International approaches to industrial energy efficiency: a comparison of countries

Meegan Kelly
Senior Research Analyst
American Council for an Energy-Efficient Economy (ACEEE)
529 14th Street, Suite 600
Washington, DC 20045
USA
mkelly@aceee.org

Keywords

energy efficiency policy, industrial energy saving, policies and measures, best practice, international approaches

Abstract

Across the globe, countries are designing and implementing national policies and programs to improve the energy efficiency of the industrial sector. This paper takes a comparative look at policy approaches to industrial energy efficiency in the top energy-consuming countries worldwide including Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Netherlands, Poland, Russia, Saudi Arabia, South Africa, South Korea, Spain, Taiwan, Thailand, Turkey, United Kingdom, and United States.

Ten key metrics are used to either measure a country's performance or assess policy criteria related to industrial energy efficiency. The performance metrics cover a country's energy intensity in industry, energy intensity in agriculture, and installed combined heat and power (CHP) capacity. The policy metrics consider government efforts to encourage energy efficiency through voluntary agreements to achieve energy savings, policies that encourage energy management and ISO 50001 certification, the adoption of minimum efficiency standards for motors, mandates requiring periodic energy audits and on-site energy managers, investment in industrial research and development (R&D), and policies that promote CHP.

In addition to presenting key information in a single resource, this paper highlights best practices and provides benchmarks for comparing the progress of individual countries toward improving their industrial energy efficiency policies. Information for each country was obtained from central sources when available and supplemented with country-specific research and personal communication with subject-matter experts. We hope this work will shine a light on successful approaches and help nations learn from one another to achieve greater energy efficiency in the industrial sector.

Introduction

The industrial sector uses more energy than any other end-use sector and is responsible for more than half of total final energy consumed in the world (EIA 2015). Most industrial companies look for opportunities to gain greater control over energy use, especially when it lowers operating costs and increases productivity and competitiveness. Energy efficiency is one of the best ways to achieve these goals and a large opportunity exists for the industrial sector to increase its adoption of energy-efficient technologies and practices. Efficiency also affords newly industrialized nations the opportunity to apply best practices developed over several decades in other countries with more mature industrial sectors.

This paper examines energy efficiency in the industrial sectors of the top energy consumers worldwide, including Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Netherlands, Poland, Russia, Saudi Arabia, South Africa, South Korea, Spain, Taiwan, Thailand, Turkey, United Kingdom (UK), and United States (US).[1] A comparative look across countries helps identify best practices and emerging trends that may serve as useful examples to other countries. However, differences in size, climate, economic structure,

1. Iran and Ukraine are also among the top 25 energy consumers, but were omitted from this analysis due to lack of comprehensive data.

Table 1. Population, GDP and final energy consumption for top energy consuming countries

Country	Population	GDP (trillion USD – current)	Total final consumption (ktoe)	Industrial consumption (ktoe)
Australia	23,125,868	1.56	80,793	25,226
Brazil	204,259,377	2.39	228,428	82,462
Canada	35,158,304	1.84	199,094	47,764
China	1,357,380,000	9.49	1,943,490	957,004
France	65,925,498	2.81	157,555	28,000
Germany	80,645,605	3.73	224,903	55,167
India	1,279,498,874	1.86	528,337	179,090
Indonesia	251,268,276	0.91	161,990	36,774
Italy	60,233,948	2.14	121,170	26,137
Japan	127,338,621	4.92	311,410	82,006
Mexico	123,740,109	1.26	118,177	34,721
Netherlands	16,804,432	0.85	61,645	12,300
Poland	38,040,196	0.53	66,981	14,382
Russia	143,506,911	2.08	434,487	123,655
Saudi Arabia	30,201,051	0.74	133,067	46,138
South Africa	53,157,490	0.37	74,320	26,444
South Korea	50,219,669	1.31	167,839	47,687
Spain	46,620,045	1.39	81,457	20,118
Taiwan	23,344,670	0.51	67,661	23,116
Thailand	67,451,422	0.39	95,803	29,896
Turkey	75,010,202	0.82	86,017	24,497
UK	64,106,779	2.68	129,033	23,353
US	316,497,531	16.77	1,495,068	261,046

Sources: Population and GDP in 2013 (World Bank 2016a, World Bank 2016b). Total final energy consumption in 2013 in thousand tonnes of oil equivalent (ktoe) on a net calorific value basis (IEA 2016).

demographics, and others factors significantly affect energy consumption and can present challenges when attempting to draw comparisons. Table 1 shows the range of differences in population, gross domestic product (GDP), total final energy consumption, and industrial energy consumption of the countries examined in this report.[2]

This analysis serves three purposes. First, it presents readers with a basic comparison of industrial energy use and efficiency policy efforts in the top energy consuming countries. Second, it identifies a number of best practices and policies that countries can implement to take advantage of untapped industrial efficiency potential. Finally, it shows where the United States stands on the global industrial energy efficiency stage and provides recommendations for further policy improvements. We hope these findings generate discussion among stakeholders to promote energy efficiency and inspire mutual learning across countries.

