Integrating strategic energy management and smart manufacturing programs

Ethan A. Rogers
American Council for an Energy-Efficient Economy
529 14th St. NW
Suite 600
Washington, DC 20045
USA
erogers@aceee.org

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Abstract

Strategic Energy Management (SEM) programs help companies implement continuous improvement programs that systematically address energy usage. In North America, SEM programs have become the platform upon which large customers are engaged and directed to other assistance programs.

Several SEM programs include Energy Information Management Systems (EMIS) software packages that automate the collection and analysis of energy data. EMIS can be a first step to implementation of smart manufacturing, the use of information and communication technologies (ICT) to automate the collection, analysis, contextualization, and dissemination of production information for optimizing the management and operation of an enterprise. The US Department of Energy predicts that smart manufacturing (also known as Industrie 4.0) will be one of the most significant technologies to affect manufacturing productivity and energy use in the next decade. DOE also noted that many manufacturers are inadequately prepared to adopt and implement smart manufacturing.

Many administrators of energy efficiency programs are finding that SEM and SM type programs are compatible and optimization in the manufacturing sector often requires investments in both. Program administrators and implementers are increasing the impacts of their programs by taking a holistic approach to engaging industrial customers and providing a portfolio of services and incentives. Researchers are helping by developing and demonstrating technologies that enable the automated collection, analysis, and exchange of energy savings resulting from continuous improvement activities. Energy markets are evolving and some now treat energy efficiency as a resource that regional transmission organizations can use in short- and long-term electric grid load management. Smart manufacturing and other ICTs are aiding this by simplifying the collection, analysis, and sharing of energy savings data. This introduction of technology into utility-customer interactions is helping to overcome the market's historical failure at fully valuing energy efficiency.

Achieving even greater energy savings from large manufacturing customers will require more companies to invest in energy efficiency practices such as SEM and technologies such as smart manufacturing. Policy makers have an opportunity to facilitate more investment in the private sector by supporting research, workforce development programs, deployment of smart manufacturing technologies, and development of energy markets that value energy savings as a resource. However, it would be an incomplete solution to address them separately. There are overlapping components of these issues that only a holistic approach can address and result in maximum energy savings.

Introduction

Industrial firms have invested in continuous improvement systems for several decades in order to stay competitive. Known by many names such as Lean Manufacturing and Total Quality Management, continuous improvement practices improve the quality of products and reduce wastes by changing the culture of organizations and empowering workers. A benefit of continuous improvement is energy savings. Many companies tailor their programs to focus on energy savings and reducing environmental impacts.

Policy makers, eager to achieve energy, environmental, and economic goals are also focusing on continuous improvement investments in the industrial sector. These investments fall into two categories: implementing best practices and adopting best technologies. Even though the two are compatible and can have magnifying effects, policy makers often address them separately. This is unfortunate because companies are likely to see greater results if they implement both simultaneously.

This research paper addresses the issue of integrating strategic energy management (SEM) and smart manufacturing (SM) programs by starting with an overview of continuous improvement programs and smart manufacturing technologies and then describing current research, development and deployment initiatives by federal agencies. The analysis will explain how some program administrators are leveraging smart manufacturing technologies and incorporating them into SEM programs. The paper then explains how ICT can enable a more complete valuation of energy resources and how the compatibility of smart manufacturing and SEM practices will facilitate this in the future. The paper concludes with few recommendations for policy makers and program administrators to consider.

Strategic Energy Management (SEM)

Strategic Energy Management has become the term of choice in North America to describe programs that assist companies to implement continuous improvement programs that systematically address energy usage. In North America, SEM programs have become the platform upon which large customers are engaged and directed to other assistance programs. SEM programs involve workforce education, training, and organizational culture change. They incorporates the plan-do-check-act approach that has been successfully applied to manufacturing quality improvement for many years through programs such as Total Quality Management (TQM), Six Sigma, Lean Manufacturing, and ISO 9001 (DOE 2014, Kolwey 2013).

