Intelligent Efficiency: Opportunities, Barriers, and Solutions

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Executive Summary

Information and communication technologies (ICT) are making possible analysis and levels of performance that could not be achieved as recently as ten years ago. Equipment and systems used in buildings, transportation, and manufacturing are becoming adaptive to environmental inputs, anticipatory in their performance, and networked to one another within a facility as well as throughout a supply chain. They display intelligent efficiency. This is the term used by the American Council for an Energy-Efficient Economy (ACEEE) for the deployment of affordable next-generation sensor, control, and communication technologies that help us gather, manage, interpret, communicate, and act upon disparate and often large volumes of data to improve device, process, facility, or organization performance and achieve new levels of energy efficiency.

These intelligent or smart technologies exist along a continuum of complexity and potential for energy savings. The defining feature of an intelligent efficiency technology is its ability to communicate and receive communications, and to respond to the external stimuli. More than being programmable or having variable responses, intelligent efficiency technologies respond, adapt, and predict. In the next two to three decades, these new capabilities will affect every sector of the U.S. and global economies and will bring about efficiencies that we are only beginning to understand. In this report we continue our effort to describe the integration of intelligent efficiency into specific sectors of the economy and to quantify the magnitude of the energy efficiency benefits that will be possible with this emergent portfolio of ICT capabilities.

Since the release of our first report on intelligent efficiency in 2012, *A Defining Framework for Intelligent Efficiency* (Elliott et al. 2012), it has become clear that the best near-term opportunities for the application of intelligent efficiency are in the commercial and industrial sectors. These sectors embrace automation more rapidly than do the public, transportation, and residential sectors due to the need for businesses and manufacturers in a competitive environment to sharply control their operating costs.

THE POTENTIAL

It is estimated that the building automation industry will reach $43 billion in sales by 2018 (ABI 2013). The growth of manufacturing sector automation may be even greater, reaching over $120 billion by 2020 (Cullinen 2013, Navigant 2012). We estimate that the annual energy cost savings of intelligent efficiency technologies for the commercial and manufacturing sectors could exceed $50 billion.

In addition to this next step change in energy savings, system optimization also brings non-energy benefits including better services and, in industry, better quality control. Lower operating costs free up capital, making it available for additional investments in productivity and capacity.

HOW INTELLIGENT EFFICIENCY SAVES ENERGY

Intelligent efficiency approaches offer three ways for businesses and manufacturers to save energy, as well as provide a mechanism for greater efficiency—and productivity—overall. First, intelligent efficiency achieves energy savings not only at the device level but at the system level and above. Intelligent efficiency approaches utilize ICT-based enabling technologies such as wireless thermostats and variable speed drives that are highly efficient in and of themselves. Then, going beyond these devices, intelligent efficiency uses a systems approach and takes into account the purpose or goal of the system and optimizes the behavior of the system's components relative to one another to achieve that goal. Specifically, the system approach requires the component parts to modulate their operation in harmony with each other and the needs and demands of the larger system. These components (highly efficient when in use) may slow or stop when other elements of the system or the supply chain communicate that they are not needed. These components also communicate their own activity to others whose activity, in turn, depends on theirs. As a systems approach, intelligent efficiency involves integrating the performance of a suite of individual technologies to function as a network.

One of the clearest manifestations of intelligent efficiency and its ability to improve efficiency through networks and system optimization is the emergence of the "Internet of Things" or the "Industrial Internet." All of the components of a manufacturing system can inform other parts of the system of their situation and react to incoming information from them. The more connected the components, the more powerful the network.

Equipped with sensors and communication capabilities, objects as small as shipping labels and as large as factories can communicate current data that enable other components and systems to react to situational changes such as a machine going down unexpectedly. The full integration of smart technology will connect facility operations to corporate enterprise management, and a corporation's system will be linked with similar systems throughout supply chains. This linkage will help to coordinate a facility's operational objectives with the corporate financial objectives as well as connect both with the corporation's energy and sustainability objectives. Intelligent efficiency has the potential to make systems, processes, facilities, and entire organizations more energy efficient and more efficient overall.

In the manufacturing sector, the networking of devices—machine-to-machine or M2M device—creates a new capability called smart manufacturing. Machine-to-machine is currently being applied in a limited fashion to specific processes, but it is only a matter of time before entire supply chains are integrated and M2M become the backbone for the industrial environment, as the application of intelligent efficiency moves from tactical to strategic. Modeling and simulation systems will be used to incorporate intelligent efficiency into initial product development and design as well as in the development of integrated facilities and processing operations. This intelligent efficiency–based process design will drive capital projects and investments, allowing a system-level efficiency to have its greatest expression and reap the greatest benefits.

One of the more vexing challenges in the energy efficiency sector is ensuring that the savings that result from an efficiency measure persist over time. Operators of complex production processes and managers of facilities that are heated, cooled, and ventilated are accustomed to the decline in energy savings that typically occurs in the months and years following the implementation of energy efficiency measures. Intelligent efficiency can prevent this decline. The self-diagnostic, comparative, and anticipatory analytical capabilities of smart devices reduce the amount of time a system spends outside of optimal operating parameters. In some instances, systems will be able to use large volumes of historical data in parallel scenario modeling to create more efficient ways of operating and increase the efficiency of the system over time.

Another way that intelligent efficiency saves energy in the commercial and industrial sectors is by eliminating the need for energy-consuming equipment or by replacing it with a device or service that uses much less energy. The primary example is cloud computing, which eliminates the need for every office and factory to have its own servers. For most businesses and other organizations, the traditional practice has been to support employees' desktop and laptop computers with a dedicated, local computer network. An increasingly popular alternative now revolves around intelligent efficiency: organizations are providing many information technology (IT) services through cloud computing, which relies on large servers located in off-site data centers that provide computing, storage, and software services connected to the user via the Internet. The energy used by centralized data centers is much less than would be used collectively by the individual companies with their local servers.

Intelligent efficiency also improves an organization's analytical capabilities. A property management company that oversees a dozen buildings may not be able to afford to put a full-time technician in each building to monitor and optimize it. If each building has an HVAC system controlled by an advanced building management system (BMS) that is networked to a central location, a small team of technicians can achieve better results than individuals in each building. Instead of technicians spending time searching for problems, the advanced BMS identifies and prioritizes them, and technicians travel to each building only as needed.

ECONOMIC ANALYSIS OF WIDESPREAD ADOPTION OF INTELLIGENT EFFICIENCY

To quantify the potential economic benefits of intelligent efficiency if it were implemented nationwide, we calculated the estimated effects of a select group of "smart" energy efficiency measures that have the most promise for near- and medium-term implementation in the commercial and manufacturing sectors, sectors with the greatest readiness for the implementation of intelligent efficiency projects. Based on prior research examining the success of efficiency programs to encourage market uptake of energy efficiency measures, we estimated that half of the commercial and manufacturing sector will adopt intelligent efficiency approaches at some level over the next 20 years (Nadel et al. 1994).

One of the challenges of our economic analysis was to separate the marginal gain in energy efficiency attributable to intelligent efficiency from the efficiency provided by the enabling technologies alone—in essence, determining when an energy measure is more than a device and becomes an intelligent energy measure that is networked, adaptive, and/or anticipatory. To accomplish this, we developed a heuristic that classified energy measures into five categories of increasing complexity. Only Level 4 measures were included in our analysis.

We analyzed over two dozen technologies for their ability to affect energy use in the commercial and manufacturing sectors, ultimately selecting a dozen for inclusion in the final analysis. Each of the Level 4 energy measures we included has broad applicability, a likelihood of reaching more than 25% of its respective market by 2035, and the ability to produce savings that could be sustained for the life of the product.

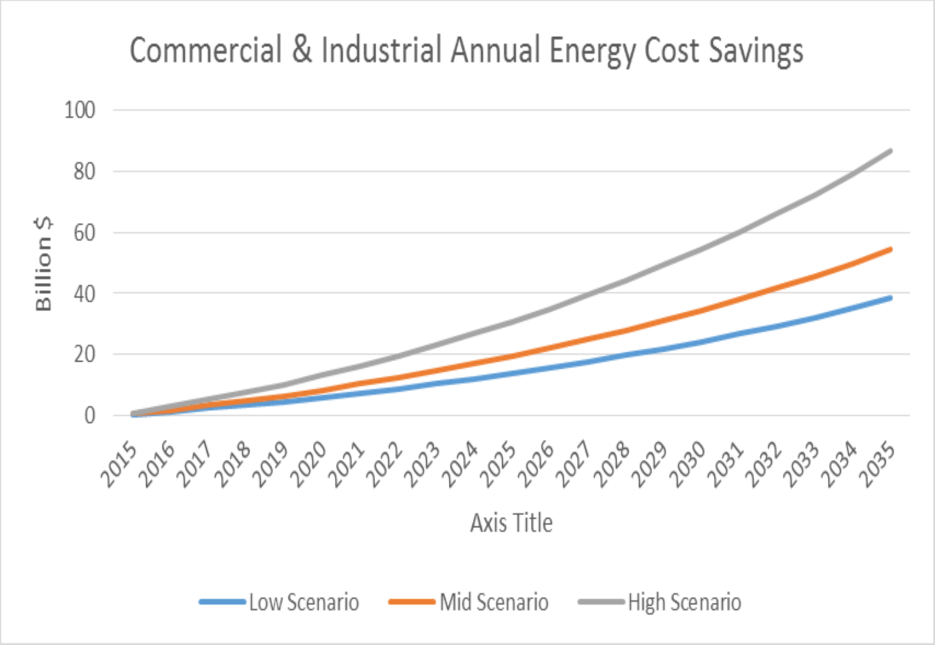
Table ES-1. Five Levels of Energy Measures

Level	Technology
Level 0	Manual On/Off
Level 1	Reactive On/Off
Level 2	Programmable On/Off
Level 3	Variable Response
Level 4	Intelligent Controls

We developed an estimate of the percent savings a commercial or manufacturing facility might expect for each intelligent efficiency measure using data from the U.S. Energy Information Agency (EIA) Commercial Building Energy Consumption Survey (CBECS) and Manufacturing Energy Consumption Survey (MECS), as well as data gathered during our literature search and discussions with energy efficiency and facility automation experts.

We then used the estimated energy savings to forecast energy cost savings by using EIA 2013 Annual Energy Outlook forecast data. We performed a sensitivity analysis with an estimate that the error of the 50% target is in the range of +/- 50%. These three scenarios are presented in Figure ES-1 below as the low, mid, and high scenarios. The analysis assumes a relatively modest increase in investments of 1% per year early in the 20-year period growing to 2% by the end of the period.

Figure ES-1: Projected Energy Cost Savings from Intelligent Efficiency



The analysis determined that the industrial sector could save between $7 and $25 billion in energy costs per year by 2035 while the commercial sector stands to save $30 to $60 billion. Given that even at the low end of these estimates, the economic impact on energy consumption in these sectors will be significant, consideration of intelligent efficiency technologies in energy efficiency programs and policies is warranted. Program developers and administrators, and public utility commissions can look to intelligent efficiency to achieve near- and long-term goals for acquisition of energy efficiency resources.

BARRIERS TO THE ADOPTION OF INTELLIGENT EFFICIENCY

Barriers to rapid market acceptance arise with every leap in technology, and intelligent efficiency is no different. Our first report identified a number of social, financial, and structural barriers to broader acceptance of intelligent efficiency:

- **Social barriers** that reflected a lack of awareness among consumers and policymakers about intelligent efficiency technologies and their associated benefits;
- **Financial barriers** such as the upfront costs of implementing these new smart building and manufacturing technologies and networked systems; and
- **Structural barriers** including incompatible communication strategies and platforms for smart devices, different methods of reporting energy savings information, and legal and regulatory structures in the utility sector that lead to utilities' efficiency programs favoring assets over services.

Since our first report, we have gained greater clarity on a number of barriers, and new issues have arisen as intelligent efficiency has evolved in the marketplace. Some barriers are already known and quantified, while others are still emerging.

Social barriers are largely being addressed through efforts to educate consumers and through the continual improvement of data security. Additionally, many of these social issues are part of larger societal challenges not specific to energy efficiency and therefore beyond the scope of this report. Financial barriers are not significantly different from those related to the adoption of other energy measures, namely, the challenges of financing capital investments in tight economic times.

A number of the technical challenges associated with deploying intelligent efficiency involve getting it to function effectively for end users. Many companies are just starting to harness the flood of energy data available to them through ICT-enabled devices. In addition, energy data may not be communicated consistently between systems and between platforms. Data from one system often must be translated before being used by another. This translation is inefficient and may lead to misinterpretation. Misinterpretation is also an issue with the determination of energy savings data. Since characterizing the volume, time, and quality of energy savings can be challenging, it is important that everyone who uses the information agrees on a common language.

Structural barriers also exist in the utility sector, specifically, in utility-run energy efficiency programs. Traditionally, these programs have focused on providing incentives for energy consumers to purchase more efficient equipment and devices. Intelligent efficiency approaches have the potential for large savings from some of utilities' largest customers; however, the efficiency measures that support intelligent efficiency tend not to be devices, at least of the sort that utilities are accustomed to supporting—rather, the efficiency is gained from a utility customer installing software or subscribing to an outside service (for example, cloud computing). Utilities' method of paying for the implementation of an efficiency measure does not capture the full efficiency benefits of intelligent efficiency systems. In addition, the time lines of efficiency programs often do not mesh well with the implementation schedules of the large, complex projects that can offer the deepest energy savings. And utilities face an attribution challenge, faced with the need to identify the source of energy savings and to distinguish between savings provided by individual devices versus savings provided by intelligent efficiency systems more broadly. Public utility commissions, utilities, program administrators, and vendors of intelligent efficiency technologies will need to work through the details of including these automation and intelligent energy measures in program offerings if the energy savings of intelligent efficiency are to be realized.

OPPORTUNITIES AND OVERCOMING BARRIERS

With their potential to bring about new levels of energy savings nationwide, intelligent efficiency measures appear likely to become part of state-level efforts to reduce energy consumption in the commercial and industrial sectors. What makes this even more promising is that many intelligent efficiency measures can provide more efficient, accurate, and timely measurement and verification (M&V) data than currently available. Leading-edge advanced building management systems and smart manufacturing control systems will be able to

- determine baseline energy consumption for multiple operating conditions.
- monitor energy consumption and production inputs and outputs.
- identify correlations that can be used to determine current energy savings.
- forecast future energy use.

This information could be provided to energy efficiency programs, thereby simplifying their M&V efforts.

These analytical capabilities also make it possible to determine energy savings on a real-time basis, and that capability in turn opens up the opportunity for energy-efficiency programs to pay for performance rather than for implementation. Programs will not only have new opportunities to secure energy savings, they will also have access to savings that are more enduring than previously possible through automation. The M&V will be of higher quality and both the achievement of savings and the M&V will be more cost effective

Before that is possible, however, it will first be necessary to create protocols to communicate and validate the energy data. To address this need, several collaborative efforts to develop common communication protocols have arisen across the country. 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 based on the Common Industrial Protocol (CIP™) architecture called CIP Energy (Automation.com 2011). The CIP Energy initiative is one of many private-sector collaborations discussed in this report that are helping to overcome barriers to the communication of energy data and the validation of energy savings. With common protocols for communicating information and connecting devices and systems, the private sector will be poised to grow the market for intelligent efficiency.

Structural barriers also exist in the utility sector, where efficiency programs tend to provide incentives to purchase devices rather services. Programs often have timelines that do not always mesh with the implementation schedules of larger, more complex projects that can offer the deepest level of energy savings. Public utility commissions, utilities, program administrators, and vendors of intelligent efficiency technologies need to work through the details of including these automation and intelligent energy measures in program offerings if these savings are to be realized.

Going forward, more research is needed around the logistics of incorporating intelligent efficiency into utility-sector energy efficiency programs. What types of projects might be eligible and how would they be incented? Such research could lay the foundation for demonstrations of building or plant automation systems that provide real-time energy performance data and utility efficiency programs paying customers not for equipment installed but for energy saved.

LOOKING AHEAD

Intelligent efficiency is making possible new levels of energy consumption analysis and energy management. These advances will have broad implications for building operations and manufacturing production management and control. Building operators now can learn immediately when systems start to operate outside of normal parameters, thereby enabling them to immediately dispatch service technicians and thus save money. Manufacturers can network entire production lines, even supply chains, in order to realize marginal savings at every point in the system.

More research is needed on intelligent efficiency going forward. Such research could lead to demonstrations of building or plant automation systems that provide real-time energy performance data, and eventually to utility efficiency programs that pay for energy saved rather than equipment installed.

Working together, utilities, public utility commissions, building operators, manufacturers, and equipment vendors can overcome the technical barriers to intelligent efficiency. Over the next two to three decades, we will see these new capabilities in every sector of the economy, enabling them to achieve new levels of energy efficiency. Multiple additional economic benefits are possible besides direct energy savings. Intelligent efficiency will reduce costs, improve product quality and employee satisfaction, and make companies more competitive.

Introduction

A number of stakeholders, including people in both the public and private spheres, agree that intelligent efficiency will generate massive economic benefits—$55 billion in annual energy cost savings by our estimate—in the near future. Intelligent efficiency is the term the American Council for an Energy-Efficient Economy (ACEEE) uses for the deployment of inexpensive next-generation sensor, control, and communication technologies that collectively enhance our ability to gather, manage, interpret, communicate, and act upon large volumes of data to improve device, process, facility, or organization performance and achieve new levels of energy efficiency. Equipment and systems used in buildings, transportation, and manufacturing are becoming adaptive to environmental inputs, anticipatory in their performance, and networked to other devices and systems. The empowering hardware and software products that form the backbone of intelligent efficiency are information and communication technologies (ICT), and these are making possible analysis and levels of performance that could not be achieved as recently as ten years ago. Building management systems (BMSs) can now determine immediately when a boiler or chiller has begun to operate outside of normal parameters and dispatch a service technician to address the problem, and production management systems can slow down or turn off equipment in response to the production demands of the day, or even the hour (Fernandez et al. 2009)**.** In the next two to three decades, these new capabilities will affect every sector of the economy and bring about efficiencies that we are only beginning to understand. How great might the benefits be when business offices and production departments of companies throughout a supply chain—from raw material suppliers to manufacturers to transportation companies to retail establishments—are all networked so that performance of and demands on one are communicated in real time to all the others in terms that enable each of them to adjust its performance accordingly? Or if the performance over the past ten years of the air-conditioning systems of several dozen similar buildings can be combined with the weather forecast for the next week to optimize the setting of a an individual building’s air conditioning system for the next day’s operations?

ACEEE first began to define intelligent efficiency in the report, *A Defining Framework for Intelligent Efficiency* (Elliott, Molina and Trombley 2012), offering examples and case studies and identifying steps policymakers could take to accelerate its adoption. Since the report’s release, other organizations such as the Center for Climate and Energy Solutions (C2ES) and the Global e-Sustainability Initiative (GeSI) have expanded on this subject, examining the potential of intelligent efficiency to reduce government agencies’ energy expenses and reduce emissions of greenhouse gases around the world. This report represents the next stage, to transition from definition and description to a focus on more strategic forms of analysis. What is the economic potential of intelligent efficiency, and how can consumers, policymakers, and the energy sector embrace it? What are the opportunities to accelerate its adoption? What are the challenges to making that happen?