Methodology

Our methodology was developed for a forthcoming ACEEE report, *The 2016 International Energy Efficiency Scorecard*, which presents a broader evaluation of energy efficiency policies and programs in the same countries.[3] The metrics and rankings presented here are preliminary findings based on research completed as of June 2016 for the industry chapter of the broader publication and are subject to change. We rank countries using 10 key metrics that either measure energy performance or assess policy activities to improve industrial energy efficiency. We allocate countries points for each metric with a maximum score of 25 points available across all metrics. Table 2 describes the metrics, indicates whether it is performance- or policy-oriented, and identifies the number points available.

It is challenging to devise a methodology that adequately captures industrial energy efficiency efforts and allows for

2. According to IEA, total final consumption is the sum of consumption by the different end-use sectors. It is broken down into energy demand in industry, transport, buildings (including residential and services) and other (including agriculture and non-energy use). It excludes international marine and aviation bunkers.

3. The *International Scorecard* evaluates each country using 35 metrics spread over 4 categories: buildings, industry, transportation, and overall national energy efficiency efforts. It is currently undergoing peer review and will be published in summer 2016.

Table 2. Industrial energy efficiency metrics.

Type	Description	Points
Performance	Energy intensity of the industrial sector	6
Performance	Energy intensity of agriculture	2
Performance	CHP installed capacity	2
Policy	Voluntary energy-performance agreements with manufacturers	3
Policy	Policy to encourage energy management	2
Policy	Minimum efficiency standards for electric motors	2
Policy	Mandate for plant energy managers	2
Policy	Mandatory energy audits	2
Policy	Investment in manufacturing research and development	2
Policy	Policy to encourage combined heat and power	2
Total		**25**

comparison across a range of countries on a common scale. Factors such as economic structure and availability of natural resources can heavily influence energy use in industry. In general, we avoid adjusting for these differences, unless we felt it was absolutely necessary. Policy implementation is another difficult factor to address and our methodology identifies the existence of certain policies but, in most cases, it does not evaluate the quality or effectiveness of a given policy at driving energy efficiency. Finally, the availability of consistent, internationally comparable data was a significant obstacle and our choice of metrics was sometimes limited by lack of data consistency.

In the following section, we compare countries across all categories, provide a short summary of the findings, and describe best practices from the top three highest-ranking countries. In a later section, we include a detailed discussion of each of the 10 individual metrics and identify the highest-ranking countries in each.

Scoring and Results

Germany earned the highest score for its industrial performance and policy efforts, followed by Japan and the United Kingdom. All three countries had voluntary agreements with manufacturers in place and complementary programs to help those companies save energy. Many of these programs include mandatory energy audits, minimum efficiency standards for motors, and financial and/or policy support for integrating energy efficiency into corporate management practices. The top countries also generally had lower energy intensities in industry and agriculture. Table 3 displays preliminary scores and rankings for each country.

No country received a perfect score, indicating that every country has room for improvement. The European Union (EU) countries tended to do well across all metrics and particularly stood out for many of the policies set forth in the EU's 2012 Energy Efficiency Directive (EED), which established a set of binding measures to reach an energy efficiency target of 20 % energy savings by 2020 when compared to projected energy use in 2020. It should be noted, however, that implementation

Table 3. Preliminary scores and ranking by country.

Industry (25 points)		
Country	**Score**	**Rank**
Germany	21	1
Japan	20.5	2
UK	19.5	3
Italy	19.5	3
South Korea	18.5	5
France	16.5	6
Indonesia	16	7
Netherlands	16	7
Taiwan	16	7
Spain	15.5	10
China	15	11
US	14.5	12
Turkey	14	13
India	13.5	14
Canada	13.5	14
Thailand	13	16
Poland	11.5	17
Mexico	11.5	17
Russia	10	19
Brazil	6	20
Australia	5.5	21
Saudi Arabia	4	22
South Africa	4	22

of the EED varies and each member country is free to interpret and implement the directive independently.[4] Some of the developing countries with lower scores such as South Africa, Thailand, and Mexico have an opportunity to build energy efficiency into their continued economic growth by implementing policies in industry and their more developed counterparts should lead by example. The following summarizes some best practices from the top three highest-ranking countries.

GERMANY

The energy intensity of Germany's industrial sector is low compared to other countries, with the majority of energy used in the chemical, iron and steel industries. Over the years, Germany has established a variety of coordinated policies to implement energy savings measures for industry. A voluntary agreement between German industry and the federal government to reduce CO_2 emissions has been in place since 1995 (IEA 2013). The most recent voluntary agreement with industry was negotiated in 2012 and sets targets for annual reductions in energy intensity until 2022 (IIP 2016a). To encourage large companies to reach savings targets, they become eligible for a large-scale tax exemption when their savings goals are met. The German government has also established a target of obtaining 25 percent of electricity generation from combined heat and power (CHP) by 2020. The CHP Act (Kraft-Wärme-Kopplungs-Gesetz – KWKG) provides investment support in the form of a feed-in tariff, which offers an incentive payment for electricity generated by CHP, depending on type of technology and size of the system (IIP 2016b). In 2015, the government increased its support for CHP by amending the CHP Act to provide 1.5 billion euros per year, effectively doubling the level of financial incentives available (BMWI 2015). The German government has also encouraged the implementation of energy management systems for large companies, which helps energy-intensive industries achieve emissions and energy savings targets.

