# 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.

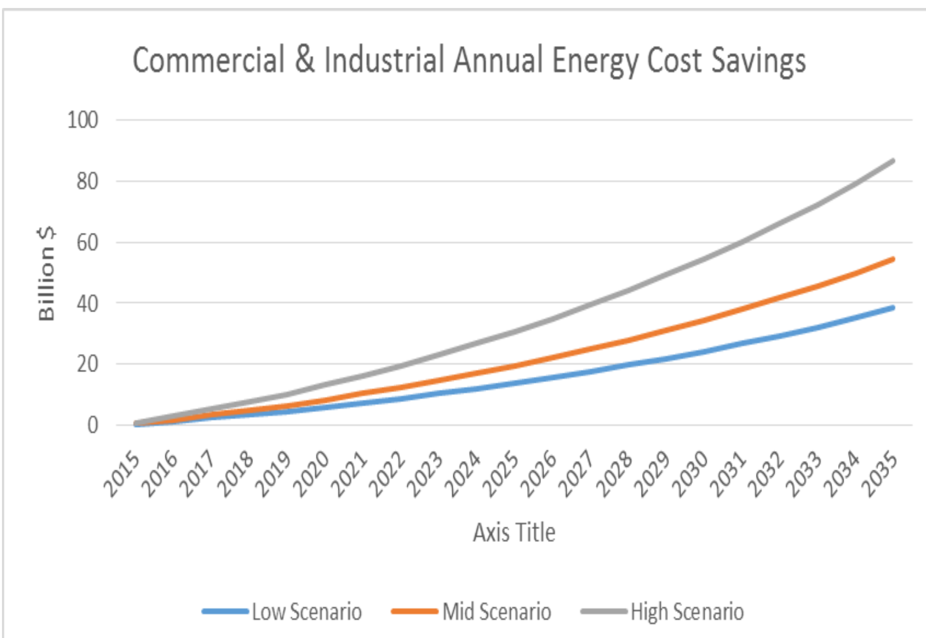
Table ES-1. Five Levels of Energy Measures

| 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 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.