SEM programs exist on a continuum ranging from modest improvements in maintenance practices to comprehensive programs that follow the International Organization for Standards (ISO) 50001 standard for energy management and are certified by the Superior Energy Performance (SEP) program that is administered by the US Department of Energy's (DOE) Technical Assistance division of the Advanced Manufacturing Office (DOE 2015a). As depicted in Figure 1, an organization can move from project-focused approach to a systematic approach to energy management when it embraces SEM. It can also enter at any point on the continuum.

A common theme with behaviour, training, and continuous improvement programs in that they all focus on equipping workers with knowledge and skills to identify opportunities and implement solutions. SEM is comprehensive in that it provides a structure for systematic and continual efforts to improve energy management. It changes the conversation from sporadic implementation of energy efficiency measures to continuous implementation of efficiency projects. Its power to transform an organization comes from the alignment of employees' routine activities with organizational goals. SEM programs help companies and assistance programs achieve energy savings that capital measures alone cannot achieve. It also establishes methods for programs to track energy savings and for management to integrate energy efficiency into operational practices (Hossein 2012).

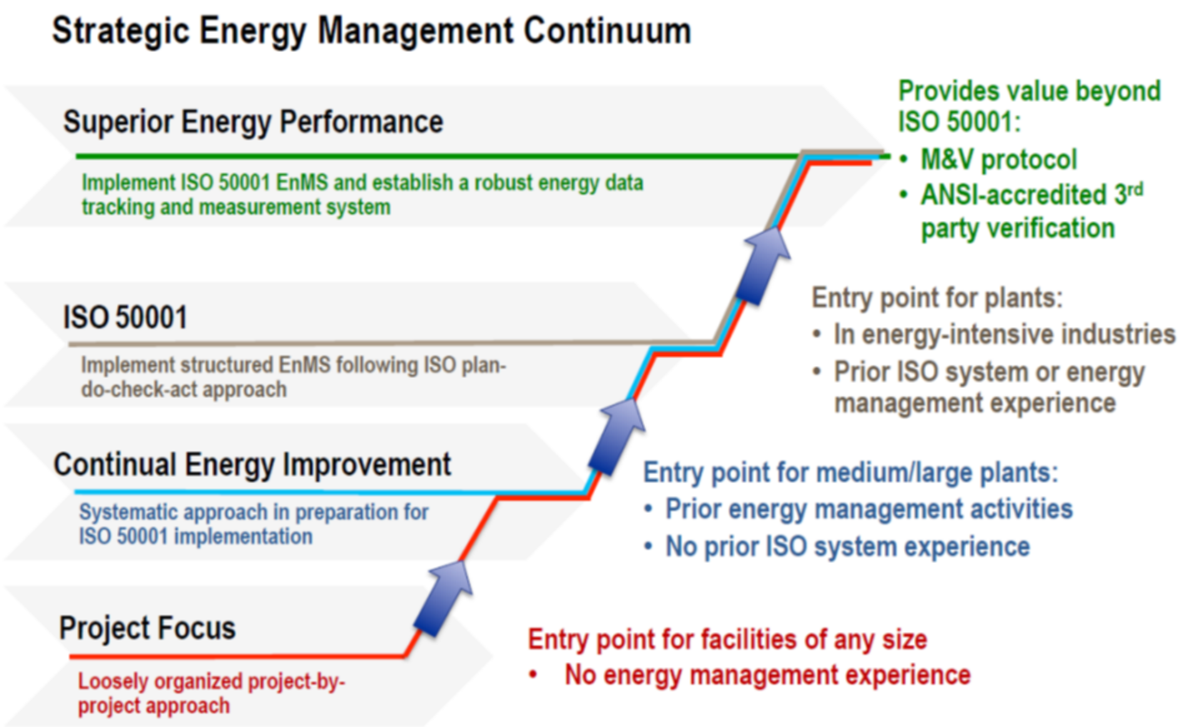

Figure 1. The Strategic Energy Management Continuum. Source: Therkelson et al. 2013.

SEM programs produce operation and maintenance (O&M) savings and increase the number of capital investments (CapEx).

The Southwest Energy Efficiency Partnership (SWEEP) analysed over a dozen industry focused efficiency programs and determined that there are four types of SEM programs.

- Co-funding of energy managers at customer facilities
- Training staff at industrial facilities on how to implement the management systems and procedures for achieving continuous, long-term energy savings goals
- Training staff to identify and implement low-cost O&M improvements and measuring the associated energy savings
- Installation of energy management information systems (EMIS) software program (Kolwey 2013).