JAPAN

Japan has developed a mix of regulatory measures, voluntary actions, and financial incentives to encourage energy efficiency in its industrial sector. The Act Concerning the Rational Use of Energy introduced mandatory energy efficiency requirements for designated industries in 1978 and continues to serve as the foundation of Japan's energy efficiency policy. It requires companies to appoint an energy manager and report on the status of energy consumption every year. In 2008, a revision to the Act introduced a benchmarking system for obligating businesses to achieve specific medium- (2015) and long-term (2020) energy efficiency targets (IIP 2016c). A tax incentive scheme supports these requirements by providing a special depreciation rate for all businesses investing in specified energy conservation and efficient equipment (ABB 2012). CHP does not contribute a significant share of Japan's total power capacity, but the government offers support to help encourage greater contribution of CHP electricity resources. The Ministry of Economy, Trade, and Industry (METI) has studied barriers to greater CHP deployment and established an office focused on promoting CHP in Japan. The Energy and Environment Council defined a CHP roadmap for 2030 that aims to more than double existing industrial and commercial CHP capacity to 22 GW in 2030 (IEA CHP and DHC Collaborative 2013). Japan also dedicates a significant amount of its investment in research and development toward the industrial sector, the highest of the countries we analysed.

UNITED KINGDOM

Industrial energy consumption in the UK has decreased by about 50 percent from 1970 to 2014, which can be attributed to structural changes in the industrial sector and improvements in the efficiency of electricity generation (DECC 2015). While the share of energy-intensive industry in the UK is small, the government has adopted a variety of policy measures to improve its efficiency primarily for carbon reductions. The Environment Agency administers Climate Change Agreements (CCA), which establish voluntary commitments with energy-intensive companies to reduce energy use. In exchange for reaching their targets, companies receive a discount on the Climate Change Levy (CLL), a tax added on electricity and fuel bills (UK Environment Agency 2016a). These voluntary agreements have been established with more than 9,000 facilities and are expected to deliver an overall 11 % energy efficiency improvement across all industries (UK Environment Agency 2016b). The government also provides tax relief to help businesses invest in specific energy-saving technologies or machinery that might otherwise be too expensive, including boiler equipment, CHP, compressed air equipment, motors and drives, and other other products. A range of other measures provide additional support for CHP, including access to financial incentives, exemptions from certain fees and taxes, and the development of a strategic framework for reducing emissions with CHP in the UK.

Discussion

This section provides a detailed discussion of all ten metrics beginning with performance metrics and continuing with policy metrics. We explain the rationale for each metric and acknowledge how various countries perform. Table 4 provides a preliminary breakdown of country scores by individual metric.

PERFORMANCE METRICS

Performance metrics are quantitative and generally capture energy use per unit activity or service extracted. They can help assess the effectiveness of national efforts to consume less energy, but are also affected by factors other than energy efficiency. Three different performance-oriented metrics affect a country's overall ranking: energy intensity of the industrial sector, energy intensity in agriculture, and share of combined heat and power in total installed capacity.

Energy Intensity of the Industrial Sector

Countries vary widely in the structure of their industrial sectors and energy consumption will vary significantly depending on the size and type of predominant industries. For example, in 2013, Australia's energy consumption was highest in non-

4. See Energy Efficiency Watch 2015 for more information about implementation of energy efficiency policies in the European Union. Additional information is also available from the ODYSSEE-MURE project, which maintains data on energy efficiency indicators and evaluates the impact of efficiency policies implemented in EU member countries (ODYSSEE-MURE 2016).

Table 4. Preliminary country scores by individual metric.

Country	Energy intensity of industry	Energy intensity of agriculture	CHP installed capacity	Voluntary agreements	Energy management policy	Standards for motors	Mandate for energy managers	Mandatory energy audits	Investment in R&D	CHP policy	Total score
Possible pts.	*6*	*2*	*2*	*3*	*2*	*2*	*2*	*2*	*2*	*2*	***25***
Germany	5	2	1.5	3	2	2	0	2	1.5	2	**21**
Japan	5	1.5	0	2	2	2	2	2	2	2	**20.5**
UK	6	1.5	0.5	3	2	2	0	2	1.5	1	**19.5**
Italy	5	1.5	1.5	3	1	2	2	2	0.5	1	**19.5**
South Korea	4	1.5	1	3	2	2	0	2	2	1	**18.5**
France	5	1	0	3	1	2	0	2	1.5	1	**16.5**
Indonesia	6	2	0	2	2	0	2	2	0	0	**16**
Netherlands	5	0	2	2	1	2	0	2	1	1	**16**
Taiwan	3	2	1.5	0	2	1	2	2	1.5	1	**16**
Spain	4	1.5	0.5	3	2	2	0	2	0.5	0	**15.5**
China	0	2	1	3	2	1	2	2	1	1	**15**
US	3	1	0.5	2	2	2	0	0	2	2	**14.5**
Turkey	3	2	0.5	3	2	1	2	0	0.5	0	**14**
India	0	2	0.5	3	2	0	2	2	0	2	**13.5**
Canada	4	0.5	0.5	3	2	2	0	0	0.5	1	**13.5**
Thailand	2	1.5	0.5	3	2	0	2	2	0	0	**13**
Mexico	5	1.5	0	0	2	2	0	0	0	1	**11.5**
Poland	3	1	1.5	0	1	2	0	2	0	1	**11.5**
Russia	1	1.5	2	3	2	0	0	0	0.5	0	**10**
Brazil	1	1.5	0.5	0	0	1	0	0	1	1	**6**
Australia	2	1	0.5	0	0	1	0	0	1	0	**5.5**
Saudi Arabia	1	2	0	0	0	1	0	0	0	0	**4**
South Africa	0	1	0	3	0	0	0	0	0	0	**4**