Since the release of the first report, we have come to understand that the best near-term opportunities for the application of intelligent efficiency are in the commercial and industrial sectors. These sectors embrace automation more rapidly than do the public, transportation, and residential sectors due to the need for businesses and manufacturers in a competitive environment to control their operating costs. The companies that supply the commercial sector with automation—the building automation industry—are estimated to do $43 billion in sales by 2018 (ABI 2013). The growth for automation of the manufacturing sector is estimated to be even greater, reaching over $120 billion by 2020 (Cullinen 2013). With significant growth in automation of the commercial and industrial sectors anticipated over the next ten years, we can anticipate corresponding gains in energy savings. The "intelligent" or "smart" automation of future investments will not be mechanical or even just programmable controls, but a combination of sensors that provide bi-directional communication between devices and controls; remote access through the internet; networks within processes, buildings, and organizations; and new software programs that can manage large quantities of data that when combined together enable self-correcting and anticipatory capabilities that yield new capabilities and additional productivity, and energy savings.

With the ability of intelligent efficiency to generate the next-step change in energy savings, multiple economic benefits are possible as energy efficiency catalyzes increased economic activity: Direct benefits accrue from the avoidance of energy use due to greater efficiency; non-energy benefits stem from system optimization, including better services and, in industry, better quality control; and lower operating costs free up capital, making it available for additional investments in productivity and capacity. Because the implementation of automation systems based on intelligent efficiency are so cost-effective and pay back so rapidly, we anticipate that a great deal of economic activity will happen with little or no influence from the public sector (M2M.WorldNews 2012). However, there is an importunate opportunity to leverage intelligent efficiency for public policy goals.

The best near-term opportunities for polices that promote intelligent efficiency are at the state, utility, and local levels, where most energy policy and programmatic activity takes place. Each state has at least one agency with responsibility for regulating electric and natural gas utilities, and these agencies are shaped by state legislatures. Additionally, many municipalities have their own utilities, which are part of or in some fashion answerable to the local government. The states function as laboratories in which many different policies and programs are tested and refined, and from these experiments federal policy will likely be constructed.

The constantly evolving policies and programs at the state and municipal levels means that great opportunities for action exit there. To wit: A majority of states have a requirement for utilities to encourage energy efficiency, and as a result there are programs of all shapes and sizes designed to help customers use energy resources more effectively. Each of these programs has one or more performance goals for which the program administrator is held accountable. Many of these programs focus on medium and large buildings and manufacturing facilities, and depending upon the details of the program, intelligent efficiency could be a mechanism that enables them to not only meet their performance goals, but to do so at a lower cost per unit of energy savings than before.

Given the great potential for intelligent efficiency to affect widespread declines in energy use and to bring a range of economic benefits, in this report we continue our examination of challenges to its broader acceptance. We give special attention to structural barriers in the electric utility sector that affect commercial and industrial customers by making it difficult for utilities to invest in automation as part of their efficiency programs. These barriers include existing business and government accounting practices, utility regulations that focus on service territories rather than an organization's energy footprint, and efficiency program policies that favor hardware over software and products over services. These are also the barriers that energy sector policymakers and stakeholders—who determine what can and cannot be included in an efficiency program and specify how its performance is evaluated—have the greatest ability to change. We identify specific actions that can be taken by utilities, public utility commissions, government agencies, and energy consumers to reduce or eliminate these barriers. These policy and programmatic recommendations focus on creating an environment in which governments lead by example, design experimentation can take place in utility efficiency programs, and utilities support investments in intelligent efficiency.

These actions on the part of governments and utilities will be justified by the magnitude of the economic impact of intelligent efficiency on the commercial and industrial sectors—up to $90 billion a year in energy cost savings. In this report we attempt to quantify the electricity savings in these sectors that could result from the recommended policies and program activities that we present. We focus on electricity because there are many more efficiency programs for electricity than for other fuels. We examine the energy savings of a set of key individual intelligent efficiency measures, each of which has a high likelihood of significant market penetration and energy savings in the near term, and we then project the potential energy and energy cost savings over the next 20 years.

The economic analysis brings us full circle. It is the reason to care and the reason to act. There is an overarching economic need at the national level to embrace intelligent efficiency as it can produce a next-step change in the efficient use of energy in all economic sectors. There is also a targeted need within the utility sector to provide more effective energy efficiency programs. However, before each of these opportunities can be realized, it is necessary to overcome existing and potential barriers to greater market acceptance of intelligent efficiency and to have a plan for accomplishing this. To that end, the report concludes with a set of recommendations for policymakers, public utility commissions, utilities, suppliers of automation equipment for buildings and manufacturing, and energy efficiency program administrators to guide them in addressing these challenges and taking full advantage of the opportunities brought by the widespread implementation of intelligent efficiency.

INTELLIGENT EFFICIENCY DEFINED

Intelligent efficiency has resulted from the convergence of several new technologies and analytical capabilities that now enable another step change in energy efficiency. Intelligent efficiency is a concept, or a capability. Much like information technology is the capability to manage information with computers, software, and networks, intelligent efficiency is a new ability to save energy that arises from our ability to gather large volumes of data and to manage, interpret, communicate, and act upon it in ways that increase the energy efficiency of complex systems.

The hardware and software products that enable intelligent efficiency are information and communication technologies. This combination of enabling technologies—sensors, computers, data storage, networks, cloud computing—allows users access to real-time information, historical information, and analytical capabilities that, when combined, enable the users to determine the most efficient method to operate a device, system, process, facility, or even network of facilities. Many of these systems have the ability to study historical information and to use that information in combination with information about ambient conditions in order to evaluate multiple possible operating scenarios before selecting and implementing a final decision. It is because of this ability to learn and improve over time that these systems are often referred to as "intelligent" or "smart." For example, a chemical manufacturing plant with an intelligent process control system could use information from multiple previous operating scenarios—production volumes, process speeds, equipment set point, outdoor temperature, and humidity—to recommend operating conditions that would improve future performance.

There are many different ways in which intelligent efficiency can be leveraged to improve a product or service, opportunities that exist along a continuum with technology and human behavior at either end (see Table 1 below). Increased "intelligence" along this spectrum falls into three broad categories (Elliott, Molina, and Trombley 2012):

- People-centered efficiency provides consumers with greater access to information about their energy use as well as the tools to reduce energy use. In this type of intelligent efficiency, technology makes individuals' energy use visible, thus guiding them toward making major efficiency gains. An example is a dashboard display on a computer screen that provides facility or process managers timely and actionable information on energy use.
- Service-oriented efficiency, often referred to as "substitution" or "dematerialization," provides individuals with the option to substitute one material-based service for one that is not material-based. An example is the replacement of physical compact discs by digital music. In this type of intelligent efficiency, the end users choose the degree to which they will utilize information and communications technologies—which use less materials—to accomplish a goal. One of the greatest emerging manifestations of this is cloud computing. No longer must every company have its own servers and IT departments. Instead, they rent space in the "cloud" and subscribe to IT services.
- Technology-centered efficiency encompasses "smart" technologies that optimize energy systems in buildings, industries, and transportation systems. Here, automated systems optimize energy use and anticipate energy needs, and human engagement is largely limited to the initial programming and commissioning of the system. A building's heating and cooling system that might have required routine adjustments to a thermostat by a person now responds to inputs from occupancy and temperature sensors, on-line weather forecasts, and stored information on the occupants' preferences.

Table 1: Types of Intelligent Efficiency within the Continuum

Types of Intelligent Efficiency Technologies	Types of Intelligent Efficiency Solutions
People-Centered	Interfaces
Technology-Centered	Control Systems
Service-Oriented	Substitution

The main focus of this report is technology-centered efficiency, with the other two types playing more minor roles. Intelligent efficiency encompasses a broad array of hardware, software, data storage, and analytical components with which a situation is analyzed automatically and the most efficient operating conditions determined. However, these systems seldom operate without some level of human interaction, and ideally these interfaces employ people-centered intelligent efficiency as well. And with much of the data storage and analytically capability remotely located, substitution, or service-oriented efficiency, is also part of the mix. Ultimately, intelligent efficiency enables workers to be more effective and managers to make more informed decisions. These are the compelling reasons for organizations to invest in this emergent technology.

Potential of Intelligent Efficiency to Save Energy

Intelligent efficiency saves energy in three fundamental ways:

1. Improved management of businesses or production processes through a systems approach
2. Elimination of the degradation of energy savings
3. Substitution of [x technology] for [y technology]

A "SYSTEMS APPROACH" TO ENERGY SAVINGS

A key feature of intelligent efficiency is that it achieves energy savings at the system level and above rather than just at the device level. Understanding this distinction and what is meant by taking a "systems approach" is fundamental to comprehending the potential of intelligent efficiency to save energy in the commercial and industrial sectors.

A traditional engineering approach operates at the level of the device: It breaks processes down into their individual components and scrutinizes them for incremental improvements. For example, every energy-consuming piece of equipment in a manufacturing setting, whether it be a lamp, a motor, or a steel melting oven, converts input energy (e.g., natural gas, electricity, gasoline) in to useful work (output) and does so at some level of efficiency that is less than 100%. A small electric motor might be 80% efficient at converting electricity to mechanical motion, and a pump might be 50% efficient at turning electricity into hydraulic energy. Boilers are often 75 to 85% efficient at turning the energy in natural gas into thermal energy in the form of steam. These are component or device efficiency levels, and energy is saved through the use of a more efficient motor, pump, or boiler.

Each of these devices is part of a larger system. The motor is connected to a pump, the pump to a piping system, and the piping system to a production line that is supplied steam produced by a boiler. In this traditional engineering approach, increasing the efficiency of the system means increasing the efficiency of each component part. However, even when every individual device is operating at its highest efficiency, the larger system is usually not. The component parts often operate at full capacity even when not needed, requiring water to be constantly recirculated and steam to be vented to the atmosphere. Their operation does not vary in response to environmental stimuli. And their operation is not informed by the most likely future conditions, input that might have been able to guide their most efficient use in the present.

A systems approach, in contrast, takes into account the behavior of the components of a system relative to one another, specifically, requiring the component parts to modulate their operation according to the needs and demands of other system components. Intelligent efficiency, as a systems approach, involves analyzing the behavior of a suite of individual technologies that are integrated together to function as a system.

In an intelligent efficiency approach, the system optimization means operating each component in concert with all other components and toward the goals of the entire system. Motors are slowed down or turned off when less or no water is needed. Boilers operate when production requires them, and the entire production line operates in response to customer demands. The system and its components respond to real-time demands and environmental conditions, rather than to an estimate of future demand and with no regard to past, current, or future environmental factors. A systems approach to efficiency can start with optimizing the pumping system and then moving to the production line, the entire factory, and the entire company. A systems approach means optimizing the entire supply chain from raw material to the end user, producing the product in response to real-time demand and ensuring that the elements of the production process are not only highly efficient individually, but that they operate only when needed and at the level necessary. Appliance manufacturers have made great strides in a systems approach. When an order is placed at a retail store, component parts from suppliers are schedule for delivery to the appliance assembly plant the next day. The appliance is not built until it is ordered and yet the customer still gets it shipped to their house in the same time as if it were in inventory at the store.

Smart Manufacturing and the Internet of Things

One of the single greatest manifestations of intelligent efficiency is the emergence of what is being called the "Internet of Things" or the "Industrial Internet" in which all of the components of a system have the ability to inform other parts of the system of their situation and react to the same information from other parts of the system. The more connected the components, the more powerful the network.

Embedded with sensors and communication capabilities, objects as small as shipping labels and as large as factories will communicate current data about various attributes that will enable other components and systems to react to situational changes. These "smart" devices and systems will make processes more efficient, give products new capabilities, and bring about new business models (Manyika and Roxburgh 2011).

A new generation of smart technology is already making its way into the production environment. Industrial motors use approximately half (EIA 2006) of all the electricity consumed in the United States. The performance of individual motors can be communicated and analyzed in real time. Unlike devices in the residential sector that can simply be plugged into an electrical outlet, industrial motors, the machines that turn electricity into mechanical motion that drives pumps, fans, and compressors must be connected to electrical drives, which condition the power for proper motor operation.

Many new drives can vary the speed of the motor and are embedded with the capability to report back to a plant's control system the energy use of a motor in real time. That control system can in turn communicate to the company energy management system. These built in meters eliminate the need to invest in meters for each major piece of equipment, a common recommendation of energy audits. This is important because a meter cannot produce an energy savings but must instead be purchased on the faith that it will produce data that management can use to identify projects that can save energy. The ubiquity of device and system performance data coming from the plant floor will usher in a new era of continuous improvement.

The technology that facilitates this connectivity is most commonly referred to as "Machine-to-Machine' or M2M. Machines are collecting, sharing, and acting upon data without human intervention. The M2M industry is projected to maintain 23% annual growth rate over the next decade expanding from a $121 billion business in 2010 to almost a trillion dollars in 2020. (Cullinen 2013) and adding $10 to $15 trillion to the global economy over the next twenty years (Evans & Annuziata 2012).

The influence of ICT will be felt throughout the industrial sector. Systems and components of systems will be embedded with smart technology that will enable information exchange between the system control level and the facility operation level. The full integration of smart technology will connect facility operations to corporate enterprise management and a corporation's system will be linked with similar systems throughout supply chains. Not only will this linkage resolve the challenges of coordinating a facility's operational objectives with its corporation's corporate financial objectives, it will connect both with the corporation's energy and sustainability objectives. This emerging ability will wring new levels of efficiency out of the manufacturing process by networking devices, systems, and facilities has come be known as "Smart Manufacturing."

The technologies that make up Smart Manufacturing that are now being applied in limited fashion to specific processes are predicted to become the backbone for the industrial environment. In the future, modeling and simulation systems will be used in initial product development and design as well as the development of integrated facilities and processing operations. Process design will drive capital projects and investments as the application of intelligent efficiency moves from tactical to strategic. Ultimately, we can expect to see data analytics used to optimize the allocation and scheduling of a company's assets and production capabilities (Davis 2009).

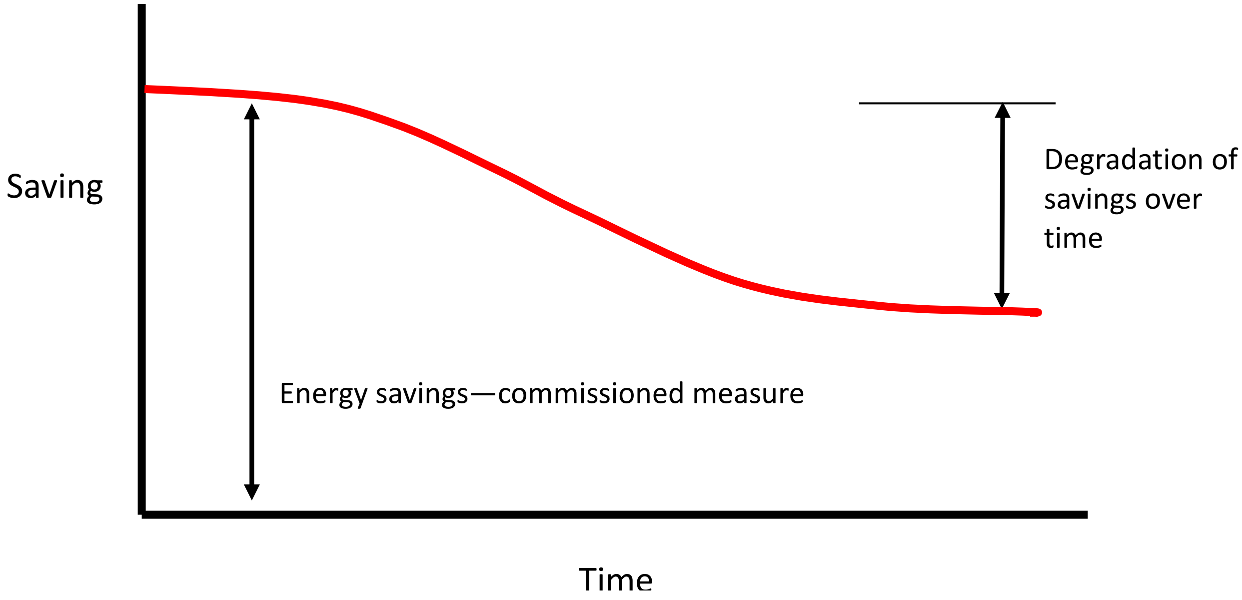
ELIMINATING THE DEGRADATION OF ENERGY SAVINGS

One of the more vexing challenges in the energy efficiency sector is ensuring that the savings that result from the implementation of an efficiency measure persist over time. The ability of intelligent efficiency to prevent the degradation of energy savings is its second fundamental contribution.

Operators of complex production processes or managers of facilities that are heated, cooled, and ventilated have become accustomed to the decline in energy savings that typically occurs in the months and years following the implementation of energy efficiency measures. Some energy measures are more sustainable than others. Replace a low-efficiency industrial motor with a high-efficiency motor and it is very likely that for every hour of the new motor's use, less energy will be used than had the old motor not been replaced.

The confidence in savings over time, however, tends to decline with the complexity of a system. Since a system is interacting with numerous elements of its surroundings, changes to those surroundings can easily cause a system optimized for efficiency to lose that optimization. A building's occupants change, and the automation system does not serve the new occupants well and is disabled. Changes may be made to the building itself, causing the automation settings to be no longer optimal. Or, major problems may occur in the building, also causing the settings to no longer be optimizing efficiency. A common example confined to one device is a programmable thermostat. When first programmed, it is likely to reduce energy use because it enables the user to reduce the level of cooling or heating during hours when a building is not occupied. But this level of savings is likely to be lost once the use of the building changes hands because the new operator, rather than reprogram the thermostat, is likely to bypass the programming and set the temperature manually. Now, some or all of the savings have been lost.

Figure 1: Degradation of Savings



This degradation of savings is a common issue at the whole-building level with building automation systems or BMS (Figure 1). When buildings are first put into service, they are often commissioned. All systems—heating, ventilating, and air-conditioning (HVAC); lighting; elevators; security systems; and others—are tested and adjusted and put into service. Boilers and chillers are tuned, louvers on ventilation systems are adjusted, cooling tower water fans are adjusted; all of the necessary steps are taken to ensure that the building operates properly for its new owners and occupants. If the building has a BMS that controls some or all of these systems, it is programmed to operate the building in a fashion that optimizes occupant comfort while also minimizing operating expenses. This could include turning lights on and off at certain times of the day and week, and turning up and down the heating or air conditioning at certain times of the day, week, and year. These systems provide building operators with routine information on the operating conditions of major building systems and can flag when something is not operating properly. A properly designed and operated system will—at least initially—save energy and lower operating costs (Capehart and Capehart 2008).

As the years go by, building tenants change, old walls come down, and new walls go in. The ductwork on a floor that supplied air to one large room now supplies air to several small offices. New tenants come with different businesses, different office equipment, and different hours of operation, all of which creates new expectations of the HVAC systems and the BMS that controls it. Without changes to the HVAC design and operating set points, the system may operate against the interests of the new tenants. Perhaps they suffer with it for a while, but ultimately they will likely begin to adjust thermostats and install work-arounds such as closing off air supply vents, overriding programs on programmable thermostats, and opening windows. These changes induce a response from the system that may exacerbate the situation. A negative feedback loop can be established, and each iteration moves the system further away from satisfying the needs of all the building tenants in the most energy-efficient manner.

