INTERNATIONAL ENERGY AGENCY

WORKSHOP REPORT 2018

Energy management systems and digital technologies for industrial energy efficiency and productivity

Report from IEA Workshop on 12 and 13 December 2017

Joe Ritchie

INTERNATIONAL ENERGY AGENCY

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Acknowledgements

This report was prepared by Joe Ritchie from the Energy Efficiency Division of the International Energy Agency, under the supervision of Brian Motherway, Head of the Energy Efficiency Division within the Directorate of Energy Markets and Security, led by Keisuke Sadamori.

The IEA Workshop on 12 and 13 December 2017 and this subsequent report was informed by contributions from: Paul Sheaffer (Lawrence Berkeley National Laboratory), Flor de María Chávez Sandoval (CONUEE), Sarah Stinson (Natural Resources Canada), Paul Waide (Waide Strategic Efficiency), Marco Matteini (UNIDO), Araceli Fernandez-Pales (IEA), Edward Kelleher (Novartis), Andrew Hejner (3M Canada), Tuğrul Kodaz (Arçelik), Thomas Björkman (Swedish Energy Agency), Hong Souk-Shim (Korean Energy Agency), Alfred Hartzenburg (National Cleaner Production Centre of South Africa), Rana Yusuf Nasir (Indonesian Society for Energy Conservation and Efficiency), Lily Zhao (EMCA) and Maher Chebbo (GE).

Additional content and information for the report was provided by Umesh Bhutoria (EnTech Ventures), David Harper (GE), Faisal Naru (OECD) and Marieke Huysentruyt (HEC Paris).

The report also benefited by comments and review from: Peter Therkelsen (Lawrence Berkeley National Laboratory), Benjamin King and Sudarsan Rachuri (US DOE), Juan Navarrete, Israel Jauregui Nares, Noé Villegas Alcántar and Eduardo Ramos (CONUEE), Gareth Savage, Fabian Allard and Bob Fraser (Natural Resources Canada) and Liisa Sheldrick (3M).

Support for the IEA Workshop and this report was provided by IEA colleagues Melanie Slade, Samuel Thomas, Kathleen Gaffney, Lucy Shedden and Paola Cajamarca.

Executive summary

Improvements in industrial energy efficiency have been aided by technological improvements, particularly the increased presence of digital technologies and the more systematic approach to energy management. To unlock future efficiency gains digital technologies and energy management systems need to be further leveraged. This report highlights global trends in relation to energy management systems, the policies that incentivise or mandate adoption and the role of digitalisation. It has been informed by a workshop on 12 and 13 December 2017, hosted by the International Energy Agency (IEA), which sought to improve collective understanding of the benefits of energy management systems and digital technologies within industry, and what policies or measures can drive greater uptake and effectiveness.

Energy management systems are a key part of industrial energy efficiency policies and are delivering outcomes

Energy management systems broadly refer to the enduring structures and processes for industrial or commercial firms to monitor energy use and improve efficiency. Since 2011, ISO 50001 has been the global standard for an energy management system and it continues to feature as a key aspect of industrial energy efficiency policies.

In North America, ISO 50001 is a fundamental part of industrial energy efficiency policies. The implementation of ISO 50001 through the involvement of industrial energy users in the Superior Energy Performance Program has unlocked verified energy and cost savings of over 10% and contributed to significant energy performance improvement. The use of networks and training initiatives in Mexico has been instrumental in helping small and medium-sized enterprises to implement energy management systems and achieve energy savings of over 7%.

Policy makers across Europe are strengthening the relationship between energy management systems and the industrial sector, as they seek to include in voluntary agreements. The German government has used tax incentives to drive certifications under the ISO 50001 standard in over 9000 companies, representing nearly half of the total number of certifications, globally, at the end of 2016. Similar voluntary agreements that seek to encourage industrial energy efficiency improvements in exchange for tax or other financial incentives have been implemented in several European countries including the Denmark, Finland, Ireland, the Netherlands, Sweden and the United Kingdom. Companies implementing ISO 50001 are also reporting energy savings well over 10%, based on measures with very short payback periods.

Approaches to energy management within the Asia and Pacific region vary across countries. As a result of the mandatory energy efficiency targets placed on energy-intensive enterprises, the People's Republic of China (hereafter "China") saw certifications under its national energy management standard (GB/T 23331) grow to around 2500 by the end of 2017, with ISO 50001 certifications quadrupling between 2015 and 2016 to now exceed 1000. In Korea, the government has instituted a number of voluntary measures to encourage the uptake of energy management systems. The voluntary Superior EnMS Programme enables Korean companies to undertake training on energy management and ISO 50001, which contributed to reported energy savings of over 5.2 PJ after just a few years of implementation.

In a number of countries, the work of organisations like the United Nations Industrial Development Organization (UNIDO) has assisted companies to reap the benefits from energy management systems, and helped governments to develop policy frameworks. The rigorous approach to energy management provided by ISO 50001 has unlocked many low- or no-cost energy efficiency measures in the companies that UNIDO have worked with. Companies are also obtaining further energy savings as a result of improvements in operating, maintenance and other business protocols, which can add an additional 20 to 50% of energy savings on top of already implemented efficiency measures.

Digitalisation improves outcomes from energy management systems

Global trends relating to digitalisation are remarkable, with improved data, analytical capabilities and connectivity having a widespread and growing impact on the global energy system. Digital technologies are continuing to prove beneficial for industrial energy efficiency. Improvements in metering, monitoring and control systems have made it easier and cheaper for industry to optimise production processes to reduce waste and enhance energy efficiency.

Data on energy use at a process and technology level are fundamental for the successful implementation of an energy management system. The ability for companies to use digital technology to accurately obtain and analyse this data is allowing energy efficiency to be optimised in real time and for performance to be continuously tracked and monitored.

Industry is also embracing new digital innovations that can unlock further energy efficiency gains. Digitalisation is allowing existing metering and monitoring equipment to be connected, both within an individual facility and across multiple sites, creating greater value from existing equipment and for knowledge about efficiency improvements to be captured and shared more readily. Innovations such as *digital twins* are using historical performance data, as captured through improved metering, to develop detailed models of industrial systems to allow for a rapid determination of how efficiency may change over time and what measures can be taken to improve performance. Government policy is supporting these innovations, with a growing emphasis on the need to build digital skills and support research and development into technologies that will unlock further efficiency gains.

While the benefits are apparent there are challenges that remain

Energy management systems are producing benefits within industry and these benefits are being enhanced through the growing impact of digitalisation. However, there are challenges that policy makers, industry and technology providers need to confront if further gains are to be achieved.

Small and medium-sized enterprises represent the vast majority of companies globally, and contribute significantly to employment opportunities and economic activity. However, limited resources and knowledge gaps hinder opportunities for these companies to gain productivity and efficiency benefits from energy management systems and digital technologies. A continuing challenge for policy makers is to develop measures that build the capacity of these companies. Measures implemented in the United States, Mexico and Korea based on training and capacity building, as opposed to firm regulation, provides a basis for future policy development.

Policies that incentivise industry to implement an energy management system through financial or tax measures can be powerful tools for policy makers. However the question of what incentives to offer and what actions to require from companies, continues to be a key consideration for policy makers. European policies provide an example of how to incentivise actions that lead to improvements in energy efficiency.

Other challenges facing industrial energy-users, technology providers and policy makers include: how to reduce concerns relating to cyber security, particularly in a more connected industrial landscape; whether to utilise digital technology to fully automate industrial process control and optimisation; and how to gain buy-in from key decision makers so that a company can take ownership of its energy management and efficiency objectives. In all cases there is a need for a clear, unbiased and well-constructed evidence base that lays out the benefits to be gained from increased adoption of energy management systems and digitalisation within industry.

Introduction

Technological improvements continue to provide great benefit to industry, enhancing productivity, quality and safety. Digitalisation is at the forefront of this ongoing technological change and while it is not always the main driver, industrial energy efficiency has and continues to benefit from this change. Efforts to improve industrial energy efficiency are central to the sector's contribution to meeting global climate targets and realising the full potential of energy efficiency requires greater understanding of measures and actions that can be taken to improve energy efficiency. Such understanding can be improved by the increased adoption of energy management systems which assist industrial companies to better understand how energy is used and what opportunities exist to improve efficiency.

Effective implementation of an energy management system can allow an industrial energy user to unlock greater efficiency benefits from the adoption or use of new technology. Similarly, digital technology can facilitate greater benefits from the introduction of an energy management system, providing more accurate and timely data on energy use. Enhancing the benefits from the combination of energy management systems and digital technologies is an important objective and one that policy makers, energy-users and technology providers should strive to achieve.

This report highlights global trends in relation to energy management systems, the policies that incentivise or mandate adoption and the role of digitalisation and how it complements energy management. The report has been informed by a workshop held by the International Energy Agency (IEA) on 12 and 13 December 2017, which examined the energy efficiency and productivity benefits from the application of energy management systems and digital technologies within industry (hereafter referred to as "IEA Workshop").

The IEA Workshop gathered government representatives from IEA member countries and countries involved in the IEA's Energy Efficiency in Emerging Economies (E4) Programme[1], as well as industry representatives, technology providers and other experts. The aim was to improve understanding about the benefits of energy management systems and digital technologies within industry and what policies or measures can be deployed by government to drive greater uptake and effectiveness. All presentations from the workshop as well as the recorded webcast of proceedings can be found through the IEA website at the following link: https://www.iea.org/workshops/iea-industrial-energy-efficiency-workshop.html.

This report draws on the presentations and discussions from the IEA Workshop and other relevant information to provide a resource for policy makers, industrial energy-users and technology and service providers seeking to improve energy efficiency through the application of energy management systems and digital technology.

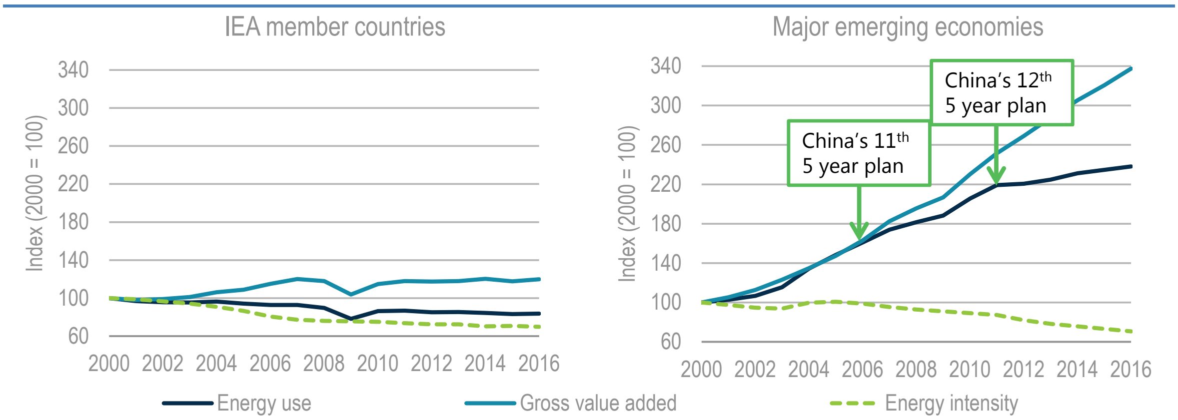
[1] The Energy Efficiency in Emerging Economies (E4) Programme is a four-year programme, established in January 2014, to support the scale-up of energy efficiency activities that generate economy-wide benefits in major emerging economies including People's Republic of China (hereafter "China"), Indonesia, India, Mexico, South Africa and Ukraine. The E4 Programme is funded by the government of Denmark and the European Commission. Mexico became an official country member of the IEA on 17 February 2018, following acceptance of Mexico's membership at the IEA Governing Board meeting in November 2017. The IEA Workshop was the first at which Mexico participated after the IEA accepted its membership, and after the Mexican Senate approved the International Energy Program.

Background

Since 2000 the energy intensity – final energy use per unit of gross value added (GVA) – of manufacturing industries has fallen by around 30% in both IEA member countries and major emerging economies (Figure 1).

Excluding the impact of the global financial crisis, the energy intensity of manufacturing industries in IEA member countries has steadily improved since 2000. Collectively, energy intensity in the major emerging economies has followed a different path, which has been strongly influenced by policy. Before 2006, energy use increased at practically the same rate as GVA. However, in 2006 the Chinese government implemented its 11th five year plan, which for the first time included mandatory energy intensity improvement targets for the country's largest 1 000 energy consuming enterprises. This was the Top 1 000 Programme and its impact can be observed from the difference between energy use and GVA trends after 2006. In 2012, China introduced its 12th five year plan, in which the Top 1 000 Programme was expanded to cover the largest 10 000 energy consuming enterprises (Top 10 000 Programme) widening the gap between energy use and GVA trends and increasing the rate of energy intensity improvement.

Figure 1 • Energy intensity of manufacturing industries in IEA member countries and major emerging economies, 2000-16



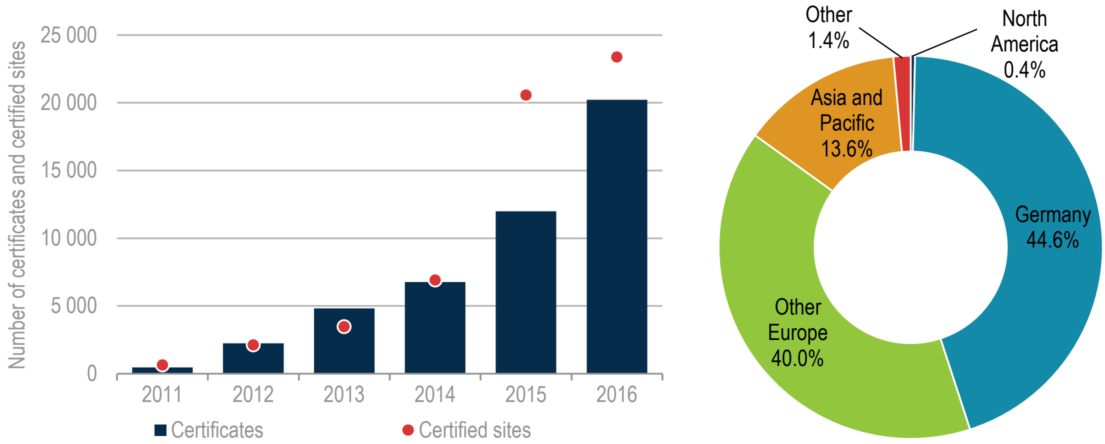
Notes: Industry includes ISIC divisions 10-18, 20-23 and 25-32 and excludes mining and quarrying, manufacturing of coke and refined petroleum products and construction. Energy use related to blast furnaces, coke ovens and petrochemical feedstocks are included. Major emerging economies include Brazil, the People's Republic of China (hereafter "China"), India, Indonesia, Mexico and the Russian Federation (hereafter "Russia").

Source: IEA (2017a).

A contributing factor to improvements in industrial energy intensity is the growing use of energy management systems, which provide enduring structures and processes for industrial or commercial firms to monitor energy use and improve efficiency. In 2011, the publication of the international standard *ISO 50001 – Energy management systems – requirements and guidance for use*, established an international consensus of the practices that constitute an energy management system. Several governments are using ISO 50001 as the basis for energy management programmes, as certification provides assurance that companies undertake certain actions required of them.

By the end of 2016, there were over 20 000 ISO 50001 certifications globally, covering nearly 25 000 sites. Nearly 85% of certificates were obtained by companies in Europe, with Germany having the largest number of certificates globally (Figure 2). As outlined in later sections, German companies are motivated to implement ISO 50001 through the provision of fiscal incentives.

Figure 2 • ISO 50001 certificates and certified sites, 2011-16 (left) and regional breakdown of certificates, 2016 (right)



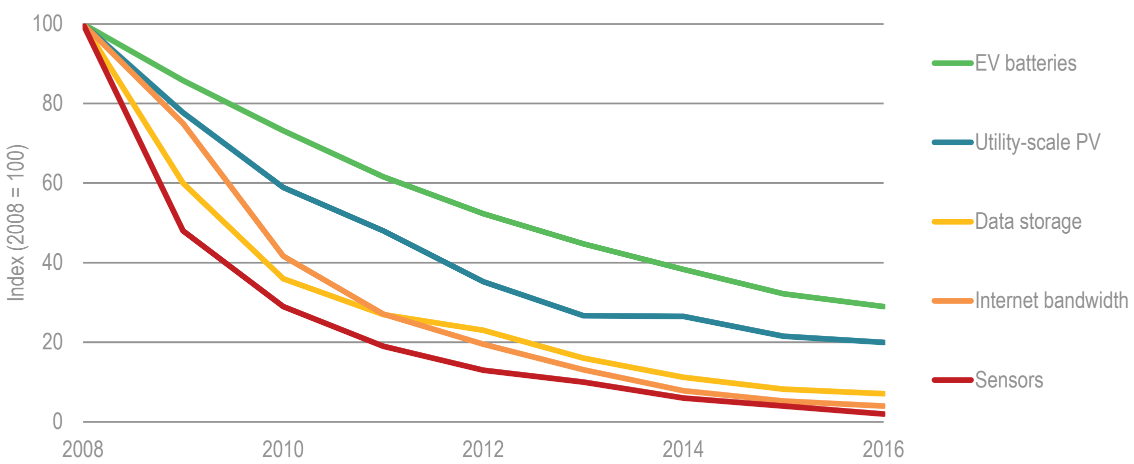
Source: Adapted from ISO (2017), *ISO Survey of certifications to management system standards – Full results* (database), https://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&viewType=1

While positive, the trends relating to improvements in industrial energy intensity and the implementation of energy management systems are dwarfed by those associated with the growing application of information and communication technologies (ICT) and digitalisation across the global economy. These digitalisation trends have led to significant increases in data availability, with around 90% of the data in the world today created over the past two years (IBM, 2017). Digitalisation itself is composed of the following three fundamental elements (IEA, 2017b):

- **Data:** digital information
- **Analytics:** the use of data to produce useful information and insights
- **Connectivity:** the exchange of data between humans, devices and machines, through digital communication networks, specifically the internet.