ferrous metals manufacturing, while Brazil's energy consumption was highest in food and tobacco production. However, across all countries, industries such as machinery and transport equipment tend to have high market value and low energy consumption relative to industries such as cement, pulp and paper, metal products, and chemicals, which have low market value and high energy consumption. Still, the efficiency of the manufacturing process itself can vary from country to country for the same industry.

Several methodological approaches could be used to compare industrial energy intensity, each with distinct advantages and disadvantages. The most basic approach could compare a measure of a country's energy intensity using total final industrial consumption divided by industrial GDP. This approach is appealing in its simplicity, but does not account for structural differences and disadvantages countries with high-energy, low-value industries. Another approach could instead compare the change in energy intensity over a given period of time, which has several advantages since it reduces the need to account for structural differences, data are available from central sources, and the methodology is clear and easy to understand. On the other hand, this approach is sensitive to the time period analysed and other externalities. For example, energy efficiency investments made prior to the baseline year are not accounted for and could disadvantage countries that invested in efficiency early. Changes in intensity could also be caused by factors unrelated to efficiency improvements, such as structural shifts among industries or the effects of economic recession.

The approach applied in this analysis compares a weighted measure of energy intensity for each country. We calculate energy consumed by industry per constant-dollar of industrial GDP and apply a weighting factor based on the intensity of

the individual industries that make up the overall sector.[5] This approach has the advantage of accounting for structural differences across countries and provides a deeper analysis than other options, but it is more complex and requires some difficult assumptions, especially when data are limited. For example, since country-level data on the energy intensity of individual industries is not consistently tracked, but the US Energy Information Administration (EIA) collects this data for the United States, our methodology assumes that the patterns of relative intensities in other countries are similar to that of the U.S.[6] In reality, subgroup intensities in other countries may be very different from the US and the need to draw on multiple sources of unstandardized data can create statistical problems. We urge caution in interpreting the rankings resulting from this metric.

The United Kingdom was the highest-ranking countries in terms of energy intensity of their industrial sectors. In 2014, the largest consuming sub-sector in the UK was the chemical industry and that sector has seen the largest improvement in intensity of any, with a 58 percent decrease between 2000 and 2014 (DECC 2015). Indonesia earned the second highest ranking, but we suspect this is a data anomaly.[7] According to the Asian Development Bank, the Indonesian industrial sector consumes energy inefficiently when compared with international benchmarks (Tharakan 2015). France, Germany, Italy, Japan, Mexico, and Netherlands also earned high scores. China, India, and South Africa were countries with the greatest room for improvement in industrial energy intensity.

Agriculture energy intensity

Energy intensity of agriculture is the total final energy consumed by the sector, per dollar of value-added measured in constant purchasing power parities (WEC 2016a).[8] This includes fuel and electricity consumed to produce crops and energy that is indirectly consumed to produce agricultural inputs, such as fertilizers and pesticides. Energy consumption in agriculture sector greatly depends on the products, production methods and climate. In colder regions or in countries with heavily industrialized food production processes, consumption tends to be higher. In warmer regions or in countries employing human and animal labour, it is generally lower. Energy required to transport or supply water and the production of high value cash crops are two additional factors affecting this metric. Countries with the least energy intensive agricultural sectors were China, Germany, India, Indonesia, Taiwan, Turkey, and Saudi Arabia. The most energy intensive were Canada and Netherlands.

CHP installed capacity

CHP systems generate electricity and useful thermal energy in a single, integrated system. The use of CHP systems is more efficient than the separate generation of thermal energy and electricity because heat that is normally wasted in conventional power generation is recovered to meet thermal demands. Our ranking compares countries according to the share of electric CHP capacity in overall electric power sector capacity (WEC 2016b). We focused on installed capacity because data was more readily available for a greater number of countries, even though the share of electricity actually produced by CHP systems may be a better measure of whether it is utilized as a key technology. Further, as a measure of industrial efficiency, it would be more useful to look at the share of industrial CHP in industrial electricity consumption, but data on the use of CHP globally is limited.[9] Access to better data is likely to improve this metric in future editions of the *International Scorecard*. In general, any indicator related to CHP is also highly subject to the technical potential for CHP in given country.