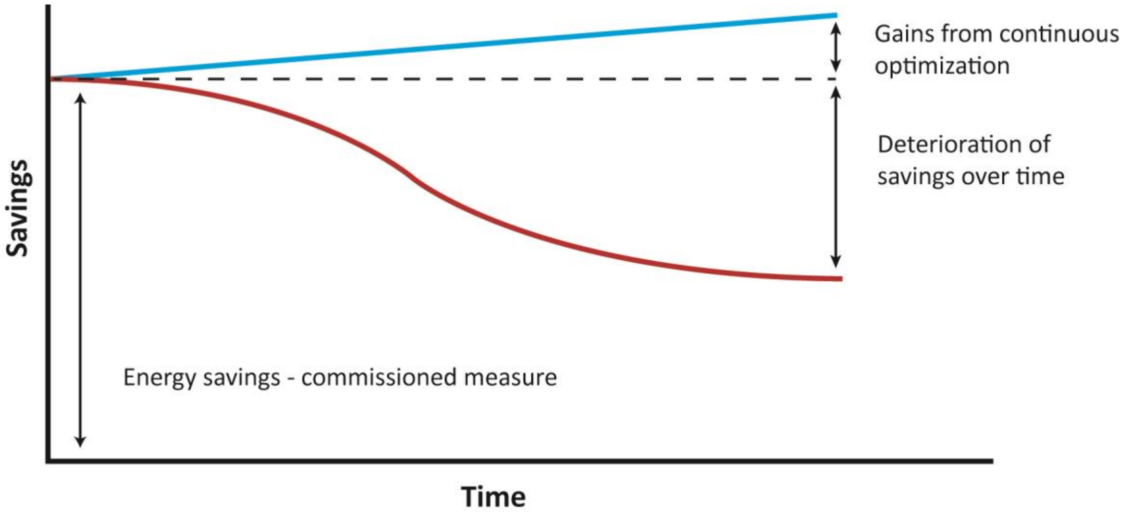
If the building management company is proactive, it may see less degradation of the energy savings provided by the BMS. This may require reprogramming the BMS with the build-out for each new tenant and having a properly staffed maintenance department that routinely checks all the building's mechanical systems and catches minor problems (for example, a plugged air filter on an air handler) before they become major problems (such as a broken air handler) that waste a great deal of energy and require expensive repairs. However, this is often not the case, and the building's performance will start to drift away from optimal, and the savings provided by the BMS, or any energy measure for that matter, will degrade (Figure 1) (Fernandez et al. 2009).

Intelligent efficiency improves upon existing efficiency technologies by reducing or eliminating the degradation of savings. It is even possible for existing energy efficiency technologies such as building automation to not only maintain initial levels of performance, but to actually improve on it over time—using an intelligent efficiency approach. Advanced BMSs learn from past performance and incorporate the information into future performance opens up new energy savings potential (Figure 2). That intelligent efficiency measures are adaptive and anticipatory is fundamental to how they are different from the conventional energy efficiency measures and the energy benefits of these attributes becomes more profound over time.

An illustrative example can be seen in the differences between the re-commissioning of buildings and its intelligent analog: continual optimization. In re-commissioning (or retro-commissioning), building systems are reviewed and adjusted through an intensive process that is intended to increase energy efficiency and overall performance. Essentially, re-commissioning is the recognition of the typical situation in which buildings drift out of optimal performance. Buildings are re-tuned to current operating conditions so that their systems will operate more effectively. This approach has proven very effective in improving energy efficiency (Mills 2009), and has garnered wide acceptance.

A limitation with this approach is that the building must be re-commissioned on a regular basis. With each re-commissioning, improvements in technology and management practices are put in place and a new levels of performance are achieved; however, the benefits are short–lived, as the operation and management of building systems move away from the most efficient settings after each re-commissioning such that the building ultimately spends more time out of optimization than in Figure 3.

Figure 2: Eliminating the Degradation of Savings

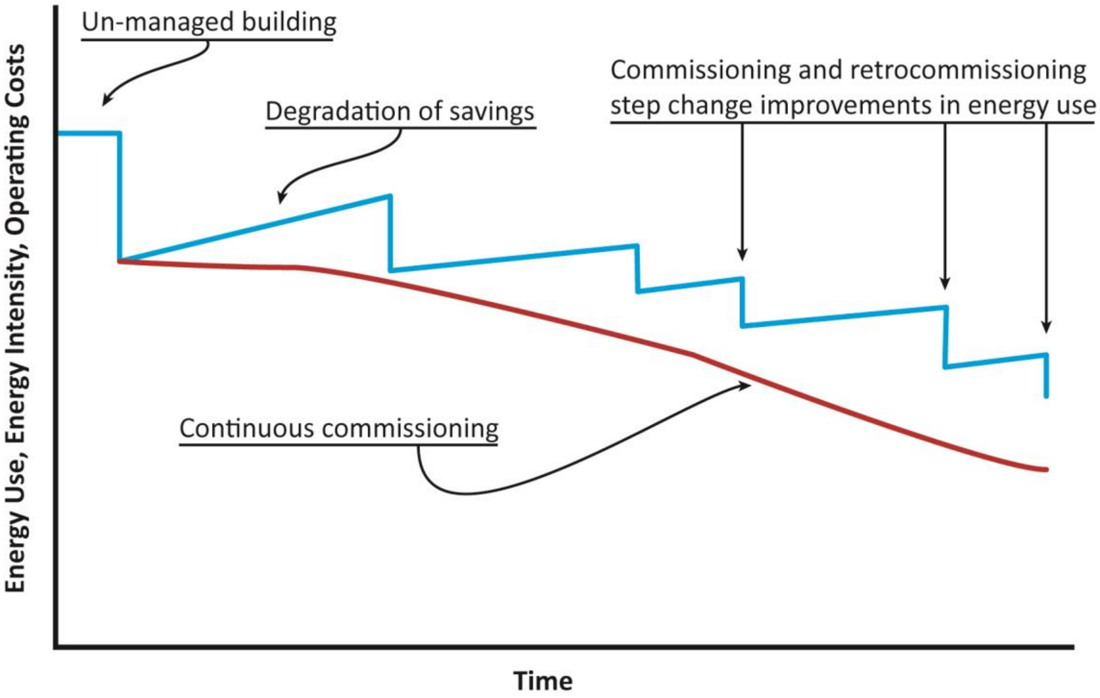


An advanced BMS—an intelligent efficiency approach—continuously collects building information and combines it with other data streams such as utility real-time pricing and weather forecasts. These data feed into a computer modeling simulation that designs and implements a plan to control the building HVAC and lighting systems and perhaps even automated window shades. With time, this building simulation will be refined so that it gets better at predicting how the building will operate given any set of circumstances. This will result in the building staying at or near optimal operating conditions the majority of the time. In this report we refer to this as continual optimization as the system is continually seeking optimal operating conditions.

Contrasting re-commissioning with continual optimization in Figure 3, we see with re-commissioning the periodic optimization of the building systems followed by a drift out of optimization, resulting in increasing energy use and the need for repeated re-commissioning. With continual optimization, we achieve similar savings to re-commissioning a building, but the savings increase with time (and energy use decreases) as the intelligent systems learn and these continual refinements ensure that the building systems remain optimized.

The attributes seen in Figure 3 are reflected in many other intelligent efficiency measures considered in this report including intelligent compressed air, pump, and fan systems, and industrial process optimization. This ability to capture energy savings that would normally be lost to saving degradation is one of the key attributes of intelligent efficiency.

Figure 3: Eliminating the Need for Re-Commissioning



ENERGY SAVINGS FROM SUBSTITUTION

The third way that intelligent efficiency saves energy is by outright eliminating the need for energy consuming equipment or by replacing it with something that uses much less energy. The primary example is "cloud computing," which eliminates the need for every office and factory to have its own energy-consuming servers. For most businesses and other organizations, the traditional practice is to support desktop and laptop computers with a dedicated, local computer network. This requires considerable costs, both initial investment and operating costs. The servers use a lot of energy and require consistent air conditioning, which also requires considerable energy. A growing alternative to this is for organizations to provide many IT services through cloud computing, which involves large servers located in data centers that provide computing, storage, and software services connected to the user via the Internet. Two approaches to cloud computing are (1) a "private cloud," where IT resources are shared among different business units in the same organization, and (2) a "public cloud," where IT resources are delivered to multiple organizations through third parties with the ability to maximize the use of their equipment.

The cloud platform achieves these savings by enabling higher utilization of servers, more efficient matching of server capacity to server demand, and "multitenancy" to serve thousands of organizations with one set of shared equipment. When not all servers are needed, some can be turned off entirely, and loads can be rerouted to other servers; with significant energy savings. The public cloud platform provided by Salesforce.com, for example, enables greater efficiency over both on-premises network and private cloud options (Salesforce.com 2012). When a user switches to Saleforce.com's public cloud platform from a private network, the carbon savings are estimated to be 95% of per-use carbon emissions, and when users switch to the public cloud option from an on-premises cloud option, the carbon savings are on average 64% (Salesforce.com 2012).

NON-ENERGY BENEFITS: SAFETY, QUALITY, JOB CREATION

The benefits of energy savings from intelligent efficiency include direct reductions in energy bills for consumers complemented by other "co-benefits" such as increased comfort, quality of life, productivity, and product quality. Smart technologies will also enable the more efficient use of raw materials, people's time, and capital assets. They make existing tasks easier and open up possibilities for businesses and manufacturers to provide new services. In the manufacturing sector, the non-energy benefits are likely to exceed energy benefits, as improved production performance is the primary driver of investments in manufacturing automation (Burgoon 2013).

In industry, where wasted energy can make a job unpleasant or even dangerous, less waste heat in a manufacturing process can mean a more comfortable and safe work environment. Intelligent process management systems that control plant utilities such as compressed air and steam not only save energy by operating them at lower pressures, but also make them safer. These systems also have the potential to reduce maintenance costs, as motors that run in an energy-efficient mode, more slowly, or less frequently, also tend to run cooler and break down less often.

On a national level, the benefits of intelligent efficiency go far beyond direct, end user savings of dollars and therms. The expanded deployment of intelligent efficiency will increase economic productivity and job creation, economic benefits that transcend the amount of money saved through lower energy usage and rest on how the money saved is ultimately spent. Money saved through energy efficiency moves consumer spending from the energy utility sector to other sectors of the economy that are much more labor intensive. For example, whereas $1 million spent on energy bills supports about ten jobs, if that money were spread throughout the economy, it could support more than 17 jobs (ACEEE 2013).[1] Moreover, because energy savings is often the result of purchasing energy efficiency services on an ongoing basis (as opposed to one-time purchases of efficient equipment), the trend of increased jobs tends to be sustained. Because of this, jobs induced through energy efficiency tend to dwarf any reductions in net jobs due to initial investments. These reductions in consumption and demand also offer the prospect of reducing future energy prices for all consumers, as the need for expensive future upgrades to the energy infrastructure (Elliott, Gold, and Hayes 2011).

The Promise of Intelligent Efficiency

Intelligent efficiency offers the new and promising ability to capture savings at the systems and enterprise levels that have historically been difficult to secure. Focusing on component or device efficiency has left a great deal of efficiency uncaptured. Even the most efficient devices waste energy when not properly used or when operated irrespective of the need for

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[1] This is a simple explanation of how energy efficiency creates jobs. For more detail, please see http://www.aceee.org/files/pdf/fact-sheet/ee-job-creation.pdf.

them. With smart technologies, systems can adjust in real time to meet the needs of the moment, thus eliminating that waste. But even more importantly, intelligent efficiency enables savings to be captured at the process, facility, and enterprise levels. Smart ICT devices networked together share information about respective current conditions, and each unit has the ability to evaluate its options. In some instances, the machines make the decisions. In others, people are provided with options, including the potential implications.

Savings from many traditional energy measures tend to disintegrate because operations change or because equipment is not properly maintained. Even with re-commissioning, there can be a decline in savings over time as systems drift out of optimization. By contrast, smart technologies take greater volumes of information into consideration in determining optimal operating conditions and can recognize when systems are not operating in accordance with their specifications. More frequent adjustments can be made automatically that achieve additional energy savings that are significant in the aggregate and over time.

Intelligent efficiency also enables the remote location of analytical capabilities. While each office building owner may not be able to afford or justify an on-site technician to monitor and maintain his or her HVAC system, it is more likely that a property management company that oversees a dozen buildings, each with its HVAC system controlled by an advanced BMS networked to a central location could justify an off-site technician to monitor and optimize its fleet of buildings. The energy cost savings that the company realizes can justify the salary of that technician. Now, instead of the technician spending time searching for problems, the advanced BMS identifies and prioritizes them and the technician travels to each building as needed.

Case Studies

The types of benefits that organizations can expect from intelligent efficiency are best explained through examples. In this section, we highlight several recent examples of deployments of advanced BMSs and "smart manufacturing." As these examples demonstrate, even already-efficient operations can benefit from intelligent efficiency.

HARVESTING THE POTENTIAL OF BUILDING AUTOMATION SYSTEMS

Building automation systems have been around since the earliest computers. But what makes the advanced BMSs more powerful is that the new generation of sensors and controls are self-configuring and can self-diagnose without human intervention. With all of the system's components connected through wireless communications that allow two-way data transfers, a step change in new efficiencies can be realized. No longer is the focus on the device, but rather on the system and, even more so, on the building. 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. A fault is a signal of something wrong. It could be a control in an improper setting, a device not responding to a signal, or device returning a signal outside of expected parameters.

With buildings constantly evaluating their performance against historical data and parallel simulations, the degradation of savings from any given efficiency measure decreases. Below, we highlight several case studies that have explored this phenomenon and documented the resulting savings. These lessons have broad applicability to many building types and demonstrate the scope of savings that is possible nationwide.

Microsoft Headquarters in Redmond, Washington[2]

Improving the efficiency of existing commercial buildings can be challenging. Most available options often fall between simple equipment replacement programs that are low cost but yield only a part of the total available savings, or more comprehensive retrofits that achieve deeper savings but are often capital-intensive. However, experience from a pilot conducted by Microsoft at its Redmond campus suggests that there is potential to save energy through the use of analytical software that is not just low cost but also yields deep energy savings. Moreover, this software solution is not disruptive of existing building operations and works well with existing infrastructure.

The 118 buildings at Microsoft headquarters include 14.9 million square feet of office space and deploy 30,000 pieces of mechanical equipment. Historically, major equipment inspections at each building were performed on a five-year cycle—engineers inspected about 25 buildings every year. These interventions achieved energy savings of about 4 million kilowatt-hours (kWh) each year. Collectively, these buildings had seven different kinds of BMSs that the engineers had to deal with to manage the equipment.

In 2011, Microsoft's facilities team started a pilot with an analytical software program, the Smart Building Solution, which is able to "talk to" these disparate BMSs. The software then acquires, aggregates, and analyzes the energy use data for different buildings to give a standardized output that is easier to act upon. Initially, 13 buildings were selected for the pilot. Later, encouraged by the success, Microsoft added more buildings, and soon the company plans to deploy the software across all the buildings on its campus (Warrick 2013) as well as with 2 million square feet of commercial property at other businesses in Seattle (Clancy 2013).

As shown in Figure 4, equipment and devices have sensors that record and send performance data to the BMSs. The analytical software communicates with the seven different building systems and integrates the data across buildings. These data are then combined with other information such as weather data, occupancy, and special occasions that alter energy use from the norm such as events or holidays in order to identify trends, patterns, and anomalies. The software collects 500 million data transactions every 24 hours. These data are then analyzed and transmitted in the form of various reports to the central operations. These reports focus on three main areas:

1. Continuous monitoring. By analyzing the data streams from the BMSs, faults such as leakages, overcooling, and sensor failure can be detected in real time. Analyzing larger spatial and temporal patterns often means that the software is able to identify more anomalies than can a conventional BMS. One example encountered at Microsoft was an air handler's chilled water valve with a faulty control code issue.

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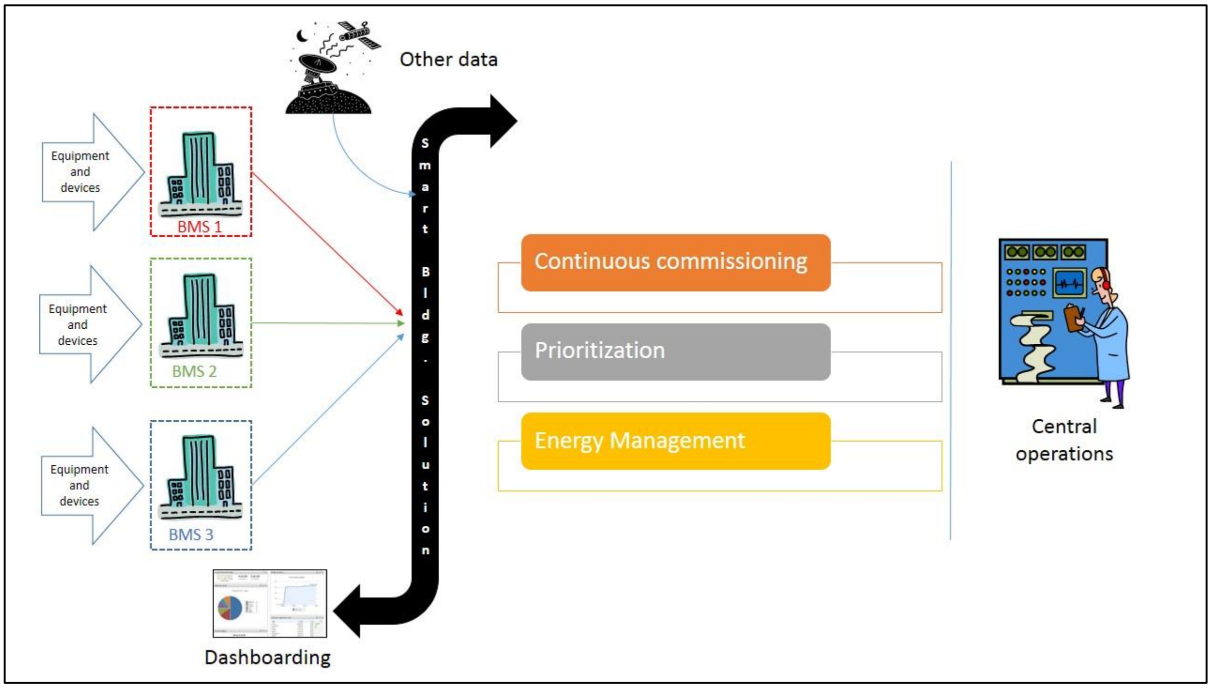
[2] This case study was taken in its entirety from a publication released by Microsoft and summarized by articles in Warrick 2013, Microsoft 2013, and Clancy 2013.

The valve was always 20% open, wasting several thousand dollars annually in energy used to chill the water. This issue had not been visible, but the analytics software detected it immediately (Microsoft 2013).

2. Prioritization. The software prioritizes the faults by estimating the cost of the inefficiency so that the engineers can focus their time and efforts on the more important tasks. Given the scale of operations, the central operations team may receive hundreds of notifications in a single day, not all of which are equally important. Analytical algorithms help the engineers to prioritize items based on multiple considerations, not just the financial cost. For instance, a fault that affects occupants in a highly critical operation—such as a hospital operating room— needs to take precedence over other faults, even if in purely economic terms it does not yield as great of savings. The software also enables better correlation of messages from related events, thus improving response time for larger or more critical problems.