Digitalisation of the global economy is underpinned by the falling cost of enabling technologies including data storage, internet bandwidth and sensors (Figure 3).

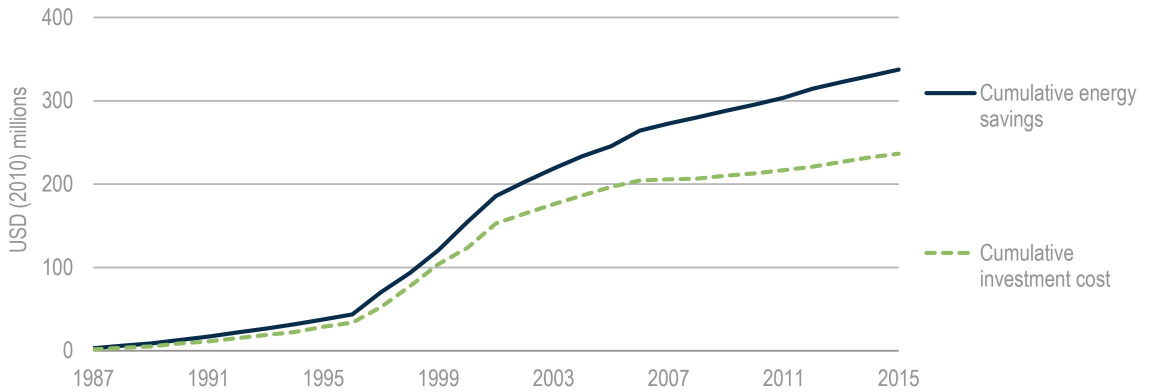
Figure 3 • Cost declines in new energy systems and digital technologies, 2008-16



Sources: Adapted from on BNEF (2017), Utilities, Smart Thermostats and the Connected Home Opportunity; Holdowsky et al. (2015), Inside the Internet of Things; IEA (2017c, 2017d, 2017e); Navigant Research (2017), Market data: Demand Response Global Capacity, Sites, Spending and Revenue Forecasts.

In comparison to other economic sectors, industry has a long-standing history with digital technologies to increase process control, automation, safety and productivity. Enhancements to process control present a low cost and effective means of improving energy efficiency, which has been made easier and less expensive thanks to digitalisation. The impact of digital technology on energy efficiency became apparent during the mid-to-late 1990s as a result of the increased use of ICT within industry following rapid technology improvements and cost declines (Figure 4).

Figure 4 • Cumulative energy savings and investment in digitally enabled optimisation of process controls in the United States, 1987-2015



Notes: These measures were identified by audits funded by the US Department of Energy and undertaken by Industrial Assessment Centers (IACs). The energy savings identified are dependent on the number of audits undertaken in a given year, the number of recommendations identified and the companies in which the audits were conducted.

Source: IAC (2017), IAC Database (database).

Continued improvements in data collection, analysis and process control have seen the impacts of digitalisation move beyond the boundaries of individual industrial sites, creating benefits for the wider energy system. Digitalisation is allowing industrial energy-users to participate in energy markets both as consumers of energy and as sources of demand reduction, which are recognised through market mechanisms such as demand side response and forward capacity markets.

In 2014, the global demand response market was worth more than USD 5 billion with over 50% of revenues coming from industrial applications (Grand View Research, 2016). The market is expected to grow fivefold by 2022 due to the growing impact of digitalisation and it is estimated that the industry, buildings and transport sectors could provide 185 GW of flexibility and avoid USD 270 billion in investment in new electricity infrastructure (IEA, 2017b).

With energy management systems providing the structures for companies to continuously improve energy efficiency and digitalisation enhancing data access, quality and process control, it is timely to understand the energy efficiency benefits that are arising and what measures can be taken to incentivise greater uptake and improve outcomes.

Energy management systems

An energy management system is a collection of procedures and practices to ensure the systematic planning, analysis, control, monitoring and improvement of energy use. When implemented, an energy management system provides an industrial or commercial company with a framework to set and track progress against energy performance improvement objectives and continuously improve the energy efficiency of key processes and end-use equipment.

To encourage the implementation of energy management systems above business-as-usual rates, governments can implement measures, referred to as energy management programmes, which are classified into three broad types:

- **Information:** Providing capacity building, guidance and training on energy management.
- **Incentives:** Providing companies that implement energy management systems with fiscal or financial rewards or recognition.
- **Regulation:** Mandating that companies implement an energy management system.

Energy management programmes have been implemented in a number of countries, with the type of programme often tailored to reflect the specific characteristics of industry in the country or region and the factors that motivate action. The way in which energy management systems have been incorporated in industrial efficiency policies and the outcomes achieved vary across country and region, as outlined in the following sections.

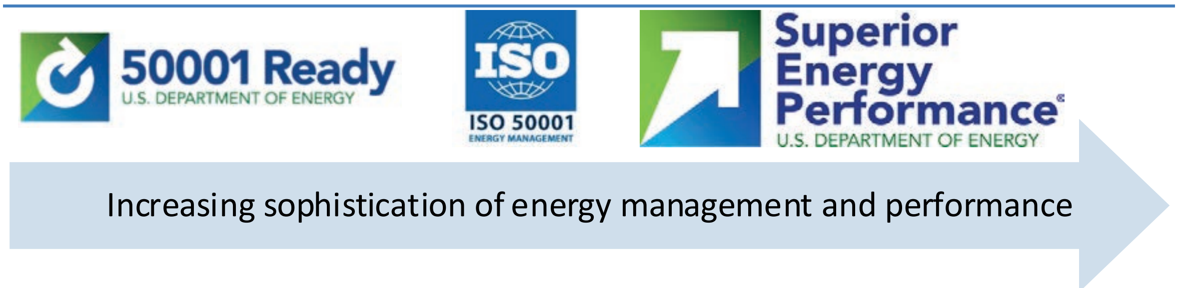
North America

North America (the United States, Canada and Mexico) have all developed programmes aimed at increasing the uptake of energy management systems based on the ISO 50001 standard.

The United States

The United States Department of Energy (US DOE) has implemented a series of voluntary measures to drive uptake of ISO 50001 within the industrial, commercial, and other sectors, which are focused on tools, training and outreach. Financial or fiscal incentives are not a feature of policy settings at the federal level (other than partial funding of some pilot projects), although some incentives are available through state-based schemes. Voluntary measures follow a progression of energy management system development (Figure 5), which scales according to an organisation's knowledge of energy management and desire to improve energy performance.

Figure 5 • Voluntary information and support measures for ISO 50001 offered by the United States Department of Energy



Source: Adapted from Sheaffer (2017), *Energy Management Systems in North America – Policies and Impacts*, https://www.iea.org/media/topics/energyefficiency/industry/2.SheafferandStinson_169.pdf.

Launched in 2017, 50001 Ready is a voluntary recognition programme designed primarily for small to medium organisations and companies that may not have a strong understanding of energy management, such as those in the commercial buildings sector. To be recognised as "50001 Ready" by the US DOE companies have to complete three key steps (US DOE, 2018a):

- Implement the principles of ISO 50001 using the 50001 Ready Navigator online tool.
- Undertake analysis of energy performance improvements using a valid analytical tool.
- File for 50001 Ready recognition by submitting energy performance data and a self-attestation of the completion of the required tasks, signed by energy management team leader and senior executive.

The 50001 Ready Navigator is an online tool and dashboard that provides step-by-step guidance on how to implement and maintain an energy management system in line with the principles of ISO 50001. Another resource developed by US DOE for 50001 Ready is an online Energy Performance Indicator (EnPI) Lite tool. Following user input of energy consumption and other relevant activity or performance data, the tool undertakes an automatic regression analysis[2] to help companies estimate the energy savings from identified efficiency measures. Mexico and Canada have recognised the potential benefits of 50001 Ready and are considering adoption 50001 Ready and hosting of the 50001 Ready Navigator and EnPI Lite tool.

US DOE's voluntary support measures (Figure 5) also include certification of a company's energy management system to the ISO 50001 standard, which is similar to that provided in other countries, and the Superior Energy Performance (SEP) Program. The SEP Program requires third-party certification to ISO 50001 and verification of energy performance improvement, as defined by the Program's Measurement and Verification Protocol.

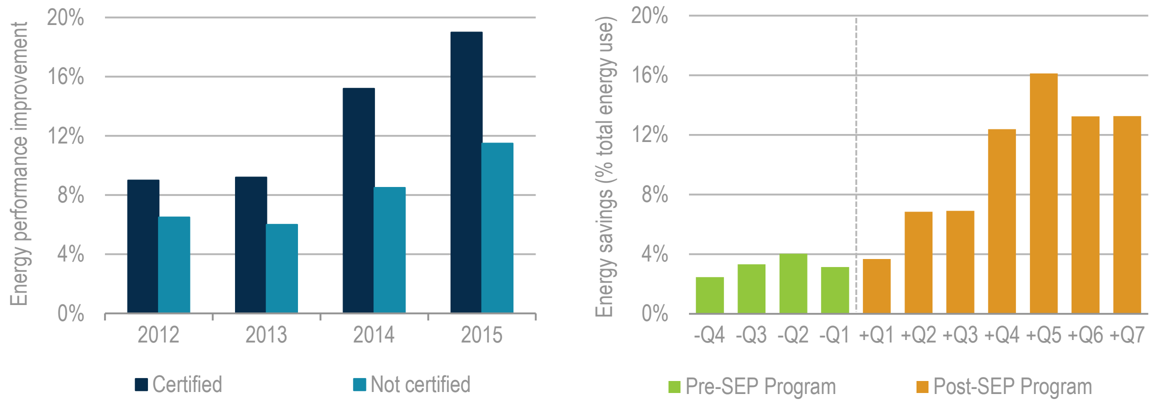
To obtain SEP certification a company must be able to prove that in addition to having an ISO 50001 certified energy management system, energy-saving projects have been implemented and that efficiency has improved in accordance with established targets. Third-party verification of energy performance is also required, which involves a comparison of the results of energy saving projects with top-down regression analysis. If successful, the company receives recognition from the US DOE in the form of silver, gold or platinum certification, depending on the level of energy performance improvement, and the active promotion of company's efforts, including case studies and other activities (US DOE, 2018b).

One of the benefits of third-party verification, that distinguishes the approach of the US DOE, is that it has allowed for the collection of data regarding the impacts of ISO 50001 and SEP certification. Such information is an important contribution to a growing evidence base for the benefits of energy management systems and ISO 50001.

Data collected as part of the SEP Program demonstrates the increased energy performance achieved through ISO 50001 and SEP certification (Figure 6). In 2015, the energy performance improvement of certified Schneider Electric sites was over 60% greater than non-certified sites. This additional improvement is also demonstrated through quarterly energy savings achieved by SEP certified companies. Quarterly energy savings prior to certification averaged 3.2% and increased to 7.5% in the four quarters after certification and 14.2% in quarters five to seven. In all cases, the improvements observed for certified sites increased over time, illustrating that the benefits of energy management can grow as sites became more knowledgeable and experienced. Information about the implementation of energy management systems at 3M Canada, another SEP certified company, is presented in later sections.

[2] In the context of energy efficiency, regression analysis allows for a determination of what factors have the greatest impact on energy use and subsequently a prediction of the energy savings that would be achieved from efficiency measures.

Figure 6 • Energy performance improvement of ISO 50001 and SEP certified Schneider Electric sites compared to non-certified sites, 2012-15 (left) and verified average quarterly energy savings from SEP certified companies, pre- and post-certification (right)

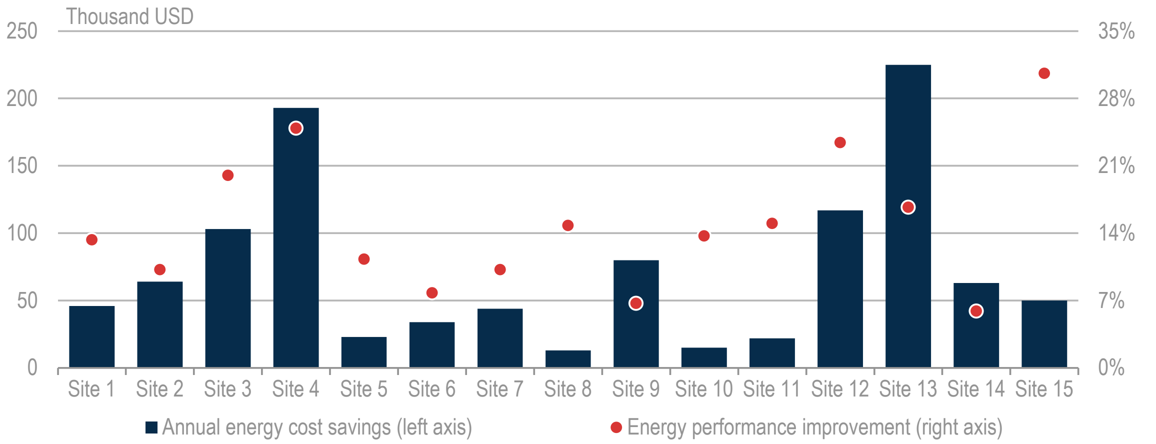


Note: Based on data analysis conducted by Schneider Electric

Source: Adapted from Sheaffer (2017), *Energy Management Systems in North America – Policies and Impacts*, https://www.iea.org/media/topics/energyefficiency/industry/2.SheafferandStinson_169.pdf; LBNL (2015) *Development of an Enhanced Payback Function for the Superior Energy Performance Program*, http://aceee.org/files/proceeding/2015/data/papers1-72.pdf

US DOE is continuing to evolve the SEP Program, with 2018 additions to include enterprise wide adoption of ISO 50001. While companies are able to obtain ISO 50001 certification for all sites via a single process, SEP certification is still undertaken on a site-by-site basis. Enhancing the ability for companies to obtain SEP certification for a number of sites within their portfolio under one certification will capitalise on the benefits associated with enterprise wide adoption of ISO 50001. As an example, verified improvements from 15 SEP certified sites within a single enterprise included average annual energy cost savings of over USD 70 000 and average energy performance improvements of nearly 15% (Figure 7). The SEP Program implementation cost was USD 18 000 per site, so if the implementation cost for all sites could be streamlined and overall costs lowered, the benefits of enterprise wide SEP certification would be enhanced.

Figure 7 • Annual energy cost savings and performance improvements from 15 sites covered by a single ISO 50001 certification, but separate SEP certifications



Source: Adapted from Sheaffer (2017), *Energy Management Systems in North America - Policies and Impacts*, https://www.iea.org/media/topics/energyefficiency/industry/2.SheafferandStinson_169.pdf.

Mexico

For almost thirty years Mexico has been promoting energy efficiency, first through its National Commission for Energy Savings and since 2008 through the National Commission for the Efficient Use of Energy (CONUEE). Since its inception, CONUEE implemented industrial energy efficiency programs that incorporated the main elements of energy management. In 2013, CONUEE began promoting the implementation of energy management systems based on ISO 50001.

In April 2014, CONUEE published the National Program for Sustainable Use of Energy 2014-2018 (PRONASE). The Program included measures for promoting and implementing energy management systems in public utilities, specifically Petróleos Mexicanos (Pemex) and Comisión Federal de Electricidad (CFE), and the private sector. PRONASE also sought to increase Mexico's bilateral and multilateral international cooperation in the promotion and implementation of energy efficiency policies and measures.

To build on PRONASE and align its activities with overarching national policy instruments, CONUEE formally established the National Program for Energy Management Systems (PRONASGEN) in 2015. With the publication of Mexico's Energy Transition Law, the update of the National Strategy to Promote the Transition to Cleaner Fuels and Technologies, and the update of PRONASE, energy management systems within the industrial sector are central to Mexico's promotion of energy efficiency.

Mexico, through CONUEE, has also been actively engaging with international partners to develop and implement additional measures relating to energy management systems, these include:

- Training professionals on the implementation, certification and verification of energy management systems.
- Piloting the implementation of energy management systems in different industrial sectors, particularly small to medium enterprises.
- Regional cooperation with Central America on the promotion of energy management systems for the industrial sector.

Through its key bilateral partnership with the German Development Agency (GIZ), Mexico has also been supporting learning networks to encourage and assist companies with implementation of ISO 50001. These networks are aided by the development of guidance documents and engagement with technical experts. This partnership is being expanded to other countries in Central America to build cooperation for industrial energy efficiency learning networks.

Another important bilateral partnership for CONUEE has been with the Danish Energy Agency. A key aspect of this has been support for energy audits in large food manufacturing companies as well as other energy-intensive sectors, including petroleum refining and cement manufacturing, and training to enhance the ability of technical experts to provide certification services for ISO 50001. Work has also extended to the use of Voluntary Agreements leveraging from experience in Europe, as outlined later in the report, and incorporating energy management systems. A focus of this work has been on identifying appropriate incentives for Mexican industry to implement energy efficiency measures through voluntary agreements.

