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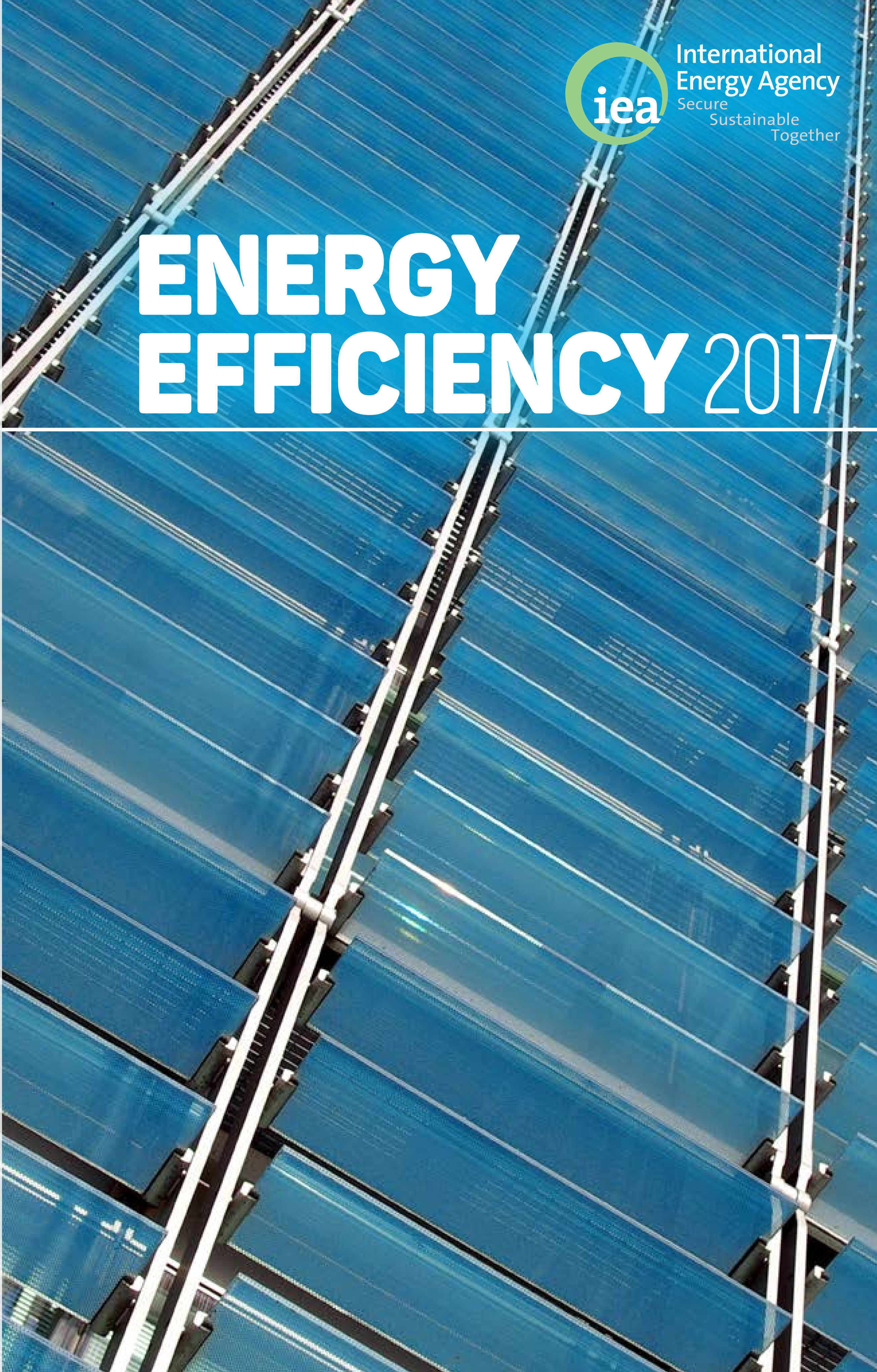
ENERGY EFFICIENCY 2017



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The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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ENERGY EFFICIENCY 2017

FOREWORD

Energy efficiency stands at a crossroads today. Strong efficiency gains continued to be made in 2016, even as energy prices fell. But at the same time, governments are not coming up with new policies fast enough, relying on existing regulations instead, precisely at the time when a pipeline of new efficiency policies should be coming into force. There is a risk that efficiency gains could take a step back.

This issue is all the more important when you consider the impact that efficiency is already having on the global energy system. This year, our report highlights the many ways in which energy efficiency is bolstering energy security, reducing energy spending and helping the environment. Notably, improved energy intensity has been the biggest factor behind the recent flattening of global greenhouse gas emissions. The arguments for stronger action on energy efficiency have never been clearer.

The IEA's *Efficiency Policy Progress Index* allows a deeper examination of the dynamics of global policy trends. It reveals very different rates of progress across countries and an increasing reliance on pre-existing policies to drive energy efficiency improvement. There was a noticeable slowdown in the implementation of new policies in 2016, and this trend appears to be continuing in 2017. And yet there is plenty of scope for further policy action. Over 68% of the world's energy use is not covered by efficiency codes or standards. Only four countries regulate the energy efficiency of trucks, a major source of fuel demand as well as emissions growth, and space-cooling demand is rising fastest in countries with the weakest air conditioning efficiency regulation.

Technological innovation is creating new opportunities for progress on efficiency. Digitalization is beginning to have a significant impact on the energy sector and energy efficiency is emerging as a key arena for innovation. It is creating exciting new opportunities for integrated solutions where efficiency and renewable energy work together to deliver clean energy outcomes at the lowest cost. As business models adapt to the digital energy world, so too must policy.

A key lesson from this report is that well-designed policy works. We are seeing plenty of good examples from all over the world and that is why the IEA is putting more emphasis on best practice policy exchange and helping countries learn from one another to focus on attacking the remaining 68% of global energy use not covered by codes or standards. This is the reasoning behind our new *Global Exchange Platform for Energy Efficiency,* which I am confident will help people better understand energy efficiency trends and the policies that shape them.

Dr Fatih Birol

Executive Director

International Energy Agency

ACKNOWLEDGEMENTS

The IEA's renamed *Energy Efficiency 2017* was prepared by the Energy Efficiency Division (EEfD) of the International Energy Agency (IEA) under the direction of Brian Motherway, Head of EEfD, within the Directorate of Energy Markets and Security, led by Keisuke Sadamori. Samuel Thomas and Joe Ritchie co-ordinated and authored the report along with Jae Sik Lee, Sacha Scheffer, Peter Lemoine, Brian Dean, Jessica Glicker, Aang Darmawan and Julie Cammell. Former IEA colleagues Tyler Bryant (Fortis BC) and Fabian Kreuzer (UN-ESCAP) also made valuable contributions.

This report benefited from important contributions from IEA colleagues including Laszlo Varro, Duncan Millard, Peter Fraser, Aad Van Bohemen, Laura Cozzi, Tim Gould, Melanie Slade, Pierpaolo Cazzola, Araceli Fernandez-Pales, Roberta Quadrelli, Urszula Ziebinska, Gianluca Tonolo, Elie Bellevrat, Stéphanie Bouckaert, Toshiyuki Shirai, Simon Bennett, John Dulac, Simon Keeling, Yoko Nobuoka, Sylvia Beyer, David Morgado, Jeremy Sung, Lucy Shedden, Kira West, Jacob Teter, Xi Xie, Zakia Adam, Marine Görner, Renske Schuitmaker and Sebastian Ljungwaldh. Mark Ellis, Hans-Paul Siderius, Stuart Jeffcott, Maarten van Werkhoven, Steven Beletich and members of the Executive Committee from the IEA Technology Collaboration Programme on Energy Efficient End-use Equipment (4E) provided valuable analysis and commentary.

Thanks to Lorcan Lyons, Trevor Morgan (Menecon) and Andrew Johnston (Words for Change) for review, writing and editing support; Rachael Boyd, Elizabeth Spong, Morgane Le Bagousse and Bérengère Merlo for legal counsel; and the IEA Communications and Information Office, in particular Rebecca Gaghen, Jad Mouawad, Astrid Dumond, Katie Russell, Christopher Gully, Robert Stone, Bertrand Sadin and Therese Walsh, for assistance in finalising the report.

Issue experts and external contributors to boxes and other content were: Takuma Inamura (Ministry of Foreign Affairs, Japan), Peter Therkelsen (LBNL), Arlan Brucal (Grantham Research Institute), Gale Boyd (Duke University), Amandine Denis and Wei Sue (Climate Works Australia), Catherine Cooremans (University of Geneva), Cristina Cardoso and Joao Pedro Correia Bernardo (Directorate General of Energy and Geology, Portugal), Rob Youngs (Coalition for Green Capital), Steven Richardson (World Green Building Council), Camille Frandon-Martinez (Climate Bonds Initiative), Kristina Klimovich (PACEnow), Holmes Hummel (Clean Energy Works), Neelima Jain (EESL), Lily Zhao (EMCA), Donald Gilligan (NAESCO), Paolo Bertoldi (JRC), Satish Kumar (AEEE), Paul Kearney (SUSI Partners AG), Enrico Biele (FIRE), Dario Di Santo (FIRE), Domenico Rotiroti (GSE), Elodie Trauchessec (Adème), Ashok Kumar (BEE) and Matt Golden (OpenEE).

The Indonesia chapter was developed with the assistance of Farida Zed, Harris and Gita Lestari from the Directorate of Energy Conservation (EBTKE) within the Ministry of Energy and Mineral Resources (MEMR). The Centre for Data and Information Technology (Pusat Data dan Teknologi Informasi, PUSDATIN) also provide data and support. Other contributors were Charles Michaelis (Strategy Development Solutions), John Manoppo (Aperlindo), Yoga Adiwinarto (ITDP), Alief Wikarta (ITS Surabaya), Hakimul Batih (Indonesian Institute for Energy Economics) and Jeffrey Sipma (ECN).

Many reviewers provided valuable feedback on the analysis presented in this report. Thanks are due to: Hans Nilsson (4-fact), Steve Nadel (ACEEE), Laura Van Wie (Alliance to Save Energy), Jon Jutsen (Australian Alliance to Save Energy), Jenny Corry (CLASP), Peter Sweatman (Climate Strategy and Partners), Odon de Buen (CONUEE), Peter Bach (Danish Energy Agency), Tom Bastin (Department of Business, Energy and Industrial Strategy, UK), Albert Dessi, Stanford Harrison, Dayne Thompson and

Vanessa Morris (Department of Environment and Energy, Australia), Murray Birt (Deutsche Bank), Oscar Krabbe (Ecofys), John “Skip” Laitner (Economic and Human Dimensions Research Associates), Chiara Martini and Alessandro Federici (ENEA), Rob Murray-Leach (Energy Efficiency Council), Adrian Joyce (EuroACE), Maciej Grzeszczyk and Diana Barglazan (European Commission), European Council for an Energy Efficient Economy (ECEEE), Phillippe Benoit (Global Infrastructure Advisory), Yang Liu (National University of Singapore), Rod Janssen (independent energy consultant), Gerben Hieminga (ING Commercial Banking), Steve Kukoda (International Copper Association), Benoît Lebot (IPEEC), Sylvain Côté, Anwar Gasim, and Lester Hunt (KAPSARC), Hiromi Sato (Ministry of Economy, Trade and Industry, Japan), Takashi Hongo (Mitsui), Kaili Levesque (Natural Resources Canada), Kathleen Gaffney and Brett Feldman (Navigant), Rodney Boyd (OECD), Harry Verhaar (Philips Lighting), Jan Rosenow (Regulatory Assistance Project), Hannah Murdock (REN21), Amory Lovins (Rocky Mountain Institute), Rurik Holmberg (Swedish Energy Agency), Christian Buehlmann (Swiss Federal Office of Energy), Marcel Alers and Bahareh Seyedi (UNDP), Paul Kellet (UNEP), Lindsay Parker and Jonah Steinbech (United States Department of Energy), Denise Mulholland (United States Environmental Protection Agency) and Kurt Emil Eriksen (Velux).

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The energy intensity of the global economy continues to fall

The world continued to generate more value from its energy use in 2016. Global energy intensity – measured as the amount of primary energy demand needed to produce one unit of gross domestic product (GDP) – fell by 1.8% in 2016. Since 2010, intensity has declined at an average rate of 2.1% per year, which is a significant increase from the average rate of 1.3% between 1970 and 2010. The improvement in intensity varies widely across countries and regions, with China once again having the most significant impact on global trends. This is avoiding huge amounts of energy use, generating financial savings for consumers and holding back the growth in greenhouse gas (GHG) emissions. Despite these positive impacts, there is no room for complacency. Policy performance is mixed and new policy implementation slowed significantly in 2016. The current level of efficiency gains will erode quickly if the pace of policy delivery does not accelerate.

The decline in global energy intensity means that the world is able to produce more GDP for each unit of energy consumed – an energy productivity bonus. Measured as the difference between actual GDP and the notional level of GDP that would have been generated had energy intensity stayed at the previous year's level, this bonus was USD 2.2 trillion in 2016 – equal to twice the size of the Australian economy.

Energy efficiency is helping to reshape the global energy system

In 2016, the world would have used 12% more energy had it not been for energy efficiency improvements since 2000 – equivalent to adding another European Union to the global energy market. In emerging economies, energy efficiency gains have limited the increase in energy use associated with economic growth. Without efficiency, total energy use among the member countries of the International Energy Agency (IEA) would still be increasing. Instead, efficiency has led to a peak in total energy use in 2007, and a subsequent fall to levels not seen since the 1990s.

Falling energy intensity is the main factor behind the flattening of global energy-related GHG emissions since 2014. Lower energy intensity, driven largely by efficiency improvements, is combining with the ongoing shift to renewables and other low-emission fuels to offset the impact of GDP growth on emissions.

In addition to the environmental benefits, energy efficiency is bolstering energy security. Efficiency improvements since 2000 avoided additional spending on energy imports in many countries. In Japan, for example, oil imports would have been 20% higher in 2016 and gas imports 23% higher had those efficiency gains not been achieved. In Germany and the United Kingdom, Europe's largest gas markets, energy efficiency improvements resulted in gas savings equivalent to 30% of Europe's total imports from Russia. Efficiency has also improved short-term energy security by reducing peak daily gas demand. Without energy efficiency improvements over the same period, the United Kingdom and France would have needed access to an additional 240 million cubic metres of daily gas supply during periods of peak demand, equivalent to more than five times the daily withdrawal capacity of the United Kingdom's largest gas storage site, in order to maintain current levels of short-term security.

Improved energy efficiency has reduced household expenditure on energy

Energy efficiency gains helped households across the world save 10 to 30% of their annual energy spending in 2016. For example, in Germany the amount that consumers spent on energy for their homes and cars in 2016 was nearly USD 580 per capita lower due to energy efficiency. Savings are also being made in large emerging economies, where demand for energy services is growing. For example, on average, Chinese households would have spent 25% more on energy in 2016 if not for efficiency.

Industrial energy efficiency has improved, with use of energy management systems increasing

Energy use per unit of economic output in the industrial sector fell by nearly 20% between 2000 and 2016. The magnitude of the declines is similar both in IEA member countries and major emerging economies. In some energy-intensive industries, such as aluminium smelting and cement manufacturing, average efficiency has improved sharply as a result of rapid expansion in production capacity, especially in emerging economies, since new facilities tend to be much more efficient than old ones. In these industries, efficiency gains help reduce the impact of volatile energy prices on competitiveness.

The application of energy management systems, which provide a structure to monitor energy consumption and identify opportunities to improve efficiency, is growing, driven by policy and financial incentives. The number of certifications for ISO 50001 – a global standard for energy management developed by the International Organization for Standardization in 2011 – grew to nearly 12 000 in 2015, 85% of which were in Europe. Early evidence suggests that companies that implement ISO 50001 or similar standards can achieve annual energy and financial savings of over 10% and other benefits including improved management of other production inputs.

Buildings' energy efficiency has improved, but far more is possible

Energy efficiency in buildings continues to improve, thanks to policy action and technological advances. Policies have focused primarily on the building envelope, rather than heating and cooling equipment. There is considerable potential to achieve further energy savings by establishing or strengthening standards. Efficiency improvements of 10% to 20% are possible in most countries from appliances, equipment and lighting products that are already commercially available. There is strong global momentum towards more efficient lighting; by 2022, 90% of indoor lighting worldwide is expected to be provided by compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs).

The motor vehicle market is changing rapidly, driven by policy, technology and fuel prices

Fuel efficiency standards for trucks, which represent 43% of total oil consumption for road transport, have come on the radar for policy makers. In 2016, only 16% of the energy use of trucks worldwide was covered by mandatory efficiency policies. Fuel economy standards are in place in only four countries – Japan, China, the United States and Canada. The European Union, India, Korea and Mexico are expected to introduce standards in the coming years.

Worldwide sales of electric vehicles, which are much more efficient than internal combustion engine vehicles, grew by 40% in 2016 due to an expansion in production capacity, a bigger range of models and improved vehicle performance. However, lower gasoline prices led to increased sales of less efficient large passenger vehicles, especially sports utility vehicles, which is dampening the global rate of improvement in passenger vehicle fuel-efficiency.