3. Energy management. The third feature of Smart Building Solution is its ability to manage energy consumption more holistically. With the analytical support provided by the software, the engineers can optimize major building systems like heating, cooling, ventilation, and lighting. They can fine tune set points and schedules, identify wasteful equipment, and act on other energy saving opportunities through a better understanding of energy use trends across the entire portfolio. The software also helps to reduce occupant-dependent plug loads such as computers, printers, and kitchen appliances, which are comparable to the base building energy use. The software benchmarks plug load data across and within buildings, which is displayed through dashboards for internal comparisons. Energy costs are broken down by organizational unit, and metrics such as kWh/employee define ownership and create incentives for a unit to outperform its peers.

Figure 4. Intelligent Efficiency at Microsoft



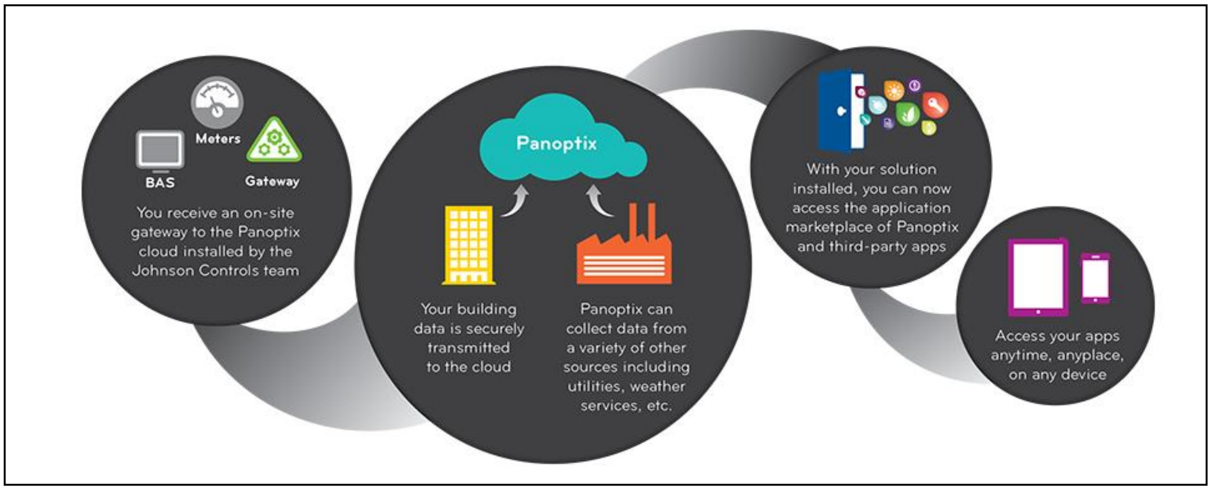
Source: ACEEE graphic based on Accenture 2011

Taking Building Energy Management to the Cloud

As the Microsoft case suggests, the full utilization of BMSs can bring significant energy savings. However, the information from a BMS is limited to equipment, appliances, and sensors. To truly unleash the potential of intelligent efficiency, this information needs to be placed in context. The energy footprint of a building is determined to a large extent by extrinsic factors, including as building type, number of occupants, operating hours, nature of business, nature of ownership, climate zone, and many others. Knowledge of these variables helps building managers identify opportunities to reduce costs, one of which is energy. However, information about these extrinsic factors often exists in an array of different formats—utility bills, employee records, spreadsheets, and web sources.

Applications are now available that help in integrating different data sources in different formats and make them more amenable to analysis. Schneider Electric offers EcoStruxture Solutions (Schneider Electric 2013), and Johnson Controls offers their Panoptix system (JCI 2013), a set of applications for monitoring, diagnosing, and analyzing buildings' energy efficiency. Both of these cloud-based data storage and analytical programs pull data from building systems, meters, equipment, and utilities, and, through specific applications, provide building efficiency solutions. The cloud-based "apps" can be accessed by any computer, tablet, or smartphone and allow users to monitor and control different devices, systems, and sub-systems. Johnson Controls has made the application programming interfaces (APIs)—software specifications that help perform a specific function, for instance pulling data from different HVAC equipment—freely available on the web, thus creating a platform for third-party app developers. Johnson Controls' Panoptix also provides a marketplace where users can browse and purchase apps of interest. The picture below from their website summarizes how the cloud bases efficiency solution works.

Figure 5. Panoptix System by Johnson Controls



Source: Panoptix website3

Some of the apps currently available in the market place include:

- Energy Performance Monitor, which helps conduct baseline energy assessments, set up savings targets, and monitor and measure energy savings from different energy efficiency projects, presenting them to building operators in a contextualized manner that simplifies their decision making process.
- Continuous Diagnostics Advisor, which constantly monitors building systems and automates the detection of problems in chillers, packaged HVAC units, air handlers, variable air volume boxes, terminal units, and boilers.

Other apps are available to calculate carbon emissions from a building, compare different buildings or different pieces of equipment, and display information about energy use through dashboards located at various facilities. Each of these apps provides end users a greater ability to manage their energy use and their businesses.

Going from Re-Commissioning to Continual Optimization

Below we present two case studies in which existing buildings with conventional automation systems were upgraded with advanced BMSs and realized significant energy savings. The first analysis was conducted by the National Resources Defense Council on three of its own buildings in Washington, DC. The second is an analysis by an engineering firm using the Continuous Commissioning ® protocol[4] for continually evaluating and adjusting the operating conditions of a building.

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[3] https://whatspossible.johnsoncontrols.com/community/panoptix/apps

[4] Continuous Commissioning ® is trademarked by Texas A&M, Energy Systems Laboratory, Engineering Experiment Station: http://www-esl.tamu.edu/continuous-commissioning

Incremental Gains from BMS optimization of three ENERGY STAR® buildings

The National Resources Defense Council conducted an analysis of the potential of advanced building management systems to reduce energy use in already well-designed buildings. In its 2013 report *Real-Time Energy Management. A Case Study of Three Large Commercial Buildings in Washington, D.C.* (Henderson and Waltner 2013), it describes an analysis that demonstrated that an advanced BMS can achieve an incremental amount of savings beyond what is possible through the use of individual enabling technologies alone. NRDC worked with Tower companies, Inc. (Tower), to improve the energy management of three large, multi-tenant office buildings in Washington, D.C.

The three buildings chosen for this analysis were already high-performing buildings having ENERGY STAR Portfolio Manager Scores of 71, 78 and 86;[5] therefore, it was reasonable to expect that there might not be much room for improvement. However, after a 12-month study period, electricity savings of 23%, 7%, and 17%, respectively were achieved by employing a continual optimization process to building management. The individual actions taken were not different than before, only they were done on an as-needed basis and in response to recommendations made by the advanced BMS. NRDC reports that the actions taken are highly replicable in other commercial office buildings. This study suggests that not only are significant savings possible in buildings without existing automation systems, they are also possible for buildings with conventional BMSs (Henderson and Waltner 2013).

Table 2: Energy Savings for Three Large Commercial Buildings

	Square Feet	2012 Occupancy	KWH Used		Study Period Savings	
			2011	2012	%	$
1707	109,926	302	1,965,135	1,516,274	23%	$ 58,352
1828	332,928	928	5,590,937	5,227,183	7%	$ 47,288
1909	239,128	462	5,197,305	4,327,589	17%	$ 113,063
		Total	**12,753,377**	**11,071,046**	**13.2%**	**$ 218,703**

Notes: The numbers in the first column are building names/numbers. Energy savings were determined using a whole-building, year-over-year method. Results are normalized for weather and occupancy. The 12-month study period was January to December 2012, and the 12-month baseline period was January to December 2011.[6]

The findings of the report indicate that even though the buildings already had building automation systems installed, the data were not being used to their fullest potential. The

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[5] Portfolio Manager is an interactive energy management tool that can be used to track and assess energy and water consumption across a portfolio of buildings.

[6] Tower's average total electricity rates for 2012 were about $0.13 per kWh (total cost with demand charges and all applicable fees and adjustments). In cities with different electricity rates, different savings and total return would be expected.

additional performance was possibly through a service provided by At Site, Inc., whose technical experts provided energy management services remotely. At Site managed the installation of meters to provide real-time energy use data and performed an assessment of each building. Their automated monitoring of the buildings revealed opportunities that were turned into actionable recommendations to the building engineers.

From Retro-Commissioning to Continuous Commissioning®

In 2009, SSRCx, LLC, an engineering firm in Nashville, Tennessee, demonstrated conclusively that more routine commissioning can result in another step change in energy savings. The company studied the energy use of a 320,000-square-foot commercial building that was built in 1999, retrofitted to U.S. Green Building Council Leadership in Energy and Environmental Design Existing Building (LEED EB) standards in 2008, and outfitted with a continuous commissioning BMS in 2009 (McCown 2009). The total unadjusted energy savings for January 2008 through August 2009 was 10% relative to the previous two years. Additional savings from the continual commissioning process during the cooling season were as high at 16% for the month of August 2009, making the combined savings for this month 28% over the 2006–07 baseline. The energy use index in January 2008 was 107.5 thousand British thermal units (kBtu) per square foot per year and was 95.2 in August 2009. This case study is an excellent example of how an advanced BMS can save considerably more energy than a conventional BMS.

SMART MANUFACTURING AND ENERGY EFFICIENCY

All of the data coming in from the production floor has the ability to overwhelm management if not properly managed. With so much data, any number of questions can be answered. But which ones are most important to meeting business goals? Without experience determining which data to collect and what questions to answer, manufacturers are at risk of investing considerable time and money to answer the wrong question or to answer the right question incorrectly. In many cases, a manufacturer will begin to incorporate information feedback and controls technologies to improve the operation of the system, and will continue to add more advanced technology in order to further reap the benefits of intelligent efficiency. At some point though, they will reach a scenario in which they have more data than can be effectively managed.

Additional Savings by Closing the Control Loop

An example of how one company dealt with this can be seen in the Air Liquide facility in Bayport, Texas (Reid 2008). Air Liquide is a global corporation specializing in cryogenic liquids and industrial gases, and their Bayport plant is one of the largest industrial gas suppliers in the world, manufacturing oxygen, nitrogen, and hydrogen for use in other industries. Producing these gases requires a lot of steam heat, which is provided by seven large boilers (four of which are fired by the exhaust of gas turbines used to cogenerate electricity). The facilities' boilers operate under several performance variables, such as production volume, reliability, energy cost, and emissions. Prior to implementing closed loop control in which the generation of and response to performance data occur all within the control system, Air Liquide had been using Visual MESA software to track and optimize against these key indicators and provide open-loop feedback to operators to guide them in optimizing their boiler systems. This use of data tracking and analysis of operations is a best practice in the industry and is an example of one type of intelligent efficiency. Operators receive data and analysis results every 15 minutes.

Air Liquide then took optimization to the next level by closing the loop between the data feedback system and the boiler control system. Instead of relying on operators to adjust the system a few times a day, the new system analyzes process variables and adjusts the system immediately, allowing it to update the boiler control settings every 15 to 30 minutes.

The data feedback system in the open-loop optimization configuration that Air Liquide had been using takes ten to 12 months to install. Upgrading to closed-loop control can take another six to 12 months, but the energy savings alone are estimated to pay for the project in just one year. There are also additional sources of savings, such as increased system productivity and the benefits of freeing up operator time for other work. Experts working on the project estimate that as more closed-loop systems are installed and the savings are properly verified, more companies and manufacturing plants will choose to install the data feedback systems with closed-loop control at the outset, bypassing the open loop configuration entirely. This would allow the entire installation to take about 12 months, and the simple payback based on total cost savings could drop to less than a year.

Networking the Supply Chain, Reducing Product Variability, and Saving Energy

General Mills Inc., one of the nation's largest food product companies, has committed to a 20 percent reduction in its energy usage rate by 2015 from a 2005 baseline. In order to reach this goal the company is investing in renewable resources such as using biomass as fuel to create steam at its manufacturing facilities, and embedding smart energy-saving technology into its manufacturing culture (General Mills 2013). This effort is part of their holistic margin management (HMM) initiative that was launched in 2005 to guide all of their decision making. General Mills had discovered that as its supply chain and product lines expanded, input costs increased and that the typical 2 to 3 percent annual increases in productivity they had come to expect was not sufficient to compensate (NYSE 2011). They needed to do a better job of incorporating farming, supply chain, manufacturing, and distribution.

Working with the Smart Manufacturing Leadership Coalition (SMLC) and Rockwell Automation, they embarked on an effort to remove variability and by extension costs from their product lines. The result is simplified product development, collaborative manufacturing between General Mills and its suppliers, and networks that connect manufacturing control systems with their enterprise resource management system. Food quality tracking for the U.S. Food and Drug Administration (FDA) is included in this automation as well (Davis and Edgar 2013).

General Mills expected HMM driven changes to yield savings of $1 billion through fiscal year 2012 and $4 billion by 2020. (NYSE 2011) Though most of these gains are not energy costs, some of them are and General Mills reported an 11 percent reduction in its energy consumption in fiscal year 2011 from the 2005 baseline (General Mills 2013).

Economic Analysis

In order to quantify the potential economic benefits of intelligent efficiency if implemented nationwide, we calculated the estimated effects of a select group of "smart" energy efficiency measures that have the most promise for near- and medium-term implementation in the commercial and manufacturing sectors. For the purpose of our analysis, we estimate that half commercial and manufacturing sector will be able to benefit from intelligent efficiency. Our focus on these sectors is driven by their readiness for implementation of intelligent efficiency projects. 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 intelligent efficiency projects can successfully be integrated

Larger energy users are also more likely to have the financial and technical capability to implement intelligent systems. Some large manufacturing firms and commercial operations with energy consumption in the hundreds of thousands if not millions of dollars per year are already investing in these systems, and we anticipate that as the cost decreases and a greater variety of products and services become available, the market for intelligent efficiency will diversify and expand. Our focus in this analysis is on technologies that have the most promise for near and medium term adoption in these two sectors.

Utility energy efficiency programs are also poised to invest in intelligent efficiency. While not all of these large consumers of energy are served by utility programs, many of them are, and in regions where they are not, it is possible or likely that energy efficiency programs will soon be offered (e.g., Louisiana and Mississippi have recently decided to begin energy efficiency programs). Programs targeting larger customers have produced some of the lowest cost savings to date (Bradbury et al. 2013).

Our analysis focuses on electricity, driven by the predominance of electricity energy efficiency programs in the North America and by the large proportion of U.S. electricity consumption that occurs in the commercial and industrial sectors (Foster et al. 2012). In addition, the electric utility industry's current focus on the smart grid represents an opportunity to complement the benefits of intelligent efficiency, as it can provide real-time two-way communication between the consumer and the utility that is related to the volume and other quantifying characteristics of the electricity it accompanies. While to quantify the overall benefits of a national smart grid is beyond the scope of this report, we do consider the smart grid a component of intelligent efficiency and anticipate that it, much like the Internet, will be part of the supporting infrastructure.

ENERGY MEASURES CONSIDERED IN THE ECONOMIC ANALYSIS

In order to estimate the potential energy savings available from intelligent efficiency, we looked at projections of energy savings resulting from a number of key enabling technologies that were selected for their ability to produce significant savings in a significant segment of the commercial and industrial sectors. Our threshold for what to treat as significant was shaped by (1) our estimation that savings would be in the billions of dollars, (2) our ability to discern whether or not a given energy measure would contribute to such a total, and (3) the availability of data. Our calculation of net savings took into account the initial cost of implementing the intelligent efficiency measures and ongoing costs of operating and maintaining the systems.

Most of the measures we identified target the building sector. The building automation market is already mature, with dozens of vendors providing a great variety of products and services covering a wide range of capabilities and price points. Most of the energy use in buildings is for environmental control and lighting; therefore, not surprisingly, most of the measures analyzed target those systems. We also wanted to capture the savings from office equipment and the many miscellaneous energy-consuming systems such as servers, elevators, and transformers, since intelligent efficiency is enabling savings in these areas that were not possible before.

In the industrial sector we focused on the ability of "smart manufacturing" to produce systemic change in the use of energy, both within production processes and throughout the plant.

DISTINGUISHING INTELLIGENT EFFICIENCY MEASURES

This report examines individual technologies that are integrated into a system that is greater than the sum of its parts. This raises the need for a heuristic to determine when an energy measure should be considered enabling technology—sensors, controls, and IT—and when it reaches the level of intelligent efficiency. Since the energy savings brought about by technologies that optimize an entire system (whether a commercial building or a manufacturing supply chain) are often in addition to savings already achieved by the enabling technologies, we have an attribution issue to resolve as well.

To address the attribution issue, we developed a methodology for determining the part of the overall energy savings that should be attributed to the intelligent efficiency measure—the difference between what is possible with enabling technology alone and what is possible with an intelligent efficiency approach. That methodology required a heuristic for determining when an energy measure should be considered enabling technology and when it reached the level of intelligent efficiency. To aid in this determination and to help the reader categorize and compare technologies along this evolutionary scale, we devised a simple hierarchy. The levels connote complexity rather than additional energy savings, although energy savings generally increase as we move toward Level 4.

Table 3: Five Levels of Energy Management

Level	Technology
Level 0	Manual On / Off
Level 1	Reactive On / Off
Level 2	Programmable On / Off
Level 3	Variable Response
Level 4	Intelligent Controls

The challenge of determining the energy cost savings from intelligent efficiency pivots on what is considered the baseline. An easy-to-understand example is lighting. The baseline for controlling the amount of light in a room is a simple manual on/off switch. As there is no automation at this baseline level, we are calling it Level 0. A more complex example is an HVAC system, where the baseline could be a simple switch to choose heating, fan, or air-conditioning. The amount of heat provided by the old hot water or steam radiators was usually a knob that the operator manually adjusted—often with a little hope and a lot of fear of what might happen next.

The next level (1) is to have a reactive control such as a motion sensor that turns the lighting on and off automatically or a temperature switch in a thermostat that turns a system on and off when certain set points are reached. In terms of complexity, the next level (2) is programmability. Examples are a building's security lighting that turns on and off at different times of the day and week, or a programmable home thermostat. These technologies do not necessarily result in greater energy savings than Level 1, but the system is more complex.

Level 3 incorporates variable response. The lights are on a dimmer, the amount of light is determined by a sensor (motion or daylight), and a controller adjusts the amount of light produced. Again, this is not necessarily a guarantee of more savings, but reflects additional complexity. In our HVAC example, a Level 3 variable response might be the ability to ramp fan speeds up and down.

Level 4 is the full integration of all of these enabling technologies with an additional software component that analyzes past performance and adjusts system outputs in anticipation of future performance. At this level, additional savings are possible because the advanced BMS is proactive and not just reactive. It has the ability to continually optimize and even improve performance over time. Much of the savings between Level 3 and 4 is achieved by reducing or even eliminating the degradation of savings that often happens following implementation of an energy measure.

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 to include in the economic analysis where 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 Level 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. However, the difference in energy savings that would result from such a system compared to a system without predictive capabilities is hard to determine, so Levels 3 and 4 are combined in the analysis for lighting.

INTELLIGENT ENERGY MEASURES INCLUDED IN THE ECONOMIC ANALYSIS

As previously discussed, we aimed to quantify the marginal energy savings attributable to intelligent efficiency. Though these technologies improve upon the previously realized efficiency gains made possible through more efficient devices and automated building controls, we aimed to disentangle the energy savings that accrue specifically from the features that define a system as having an intelligent efficiency approach.

