technology, the White House Subcommittee on Standards, and other agencies to promote voluntary standards for ICT (ITIC 2013b).

The Energy Information Standards Alliance (EIS Alliance), a trade association for companies that provide energy management and smart-grid products and services, has been involved in developing a common framework for customer equipment to use, generate, and communicate energy data. They have collaborated with the DOE initiative to implement simple consumer energy management system products under the "Green Button" label (EIS 2012).

Common Protocols for Determining and Attributing Energy Savings

Energy management protocols such as the International Performance Measurement and Verification Protocol[3] are giving programs the ability to measure energy savings with increased accuracy. These protocols can be and in some cases already are being incorporated into advanced BAS and smart manufacturing control systems. Intelligent efficiency platforms, such as the Panoptix® Energy Performance Monitor app, can provide the analytics to measure and verify the savings of operations.

The many companies engaged in developing and selling IE products and services can seek opportunities to collaborate on noncompetitive research and development as well as to educate about and create awareness of the benefits of ICT. Activities such as those by the Information Technology Industry Council to bring awareness to IT issues within policy circles and by the EIS Alliance to develop a common communication framework for equipment to generate, communicate, and use energy data (EIS 2013) are all examples of what is helpful and necessary to move the adoption of intelligent technologies forward. Only the companies engaged in this sector have the detailed understanding of the many unique software products that are needed to enable the level of interoperability that will facilitate greater market penetration of IE technologies.

Organizational Factors

Energy efficiency, in general, is rarely a priority for organizations. Most often, efficiency measures are implemented based on expediency to save on costs in the minimum span of time. It takes visionary thinking and strategic planning to invest in a high-cost, long-term approach. In our phase II report (Rogers et al 2013), we cite several case studies demonstrating the organizational process for adopting IE. One thing we found in common across organizations is the presence of an "efficiency ambassador"—usually a senior employee who champions the cause of IE. For instance, in the case of Microsoft, Darrell Smith, Director of Facilities and Energy, provided the vision and leadership for deploying IE solutions at their Redmond campus. Like other comprehensive projects, IE projects require significant initial investment, but the energy cost savings far outweigh the costs. Smith's team at Microsoft implemented changes that

[3] For more on the IPMVP, see the Efficiency Valuation Organization website: http://www.evo-world.org/index.php?lang=en

resulted in annual energy cost savings of $1 million, with a payback of only two years. Organizations that experience positive initial results from efficiency projects are more likely to embrace the concept of IE.

Enabling Policies and Programs

With the potential to produce a step change in energy efficiency and the associated cost savings throughout the economy, IE is an ideal strategy for government policies and ratepayer-funded efficiency programs to encourage.

Codes and Standards

Building energy codes and equipment energy conservation standards play a significant role in determining the minimum energy efficiency requirements for buildings. However, currently codes and standards are based on a prescriptive approach that emphasizes efficiency for individual components. Shifting to a whole-building performance-based approach offers the potential for maximum efficiency gains (Kwatra and Essig 2014). Systems-based IE applications are best placed to provide the analytical rigor and the technological control needed to optimize whole-building energy performance.

Role of the Government

The federal agencies that consume a great deal of energy can lead by example through incorporating smart BAS and other IE measures into their buildings. Government also has a role to play in catalyzing innovation by funding research, development, and demonstration projects. Current examples include the funding of pilot projects that include the software, firmware, network, and data analytic components of smart manufacturing at Department of Defense facilities, smart-grid research projects by the DOE at its national laboratories, development of communication standards by National Institute of Standards and Technology, and demonstration of performance contracting by the General Services Administration (Ye and Seidel 2013; ITIC 2013b). As the technology continues to evolve, so too can the projects these agencies use to demonstrate and realize the benefits of intelligent efficiency.

Leveraging Energy Efficiency Programs

Leading efficiency programs are seeking new approaches to gain greater volumes of energy savings from each customer and an emerging trend is to create programs that capture savings from multiple systems in one project, such as whole-building retrofits and building automation. What is promising about including smart automation and controls in efficiency programs is that if done right, it will not only provide additional savings, but also will provide an improved measurement capability. Advanced BASs now have the ability to measure current performance, compare it with past performance, and then forecast future performance. This solves the issues of attribution and energy intensity. The IE measures can track energy consumption at the device level, match that with facility use, and provide both facility operators and efficiency program administrators with energy performance data and forecasts that they can use to forecast future energy resource needs. Moreover, since this is an automated process, the exchange of information can happen in or near real time and at a lower cost than conventional data collection and reporting.

IE provides an opportunity to move from energy efficiency programs that are device based to comprehensive performance-based programs. Performance information is reported to the program administrator and the incentive paid is based on energy saved. Programs may provide the bulk of the incentive up front based on forecasted energy savings and later, as actual performance is reported, the balance is released. That balance may increase or decrease depending on whether more or less energy has been saved than forecasted, and it may be released over a period of one or more years. The New Jersey and New Hampshire Pay for Performance programs have experienced excellent results using this strategy (Kwatra and Essig 2014).

Inclusion of intelligent efficiency in performance contracts is increasing. The DOE is investigating the use of performance contracts to fund upgrades in IT and data centers (Ye and Seidel 2013). Johnson Controls includes BASs in most of its performance contracts because of the additional energy savings they provide and because they simplify performance monitoring. (C. Nesler, VP, Johnson Controls, pers. comm., September 9, 2013).

Conclusion

Intelligent efficiency is making possible new levels of energy consumption analysis and energy management. This will have broad implications for building energy operations. Building operators now have the ability to learn immediately when systems start to operate outside of normal parameters, thereby enabling them to dispatch service technicians to address small problems before they become big problems or, at the very least, use energy unnecessarily.

Many of these smart technologies are already cost-effective and therefore we can anticipate that a great deal of economic activity will happen with little or no influence from the public sector; however, there is an opportunity to leverage IE for public policy goals. With their potential to bring about new levels in energy savings nationwide, IE measures appear very likely to become part of state-level efforts to reduce energy consumption in the commercial and industrial sectors.

This previously unavailable method to save energy is attributable to IE systems' having the ability to determine the baseline energy consumption for multiple operating conditions, to monitor energy consumption and production inputs and outputs, to identify correlations that can be used to determine current energy savings, and to forecast future energy use.

Adding the financial resources that are currently funding conventional utility investments and device-level energy efficiency investments into the total investment mix targeting IE would mean an accelerated adoption profile for IE measures.

This is an opportunity that federal and state policymakers, utility regulators, energy efficiency program administrators and evaluators, and vendors of ICT products and services should embrace.

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