The global energy efficiency market continued to expand in 2016

Global investment in energy efficiency increased by 9% to USD 231 billion in 2016, maintaining the upward trend of recent years. The rate of growth was strongest in China at 24%, though Europe is still responsible for the largest share of global investment (30% of the total). Among end-use sectors, buildings still dominate energy efficiency investment, accounting for 58% of the world total in 2016, with most investment in that sector going to building envelopes, appliances and lighting.

The global energy service company (ESCO) market expanded by 12% to USD 26.8 billion in 2016. China has by far the largest market, making up over 60% of global revenues, thanks to strong government incentives. The United States (20%) and Europe (10%) are the other two major ESCO markets. Over 1 million people are now employed by ESCOs around the world.

Energy efficiency has become a tradeable commodity in several countries. In 2016, changes in policy drove up the market value of energy savings substantially in France and Italy, the world's two biggest markets where savings, in the form of white certificates, are traded. In 2016 and early 2017, a record amount of demand savings from energy efficiency was also accepted in the two biggest electrical capacity auctions in the United States. Digital technology is expected to enhance the ability for energy efficiency to participate in electricity markets.

The deployment of connected devices is growing, which will impact energy efficiency

By the end of 2016, 4 billion connected devices were in use by households worldwide. Another 1 billion devices are expected to be brought into use in 2017, a rate that may triple by 2020. These devices, which can be connected to networks and other devices, provide new opportunities for energy savings through more accurate control of consumption. By the end of 2016, half a billion smart meters, which track and display electricity use in real time, had been or were contracted to be installed. Among other benefits, smart meters can complement connected devices, allowing consumers to adjust energy use in response to changes in energy price.

Policy implementation slowed in 2016, putting future energy efficiency gains at risk

Over 68% of global final energy use remains uncovered by policies that mandate energy efficiency improvements. Mandatory policies either stipulate the minimum energy performance levels that appliances and equipment must meet in order to enter the market, or require efficiency targets to be met by firms or economic sectors. Global coverage grew by 1.4 percentage points in 2016; however, in stark contrast with previous years, nearly all the 2016 increase was due to the continuing impact of existing policies, as old energy-using equipment was replaced. Just 1.5% of the increase was due to new policies, an historic low, with the only additions coming through air conditioning standards in Indonesia and refrigerator and freezer standards in China.

The strength of mandatory efficiency policies also increased at its lowest rate in recent years. While several governments around the world continued to strengthen standards for heavy- and light-duty vehicles, few did so to any significant degree in other sectors in 2016. The most significant change was a tightening of space heating standards in Denmark and Germany.

Overall policy progress in 2016 was the slowest since 2009. The IEA Efficiency Policy Progress Index (EPPI), which measures changes in the coverage and strength of mandatory energy efficiency policies since 2000, increased by half a point to 6.3 globally in 2016, compared with average increases of around 0.75 since 2010. The slowdown in the EPPI was largely due to fewer new policies coming into force, a trend that continued in the first half of 2017. China, with an EPPI of 10.9 in 2016, has been the global leader in implementing mandatory efficiency policies in recent years, accounting for more than half of the increase between 2000 and 2016, mainly due to policies in the industrial sector. Worldwide, the EPPI would have been just 2.9 without China. Standards for freezers, refrigerators and space heating and cooling have progressed most since 2000, while motor-driven systems, heavy-duty vehicles and clothes dryers have seen the least progress.

Obligations on utilities to deliver energy savings are becoming more common and ambitious, but progress stalled in 2016. Overall, the percentage of global final energy use covered by obligation programmes rose from 7.1% in 2005 to 18.3% in 2016. There was no increase in coverage in 2016, although two new obligations were introduced in Europe in 2017.

Stronger policy development and implementation is essential if the current level of efficiency gains is to be maintained or accelerated. 2016 was a poor year for policy progress and so far 2017 has not seen significant developments either. If stated policy ambitions are to be met, governments must recognise the importance of developing and putting into force new and more ambitious policies.

There is great potential to boost energy efficiency in Indonesia

Indonesia, which is the subject of a special focus in *Energy Efficiency 2017*, is the largest energy consumer in Southeast Asia. Economic growth is expected to continue to drive up Indonesia's energy needs. Efficiency will be essential to avoid unnecessary energy use and expenditure. Implementing and enforcing current energy efficiency policies is expected to reduce energy use by 2% by 2025. Enhancing existing policies and implementing all planned policies could further reduce energy use by 4.5% compared with a scenario with no policy change. Without such action, an additional 4.1 GW of electricity generation capacity would be needed each year to 2025. Beyond such action, there remains considerable scope for even bigger savings from energy efficiency.

Significant electricity savings are possible by further improving the energy efficiency of lighting and space cooling. Switching to CFLs with the help of government programmes over the past decade saved Indonesian consumers USD 3.3 billion on their electricity bills in 2016. LEDs are now taking a growing market share. If the current rate of LED adoption continues, Indonesian consumers could save nearly USD 560 million per year by 2030. Demand for space cooling is likely to double between 2016 and 2020. A performance standard was introduced in 2016, but its current levels are not having a substantial effect on the market. There is considerable scope for improving the minimum energy performance standard for air conditioners. Accelerating progress to keep pace with shared targets within Southeast Asia could save Indonesian consumers nearly USD 690 million per year by 2030.

There is considerable potential to improve energy efficiency in the transport sector by encouraging the uptake of electric motorcycles and adopting fuel efficiency standards for trucks. Motorcycles are the leading form of passenger transport in Indonesia. If the penetration of electric two-wheelers was boosted to match the current level in China, Indonesia would avoid USD 800 million of oil imports in 2030 compared with current projections. Trucks account for 40% of Indonesia's total road transport energy use. If fuel efficiency standards that improved efficiency at the same rate as in China were introduced, USD 630 million in oil imports could be avoided in 2030 alone. Together, these two measures would reduce energy use in 2030 by over 75 000 barrels of oil per day, equivalent to 13% of Indonesia's current net oil imports.

1. ENERGY EFFICIENCY TRENDS AND INDICATORS

Highlights

- **Global energy intensity – primary energy demand per unit of gross domestic product (GDP) – fell by 1.8% in 2016.** Since 2010, intensity has declined at an average rate of 2.1% per year, which is a significant increase from the average rate of 1.3% between 1970 and 2010. The rate of intensity improvement varies widely across countries and regions; energy intensity improved faster in China than in other major economies. Without China, global energy intensity would have improved by only 1.1% in 2016.

- **The fall in global energy intensity means that the world is able to produce more GDP for each unit of energy consumed – an energy productivity bonus**. This bonus was USD 2.2 trillion in 2016 – equal to twice the size of the Australian economy. Owing to its big fall in intensity and the sheer size of its economy, China accounted for half of this bonus, with the United States contributing another quarter.

- **Falling energy intensity is the main factor behind the flattening of global energy-related greenhouse gas (GHG) emissions since 2014, offsetting three-quarters of the impact of GDP growth.** An increase in the share of renewable energy and other low-emission fuels was responsible for offsetting the other quarter.

- **Without efficiency improvements since 2000, the world would have used 12% more energy than it did in 2016 – equivalent to adding another European Union to the global energy market.** Improvements in energy efficiency are the biggest contributor to reduced energy use and emissions, more than double the impact of the shift in economic activity towards less energy-intensive sectors.

- **In emerging economies, energy efficiency gains have limited the increase in energy use associated with rapid economic growth.** Without efficiency, total energy use among the member countries of the International Energy Agency (IEA) would still be increasing. Instead, efficiency has led to a peak in total energy use in 2007, and a subsequent fall to levels not seen since the 1990s.

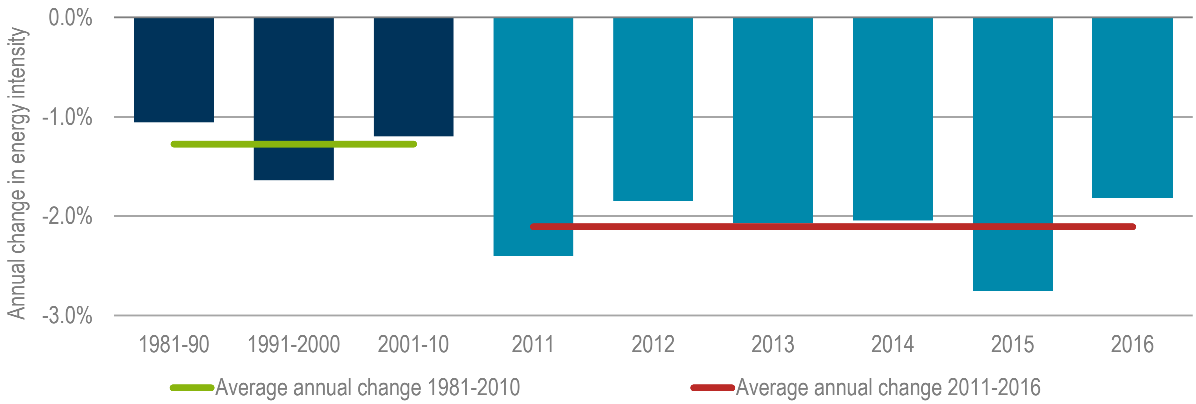
- **Energy efficiency has made a big contribution to strengthening energy security.** Efficiency improvements since 2000 avoided additional spending on energy imports in many countries. In Japan, for example, oil imports would have been 20% higher in 2016 and gas imports 23% higher had those efficiency gains not been achieved. In the United Kingdom and France, energy efficiency gains contributed to reducing the daily supply capacity needed to maintain current levels of short-term gas security.

Global trends in energy intensity

The energy intensity of the global economy continues to fall

Global energy intensity – measured as primary energy demand[1] per unit of GDP at 2016 US dollars (USD) on a purchasing power parity (PPP) basis – fell by 1.8% in 2016.[2] This decline continued the recent trend of steady improvement.[3] Although it was lower than that in 2015, it was a significant increase on averages seen in preceding decades (Figure 1.1). While GDP grew by 3% in 2016, global energy demand increased by only 1.1%.

Figure 1.1 Annual changes in global primary energy intensity, 1981-2016



Note: Energy intensity is calculated as primary energy demand per USD 1 000 of GDP in 2016 prices at purchasing power parity.

Sources: Adapted from IEA (2016a), *World Energy Outlook 2016*; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Trends in energy intensity vary widely among countries and regions. In the People's Republic of China (hereafter "**China**"), energy intensity fell by 5.2%, reflecting strong economic growth with minimal increase in energy demand. The size of the Chinese economy and its energy consumption means that it has a big impact on global energy intensity trends. Without China, the fall in global intensity in 2016 would have been only 1.1%.

Energy intensity improved by 2.9% in the **United States** and by 1.3% in the **European Union**. The fall in energy intensity was less marked in other parts of the world (Figure 1.2).

Final energy intensity – measured as total final energy consumption[4] per unit of world GDP, in 2016 USD on a PPP basis – has followed a similar trend to that for primary energy intensity. In 2016, final energy intensity fell by 1.5%. This rate of improvement was lower than in 2014 and

[1] Equivalent to total primary energy supply (TPES).

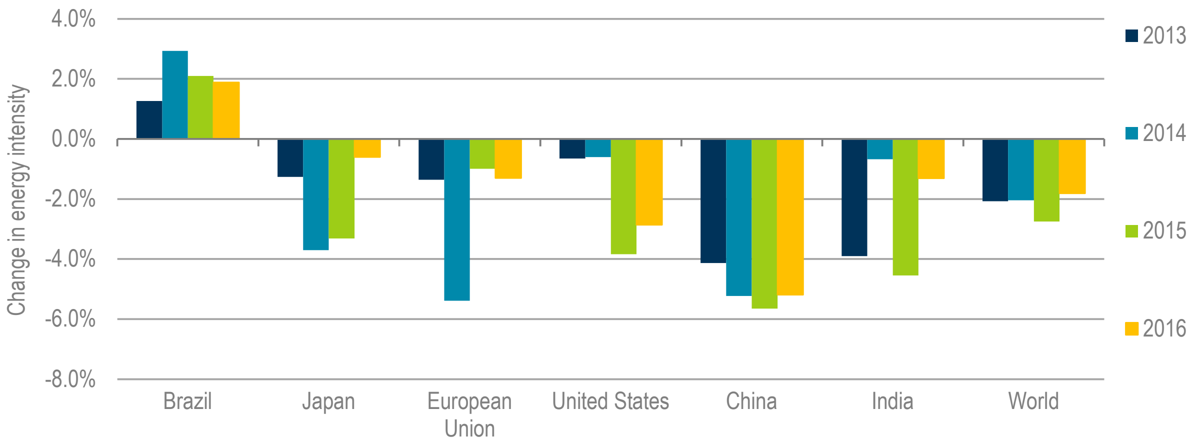
[2] All primary energy demand (TPES) and final energy use (TFC) data for 2016 are preliminary.

[3] In *Energy Efficiency 2017*, changes in energy intensity are presented on the basis of energy per unit of gross domestic product (GDP) at purchasing power parity (PPP) in 2016 prices. In previous editions, GDP was defined at market exchange rates at 2010 prices. This results in annual changes in global energy intensity higher than those presented in the past. For example, the change in global energy intensity in 2015, with GDP defined at market exchange rates, was 2.4%. Global energy demand data for 2015 have also been revised downwards, resulting in a larger improvement in global energy intensity than in the IEA *Energy Efficiency Market Report 2016*.

[4] Also referred to as total final consumption (TFC).

2015, but similar to primary energy intensity. The average rate of improvement since 2011 (1.9%) is higher than that in preceding decades (1.6%).

Figure 1.2 Change in primary energy intensity in selected countries and regions



Sources: Adapted from IEA (2016a) *World Energy Outlook 2016*; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Box 1.1 Energy intensity as an indicator of energy efficiency

Energy intensity is a measure of the amount of energy used to produce a unit of output. If data are available, it can be calculated for any economic sector or production process. The headline energy intensity indicator used in this report is calculated at the highest level of aggregation – primary energy demand per unit of global GDP, i.e. the amount of energy needed before it is converted into end-use fuels such as electricity and gasoline.

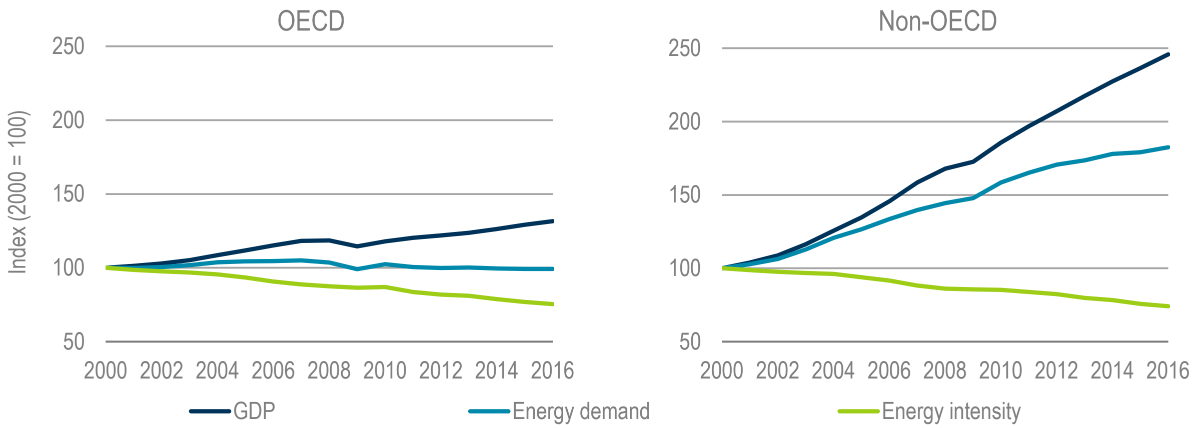
Changes in global primary energy intensity are influenced by improvements in energy efficiency as well as changes in economic structure, such as the movement of economic activity away from energy-intensive industry towards less intensive service sectors. Reductions in global energy intensity are therefore not solely an indication of energy efficiency improvements. Decomposition analysis, as presented later in this chapter, is used to more accurately determine changes in energy efficiency and its impact on global energy use.

Intensity has fallen at a similar rate in OECD and non-OECD economies

In OECD countries and non-OECD economies, energy intensity has declined almost without interruption since 2000, averaging 1.6% per year to 2016 (Figure 1.3). In OECD countries, primary energy demand fell by 1%, despite a 32% increase in GDP; in other countries, energy demand rose 80% while GDP increased 150%.

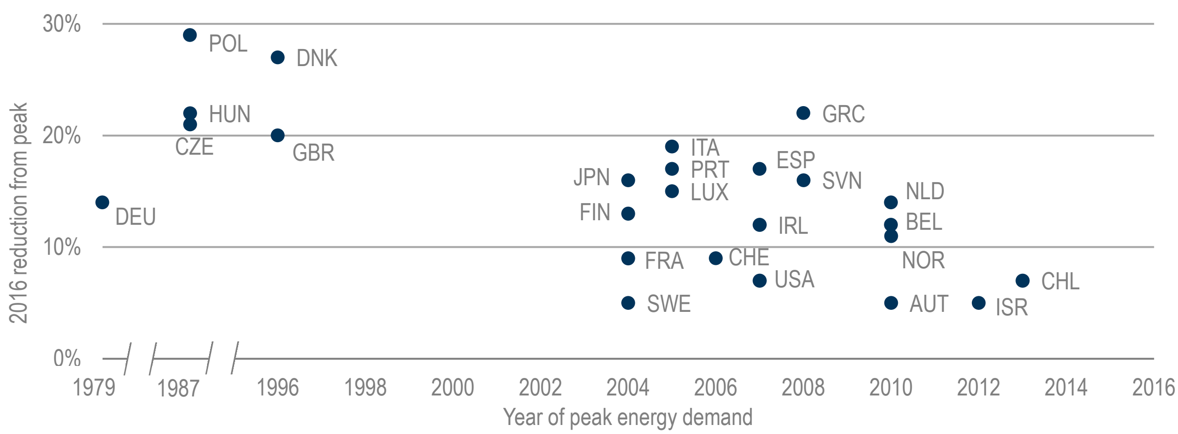
There is clear evidence that energy use has peaked in many advanced economies. Twenty-two IEA member countries, representing more than 80% of IEA primary energy demand, have already reached an historic peak (Figure 1.4). In the majority of countries, this peak occurred between 2005 and 2010. Total energy demand for OECD countries as a whole peaked in 2007.