We analyzed over two dozen technologies for their ability to affect energy use in buildings in the commercial and manufacturing sectors. Each of the Level 4 energy measures (EM) considered has broad applicability, a likelihood of reaching more than 25% of its respective market by 2035, and the ability to produce savings that can be sustained for the life of the product. The analysis assumes a relatively modest increase in investments of 1% per year early in the twenty year period and finishing at 2%.

The commercial sector analysis included a dozen energy measurers that, for reasons explained below, were grouped by the buildings systems whose energy use they are intended to impact. A different approach was taken in the analysis for the manufacturing sector. This sector is not as homogenous as the commercial sector; therefore, our ability to discern large-scale impacts of specific smart technologies is limited. Instead, the analysis applies broadly the potential of smart manufacturing overall to reduce the variable costs of production, one of which is energy, throughout the manufacturing sector.

Motivating our analysis is the notion that these projects are justified on the basis of potential energy cost savings. Conversations with people in the manufacturing automation sector, however, indicated that this is not often the case. Rather, primary motivations for investment in the industrial sector are to improve production efficiency, product quality, safety, and regulatory compliance, with energy savings often perceived to be an ancillary benefit. The energy cost savings however can justify the supporting investment, therefore it likely that there will be much greater investment in smart manufacturing over the next 20 years and our estimates are conservative.

Given the premise that intelligent efficiency investments can indeed pay for themselves through energy cost savings, the analysis assumed that investments in the commercial sector are made with an expectation of a 20% annual return, or a five-year payback and that investments in the manufacturing sector are made with an expectation of a 50% return or 2-year payback. The first year cost of any licensing and services fees are built into these cost estimates.

INTELLIGENT EFFICIENCY MEASURES FOR THE COMMERCIAL SECTOR

Buildings consume 23 percent (Navigant 2013a) of all electricity globally. The six major uses of energy in buildings are space heating, ventilating, and air-conditioning (HVAC); water heating; lighting; and plug load (all office equipment and other machinery "plugged" into the building). We placed intelligent efficiency measures into the following categories: smart building components, smart lighting, smart HVAC components, advanced BMSs, user interfaces, smart grids, office equipment and cloud computing, and miscellaneous. For each measure, an estimate was made of the average amount of energy saved. These estimates were based on one or more references. Each estimate number was applied to the energy use categories used by the Energy Information Agency (EIA) Commercial Building Energy Consumption Survey (CBECS). A second estimate of the percent of commercial buildings that could use the energy measure. A more detailed explanation of the analysis is contained later in the narrative and in the Appendix. These three variables are pointed out here because they are referred to in the energy measure subsections below.

Smart Building Components (Smart Windows)New developments in material 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). For the purpose of this analysis, the efficiency gains of smart windows are used as a proxy for the average collective gains from all existing and future smart building components and that at least some of these energy measures will be of use to half of all commercial buildings and that it will reduce energy for heating and ventilating by 5%, air conditioning by 10% and lighting by 20%.

Lighting Automation

There continue to be incremental gains in the area of lighting. When a BMS has information related to current and future occupancy and current and future weather, it can not only bring lights on and off at optimal times and luminosities, it can 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 OsramSylvania (OsramSylvania 2013) indicate potential savings of 40 to 75% beyond what is possible with standard occupancy-based lighting controls. Recognizing that many buildings already have some level of enabling technologies such as sensors and time of day programming, for the purpose of our analysis, we estimated that about half of this (35%) will be the average efficiency gain for a commercial or manufacturing building and applied it to the CBECS "Lighting" category. We also estimated that 75% of buildings will be able to utilize this technology.

Smart HVAC Components

Technologies are coming on the market now that enable each subset of a BMS to self-optimize. For example, motors can monitor their own performance and adjust their operation, as well as send information to the BMS that can be aggregated to get a global picture of the system's performance (Wang 2010). Although the savings from each component is small, in aggregate they can reduce the energy use of an HVAC system by 10 to 30% (Sinopoli 2010) and enable the holistic management of the system by advanced BMSs. We estimated that half of all buildings could get value from such measures and that on average they will see a 10% reduction in energy use by heating and ventilating systems and a 15% reduction in air conditioning and refrigeration systems.

Intelligent Building Management Systems (advanced BMS)

The difference between a Level 3 BMS and a Level 4 BMS 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. Therefore, these savings will not be realized in the first year of deployment but over time as a system's self-correcting capability starts to pay dividends. Research done by the Pacific Northwest National Laboratory, the National Institute of Standards and Technology, the Natural Resource Defense Fund, and Energy Design Resources found savings ranging from 24 to 46% for enabling Level 3 BMSs and an additional 10 to 30%with intelligent Level 4 systems that have fault detection, historical analysis, and predictive capabilities (Wang et al. 2011, Sinopoli 2010, Henderson and Waltner 2013). In the analysis we estimated that advanced BMSs will be of value to threefourths of all commercial buildings and that they will provide a marginal increase of 10% savings for cooling and ventilating and a 20% improvement in electric heating.

Smart Grids

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 BMS to determine how to run the building to minimize energy costs. Although the BMS will likely be programmed to prioritize energy costs over energy use, it is still likely to reduce overall energy use because much of the cost savings for buildings will result from reducing energy use when energy prices are highest, usually during the hottest time of the day. For the most part, these loads cannot be shifted to other times of the day, so on net, there will be savings. A study by Pacific Northwest National Laboratory indicated that electric utility customers could realize 10% energy savings through transactive controls (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, the install smart meters which make visible their energy consumption 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 Building IQ, 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. In our analysis, we estimated that 75% of all commercial buildings could get value from connection to a smart grid and that it would reduce electricity use by HVAC systems by 10 percent.

Dashboards and other User Interfaces

The common method of conveying performance information today is through a computer screen. Displaying the raw data though is seldom useful to an operator or manager. The information needs context. Is a device running within its normal operating parameters? How does the performance of one device compare to another identical device? User interfaces conveying information to end users. A new generation of interfaces called "dashboards," named after automobile dashboards, attempt to convey pertinent information in a contextual manner that aids decision making.

Energy dashboards communicate to workers, technicians and managers energy information in a way that is instructive and actionable. We described the benefits of the Envision Charlotte (Envision Charlotte 2010, Downey 2012) piloting of this technology in our first intelligent efficiency report. The potential energy savings are anticipated to be as high as 20% for some participants who may be focused on energy use for the first time. For the purpose of our analysis, we estimate that half of this will be the average efficiency gain and that a fifth of all commercial buildings' could find value in it. Energy savings will come from HVAC systems, computers and other miscellaneous loads.

Office Equipment and Cloud Computing

Electricity used to power office computers, copiers, and servers can be saved through any of the three types of intelligent efficiency: technology-centered, people-centered, and service-oriented. In the technology-centered approach, intelligent controls turn office equipment on or off, or put in idle mode, according to historical trends and current conditions. ENERGY STAR estimates these savings to be approximately 5% of office equipment's energy demand (ENERGY STAR 2013).

In the people-centered approach, employees can optimize their use of equipment in ways that save energy. As described above with reference to the Envision Charlotte project, savings of up to 20% are possible, although we assume only half of that in our analysis.

The service-oriented approach likely produces the greatest savings. Most offices have a series of servers that handle their accounting, payroll, email, and other IT needs. These servers are seldom operating at peak capacity and yet use almost as much energy at partial load as at full load. When an organization switches to cloud-based computing, many of these servers—along with the energy they use and the air-conditioning they require—can be completely eliminated. A report for the General Services Administration estimated that cloud computing alone could reduce federal IT budgets by 25%, or $20 billion per year. (Kundra 2011)

In our first report on intelligent efficiency, we identified analyses conducted by Google, Holler, and the Carbon Disclosure Project that on average estimated that a company could reduce its IT energy demands by 50% (Google 2011, Holler 2010, Carbon Disclosure Project 2011) by switching to cloud-based computing. Salesforce.com estimates that carbon reductions greater than 80% are possible (Salesfore.com 2013). Though not always correlated 1 to 1, energy use and carbon emissions are directly related, and therefore it would not be unreasonable to expect that energy use might decrease by this amount.

For the purpose of our analysis, we estimated that 50% of all buildings will implement some mix of these energy measures and that the average benefit will be a reduction in the energy use that falls under the CBECS "Other" category by 50%.

Refrigeration Energy Management Systems

For many restaurants and food service facilities, walk-in refrigerators are the largest single energy-consuming system. They run 24 hours a day and every day of the year. Fortunately, there are control systems available that turn fans and chillers up or down in response to demand. The sophistication of these systems is increasing, and components will be able to be integrated into a holistic building automation system with the ability to respond proactively to environmental inputs (Baxter 2004). In the analysis, an estimate of 30% was used and applied to the amount refrigeration energy use and that it will be of value to 75% of all buildings with large refrigeration loads.

Smart Fume Hoods

Smart fume hoods for kitchens and laboratories can adjust the volume of air evacuated so as to reduce the energy used by the hood fan and the room's heating or cooling system. The food service sector uses hoods in kitchen areas, and research organizations use them to extract dangerous fumes safely from laboratories. While these devices represent a small portion of the commercial sector's energy consumption, they are often major energy consumers for the facilities that have them. Therefore, it is likely that the new technology that regulates the speed of hood fans in response to need will gain broad market acceptance. Since it is important that these systems always work when needed, higher levels of automation will be required. Technologies examined by the Lawrence Berkeley National Laboratory have the potential to reduce energy use by 10–30% (Desroches and Garbesi 2011). For our analysis, we estimated that these measures could be used by 10% of the buildings covered in the *Commercial Buildings Energy Consumption Survey*. Buildings that have such equipment could on average realize a 15% energy reduction in energy use by cooking and ventilating systems.

Miscellaneous Intelligent Efficiency Measures

In the search for intelligent efficiency measures to be considered in the economic analysis, several technologies were identified for which insufficient economic energy consumption data was available. In this section a few of those technologies are highlighted to bring attention to the breadth of impact intelligent efficiency will have on the economy. To reflect them in the analysis, we estimated collectively they might reduce by 2% the amount of energy used that falls under the CBECS "Other" category for all buildings.

Smart escalators can turn off or slow down when no one is onboard and speed up once an approaching person is detected. Smart elevators can coordinate with one another and can be programmed with the ability to optimize scheduling during peak demand based on historical performance data. Collectively, these are not major uses of energy within a building, but they are significant and research has indicted a potential to reduce energy consumption at the system level by 20 to 46% (Otis 2011, Schindler 2013, KONE 2013).

The efficiency of vending machines continues to improve, and a recent study done for the U.S. Department of Energy indicates the next generation of vending machines could reduce energy use by 40 to 50% over standard equipment. An additional 20% is the potential gain on top of already realized efficiencies with the next level of technology. (McKenney et al. 2010).

Healthcare facilities are among the most energy-intensive commercial buildings (Singer and Tschudi 2009). In particular, the energy consumption of medical equipment such as magnetic resonance imaging (MRI) and computerized tomography (CT) equipment has grown considerably as more powerful technology provides better resolution and advanced diagnostics. Many types of medical equipment have a very high power draw and are often left in standby mode when not in use (McKenney 2010). The standby power draw of an MRI machine could be half of the 14,000 Watts it consumes when in use (McKenney et al. 2010). This suggests that the use of intelligent controls to run the equipment only when needed could save significant amounts of energy. With over 30 million pieces of medical equipment in the country (McKenney et al. 2010), the healthcare sector presents a new avenues of savings through deployment of intelligent efficiency.

Table 4: Intelligent Energy Measures for Commercial Sector

Energy Measure	Range of Savings from Literature Search	Estimate Use in Economic Analysis
Smart Building Components	5–20%	10%
Smart Lighting	Up to 75%	35%
Smart HVAC Components	15%	10–15%
Advanced BMS	10–30%	10–20%
Smart Grid	10%	10%
User Interfaces	10–20%	10%
Office Equipment and Cloud Computing	2--50%	50%
Refrigeration Energy Management	30%	30%
Smart Fume Hoods	10–30%	15%
Miscellaneous Measures	20–50%	2%

ACCOUNTING FOR INTERACTIONS BETWEEN ENERGY MEASURES IN THE COMMERCIAL SECTOR

The challenge in a quantitative analysis of energy savings that results from multiple energy measures, each of which impacts the energy use of one or more systems in a building or manufacturing plant, is parsing out the savings attributable to given energy measures and individual building systems.

First, assuming no amplifying interactions between multiple measures operating simultaneously, the energy savings are not additive but factorial. For example, five energy measures targeting the energy use of an HVAC system are implemented (e.g., motors are replaced with more efficient motors, fans are replaced with more efficient fans, duct work is upgraded to produce less resistance, and boilers and chillers are tuned), and each measure has the potential to reduce energy use by 10%. The net benefit of these five measures is not a 50% reduction in energy use by the HVAC systems. Rather, the first measure will save 10% of the original energy use, the second measure 10% of the remaining energy use, and so on. The total savings will be 41%, since each measure subtracted 10% of a number that was growing smaller and smaller.

$$\text{Total Energy Savings} = [1 - (1\text{-}EM_1\%)\text{x}(1\text{-}EM_2\%)\text{x}(1\text{-}EM_3\%)\text{x}(1\text{-}EM_4\%)\text{x}(1\text{-}EM_5\%)]$$

In our analysis of HVAC systems, we used this methodology to determine the net savings from multiple energy measures. Five intelligent efficiency measures affect the energy use of an HVAC system: smart building components, smart HVAC components, advanced BMSs, user interface, and smart grid. The impacts of these energy measures on other building systems such as lighting was dealt with separately in the analysis.

In Table 3 below, we show the energy savings possible for three energy end uses, space heating, space cooling, and ventilation, for each of the five intelligent efficiency measures mentioned above. The three categories for buildings' energy use are taken from categories used by the U.S. Energy Information Administration's (EIA) in its *Commercial Buildings*

Energy Consumption Survey. We have adopted the EIA's categories in order to be able to use EIA data in our analysis when we determine energy savings on a national level.

Table X demonstrates that if the net savings were additive, we could potentially see energy savings exceeding 100% of energy used, which is of course not possible. Instead, by using the equation above, a more realistic number is determined for each of the three categories.

Table 4: Interaction of Energy Savings Measures and Determining Net Savings

Energy Measure / System	Space Heating	Space Cooling	Ventilation
Smart Building Components	5%	10%	5%
Smart HVAC Components	10%	15%	10%
Advanced BMS	20%	10%	10%
User Interface	10%	10%	10%
Smart Grid	0%	10%	10%
Cumulative Savings (Additive)	45%	55%	45%
Net Savings (Factorial)	38%	44%	38%

INTELLIGENT EFFICIENCY MEASURES FOR THE INDUSTRIAL SECTOR

The industrial sector is not as homogeneous as the commercial sector; therefore, it is much more difficult to identify a limited number of specific types of efficiency measures that will have broad applicability. A next-generation manufacturing process for plastic injection molding operations, for example, will not have applicability in metal casting or fabrication. With this limitation in mind, we identified generic smart technologies within manufacturing that, much like advanced BMSs in the commercial sector, have broad applicability across multiple manufacturing sectors, construction, agriculture, and mining.

Using this criterion, we examined the five levels at which intelligent efficiency can be implemented in the manufacturing sector, within specific processes and within the organization overall.

- Device level: motor, pump, fan, compressor
- System level: pumping system, air handling system
- Production level: individual product line
- Facility level: manufacturing facility
- Enterprise level: corporation

As described earlier in this report, motors and the systems they drive can communicate with production-level control systems. The production control system provides plant management with up-to-date information on the state of the manufacturing process and progress against production targets. The production control system can interact with the facility's BMS and both of them communicate information to the engineering and maintenance departments to alert them to devices and systems that are not functioning properly. The production system communicates with the enterprise resource planning system, which provides corporate management with the information it uses to direct the company.

All of this communication between levels improves energy use throughout an organization. Prior to the advent of automation, information had to be recorded manually and communicated often in person. This was time consuming and inefficient. It is for this reason that manufacturing and automation go hand in hand and why it is a natural fit for intelligent efficiency to take root in manufacturing. The term "smart manufacturing" has come to represent the combination of capabilities that result from integrating ICT into the production process.

The type of manufacturing will dictate which specific intelligent efficiency measures are incorporated into production and how they are integrated within an organization; however, each segment of manufacturing will have some version of the categories described above into which common energy measures fit.

PLANT AUTOMATION AND CONTROL

There are different types of plant-wide automation and control. Some factories use distributed control systems[7] that are able to connect to analog equipment and systems, while others purchase equipment that is already embedded with programmable logic controllers[8] that can be networked in a plant control system. Either process control methodology can benefit from intelligent efficiency. Research by the Smart Manufacturing Leadership Council has indicated that ICT-enabled smart process and production control technologies have the potential to improve operating efficiency by 10%, water usage by 40%, and energy usage by 25%. For the purpose of our analysis we estimated the average savings realized by to be 20% (SMLC 2013).

Determining the marginal energy efficiency savings that result from the smart manufacturing/intelligent efficiency overlay to the plant-wide control system is more challenging than for a BMS because it is harder to discern the break between Level 3 and Level 4 technologies. Most production devices and systems have embedded intelligence in the form of "firmware" that governs their operation and enable connectivity with other ICT-enabled systems. A typical factory has dozens if not hundreds of discrete software packages each with its own specific functionality. These programs may be commercial off-the shelf products, purchased from an equipment vendor or developed in-house. With this complexity it is difficult to determine at what point a manufacturing process or facility becomes "smart;" therefore, our solution in the economic analysis was to assume that all ICT-enabled devices are indeed intelligent efficiency measures and should be included.

In addition to initial capital costs, these automated systems also have recurring costs such as licensing or subscription fees, service contracts, preventive maintenance, and other fixed operating costs (Navigant 2013b). Based on conversations with vendors of manufacturing automation systems, in our analysis we assumed 20% of the original investment as the cost of recurring subscription and services contracts.

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[7] DCS is a control system that collects data from the field for use for current and future control decisions.

[8] PLCs are computers used in automation of production processes. The devices make control decisions based on information provided by one or more signal inputs and affect control via one or more outputs.

INDUSTRIAL BUILDING AUTOMATION

These systems are no different from those used in the commercial sector, therefore, we estimated the same level of potential savings as we used in the commercial sector. The one major distinction is that we assumed that these investments would have a simple payback of two years versus four years for the commercial sector, because investment hurdle rates in industry tend to be much higher than the commercial sector.

RESULTS: CUMULATIVE POTENTIAL ENERGY SAVINGS FROM INTELLIGENT EFFICIENCY

Having developed an estimate for the amount of savings likely for each of the selected intelligent efficiency measures, we then determined the ratio of energy that could be saved for several end uses. The savings of each of the intelligent efficiency measures for the commercial sector were put into a matrix with the EIA's *Commercial Buildings Energy Consumption Survey* to determine the amount of energy savings that might be possible by building type and by energy use. The output of the matrix, described in detail in the appendix, was a percent of potential energy savings that any investment in intelligent efficiency in the commercial sector can be expected to achieve.