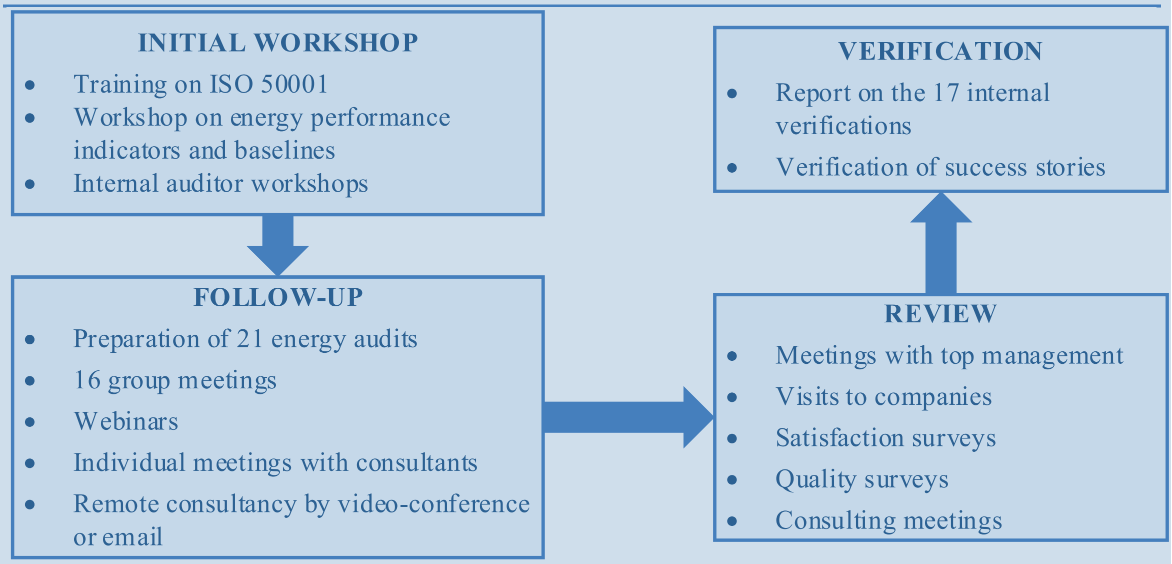
With the support of the German Metrology Institute, CONUEE have also developed a pilot project working with small and medium industrial enterprises (SMEs) to improve efficiency and implement an energy management system (Box 1).

Box 1 • Pilot project for the implementation of energy management systems in Mexican SMEs

Between December 2013 and November 2017, CONUEE worked alongside the German Metrology Institute, funded by the German Federal Ministry for Economic Cooperation and Development, to implement a pilot program for the implementation of energy management systems using ISO 50001 in SMEs. The two objectives for the program were to introduce SMEs to the adoption of energy efficiency practices and implement an energy management system.

CONUEE worked with national industry associations, universities, research centres and certification and standardisation bodies to identify interested SMEs, with 21 companies ultimately selected. The companies were split into two groups and worked through a sequential process to implement an energy management system (Figure 8).

Figure 8 • Process for the implementation of ISO 50001 in Mexican SMEs



Results from the implementation of energy management systems in the companies involved in the project were cumulative annual energy savings of 57.7 GWh, over MXN 62 million in cumulative annual financial savings and total emissions abatement of nearly 15 000 tonnes of carbon dioxide equivalent (Table 1). The project also identified potential for another 47.6 GWh of energy savings from measures relating to operational control (16.8 GWh), heat recovery (16.5 GWh) and combined heat and power (14.3 GWh). Through the implementation of energy management systems the SMEs involved in the project were able to reduce their energy use by an average of 7%.

Table 1 • Summary of successful results from implementation of ISO 50001 in Mexican SMEs

Action area	Annual energy savings (MWh/year)	Total cost savings (MXN/year)	Total investment costs (MXN)
Compressed air systems	986	1 099 899	200 000
Cogeneration	14 305	45 064 560	211 471 400
Operational control	18 547	5 617 386	1 089 404
Lighting	446	848 130	2 409 907
Heat recovery	22 027	8 367 779	2 540 000
Equipment repair	855	1 027 689	4 235 999
Others	534	60 000	-

Source: Adapted from CONUEE (2017), Proyecto piloto Introducciyn a la Eficiencia Energйtica y Sistemas de Gestiyn de la Energнa en Pymes de Mйxico [Introduction to Energy Efficiency and Systems of Energy Management in SMEs in Mexico]. https://www.gob.mx/cms/uploads/attachment/file/286688/Documento_Memoria_del_Proyecto_Piloto.pdf.

Canada

The Pan-Canadian Framework on Clean Growth and Climate Change was launched in late 2016 with the goal of establishing the framework required for Canada to meet its emissions targets as established through the Paris agreement. The framework included a number of actions aimed at improving energy efficiency, with specific industry measures aimed at accelerating the uptake of energy management systems.

The industrial energy management program within the Pan Canadian Framework is structured around three key measures with increasing levels of stringency:

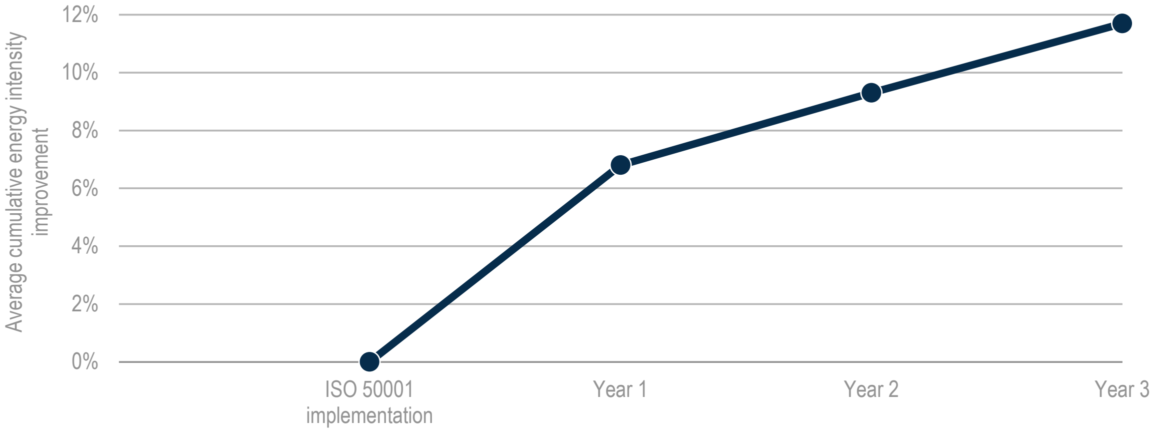
- **ENERGY STAR® for Industry:** Launched in 2017, the program builds on similar measures in the United States that are based on benchmarking of energy performance against other companies in the same industry sector. The measure has a certification component, in which companies are ENERGY STAR® certified if energy performance is in the top quartile of their industry sector, and a challenge component if an improvement of 10% can be demonstrated over a period of five years.
- **ISO 50001 certification** (available since 2012).
- **Superior Energy Performance (SEP) Program:** Based on the US DOE Programme, SEP certification will soon be launched in Canada for high-performing Canadian companies.

The Canadian government also provides incentives and support tools for industry to assist with the uptake of energy management systems, these include:

- Up to CAD 40 000 (50% of eligible project costs) towards energy management system implementation, which can be complemented by additional incentives provided by regional governments.
- Support tools including an energy savings toolbox, technical guides, calculators, newsletters, webinars, and case studies.
- Collaborative networks, specifically the Canadian Industry Partnership for Energy Conservation (CIPEC), which comprises over 2000 industrial companies and trade associations which serves as a platform for launching and implementing programmes and sharing knowledge.

There are currently 36 organisations in Canada that have obtained ISO 50001 certification. These organisations have achieved on average a 10% improvement in energy intensity, resulting in an average annual energy cost savings of CAD 2 million for a large Canadian company (Figure 9). To grow the benefits of energy management within Canada, the financial support offered by the Canadian government is being extended in 2018 to include commercial and institutional buildings, with enhanced collaboration between federal, provincial and territorial governments to increase uptake of energy management.

Figure 9 • Average impact of ISO 50001 certification in Canadian industry



Source: Adapted from Stinson (2017), *Canadian Experience: Energy Management Systems*, https://www.iea.org/media/topics/energyefficiency/industry/2.SheafferandStinson_169.pdf; Natural Resources Canada (personal communication 16 March 2018).

North American case study: Energy management at 3M Canada

3M is a global science company, which started in the United States and has since expanded to have subsidiaries in more than 70 countries. The first of these subsidiaries was launched in Canada in 1951 and includes seven manufacturing facilities covering the production of abrasives, tapes, safety and healthcare products. 3M Canada was also the first subsidiary to appoint a full time energy manager.

The motivations for the implementation of energy management within 3M link to the company's overall sustainability focus and include:

- Mitigating the impact of increasing energy costs.
- Enhancing competitive position.
- Contributing to the achievement of global sustainability commitments.

Energy management objectives are also contained in 3M's corporate policies, through a specific energy policy. This outlines how 3M Canada will seek to both promote the efficient use of energy in its operations and to deliver products to customers that help them save energy.

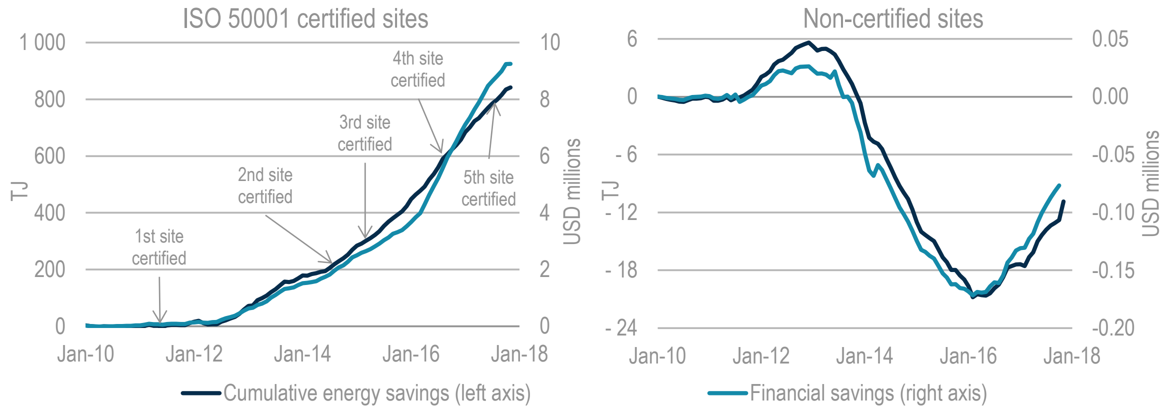
Using ISO 50001 and collaborating with the Canadian government through the SEP Program, 3M Canada implemented ISO 50001 across six facilities. This made 3M Canada the first enterprise in Canada to achieve enterprise wide certification. Energy management at 3M Canada was implemented on three pillars: metering and targeting; technology and projects; and people.

People, particularly operating personnel, were indispensable to the implementation of energy management due to the knowledge about energy consuming equipment. 3M Canada also sought to engage people from across the company in energy management through a series of measures aimed at enhancing retention and satisfaction, and ultimately improve trust in energy management. These measures included: energy conservation awareness campaigns; energy training; employee suggestion programs; and ongoing communication.

The energy training component of employee engagement at 3M Canada involves a requirement that all employees follow a training exercise, which aims to develop an understanding of energy efficiency and how it can be improved. Even senior management are required to go through this energy training exercise, which helps gain their support for energy management

The impacts of ISO 50001 certification at 3M Canada have been substantial. Between 2008 and 2017 a total of CAD 15 million in energy savings have been achieved, resulting from 126 GWh of electricity savings and 20 million cubic metres (mcm) of natural gas savings. The energy and financial savings achieved at 3M sites that have obtained ISO 50001 certification and SEP certification and those that have not highlight the benefit 3M Canada has obtained from the structured approach to energy management provided through ISO 50001 and SEP certification (Figure 10). Since 2010, ISO 50001 and SEP certified sites have achieved cumulative energy savings of over 800 TJ, and saved nearly USD 10 million, while non-certified sites had seen energy use increase by up 20 TJ and costs by up to USD 170 000.

Figure 10 • Cumulative energy and financial savings at 3M Canada sites that have ISO 50001 and SEP certification and non-certified sites, 2010-18



Source: Adapted from Hejnar (2017), *Energy Management 3M Canada*, https://www.iea.org/media/topics/energyefficiency/industry/8.3M.pdf; 3M Canada (personal communication 18 January 2018)

Europe

The history of energy management in Europe extends back to the 1970s when several countries started promoting energy audits within the industry sector as a means of driving efficiency improvements. In recognition of the need to improve the organisational culture of industry in relation to energy management, European countries started to develop national energy management programmes, with measures most apparent from 1990 to 2010. National energy management standards were developed to structure these programmes, which were subsequently merged with European standards and ultimately contributing to the development of ISO 50001.

Since 2012, the policy environment for energy management has been influenced by the European Union’s Energy Efficiency Directive (EED). Specifically, Article 8 of the EED requires member states to ensure that large enterprises carry out regular energy audits. Enterprises that implement an energy management system can be exempted from the obligations of Article 8, with ISO 50001 specifically mentioned as a standard that should be considered by member states when transposing Article 8 in domestic regulations. While conducting an energy audit is mandatory, implementation of some or all the recommendations that emerge is not required.

In addition, voluntary policy measures have been implemented in several European Union member states, as well as at regional level, to encourage the improvement of energy efficiency and implementation of an energy management system. These long-term agreements involve a company committing to reduce its energy intensity or emissions by a specified amount in return for an incentive provided by government. Incentives can include a reduction of tax burdens or financial support for the implementation of energy efficiency measures. Examples of long-term agreements implemented in Europe are provided Table 2, with details of the Swedish Programme for Improving Energy Efficiency in Energy Intensive Industries (PFE), which was presented at the IEA Workshop, provided in Box 2.

Table 2 • Examples of national level long term agreements for energy efficiency within European Union member states

	Denmark	Ireland	Netherlands	Finland	United Kingdom
Programme name	Long term agreements	Large Industry Energy Network and Energy Agreements Programme	Long term agreements	Energy efficiency agreements	Climate Change Agreements
Period of operation	1996-2013 2015-present	1995-present	1992-present	2008-present	2001-present
Incentives to participate	Rebate to energy savings tax	Subsidised energy audits and support	Participants pay a lower energy tax	20% subsidy for energy efficiency related capital expenditure	Reduction of the Climate Change Levy (65% for gas, 90% for electricity)
Requirements	Implementation of ISO 50001 and cost-effective efficiency measures, with payback of up to five years, is binding for a three year period	Agree to work towards achieving ISO 50001 certification	Enterprises must develop an energy efficiency plan every four years and develop roadmaps to reduce emissions by 50% by 2030	Companies agree to improve their energy efficiency, in accordance with an Action Plan developed for numerous sectors	Companies agree to implement measures to meet agreed energy efficiency targets every two years
Sectors covered	Industry	Industrial sites, which in total cover over 50% of industrial energy use	Industry, services and agriculture	Industry, services and energy	Energy intensive industry sectors and over 30 smaller sectors

Sources: Waide Strategic Efficiency (2016), *The Scope for Energy Saving from Energy Management, Final Report*, http://leonardo-energy.pl/wp-content/uploads/2017/07/The-scope-for-energy-savings-from-energy-management.pdf; Motiva (2018), *Energy Efficiency Agreements*, http://www.energiatehokkuussopimukset2017-2025.fi/en/energy-efficiency-agreements/; United Kingdom Environment Agency (2017), *Climate Change Agreements*, https://www.gov.uk/guidance/climate-change-agreements--2.

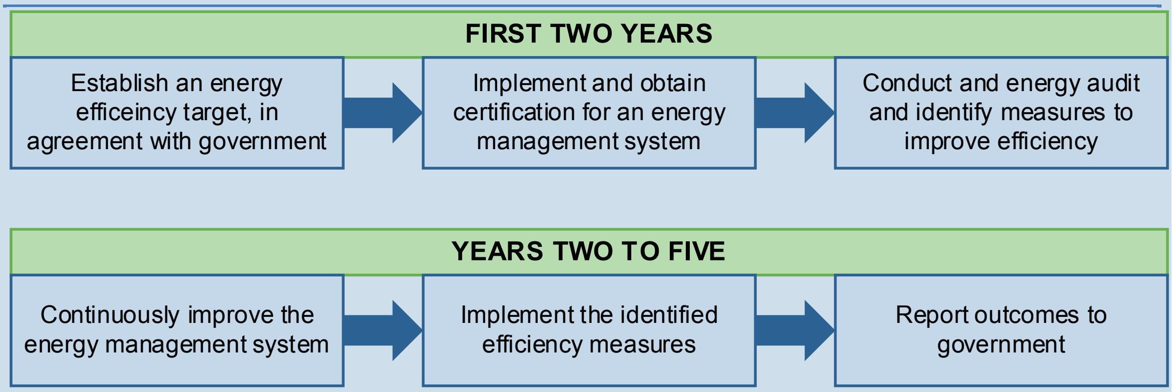
Box 2 • Swedish Programme for Improving Energy Efficiency in Energy Intensive Industries (PFE)

PFE was implemented in Sweden in 2004 leveraging the newly developed Swedish energy management standard, which drew of lessons from the Danish energy management standard. Although PFE was a voluntary programme, participation was incentivised through a reduction in a company's electricity tax liability of 0.5 EUR/MWh. This incentive assisted in gaining the participation of over 100 Swedish companies operating in energy-intensive industry sectors.

The requirements for companies participating in PFE were structured over a five-year compliance period (Figure 11). Key amongst these requirements was undertaking an energy audit and implementing an energy management system certified to the ISO 50001 standard within the first two years. Subsequent to this, companies were required to demonstrate continual improvement in energy management practices and the implementation of energy efficiency measures.

During the 10 years of PFE, participating Swedish companies achieved a 10% reduction of specific electricity consumption (electricity per unit of production or value added) above business as usual levels. Other major benefits included an improvement in the strategic focus on energy efficiency within the company aided by greater organisational planning, budgeting and improvements in staff skills and awareness.