Figure 1.3 Primary energy demand, GDP and energy intensity by region



Sources: Adapted from IEA (2016a) *World Energy Outlook 2016*; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Figure 1.4 Year of peak energy demand, and reduction in 2016 compared with peak



Note: Countries included are those for which there has been a drop of at least 5% in energy demand that has been maintained for at least two consecutive years.

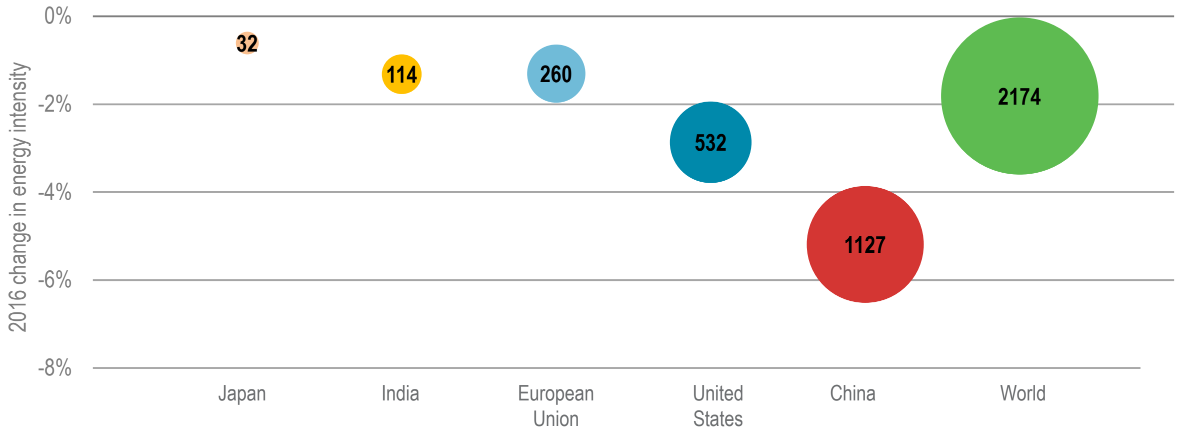
Source: Adapted from IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Intensity gains deliver a big energy productivity bonus

An alternative way of viewing global energy intensity improvements is that they deliver an energy productivity bonus, because the world is able to produce more GDP for each unit of energy demand. Measured as the difference between actual GDP and the notional level of GDP that would have been generated had energy intensity stayed at the previous year's level, in 2016 this amounted to USD 2.2 trillion, or twice the size of the Australian economy (Figure 1.5).

The energy productivity bonus in China was larger than that of any other country, at just over USD 1.1 trillion; in the United States, it amounted to just over USD 500 billion. Combined, the two countries accounted for over three-quarters of the total world bonus.

Figure 1.5 Energy productivity bonus from energy intensity gains, USD billion (PPP), 2016



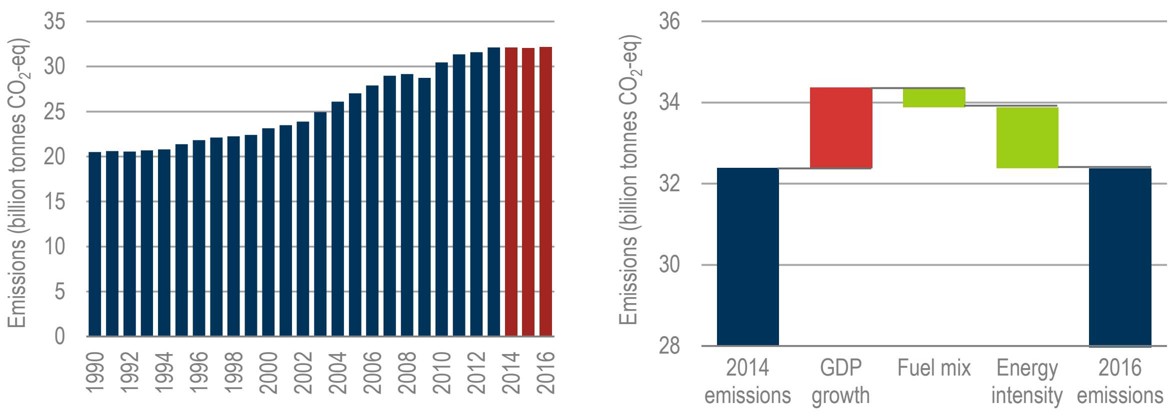
Notes: The energy-productivity bonus is the difference between actual GDP (in PPP terms) and the notional level of GDP that would have been generated had energy intensity stayed at the level of the previous year. Bubble size represents the magnitude of the value.

Source: Adapted from IEA (2016a), *World Energy Outlook 2016*.

Energy intensity gains are holding down greenhouse gas emissions

After decades of consecutive increases, GHG emissions from fuel combustion have been steady at around 32 billion tonnes of carbon-dioxide equivalent ($GtCO_2$-eq) since 2014. This is due to a combination of the decline in energy intensity and the change in the energy mix towards natural gas and renewable energy. Falling energy intensity offset 77% of the impact on global emissions from GDP growth since 2014; the changing fuel mix offset the remaining 23%. This result affirms the vital role of energy efficiency in steadying and reducing emissions (Figure 1.6).

Figure 1.6 Global energy-related GHGs since 1990 (left) and an analysis of the factors that influence GHGs, 2014-16 (right)



Note: Energy intensity is calculated as TPES per thousand USD of GDP in 2016 prices and PPP.

Sources: Adapted from IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics; IEA (2017b), *CO_2 Emissions from Fuel Combustion* (database), www.iea.org/statistics.

The factors affecting energy-related emissions are interlinked. Improvements in energy intensity, which hold down energy demand growth, can lead to an increase in the penetration of renewable energy. In China, for example, recent improvements in energy intensity have reduced energy demand growth to just 1%, while economic growth continued at around 7%. The slowdown in energy demand growth has allowed demand to be met to a greater extent by the continued expansion of renewable energy, leading to an improvement in the carbon intensity of the fuel mix. Increased penetration of renewable energy in turn improves primary energy intensity because renewable generation is more efficient than fossil fuel alternatives, highlighting the complementary nature of energy intensity reductions and renewable energy.

Measuring the impact of energy efficiency on energy use

In this report, decomposition analysis is used to assess the extent to which energy efficiency contributes to changes in final energy use, taking into account a variety of other factors. Within each country for which data are available, changes in energy use are decomposed, by sector, into three distinct effects:

- The growth effect: Changes in the level of economic activity (gross value added, or GVA); population; distance travelled by passengers; and tonne-kilometres travelled by freight.
- The structure effect: Changes in the share of different sub-sectors; appliance ownership rates, floor area and number of dwellings per person; and the share of different modes of transport.
- The efficiency effect: Changes in the amount of energy used per unit of GVA in the industry and services sector, per vehicle-kilometre in passenger transport and per tonne-kilometre in freight transport. In the residential sector, the efficiency effect varies depending on end-use. For heating, cooling and lighting, it is the energy use per unit of floor area; for cooking and water heating, it is energy use per number of dwellings; and for appliances it is energy use per unit of stock.

The efficiency effect constitutes the impact of energy efficiency on final energy use and provides a more accurate reflection of energy efficiency progress. For further details on decomposition analysis, please refer to Annex 1.

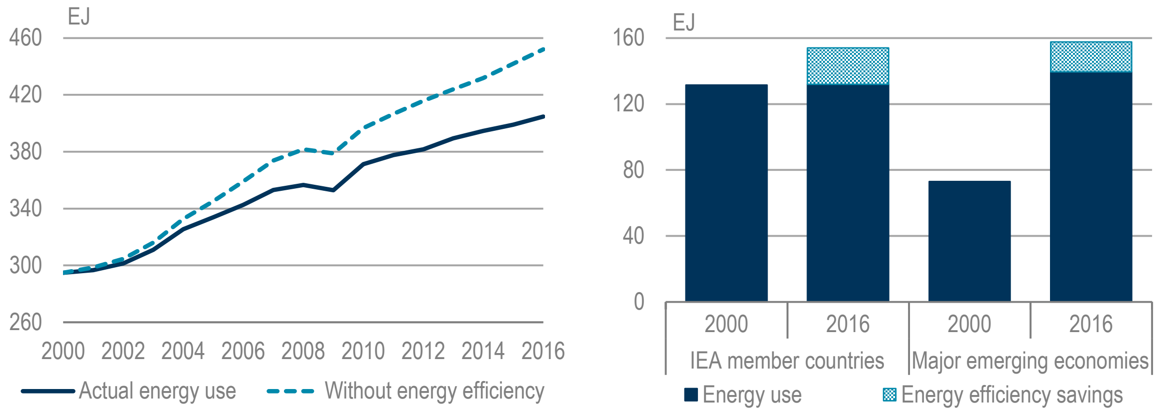
In this report, decomposition analysis covers IEA member countries[5] and six major emerging economies: Brazil, China, India, Indonesia, Mexico and the Russian Federation (hereafter, “Russia”). IEA member countries account for 36% of global final energy use and the six major emerging economies a further 38%.

Energy efficiency reduces energy use worldwide

Globally, energy efficiency improved 13% between 2000 and 2016. Without this improvement, global final energy use in 2016 would have been 12% higher – equivalent to adding the annual final energy use of the European Union to the global energy market (Figure 1.7). Energy savings from efficiency improvements in IEA member countries made up nearly half of the global total, equivalent to the current energy use of Germany, France and the United Kingdom combined, with the major emerging economies accounting for around 40%.

[5] The decomposition analysis for IEA member countries is based on data submitted by member countries. Data for 2015 and 2016 are preliminary, based on IEA analysis.

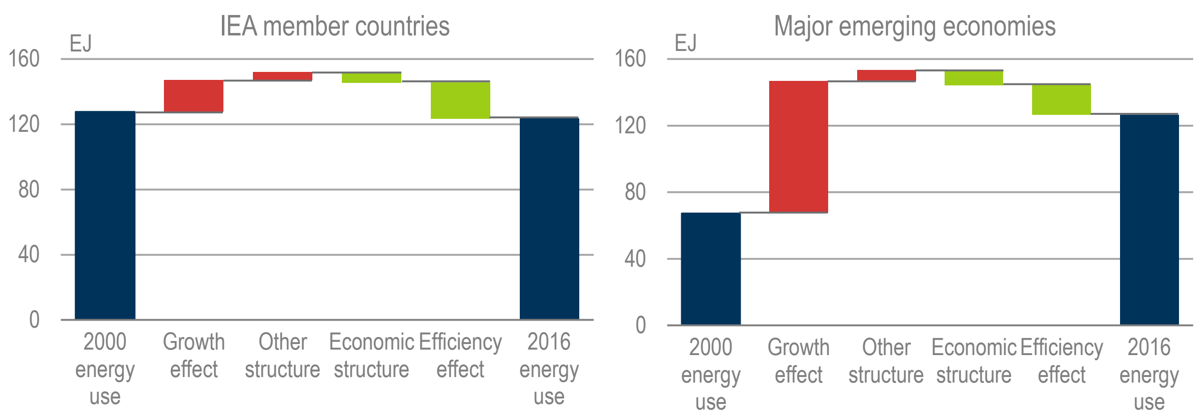
Figure 1.7 Energy use with and without energy savings from efficiency improvements globally (left) and by country grouping (right)



Notes: Global energy savings are a combination of improvements in IEA member countries, the six major emerging economies analysed, plus the rest of the world, which represents 26% of global energy use. Energy savings for the rest of the world are estimated by applying the ratio of efficiency improvements to intensity gains observed in emerging economies to the gains in intensity observed in these other countries.

Sources: Timmer et al. (2015), *World Input Output Database* (database), www.wiod.org; IEA (2017c), *Mobility Model* (database) www.iea.org/etp/etpmodel/transport; and IEA (2017d), *Energy Technology Perspectives 2017* (Residential Model); IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics; and IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics.

Figure 1.8 Decomposition of final energy use in IEA member countries and major emerging economies



Notes: "Energy use" covers the residential, industry and services, passenger and freight transport sectors. It excludes non-energy and energy supply. "Other effects" include changes in residential dwellings, floor space and appliances per capita, and transport modal shifts. "Economic structure" reflects the movement from energy-intensive industry sectors to less intensive service sectors.

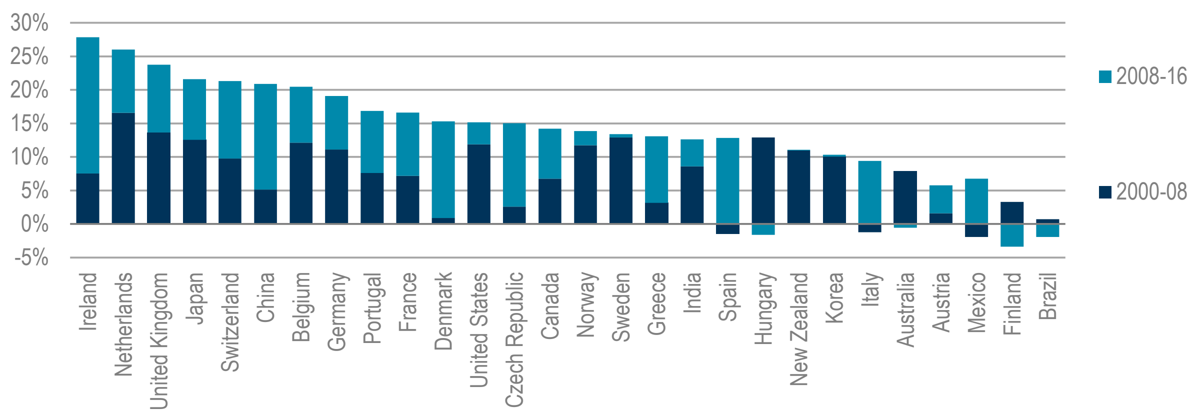
Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; Timmer et al. (2015), *World Input Output Database* (database), www.wiod.org; IEA (2017c), *Mobility Model* (database), www.iea.org/etp/etpmodel/transport; IEA (2017d), *Energy Technology Perspectives 2017* (Residential Model); and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Efficiency gains since 2000 in IEA member countries have more than offset the effect of economic growth, reducing final energy use to levels not seen since 1999. In the six major emerging economies, the efficiency effect has also been significant, offsetting 23% of the impact from economic growth. These trends are illustrated in the decomposition analysis in Figure 1.8, in which dark blue columns represent energy use in 2000 and 2016, red columns show factors that increase energy use, such as economic growth, and green columns show factors that reduce energy use, such as efficiency.

Box 1.2 Recent progress on efficiency by country

The size of the efficiency effect varies across countries (Figure 1.9). Eight of the top ten countries that show the largest improvement in the efficiency effect since 2000 are European, with all except Switzerland covered by the European Union's Energy Efficiency Directive (EED). The difference in improvement rates before and after 2008 also highlights the impact of policy developments, particularly in China, where the influence of the 11th and 12th Five-Year Plans is seen via a 16% improvement in the efficiency effect since 2008.

Figure 1.9 Percentage improvement in the efficiency effect for select countries, 2000-16



Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; Timmer et al. (2015), *World Input Output Database* (database), www.wiod.org; IEA (2017c), *Mobility Model* (database), www.iea.org/etp/etpmodel/transport; IEA (2017d), *Energy Technology Perspectives 2017* (Residential Model); and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Although improvement in the efficiency effect in the United States has been slower than that in China and nine European countries over recent years, efficiency progress commenced long before 2000, particularly vehicle fuel efficiency standards, a major driver of efficiency gains, which have been in place since the 1970s.