Next, we developed a projection of energy savings using EIA *2013 Annual Energy Outlook* forecast data and, based on prior ACEEE research (Nadel et al. 1994), selected 50% as the ratio of all commercial building space will adopt at least some level of intelligent efficiency by 2035. A sensitivity analysis was performed with an estimate that the error of the 50% target is in the range of +/- 50%, and these three scenarios are presented in Graph A as the low, mid, and high scenarios. The three of them represent the range of potential energy cost savings that we estimate is possible in the commercial sector. The analysis also assumes a relatively modest increase in investments of 1% per year early in the twenty year period and finishing at 2%.

Investments were assumed to be made with an expectation of a 20% annual return, or a five-year payback. The first year cost of licensing and services contracts are built into these cost estimates.

In the analysis of the industrial sector, the scope of this report did not allow for the analysis of dozens of individual energy measures as was done in the commercial sector. This is an area ripe for additional research, as the number of emerging technologies and their potential to affect changes is great. To determine the potential energy savings likely in the industrial sector, four fundamental assumptions were made. The first assumption was that 80% of all energy use in the manufacturing sector is attributable to manufacturing processes, a number supported by EIA data and previous ACEEE research (MECS 2006, Elliott et al. 2000). The second assumption was that the average energy savings realized by manufacturing facilities adopting intelligent efficiency would be 20%. This value is based on past ACEEE analysis, reports by the Smart Manufacturing Leadership Council (SMLC 2011) and conversations with others investigating smart manufacturing. The third assumption was that the balance of energy use in manufacturing, 20%, is consumed by buildings and that they have the same opportunities for energy savings as commercial buildings. The fourth assumption is tied to data reported by the EIA *Manufacturing Energy Consumption Survey* (MECS). Thirty-nine percent of energy used in the manufacturing sector was not attributed to specific end uses in responses to the *End Uses Fuel Consumption 2010* survey. To compensate for this omission, we assumed that the breakdown of that 39% mirrored that of the 61% reported and increased the values of energy used in manufacturing processes and buildings accordingly.

Figure 6: Commercial Sector Annual Energy Cost Savings

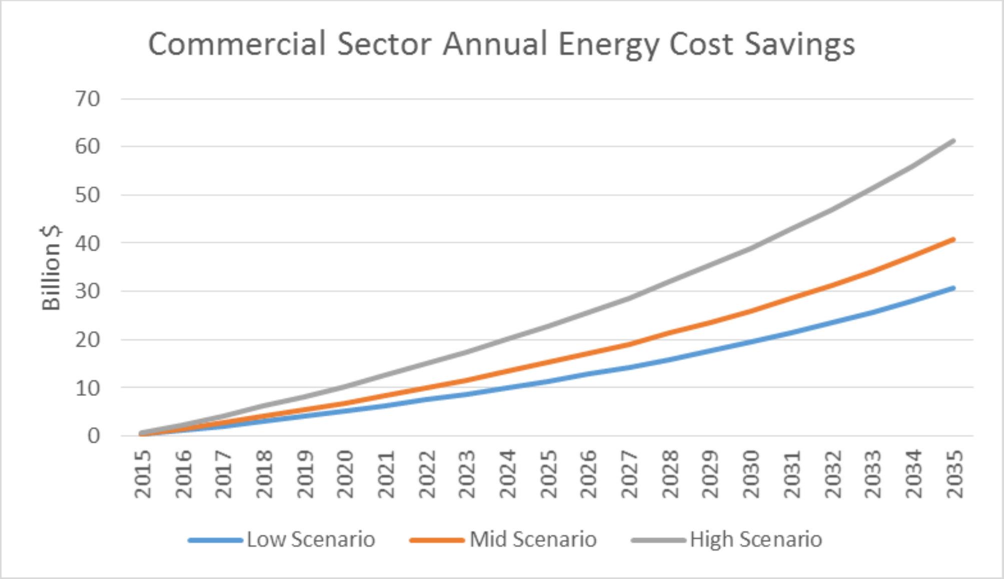
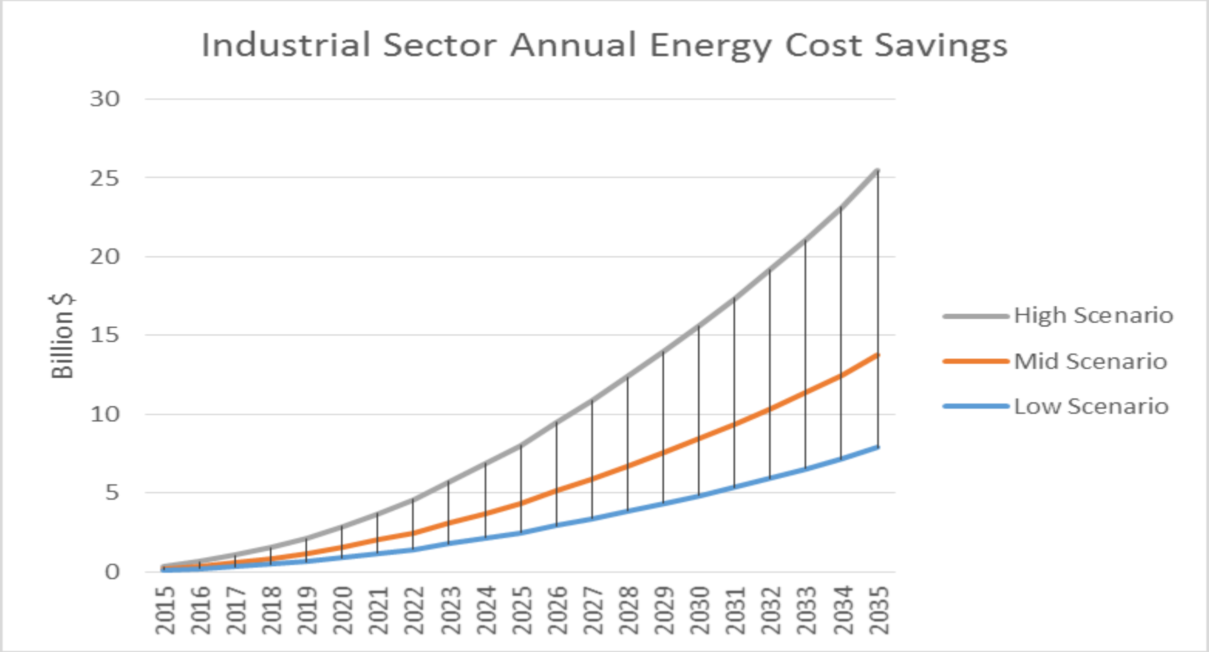


Figure 7: Industrial Sector Annual Energy Cost Savings

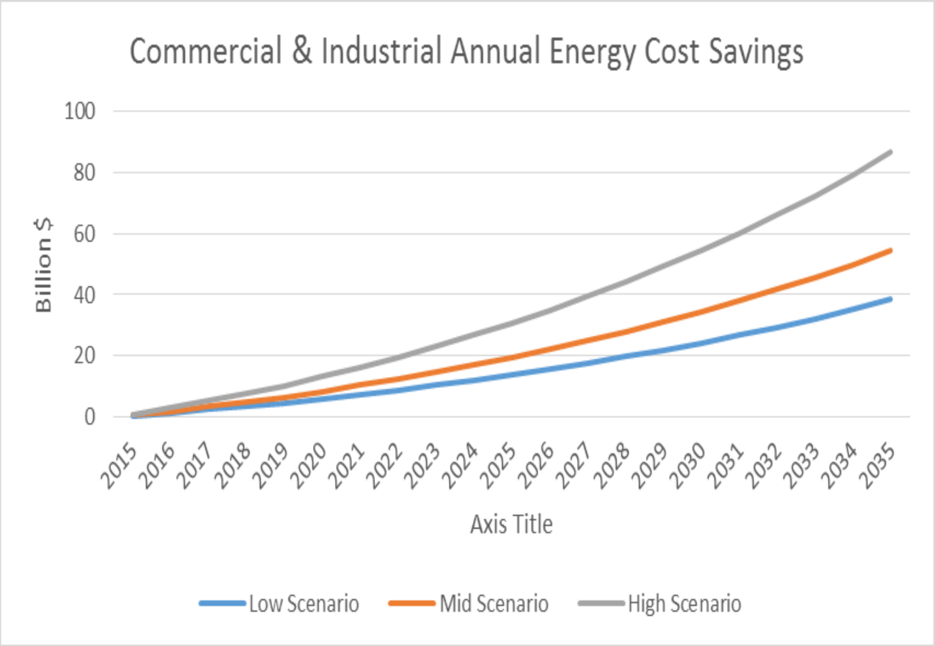


The balance of the analytical method followed the analysis of the commercial sector. A target of 50% of all manufacturing electrical load is assumed be influenced by intelligent efficiency by 2035. Investments will increase initially at 1% per year and rise over the 20-year period to culminate at 3% per year. Investments will produce a 50% return (two-year payback), and licensing and service contracts will equal 20% of annual investments.

A similar sensitivity analysis was done estimating that the error of our original estimate is +/- 50%. Built into all of this analysis is that these projects are justified on potential energy cost savings. Conversations with people in the manufacturing automation sector indicated that this is seldom the case. Primary motivations for investment in the industrial sector are to improve production efficiency, product quality, safety, and regulatory compliance. Energy savings is often perceived to be an ancillary benefit. This detail though does not deter us from our findings as the energy cost savings still can justify the supporting investment. If anything, it supports the perspective that our estimate is conservative and that much greater investment is likely in smart manufacturing over the next twenty years.

Our analysis indicates that the potential energy cost savings from intelligent efficiency measures for these two sectors could exceed $55 billion annually by 2035.

Figure 8: Combined Energy Cost Savings from Intelligent Efficiency



Even though energy consumption in both sectors is similar, a greater amount of savings is forecast for the commercial sector. This is because the commercial sector accepts a lower rate of return on its investments and because most of the energy in this sector is consumed in heating, cooling, ventilation, and lighting—areas that are fairly easy to automate. The same is not true for the manufacturing sector, which is much more complex and difficult to automate. Nevertheless, the potential for dramatic energy and cost savings in both sectors is very large and worthy of further attention and analysis. Policymakers and organizations with an interest in the energy sector need to take notice of intelligent efficiency approaches—cost-effective and broadly applicable to companies and industries nationwide— and develop ways to advance and encourage them.

Barriers and Needs at the National Level

With so many benefits to intelligent efficiency, one might expect natural market forces to bring about market transformation with little or no change in public policy. However, with every leap in technology, there have been barriers to rapid market acceptance, and intelligent efficiency is no different. Some barriers are already known and quantified while others are still emerging.

Since our first report, we have gained greater clarity on a number of barriers, and new issues have arisen as we have seen intelligent efficiency evolve in the marketplace. In our first report we identified a number of social, structural, and financial barriers to broader acceptance of intelligent efficiency:

- The **social barriers** reflected consumers' concerns about the privacy of data on their energy use, and the lack of awareness among consumers and policymakers about intelligent efficiency technologies and their associated benefits.

- The **financial barriers** included the upfront costs of implementing these new smart building and manufacturing technologies, barriers that frequently inhibit the broader acceptance of other kinds of efficiency efforts as well.

- The **structural barriers** included incompatible communication strategies and platforms for smart devices, different methods of reporting energy savings information, and existing legal and regulatory structures in the utility sector that favor assets over services.

Here, we focus most intently on the structural barriers. The social barriers are largely being addressed as procedures for anonymizing customer data are being established and the security of data improves. Additionally, many of these social issues are part of larger societal challenges not specific to energy efficiency and therefore beyond the scope of this report. There is however some overlap between social and structural barriers; therefore, within the structural barriers context, we do include discussion of some social barriers. Financial barriers are touched on below, although the challenges faced by intelligent efficiency measures with respect to financing is not significantly different from those faced by other energy measures, namely, the challenges of financing capital investments in tight economic times.

Many of the challenges associated with deploying intelligent efficiency are related getting it to function effectively for end users. Even though the human interfaces of building and process control systems are improving by doing a better job of providing people with actionable information in an easy-to-understand format, there is much up-front work that often needs to be done to ensure that the system is collecting the correct data and analyzing it to produce the most useful information.

Currently, primary technical challenges related to intelligent efficiency that are facing end users are learning how to process the exponentially larger volumes of data they are now collecting and doing so in ways that help them make proper decisions.

Adding an additional level of complication to this issue is that there often isn't always consistency between systems and between different vendor platforms in how energy data is communicated. This means that before data from one system can be used by another, it must first be translated. This is both inefficient and opens up the opportunity for misinterpretation.

Misinterpretation is also an issue with the determination of energy savings data. Characterizing the volume, time and quality of energy savings can be challenging, therefore it is important to have a common language that all who use the information can agree upon.

THE CHALLENGES OF BIG DATA AND DATA ANALYTICS

The revolution we have seen in recent years in sensors, data collection, data storage, and computational capabilities has transformed the way we think about data and has ushered in an era of "big data." Today, we can afford to collect massive amounts of data in real time, and with the dramatic decrease in data storage costs, we can afford to keep those data indefinitely (Economist 2012). These technology innovations have transformed many markets from having the limiting factor being the cost of collecting data to being the need for understanding of data analytics and techniques to discern meaningful information from a flood of data.

Big data and data analytics are fundamental to intelligent efficiency as they enable all of the computational and optimizing abilities described thus far in this report. But before the BMSs or production control systems can provide management 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. Distinguishing the information the end user needs, the "signal," from other non-relevant information "noise" requires considerable computation capabilities and this is where data analytics come in. They enable the parsing of key information such as a fault of a minor component of an HVAC system, or trends such as compressed air usage spikes on production line #1 in on mornings when product "A" is being made on production line #2.

Once pertinent data are collected, operators of buildings and processes face a new problem in how to manage those data and how to turn them into actionable 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, again, challenged to turn it into useful information. Companies need help determining what data to collect, which data to discard, and what questions to ask of the data, and how best to get actionable answers.

The challenges of dealing with big data are not unique to energy efficiency, however the interest in harnessing the ability of big data and intelligent efficiency to produce economic growth, energy savings, and associated environmental benefits has produced efforts to quickly overcoming these barriers at the highest levels of government.

Big Data Management Demonstrations and Education

The federal government has the largest ICT infrastructure in the world and therefore has the greatest potential to benefit from implementing best practices. Government can demonstrate what big data and data analytics can do with projects like traffic control, fleet management, and building energy management to demonstrate what can work for large complex organizations. A product of these demonstration projects will be information on what data to collect and how to mine it for actionable information.

An example of this is the Open Data Format initiative that will make available energy consumption and intensity data from all government buildings (Whitehouse.gov 2011). From these data, not only have building energy consumption trends be identified, but new data mining efficiency products and services have been created (Whitehouse.gov 2013). These new services are now or will shortly be available to help organizations that are finding it challenging to benefit from big data.

Utilities also have a role to play in demonstrating the power of big data to help customers reduce energy usage. They have experience processing large volumes of energy information for their own use. New smart grid systems will only increase their ability to identify trends in customer consumption patterns. Some utilities and the commissions that regulate them are already considering how this might evolve. The California Public Utility Commission (CPUC) 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). Utilities can also help customers understand their energy data and how different responses, in the form of changes to consumption patterns, can impact not only their use of energy, but also their energy expenditures. Since it is unlikely utilities will have all the answers at first, such customer engagements can evolve as smart grids are rolled out and the ability to decipher meaningful information from the exchange of data across them.

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. Demand response is the curtailment of load at the customer level at the request of its supplying utility. 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.

A COMMON INTERCONNECTION TO COMMUNICATE ENERGY DATA

Hundreds 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 (Burgoon 2013) 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 that do so through some type of translation process.

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 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).

Another private sector effort to address the emerging issues around working with big data in general and energy and environmental data in particular is the Information Technology Industry Council, whose membership is composed of the world's leading software and electronics companies (ITIC 2013a). It was formed to lead the advocacy and policy discussions on a national level around the transformative potential of ITCs. The council has engaged the White House Council for Environmental Quality on multiple occasions as well as several energy legislation–focused senators and representatives.

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). It is also working internationally with industry-led standards groups in Brussels, Beijing, and elsewhere. It has sponsored the InterNational Committee for Information Technology Standards, a forum of 1700 members interested in promoting voluntary ICT standards (ITIC 2013b).

The Energy Information Standards Alliance (EIS Alliance) is a trade association for companies that provide energy management and smart grid products and services and whose members work collaboratively to educate policymakers, utilities and other stakeholders on how energy management systems can help them reduce energy usage (EIS 2013). They have been involved in developing a common framework for customer equipment to use, generate, and communicate energy data. They have collaborated with the White House its initiative to implement simple consumer energy management system products under the "Green Button" label (EIS 2012).

The ODVA, ITIC, and EIS efforts are great examples of the private sector coming together to facilitate intelligent efficiency through development of common protocols. A second piece of the puzzle is development of a common protocol for determining energy savings.

COMMON PROTOCOLS FOR DETERMINING ENERGY SAVINGS

As more and more companies focus on energy, they are confronting challenges in determining and reporting on energy savings. The fundamental challenge determining energy savings is the need to measure a counterfactual. This can be challenging because in order to determine how much energy has been saved, an operator of a business or manufacturing plant must first determine how much would typically have been used—how much has been used for a given process in the past. This "baselining" often involves a regression analysis of multiple production and environmental factors for the purpose of determining what drives energy consumption. Then, once an energy measure is implemented, these mathematical models can be used to determine net savings.

The challenge is two-fold. First, this process is time-consuming and therefore expensive. The second is that energy use is dependent upon production levels. As product volumes and mixes change, so does the energy consumption profile. The resulting energy savings of any given energy measure can be difficult to determine when no two days of production are the same. However, it is not necessary to determine the precise amount of energy saved at any given time by a specific energy measure, only the average amount over time, because energy use is observed in the aggregate. Accuracy in the determination of energy savings improves with time as more data is collected, collated and analyzed. What is needed is a common method that accommodates fluctuation in energy usage, perhaps by leveraging the increased volumes of data, to produce more accurate and reliable energy savings values.

New energy management protocols such as International Performance Measurement & Verification Protocol (IPMVP) (see the box on the next page) are giving companies the ability to measure energy savings with increased accuracy. This protocol, first published in 1996, encourages good measurement and verification (M&V) design and ongoing monitoring of performance. These protocols can be and in some case already are being incorporated into advanced BMS and smart manufacturing control systems. Intelligent efficiency platforms, such as the Panoptix Energy Performance Manager app highlighted in a case study above, can provide the analytics to measure and verify the savings of operations (IPMPV 2002).

Energy Management Standards

Some industrial companies are going the extra step of implementing a system to manage their energy use and guide their energy efforts that is compliant with international standards. One such system, Superior Energy Performance, is designed to provide companies with a transparent, globally accepted method for verifying energy performance improvements and management practices. A key component of Superior Energy Performance is that companies also implement the globally energy management standard, ISO 50001, which has additional requirements to achieve and document energy performance improvements. The program includes methodology to verify energy performance improvements, certified professionals to assist in implementation, system assessments and verify conformance (SEP 2013). U.S. Department of Energy (DOE) developed Superior Energy Performance in collaboration with the U.S. Council for Energy-Efficient Manufacturing (U.S. CEEM).

To date, few companies in the United States have implemented an ISO 50001 Certified energy management system or the Superior Energy Performance system as the up-front investment and long-term commitments are significant. Still, the value of them, and the IPMVP is that organizations that abide by them produce energy savings values that other organizations can trust and by extension, might be willing to pay for. It is this second point that directs our analysis to focus on how energy efficiency programs might benefit from intelligent efficiency.