These four types of programs do not exist in isolation. Many programs include multiple elements. The Consortium for Energy Efficiency (CEE) also analysed SEM programs in 2014 and found that almost all of them included the development of an energy plan and the training of staff, but less than half included an on-site energy manager or EMIS software.

In its Industrial Strategic Energy Management Initiative CEE has established three Minimum Elements for SEM programs (Burgess 2014).

- Customer commitment through policies, goals, and allocation of resources
- Planning and implementation through assessments, mapping exercises, establishing goals and metrics, project registering and tracking, and employee engagement
- System for measuring energy performance that routinely collects, stores, analyses, and reports

All three of these features are important to keep in mind as we discuss how to incorporate smart manufacturing into SEM programs.

Smart manufacturing

Smart manufacturing comprises a broad suite of technologies and practices that in combination affect almost every function of a company in order to achieve superior control and productivity. Smart manufacturing systems provide everyone in an organization the actionable information they need, when they need it, and in context that enables them to contribute to the optimal operation of the enterprise through informed, data-driven decision-making (Rogers 2014). Smart manufacturing is possible because networks enable sensors and devices to communicate with one another and with other systems throughout an enterprise. Sensors, connected devices, networks, and cloud-computing enable the harvesting of big data for use in analyse of operations, identify faults in systems, understand customer interests, and informing operators of current conditions (Rogers 2014).

Though the term “smart devices” has come to encompass many new technologies that improve and expand the performance of a device over that of a contemporary devices, in this paper we consider devices, systems, or facilities to be “smart” if they have the ability to make logical choices about future actions. It may be useful to think of a dumb device as having no embedded logic, a smart device as having embedded logic, and an intelligent device as one that is networked and has adaptive and anticipatory capabilities. At its fullest manifestation, smart manufacturing involves network of intelligent devices and systems.

HOW SMART MANUFACTURING SAVES ENERGY

Information and communication technology (ICT) enables companies to save energy in ways not possible in the past. Through connectivity, devices can share information between themselves and with operators allowing operators to identify correlations and trends. Energy consumption information, when put in context of a process productivity, becomes knowledge. When combined and compared with historical information, it becomes wisdom. In manufacturing, wisdom is an understanding of how to optimize a system, process or facility (Rogers 2014).

Smart manufacturing uses ICT to save energy at the system and facility levels. A conventional energy measure involves installing a new device or system. After installation, there is little to no re-optimization. This often means that savings degrade over time. However, a intelligent system will continually evaluate its operating state, compare with current performance with historical performance and identify the optimal operating scenario. As a smart manufacturing control system gains knowledge of the variables that affect process performance, it can identify operating parameters that will result in the most efficient operation. This capability if often referred to as machine learning (Rogers et al. 2013).

Glatt, Goldberg and Taylor (2015) provides examples of how two companies, a plastic injection moulding operation in Vermont, and a biotech company in Colorado, integrated smart manufacturing technologies and continuous improvement practices to reduce energy consumption. The companies invested in sub-metering equipment, connecting major systems to networks, and displayed contextualized performance information on dashboards. They also implemented energy management practices that involved worker empowerment and the systematic monitoring and improvement of energy use. Both companies realized energy savings through preventative maintenance, proper equipment operation, improved process control, and better decision-making.

Policies and programs

Federal policies and program tend to have a wholesale approach and focus on research, development, and demonstration of continuous improvement practices and smart manufacturing technologies. Regional and local programs are more retail in nature and deliver training, technical and financial assistance directly to businesses. Federal agencies invest in programs that can transform markets over many years. Utilities and their program administrators often have yearly energy savings goals and so are short and near term focused.

EXAMPLES OF SEM PROGRAMS

In North America, federal, state, and provincial governments are supporting the development and deployment of SEM-type continuous improvement programs. At the national level, the

US Department of Energy (DOE) and US Environmental Protection Agency (EPA) have focused on developing standard practices and funding demonstration projects. At the state and regional level, public utility commission is supporting delivery of SEM programs to achieve energy savings targets. State and regional organization are also supporting professional collaborations among SEM program practitioners.