Energy efficiency is improving in all end-use sectors

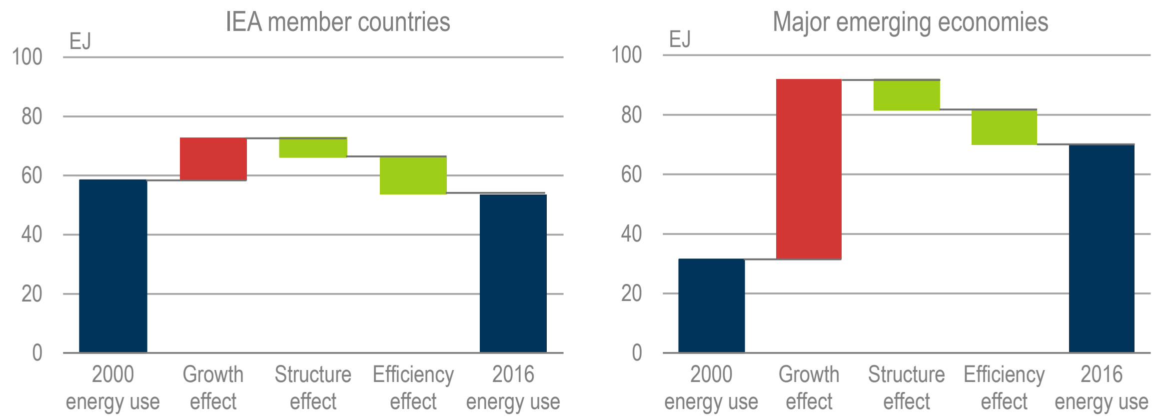
Industry and services sector

Without the combined impacts of energy efficiency and structural change, final energy use in the industry and services sector[6] would have been much higher. The efficiency effect has been more

[6] The industry and services sector is comprised of industry, services, agriculture and, where data are available, fishing.

dominant in IEA member countries, where the growth effect drove up underlying demand for energy services between 2000 and 2016, but this was more than offset by a 20% improvement in energy efficiency and a shift from industry towards the less energy-intensive services sector. These factors drove actual energy use in 2016 down by 8% compared with 2000 (Figure 1.10).

Figure 1.10 Decomposition of final energy use in the industry and services sector by country grouping



Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; Timmer et al. (2015), *World Input Output Database* (database), www.wiod.org; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

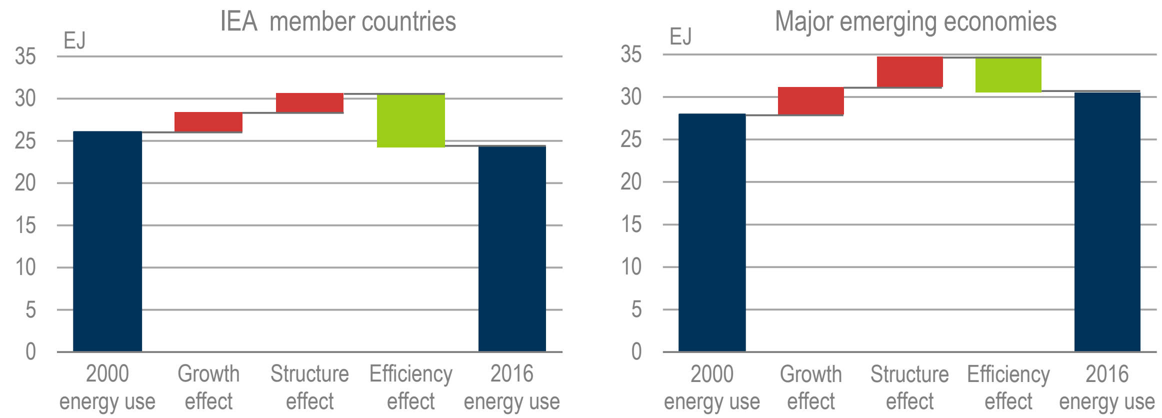
The growth effect was stronger in the major emerging economies, where it boosted demand for energy services by 250% over the same period. A 21% improvement in energy efficiency, heavily influenced by China and India, offset almost one-fifth of the growth effect. The structural effect in the emerging economies was almost as strong as the efficiency effect, offsetting just over 17% of the growth effect. This structural effect has grown over the last five years in particular, largely due to China's shift towards less energy-intensive industry and service activities.

Residential sector

Among all end-use sectors, the effect of energy efficiency gains was strongest in the residential sector. Efficiency gains between 2000 and 2016 were particularly significant in IEA member countries, totalling 22% (Figure 1.11). The growth effect, reflecting population change, boosted demand for energy services by 10%, while structural effects such as increased floor area and ownership of appliances raised demand by 9%. Energy efficiency improvements completely offset these effects, resulting in a 7% net reduction in final energy use. More efficient space heating was a leading contributor, especially in Europe: heating intensity (energy use per floor area) has improved by 45% in Germany and 36% in France since 2000.

In the emerging economies analysed, final energy use was boosted 12% by population growth and 13% by structural effects between 2000 and 2016. Energy efficiency improvements of 13% held the net increase in energy use to 9%.

Figure 1.11 Decomposition of final energy use in the residential sector

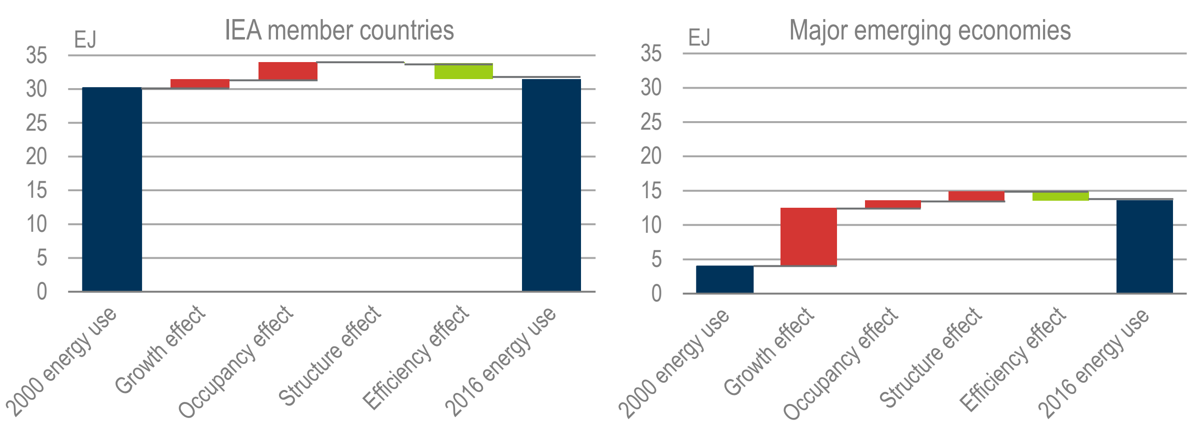


Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; IEA (2017d), *Energy Technology Perspectives 2017* (Residential Model); and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Passenger transport

Efficiency has had less of an impact in the transport sector. The growth effect, reflecting increased demand for mobility, lower occupancy rates in vehicles and structural shifts between modes of transport, drove up final energy use for passenger transport between 2000 and 2016. In IEA member countries, the largest of these effects came from the decrease in the average number of passengers for each vehicle and transport mode, which pushed up energy demand by 8%. Energy efficiency, measured as fuel use per vehicle-kilometre, improved by 7%, largely due to mandatory fuel efficiency policies. However, this was not sufficient to entirely offset other effects, resulting in a net 4% increase in energy use (Figure 1.12).

Figure 1.12 Decomposition of final energy use in the passenger transport sector



Notes: Passenger transport energy use includes passenger motor vehicles, rail, buses and, where data is available, shipping. Air transport (aviation) is excluded.

Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; IEA (2017c), *Mobility Model* (database), www.iea.org/etp/etpmodel/transport; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

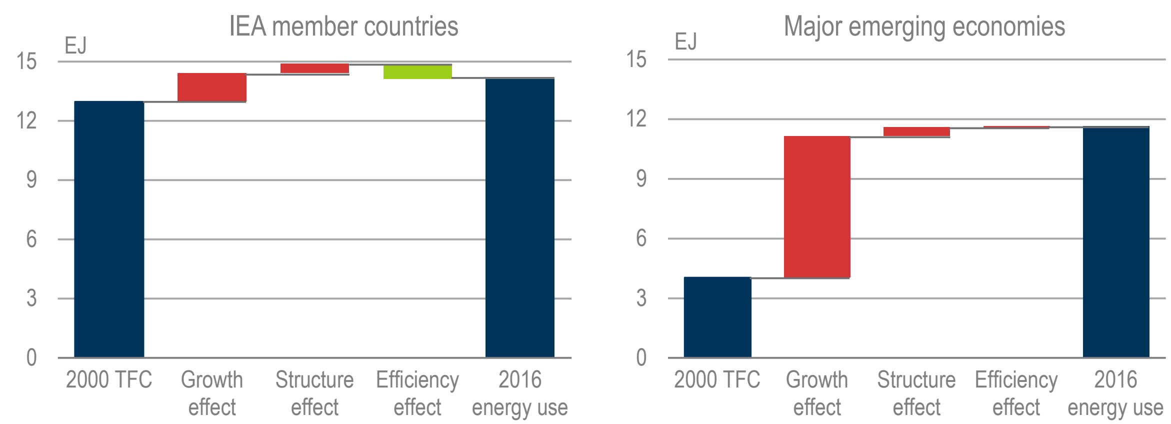
In the major emerging economies, the growth effect was much more dominant, leading to a 180% increase in demand. Fewer passengers per vehicle and increased vehicle ownership reduced average vehicle occupancy, boosting demand by a further 15%, while structure effects, driven by the shift towards the use and ownership of personal vehicles, added another 21%. Energy efficiency improvements, linked to policy and technology, lowered demand by around 15%, offsetting the entirety of the occupancy effect. Nevertheless, net passenger transport energy use more than tripled between 2000 and 2016.

Freight transport

The energy savings from efficiency improvements in the freight transport sector are the smallest of all the sectors analysed, partly because policy efforts to improve the fuel efficiency of heavy-duty vehicles (HDVs) have been limited, though now taking off in several key regions (Figure 1.13).

In IEA member countries, energy efficiency measured as fuel use per tonne-kilometre fluctuated between 2000 and 2016, reflecting changes in freight load and load per vehicle, both of which vary according to economic conditions. Overall, efficiency improved by 5%, which was not sufficient to offset growth and structure effects, resulting in a net 9% increase in final energy use. The growth effect was marked in the emerging economies, increasing by more than 250%. Some structure effects are also apparent, notably a shift from medium- to heavy-duty trucks. Energy efficiency did not improve, in part due to the absence of fuel efficiency policies.

Figure 1.13 Decomposition of final energy use in the freight transport sector



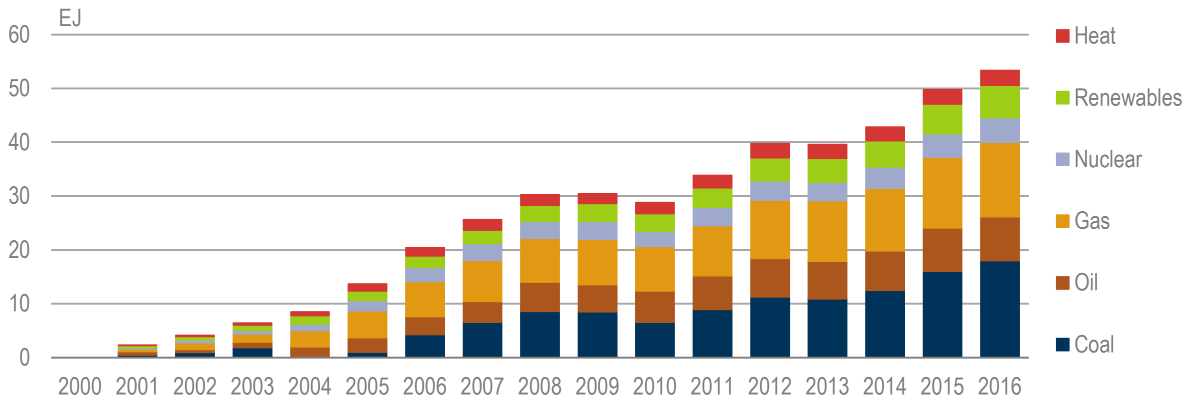
Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; IEA (2017c), *Mobility Model* (database), www.iea.org/etp/etpmodel/transport; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Energy efficiency has reduced the need for additional primary energy

The total amount of primary energy saved in 2016 as a result of end-use efficiency gains compared with 2000 was 30 EJ in IEA member countries and 23 EJ in the major emerging economies (Figure 1.14). Of these savings, around 40% came from reduced inputs to power generation.

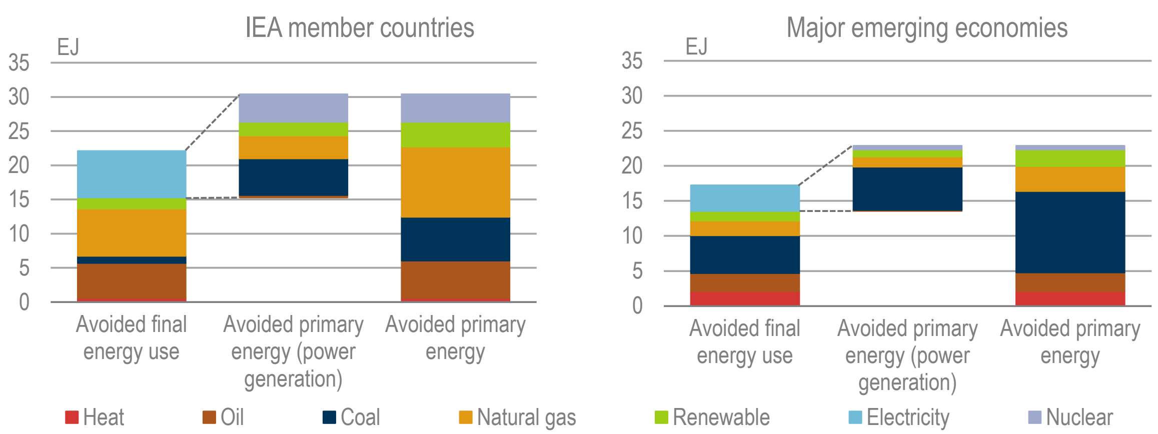
Based on the 2016 fuel mix, coal savings, most of which came from China, were the largest source of savings, equivalent to current annual coal demand in the United States. After coal, the biggest savings were in the form of natural gas, reaching 11% of global gas demand. These savings reflect the growing importance of gas in power generation. Global oil savings, due almost entirely to efficiency improvements in passenger transport, were equivalent to 3.6 million barrels of oil per day (mb/d), the daily oil consumption of Japan.

Figure 1.14 Avoided annual primary energy demand in IEA member countries and major emerging economies from efficiency improvements since 2000 by fuel



Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; Timmer et al. (2015), *World Input Output Database*, www.wiod.org; IEA (2017c), *Mobility Model* (database), www.iea.org/etp/etpmodel/transport; IEA (2017d), *Energy Technology Perspectives 2017* (Residential Model); and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Figure 1.15 Energy savings in 2016 from efficiency improvements since 2000, by country grouping



Note: Primary energy savings in power generation are determined from the generation mix in IEA member and major emerging economies.

Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; Timmer et al. (2015), *World Input Output Database*, www.wiod.org; IEA (2017c), *Mobility Model* (database), www.iea.org/etp/etpmodel/transport; IEA (2017d), *Energy Technology Perspectives 2017* (Residential Model); and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

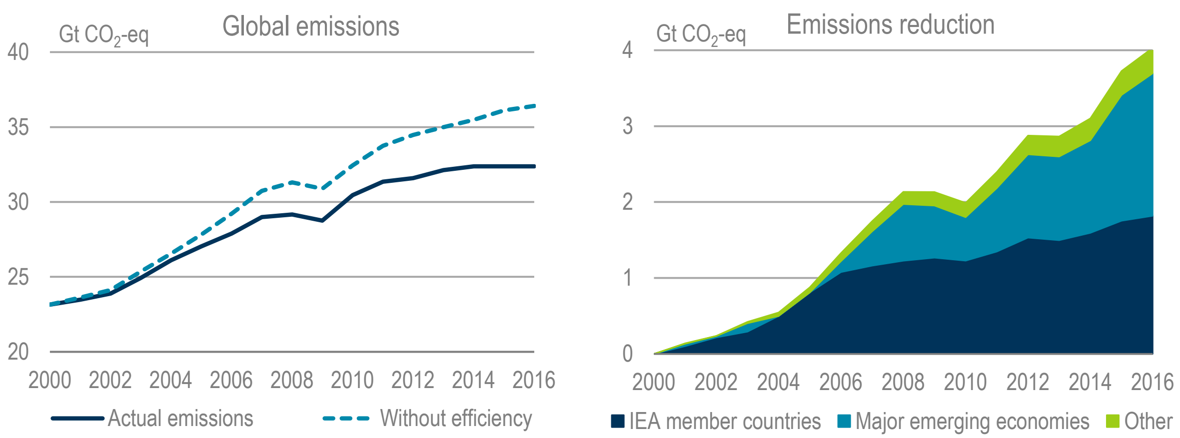
In IEA member countries, natural gas accounted for the biggest share of primary energy savings, amounting to one-third of total savings. End-use efficiency improvements in direct uses for space heating and in industry were the main sources of savings, with less than a third coming from power generation (where coal and nuclear power are more important). In the major emerging economies, coal was the leading contributor to primary energy savings, accounting for half of the total. This reflected efficiency improvements in the direct use of coal in industry and electricity savings, which reduced the need for coal-fired generation (the dominant source of power in most of the countries included in this grouping).

Without the electricity savings made in IEA member countries and major emerging economies since 2000, global electricity use would have been 14% higher in 2016. To meet this additional demand, more than 1000 GW of additional power plant capacity would have been needed at an investment cost of USD 1.9 trillion.