For countries where CHP makes up 15 % or more of installed capacity, maximum points were awarded. Russia (59 %), Netherlands (41 %), and Italy (23 %) had the highest percentage of installed CHP capacity. For countries where CHP made up less than 5 % of installed power capacity, no points were awarded. These countries included France, Indonesia, Japan, Mexico, Saudi Arabia, and South Africa.

POLICY METRICS

Policy metrics are mostly qualitative and can highlight good approaches to encouraging energy efficiency. However, it is not always easy to determine the effectiveness of a given policy or document how well a policy is being implemented on the ground. These metrics recognize the presence of policies, but do not attempt to evaluate their impact. Seven policy metrics influence a country's overall ranking: voluntary energy-performance agreements with manufacturers; policies to encourage energy management; minimum efficiency standards for electric motors; mandates for plant energy managers; mandate for energy audits; investment in manufacturing research and development; and policies to encourage combined heat and power.

Voluntary energy-performance agreements with manufacturers

This metric is based on the presence of a national government program for entering into voluntary agreements with businesses in the manufacturing sector to improve energy efficiency. Best practice agreements set measurable savings targets as part of a set of policies that provide both technical and financial support to help participating manufacturers reach targets outlined in the agreements. The most successful programs are also often legally binding, although we do not award additional points for mandatory agreements in this category.

Countries that establish agreements *and* provide incentives or other financial support received maximum points and the majority of countries we analysed fall in this category, including Canada, China, France, Germany, India, Italy, Russia, South Africa, South Korea, Spain, Thailand, Turkey, and the United

5. All data in 2013. Energy consumption from IEA 2016 and industrial GDP calculated using industry value add (% of GDP) from World Bank 2016c and GDP from World Bank 2016b.

6. Industries are grouped into the following categories: iron and steel; chemical and petrochemical; non-ferrous metals; non-metallic minerals; transport equipment; machinery; mining and quarrying; food and tobacco; paper, pulp and printing; wood and wood products; textile and leather; and non-specified (industry). It does not include energy consumption in agriculture.

7. For certain countries, final energy consumption data reported by industry grouping did not appear consistent. For example, the majority of final energy consumption in Indonesia (69 %) was reported as "non-specified" instead of categorized in a particular industry group, which distorted results and warrants further investigation.

8. Agriculture includes cultivation of crops, horticulture, gardening, animal husbandry, hunting, and related activities (ISIC 2016).

9. Most CHP is installed in the industrial sector, but some countries have greater use of CHP in commercial, institutional, and municipal applications.

Kingdom. Four countries earned partial points because they have agreements, but do not provide incentives to support them (Indonesia, Japan, Netherlands, and United States). Australia, Brazil, Mexico, Poland, Saudi Arabia, and Taiwan do not currently have agreements or incentives in place.

China's Top 10,000 Energy-Consuming Enterprises Program is a good example of energy-performance agreements. Top 10,000 is a comprehensive energy efficiency program established for the industrial sector by the Chinese government in its 12th Five Year Plan. It includes agreements with 15,000 industrial enterprises and offers financial incentives for implementing energy-savings projects (Lu et al, 2014). The industrial program covers about two-thirds of China's total energy consumption and set a sector-wide savings target of 250 metric tons of carbon equivalent during the period of 2011–2015 (Lu et al, 2014).

Policy to encourage energy management

Several countries have policies to encourage large companies to improve their internal energy management practices. These policies, sometimes referred to as energy management system (EnMS) standards, often focus on helping facilities integrate energy efficiency into their management practices, including fine-tuning production processes and improving the energy efficiency of industrial systems (McKane et al, 2009). Some policies may also require companies to take into account relevant national or international standards such as ISO 50001. In 2011, the International Standards Organization (ISO) adopted the ISO 50001 energy management system standard, which provides a common framework for industrial facilities, commercial facilities, or entire organizations to manage energy. More than 6,700 sites worldwide achieved ISO 50001 certification as of 2014 (ISO Survey 2014).

We awarded each country 2 points if it has national policies in place to promote energy management systems that reference ISO 50001 certification. Countries that have not yet embraced the ISO 50001 standard, but have an energy management policy in place received 1 point. The majority of countries have a policy to address energy management in industry and only four countries (Australia, Brazil, Saudi Arabia, and South Africa) did not earn points.

Countries assign different priorities to ISO 50001 and those with incentives for introducing energy management systems or penalties for not pursuing them are likely to have a greater number of companies seeking certification. Tax relief and other similar policies have driven companies in some countries to pursue ISO 50001 certification. For example, in Germany, companies must introduce energy management systems or audits with certification to be eligible for an energy tax rebate (IIP 2016a). With 3,402 companies certified ISO 50001, Germany has the greatest number of certifications of the countries we surveyed, followed by the United Kingdom (376) and Spain (310).

Minimum efficiency standards for electric motors

Electric motors and the systems they drive consume 43–46 % of all global electricity consumption and are the single largest electricity end-use (Waide and Brunner 2011). In industrial applications, electric motors are used to drive pumps, fans, compressors, and other processing equipment, and generally account for most of electricity consumption in the sector. Many countries have established standard performance requirements to limit the amount of energy that motors can consume, and minimum energy performance standards (MEPS) are one of the best ways to improve mass-produced equipment (Brunner, Waide, and Jakob 2011).