IPMVP Protocol

When IPMVP was first published it contained methodologies compiled by a technical committee from the United States, Mexico, and Canada. IPMVP's direction on M&V practice encourages the good design of energy management projects, providing participants in an energy project a common set of terms with which to discuss key M&V project-related issues and establishes methods that can be used in energy performance contracts. The protocol defines broad techniques for determining savings from and the facility overall as well as an individual technology. It is flexible enough to be relevant to a variety of facility types, including residential, commercial, institutional, and industrial buildings, and industrial processes. It provides an outline for applying procedures to similar projects throughout all geographical regions and that are internationally accepted, impartial, and reliable.

The IPMVP:

- Presents procedures, with varying levels of accuracy and cost, for measuring and/or verifying baseline and project installation conditions, and long-term energy savings.
- Provides a comprehensive approach to ensuring that buildings' indoor environmental quality issues are addressed in all phases of project design, implementation, and maintenance.
- Creates a living document that includes a set of methodologies and procedures that enable the document to evolve over time.

The protocol is intended for facility energy managers, project developers and implementers, energy service companies, water service companies, non-governmental organizations, finance firms, development banks, consultants, utility executives, environmental managers, researchers, and policymakers.

EXAMPLE: FEDERAL ENERGY MANAGEMENT PROGRAM (FEMP)

The U.S. Department of Energy's Federal Energy Management Program (FEMP) was established, in part, to reduce energy costs to the U.S. government from federal facilities. FEMP assists managers at federal facilities by identifying and procuring energy-saving projects. The FEMP *M&V Guidelines* follow the IPMVP and provides guidance and methods for measuring and verifying the energy and cost savings associated with federal agency performance contracts. It is intended for federal energy managers, federal procurement officers, and contractors implementing performance contracts at federal facilities. The FEMP *M&V Guidelines* have two primary uses:

- They serve as a reference document for specifying M&V methods and procedures in delivery orders, requests for proposals, and performance contracts.

- They are a resource for those developing project-specific M&V plans for federal performance contracting projects.

Many states in the United States have incorporated the IPMVP into their energy efficiency programs and their determination of energy savings from energy performance contracting. The New York State EnVest program, for example, is structured to be consistent with the IPMVP, and the New York State Energy Research and Development Authority strongly recommends the use of IPMVP for institutional projects. Other states that have incorporated the IPMVP in state energy performance contracting and other energy efficiency programs are California, Colorado, Oregon, Texas, and Wisconsin.

The Opportunity for Intelligent Efficiency in Energy Efficiency Programs

The typical base-load generation produces electricity at a cost of $0.073 to $0.135 per kWh while energy efficiency can achieve savings at an average cost of $0.03 per kWh saved (Friedrick et al. 2009). These economics have encouraged states utility commissions to view energy efficiency as the least-cost energy resource and consequently there has been an increase in the number of programs and respective targets for energy savings. (Chittum, Elliott, and Kaufman 2009). These energy efficiency programs provide technical assistance and financial incentives to encourage the purchase of energy savings equipment. Incentives in 2010 totaled more than $1 billion in the industrial sector alone (Chittum and Nowack 2012).

Utility-sector energy efficiency programs are intended to mitigate the need for utilities to invest in conventional generation and transmission by instead using funds to assist their customers in reducing their energy consumption. Energy efficiency programs within the utility sector are created by state governments and public utility commissions, the utilities that serve electricity and natural gas customers, and the administrators of those programs. Each stakeholder has its own goals and priorities and tries to incorporate them during the process of developing a program.

UTILITY SECTOR EFFICIENCY PROGRAMS

Many commercial sector programs targeting building efficiency focus on the building envelope, lighting, and the components of HVAC systems. When any of these components are upgraded, a certain reduction in existing energy use can be predicted with a fair level of certainty. However, upgrading the devices is only part of the solution. Lighting and HVAC systems do not run continuously but are turned on and off, and up and down throughout the work week. A light that is off uses less energy than a light that is on, so building operators and efficiency program administrators are always looking for methods to turn lighting and other equipment off. This can be accomplished through automation or worker training.

The industrial sector has been challenging for energy efficiency programs to penetrate due in large part to the heterogeneity of the sector (Chittum, Elliott, and Kaufman 2009). Where efficiency programs may be able to commoditize their offerings to residential and commercial sectors, the industrial sector often requires a more custom approach. In custom programs, the building operator or factory manager establishes a baseline of performance. Energy measures are evaluated and future energy use, based on past building use, or factory production, is forecasted. Using forecasted savings numbers, the program administrator commits to a specific financial incentive which the customer then uses to help finance the implementation of the identified energy measures. Though these projects can save a great deal of energy, they often require a considerable up-front investment in time.

Simplicity of administration is major reason that the majority of energy efficiency programs focus on increasing the efficiency of individual devices rather than larger systems. Installing a motor that is 3% more efficient results in 3% energy savings. The cost of such assets and the savings they provide are easy to measure and verify.

M&V is an important part of any efficiency program. Programs must ensure that the savings—energy efficiency resources as they are often called—they are claiming will be available some months or years in the future when needed. Evaluating energy savings attempts to measure something that does not exist—the energy that is not being used—and so program evaluators must rely on assumptions and estimates to make their determinations.

With simple projects such as replacing lighting or motors with more efficient units, the amount of energy saved can be established at the outset of the project. With more involved projects, engineering analysis, surveys, and analysis of energy bills may be required (Chittum 2012). One of the challenges with this approach is that a thorough engineering analysis to determine the exact energy savings realized over time by a large industrial project could be so expensive as to make the energy savings cost-prohibitive.

CHALLENGES FACING EFFICIENCY PROGRAMS

Program administrators of older energy efficiency programs may soon find it challenging to meet targets that continually rise while keeping down the programmatic cost per unit of energy saved. The first projects that a utility implements are often the lowest cost and the easiest to evaluate. As utilities get further into their energy savings journey, the projects become more complex, as does the determination of savings. For the program administrator with responsibility for effective use of ratepayer or taxpayer funds, this is an important issue and one about which many of their stakeholders have opinions.

Some program managers are realizing that greater savings are possible and at lower costs with investment in projects that focus on system optimization. For example, the Northeast Energy Efficiency Alliance (NEEA) focuses much of its engagement in the manufacturing sector on assistance with the implementation of energy management practices (NEEA 2013b). The companies engaged adopt a systematic approach to energy management, tracking energy use and implementing best practices on a continual basis. These engagements can be very effective, however determining the energy savings that results from them can be challenging.

To determine energy savings with accuracy, it is first necessary to establish a baseline of energy use at different times of the year prior to the installation of an energy measure. Energy use data from after the efficiency measure(s) are implemented can then be compared to that baseline and net savings determined. Beyond the challenge of determining the baseline, all of this can be time consuming and therefore costly. So even though energy efficiency has consistently proven to be cheaper than other types of resources (Friedrich et al. 2009), program administrators for efficiency programs can still be challenged to secure sufficient savings to meet their targets in a cost effective manner and with a high degree of confidence.

Two additional M&V challenges are those of attribution and energy intensity. If several energy measures are implemented at the same time and there isn’t before and after system specific energy consumption data, it is very difficult to attribute energy savings to each measure using conventional analysis techniques. Energy intensity refers to the amount of energy needed to perform a specific task. If a company installs a new product line that employs cutting-edge technology, energy savings in terms of energy per unit of production (energy intensity) is likely to decrease as a result of more efficient components but also from a more efficient process. However, the new production line might produce twice as much product as the previous line and therefore use more energy overall. With all of these M&V issues it is clear that a more effective method of measuring and verifying energy savings is critically needed.

In an effort to overcome these challenges, some programs are considering projects involving automation and controls (Monsalves-Salazar 2013, Goldman 2013). These projects are a promising opportunity for efficiency programs not only because they provide programs a new set of energy saving assets to incent, but also because they may yield savings at a lower cost and with a higher level of confidence.

INCLUDING AUTOMATION AND CONTROLS IN EFFICIENCY PROGRAMS

Leading efficiency programs are seeking new programmatic methods 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. As described in the case studies earlier in this report, conventional BMSs have a proven ability to reduce energy consumption by 10 to 30 percent and advanced BMS even more so. 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 provide an improved measurement capability.

The computational power of data analytics enables the establishment of a baseline much more easily and inexpensively than before, even with historical data that is not of the quality of current BMS generated data. Advanced BMS and manufacturing process control systems now have the ability to measure current performance, compare with past performance, and then forecast future performance. This solves the issues of attribution and energy intensity. The intelligent efficiency measures can track energy consumption at the device level, match that with facility use or production values, and provide both facility operators and efficiency program administrators energy performance data and forecasts that they can use to forecast future energy resource needs. And since this is an automated processes, the exchange of information can happen at or near real time and at a lower cost than conventional data collection and reporting.

CHALLENGES OF INCORPORATING AUTOMATION AND CONTROLS INTO EFFICIENCY PROGRAMS

Though it may also be easy to understand how automation can save energy, it is more difficult to determine how it can be incorporated into an energy efficiency program. And though the net energy savings is not in dispute, this type of measure creates challenges for the conventional energy efficiency program.

Utility sector energy efficiency programs operate on a cycle determined by the utility and public utility commission. They may be as short as a year or more than five, but most programs tend to be two or three years in duration. At the end of a cycle they are subject to review and may or may not be renewed. This is problematic for commercial and industrial customers making long-term investment plans. Furthermore, many programs do not allow for applications throughout the year but instead have specific application windows. These cycles are not likely to be in sync with a company's capital investment cycle or compatible with the multi-year implementation period of larger capital projects. This can cause the financial incentive and the measurement of savings to be split between the year(s) of installation and the first year of operation (Chittum 2012). If a program totals the savings of a project at the end of its first year, it may capture only a fraction of possible savings. Due to performance pressures by program evaluators, program managers attempt to book savings as early as possible, which means that savings from larger long-term projects are not properly counted (Chittum 2012).

As described earlier regarding the benefits of continual optimization, with some intelligent efficiency technologies, it is not appropriate to calculate savings prior to installation since the ability of automation to wring savings from a system is influenced by many variables. Instead, programs wanting to influence the full use of the automation will seek a method to determine actual savings and let those values drive the amount of financial assistance. Programs may also want to provide assistance over a period of one to three years as a method to encourage customers to get full value of the investment.

Conventional energy efficiency programs have focused on component energy efficiency, which poses several challenges to advancing intelligent efficiency measures. The first is a connectional challenge—in a complex project involving multiple components and controls, the energy savings happens at the device level even though it is influenced at the control level. What, if any, portion of the energy savings realized can be attributed to the controls? When performing M&V, how should energy savings be attributed? For example, a building retrofit project might include new lighting, new HVAC components, replacement windows, and a new BMS. It is easy enough to verify that equipment has been installed and to measure the amount of energy saved, but determining the portion of energy saved attributable to the BMS in this situation will be difficult if not impossible.

And it would not be necessary if for not the fact that many programs are organized around encouraging the purchase of efficient equipment such as high efficiency lighting or motors. The reason for this is straight forward. Determining prior to implementation the maximum energy savings possible with these assets is straight forward. With a little more effort, reasonably accurate estimates of savings under common usage can be determined and applied broadly. For example, a program can estimate with confidence that for every hundred lighting projects, the average reduction from prior usage will be 20% and with this knowledge set an incentive at an amount related to the value of energy saved.

The administration of such a program is simplified by the ability to determine future savings for a given energy measure before implementation and then only need to verify implementation to satisfy M&V requirements. However, in some intelligent efficiency measures do not require the purchase of physical assets but instead involve the use of on-site software and/or off-site, online computational capabilities. Some utility programs have encountered challenges providing incentives to these types of projects because of what some in the intelligent efficiency community have come to characterize as the "asset tag" problem. What exactly is it that they pay for when they provide a financial incentive?

For example, a new software program that has improved diagnostic abilities due to its ability to process larger volumes of data could produce energy savings by providing building operators with improved building performance metrics that alert them to opportunities to adjust set points for more efficient HVAC operation. Such savings would not be possible without the software or the building operator training.

Another example of “asset tag” challenge is the opportunity for “virtualization” of data centers—the rooms filled with routers, servers and switches that have become ubiquitous throughout all sectors of our economy. Millions of these data centers exist across the country contributing to the growth in miscellaneous energy use that was documented in a recent ACEEE report (Kwatra, Amann, and Sachs 2013). In virtualization, a majority of the functions performed by local servers are migrated into the “cloud” resulting in a substantial reduction in net energy use since the energy intensity of the data centers that enable cloud computing are lower because of scale and the ability to manage loading across multiple data centers ensuring optimal use of resources, which is also results in lowest energy consumption (EMC^2 2010).

In virtualization projects such as just described, no new equipment is acquired, and in fact existing equipment is often retired in the process. In its place an ongoing service is subscribed to and while onsite energy use is clearly reduced due to the retirement of equipment, some of the remaining energy use now occurs off site at a facility that may or may not be in the program service territory. In fact, it may occur anywhere in the world.

This inability to associate net savings with an asset requires a paradigm shift in how we think about an energy efficiency measure. Instead of paying for the assets, programs may start paying for actual savings. And in a very interesting and serendipitous development, intelligent efficiency may provide the very ability to do so.

Performance Based Efficiency Program

Intelligent efficiency provides an opportunity to move from energy efficiency programs that are device-based to programs that systems- and performance-based. Older programs that may be reaching the limits of what can be achieved with fixed rebates for purchasing specific items may find the concept of paying for performance of interest, especially if they are looking for new program ideas that will appeal to their larger industrial and commercial customers.

With the ability to determine current and future savings, a building operator or factory manager and the efficiency program administrator can begin a conversation on paying for performance. Once in place, the advanced BMS or the smart manufacturing system is able to compare current operating conditions with a previous baseline under similar operating conditions and determine the net energy savings. It may also have the ability to forecast future energy demands. Performance information is reported to the program administrator and the incentive paid is based on energy saved. Programs may provide a bulk of the incentive upfront based on forecasted energy savings and later, as actual performance is reported, the balance is released. That balance may increase or decrease depending whether more or less energy has been saved than forecasted and it may be released over a period of one or more years.

So long as the protocols for determining energy savings are agreed to by both parties at the beginning of the project, this arrangement has promise. As previously highlighted, the

IPMVP has gained broad acceptance and is currently in use in many states. The ability of a smart technology to follow this protocol and report performance data on a timely basis lowers the cost of measurement and verification and ultimately the utility's cost of running an energy efficiency program and acquiring these energy efficiency resources.

Performance Contracting: a Model for Pay-for-Performance

An example of paying for performance is performance contracting. Energy service companies (ESCos) have been helping public sector facilities reduce energy consumption through performance contracts. In these arrangements, the ESCo makes the capital investment in upgrading the energy consuming equipment of a facility: lighting, heating, air-conditioning, hot water systems, etc. As a result of these investments, the facility's energy costs go down thereby freeing up cash flow for the facility repay the ESCo. The energy cost savings are essentially split between the facility and the ESCo so the more energy saved, the more the ESCo can potentially earn[9].

The determination of savings of course requires the establishment of a baseline. Baselines and verification requirements are determined in the design phase of a project, and included in the contracts. To ensure that savings continue after equipment installation, many performance contracts include service agreements. Inclusion of intelligent efficiency in performance contracts is increasing. The Department of Energy is investigating the use of performance contracts to fund upgrades in IT and data centers (C2ES). Johnson Controls includes BMSs in all of its performance contracts because of the additional energy savings they provide and because they simplify performance measurements (Nesler 2013.

Though these agreements do not usually include per unit energy savings payments, the methodology used to determine baselines, measurement, and verification is similar to that used by utilities in their custom programs. An important feature of these agreements is that they are focused on energy savings rather than specific assets. In fact, because they are paid for their performance, ESCos are motivated to achieve as much energy cost reduction for as little capital investment as possible. With such potential for a new, more effective method of securing energy savings, the idea of energy efficiency programs paying for performance is an area worth of more research.

Summary

Intelligent efficiency is making possible new levels of energy consumption analysis and energy management. This will have broad implications for building operations and manufacturing production management and control. 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. Manufacturers have the ability to network entire production lines, even supply chains, so that they can eke out marginal savings at every point in the system.

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[9] There are many types of performance contracts, each with different features and benefits. The example used here was chosen for its simplicity and relevance to the pay for performance concept.

Over the next two to three decades we will see these new capabilities available to every sector of the economy. With the ability of intelligent efficiency to generate the next-step change in energy savings, multiple additional economic benefits are possible. Non-energy benefits stem from system optimization, including better services and, in industry, better quality control. Lower operating costs free up capital making it available for additional investments in productivity and capacity. Environmental benefits related to energy savings will be realized at the point of use and across the nation as the need for new generation decreases.

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 importunate opportunity to leverage intelligent efficiency for public policy goals. With its potential to bring about new levels in energy savings nationwide, intelligent efficiency 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 intelligent efficiency systems' having the ability to determine the baseline energy consumption for multiple operating conditions, monitor energy consumption and production inputs and outputs, identify correlations that can be used to determine current energy savings, and forecast future energy use. Intelligent efficiency systems can also confirm these correlations by regularly comparing current performance with past predictions, adding even greater levels of confidence in reported savings numbers. Automated control systems can be programmed to follow energy savings determination protocols that are broadly accepted. This combination of analytical capabilities presents us with an opportunity to determine energy savings on a real-time basis. That capability in turn opens up the opportunity for energy efficiency programs to pay for performance rather than for implementation.

Adding the financial resources that are currently funding conventional utility investments and device-level energy efficiency investments into the total investment mix targeting intelligent efficiency means an accelerated adoption profile of intelligent efficiency measures. By our estimate, it could reach $55 billion by 2035. 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. With that goal in mind, we offer the following recommendations.

RECOMMENDATIONS

In this report, we have recommended several actions that different stakeholders can pursue to facilitate the implementation of intelligent efficiency approaches across the commercial and manufacturing sectors. These recommendations are not exhaustive but are intended as jumping off points to more in-depth discussions, research, and analysis. The potential economic impacts are clear and the barriers manageable. Here we outline key actions by key stakeholders that will significantly increase the likelihood of widespread adoption of intelligent efficiency throughout the U.S. economy.

Role for Government

With the potential to produce a step change in energy efficiency and the associated cost savings throughout the economy, intelligent efficiency is an ideal strategy for government policies and programs to encourage. The federal agencies that consume a great deal of energy can lead by example through incorporating smart BMSs and other intelligent efficiency measures into their buildings. This can be done through direct investments and energy service performance contracts. Specifications for performance contacts can include requirements for advanced building automation with the ability to self-correct and continuously optimize.

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, funding of smart grid research projects by the Department of Energy 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 2012, 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.

Role for Utilities and Energy Efficiency Program Administrators

Program administrators for utilities sector energy efficiency programs should seek out opportunities to include intelligent efficiency measures as qualifying projects in their existing programs. They can pilot programs that target smart technologies and experiment with these technologies' ability to provide timely performance data.

Programs can also experiment with paying for performance, refining the approach as they learn what does and does not work, then gradually expanding to other appropriate larger customer pools. They would do well to participate in collaborative efforts to establish common energy management practices and energy savings determination protocols. Existing efforts to develop common protocols for demand response such as the Open ADR Alliance can be leveraged and expanded to communicate energy data between utilities and their customers.