Greenhouse gas emissions savings from energy efficiency improvements

Global energy savings from efficiency improvements since 2000 led to a reduction in GHG emissions of just over 4 billion tonnes of carbon dioxide equivalent ($GtCO_2$-eq) in 2016 (Figure 1.16). Without these efficiency improvements, emissions in 2016 would have been 12.5% higher. Of these emissions savings, 45% came from IEA member countries, while the major emerging economies accounted for 47%. The avoidance of fuel combustion that results from efficiency improvements also reduces local air pollutants, benefiting air quality and public health.

Figure 1.16 Avoided global GHG emissions from energy efficiency improvements



Note: Energy savings for countries other than IEA members and the major emerging economies are estimated by applying the ratio of efficiency improvements to intensity gains observed in emerging economies to the gains in intensity observed in these other countries.

Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; Timmer et al. (2015), *World Input Output Database*, www.wiod.org; IEA (2017c), *Mobility Model* (database), www.iea.org/etp/etpmodel/transport; IEA (2017d), *Energy Technology Perspectives 2017* (Residential Model); IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics; and IEA (2017b) *CO_2 Emissions from Fuel Combustion* (database), www.iea.org/statistics.

Special focus: Energy efficiency improves energy security

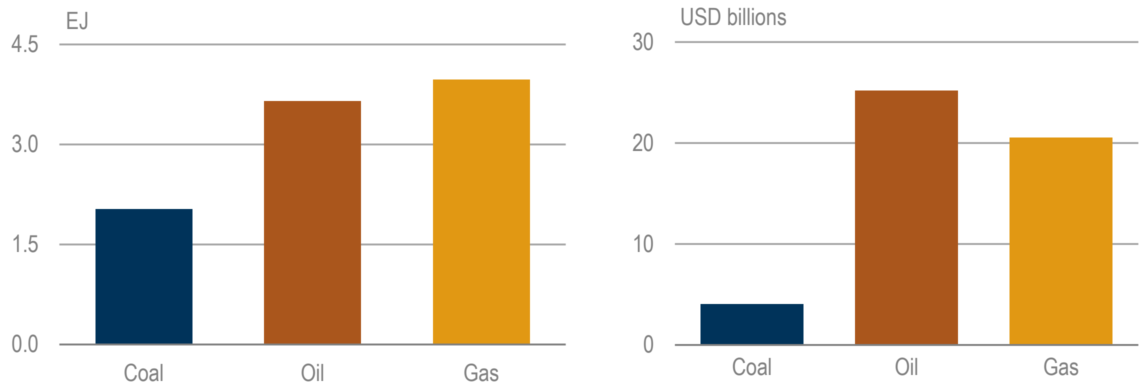
In this year's report, we provide a special focus on the means by which energy efficiency improves energy security; one of its many key strategic and economic benefits. More efficient energy use can bolster energy security – the uninterrupted supply of energy sources at an affordable price. Long-term energy security requires adequate and timely investments that take account of economic development and environmental concerns. Short-term energy security requires the energy system to react promptly to sudden disruptions in energy supply, changes in market conditions or government intervention via emergency measures to maintain system balance. Energy efficiency can play a crucial role in ensuring both long- and short-term energy security in a cost-effective manner.

One way in which energy efficiency can benefit a country's energy security is by reducing its reliance on imported energy. Energy efficiency also reduces the likelihood of supply interruptions; the only energy source that cannot be interrupted is the energy that is not used. Also, in the event of a disruption, efficiency measures can work with emergency conservation measures to reduce demand. This was the case in the wake of the Great East Japan Earthquake of 2011 and has been the subject of previous IEA publications.[7]

Energy efficiency reduces the amount and cost of energy imports

In countries that rely on imports to meet domestic energy demand, energy efficiency can enhance energy security by reducing imports of coal, oil and gas (Figure 1.17). Efficiency improvements between 2000 and 2016 avoided nearly USD 50 billion in expenditure on energy imports. Gas import savings were significant in IEA member countries, equivalent to 10% of global annual gas imports. Oil import savings were also significant, equivalent to 2.2 mb/d – equal to almost one-third of China's total oil imports in 2016. Import savings were also achieved in the six major emerging economies analysed. However, due to lower import reliance, total savings (in energy terms) were only one-quarter of those in IEA member countries.

Figure 1.17 Import reductions (left) and avoided import costs (right) in IEA member countries in 2016 from efficiency improvements since 2000 by fuel



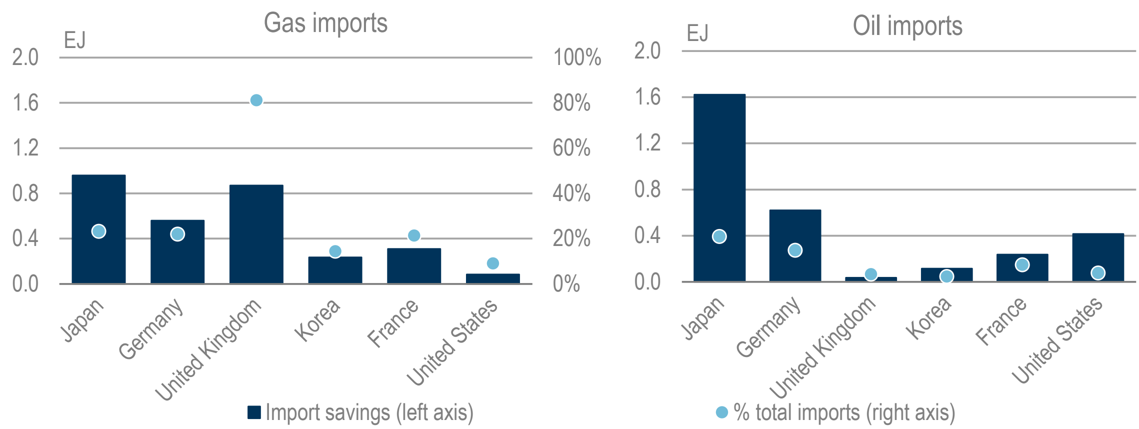
Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; Timmer et al. (2015), *World Input Output Database*, www.wiod.org; IEA (2017c), *Mobility Model,* www.iea.org/etp/etpmodel/transport; IEA (2017d), *Energy Technology Perspectives 2017* (Residential Model); IEA (2017f), *Energy Prices and Taxes*, Q1, www.iea.org/statistics; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Among the IEA member countries most dependent on imports of oil and gas, Japan had the most import savings from improved energy efficiency. This result reflects Japan's almost total dependence on imports of both fuels as well as its long history of rigorous efficiency policies, especially fuel efficiency standards for passenger vehicles and HDVs (Figure 1.18). Oil savings in Japan were over 20% of imports in 2016 and nearly three times bigger than those in Germany, which had the second-largest oil import savings. Although gas import savings in the United Kingdom were slightly smaller than in Japan in absolute terms, they were much larger relative to

[7] *Saving Electricity in a Hurry* (2005) highlighted how the use of mass media and other strategies can reduce electricity demand by 3% in a few days and 20% in a few months.

total imports, reaching over 80% in 2016. This reflects the fact that the United Kingdom uses local resources to meet more than 50% of its domestic gas demand.

Figure 1.18 Reductions in gas and oil imports in 2016 from efficiency improvements since 2000 in the largest IEA member country importers



Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Reducing energy imports (or increasing exports) through efficiency can also benefit a country economically, particularly where energy is a large contributor to trade balances, by improving national accounts and reducing the need for costly supply and storage infrastructure. Reductions in electricity demand resulting from efficiency can also limit requirements for new electricity transmission and generation infrastructure, particularly during a transition from fossil fuels to renewables-based generation.

In the United States, gas import savings in 2016 were the lowest of the countries analysed because domestic production largely satisfies demand. Efficiency gains along with abundant production have changed the dynamics of gas supply and demand in the United States. In 2015, 1.7 EJ of natural gas was exported, with 2.6 EJ imported. In the same year, 5.0 EJ of gas savings can be attributed to efficiency improvements since 2000.

Energy efficiency has substantially reduced European gas imports

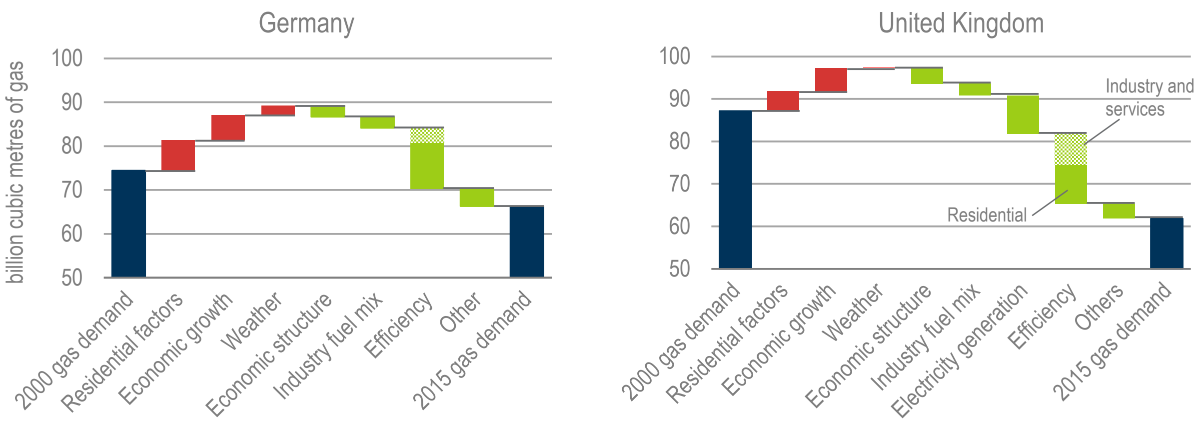
The impact of energy efficiency improvements on gas imports has been particularly striking in the European Union, which accounted for more than half of gas imports by IEA member countries in 2016 and where domestic production has been declining in recent years. In 2016, the primary sources of gas imports to the European Union were Russia, Norway and Algeria (Eurostat, 2017).

Energy efficiency gains since 2000 in Germany and the United Kingdom – the two largest EU gas markets – have been the main factor behind lower gas use and the need for imports. Between 2000 and 2015, overall gas demand fell by 11% in Germany and 29% in the United Kingdom (Figure 1.19). This decline more than offset the impact of factors that drove up gas demand, including changes in floor area, population, the number of households, the fuel mix and economic growth. The larger reduction in demand in the United Kingdom resulted from the reduced need to use gas to generate electricity, as well as other factors, including lower demand for industrial feedstocks.

Had the efficiency of gas use in the residential and industry and services sectors not improved since 2000, gas consumption in 2015 would have been 21% higher in Germany and 27% higher in the United Kingdom. The savings from these two countries alone are equivalent to nearly a quarter of the Europe Union's entire gas imports from Russia in 2015.

In both countries, the bulk of the savings came from efficiency improvements in the residential sector, particularly space heating. Between 2000 and 2015, the amount of gas needed for space heating per unit of floor area fell by 44% in Germany, saving 11.5 billion cubic metres (bcm), and by 28% in the United Kingdom saving 7.5 bcm.

Figure 1.19 Decomposition of gas demand in Germany and the United Kingdom, 2000-15



Notes: Residential factors combine changes in residential floor area, population, the number of households and the fuel mix. For the United Kingdom, electricity generation refers to the shift from gas-fired generation to other fuels and technologies.

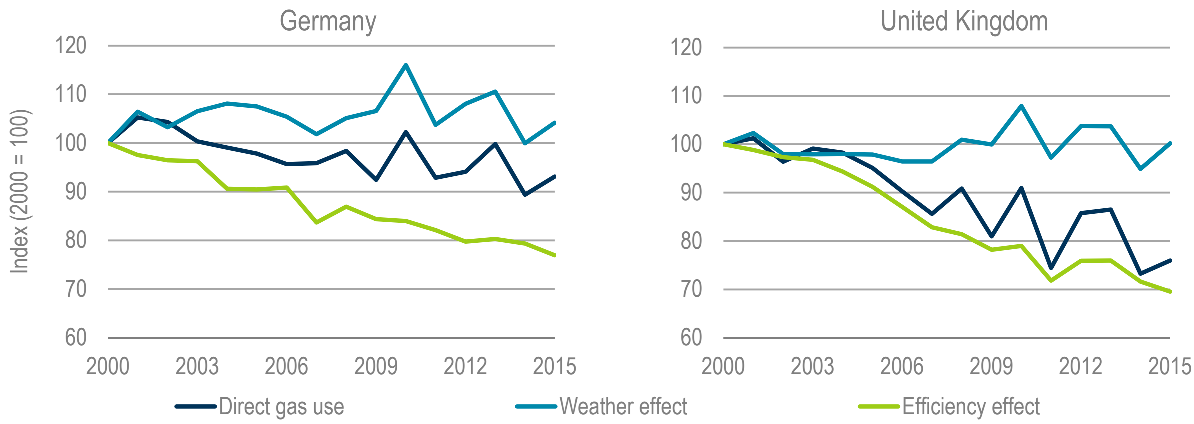
Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Policy has been an important driver of the energy efficiency improvements that have saved gas in the residential sector in Germany and the United Kingdom. In response to the European Union's Energy Performance of Buildings Directive, Germany increased the strength of residential building codes by more than 60% between 2000 and 2016 and the United Kingdom increased strength by more than 55%. Other measures such as minimum energy performance standards and financial assistance programmes have also contributed to savings.

The impact of energy efficiency on the sensitivity of gas demand to cold weather

Improved efficiency has also enhanced long-term energy security by reducing the sensitivity of annual European gas demand to fluctuations in the weather. For example, the spike in demand in the European winter of 2010-11 caused by exceptionally cold weather required an additional 8.2 bcm of gas in Germany and 3.8 bcm in the United Kingdom. However, this was more than offset by the reduction in demand as a result of energy efficiency improvements over the previous decade, amounting to 9.7 bcm in Germany and 11.7 bcm in the United Kingdom (Figure 1.20). Energy efficiency improvements did not eliminate the peak but did lessen its severity. Without these efficiency improvements, the additional gas demand from the cold winter would have raised German gas imports by just under 12% and imports to the United Kingdom by more than 24% in that year.

Figure 1.20 Final consumption of natural gas and weather and efficiency effects in Germany and the United Kingdom, 2000-15



Notes: Consumption includes the residential, commercial and industry sectors and excludes the use of gas for electricity generation and co-generation (the combined production of heat and power). The weather effects indicate the consumption that would have occurred in the absence of any efficiency, structure or other economic effects.

Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Energy efficiency improves short-term energy security

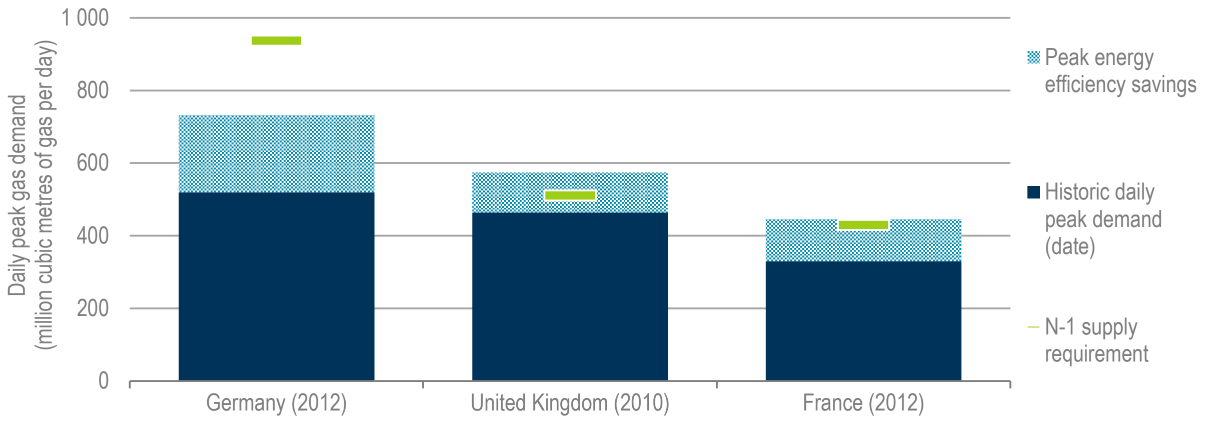
Energy efficiency improvements have also strengthened short-term supply security in Europe by reducing peak daily gas demand. The 2010 EU Security of Gas Supply Regulation created a common security indicator, the N-1 standard, which refers to a country's ability to maintain supply to end-users even when a critical piece of gas supply infrastructure is disrupted, such as a pipeline or storage unit. The standard ensures that in the case of a disruption the country's remaining available gas infrastructure can meet the total daily gas demand during a day of exceptionally high demand, defined as its historical peak.

Most EU member states meet the standard: Germany's N-1 indicator is 180%, United Kingdom's 110% and France's 130% (European Commission, 2014), but this is in large part due to efficiency gains. If there had been no improvement in energy efficiency since 2000 in Europe's three largest gas markets, Germany's historical peak daily gas demand in 2012 (ENTSOG, 2017) would have been 41% higher, reducing the N-1 indicator to 128% (Figure 1.21). In France, the record daily peak gas demand in 2012 would have been 32% higher and in the United Kingdom, peak daily demand in the record year of 2010 would have been 20% higher. In both cases, these increases would mean that the N-1 indicator would not have been met with current supply infrastructure.