Figure 11 • Requirements for companies participating in Swedish PFE

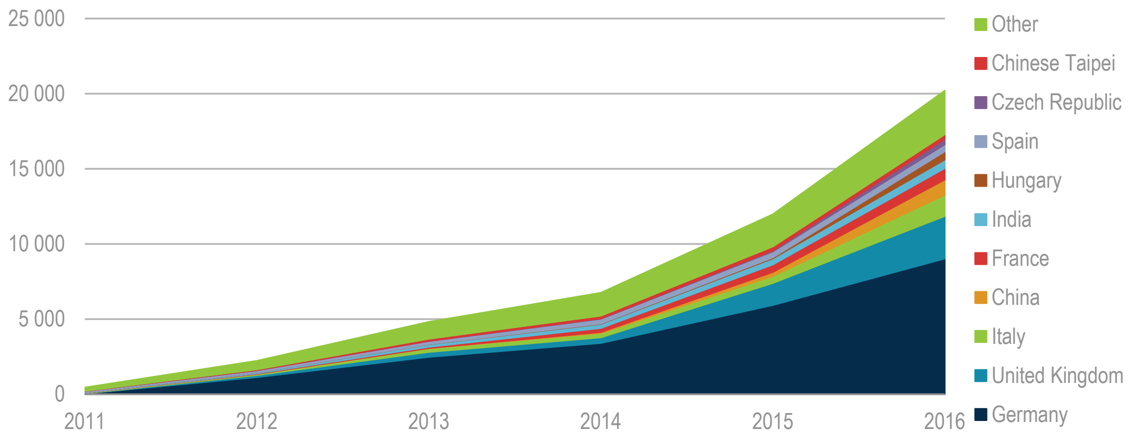


Note: The energy management system that companies participating in PFE were required to implement and obtain certification for was originally the Swedish national standard, which ultimately transitioned to ISO 50001.
Source: Bjцrkman (2017), *Energy management in energy intensive industries and digital technology in government policies*, https://www.iea.org/media/topics/energyefficiency/industry/3.Sweden.pdf.

Germany also uses taxation as a means of incentivising uptake of energy management systems. In 2007, Germany introduced an electricity tax, payable by industrial firms, which was set at EUR 20.5 per MWh. Since 2012, large energy users, defined as those companies that pay over EUR 1 000 per year under this tax arrangement, are eligible to apply for a 90% reduction of this tax liability if they are able to prove that they have implemented an energy management system certified to ISO 50001 or the German national standard (DIN EN 16001). As of 2014, it was estimated that around 25 000 firms were eligible to receive tax exemptions, which if claimed would total EUR 2.3 billion.

The impact of this sizeable tax incentive can be seen from the number of German companies that have obtained ISO 50001 certification (Figure 12). By the end of 2016, over 9 000 Germany companies had obtained ISO 50001 certification, making it by far the country with the largest number of certifications globally, with over 3 000 new certificates registered in 2016 alone.

Figure 12 •Breakdown of ISO certifications by country, 2011-16

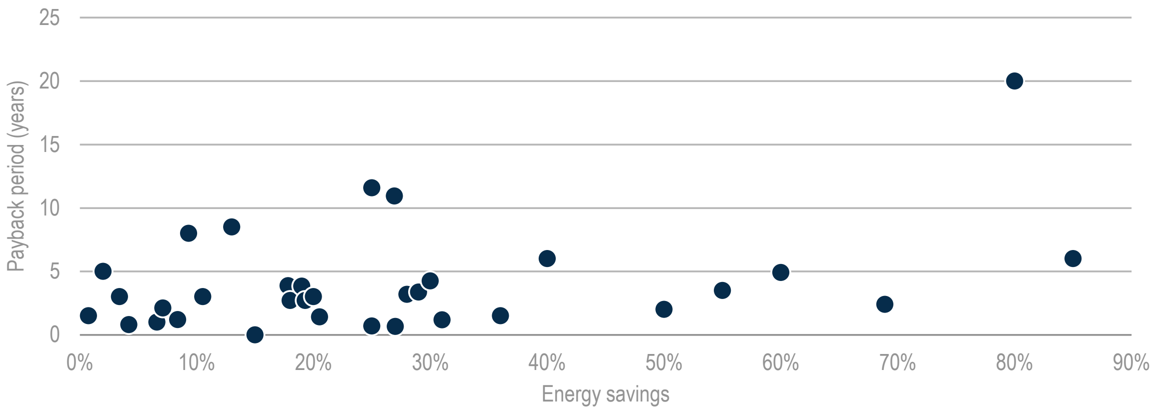


Source: Adapted from ISO (2017), *ISO Survey of certifications to management system standards – Full results* (database), https://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&viewType=1

Although companies operating in European Union member states are able to obtain an exemption from the energy audit obligations imposed by Article 8 of the EED, additional incentives continue to be provided for implementation of an energy management system. This in part recognises that because ISO 50001 certification can be expensive, companies may opt to comply with the audit requirement, as it is cheaper and does not mandate the implementation of any identified efficiency measures.

Data relating to the impacts from energy management systems in Europe can be obtained from case studies for companies that have implemented ISO 50001. Although not verified by a third party, 33 case studies from companies in Germany, France and United Kingdom, highlight that ISO 50001 has unlocked energy savings[3] exceeding over 50%, with the majority of measures having paybacks of less than 5 years (Figure 13).

Figure 13 • Energy savings and payback period reported in 33 case studies of ISO 50001 implementation in Germany, France and the United Kingdom



Notes: Reported savings cover individual processes, technologies and entire companies.

Source: Waide Strategic Efficiency (2016), *The Scope for Energy Saving from Energy Management, Final Report*, http://leonardo-energy.pl/wp-content/uploads/2017/07/The-scope-for-energy-savings-from-energy-management.pdf

European case study: Energy management at Novartis in Ireland

Novartis is a global pharmaceuticals manufacturer whose operations in Ireland employ over 1 500 people. Novartis' major energy using facility in Ireland – the Ringaskiddy plant, located around 250 kilometres southwest of Dublin – manufactures constituent ingredients for drugs produced at other Novartis facilities throughout Europe.

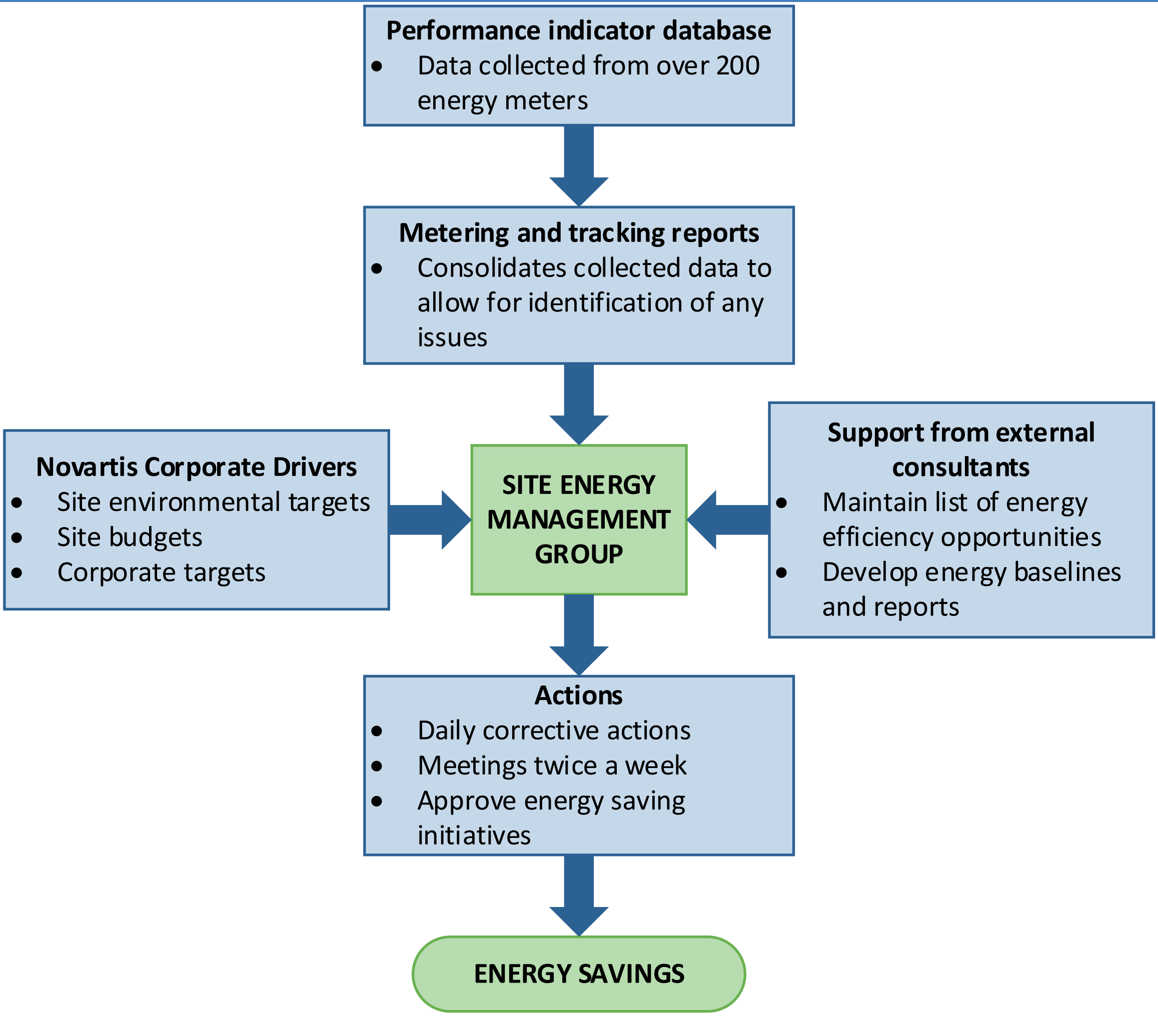
The motivations for energy efficiency within Novartis stem from the company's strong corporate commitments. These include a target to reduce emissions by 30% in 2020 compared to a 2010 baseline and a Ringaskiddy site-specific emissions reduction target of 4% in 2017. While not currently certified in accordance with ISO 50001, for the past 22 years, the Ringaskiddy operations have been continuously accredited with the European Union Eco-Management and Audit Scheme (EMAS). EMAS encapsulates many of the practices associated with ISO 50001, but also extends to other environmental aspects, including annual public reporting. Novartis has also implemented an internal carbon price, to incentivise further emissions savings.

To drive energy management at Ringaskiddy, Novartis established an interdisciplinary site energy management group, drawing representatives from the production, engineering, projects and finance areas of the plant. This broad approach was important to gathering perspectives and understanding the impacts of energy use and efficiency across the production process.

[3] Reported savings cover individual processes, technologies and entire companies.

The work of the energy management group has been facilitated by a comprehensive digital energy metering and monitoring system, which allows for the collection and subsequent analysis of energy use and activity data. The automated production of metering and tracking reports informs the work of the energy management group by allowing for the identification and implementation of actions to improve energy efficiency (Figure 14).

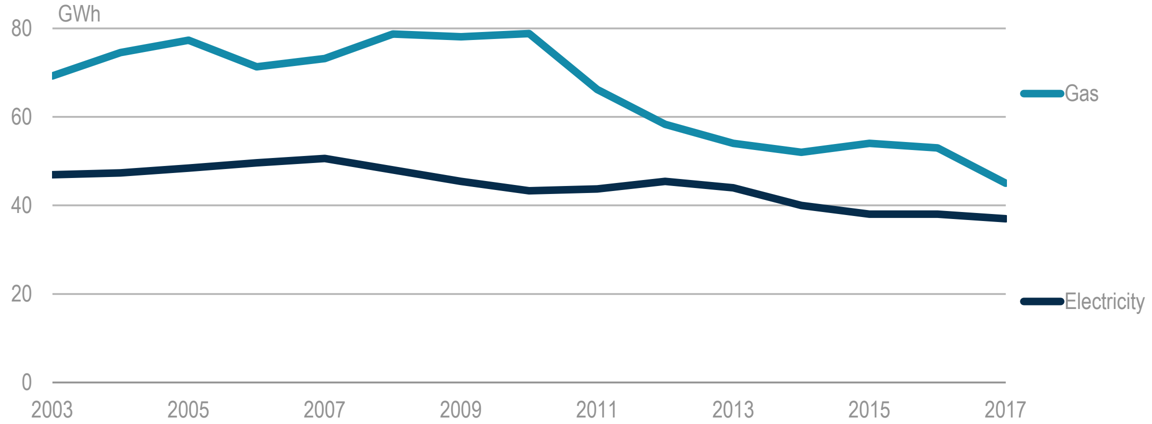
Figure 14 • Energy management structure at Novartis Ringaskiddy plant



Source: Adapted from Kelleher (2017), *EnMS and Digital Technologies for Energy Efficiency and Productivity at Novartis*, https://www.iea.org/media/topics/energyefficiency/industry/7.Novartis16.9.pdf.

As a result of the implementation of its energy management system, Novartis Ringaskiddy is continuing to reduce energy use and obtain economic and productivity benefits. From a peak in 2007, the plant's electricity use has reduced by 10% and following a peak in 2010, gas use has fallen by 43% (Figure 15). One of the major reasons for the sizeable reduction in gas consumption has been the capture of waste heat from the plant's incinerator for subsequent re-use for site heating. This opportunity was identified and implemented through the site's energy management system.

Figure 15 • Electricity and gas consumption at Novartis Ringaskiddy plant, 2003-17



Source: Adapted from Kelleher (2017), *EnMS and Digital Technologies for Energy Efficiency and Productivity at Novartis*, https://www.iea.org/media/topics/energyefficiency/industry/7.Novartis16.9.pdf.

Asia and Pacific

Energy management programmes within the Asia and Pacific region vary across countries. In this section, we provide examples for China, Australia, Korea and Indonesia.

China

China uses a regulatory measure in the form of the Top 10 000 Programme to drive uptake of energy management systems. This Programme sets mandatory energy intensity improvement targets for industry sectors, which are passed down to regional and local levels. The requirement to implement an energy management system is included in the Top 10 000 Programme. Instead of ISO 50001, the Top 10 000 Program requires energy management systems to be certified compliant with the Chinese national energy management standard (GB/T 23331). By the end of 2017, there were around 2500 GB/T 23331 certifications, a 25% increase in levels since 2016.[4] Nevertheless, ISO 50001 certifications are also growing: by the end of 2016, ISO 50001 certifications in China exceeded 1000, which quadrupled the amount recorded at the end of 2015 (ISO, 2017).

The impact of the Top 10 000 Programme has been substantial. As Chinese industry is the largest component of global industrial energy use, changes in efficiency are reflected in regional and global trends. As highlighted in Figure 1, the implementation of the Top 1 000 Programme in 2006, which transitioned to the Top 10 000 Programme in 2011, led to a divergence in trends for industrial energy use and gross value added and a noticeable improvement in energy intensity.

Australia

Between 2006 and 2014, Australia implemented a mandatory energy management programme – the Energy Efficiency Opportunities (EEO) Programme (Box 3). The EEO Programme pre-dated the introduction of the ISO 50001 standard in 2011 but encompassed similar requirements and reflected many of the same core principles as ISO 50001.

[4] China National Institute for Standardization, personal communication.

Box 3 • Australia's Energy Efficiency Opportunities (EEO) Program

The Energy Efficiency Opportunities (EEO) Program was a mandatory energy management programme enacted in Australia between 2006 and 2014. The EEO Program was mandatory for companies with annual energy consumption over 0.5 PJ and required the implementation of an energy management system in accordance with six key elements:

- **Leadership:** Obtaining explicit endorsement of senior management for energy efficiency objectives.
- **People:** Engaging people with the necessary expertise to implement energy management and achieve efficiency objectives.
- **Information data and analysis:** Gathering detailed energy use and activity data to analyse how energy is used, transformed or wasted.
- **Opportunity identification and evaluation:** Drawing on the outcomes of analysis to identify and evaluate opportunities to improve energy efficiency.
- **Decision making:** Establishing an appropriate system to determine the business response to identified energy efficiency opportunities.
- **Communicating outcomes:** Communicating the business response to the efficiency opportunities identified to the public, government and internally.

The EEO Program started before the introduction of the ISO 50001 standard, but the requirements placed on companies reflected many of the standard's core principles. Companies from the industrial, commercial and transport sectors participated in the EEO Program though a five year assessment cycle, in which they were required to apply the six key program elements to at least 80% of corporate energy use. Companies were actively supported through capacity building resources, information workshops and dedicated points of contact within the Australian government.

The 174 companies that completed the first EEO Program assessment cycle (2006 to 2011) adopted energy savings of nearly 89 PJ, equivalent to 3% of Australia's total final energy use and saved over AUD 3.5 billion (Table 5). At the end of their first cycle, these companies represented over half of all companies participating in the EEO Program. The remaining companies were still in the process of completing their first assessment cycle.

The EEO Program also provided valuable insight to the way in which industry approached energy efficiency, in particular the preference for implementation of opportunities with short payback times, which represented over two-thirds of the efficiency measures implemented.

Table 3 • Results for 174 companies that completed the first EEO Program assessment cycle, 2006-11

Cumulative energy savings	Cumulative emissions reductions	Cumulative costs of program administration	Cumulative private sector implementation costs	Cumulative private sector savings	Financial benefit to cost ratio
88.8 PJ	26.4 $MtCO_2$-eq	AUD 19 million	AUD 914.5 million	AUD 3.53 billion	3.67

Source: Acil Allen (2013), *Energy Efficiency Opportunities Program Review*, http://www.acilallen.com.au/cms_files/ACIL_EnergyEfficiencyOpportunies_2013.pdf.

Korea

The motivation for energy management within Korea is strongly linked to the country's continued reliance on energy imports. In its second Energy Master Plan, the Korean government made a commitment to reducing energy use by 13% by 2035 compared to a business-as-usual projection and improving energy intensity by 30% compared to levels in 2011. Improvements in the industry sector are critical to achieving these targets, with industry responsible for just under half of the energy savings required to meet the 2035 target.

Korean companies that use more than 2 000 toe of energy per year are required by law to periodically undertake an energy audit and identify actions to improve energy efficiency. However, it is recognised that increased uptake of energy management systems is important if the industry sector is to contribute to achieving Korea's national energy efficiency target. As businesses remain uncertain about the benefit and cost trade-offs associated with implementing energy management systems, including the added value of ISO 50001 certification, the Korean government has implemented measures to encourage and support industry to adopt energy management systems. Specifically, Article 28-2 of Korea's Energy Use Rationalization Act states:

> The Minister of Trade, Industry and Energy shall encourage energy users or energy suppliers to introduce company-wide energy management systems for enhancement of energy efficiency, and may provide support to any person who introduces such.