DOE supported development of the ISO 50001 Energy Management Standard, a voluntary global standard for energy management systems in industrial, commercial, and institutional facilities. It also developed and tested the Superior Energy Performance (SEP) energy management system. It has funded demonstration projects of both. In 2013, DOE initiated the Industrial SEP Ratepayer-funded Accelerator to work with utility Commercial and Industrial (C&I) programs to develop program initiatives that assist customers to achieve SEP certification. It will include implementation of the ISO50001 and third party measurement and verification of energy performance improvement (DOE 2015b).

DOE recently released the 50001 Ready on-line tool. It is a self-guided approach for facilities to establish an energy management system and self-attest to the structure of ISO 50001. The 50001 Ready program offers companies of all sizes a no-cost way to receive recognition for establishing a business practice around energy (AMO 2018).

The US Environmental Protection Agency (EPA) Building Performance with ENERGY STAR

EPA's program uses an SEM approach to encourage building owners to pursue comprehensive retrofits. The ENERGY STAR for Industry program works with manufacturers to adopt plan-do-check-act energy management practices since the early-2000s (EPA 2015a). Industrial plants participating in the ENERGY STAR Challenge for Industry are required to implement SEM practices. On average, they have reduced total energy use of all energy sources by 20 % over two years (EPA 2015b).

Utility ratepayer funded SEM programs in the Pacific Northwest

Several electric utilities in the northwest part of the US and southwest part of Canada offer SEM programs in their portfolios. The regional market transformation organization, Northwest Energy Efficiency Alliance (NEEA), lead the creation of one of the first SEM programs in 2005. It focused on optimizing energy-consuming systems at C&I customers (York et al. 2013). NEEA targeted both the supply side and the demand side of the energy-efficiency market by forging alliances with industrial firms and by establishing close working relationships with key market players such as utilities, vendors, consultants and non-governmental organizations (Hossein 2012). After three years, NEEA and its partners demonstrated persistent energy savings that were distinct from capital improvement investments (Jones et al. 2011). An independent evaluation of savings from participating food processors identified 3 % annual behaviour-related energy savings (Cadmus 2011).

The ten facilities participating in the Energy Trust of Oregon (ETO) Industrial Energy Improvement (IEI) program saw an average reduction in energy intensity of 7.9 % due to O&M improvements (Jones et al. 2011). The sixteen customers participating in Bonneville Power Administration (BPA)'s High Performance Energy Management (HPEM) and the fourteen plants participating in the DOE's Superior Energy Performance Pilot programs saw average reductions in energy intensity of 2.7 % and 4.0 % respectively just from O&M projects (Burgess 2014). In its analysis of a SEM programs, CEE concluded that programs in the future would likely achieve energy intensity reductions of 5.4 % on average (Burgess 2014, CEE 2015).

In all of these examples, SEM programs are part of a larger portfolio of business-customer focused programs. The SEM program benefit from the other programs and benefit those other programs by providing a platform for additional engagement by program implementers. As a result, some programs adopt a portfolio approach to energy savings evaluation and do not attempt to attribute savings specifically to individual programs.

SEM collaborations

Although other organizations in the Northwest now administer the region's SEM programs, NEEA is still active in SEM program development. It is the administrator for the Northwest Industrial SEM Collaborative, a voluntary initiative formed by US and Canadian organizations and practitioners engaged in delivering continuous improvement programs to manufacturing facilities in the Pacific Northwest. The group meets regularly to share best practices and share ideas on how to help companies achieve greater energy savings. BC Hydro, BPA, Cascade Energy, CLEAResult, Ecova, CEE, ETO, Idaho Power, PacificCorp, Puget Sound Energy, Snohomish Public Utility District, Stillwater Energy, and US Department of Energy (NEEA 2018) support the collaborative.

Stakeholders in SEM programs in the Northeast part of the country came together in 2016 to organize a collaborative similar to the one in the Northwest. Since then they have hosted workshops and participated in a national summit of practitioners at the 2017 ACEEE Summer Study. The Northeast collaborative is supported Cadmus, Cascade Energy, Northeast Energy Efficiency Partnerships (NEEP), New Hampshire Saves, and New York State Energy Development Administration (NYSERDA) (NEEP 2017).