International standards classify motors on a scale of energy efficiency from lowest efficiency (IE1) to highest (IE4).[10] This metric was scored according to the efficiency classification of the MEPS in place for electric motors. Countries with a MEPS of IE3 or higher earned 2 points. Countries with MEPS of IE2 or lower earned 1 point.

Eighteen of the 23 countries surveyed have standards in place (CLASP 2016). The majority of energy use from motors occurs in three regions – the United States, the European Union, and China – and all three will require most motors to meet the IE3 classification by 2017 (Brunner, Waide, and Jakob 2011). Canada, Mexico, Japan, and South Korea, also currently have IE3 standards in place (Werle 2015).

Mandate for plant energy managers

A dedicated, on-site energy manager can improve processes, identify waste, and maximize the efficient use of energy resources. Countries with a national law or regulation requiring industrial facilities to employ an energy management expert on site received a maximum of 2 points. Despite of the economic benefits of reduced energy waste and increased economic productivity that can come from having an on-site expert, only eight of the countries analysed had such a requirement. They include China, India, Indonesia, Italy, Japan, Taiwan, Thailand, and Turkey. Mandatory regulations can be very effective at improving the efficiency of industry, but they may not be politically workable options for some governments.

Italy is the only country from the EU region with a mandate for energy managers. Since 1992, every industrial organization with an annual consumption of more than 10,000 tonnes of oil equivalent has been required to appoint an energy manager. The goal of the mandate is to ensure that energy consumption is monitored and controlled and that energy efficiency measures are promoted and implemented at facilities consuming large amounts of energy. The country has also established a non-profit organization, the Italian Federation for the Rational use of Energy (FIRE), to manage, support, and strengthen the energy manager network (Di Santo 2006).

Mandatory energy audits

Periodic energy audits can help businesses identify opportunities to improve energy efficiency, benchmark improvements, and identify negative trends. Countries earned 2 points if there was a national law or regulation requiring periodic energy audits of industrial facilities.

More countries have mandatory energy audits in place compared to those with a mandate for plant energy managers. Of the 23 countries analysed, nine did not have an energy audit requirement for industrial facilities including Australia, Brazil,

10. For more information on energy efficiency of electric motors and IE classification of motors, see 4E 2015.

Canada, Mexico, Russia, Saudi Arabia, South Africa, Turkey, and the United States.

According to Article 8 of the EED, large enterprises in EU member states are subject to mandatory energy audits. Large enterprises are generally defined as having 250 employees or more. The audit obligation can also be satisfied by introducing or implementing an energy or environmental management system, and in that case, large companies are exempt from the audit obligation. Some member states define a minimum percentage of the company's energy consumption be covered by the audit, including Germany and the United Kingdom, which require 90 % coverage (Eichhammer and Rohde 2016; European Commission 2016). Some member states, such as Spain, impose financial penalties to ensure compliance.

Investment in industrial research and development

While industrial R&D spending is not exclusively invested in energy efficiency, it is a major focus of R&D investments as it reduces waste and energy costs and improves competitiveness. Spending included in this metric, therefore, represents R&D expenditures in the business enterprise sector according to the International Standard Industrial Classification (ISIC) revision 4 (OECD-Eurostat 2016). We divide business enterprise R&D expenditure in industry by industrial GDP and report the resulting percentage (in US dollars).

We gave countries the full 2 points for investment in R&D equal to or more than 8 % of industrial GDP, and 1.5 points for investment equal to or more than 5 % of industrial GDP. Investment greater than 3 % earned 1 point, and investment greater than 1 % earned 0.5 points. Japan has the highest investment in manufacturing R&D at 9.5 % of industrial GDP, followed by the United States (8.8 %) and South Korea (8.7 %). The majority of Japan's business enterprise R&D expenditure was invested in manufacturing with significant amounts for the manufacture of computer, electronic and optical products and for the manufacture of motor vehicles, trailers, and semi-trailers.[11]

Policy to encourage CHP

Countries can encourage or discourage CHP deployment in many ways. This metric recognizes countries for their adoption of policies and other regulations that promote deployment of CHP systems. First, we looked for the presence of a national goal or target for CHP. Second, we looked for other supportive policies such as access to tax credits, financial incentives, or regulatory support for CHP production.

Countries could earn up to 2 points for policies to encourage CHP. We awarded the full 2 points to countries with both a national target for CHP deployment and supportive policies such as incentives, in place. Countries with either a national target or incentives received 1 point. Policies in some countries may primarily apply to only a segment of CHP systems, often determined by locally available fuel resources or a certain system size. For example, CHP policies in India and Brazil are limited to bagasse-based applications and apply mainly in the sugar industry.

Germany, India, Japan, and the United States were the highest-ranking states. In the United States, for example, a national target was set in 2012 to install of 40 GW of new CHP capacity by 2020. The Department of Energy supports this goal by providing dedicated technical assistance to stakeholders across the country and the government offers a federal tax credit for 10 % of CHP project costs (although the credit is currently set to expire December 31, 2016). While only a few countries have established a target specific to CHP, many more have incentives in place to support CHP. Our research indicates no evidence of a national policy to promote CHP in Australia, Indonesia, Russia, Saudi Arabia, Spain, Turkey, Brazil and Thailand.