In response to this, the Korean Energy Agency (KEA) introduced the Superior-EnMS (S-EnMS) Programme, which was modelled on the US SEP Program. As part of S-EnMS, energy-intensive companies voluntarily sign a memorandum of understanding with KEA to participate in the Programme. As part of the programme, KEA provides training twice a year to each of the participating company's sites and the company is also exempt from Korea's mandatory energy audit obligation. Companies are awarded S-EnMS certificates depending on the magnitude of energy performance improvement, the period over which the achievement has been made, and whether or not the company has obtained ISO 50001 certification (Table 6).

Table 4 • Achievement periods and performance improvements required for certification under Korea's Superior-EnMS Programme

Achievement period	Energy performance improvement	
	Non-ISO 50001 certified	ISO 50001 certified
1 to 3 years	Over 3%	Over 2%
4 years	Over 4%	Over 3%
5 years	Over 5%	Over 4%

Source: Shim (2017), *EnMS Program in Korea*, https://www.iea.org/media/topics/energyefficiency/industry/2.EnMSProgramInKoreaNew_169.pdf.

To date, memorandums of understanding have been signed with energy-intensive companies covering 35 sites, representing around 4% of Korean industrial energy use. Of these sites, 18 have obtained S-EnMS certification achieving total annual energy savings of over 5.2 PJ, with an average annual energy performance improvement rate of 4.6% (Table 7). The work of Korean companies in implementing energy management has also been recognised through the awarding of a Clean Energy Ministerial (CEM) Energy Management Award of Excellence in 2016 to the LG Chemicals Ochang 1 Plant, which achieved an energy performance improvement rate of 9.4%.

The Korean government is also providing support for SMEs to implement an energy management system. This support involves a series of measures starting with consulting services about how to implement ISO 50001 and then financial support to install digital energy metering and monitoring equipment.

Table 5 • Results for S-EnMS certified sites, 2015-17

Site name	Year certified	Achievement period	Energy performance improvement rate	Energy savings (GJ)
LG Electronics, Inc. LG Digital Park	2017	2 years	5.4%	51 489
LG Electronics, Inc, Cheongju Plant	2017	1 year	3.9%	14 660
LG Electronics, Inc. R&D Campus Gasan	2017	1 year	4.8%	14 386
Kangwonland, Inc.	2017	1 year	3.6%	33 137
SUNGSHIN CEMENT Co., Ltd. Danyang Plant	2017	3 years	2.2%	627 725
Maeil Dairies Co.,Ltd. Pyeongtaek Plant	2017	1 year	4.0%	31 657
LG Display Co., Ltd Paju Display Cluster	2017	1 year	3.2%	1 180 412
LG Innotek Gumi 1/1A Plant	2017	3 years	4.8%	64 476
SHINSUNG DELTA TECH CO. Changwon Plant	2017	1 year	5.5%	5 183
LG Chem Inc. Gimcheon Plant	2016	1 year	3.5%	27 067
LG Chem Inc. Daesan Plant	2016	1 year	4.9%	2 079 919
LG Chem Inc. Yeosu SM Plant	2016	2 years	7.5%	302 449
LG Chem Inc. Ulsan Plant	2016	1 year	5.3%	16 312
LG Chem Inc. Cheongju Plant	2016	1 year	4.0%	80 438
LG Chem Inc. Naju Plant	2015	1 year	4.3%	95 015
LG Chem Inc. Ochang 1 Plant	2015	1 year	9.4%	575 258
LG Electronics, Inc, Changwon 1 Plant	2015	1 year	3.0%	31 730
3M Korea Ltd. Naju Plant	2015	1 year	3.2%	18 422

Source: Shim (2017), *EnMS Program in Korea*, https://www.iea.org/media/topics/energyefficiency/industry/2.EnMSPrograminKoreaNew_169.pdf.

In 2017, the Korean government also piloted an Energy Champion Program. This involved KEA signing a memorandum of understanding with 21 energy-intensive companies, covering 27 sites. This was then followed by a benchmarking exercise, in which the energy performance of the companies was compared to that in other countries including the United States, Japan and Germany, to determine whether the rate of energy performance improvement was above average. If the company was deemed to have performance above average it was subsequently designated as an “Energy Champion of the Republic of Korea”, with the designation publicised through national media.

Indonesia

The Indonesian government is seeking to increase the rate of energy management adoption through the implementation of Government Regulation Number 70/2009. Under this regulation, a facility with an annual energy consumption that exceeds 6000 tonnes of oil equivalent (toe) is required to implement energy management practices, including:

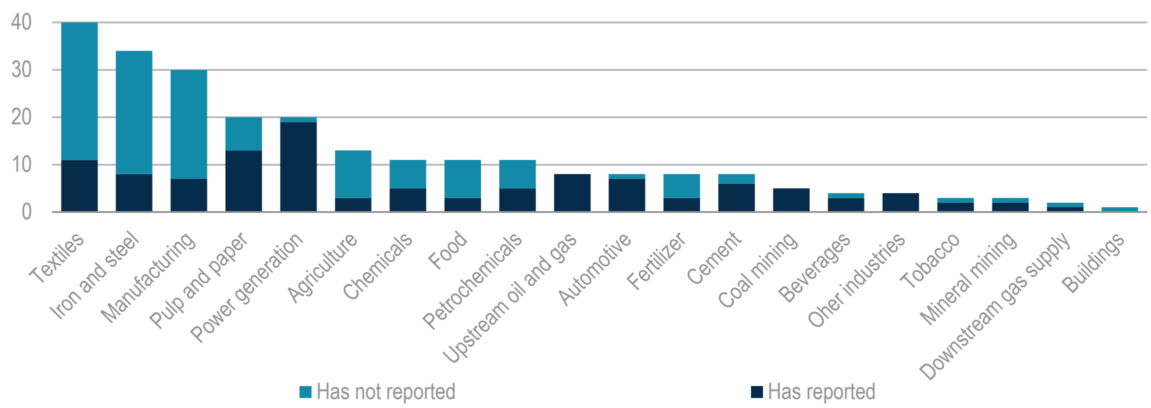
- Appointing an energy manager;
- Developing an ‘Energy Conservation Program’;

- Periodically conducting an energy audit;
- Implementing the recommendations from that energy audit; and
- Periodically submitting an implementation report to the government.

To guide this process, Indonesia has adopted ISO 50001 as its national energy management standard (SNI ISO 50001), which has subsequently been adopted as the national personnel competence standard for an energy manager. This means that ISO 50001 principles will be embedded in the skills of energy managers appointed by large energy using corporations increasing the prospects for certification. ISO 50002, the international standard that specifies the principles, requirements and deliverables for energy audits, has also been adopted as the Indonesian national standard. The Ministry of Energy and Mineral Resources has set a target of certifying 1000 energy managers and 700 energy auditors by 2020, and is promoting energy conservation, including energy management, to engineering professionals and students.

A total of 244 companies have been identified as using more than 6000 toe per year, meaning that they are required to comply with the obligations of the government regulation. However, by 2016 less than half of the identified companies had completed an implementation report to the government (Figure 16). Despite this lag in participation, it has been proposed that the energy use threshold for compliance with the regulation be lowered. Such a push to expand the coverage of the regulation would not only increase the number of companies captured, but also increase the regulation's potential impact.

Figure 16 • Compliance rates for industrial sub-sectors with Indonesia's government regulation 70/2009, 2016



Source: Adapted from Directorate-General of New Renewable Energy and Energy Conservation (2016), *Energy Conservation 2017 Data & Information*.

Other regions and developing economies

The United Nations industrial Development Organization (UNIDO) is also working with industry and governments in emerging economies to implement energy management systems in line with ISO 50001. UNIDO's work with energy management commenced prior to the launch of the ISO 50001 standard, with the organisation's project on promotion of international energy management system standards starting in 2007. In late 2008, UNIDO commenced the development and implementation of its energy management system portfolio, characterised by Industrial Energy Efficiency (IEE) Projects in developing and emerging economies. UNIDO drew on its experience in working with industry and with the implementation of energy management systems to contribute to the development of ISO 50001 through the work of the ISO Project Committee 242 – Energy Management.[5]

UNIDO's global energy management systems and energy systems optimisation programme is now operational in 18 countries including South Africa, Russia, Turkey, Indonesia and India, with activities planned in over ten countries including China, Brazil and Mexico. A typical IEE Project implemented by UNIDO includes:

- Policy support to develop government programmes to promote industrial energy efficiency and energy management.
- Assistance for national campaigns to promote energy management and increase skills and services availability through training and qualification of experts and enterprises' personnel.
- Implementation within industry, usually with a target of 15 or more medium or large companies implementing an energy management system and as many low- or no-cost efficiency measures as possible (between 4 to 20 measures per company per year have been reported by partner companies).
- Development of mechanisms to mobilise available finance for industrial energy efficiency within the country, including capacity building for banks and other investors on industrial energy efficiency investment.

By the end of 2016, UNIDO's Energy Management System (EnMS) Programme had reached over 6 000 decision makers, trained more than 2 000 enterprises and over 600 consultants, resulting in the implementation of energy management systems in over 400 enterprises and cumulative direct final energy savings of over 7 000 GWh. These energy savings are estimated to be equivalent to the annual energy consumption of over 1.1 million European households and in 2015 the financial benefits accruing to companies exceeded USD 100 million, without considering non-energy benefits (Matteini, 2017).

An example of the outcomes from an IEE Project across government and industrial firms is the Former Yugoslav Republic of Macedonia (hereafter "Macedonia"). Starting in 2015, the Macedonian pilot EnMS Programme obtained the participation of 12 partner enterprises and involved contributions from 23 national consultants and experts. After the first year of the EnMS Programme, 13.2 GWh of energy savings had been achieved, resulting in over USD 850 000 in financial savings. The majority of these measures were implemented at no cost and by the fifth year of the project, energy savings are estimated to reach 165 GWh, compared to a scenario without an energy management system, for nearly USD 10.8 million of financial savings.

The project also involves work with the Macedonian government to develop programmes and measures aimed at improving industrial energy efficiency, increasing the adoption of energy management systems and recognising good energy performance (Figure 17).

An example of the company level benefits obtained through the IEE Project in Macedonia is Mining and Energy Combine (REK) Bitola, which meets about 70% of Macedonia's demand for electricity. The focus for the company's implementation of energy management, which was initiated in 2016, was its 700 MW brown coal fired power plant. In 2016 the plant's electrical output was 2 685 GWh, with the plant's own consumption around 286.2 GWh.

The implementation of an energy management system within REK Bitola's power generation facilities has resulted in energy savings equivalent to 3% of the plant's own consumption, financial savings of EUR 322 000 and emissions reductions of just over 10 500 tonnes of CO_2. If REK Bitola had paid for the training and technical assistance provided by UNIDO, the payback time for the measures would be less than 1 month. Following the successful implementation of

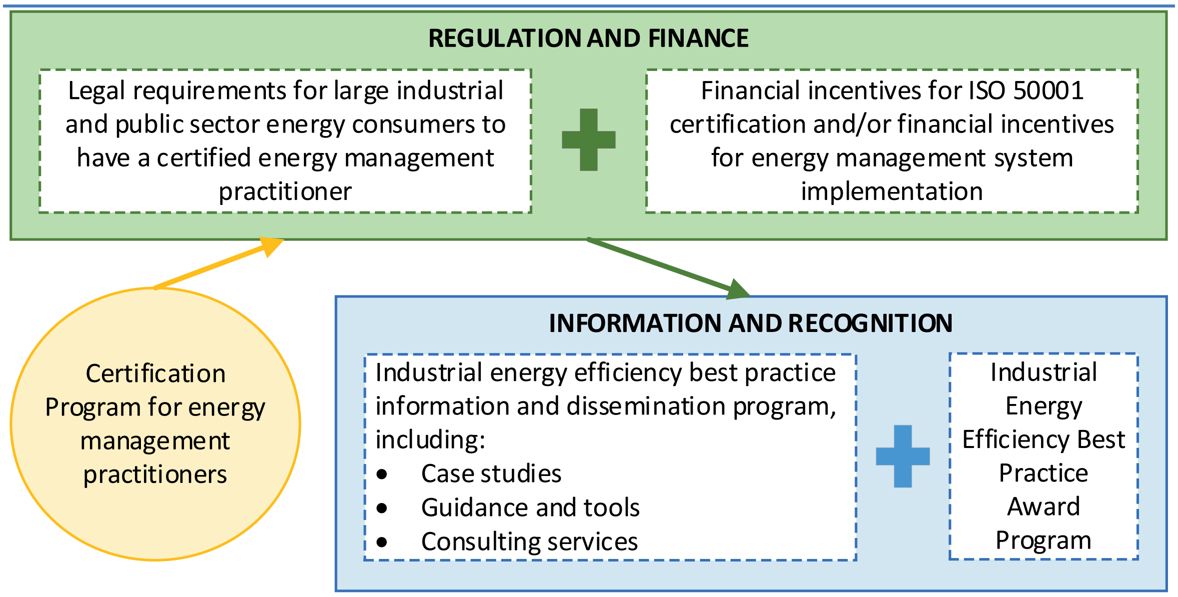
[5] Now referred to as ISO Technical Committee 301 – Energy Management and Energy Savings

an energy management system within REK Bitola's power generation operations, the company expanded its work to cover also its mining operations.

The savings achieved by REK Bitola not only exceeded targets set by the company, but also the calculated savings of the four, no-cost, energy efficiency projects planned and implemented through its energy management system (Figure 18). In 2016, the implemented projects delivered just over 6 000 MWh of energy savings. However, total savings were observed at just under 8 400 MWh. This represented nearly 40% (over 2 300 MWh) of savings additional to implemented projects that resulted from the combination of: improved staff awareness of energy efficiency, greater competencies for energy management, changes in daily routine operations like maintenance, procurement and production planning; systematic monitoring of and staff accountability for energy performance; and other factors.

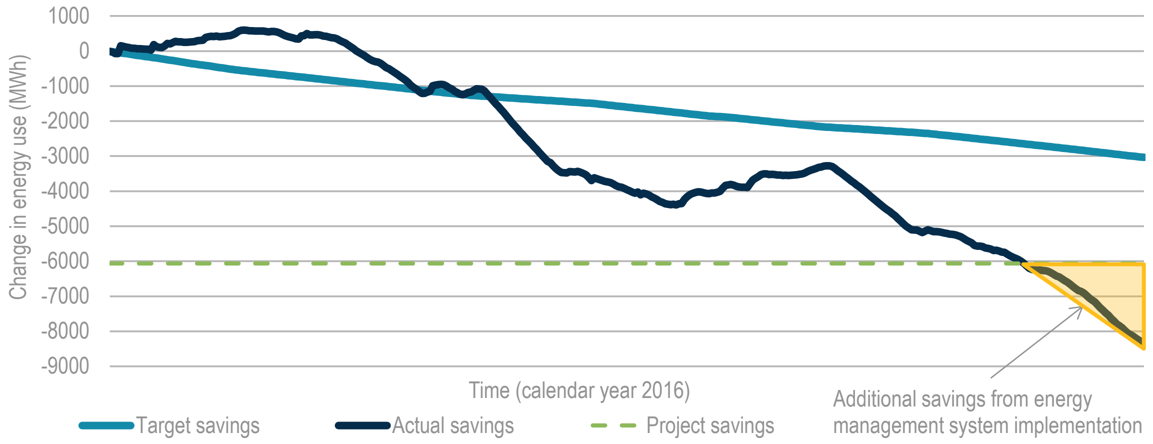
In the companies that UNIDO partners with to implement energy management systems, the share of total annual energy savings that are not attributed to specific energy efficiency projects ranges between 20 and 50 per cent. This represents an additional and unique benefit that energy management systems can provide to industrial energy-users.

Figure 17 • Government measures and programmes promoted by UNIDO in Macedonian IEE Project



Source: Adapted from Matteini (2017), *Overview of impact of EnMS in emerging economies and developing countries, including companies examples*, https://www.iea.org/media/topics/energyefficiency/industry/4.UNIDO16912DEC.pdf.

Figure 18 • Targeted and actual savings from energy efficiency measures implemented at REK Bitola, 2016



Source: Adapted from Matteini (2017), *Overview of impact of EnMS in emerging economies and developing countries, including companies examples*, https://www.iea.org/media/topics/energyefficiency/industry/4.UNIDO16912DEC.pdf.

Emerging economy case study: South Africa

In South Africa, industry represents a significant proportion of the country's total final energy use – 40%, the largest of any economic sector – and implementation of energy management systems have had a substantial impact on the efficiency of South African companies. One of the major motivations for improving energy efficiency within South Africa's industry sector was the country's electricity crisis. Beginning in 2008, the electricity tariff charged by Eskom, which generates about 95% of the electricity used in South Africa, increased markedly; South African electricity consumers experienced a 300% increase in electricity tariffs between 2007 and 2015.

The regulatory landscape, which gave rise to the South African governments' pursuit of greater levels of energy management within the industry sector, included:

- National Climate Change Response Strategy
- National Energy Act Number 34 of 2008
- Income tax amendments, which provide tax incentives for energy efficiency equipment and associated savings and are estimated to result in annual energy savings of 1.5 TWh
- National Energy Efficiency Strategy, 2005-15 and 2016-30.

To implement the actions required to increase the levels of industrial energy efficiency, the South African government began an Industrial Energy Efficiency (IEE) Project in collaboration with UNIDO. The objective of the IEE Project was to mainstream energy management systems, energy systems optimisation and ISO 50001, in order to increase industrial energy efficiency. The IEE Project involved: support and guidance in policy development; promotion of energy management standards; capacity building and demonstration; and awareness raising.

The IEE Project gained the engagement of 45 companies across various sub-sectors, with the largest number of companies from the iron and steel sector and 23 of the participants classified as large companies. Evaluation of the IEE Project between 2010 and 2015 identified the following key outcomes:

- 3 200 industry stakeholders trained, including 40 lead energy auditors, 156 experts and 53 national trainers in energy management and energy systems optimisation.
- 70 case studies published highlighting the benefits from the implementation of an energy management system.

- Publication of key energy efficiency policy documents including the second National Energy Efficiency Strategy and the steel sector energy baseline study.
- 22 industrial plants obtaining ISO 50001 certification of which 18 were supported by the IEE Project.