EXAMPLES OF SMART MANUFACTURING RD&D PROGRAMS

Around the world, several collaborative efforts have evolved to facilitate the development of smart manufacturing technologies and practices. Each of these initiatives has a different set of goals but they all seek to accelerate the adoption of smart manufacturing technologies. In the US, the Department of Energy (DOE) and National Laboratories are leading the nation's research, development, and deployment of smart manufacturing related technologies.

The DOE's Advanced Manufacturing Office (AMO) leads the Department's efforts to advance the development of sensors, controls, platforms and modelling technologies that are interoperable, able to function in manufacturing environments and less expensive than existing technologies. AMO is focused on three main opportunities: 1) Process and operational effectiveness and optimization, 2) digital to physical and physical to digital transformation, and 3) data intelligence and fact-based decision-making (AMO 2017).

To accomplish goals related to these opportunities, the US Department of Energy created the Manufacturing USA initiative. It is also funding 14 institutes to develop next generation manufacturing technologies and to support their adoption by the domestic manufacturing sector. The Manufacturing USA has created public private partnerships to facilitate innovation, technology transition, workforce training, and create new markets to secure the USA's future in manufacturing. (Manufacturing USA 2018a)

Four of the partnerships have a focus on smart manufacturing or are engaged in precompetitive research that will positively affect smart manufacturing. They are Clean Energy Smart Manufacturing Institute (CESMII), Digital Manufacturing and Design Innovation Institute (DMDII), Advanced Robotics Manufacturing (ARM), and PowerAmerica.

Clean Energy Smart Manufacturing Institute (CESMII)

The Clean Energy Smart Manufacturing Innovation Institute (CESMII) is a partnership of U.S. Department of Energy, several universities and manufacturers, and technology vendors. The partnership brings over $140 million in public-private investment to "radically improve the precision, performance and efficiency of U.S. advanced manufacturing" (CESMII 2017).

Smart Manufacturing Leadership Coalition (SMLC), a collaboration of companies focused on smart manufacturing, formed CESMII. SMLC's purpose is to lower the cost of applying advanced analytics to manufacturing, build pre-competitive software infrastructure, establish an industry-shared, community-source smart manufacturing (SM) platform and create test beds for SM concepts (SMLC 2011, SMLC 2014).

Digital Manufacturing and Design Innovation Institute (DMDII)

DMDII is intended to establish a state-of-the-art proving ground for digital manufacturing and design that links IT tools, standards, models, sensors, controls, practices and skills, and transitions these tools to the U.S. design & manufacturing industrial base for full-scale application (DMDII 2017). The partnership includes over 190 companies, universities and laboratories engaged in precompetitive collaboration focused on what it refers to as the "digital thread" that ties together all aspects of product design, development, manufacture, and distribution (DMDII 2017, UI LABS 2018).

Advanced Robotics Manufacturing (ARM)

As the name implies, ARM engages in research and deployment of robotic technology by integrating diverse collection of industry practices and institutional knowledge across many disciplines including sensor technologies, end-effector development, software and artificial intelligence, material science, human and machine behaviour modelling, and quality assurance (Manufacturing USA 2018b).

Power America Institute

PowerAmerica focuses on wide bandgap (WBG) semiconductor and its members include many of the largest semiconductor manufacturers and companies that use power semiconductors in their products. Members are conducting precompetitive research to accelerate the adoption of next generation silicon carbide (SiC) and gallium nitride (GaN) power electronics. The institute's goal is to reduce the cost and the risks of deploying WBG semiconductors and to help American industry develop more innovative power electronics products and systems (PowerAmerica 2018).

NIST Cyber Security for Smart Manufacturing Systems

DOE is not the only federal agencies focused on smart manufacturing. The U.S. Department of Commerce, National Institute of Science and Technology (NIST) launched the Cybersecurity for Smart Manufacturing Systems research initiative to address the vulnerabilities of sensors, wireless communications, networks, and control systems that are making manufacturers hesitant to adopt smart manufacturing technologies. It is developing a risk management framework with supporting guidelines, methods, metrics, and tools to enable manufacturers, technology providers, and solution providers to assess and assure cybersecurity for smart manufacturing systems. NIST is working with private sector stakeholders to develop a framework and methodology that will stimulate the adoption and use of new security technologies and development of smart manufacturing systems that offer the security, reliability, resiliency, and protection against disruption that manufacturers want (NIST 2014, Stouffer 2016).