Conclusion

As we have seen in this analysis, many of the world's largest energy consumers have implemented policies and programs to improve the energy efficiency of their industrial sectors. Germany, Japan, and the UK earned the highest preliminary scores across our 10 metrics and these countries demonstrate a variety of successful approaches to reducing energy use in industry. While some countries are clearly outperforming others, it is also evident that all countries have substantial room for improvement. The highest score obtained was 21 out of 25 points and the average score was just 14. With significant opportunities to improve, countries may look to a number of the best practices and policy approaches identified in this analysis and learn from one another to achieve greater energy efficiency in the industrial sector.

A parallel objective of this analysis was to take a careful look at where the US stands, and its industrial sector ranked 12th place and scored marginally above average when compared to other countries. The US scored well for its policies encouraging investment in CHP and for having one of the highest levels of investment in industrial R&D, second only to Japan. To improve its ranking, the US could expand the scope of voluntary partnerships between the government and large manufacturers, which is a strategy other top-scoring countries have pursued. The federal government could set targets for reductions in industrial energy use and consider incentivizing the adoption of a globally recognized standard for energy management, such as ISO 50001. Increased participation by large manufacturers in the U.S. Department of Energy's (DOE's) Superior Energy Performance (SEP) program would also strengthen voluntary partnerships to improve energy performance and create more corporate leaders in industrial efficiency. Increasing federal investment in workforce development and training programs such as DOE's Industrial Assessment Centers (IAC) program is another strategy that could lead to increased energy savings.

We hope these findings help generate discussion among stakeholders on how to make more progress reducing energy use in industry globally. The comparisons drawn and best practices identified here can be a useful first step in facilitating future partnerships and knowledge transfer between countries. Through greater understanding and information sharing, all nations can learn how to use energy more efficiently and create cleaner, more competitive industries while wasting fewer natural resources than ever before.

11. ISIC Rev. 4 code 26 includes the manufacture of computers, computer peripherals, communications equipment, and similar electronic products, as well as the manufacture of components for such products. ISIC Rev. 4 code 29 includes the manufacture of motor vehicles for transporting passengers or freight and the manufacture of various parts and accessories.

References

4E (Energy Efficient Energy-use Equipment). 2015. *Energy efficiency roadmap for electric motors and motor systems.* Paris, France: International Energy Agency (IEA). https://www.motorsystems.org/files/otherfiles/0000/0184/4e_roadmap_for_motors_and_vfd_oct2015.pdf.

ABB. 2012. *Japan Energy Efficiency Report*. Zurich, Switzerland: ABB. https://library.e.abb.com/public/cd8e2662ae4b1340c12579d0004f1b13/Japan%20Energy%20efficiency%20Report.pdf.

Brunner, C. P. Waide, and M. Jakob. 2011. *Harmonized Standards for Motors and Systems: Global progress report and outlook.* https://www.motorsystems.org/files/otherfiles/0000/0080/brunner_global_progress_12092011.pdf.

BMWI (Bundesministerium für Wirtschaft und Energie). 2015. "Gabriel: Cabinet decision on the promotion of cogeneration strengthens efficient heat and power supply." September 23. http://www.bmwi.de/DE/Presse/pressemitteilungen,did=727468.html.

CLASP. 2016. Global Standards and Labeling Database. Accessed April 12. http://clasp.ngo/en/Tools/Tools/SL_Search.

DECC (Department of Energy & Climate Change). 2015. *Energy Consumption in the UK.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449108/ECUK_Chapter_4_-_Industrial_factsheet.pdf.

Di Santo, Dario. 2006. *Evaluation of the Energy Manager Program (Italy)*. http://www.ecofys.com/files/files/aid-ee-2006-evaluation-energy-manager-programme-italy.pdf.

EIA (Energy Information Agency). 2015. "Frequently Asked Questions: How Much Energy is Consumed in the World by Each Sector?" Accessed February 2016. https://www.eia.gov/tools/faqs/faq.cfm?id=447&t=1.

Eichhammer and Rohde 2016. *Enhancing the Impact of Energy Audits and Energy Management in the EU: A Review of Article 8 of the Energy Efficiency Directive.* Stockholm, Switzerland: European Council for an Energy-Efficient Economy. http://www.eceee.org/policy-areas/Industry/eceee-report-article-8-review-corrected.

Energy Efficiency Watch. 2015. *Survey Report 2015: Progress in energy efficiency policies in the EU Member States – the experts perspective*. http://www.energy-efficiency-watch.org/fileadmin/eew_documents/EEW3/Survey_Summary_EEW3/EEW3-Survey-Report-fin.pdf.

European Commission (Ed.) 2016. *A Study on Energy Efficiency in Enterprises. Energy Audits and Energy Management Systems. Report on the fulfilment of obligations upon large enterprises, the encouragement of small- and medium-sized companies and on good-practice*. https://ec.europa.eu/energy/sites/ener/files/documents/EED-Art8-Implementation-Study_Task12_Report_FINAL-approved.pdf.