Without energy efficiency improvements since 2000, maintaining current levels of short-term gas security would have required additional daily supply capacity in these countries. Although Germany would still have met the N-1 standard without efficiency improvements, to maintain its current 180% level it would have needed 382 million cubic metres per day (mcm/d) of additional daily capacity. The United Kingdom would require an additional 102 mcm/d and France 141 mcm/d to maintain their current N-1 levels. In total, this additional daily capacity in France and the United

Kingdom is more than five times the maximum daily withdrawal capacity from the United Kingdom's largest gas storage site (Centrica, 2017).[8]

Figure 1.21 Historical peak daily gas demand and energy efficiency savings in selected European markets



Note: Energy savings from efficiency improvements since 2000.

Sources: Adapted from IEA (2017e), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics; and ENTSOG (2017), *Ten-Year Network Development Plan 2017: Main Report*.

Energy efficiency improvements in seasonal gas demands, specifically space heating, are largely responsible for reducing the severity of peaks in demand. In Germany, for example, the energy intensity of residential space heating improved by 35% between 2000 and 2012, while industry improved by 10% and residential cooking by 6%. This resulted in a reduction in daily peak demand in 2012 of almost 30%.

Efficiency helped energy conservation contribute to emergency response in Japan

Energy efficiency and conservation efforts played a major role in Japan's response to the energy emergency that resulted from the Great East Japan Earthquake. The magnitude 9 earthquake and the subsequent tsunami on 11 March 2011 caused widespread devastation and significant loss of life in north-east Japan. This natural disaster also triggered a serious accident at the Fukushima Daiichi nuclear power plant – level 7; the most severe on the international nuclear event scale. Significant off-site radiation was released from fuel meltdowns in the three reactors in operation at the time at the six-unit facility. As a result of the accident and investigations into its causes, the remaining 48 operational nuclear reactors in Japan were gradually taken offline during regularly scheduled maintenance outages, leading to a shortfall in electricity supply (IEA, 2016b).

To rectify the supply shortfall and compensate for the loss of Japan's nuclear capacity, power generation from coal-, oil- and gas-fired plants increased, and energy savings measures were implemented (Table 1.1). Energy savings measures initially focused on emergency conservation, called "Setsuden" (saving electricity), in the service area of the Tokyo Electric Power Company

[8] The Rough Facility (Centrica, 2006), for which closure plans are being developed (Centrica, 2017)

(TEPCO), which was most directly affected by the nuclear shutdown. These were successful in avoiding blackouts over the summer peak time in 2011 and 2012. Building on the pre-existing "Cool Biz" campaign, settings on office air conditioners were raised by over 1.5°C on average, encouraging workers to make changes such as wearing short-sleeved shirts. Other measures included policies to reduce the number of lighting fixtures in use. In 2011 and 2012, the Japanese government also put regulatory restrictions on large buildings and factories to save 15% of electricity consumption from July to September relative to the previous year. These measures were gradually relaxed and formally ended in 2016.

Table 1.1 Japanese energy conservation measures following the Great East Japan earthquake and Fukushima Daiichi nuclear accident

Year	Description of measures
2011	For 10 weekdays between 14 March and 28 March, planned power outages were executed across the TEPCO service area, which was heavily affected by the nuclear shutdown.
	In August, large electricity users in the TEPCO area were forced to limit electricity use in accordance with the Electricity Business Act.
	From July to September, large companies and factories were required to cut electricity use by 15% compared with the previous year.
2012	During summer and winter, consumers were required to save electricity through the continuation of the mandatory requirement to meet numerical targets for electricity savings.
2013	In May 2013, a partial amendment was implemented to the Act on the Rational Use of Energy allowing for the adoption of peak demand shift, giving large electricity consumers, particularly in industry, incentives to shift times of peak demand.
2013-15	Unlike the requirements in 2011 and 2012, savings were not governed by numerical targets.

Source: Yoshikawa (2017), "Energy Efficiency and Conservation Policies after the Great East Japan Earthquake in Japan".

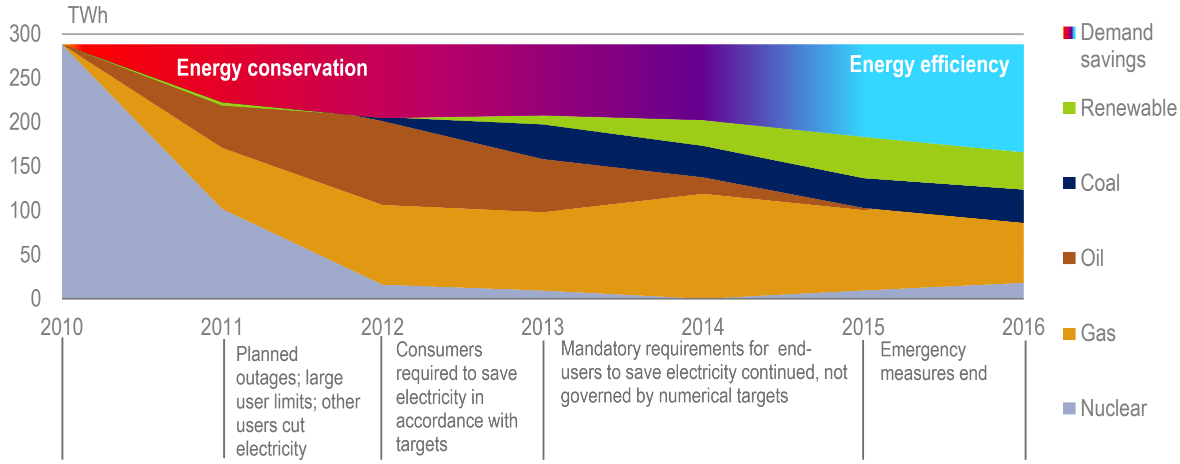
Given that Japan's energy saving measures came to an end in 2016, it is timely to examine the evolving contributions of both demand-side and supply-side measures to the replacement of nuclear power generation and the reduction in electricity demand. As of 2016, gas (30%), renewables (13%) and coal (12%) cumulatively made up for 55% of the energy that was being generated by nuclear power in 2010, with some nuclear capacity back in operation (6%). Demand savings from the combination of conservation and efficiency measures have provided the greatest single contribution to the replacement of nuclear generation, representing 39% of the original nuclear power generation (Figure 1.22).

Electricity consumption, which initially declined by 6% in 2011, mainly driven by conservation measures, has not subsequently recovered to the pre-earthquake level. Instead, consumption has continued to decline since 2011, even though the conservation measures have gradually been relaxed; the government has not applied mandatory targets for large electricity users since 2013. However, the demand-side contribution to the replacement of the nuclear power loss increased from 21% in 2011 to 39% in 2016.

The temporary conservation measures cannot fully explain the continuing fall in electricity demand. The initial conservation measures did hamper economic activity and output, particularly in the industry sector. After 2012, however, activity and energy use in the industry and services sectors decoupled, as the stringency of conservation measures was reduced (Figure 1.23). This trend appears

to be driven more by energy efficiency than conservation measures, as more activity was achieved for less energy use. Policies that have driven these improvements included the mandatory energy efficiency benchmarking policy, introduced in 2010, which required large firms to set energy efficiency targets by sector and introduced an obligation to improve energy efficiency by 1% per year. Japan's Top Runner programme was also expanded after the earthquake to cover heat pumps and induction motors, as well as LED bulbs.

Figure 1.22 Replacement of nuclear electricity generation in Japan after shutdown



Source: Adapted from IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

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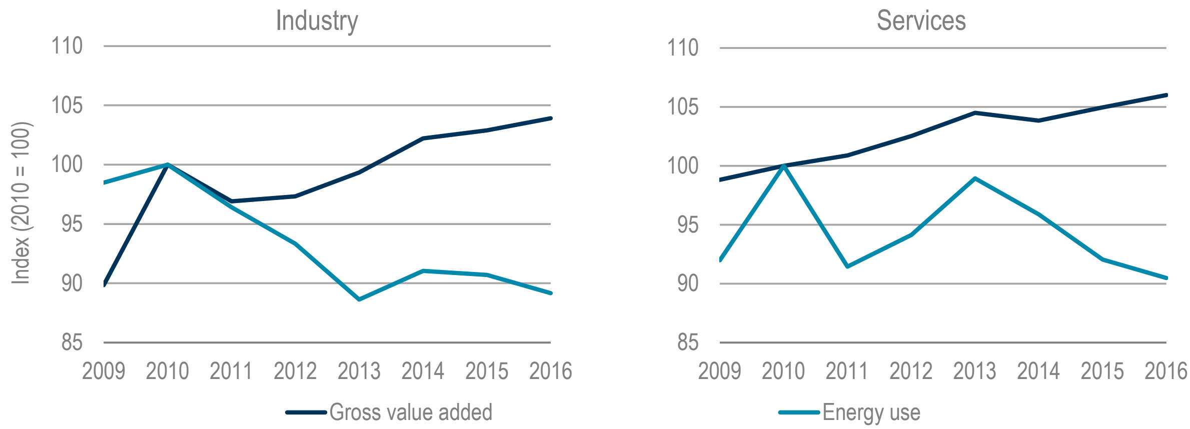
The emergency in 2011 and subsequent electricity price increases also raised people's awareness of energy efficiency measures. For example, it appears that air conditioning thermostats, which were required to be set at higher temperatures as part of initial conservation measures, have not subsequently returned to pre-earthquake levels. Thermostat settings in summer for air conditioners averaged 26.1°C in 2010, increased to 27.7°C in 2011; by 2014 temperatures had only fallen back to an average of 27.2°C (CRIEPI, 2014).

The response to the Great East Japan Earthquake illustrates the enormous remaining potential for energy efficiency improvements even in countries with low energy intensity. Before the disaster, Japan was considered to have one of the more energy-efficient economies in the world, with an energy intensity in 2010 that was 21% lower than the global average and 9% lower than the average for IEA member countries. Yet Japan was still able to identify short-term conservation and efficiency measures, which resulted in durable energy savings through behaviour change and targeted policy measures.

Figure 1.23 Changes in gross value added and energy use in Japan's industry and service sectors, 2009-16



Source: Adapted from IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

In recognition of the contribution of demand-side measures to the replacement of Japan's nuclear power capacity, Japanese transmission service operators included demand response in their auctions for flexible power generation capacity in 2017, procuring 1 GW of demand response in the first series of auctions. Japan is also planning to establish electricity balancing and capacity markets by 2020, in which demand response is expected to play a significant role.

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2. DRIVERS OF ENERGY EFFICIENCY GAINS

Highlights

- **Policy action to improve energy efficiency slowed in 2016, putting at risk the continuation of current efficiency trends.** Over 68% of global final energy use remains uncovered by policies that mandate efficiency gains via standards or targets. Global coverage grew by 1.4 percentage points in 2016; however, in contrast with previous years, nearly all of this increase was due to the continuing impact of pre-existing policies as old energy-using equipment was replaced. Only 1.5% of the increase in the coverage of standards was due to new policies. The increase in the strength of those policies also slowed; in 2016, it was just one-third the rate in 2015 and preliminary data point to another small increase in 2017.

- **The IEA Efficiency Policy Progress Index (EPPI), which tracks the global coverage and strength of mandatory efficiency policies since 2000, increased by just 0.6 points to 6.3 in 2016.** This was the smallest increase since 2009. China remains the global leader in mandatory policy implementation, notably in its industrial sector. China's EPPI score reached 10.9 in 2016 – the most progress of any country. Globally, the Index would have stood at just 2.9 without China.

- **Obligations on utilities to deliver energy savings are becoming more common and ambitious, but progress stalled in 2016.** Overall, 18.3% of global final energy use was covered by obligation programmes in 2016, up from 7.1% in 2005. There was virtually no increase in coverage in 2016, although two new obligations were introduced in Europe in 2017.

- **Energy efficiency gains helped households across the world save 10 to 30% of their annual energy spending in 2016**. Savings were highest in developed countries with a longer history of efficiency policy and higher prices. For example, without the gains achieved since 2000, German households on average would have spent USD 580 per capita more on energy in 2016. Household energy expenditure is also being avoided in large emerging economies, where demand for energy services is growing. On average Chinese households would have spent 25% more on energy in 2016 if not for efficiency. Energy prices paid by households continued to fall in 2016 in most countries, in contrast with the long-term trend. Prices fell most for transport fuels, while electricity prices remained more stable.

- **By the end of 2016, 4 billion connected devices were in use by households worldwide.** Another 1 billion devices are expected to be brought into use in 2017, a rate that may triple by 2020. These devices could make homes "smart", yielding energy savings through real-time control of consumption, but they may also increase electricity demand, including for standby power. Half a billion smart meters, which track and display electricity use, had been or were contracted to be installed by the end of 2016. Among other benefits, smart meters can complement connected devices, by allowing consumers to adjust energy use in real time in response to changes in energy price.

Government policy progress on efficiency slowed in 2016

Mandatory energy efficiency policies include **codes and standards,** such as building energy codes, minimum energy performance standards (MEPS) for lighting, appliances and buildings, fuel economy standards for vehicles, and sectoral standards such as mandatory energy intensity targets for industry. They also include **energy utility obligation programmes,** which require energy utilities to deliver energy efficiency outcomes (Table 2.1). The IEA tracks the coverage and strength of these policies, reporting on their expansion into new end-uses and markets, and on updates that strengthen existing policies (Box 2.1).

The IEA Efficiency Policy Progress Index (EPPI) integrates progress since 2000 on the increasing coverage and strength of mandatory codes and standards (Box 2.2). Progress on obligation programmes is reported separately, as they typically have very broad coverage, in some cases taking in all final energy consumption.

Table 2.1 Mandatory energy efficiency policies and metrics tracked in this report

Policy			Key metrics tracked		
Category	**Type**	**Definition**	**Coverage**	**Strength**	**EPPI**
Codes and standards	Building energy codes and standards	Policies setting thresholds for residential and non-residential building energy use*	Yes	Yes	Yes
	Product standards	Policies setting maximum energy use for lighting, appliances, heating and cooling equipment, and other products	Yes	Yes	Yes
	Vehicle standards	Policies setting average standards for manufacturers' new vehicle fleets.	Yes	Yes	Yes
	Industry standards or targets	Policies setting energy intensity or savings targets for industry	Yes	Yes	Yes
Energy utility obligations	Obligations and white certificate schemes	Obligations on energy suppliers requiring them to deliver efficiency outcomes, usually energy savings	Yes	Yes	No

* Types include prescriptive, trade-off, reference building, energy frame and energy performance.

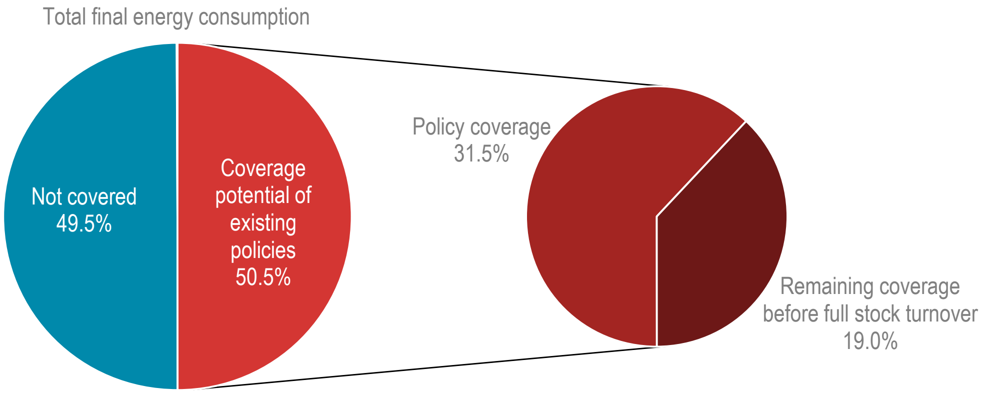
Box 2.1 Policy coverage and policy strength as energy efficiency terms

Mandatory codes and standards apply to specific products (such as lighting and appliances), vehicles (transport), building types (residential and non-residential) or sectors (industry). When a policy is enforced, the applicable energy uses are said to be "covered".

Policy coverage is the share of total final energy used by applicable equipment covered by policy. For example, if a country adopts new MEPS for specific refrigerator types, the energy use coverage is the amount of energy used by the specific refrigerator types, divided by the total amount of energy used by all refrigerators. Once the policy is in place, energy use coverage will grow each year as more of the stock is replaced by refrigerators subject to the policy. Policy coverage is a subset of coverage potential (Figure 2.1).

The **coverage potential of existing policies** is the share of total final energy use that would be covered if all the relevant energy-using stock was replaced by applicable equipment. For some covered end-uses in some countries, coverage potential is already equal to energy use coverage because the whole stock is assumed to have turned over since the first policy was put in place. This is the case for lighting in many countries, since MEPS have been in place for more than four years and lamps are assumed to last for one to four years.

Figure 2.1 Policy coverage is a subset of the coverage potential of existing policies



Policy strength measures the extent to which efficiency levels are required to improve. In this report, we do this by comparing the current policy requirement with the standard in 2000. For example, if maximum refrigerator energy use was 1 000 kilowatt hours (kWh) per year in 2000, and a new policy in 2010 lowered this to 750 kWh, the strength improvement is 25%. If the standard was lowered again in 2015 to 600 kWh, the strength improvement is 20% (and a cumulative strength increase of 40% since 2000). If no policy was in place in 2000, the minimum efficiency model available in the market place is used as the baseline against which to measure ambition.