These and other initiatives and collaborative efforts are helping to advance smart manufacturing. Each of them demonstrates the important roles government agencies can play in fostering economic development through an emerging suite of technologies. Agencies, like the DOE, EPA and NIST are providing financial and technical assistance as well as leveraging their ability to convene stakeholders and facilitate the development of common protocols and platforms.

INCORPORATING SMART MANUFACTURING INTO RETAIL PROGRAMS

A recent development in conventional programs targeting large commercial and industrial customers is the inclusion of EMIS installation and deployment. As identified by SWEEP and CEE, some SEM programs do too. Program administrators are motivated to do this because it aids energy savings tracking and reporting. They are also aware that ensuring the persistence of energy savings requires energy management and that requires data management.

For many companies, introduction to smart manufacturing will start with the installation and deployment of an EMIS. Once decision makers get used automatic availability of energy information, they will likely seek additional information. This will lead to the installation of more sensors, more connected devices, and more analytical capabilities. It also simplifies reporting and sharing of energy savings data.

An example of this is a program offered to larger customers by Efficiency Nova Scotia, a Canadian electricity efficiency utility. Efficiency Nova Scotia has offered an EMIS-based program that targets industrial and institutional facilities since 2012. The program offers financial incentives up to 50 % of the cost to develop, design, and implement an EMIS. Program participants complete three steps: EMIS audit, EMIS Implementation Plan, and Implementation.

The program developers determined that in order for energy savings to be persistent, they needed to combine implementation of an information system and an energy management system with worker competency at the management and operator levels. They had seen installed but unused or underutilized EMISs in multiple facilities in prior engagements and concluded that only a holistic approach to energy management would work.

The program helps companies implement an energy management system of which the EMIS is key. Operators learn how to determine key performance indicators and enter relevant product data into the EMIS. The EMIS provides operators and management the information they need to optimize facility energy use. After Implementation, participant benefit from a customized 12-month support plan.

Customer engagement starts with an audit of a facility to identify sources of energy information and other data needed to formulate energy management strategies and make the EMIS useful. After installation of the EMIS and worker training on its use, the company is able to translate various data streams into actionable information. Operators and management can use the new information to develop and carry out operational energy efficiency measures. Plant personnel can track the performance of each implemented energy measure (Henwood and Bassett 2015). Efficiency Nova Scotia also benefited from more timely and detailed project energy savings data.

Efficiency Nova Scotia's engagement of large customers is an example of a program taking a holistic approach to energy savings. It combines worker training, sensors and controls, data management, and conventional O&M improvements and device upgrades.

Enabling the transition from programs to markets

SEM programs and implementation of smart manufacturing technologies open up new opportunities for companies to monetize the value of their energy savings and ability to shed load upon request. SEM provides the foundation for systematic energy management. This includes identifying, implementing and tracking energy savings projects. Smart manufacturing involves the application of technologies that enable the automation of quantifying and reporting energy savings and demand reductions. Together, these two practices enable companies to efficiently characterize their energy efficiency and demand response resources.

Smart manufacturing also enables companies to engage their energy suppliers in a more interactive fashion than before. ICT enables utilities to have bidirectional communication with their customers. With the appropriate investments in hardware and software, companies can also leverage ICT to exchange information related to their current and future energy demands with a utility. Companies can also use their smart manufacturing and other ICT investments to dynamically control building heating and air conditioning systems, chilled water systems, air compressors, production equipment and any onsite distributed generation and battery storage to adjust their demand for power from a utility. This will enable them to participate in the day-to-day and long term balancing of the electric grid (IBM 2014, Cochrane et al. 2013).

Historically, programs have functioned as a mechanism to compensate for our energy markets' failure to value fully the benefits of energy efficiency. When markets can accurately value energy efficiency as a resource, the need for programs diminishes. With the use of ICT by utilities and their customers, energy markets are evolving and some now enable companies to monetize the value their investment create for the grid.