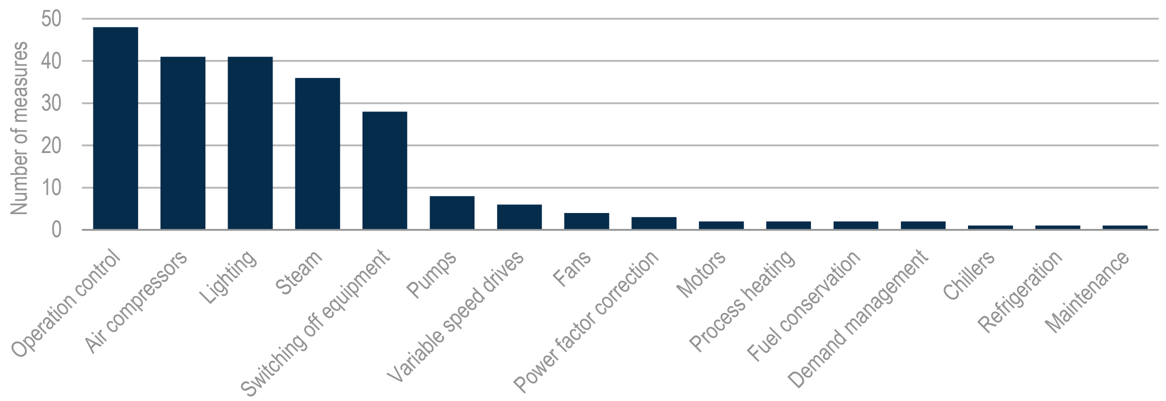
As of 2017, efficiency measures implemented under the IEE Project had resulted in 3.8 TWh of energy savings, emissions reductions of 3.7 $MtCO_2$-eq and financial savings of ZAR 3.1 billion. Over 220 energy efficiency measures were implemented as part of the IEE Project, with low cost measures relating to changes in operational control, compressors, lighting and steam systems the most common measures implemented (Figure 19).

In addition to the energy savings and related financial benefits, there were other qualitative outcomes from the IEE Project including:

- Fostering the growth of a viable energy services sector in South Africa.
- Pioneering a change in focus from component to overall systems optimisation.
- Promoting dialogue within industry sectors, supply chains and technology and equipment providers.
- Elevating the importance of achieving behaviour change in driving and sustaining efficiency gains within industry.
- Creating conditions for similar collaborative programs between international organisations and the South African government and industry sector.

Two notable case examples from the IEE Project included an integrated steel mill operated by ArcelorMittal and an assembly plant operated by Toyota South Africa (Box 4).

Figure 19 • Breakdown of industrial energy efficiency measures implemented by companies participating in the South African IEE Project, 2011-17



Source: Adapted from Hartzenburg (2017), *Energy Management Systems and Programmes in South Africa Industrial Energy Efficiency Project*, https://www.iea.org/media/topics/energyefficiency/industry/4.SouthAfrica_IEA_Paris_131217.pdf.

Box 4 • Energy management systems at Arcelormittal and Toyota South Africa

ArcelorMittal were one of the first companies to participate in the IEE Project and before joining, the company's Saldanha works were nearing closure due to poor performance. As a result of participation in the IEE Project, the plant implemented an energy management system following critical support from the plant's director and strong leadership from the site's energy manager.

Working with UNIDO and the South African government, the plant implemented innovative training and communication measures to secure the commitment of employees for energy management, leading to enhanced collaboration. Implementation of the energy management system lead to the implementation of opportunities including fuel switching and optimising existing process controls, leading to significant energy savings (Table 8). The cost savings and performance improvements generated from the implementation of energy management contributed to a reversal of the plant's performance, as a result the Saldanha works were saved from closure.

Another notable case study from the IEE Project in South Africa was the Toyota Automotive Assembly plant in Durban. In 2010, it was rated as the worst Toyota plant in the world in terms of GJ per unit produced. The plant became one of the first participants in the IEE Project and worked to obtain necessary internal engagement to implement an energy management system. The rigorous and structured approach to energy management coupled with the plant's previous poor performance led to the implementation of a large number of measures to improve energy efficiency, which collectively had a very short payback time (Table 8). As a result of the measures implemented, the plant's performance improved so markedly that within one year it moved from being the worst performing Toyota plant globally, to one of the top three.

Table 6 • Results from implementation of energy management systems at ArcelorMittal and Toyota South Africa

Metric	ArcelorMittal Saldanha Works (2011)	Toyota South Africa (2010-13)
Number of projects / measures implemented	11	73
Total capital investment	EUR 31 250	EUR 5.2 million
Gross financial savings	EUR 3.75 million	EUR 9.1 million
Overall payback period	2.4 months	0.6 years
Annual energy savings (GWh)	80 GWh	15.6 GWh (15% of total consumption)
GHG reductions (tonnes CO_2)	77 000	13 058 (in 2011)

Source: Hartzenburg (2017), *Energy Management Systems and Programmes in South Africa Industrial Energy Efficiency Project*, https://www.iea.org/media/topics/energyefficiency/industry/4.SouthAfrica_IEA_Paris_131217.pdf.

Digital technology for industrial energy efficiency

Digitalisation has been influencing productivity and safety within the industry sector for a long time. As shown in Figure 4, investment in digital technologies to improve industrial process control rose rapidly during the mid-to-late 1990s as a result of the increased capability and reduced cost of digital metering, monitoring and control systems. Ongoing technology development and cost declines are enhancing the ability of industry to collect more detailed and accurate performance data in real time, and analyse this data leading to improvements in energy efficiency.

Government policy and support measures

Support measures aimed at increasing the adoption of digital technologies within the industry sector include the provision of financial support to companies to cover the cost of purchasing and installing more advanced metering and monitoring equipment. One example is Korea, where the recently launched support program for the implementation of energy management systems within SMEs includes financial assistance to purchase digital energy metering equipment and monitoring systems. Such measures improve a company's understanding of its energy use and the influencing factors, allowing for more detailed analysis of key trends and energy efficiency.

A key analytical approach required for the effective implementation of an energy management system is regression analysis, which requires energy use, production and other contextual data to identify the factors that influence energy use and the impact of potential efficiency measures. Digital metering equipment allows for the enhanced collection of necessary data, but depending on the monitoring and analytical systems within the organisation, regression analysis to the level of detail required for an effective energy management system may not be possible. It is for this reason that governments including the United States, Canada and Korea, provide online regression analysis tools, which are particularly targeted at SMEs with less analytical capabilities and resources.

At a broader level, governments are developing strategies to increase the preparedness of companies and individuals for digitalisation. An example of such a strategy was presented by Sweden at the IEA Workshop, whose digital strategy is structured on the following principles (Björkman, 2017):

- **Skills:** Everyone in Sweden will be able to develop and use their digital skills.
- **Security:** Sweden will provide the best conditions for securely taking part in, taking responsibility for and building trust in the digital society.
- **Innovation:** Sweden will provide the best conditions to ensure that digitally driven innovations are developed, disseminated and used.
- **Leadership:** In Sweden, the digital transformation will promote relevant, targeted and legally sound efficiency improvements.
- **Infrastructure:** All of Sweden should have access to infrastructure that provides high-speed broadband and reliable mobile services, and that supports the digital transformation.

From an industry perspective, Sweden's digital strategy also includes ambitions for companies to lead the digital transformation and exploit the potential of digitalisation.

Another example of a government initiative being implemented to support technology innovation comes from the United States. The US DOE works with other federal government departments through the Manufacturing USA Initiative to support the development and uptake of digital technologies within industry (Box 5).

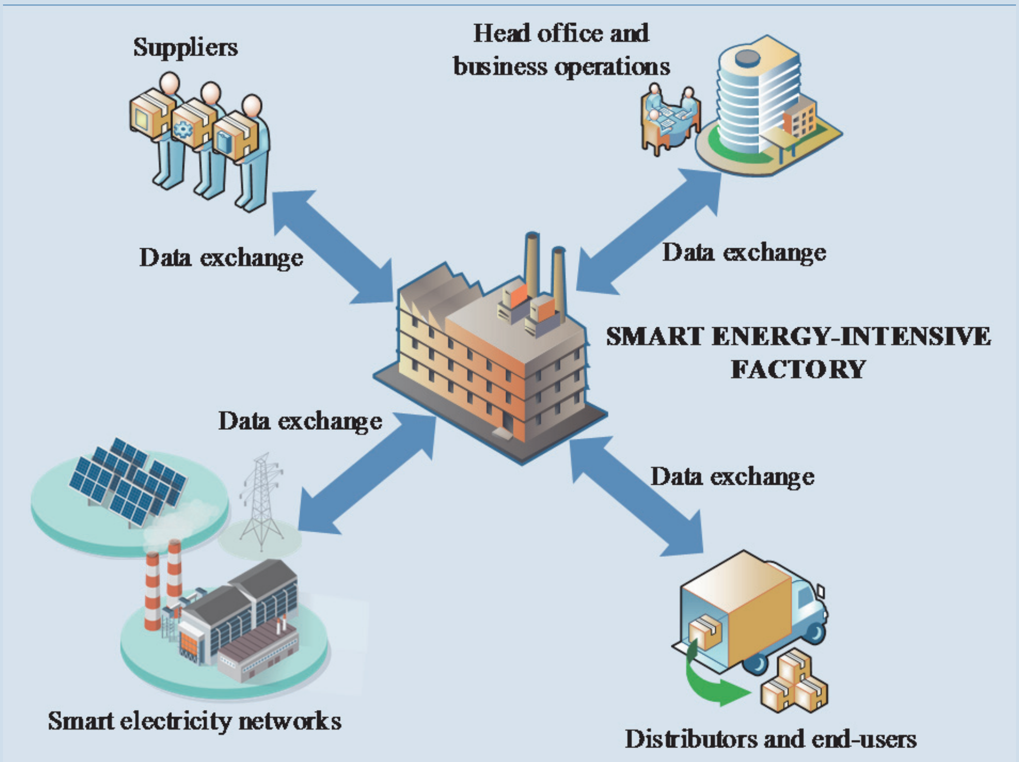
Box 5 • Manufacturing USA and the Clean Energy Smart Manufacturing Innovation Institute

Manufacturing USA was formally established in 2014 to bring together industry, academia and federal government partners, including the US DOE, to increase manufacturing competitiveness and research and development infrastructure. The Programme supports manufacturing institutes, each concentrating on a specific technology. The ninth institute established was the Clean Energy Smart Manufacturing Innovation Institute (CESMII). The main focus of CESMII is to address the research and development challenges and to identify knowledge gaps for Smart Manufacturing.

CESMII defines Smart Manufacturing as the process of securely integrating manufacturing systems with information, communication, and computation technologies. This is achieved through the integration of data collected by multiple sensors and meters with advanced analytics to allow for on-time and real-time prediction and control of industrial processes. CESMII's work includes development and deployment of advanced sensors and controls allowing for real-time process control and energy management, as well as greater connectivity between an industrial plant and supply chains, distributors, end-users, business operations and, from an energy perspective, the electricity market (Figure 20).

The ultimate goal of CESMII is to create research breakthroughs that contribute to doubling energy productivity gains in US manufacturing in 10 years. CESMII also seeks to decrease Smart Manufacturing technology costs and increase workforce capacity in the US five-fold by 2030.

Figure 20 • Principles of smart manufacturing with a specific focus on energy



Sources: Adapted from Clean Energy Smart Manufacturing Innovation Institute (2018), *What is Smart Manufacturing,* https://www.cesmii.org/what-is-smart-manufacturing; US DOE (personal communication 15 March 2018).

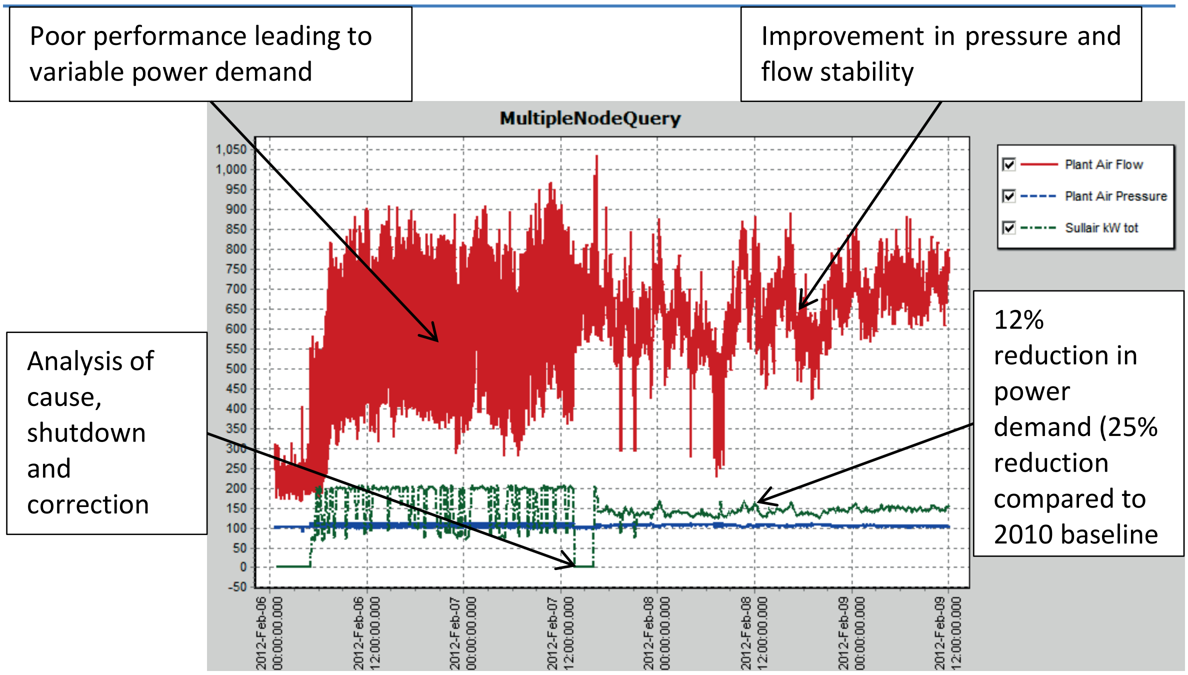
Company-level benefits

Digital technologies are enhancing the efficiency outcomes achieved by companies following the implementation of an energy management system. As discussed in earlier sections, 3M Canada views digital technology – in the form of advanced metering and sub-metering equipment – as a key enabler of the company's energy management strategy. The analytic processes enabled through enhanced metering technology allows the company to develop more accurate energy use baselines and consumption targets, which can be normalised against other production or environmental variables, such as product specifications or weather conditions.

The coupling of these advanced metering systems with process monitoring and control software allows operating personnel to identify, in real-time, key factors impacting energy use and efficiency. An example of this is the identification and remedy of issues relating to the operation of a spiral valve, which regulates output from an air compressor system in one of 3M Canada's plants (Figure 21). Due to presence of sub-metering and digital control systems, operational personnel at 3M were able to identify a performance issue creating variable power demand and reducing efficiency. Analysis of the issue and the subsequent corrective measures led to a readily-verified 12% reduction in power demand.

The value of accurate and comprehensive metering has been recognised by 3M both in Canada and globally. The company has a requirement that all projects must have sub-metering in order to be eligible for approval and funding. This ensures that the performance of new equipment can be monitored and tracked from the start of operation, reducing the likelihood of extended performance issues and poor performance.

Figure 21 • Air compression "Spiral Valve" optimisation at 3M



Source: Adapted from Hejnar (2017), *Energy Management 3M Canada*, https://www.iea.org/media/topics/energyefficiency/industry/8.3M.pdf.

Energy management at the Novartis Ringaskiddy plant is facilitated via a comprehensive digital energy metering and monitoring system, along with automated analysis and tracking of key performance indicators. As described in Figure 14, this system informs the work of the energy management group and has led to faster identification and response to adverse energy consumption trends. In addition to process and equipment monitoring, Novartis also use metering and monitoring outputs to provide automated site reports (Figure 22). These reports track the energy performance of key site processes over the previous seven days and year to date, determining whether it is in line with corporate targets. Importantly, the site reports translate variances in energy use compared to targets into financial savings, or financial costs, providing a necessary input to the business case for any capital expenditure required to fix underperformance.

Figure 22 • Example of an automated site report at Novartis Ringaskiddy

SERVICE	TARGET	CONSUMPTION	SAVINGS			COST	AVERAGE
	last 7 days	last 7 days	%	YTD	last 7 days	last 7 days	last 7 days
CICLO: Thermal	4,923 kWh	5,309 kWh	-5.2%	-€ 775	€ 7	€ 284	32 kW
CICLO: Flow	3,412 m3	3,680 m3	-5.2%	-€ 107	€ 1	€ 39	22 m3/h
DIOVAN: Thermal	22,495 kWh	58,438 kWh	-34.7%	-€ 34,083	€ 1,857	€ 3,121	348 kW
DIOVAN: Flow	11,442 m3	13,472 m3	-12.3%	-€ 858	€ 15	€ 144	80 m3/h
PEPTIDES: Thermal	589 kWh	656 kWh	-20.9%	-€ 8,067	€ 0	€ 7	4 kW
PEPTIDES: Flow	5,753 m3	-1,558 m3	-23.9%	-€ 87	-€ 81	-€ 17	(9) m3/h
PB1: Thermal	77,231 kWh	136,339 kWh	14.8%	€ 24,074	€ 2,940	€ 7,282	812 kW
PB1: Flow	13,476 m3	7,588 m3	-15.3%	-€ 1,082	-€ 70	€ 81	45 m3/h
PB1A: Thermal	21,309 kWh	45,337 kWh	-10.0%	-€ 6,690	€ 1,223	€ 2,422	270 kW
PB1A: Flow	8,998 m3	10,037 m3	5.3%	€ 217	€ 6	€ 107	60 m3/h
TOTAL Thermal	126,547 kWh	246,080 kWh	**-6.7%**	**-€ 25,540**	**€ 6,027**	**€ 13,115**	
TOTAL Flow	43,083 m3	33,220 m3	**-9.3%**	**-€ 1,917**	**-€ 130**	**€ 355**	

Source: Kelleher (2017), *EnMS and Digital Technologies for Energy Efficiency and Productivity at Novartis*, https://www.iea.org/media/topics/energyefficiency/industry/7.Novartis16.9.pdf.