IEA (International Energy Agency). 2016. "Statistics Search: Balances for 2013." Paris, France: IEA. http://www.iea.org/statistics/statisticssearch/.

IEA (International Energy Agency). 2013. *Energy Policies of IEA Countries: Germany 2013 Review.* Paris, France: IEA. http://www.iea.org/publications/freepublications/publication/Germany2013_free.pdf.

IEA CHP and DHC Collaborative (International Energy Agency Combined Heat and Power and District Heating and Cooling Collaborative). 2013. *CHP/DHC Country Scorecard: Japan*. Paris, France: IEA. https://www.iea.org/publications/insights/insightpublications/IEAJapanScorecardMASTERFINALdraft_060913_AF.pdf.

IIP (Institute for Industrial Productivity). 2016a. "GE-2: Voluntary agreements with German industry." Industrial Efficiency Policy Database. Accessed April 12. http://iepd.iipnetwork.org/policy/voluntary-agreements-german-industry.

IIP (Institute for Industrial Productivity). 2016b. "GE-5:CHP Law (Kraft Wärme Kopplungsgesetz)." Industrial Efficiency Policy Database. Accessed April 12. http://iepd.iipnetwork.org/policy/chp-law-kraft-w%C3%A4rme-kopplungsgesetz.

IIP (Institute for Industrial Productivity). 2016c. "JP-3: Mandatory energy efficiency benchmarking in industry." Industrial Efficiency Policy Database. Accessed April 12. http://iepd.iipnetwork.org/policy/mandatory-energy-efficiency-benchmarking-industry.

ISIC (International Standard Industrial Classification). 2016. "Detailed structure and explanatory notes, ISIC Rev.4 code A." Accessed April 18. http://unstats.un.org/unsd/cr/registry/regcs.asp?Cl=27&Lg=1&Co=A.

ISO (International Organization for Standardization). 2014. "ISO Survey." Accessed April 12. http://www.iso.org/iso/iso-survey.

Lu, H., L. Price, A. Thekdi, S. Nimbalkar, M. DeGroot, and S. Jun. 2014. "Energy Assessments under the Top 10,000 Program – A Case Study for A Steel Mill in China." In Proceedings of the 2014 eceee Industrial Summer Study on Energy Efficiency. Stockholm, Sweden: eceee. http://proceedings.eceee.org/visabstrakt.php?event=4&doc=1-014-14.

McKane, A. D. Desai, M. Matteini, W. Meffert, R. Williams, and R. Risser. 2009. "Thinking Globally: How ISO 50001 – Energy Management Can Make Industrial Energy Efficiency Standard Practice." In *Proceedings of the ACEEE 2009 Summer Study on Energy Efficiency in Industry.* Washington, DC: ACEEE. http://aceee.org/files/proceedings/2009/data/papers/5_79.pdf.

ODYSEE-MURE. 2016. "Key Indicators." Accessed June 13. http://www.indicators.odyssee-mure.eu/online-indicators.html.

OECD-Eurostat (Organisation for Economic Co-Operation and Development). 2016. "Joint OECD-Eurostat international data collection on resources devoted to RD." Accessed April 18. http://stats.oecd.org/Index.aspx?DataSetCode=BERD_INDUSTRY_ISIC4.

Tharakan, Pradeep. 2015. *Summary of Indonesia's Energy Sector Assessment*. Manila, Philippines: Asian Development Bank. http://www.adb.org/sites/default/files/publication/178039/ino-paper-09-2015.pdf.

UK Environment Agency. 2016a. "Climate Change Agreements." Accessed June 13. https://www.gov.uk/guidance/climate-change-agreements--2.

UK Environment Agency. 2016b. *2010 to 2015 government policy: energy demand reduction in industry, business and*

the public sector. February 2016. https://www.gov.uk/government/publications/2010-to-2015-government-policy-energy-demand-reduction-in-industry-business-and-the-public-sector.

Waide, P. and C. Brunner. 2011. *Energy-efficiency policy opportunities for electric motor-driven systems.* Paris, France: International Energy Agency. https://www.iea.org/publications/freepublications/publication/EE_for_ElectricSystems.pdf.

WEC (World Energy Council). 2016a. Energy Efficiency Indicators: Energy Intensity of Agriculture. Accessed January 2016. https://www.wec-indicators.enerdata.eu/agriculture-energy-intensity.html.

WEC (World Energy Council). 2016b. Energy Efficiency Indicators: Share of CHP in power capacity. Accessed January 2016. https://www.wec-indicators.enerdata.eu/industrial-chp.html#/chp-power-capacity.html.

Werle, Rita. 2015. (Program coordinator of the IEA 4E Electric Motor Systems Annex) Personal communication. August 2015.

World Bank. 2016a. "Population (Total)." Accessed September 2015. http://data.worldbank.org/indicator/SP.POP.TOTL.

World Bank. 2016b. "GDP at market prices (current US$)." Accessed April 18. http://data.worldbank.org/indicator/NY.GDP.MKTP.CD/countries?display=default.

World Bank. 2016c. "Industry, value added (% of GDP)." Accessed April 18. http://data.worldbank.org/indicator/NV.IND.TOTL.ZS?display=default.