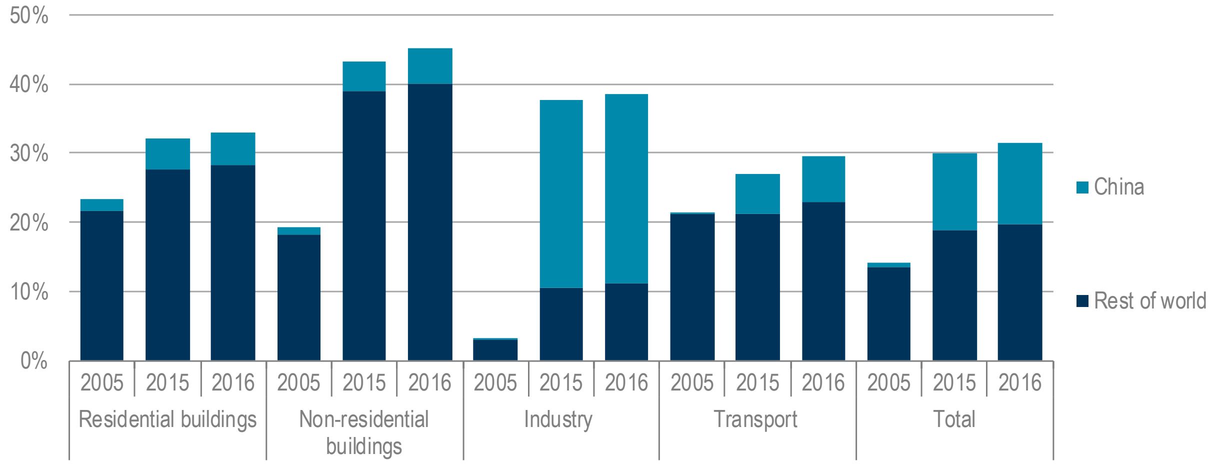
For **energy utility obligation programmes**, policy coverage is calculated as the share of final energy consumption supplied by obligated parties. Policy strength is the share of total final energy consumption required to be saved under the obligations in a given year. Because of the different nature of the coverage and strength calculations, obligation programmes are not included in the EPPI and are reported on separately.

Coverage of energy efficiency policy continues to grow with stock turnover

Mandatory codes and standards covered 31.5%[1] of global energy use in 2016, up 1.4 percentage points on 2015, but leaving over 68% still uncovered. Total coverage has increased 17 percentage points since 2005, led by the introduction of mandatory industry targets. Transport coverage increased by 8 percentage points, less than any other sector. China accounted for more than one-third of total global coverage, and 70% of industrial coverage. In the rest of the world, mandatory codes and standards covered 19.7% of global energy use in 2016, an increase of 0.8 percentage points over 2015 (Figure 2.2).

[1] All primary energy demand (TPES) and final energy use (TFC) data for 2016 are preliminary.

Figure 2.2 Energy use coverage of mandatory codes and standards

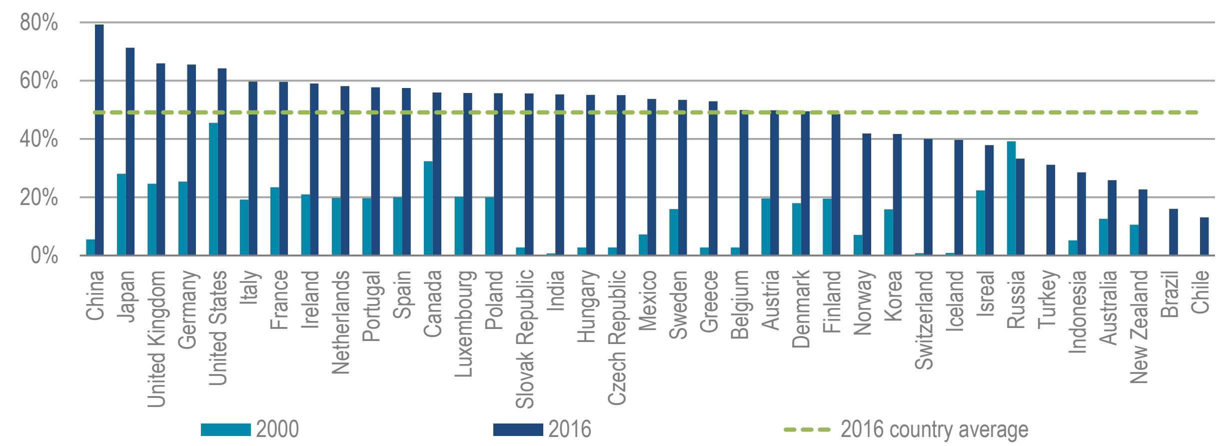


Notes: Residential building coverage in 2015 is 1% lower than that published in the *Energy Efficiency Market Report 2016* due to improvements in data on building envelopes. Transport coverage in 2015 is 3% lower than that published in 2016 due to improvements in data on heavy-duty vehicle stocks. Total energy use includes agriculture and non-energy use, such as industrial feedstocks.

Sources: Analysis based on energy data from IEA (2017a) *Energy Technology Perspectives*; IEA (2016) *World Energy Outlook;* IEA (2017b), IEA *Mobility Model* (database). Analysis based on policy data from IEA (2017c), *Policy and Measures Energy Efficiency Database 2017*, www.iea.org/policiesandmeasures/energyefficiency/; CLASP (2017), *CLASP Global S&L Database*, http://clasp.ngo/en/Tools/Tools/SL_Search.aspx; EES and Maia Consulting (2014), *Energy Standards and Labelling Programs* throughout *the World in 2013*, www.iea-4e.org/document/343/energy-standardslabelling-programs-throughout-the-world-in-2013; IEA 4E-TCP (2016-17), (Benchmark and Policy Reports), https://mappingandbenchmarking.iea-4e.org/matrix; IIP (2017), *Industrial Efficiency Policy Database*, http://iepd.iipnetwork.org/; BCAP (2017), *Code Status* (database), http://bcapcodes.org/code-status/; GBPN (2017), Databases and Tools, www.gbpn.org/databases-tools; Odyssee-Mure (2017) (Mure database), www.measures-odyssee-mure.eu/, (accessed 11 July 2017).; Siemens (2015), *Minimum Energy Performance Standards: MEPS Regulations Worldwide,* www.industry.siemens.com/drives/global/en/motor/low-voltage-motor/efficiencystandards/Documents/meps-regulation-en.PDF and ICCT (2017), *TransportPolicy.Net* (database), Washington DC, http://transportpolicy.net/index.php?title=Main_Page.

When energy-using equipment expires, it is usually taken out of use and replaced. For new types of products and growing markets, products or equipment sold are added to the stock. This combination of retirement, renewal and expansion is stock turnover. Existing mandatory codes and standards would cover half of global energy use if the entire stock turned over instantaneously (Figure 2.3).

Figure 2.3 Coverage potential of existing mandatory codes and standards



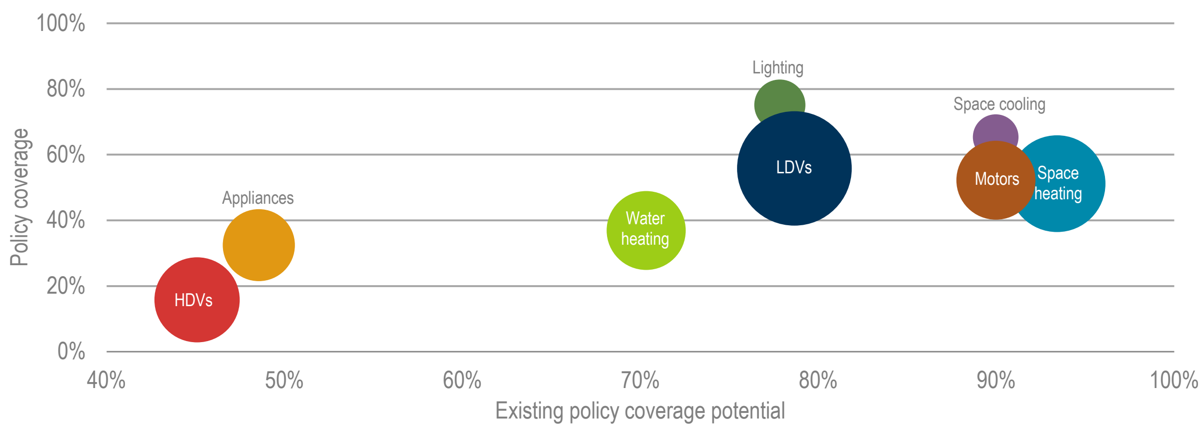
Note: The dotted green line in the chart is the arithmetic (unweighted) country average (mean) of coverage potential across the 37 countries.

Energy use coverage varies widely according to end-use.[2] Lighting is the end-use with the highest coverage (75%), with only marginal growth in the past three years (Figure 2.4). Light bulbs do not last as long as other end-use equipment, so the stock turns over quickly and coverage rates increase rapidly with the implementation of new policy. However, since lighting accounts for a small amount of global final energy use, its share of global coverage is less than 2%.

Heavy-duty vehicles (HDVs) have the lowest coverage among the end-uses analysed (16%), although it is increasing quickly because of recent fuel economy standards in Canada, China, Japan and the United States. HDVs also have a relatively large share of global final energy use, so new policies will have a significant impact on global coverage. With the exceptions of refrigerators and freezers, energy use coverage for appliances is also low but expanding.

Space cooling coverage is high and its share of global final energy use is expanding quickly because demand is growing in countries such as India, Indonesia and Mexico. Space cooling also has high potential under existing policies, but coverage will fall far short of its potential unless standards are introduced in more countries where demand for air conditioning is rising. Space heating has the highest potential coverage under existing policies once the entire stock has turned over, because equipment standards and building codes are prevalent in countries with colder climates.

Figure 2.4 Policy coverage and coverage potential of existing mandatory codes and standards by end-use, 2016 (size of bubble indicates share of global final energy consumption)



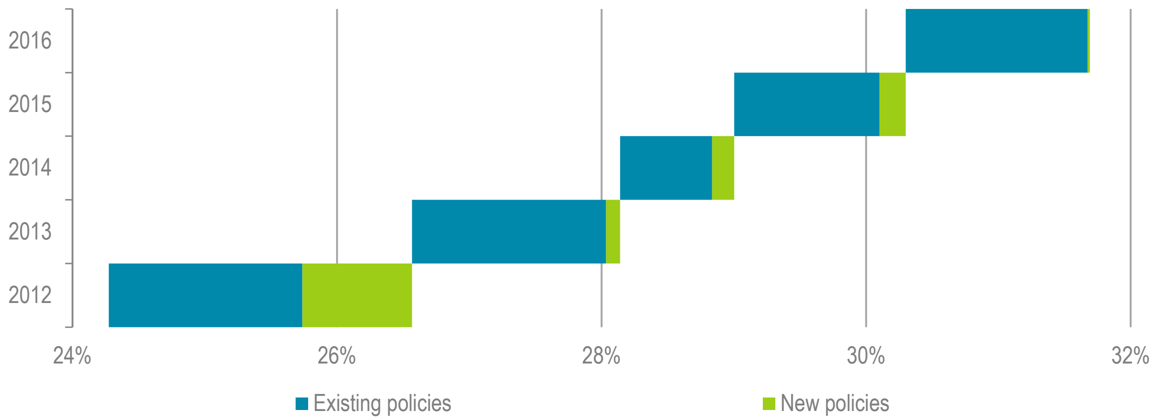
Note: To provide a sense of the scale of the bubble sizes, LDVs account for 13% of global energy use – about twice that of water heating.

Sources: Analysis based on energy data from IEA (2017a) *Energy Technology Perspectives*; IEA (2016) *World Energy Outlook;* IEA (2017b) IEA *Mobility Model* (database). Analysis based on policy data from IEA (2017c), *Policy and Measures Energy Efficiency Database 2017*, www.iea.org/policiesandmeasures/energyefficiency/; CLASP (2017), *CLASP Global S&L Database*, http://clasp.ngo/en/Tools/Tools/SL_Search.aspx; EES and Maia Consulting (2014), *Energy Standards and Labelling Programs* throughout *the World in 2013*, www.iea-4e.org/document/343/energy-standardslabelling-programs-throughout-the-world-in-2013 IEA 4E-TCP (2016-17), (Benchmark and Policy Reports), https://mappingandbenchmarking.iea-4e.org/matrix ; IIP (2017), *Industrial Efficiency Policy Database*, http://iepd.iipnetwork.org/; BCAP (2017), *Code Status* (database), http://bcapcodes.org/code-status/; GBPN (2017), Databases and Tools, www.gbpn.org/databases-tools; Odyssee-Mure (2017) (Mure database), www.measures-odyssee-mure.eu/, (accessed 11 July 2017).; Siemens (2015), *Minimum Energy Performance Standards: MEPS Regulations Worldwide,* www.industry.siemens.com/drives/global/en/motor/low-voltage-motor/efficiencystandards/Documents/meps-regulation-en.PDF and ICCT (2017), *TransportPolicy.Net* (database), Washington DC, http://transportpolicy.net/index.php?title=Main_Page.

[2] Coverage does not include other plug loads, such as consumer appliances and data centres.

Policy coverage grew faster in 2016 than in the previous two years, but the share of coverage due to new policies was small (Figure 2.5). As the global stock of equipment and appliances is replaced and expands, more energy use is automatically covered by existing standards. In contrast to previous years, almost all the increase in the coverage of mandatory standards came from existing policies. Just 1.5% of this increase resulted from new policies – primarily standards for space cooling in Indonesia, and for refrigerators and freezers in China. In both 2014 and 2015, 15% of additional policy coverage was due to new policies, while in 2012 it was 34% (because of the introduction of the Top 10 000 programme in China). The lower coverage growth in 2014 was largely due to the mild winter in Europe.[3]

Figure 2.5 Annual additions to the global policy coverage of mandatory codes and standards owing to new and existing policies, 2012-16



Note: Horizontal axis starts at 24%, reflecting that policies prior to 2012 covered 24% of global energy use.

The lack of new policy coverage in 2016 is worrying, as future increases in coverage rely on the current pipeline of implementation. However, expanding coverage on its own does not guarantee efficiency outcomes. Policy coverage must be accompanied by policy strength. Unfortunately, in this domain too, 2016 was a year of slow progress.

2016 was a weak year for efficiency policy

Increases in the strength of mandatory efficiency policies were small in 2016 compared with the previous four years. The most important strength increases were in fuel economy standards for LDVs and in space heating energy performance standards (Table 2.2). The global increase in policy strength was just 0.3% in 2016, well short of the increases seen in recent years (Figure 2.6).[4]

Preliminary data for 2017 point to another small increase in policy strength – a worrying development in view of the recent deceleration in policy coverage. The most important development in 2017 so far has been the first phase of fuel economy standards for LDVs in India. Motor standards in Saudi Arabia and elsewhere are also being updated. New building energy codes are being introduced in Japan, and standards for air conditioners and pool pumps have been updated in the United States.

[3] The combination of lower heating fuel use and high policy coverage for space heating acted as a restraint on the growth in total coverage.

[4] Strength increases are weighted by end-use shares of global energy use.

Table 2.2 Best-performing mandatory policies for strength improvement, 2016

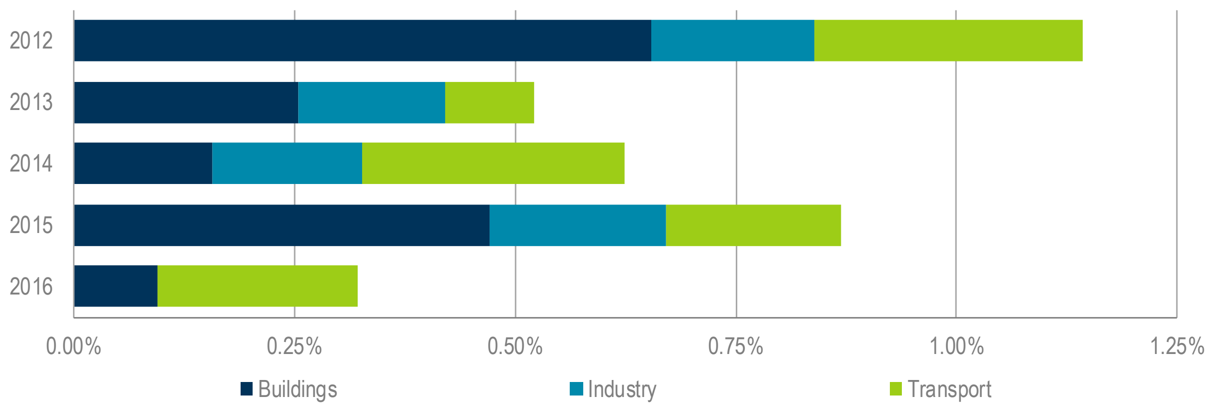
Policy type	Sectors covered	Country	Strength increase*	Share of global strength score
Fuel economy standards for light-duty vehicles	Transport	United States	5%	45.3%
		Canada	8%	6.6%
		Mexico	4%	5.6%
Space heating energy performance standards	Buildings	Germany	25%	22.4%
		Denmark	42%	3.5%
Fuel economy standards for heavy-duty vehicles	Transport	United States	3%	12.9%
Air conditioner standards	Buildings	Indonesia	28%/17%**	1.5%
Refrigerator standards	Buildings	India	20%	1.2%
			Total	**98%**

* These values are approximations of strength improvement based on representative configurations, in case regulations target various subtypes (e.g. refrigerators) or stretch over several years to a fixed limit (LDVs and HDVs).