Digital innovation and planning at Arçelik

Another company embracing the benefits from digitalisation is Turkish consumer goods manufacturer Arçelik. An ISO 50001 certified company, Arçelik has implemented a comprehensive energy management strategy, with targets for 2020 relating to efficiency and renewable energy, specifically:

- A 45% reduction in energy consumption per product manufactured, compared to a 2010 baseline. By 2016, a 34% reduction had already been achieved.
- Establish a renewable power plant with a total capacity of 6 MW.
- Increase the amount of electricity consumed from renewable resources to 100%. By 2016, 88% of electricity consumed was generated from renewable sources.

Digital technology will be a key factor for Arçelik to achieve its goals. Digital technology is currently used at Arçelik for energy metering, monitoring, process automation and control, but the company is seeking to increase the level of connectivity between these functions to achieve greater outcomes.

To drive the company's digital transformation, Arçelik has implemented three key projects. The first is the company's *TechPro Academy*, which was established to allow experts from outside Arçelik to provide training to employees on topics including data analytics and visualisation, network and data security, machine learning, modelling and smart production systems.

Developing these skills will enable Arçelik to build its internal capabilities with digital technology, improving ownership and outcomes.

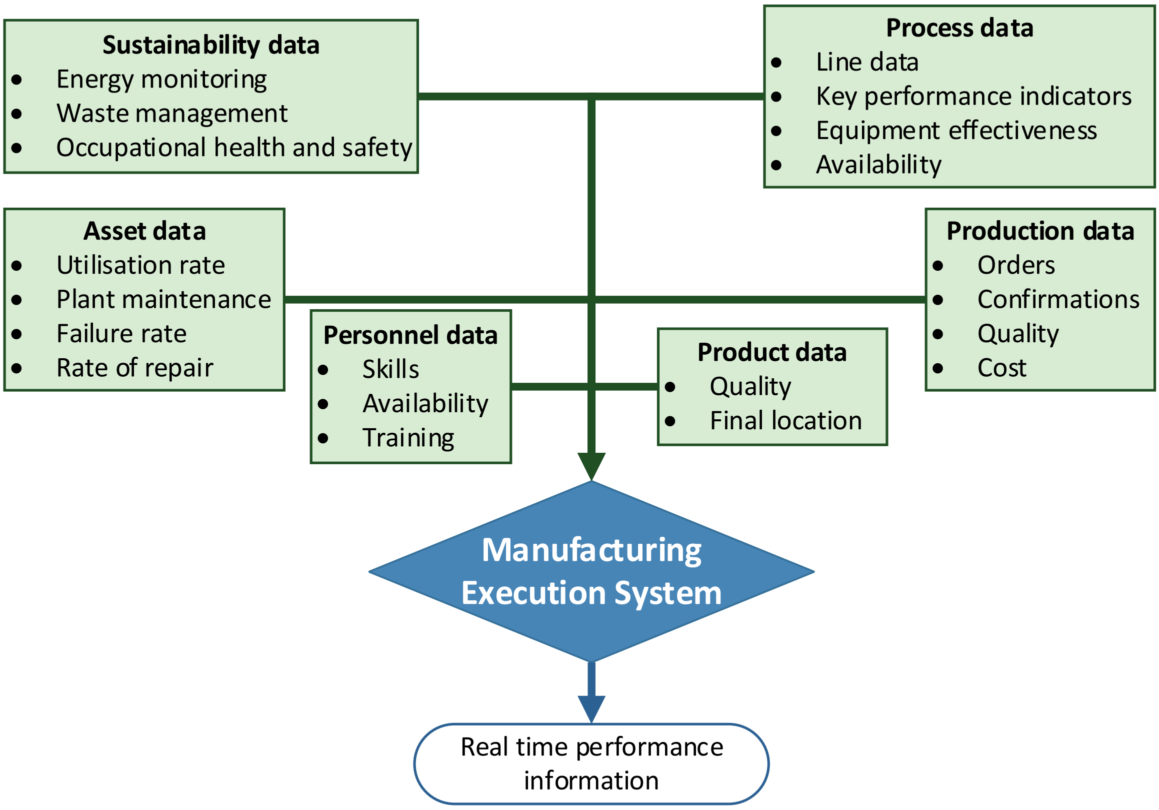
Arçelik's second key measure is its digital factory (Atölye 4.0) in Istanbul, Turkey. The factory provides a workshop for employees to develop an understanding of the integration of artificial intelligence and data science to the company's current processes. The factory also incorporates the use of digital twins, which, as discussed in more detail in a later section, enable advanced simulation of industrial equipment and processes to improve productivity and efficiency.

The third key measure implemented by the company is *Arçelik Garage*, which provides a space for research and development and sharing of ideas and concepts about using digital technology to improve production processes. *Arçelik Garage* includes the use of additive manufacturing technology (also known as 3D printing) to allow for concept testing and prototype design.

In addition to connecting key processes and equipment within individual factories, Arçelik is also planning to increase connectivity between its factories across the world. This process will commence with the construction of the company's new digital factory in 2018 in Romania, which will be fully connected in accordance with standards established by Arçelik. The lessons learned by Arçelik in running this digital factory will be shared with factories in other parts of the world, with the ultimate aim that the enhanced connectivity will allow efficiency and productivity improvements made at one Arçelik plant to be promptly replicated at other facilities.

The central aspect of Arçelik's digital factory is its Manufacturing Execution System (Figure 23), which gathers information in real time from within the plant and broader market, to allow for a determination of system performance and of opportunities to improve efficiency.

Figure 23 • Manufacturing execution system at Arçelik digital factory



Source: Adapted from Kodaz (2017), *Arçelik A.Ş. Energy Management & Digitalisation*, https://www.iea.org/media/topics/energyefficiency/industry/9.arcelik.pdf.

The Manufacturing Execution System requires inputs from accurate and comprehensive digital metering equipment as well as connection to key control systems and broader market data in order to be fully effective. Such technology greatly enhances the ease with which Arçelik is able to implement energy management within its factory, based on four key components:

- Understanding the flow and consumption of energy within a factory.
- Determining the outputs from each key process and identifying excessive energy consumption and sources of inefficiency.
- Establishing the key performance indicators to track the improvement over time.
- Continuous improvement of plant efficiency and performance.

New innovations

The discernible presence of digital technology in the industrial sector is creating opportunities for innovations that obtain more value from existing equipment, leading to energy efficiency improvements. This is particularly the case for existing energy metering and monitoring equipment, which may not be connected or is producing data that are either inaccurate or not used in a sophisticated manner to drive efficiency gains (Box 6).

Box 6 • Improving outcomes from existing metering and monitoring equipment at one of Asia's largest textiles manufacturer

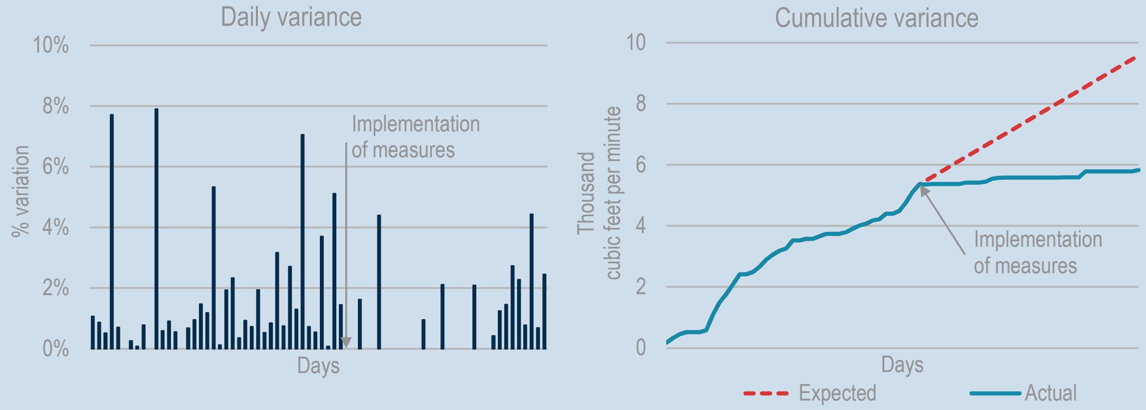
One of Asia's largest Terry Towel manufacturers had made a significant investment in metering and monitoring equipment for electricity, stream, compressed air and other production inputs. This equipment led to the identification of numerous low cost opportunities to improve energy efficiency. However, with many of these opportunities implemented, company management were interested in how to make better use of existing data collection assets and establish an unsupervised decision support system to generate greater efficiency savings.

Working with energy analytics start-up EnergyTech Ventures, the company implemented a series of measures to improve outcomes from existing systems, specifically:

- Different measurement assets were connected to allow all data to be collected and stored in a central repository.
- A central processing engine was deployed to analyse data collected in the central repository, report outcomes and identify actions to improve efficiency and performance.
- Energy performance indicators, as produced from the analysis, were integrated into an existing business intelligence tool to ensure ongoing tracking.

The implementation of this system led to the correction of over 70 meters, the performance of which had previously gone unnoticed, as well as other factors impacting key equipment. In particular, performance of the compressed air system, which produces around 70 000 cubic feet of compressed air per minute, was optimised leading to a reduction in performance variation across the day from around 5% to 2%, reducing unnecessary energy use (Figure 24). Leaks in the plant's steam and compressed air network were also identified along with the development of performance benchmarks for all air compressors within the plant's network.

Figure 24 • Variation in compressed air network performance before and after implementation of measures to improve performance of existing data collection and analysis systems



Source: EnergyTech Ventures (Personal communication 5 March 2018).

Digital twins

The work of General Electric (GE) on digital twins is another example of digital innovations affecting major energy using industries. A digital twin is a virtual/software-based representation of an industrial asset, equipment or system, which enables companies to understand, predict and optimise the performance of complex energy using assets. A digital twin requires three major components:

- **An asset model:** A description of the energy using equipment or system, including the structure of all sub-systems, sub-assemblies and components.
- **Analytics:** Drawing on the laws of physics, technical design knowledge, historical energy performance and contextual data, a physical model of the asset is developed. This then allows for detailed analysis to predict, describe and prescribe the operational behaviour of the asset, including its expected performance and remaining useful life.
- **A knowledge base:** A collection of insights about the industrial system including performance indicators, operational risks, failure modes, service and work order requests.

Each digital twin is unique to the asset or industrial system and the ability to leverage digital metering and monitoring equipment allows for real-time updates, leading to more accurate forecasts of future performance.

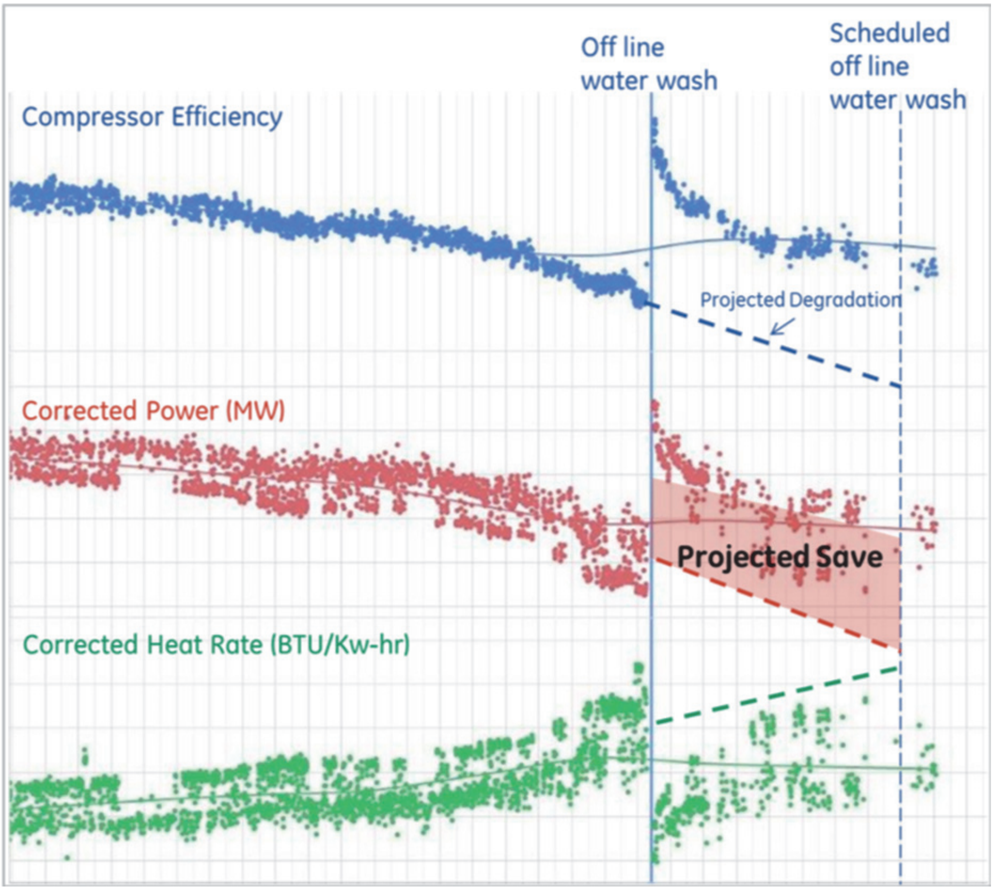
From an energy efficiency perspective, the key benefit of a digital twin is that it enables industrial companies and equipment operators to identify performance issues and take corrective action in a shorter time frame. Issues are identified when the performance of the industrial asset departs from that expected based on the analytics produced by the digital twin.

The ability for a digital twin to process and analyse performance data also results in plant operators and equipment experts spending less time collecting, sorting and analysing performance data and more time analysing performance trends and using their knowledge to implement corrective actions as necessary. The software-based nature of a digital twin also makes it easier for knowledge about operational issues and corrective actions to be collected and shared.

An example of the potential benefit from a digital twin is provided through a case study of a gas turbine. Like many other complex industrial systems, the performance of a gas turbine is influenced by numerous factors including weather conditions, operator settings and normal wear and tear. As a result, it can be difficult for plant operators to identify and correct performance issues.

In this case, a digital twin of a gas turbine was developed by GE to model performance of the system, drawing on a detailed thermodynamic model, historical performance and operating data. Combining this model with data about current operating conditions allowed the digital twin to produce a prediction of how the turbine should be performing, which was then compared to its current operation. As shown in Figure 25, the data produced by the digital twin allowed for the correct identification of accelerated wear of the turbine's compressor, leading to a recommendation that it be cleaned earlier than scheduled. This resulted in increased performance and subsequent revenue, which offset the cost of having the turbine offline for cleaning at an earlier point than originally planned.

Figure 25 • Example of digital twin identification of gas turbine performance issue and trigger for corrective action

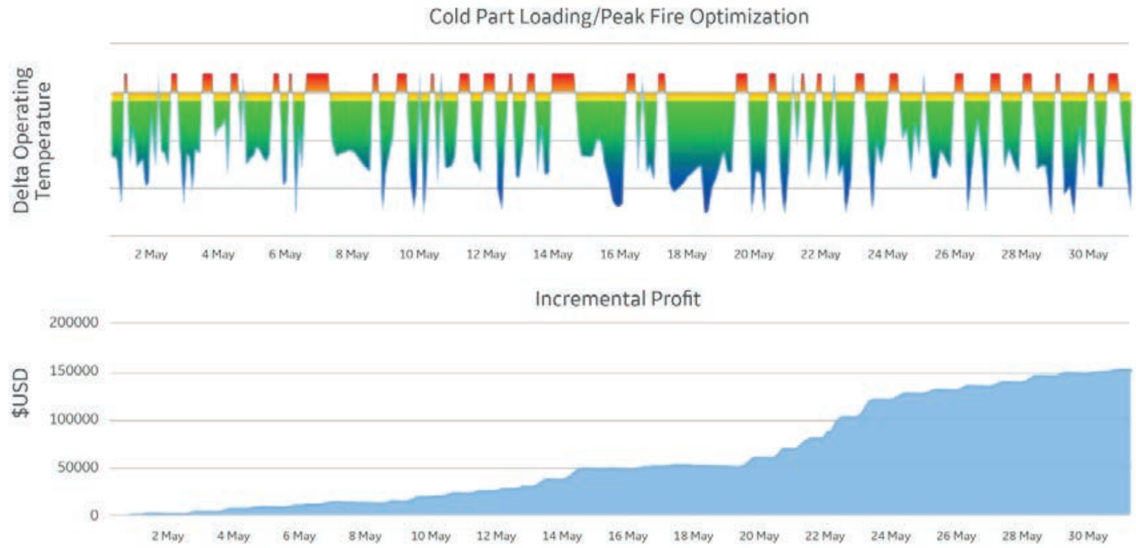


Source: © General Electric Company, 2018

The power of a digital twin is that it can be extended to sub-systems and specific components within an industrial asset. In the case of the gas turbine, a digital twin can be created for each individual turbine blade, drawing on information about the type of material from which the blade is manufactured. Blades in modern gas turbines are manufactured from advanced materials that can operate at high temperatures to deliver higher levels of efficiency and power. However, increasing the operating temperature reduces the life of the blades leading to shorter maintenance intervals and higher operating costs.

The information contained in the digital twin about blade performance can also be combined with real time electricity price and fuel cost data. This allows turbine operation to be adjusted and blade operating temperature increased such that more power is delivered when it is economically beneficial to do so, specifically when electricity prices are higher, and reduce power output at other times to sustain maintenance intervals and operating costs. One example for this application of a digital twin from GE is for a large combined cycle gas turbine, which resulted in cumulative profit of USD 150 000 after just one month of operation (Figure 26).