As utilities install smart grids, they can work with their commercial and manufacturing customers to integrate the ability of a smart grid to communicate the value of energy given the time of day and the customer's location to customer's advanced BMS or smart manufacturing systems. Each customer can then respond with changes in energy usage that reflects internal priorities, one of which may be reducing energy expenses.

Role for Public Utility Commissions

Public utility commissions should allow utilities' energy efficiency programs to do pilots in order to learn what works and what doesn't, as well as discover solutions to M&V challenges. There is no substitute for the learning that occurs through doing, and pilot projects enable this learning with a low level of risk. Programs may run into unanticipated barriers and will have the opportunity to work through them on a small scale. Once the concepts are proven and ICT performance standards are developed, public utility commissions can then authorize broader program acceptance of smart technologies and systems.

Suppliers of ICT Products

The many companies engaged in developing and selling intelligent efficiency products and services can seek opportunities to collaborate on non-competitive research and development as well as to education and create awareness of the benefits of ICT. Activities such as those by the Information Technology Industry Council (ITIC) to bring awareness to IT issues within policy circles; the Smart Manufacturing Leadership Coalition (SMLC) to form collaborative research, development, and implementation teams to develop common software platforms, standards, and approaches (SMLC 2013a); and the Energy Information Standards (EIS) Alliance to develop 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. Private sector leadership in this area is necessary as there is insufficient technical knowledge or capacity elsewhere. 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 intelligent efficiency technologies.

Conclusion

Broad action on these recommendation will help to diminish—and eventually eliminate—the barriers standing in the way of the U.S. economy's reaping intelligent efficiency's benefits. These actions, taken simultaneously by a diverse group of stakeholders, will advance the energy efficiency options of the commercial and industrial sectors to a level not seen before, helping those sectors to reduce their energy consumption and costs, improve product quality and employee satisfaction, and strengthen their resilience in the global economy

Going forward, more research in the area of intelligent efficiency and utility section energy efficiency programs is warranted. Such research could lead to demonstrations of building or plant automation systems that provide real-time energy performance data, and eventually to utility efficiency programs that pay for energy saved rather than equipment installed.

The potential for intelligent efficiency technologies such as machine-to-machine and smart grid to bring about new efficiencies in manufacturing is only beginning to be understood. Additional research is required to gain a better understanding of this opportunity and its ramifications. Will this new level of automation, as we have seen in previous industrial revolutions, grow the size of the manufacturing sector? Will it bring about more and more satisfying jobs than it replaces? What will be required of workers if they are to successfully utilize smart technologies? These are but a few questions that would be useful to answer early in the journey to embracing intelligent efficiency.

More research is needed to understand the specifics of not just how data analytics can mine big data to facilitate efficiency gains within organizations, but also how external data can be harvested for the benefit of the supply chain. It is likely that this new level of connectivity will soon integrate customers into product and service design processes. It would be beneficial to understand the broad implications for energy consumption of such a streamlined process as it will likely have significant economic implications.

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Appendix—Economic Analysis Methodology

Overview

In order to understand how significant the potential of intelligent efficiency is, we performed a limited economic potential analysis of the ability of select smart energy efficiency measures to reduce energy consumption and energy costs in the United States if implemented nationwide.

This analysis is intended to provide a general indication of the economic potential of intelligent efficiency to influence energy consumption in the targeted sectors. There are many assumptions built into the analysis and every one of them has a high degree of error. This analysis should not be taken to be a rigorous quantitative analysis of economic potential of individual technologies or groups of technologies. The analysis demonstrates the scope of energy savings that is possible with a proactive policies that encourage increased investment in intelligent efficiency measures.

METHODOLOGY

A conventional energy savings analysis considers specific energy measures and attempts to quantify the potential energy savings of each, and then totals the savings of the set of energy measures considered. In this analysis, we followed a similar convention, attempting to quantify the energy savings that each intelligent efficiency measure might produce within the commercial or manufacturing sector. However, in the commercial sector, since each measure will influence differently the energy consumption of the many systems within a building, and since these systems are not present in buildings uniformly throughout the sector, it is necessary to first determine the potential savings by end use and then by building type before a total for the commercial sector can be determined. Once a total for the sector is determined, it is possible to establish an average energy savings that a building greater than a certain size in the commercial sector can anticipate to achieve by investing in intelligent efficiency measures.

To determine energy savings in the manufacturing sector, it was not possible to perform an analysis of individual intelligent efficiency measures because of the heterogeneity of the sector. Any given measure might affect the energy use of only a small segment of the sector, and the micro-level data needed to perform such an analysis are not available. However, because most energy use in manufacturing is consumed in the core processes, it is acceptable to assume that the automation and control provided by intelligent efficiency will have broad applicability throughout the sector; therefore, a certain level of savings will be observed by the sector in the aggregate.

With the average energy savings for each sector established, those values can be applied to the sectors' original forecasted energy consumption, and potential energy savings determined. Since no empirical method can determine the level of market penetration of intelligent efficiency by the year 2035, a projection of 50% was determined to be a reasonable estimate (Nadel et al. 1994). The forecasted savings are expressed in terms of annual energy savings (kWh) and energy cost savings ($ billion). Given the relative lack of precision of this analysis, we performed a sensitivity analysis assuming a range of +/- 50% of the estimated market penetration.

DISCUSSION OF DATA

Economic and energy consumption data for this analysis came from the U.S. Energy Information Agency's (EIA) 2003 *Commercial Buildings Energy Consumption Survey* (CBECS), 2003 *Manufacturing Energy Consumption Survey* (MECS), and *2013 Annual Energy Outlook* (AEO) reports. Estimates of savings for each energy measure were based on one or more sources that described field results from actual projects. For emerging technologies without a documented performance history, estimates based on similar technologies were used. Sources for field-tested as well as emerging technologies included research reports, trade articles, and vendor claims.

In the commercial sector analysis, we grouped intelligent efficiency measures using the same categories used by the CBECS to organize energy consumption data. This enabled the translation of savings potential for individual measures into energy savings on a national level.

In the industrial sector analysis, the energy consumption data reported the 2003 MECS were used to calculate the amount and percent of energy consumed by manufacturing processes, and the energy consumption data reported in the 2003 CBECS were used to determine energy savings from industrial buildings.

These 2003 energy savings values for the commercial and manufacturing sectors were converted to percentages of energy savings, and those ratios were applied to respective energy consumption forecasts contained in the AEO 2013. This report projects energy consumption values by type and end use. Projections of purchased electricity consumption for the commercial sector and purchased electricity for all manufacturing were used in this analysis. Non purchased electricity would be power generated on site.

EIA reports consulted are:

- AEO: Commercial Sector Key Indicators and Consumption Reference Case (EIA 2013b)
- CBECS: Electricity Consumption by End Use for All Buildings (EIA 2003b)
- CBECS: Building Size, Floorspace for All Buildings (Including Malls) EIA 2003b)
- AEO: Industrial Sector Key Indicators and Consumption, Reference case (EIA 2013a)
- MECS: End Uses of Fuel Consumption, 2010 (EIA 2006)

Allowance for Existing Energy Savings within EIA Data

The EIA based its forecast data on a projection of current trends. Within those trends are existing intelligent efficiency products and services. If the integration of information and communication technology (ICT) into building and process controls was nothing more than a continuation of current trends, then the AEO estimates would likely contain all of the needed multipliers to reasonably predict future energy consumption trends. However, our analysis predicts a step change in the ability to reduce energy use as a result of intelligent efficiency. This will produce a steeper curve than that indicated by the AEO report even though there is a certain amount of intelligent efficiency already included in its estimates.

The Smart Manufacturing Leadership Council estimates that the EIA has underestimated the amount of smart manufacturing and by extension its ability to reduce energy intensity in manufacturing (SMLC 2013b). This analysis estimates the true value to be 1% more of total affected energy use in year one trending to 3% in year 20 than is already incorporated into AEO estimates.

Commercial Sector Analysis

The analysis of the commercial sector started with establishing the savings potential of individual intelligent efficiency measures and then converting that potential into national energy savings numbers. These numbers were used to develop a percentage of expected average energy savings for the commercial sector, and that percentage was applied to forecasted energy consumption data to determine future energy cost savings.

ESTIMATES OF ENERGY SAVINGS

There are a number of ways to estimate the potential energy savings from the implementation of energy efficiency measures. One extreme option, at least for some devices, can be to calculate the theoretical possible efficiency and hence estimate the potential savings that can be achieved by reaching this maximum efficiency level should the efficiency measure be adopted universally. Another approach is to evaluate the bar set by the minimum efficiency standards or voluntary ratings and the savings that can accrue if the entire stock conforms to these standards and ratings. A third approach, somewhere between the two, is to look at the efficiency of the best-in-class devices available today and project savings by replacement of the current stock with best-in-class products.

The first approach requires information not available at this time. The second approach requires the setting of a minimum level of efficiency across a broad spectrum of intelligent efficiency measures and an assumption that all buildings are capable of meeting that minimum level. This assumption is neither realistic nor helpful. The last approach gives a more pragmatic approximation of the savings that are possible in the short term. Intelligent efficiency measures are almost by definition best-in-class products and therefore it is only necessary to select a probable end point of market penetration, identify the baseline of energy consumption, and then apply the marginal energy savings of best-in-class compared to other technologies (Level 4 compared to Level 3) to determine the volume of energy saved.

In the analysis for the commercial sector, for each intelligent energy measure we attributed an estimate of average gain based on best-in-class values derived values identified during in our research. A matrix of intelligent efficiency measures and CBECS end use categories (space heating, cooling, ventilation, water heating, lighting, cooking, refrigeration, office equipment, computers, and other) was created and populated with estimates of energy savings.

The next step was the determination of a factor that would capture the percent of buildings likely to be able to benefit from the intelligent energy measure, the percent of buildings likely to implement the measures, and likely percent of buildings likely to realize benefit from the measures. Since all of these values are approximations, they were they were estimated to values of 0%, 1%, 10%, 25%, 50%, 75%, or 100%.

We determined the percentage of buildings that could use an energy measure, such as improvements to HVAC or office equipment, using professional judgment, observation, and consultation with field professionals. These estimates took into consideration the types of buildings that could and could not use a given measure as well as the percentage of buildings that would already have the energy measure in place. For example, consultation with professionals in the building automation sector led us to estimate that advanced BMSs are more likely to be of value initially only to buildings larger than 100,000 square feet in size, that at least 10% of them already had advanced BMSs installed, and that the BMSs influence electric heating to a greater degree than air-conditioning and ventilating because of the potential to better control variable-air-volume box reheat coils. Further discussions with vendors currently supplying the building automation market revealed that the current percentage of buildings with BMSs increases from essentially zero for buildings less than 100,000 square feet to 30% for those over 500,000 square feet (Nessler 2013). This translates to approximately 7% of current floor space with some type of BMS. Subtracting 7% from total building floor space established the baseline of available building space.

The values of the matrix were multiplied by their respective factors to create an adjusted energy measure savings estimate. These estimates were totaled by end use category and put into second matrix with CBECS Commercial Building categories. The second matrix contained EIA 2003 energy consumption values by building type and end use.

CBECS Energy Consumption (Values as a %)

Space heating, Space cooling, Ventilating, Water heating, Lighting, Cooking, Refrigeration, Office Equipment, Computers, Other

CBECS Building Type (Values in Trillion Btu)

Education, Food Sales, Food Service, Healthcare, Lodging, Mercantile, Office, Public Assembly, Public Order and Safety, Religious Worship, Service, Warehouse and Storage, Other, Vacant

We applied the percentages of end use energy savings potential to energy consumption for each building type and totaled them to yield an energy savings value by building type. These values were then totaled to produce a weighted average energy savings average for the commercial sector of 28 percent.

Table A-1: Efficiency Estimate for Intelligent Efficiency Measures by CBECS Energy Use Category

		CBECS End Use Categories									
Intelligent Efficiency Measure	Estimated Savings	**Space Heating**	**Cooling**	**Ventilation**	**Water Heating**	**Lighting**	**Cooking**	**Refrigeration**	**Office Equipment**	**Computers**	**Other**
Smart Grid L4	10%	0%	10%	10%	0%	0%	0%	0%	0%	0%	0%
HVAC Controls L4	20%	20%	10%	10%	0%	0%	0%	0%	0%	0%	0%
Smart HVAC components	15%	10%	15%	10%	0%	0%	0%	15%	0%	0%	0%
Customer Interface	10%	10%	10%	10%	10%	0%	0%	0%	0%	0%	0%
Smart building components	5 to 20	5%	10%	5%	0%	20%	0%	0%	0%	0%	0%
Total for HVAC*		38%	44%	38%	10%	20%	0%	15%	0%	0%	0%
Virtualization	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%
Smart Equipment Controls	5-10%	0%	0%	0%	0%	10%	10%	10%	15%	15%	0%
Lighting automation L3, L4	35%	0%	0%	0%	0%	35%	0%	0%	0%	0%	0%
Smart Fume Hoods	15%	0%	0%	15%	0%	0%	15%	0%	0%	0%	0%
Smart Refrigeration	30%	0%	0%	0%	0%	0%	0%	30%	0%	0%	0%
Miscellaneous Energy Loads	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%
Total for all Measures		38%	44%	53%	10%	65%	25%	55%	15%	15%	52%

***Factorial Total**

ESTIMATION OF INVESTMENT COSTS

Initial costs of investments were estimated by first assuming that businesses' and manufacturing plants' investments in intelligent efficiency recover the initial costs and operating costs through energy cost savings, and we considered only investments that do so within a defined period of time. The analysis assumes that all commercial projects will achieve a five-year payback (a 20% return) and all industrial projects will achieve a two-year payback (a 50% return). Both of these estimates are based on common practices used by the respective sectors and, as demonstrated by examples and case studies given in the report, are achievable. Cost estimates for both sectors also include the cost of the first year of all recurring variable costs.

As with any capital investment, there is an initial cost and the ongoing cost of maintaining the equipment or software. In the commercial sector, BMSs may be monitored by the building owner, which will require appropriate staff with appropriate training, or by a third-party vendor that may also be the provider of the BMS and its software. This is just one of many recurring fees and costs for which operators must budget. Others include routine maintenance, system upgrades, and expansions, as well as the occasional component replacements.

It is a common business model in the software business to update software routinely and discontinue support of old versions in short order. This model enables the vendor to generate additional sales and to level out cash flows. Another business model is to charge an annual subscription fee for software rather than a one-time fee, and to provide the customer with continuously updated product. A common rule of thumb for estimating the subscription fees associated with a software product is 15 to 20% (Navigant 2013b) of the initial purchase price. A higher level of service translates to a higher fee. This analysis assumes either dedicated staff or contracted third-party services, and uses a value of 25% for all recurring costs.

FORECAST

The analysis assumes that by 2035, 50% of commercial buildings, by floor space, will employ some level of intelligent efficiency. Starting with the finding that 7% of existing floor space is already affected by some level of automated control, the analysis assumes that affected building floor space covered by advance intelligent efficiency measures increases initially at 1% in year one and increases incrementally to 3%in year 15.

Next, we developed a projection of energy savings using AEO 2013 forecast data, again assuming that 50% of all commercial building space will adopt at least some level of intelligent efficiency by 2035. A sensitivity analysis was performed with an estimate that the error of the 50% target is in the range of +/- 50%. These three scenarios are presented in the graph below as the low, mid, and high scenarios representing the range of potential energy cost savings possible in the commercial sector. The analysis also assumes a relatively modest increase in investments of 1% per year early in the 20-year period and finishing at 2%.

Manufacturing Sector Analysis

For the industrial analysis, it was not possible to perform as detailed an analysis on individual efficiency measures as we did for the commercial sector. Most energy use in manufacturing is consumed in the core processes of the facility, and those vary by facility. Only a big-picture analysis is possible since the potential energy savings intelligent efficiency can provide a given facility is process-specific.

ESTIMATED ENERGY SAVINGS

The analysis of the manufacturing sector started with establishing the savings potential of intelligent efficiency, as manifest in smart manufacturing, to affect energy savings within manufacturing processes in aggregate. That value, based on literature search was determined to be 20 percent. Previous ACEEE (Elliott et al. 2000) research has identified that approximately 80 percent of energy use in the manufacturing sector is used to process raw materials and the balance for facilities. A review of MECS End Uses Fuel Consumption data 2010 data confirmed that this is still a reasonable number to use in the analysis.

These percentage of expected average energy savings for the manufacturing sector was applied to forecasted energy consumption data from the *2013 Annual Energy Outlook* to determine future energy cost savings. We broke down energy use by type of manufacturing process (e.g., process heating, process cooling and refrigeration, machine drive, electro-chemical processes) and building energy uses (lighting and HVAC).

Efforts to determine total energy allocation is complicated by the fact that the EIA gathers these data through a survey and that 39% of all energy use was not fully itemized by respondents in 2010 To compensate for the incomplete data, an assumption was made that the breakdown of non-itemized energy use mirrors the breakdown of itemized energy use and the values for total energy consumption adjusted accordingly.

Since the results of implementing intelligent efficiency measures will vary by the size and purpose of a manufacturing facility, the analysis estimated 20% savings to be the average result that manufacturers can expect from investments in smart manufacturing. This estimate is based on our conversations with vendors of ICT products, including Rockwell Automation, Schneider Electric, and Honeywell and by research by the Smart Manufacturing Leadership Council and the European Commission Information Society and Media (EC ISM 2009). Their estimates ranged between 15 and 40%.

With 80% of energy use attributed to manufacturing processes, the balance is attributed to building systems and can expected to benefit from the same HVAC, lighting, and software technologies as the commercial sector. Thus, the equation for process efficiency gains is 20% of the manufacturing energy consumption (constituting 80% of the total), and the equation for building efficiency gains is 28% (the value determined for buildings in the commercial sector analysis) of the remaining manufacturing energy consumption (20% of the total).

ESTIMATE OF INVESTMENT COST

The analysis assumes that the investments that will be made are only those that will have a 50% return and pay off in two years. This estimate is based upon consultation with individuals with extensive experience in the manufacturing sector over many years.

As in the commercial sector, investments in intelligent efficiency in the manufacturing sector include some combination of costs from a subscription service and/or the maintenance, updating, and replacement of the system. In manufacturing facilities, it is more likely that the unique needs of a facility will require it to have trained personnel within the company who are familiar with facility processes and can interpret and act upon the recommendations of the integrated system. Therefore, the recurring costs are likely to be a lower percentage of the original investment than in the commercial sector. For that reason, the analysis assumes recurring costs of 20% instead of the 25% assumed in the commercial sector analysis. As mentioned above, the first year of this cost is built into the estimated capital cost of the investments.

FORECAST

Based on prior ACEEE research, based on prior ACEEE research (Nadel et al. 1994), we estimated that 50% of all manufacturing electrical load will be influenced by intelligent efficiency by 2035. At the outset, investment increases at an annual rate of 1% and by 2026 stabilizes at 3% per year. A sensitivity analysis was done for this sector as well, estimating that the error of our original estimate is +/- 50%. The low scenario assumes an investment profile that results in half of the base case while the high scenario results in 1.5 of the base case. Although the mid and high scenarios might be considered aggressive with very short-term payback expectations and aggressive investment profiles, both are feasible and have historical precedents (Laitner et al. 2012).