In some Regional Transmission Organization (RTO), efficiency program administrators and third party energy service companies (ESCOs) are able to monetize the value to the grid from investments in energy efficiency by treating them as an energy resource in energy markets designed to ensure immediate, near-term, and long-term energy needs. For example, in Efficiency Vermont, the state-wide energy efficiency utility, bids future energy savings resulting from its programmatic activity into the ISO New England (the RTO for six New England states) forward capacity markets (Efficiency Vermont 2015).

Several different value streams may be available to energy efficiency projects in some RTOs. These benefit streams may include (depending upon the RTO market structure): reduced electricity purchases; utility efficiency program incentives; RTO capacity payments; RTO load curtailment payments; and RTO ancillary services payments. The PJM and New England ISO both treat energy efficiency as a capacity resources eligible for capacity payments (a similar opportunity is planned for the New York State ISO). These RTOs also operate curtailment and ancillary service markets. By stacking these value streams with energy cost savings, ESCOs are making the economics of energy efficiency even more compelling (Rogers and Junga 2016). The ESCO enables monetization of RTO payments by verifying the RTO service; acting as the agent for the customer bidding the service into the RTO market; and handling payment to the customer (Navigant 2017, Cochrane et al. 2013).

The period that the distributed resource can be bid into the market varies by RTO. In the PJM market, the resource is eligible for 4 years of capacity payment from the time the project is completed. The ISO NE market forecasts regional energy savings of over 11,500 gigawatt hours (GWh) of energy efficiency capacity clearing the market, or about 1,923 GWh per year. This represented about 9 % of total energy requirements for the region in 2018 alone (ISO New England 2018). In the PJM market approximately 1,515 MW of energy efficiency cleared auction in 2016 for delivery in 2019/2020. That was three times this volume cleared for delivery in 2012/2013 (Baatz 2016).

Participation in these RTO markets is not open to every customer. Participating entities must be capable of validating energy savings and providing a financial guarantee to the RTO market for delivery of services. ESCOs provide experience in identifying the perspective value of customer side services and important analytic services to customers, enabling them to identify and appropriately value the additional benefits that energy efficiency projects can provide. Some RTOs will accept ESCO's analytical assessments of energy savings, a necessary requirement to participating in an energy market, from customers and aggregators.

ESCOs have developed advanced analytical capabilities to determine future energy savings potential and document them as they take place. In many instances, they use data analytics to perform such analyses remotely. If a customer has made the appropriate investments in ICT, such as a smart manufacturing platform, an ESCO can automatically communicate with them and dispatch their energy resources in response to commands from grid operators. Since RTOs can dispatch conventional generation resources automatically, the introduction of automated dispatch to demand side resources can bring parity between energy efficiency and conventional resources (Navigant 2017).

In many cases, RTO resource payments are in addition to any efficiency program incentives. They are an addition value stream for customers. In addition, if the customer has a controllable load, such as a building or process control system that they can curtail consumption upon demand from the RTO, the customer can also receive demand response payments. Further, if the customer has distributed generation resources, the customer can operate their systems to provide other ancillary services to the RTO.

Participation in markets requires a considerable amount of sophistication and a large enough demand for energy to make bidding services into the RTO cost effective. Some ESCOs may also aggregate multiple, smaller customers together when bidding into the market allowing them to benefit from these value streams that they would not otherwise. They also bring the necessary networks and automation needed to facilitate communications related to dispatch and verification of energy resource deployment.

EXAMPLES OF SELLING ENERGY RESOURCES INTO AN RTO MARKET

Efficiency Vermont offers a Continuous Energy Improvement (CEI) program to its larger industrial customers. The CEI program is a SEM type of program and Efficiency Vermont integrates it with other programmatic activities promoting smart manufacturing. In addition to installing EMIS, Efficiency Vermont has programs focused on metering and data-logging, and networking energy-intensive systems like pumps and compressors to data management systems and dashboards (Glatt, Goldberg and Taylor 2015). Future energy savings resulting from current CEI programmatic activity contribute to the energy resources Efficiency Vermont bids into the ISO NE capacity market (Efficiency Vermont 2015).