Figure 26 • Optimisation of gas turbine operating temperature (top) and incremental profit obtained from the application of a digital twin (bottom)



Source: © General Electric Company, 2018

Challenges and opportunities for energy management systems and digital technology

Despite the positive results obtained within the industry sector through implementation of energy management systems and digital technologies, there remain several challenges that policy makers, industry and technology providers need to overcome in order to unlock greater efficiency gains. These challenges and potential future opportunities were discussed at the IEA Workshop, drawing on the experiences and observations of the attendees.

Improving outcomes in small and medium-sized enterprises

Large energy-intensive companies often have access to the necessary technology and skills to achieve efficiency gains. These include digital metering and monitoring equipment, qualified personnel in roles such as site or corporate energy manager, and energy management systems certified to ISO 50001 or other international standards. Small and medium-sized enterprises (SMEs) typically do not have access to such technology and skills, let alone capital, making the implementation of energy management and digital technology a more challenging prospect.

SMEs are a significant component of the global industrial and economic landscape and are major drivers of innovation. In OECD countries, SMEs account for approximately 99% of all firms, about 70% of jobs and generate between 50 to 60% of total gross domestic product (GDP). In emerging economies, SMEs contribute up to 45% of total employment and one third of GDP (OECD, 2017). An improvement in the productivity and efficiency of SMEs is therefore critical to advancing economic productivity and prosperity.

Governments are recognising the difficulties that SMEs face in implementing energy management systems and digital technologies. While approaches differ, there is a consistent focus on capacity building and in some cases financial support to increase levels of adoption. The US DOE's 50001 Ready Programme and Mexico's recent pilot program for SMEs provide examples of measures intended to provide tools and build capacity within SMEs to implement energy management systems. Similarly, the Korean government's support to SMEs through financial assistance to obtain digital metering and monitoring equipment recognises the value of this technology but also the limited financial resources and skills SMEs might have to implement digital technology. The energy performance indicator (EnPI) lite tool developed by the US DOE and the regression analysis tool developed by the Korean government, are examples of online tools developed by government and freely available to SMEs to help with the analytical and technical aspects of an energy management system. Such tools reduce the need for companies to hire additional personnel or engage external consultants, which they may not be able to afford.

Another common feature of SME programmes currently in place is that they do not include mandatory implementation of ISO 50001. While the implementation of ISO 50001 has become a component of industrial energy efficiency programmes targeted at large industry, certification does come with administrative and financial costs that may be too high for SMEs. The 50001 Ready Programme in the United States prepares an SME for certification by helping develop necessary skills and procedures, but leaves the final decision to the company's discretion. The US DOE also provides formal recognition to those organizations that meet 50001 Ready requirements, whether they chose to pursue third-party certification or not.

As many of these SME programmes have only been in operation for a short period, it will be important that the outcomes achieved can be shared and understood so that best practice can be replicated in other countries or regions. Opportunities for knowledge sharing between policy makers will continue to be an important means of developing measures and programmes that assist SMEs with the adoption of energy management systems and digital technologies.

Incentivising industry action

Incentives are a key component of industrial energy efficiency programmes in several countries. Tax incentives have been used in Germany and Sweden to encourage the uptake of ISO 50001, with financial support for the implementation of ISO 50001 also provided by the Canadian government. These incentives acknowledge that for some industrial firms, particularly less energy-intensive firms, implementation of an energy management system is not core business and may require additional incentive in order to take action. Important questions for policy makers considering the use of incentives is what type of incentive is appropriate to provide to companies and what actions do companies need to take to obtain the incentive.

In Germany, the sizeable tax incentives offered by government to increase the adoption of ISO 50001 have contributed to the country having by far the largest number of certifications both in Europe and globally (Figure 12). As a means of creating demand for (and thus a market for) ISO 50001 certification services, the German incentive scheme has been effective. However, other than obtaining ISO 50001 certification, companies are not required to implement any energy efficiency measures or achieve improvement targets. Further study is warranted to assess the overall effectiveness of this scheme in progressing industry toward its energy efficiency targets.

In Sweden, the PFE Program provided a similar, although smaller, tax incentive for companies to implement an energy management system, but also included a requirement to achieve an efficiency target. This additional requirement may have discouraged some companies from participating in the program, although the government did have greater assurance that the tax incentive being provided would lead to an improvement in industrial energy efficiency.

The outcomes from incentive schemes and the approach that companies take in obtaining them is also dependant on the type of the incentive being offered (Box 7). Extrinsic incentives, such as financial rewards, can result in a compliance driven approach, whereby companies only do what is needed to obtain the incentive. While extrinsic incentives for industrial energy efficiency can be effective at achieving some outcomes, such as increasing the amount of ISO 50001 certifications, it is not certain whether they lead to greater levels of organisational change with longer lasting effects.

Intrinsic incentives, such as developing new skills and capacities within an organisation, may not be as powerful drivers of company action, but can result in sustained organisational change and improvement. The US SEP Program provides an example of a program that provides an intrinsic incentive for companies to participate, in addition to public recognition. As evidenced by the results obtained by companies that have obtained SEP certification (Figures 6 and 10), the intrinsic value obtained by companies, in terms of enhanced energy management skills and knowledge, has led to positive and sustained benefit (although data is only available for a short period). However, the absence of financial incentives in the SEP Program has contributed to lower participation rates compared to measures such as the German tax incentives.

For policy makers considering the use of financial incentives to encourage implementation of an energy management system, the size of the incentive being provided is an important factor. A large financial incentive may encourage participation from a number of companies. However, the ability for governments to continue providing this over an extended period needs to be evaluated, as early removal may limit its impact and alter the way in which any future financial incentives are viewed. As energy efficiency measures within industry will lead to enhanced productivity and reduction in operating costs, the size of the financial incentive in comparison to potential savings achieved should also be considered, to ensure that it is appropriate in comparison the outcomes that could be obtained by industry.

Box 7 • Motivations for taking up incentives

There are different motivations for people or companies to adopt certain practices or participate in targeted support programs that are either government or privately led. Motivations can be distinguished as either extrinsic, due to external factors such as rewards or avoiding negative consequences, and intrinsic, which are due to internal factors such as aligning with one's values, beliefs or convictions.

In a recent field experiment, researchers tested the effect of extrinsic versus intrinsic incentives (through subtle rewards) on individuals' decision to apply for a major support programme targeted at early stage social entrepreneurs. The researchers found that an emphasis on extrinsic incentives resulted in greater effort spent on the actual application, and hence a higher application success rate. However, the extrinsic motivations also strongly affected who applied. Specifically, the extrinsic incentive resulted in more money-oriented candidates applying to the programme, which "crowded out" other applicants that were oriented towards societal outcomes.

Importantly, while the proposals of candidates in the extrinsic incentives groups were more successful at the application stage, their social enterprises were less likely to be successful at the end of the one-year grant period. The findings highlight the critical role of intrinsic motivations to the selection and performance of early stage social enterprises. It suggested that using extrinsic incentives to promote the development of successful social enterprises may not be as effective as using intrinsic incentives.

Source: Ganguli, Huysentruyt, and Le Coq (2018), *How do nascent social entrepreneurs respond to rewards? A field experiment on motivations in a grant competition*.

Establishing a clear evidence base

Understanding the costs and benefits of energy management systems and digital technologies will continue to be important in driving uptake. The evidence base regarding the benefits of energy management systems, particularly ISO 50001, is continuing to grow. Although, considering that the standard only started in 2011, outcomes are limited to the first few years after implementation, meaning that evidence about longer term benefits are still being established. It will be important for these experiences and results to be captured and verified in order to highlight potential benefits and dispel negative perceptions and risks.

Despite an extended presence within the industry sector, new digital technologies and applications are continuing to become available. New technology can be daunting and confusing for some companies, depending on available skills and previous levels of experience. The provision of information that highlights the experience of other companies implementing digital technology can improve knowledge and reduce first mover risk, which prevents some companies from implementing new technology.

Continued knowledge sharing between government, industry and technology providers will be important to build and communicate the evidence base on energy management systems and digital technologies.

Automation of decisions relating to energy efficiency measures

Greater connectivity across energy metering, monitoring and control systems has led to the development of data collection and software applications that allow for enhanced analysis and the identification of performance issues and opportunities to improve efficiency. While technology and software exists for corrective measures, which do not require new capital equipment, to be automatically implemented, many companies, including those participating in the IEA Workshop, prefer to leave some or all decisions regarding implementation at the discretion of operating personnel.

The desire for companies to maintain discretion over energy saving actions may be seen as an impediment to greater efficiency savings from digital technology. However, some companies still show a preference to maintain transparency about changes made to operating conditions. Additionally, even with the need for company discretion, the time between the identification of potential inefficiencies and corrective actions can be relatively short. As shown in Figure 21, 3M Canada's identification of a spiral valve performance issue was remedied a day after identification.

There are potential energy efficiency benefits from the increased automation of corrective actions within industry. Building the evidence base about the benefits of such automation may reduce company hesitation and uncertainty, but also creating a culture within a company such that any identified issues are addressed within as short a timeframe as possible will also lead to positive outcomes.

The value of standards and certification

ISO 50001 provides an internationally consistent benchmark for industrial energy management. As a result it has become the basis for industrial energy management policies and programmes in many countries. The ability for companies to obtain certification provides government with a level of assurance that actions have been taken and systems have been implemented, which may reduce the costs associated with verifying compliance with legislation.

For companies that are not subject to regulations requiring ISO 50001 certification, or do not receive any incentive for doing so, a question which may be raised is whether obtaining certification provides additional benefit, given the administration, time and financial cost involved. Novartis Ireland are an example of a company that have implemented an energy management system, but have not sought to obtain ISO 50001 certification. Given the benefits obtained from the company's existing systems, it is uncertain what additional gains certification would have provided.

One of the benefits of ISO 50001 certification is that it leads to a more rigorous implementation and documentation of energy management practices and processes. This benefit is highlighted by 3M Canada (Figure 10), where there has been a clear difference in performance between certified and non-certified sites. Similarly, savings obtained by companies participating in the SEP Program before ISO 50001 implementation are noticeably lower than that achieved post-implementation (Figure 6). In these cases, certification has forced the implementation of a structured, consistent and documented approach to energy management, which may not have been the case previously.

Whether policy makers include ISO 50001 certification as part of industrial energy efficiency policies or programmes will depend on the outcomes being sought as well as the companies being targeted. At present, policies focusing on SMEs have used ISO 50001 and its principles as a basis for providing training and capacity building, but have not mandated certification, leaving this at the discretion of the company. Such an approach reflects the steeper learning curve that some SMEs face in implementing energy management and the costs associated with seeking certification.

Obtaining senior management engagement

A consistent observation from all companies that have gained substantial benefit from the implementation of energy management systems is the critical importance of senior management engagement and support. Such engagement, whether through explicit statements from Chief Executives or company policies, provides the endorsement necessary for personnel to pursue actions that lead to improvements in energy efficiency.

The importance of senior management engagement also extends to increasing the application of digital technology. Such endorsement can help combat resistance at various levels within the company, particularly where there is uncertainty about the adoption of new technology.

To obtain the endorsement of senior management, it is necessary for the benefits of energy management systems and digital technology to be communicated in a manner that is understood and, importantly, appeals to their key motivations. It is particularly important that energy efficiency outcomes are translated in to financial and profitability benefits, which are of great importance to senior management.

The continuing development of an evidence base regarding the benefits of energy management systems and digital technologies will provide information and data that can contribute to the development of business cases for senior management support. It will therefore be important that evidence be developed that takes into consideration the motivations of senior management.

Unlocking benefits through increased connectivity

Greater levels of connectivity between industrial processes and facilities can unlock productivity and efficiency gains. As highlighted by the work of Turkish consumer goods manufacturer Arçelik, leveraging digital technology to connect currently installed metering and monitoring equipment within a single facility and increasing connectivity between facilities is a potential next step for companies that have already made investments in digital technology.

Connection beyond an individual facility to suppliers, end-users, business operations, other facilities and the energy market, is the underpinning concept of smart manufacturing. The technology exists for more facilities to transition to smart manufacturing and the evidence base to support investment is being developed. Smart manufacturing practices can allow an industrial operation to respond, in real-time, to changes in market or environmental conditions, thereby reducing productivity and efficiency losses resulting from delayed response.

The ability for an industrial plant to be connected to an electricity grid creates an opportunity to increase its participation in demand side response schemes. Such schemes reward industrial plants for reducing their energy demand during peak periods, thereby reducing the need for additional and potentially more expensive supply. Participation can include temporary reductions in electrical load, switching consumption to other periods of the day, or sourcing electricity from on-site generation. Novartis Ringaskiddy has leveraged its extensive metering, monitoring and control systems to participate in demand side response schemes and 3M Canada also increases consumption via on-site combined heat and power systems during peak demand periods, taking pressure of the electricity grid.

Increased participation from industrial energy users in energy markets is highly beneficial for reducing the severity of peaks and also buffering output from variable power sources, such as wind or solar generation, thereby increasing system stability. It is nevertheless important for policy makers and regulators to establish market mechanisms, such as demand-side response schemes, which reward industrial plants for increasing their involvement in the energy market. The design and operation of such schemes has also been influenced by digital technologies, as grid operators are able to communicate with energy users with greater speed and ease when action is required.

Addressing data privacy and security concerns

A major barrier to increasing the application and impact of digital technologies are industry concerns about data privacy and security. As data relating to a company's energy use, cost and production can be highly sensitive, the potential for this information to be lost or acquired as a result of increased connectivity can discourage companies from fully embracing digitalisation.

An important component of the evidence base for scaling up digitalisation in the industry sector should be how data privacy and security concerns are addressed. Industry will gain confidence with increased digitalisation once an understanding has been developed about how privacy and security concerns can be mitigated.

Policy makers seeking to increase the impact and benefits of digitalisation will also need to consider ways to reduce privacy and security risks. Such considerations should be made when designing technology research and development programmes, as well as any product or operational standards that may touch on digital technologies.

Service providers add value, but best results come through ownership

All companies participating in the IEA Workshop noted that implementation of energy management systems and digital technologies did benefit from the targeted use of service and technology providers. The expertise provided by such groups included establishing data collection and monitoring systems, analysing data to determine performance indicators and conducting energy audits. In addition, policy and programme measures, such as that developed in South Africa with the support of UNIDO, had led to the development of a service industry to provide energy efficiency consulting and analysis services to industry.

Industrial energy efficiency policies and programmes can assist in the development of a local service industry. When policies are directed at companies that have not had prior experience with energy management, service providers can assist with improving capability and knowledge. Service providers can also assist in filling technology gaps that might prevent more detailed data collection and analysis. Specifically, the use of portable or temporary metering devices, as installed by service or technology providers, can lead to the acquisition of the detailed data necessary for an energy audit and assist in forming the business case for companies to invest in permanent metering.

While there are benefits provided by service providers, the strongest outcomes can be achieved when the industrial energy-user takes ownership of its energy management system. Ownership provides greater confidence that senior management will be engaged and that people from across the company will be involved in the process, providing their knowledge and expertise. 3M Canada's ownership of energy management, as evidenced by its energy policy, the appointment of a corporate energy manager and ongoing staff training and engagement, has been complemented with external expertise from service providers where needed, to provide substantial and long lasting productivity and efficiency benefits.

Conclusions and next steps

Energy management systems are unlocking opportunities to improve energy efficiency in diverse industry sectors. In many countries, implementation is being driven by government policies ranging from direct regulation to voluntary agreements and fiscal or financial incentives. Digital technologies are continuing to drive improvements in industrial energy efficiency and productivity. Timely and reliable data is a central pillar for the implementation of an energy management system. Digital metering and monitoring equipment is providing this critical data at an increasingly lower cost, with innovations in terms of data storage and analysis creating greater value.

The benefits from energy management systems and digital technologies are becoming increasingly apparent. However, there remain issues to be addressed if these benefits are to grow. The value proposition for the combination of energy management systems and digital technology needs to be enhanced through the development of a relatable evidence base and the barriers preventing greater uptake need to be clearly identified. It will also be important that the roles for industrial energy users, technology and service providers and policy makers be clearly established so that an environment that fosters innovation to unlock the energy efficiency potential within industry can be established.

Acronyms, abbreviations and units of measure

Acronyms and abbreviations

AUD	Australian Dollars
BNEF	Bloomberg New Energy Finance
CAD	Canadian Dollars
CESMII	Clean Energy Smart Manufacturing Innovation Institute
CO_2	Carbon Dioxide
CONUEE	National Commission for the Efficient Use of Energy
DOE	Department of Energy
E4	Energy Efficiency in Emerging Economies
EED	Energy Efficiency Directive
EEO	Energy Efficiency Opportunities
EnMS	energy management system
EnPI	energy performance indicator
EUR	Euros
GDP	gross domestic product
GE	General Electric
GVA	gross value added
IAC	Industrial Assessment Center
ICT	information and communications technologies
IEA	International Energy Agency
IEE	industrial energy efficiency
ISO	International Organization for Standardization
$MtCO_2$-eq	Million tonnes of carbon dioxide equivalent
MXN	Mexican Pesos
OECD	Organisation for Economic Cooperation and Development
PFE	Programme for Improving Energy Efficiency in Energy Intensive Industries
PRONASE	National Program for Sustainable Use of Energy (Spanish translation)
PRONASGEN	National Program for Energy Management Systems (Spanish translation)
S-EnMS	Superior Energy Management System
SEP	Superior Energy Performance
SME	small and medium enterprise
UNIDO	United Nations Industrial Development Organization
US	United States
USD	United States Dollars
ZAR	South African Rand

Units of measure

GW	gigawatt
GWh	gigawatt-hour
TWh	terawatt-hour
mcm	million cubic metres
TJ	terajoules
PJ	petajoules
toe	tonne of oil-equivalent

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IEA/OECD possible corrigenda on: www.oecd.org/about/publishing/corrigenda.htm

IEA Publications
International Energy Agency
Website: www.iea.org
Contact information: www.iea.org/about/contact
Typeset in France by IEA - June 2018
Cover design: IEA