As markets for energy efficiency and demand response develop, some customers may choose to participate in them directly or through a third party rather than participate in a conventional energy efficiency program. Policy makers will want to consider if or when it makes sense to allow customers to participate in both programs and markets. They will also want to consider how to structure markets so that they encourage greater investment in lower cost resources such as demand response and energy efficiency, but do so without causing unintended consequences.

Participating in a market requires a certain amount of sophistication and interest. Many companies will not have the technical capability nor the interest to interact with RTO markets and therefore will contract with an aggregator that can combine their resources with those of others and trade them into the regional market. In some cases, that solution provider might be the utility-sponsored energy efficiency program. For example, Vermont Energy Investment Corp. (VEIC), the program administrator for Efficiency Vermont, also administers programs in others states and the District of Columbia. It trades some of the energy resources resulting from those programs' customer investments in energy efficiency in the PJM energy market.

Many small companies will likely continue to participate in energy efficiency programs offered by their local utility while some small and medium companies will work with aggregators such as VEIC, Comverge/Itron, and EnerNOC to participate in RTO energy markets. Large companies may participate directly in markets or contract with energy service companies to do so.

Summary and Recommendations

Achieving greater energy savings from large industrial customers requires them to invest more in energy efficiency practices such as SEM and technologies such as smart manufacturing. Policy makers have an opportunity to facilitate this by supporting the policy mechanisms discussed in this paper: programs encouraging adoption of SEM and deployment of SM; research, development and demonstration; and development of energy markets. However, it would be an incomplete solution to address them separately. As demonstrated by the Efficiency Nova Scotia and Efficiency Vermont programs, combining continuous improvement practices with information management technologies will yield greater savings than either might by itself. EMIS are of course only the beginning of smart manufacturing implementation. In order for companies to realize all of the productivity and energy savings benefits of smart manufacturing, they also need to invest in data historians, predictive analytics, and integrating multiple business systems.

Another requisite part of the solution is the ability to monetize all available energy efficiency resources. Programs can only acquire as much energy efficiency as they are funded to acquire. This funding is limited by utility or government budgets. Therefore, numerous opportunities to save energy that might take place with incentives from programs go unrealized. Because of limited funds, government activity cannot scale to meet all of the opportunities that exist in the marketplace. However, markets in which companies can monetize most of the value of their energy resources may be the pathway to address opportunities at scale. It is still early in the development of markets for energy efficiency and demand response resources, but the experience to date in the two markets in the US shows promise.

Policy makers and program administrators can accomplish greater economic impacts by taking a holistic view on how to encourage energy savings and demand response from C&I customers. Rather than offering programs as standalone services for customers to choose from, they can engage customers as any solution provider might and in that engagement have available a portfolio of services and incentives. The engagement might start with worker training via a SEM program and then lead to capital investment aided by incentives. Ultimately, programs might help companies participate in energy markets by aggregating their resources with others or by training them how to participate directly. The volume of energy efficiency resources monetized will only be limited by the size of the market. Not an arbitrary or limited budget.

SEM and SM are mutually compatible and optimization in the manufacturing sector requires investments in both. Therefore, policies should not address them in isolation. Agencies will accomplish more by combining and coordinating their activities. Coordination is required vertically and horizontally. For example, DOE should coordinate with state and local level efficiency focused programs. At the federal level, DOE, EPA, and Commerce should coordinate their activities and encourage state level energy, environmental, and economic development offices to work together.

Continuous improvement programs like SEM require continuous improvement. Policy makers can facilitate better programs by supporting collaboration among SEM program practitioners and other stakeholders and by supporting the development of and advocating for the use of common energy management standards and tools like ISO 50001 and 50001-Ready. Other actions government agencies can take to advance deployment of advanced technologies and best practices include:

- Fund research, development and deployment projects
- Support precompetitive collaboration and public-private partnerships with funding and participation
- Use power of convening to bring stakeholders together to identify best practices and develop common protocols.

Continuous improvement practices and smart manufacturing are the two greatest near-term opportunities to reduce energy use in the industrial sector. Both can contribute to the economic health of companies and drive a nation's economic growth. It therefore makes sense for policy makers to support coordinated programmatic approaches to encouraging companies to invest in them. Such policies will all contribute to the continued health, growth, and decreasing energy intensity of the manufacturing sector.

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