** Standards differ for residential air conditioner units and non-residential air conditioner units.

Sources: ICCT (2017), *TransportPolicy.Net* (database), http://transportpolicy.net/index.php?title=Main_Page; DieselNet (2017), www.dieselnet.com; GBPN (2017), *Databases and Tools*, www.gbpn.org/databases-tools; Ministry of Energy and Mineral Resources, Indonesia (2015), *Regulation No.7/2015: MEPS and Labelling for Air Conditioning,* http://jdih.esdm.go.id/peraturan/Permen%20ESDM%2007%20Thn%202015.pdf; BEE (2015), *Energy labelling requirements for refrigerators,* www.beestarlabel.com/Content/Files/Schedule1_FFR.pdf.

Figure 2.6 Annual global increases in the strength of mandatory codes and standards, 2012-16



The slowdown in policy strength increases is troublesome because there is a lot of ambition to fulfill and many countries are considering or developing new or updated policies, especially in the context of implementing the Nationally Determined Contributions (NDCs) that they have submitted under the Paris Agreement. Furthermore, many countries announced strategies focused on or incorporating efficiency in 2016, including the National Action Plan in Brazil, the Pan-Canadian Framework on Clean Growth and Climate Change, national energy savings targets in Indonesia, the Energy Efficiency Technology Strategy in Japan, Saudi Arabia's Vision 2030, Mexico's Energy Transition Law, and the Post-2015 National Energy Efficiency Strategy in South Africa. This suggests that there are many new policies in the pipeline, but full implementation is required before they have an impact.

Total policy progress continues, but decelerated in 2016 due to a lack of new policies

The IEA Efficiency Policy Progress Index (EPPI), introduced for the first time in the 2016 edition of the *Energy Efficiency Market Report*, combines coverage and strength of codes and standards into a single index for measuring overall policy progress. The EPPI covers seven energy end-uses: space cooling, space heating, appliances, water heating, industrial motors, lighting, LDVs and HDVs. The countries included in the EPPI account for two-thirds of global energy use.

Box 2.2 How the EPPI is calculated and what it means

The EPPI integrates policy coverage and strength into a single metric for tracking country-specific and global efficiency policy progress since 2000. To calculate an EPPI score at country level for each end-use, the increase in the strength of codes and standards enacted or updated since 2000 is multiplied by policy coverage. The following formula summarizes the main calculation for calculating the 2016 EPPI:

$$\mathrm{EPPI}_{\mathrm{2016,\ end\text{-}use}} = \sum_{i=2000}^{2016} \left(\frac{\mathrm{Sales}_{\mathrm{Model\ Year\ i}}}{Stock_{2016}} \times \mathrm{Strength}_{\mathrm{Model\ Year\ i}}\right)$$

Since codes and standards apply to specific products, building types and sectors, and not to all the energy used by a country, the individual end-use scores are then weighted by total country energy use to produce a country-level EPPI score. If a country has an EPPI score of 1, broadly this means codes and standards implemented since 2000 are designed to improve the minimum energy efficiency performance of the entire country by 1% relative to 2000.[5]

The global EPPI score is the sum of the country-level EPPI scores weighted by country total energy use. A global EPPI score of 1 means that the codes and standards implemented since 2000 are designed to improve global energy efficiency by 1%.

It becomes increasingly difficult to reach higher EPPI scores as codes and standards push technology towards maximum theoretical efficiency. This makes it harder for countries that made significant progress before 2000 to reach higher EPPI scores, since they have technically less “room for improvement” than other countries. The EPPI provides an indication of policy progress but does not account for policy compliance or measure actual efficiency effects.

For more information, see Annex 2.

The global EPPI score in 2016 was 6.3 (Figure 2.7). Progress from 2011 to 2015 was strong: two-and-a-half times greater than during the previous decade. But the incremental EPPI score for 2016 was 0.6, a decline from the average increment of the previous five years of 0.7-1.0. This decline is the result of the slowdowns in policy coverage and strength discussed above.

Three policy types account for 83% of the progress in energy efficiency policy between 2000 and 2016 period (Table 2.2): industrial sector savings targets, fuel economy standards for LDVs, and space heating energy performance standards for buildings.

[5] For the majority of passenger vehicles subject to standards, the EPPI tracks average energy efficiency performance.

Figure 2.7 Efficiency Policy Progress Index, 2000-16

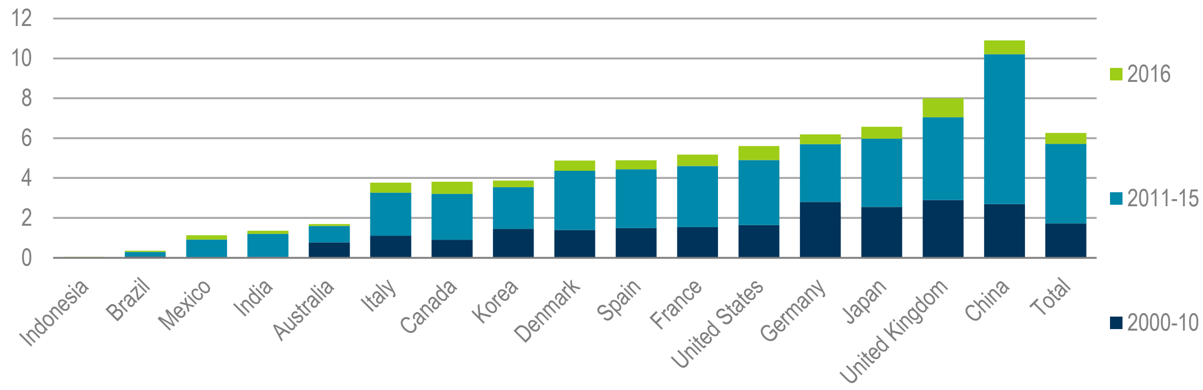


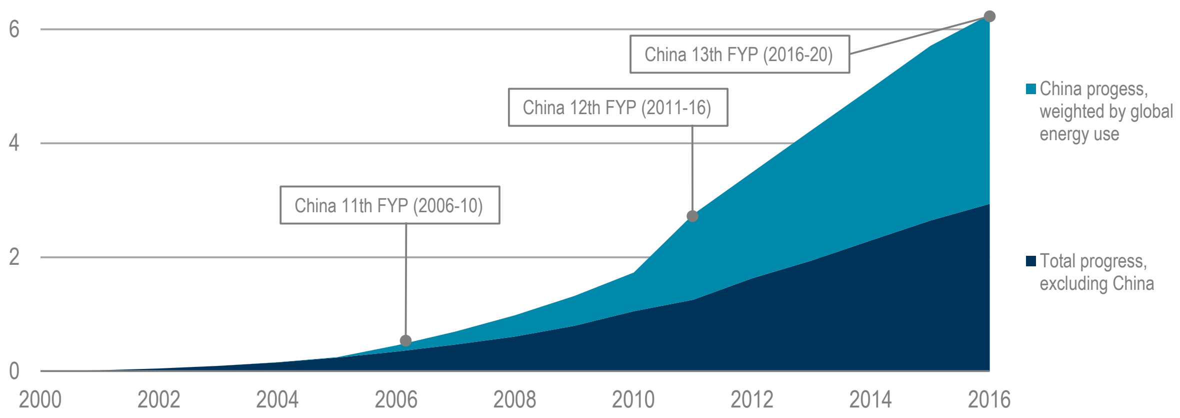
Table 2.3 Top three policy types in the EPPI

Policy type	Sectors covered	Country	Year introduced or updated	Share of total EPPI
Sector savings targets	Industry	China	2011	42%
		India	2012	1%
		Japan	2011	1%
		Subtotal		**44%**
Fuel economy standards for light-duty vehicles	Transport	United States	2005, 2008, 2012	12%
		China	2005, 2008, 2012; 2015	5%
		Japan	2003, 2007, 2010, 2015	2%
		All other		6%
		Subtotal		**25%**
Space heating energy performance standards	Buildings	United States	2003, 2006, 2007, 2009, 2012, 2015	5%
		China	2001, 2002, 2003, 2006, 2010, 2012	3%
		Germany	2004, 2009, 2014, 2015	2%
		United Kingdom	2002, 2006, 2010, 2013	1%
		All other		3%
		Subtotal		**14%**
		Grand total		**83%**

China accounted for more than half of total policy progress between 2000 and 2016 (Figure 2.8), mostly due to its aggressive industry targets. The Top 1 000 programme for industry was launched during China's 11th Five-Year Plan (FYP). The programme targeted the largest 1 000 industrial firms in China and saved over 150 million tonnes of coal-equivalent (Mtce). The 12th FYP included the Top 10 000 programme, which built upon the Top 1 000 programme to cover more than 15 000 industrial firms and two-thirds of China's total energy use. The Top 10 000 programme included an energy savings target of 250 Mtce by 2015 compared with 2010. Under the 13th FYP (2016-20), industrial sector targets have not yet been set (IEPD, 2017).

China accounts for a large share of progress both because of its aggressive industry targets and because it started from a low base: in 2005, Chinese industry was relatively inefficient. Industrial energy intensity in China was 3.5 times the OECD average, and more than 2.5 times that of India and Brazil. Between 2005 and 2014, industrial intensity declined at 3% per year on average, compared with 2% per year in the OECD. Despite its decline, energy intensity in China was triple the OECD average in 2014. Industry accounts for about half the energy used in China and 15% of all energy consumed by countries tracked by the EPPI.

Figure 2.8 Efficiency Policy Progress Index with and without China

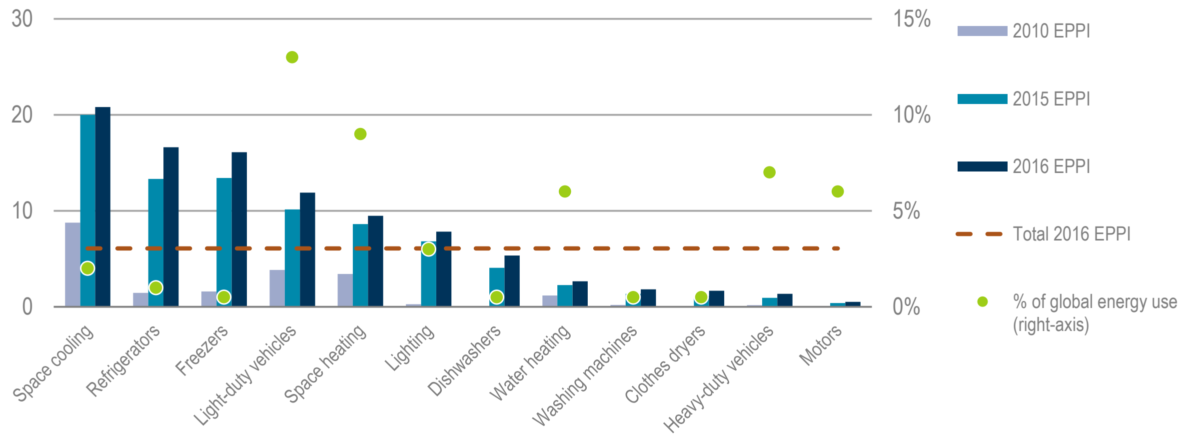


For many end-uses, far more progress was made between 2010 and 2016 than in the previous decade. At 21 points, **space cooling** has made the most progress of all end-uses (Figure 2.9). Policies requiring new buildings to keep out heat, by improving the building envelope, are substantially more stringent, as are new air conditioner standards. Standards for space cooling in the United States carry particular weight, as the United States accounted for almost one-third of global cooling energy use in 2016. Overall, space cooling accounts for just 2% of global energy use, but higher standards of living and migration towards warmer regions are causing demand to increase quickly, where efficiency standards are weakest (IEA 2017a).

Policy coverage and strength for **freezers and refrigerators** has progressed by 16 points, even though many countries had regulations in place before 2000. As with space cooling, this improvement had a small impact on total progress because refrigerators and freezers account for less than 1.5% of global energy use. By contrast, although representing 6% of global final energy use and having high coverage (52%), policy for **industrial motors** advanced the least, due to smaller percentage gains between motor efficiency levels.

Space heating accounts for 9% of global final energy use; recent new policy, led by the United States, China the European Union, had a big impact on total progress. **LDVs** account for 13% of global energy use and have an EPPI score of 12, almost double the global average. Fuel economy standards for **HDVs**, which account for 7% of global energy use, advanced markedly in 2016 in Canada, China, the European Union, Japan and the United States. However, policy progress for HDVs since 2000 lags far behind that for LDVs.

Figure 2.9 Efficiency Policy Progress Index and share of global energy use by end-use



Sources: Analysis based on energy data from IEA (2017a), *Energy Technology Perspectives*, www.iea.org/bookshop/758-Energy_Technology_Perspectives_2017; IEA (2016), *World Energy Outlook,* www.worldenergyoutlook.org/publications/weo-2016/*;* IEA (2017b), *Mobility Model* (database), www.iea.org/etp/etpmodel/transport; policy data from IEA (2017c), *Policy and Measures Energy Efficiency Database;* www.iea.org/policiesandmeasures/energyefficiency/; CLASP (2017), *CLASP Global S&L Database*, http://clasp.ngo/en/Tools/Tools/SL_Search.aspx; EES and Maia Consulting (2014), *Energy Standards and Labelling Programs* throughout *the World in 2013,* www.iea-4e.org/document/343/energy-standardslabelling-programs-throughout-the-world-in-2013; IEA 4E-TCP (2016-17), (Benchmark and Policy Reports), https://mappingandbenchmarking.iea-4e.org/matrix; IIP (2017), *Industrial Efficiency Policy Database*, http://iepd.iipnetwork.org/; BCAP (2017), *Code Status* (database), http://bcapcodes.org/code-status/; GBPN (2017), Databases and Tools, www.gbpn.org/databases-tools; Enerdata (n.d.), www.measures-odyssee-mure.eu; Siemens (2015), *Minimum Energy Performance Standards: MEPS Regulations Worldwide,* www.industry.siemens.com/; and ICCT (2017), *TransportPolicy.Net* (database), http://transportpolicy.net/index.php?title=Main_Page.

Energy utility obligations are becoming more common and ambitious, but progress stalled in 2016

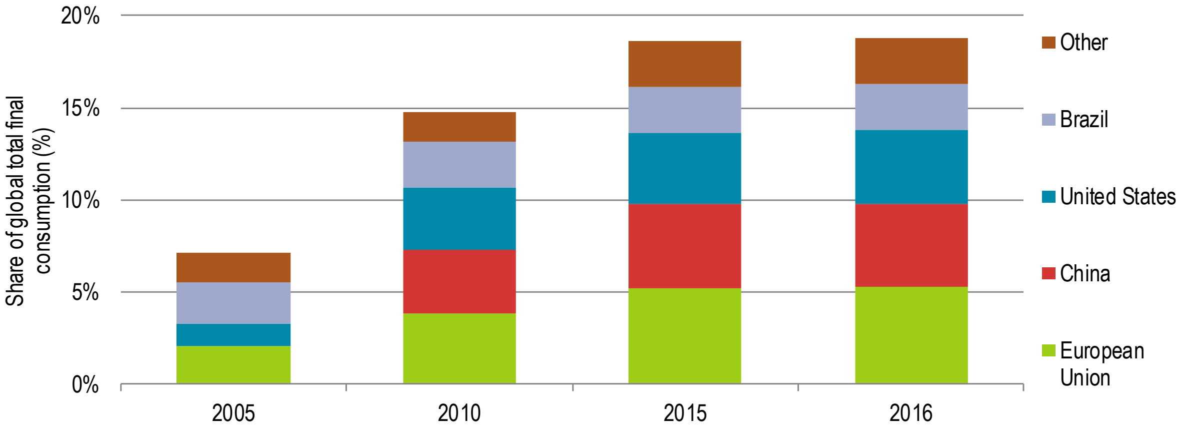
As with efficiency policies, the coverage and strength of energy utility obligations has increased markedly over the past decade. Rather than setting standards for individual end-uses or industries, utility obligations require energy companies to deliver energy efficiency outcomes – typically energy savings, but in some cases carbon emission reductions or fuel poverty reductions. In 2005, there were only 12 obligation programmes in the world, seven of which were in the United States, three in Europe, one in Brazil and one in Korea. By 2016, this had risen to 45, with programmes in all six continents. Nevertheless, programmes are concentrated in three regions: more than half are in the United States, 12 are in Europe and four in Australia. While no new obligation programmes began in 2016, Greece and Latvia began programmes in 2017 and Croatia is about to launch a programme.

The energy use coverage of obligations varies. All programmes cover electricity use. Many of the obligations in Australia, Europe and the United States – where they are commonly known as Energy Efficiency Resource Standards (EERSs) – cover natural gas too. A few programmes also cover transport fuel, district heat, thermal energy and process fuels. Overall, the percentage of global final energy use covered by obligation programmes rose from 7.1% in 2005 to 18.3% in 2016. There was almost no increase between 2015 and 2016 owing to the lack of new programmes (Figure 2.10).

The strength of obligation programmes is calculated as the percentage reduction in energy consumption targeted in a given year. Globally, the strength of obligation programmes stood at 0.4% in 2016 across all the final energy consumption covered. Global strength has doubled over the last decade. Among the 25 US states that have EERSs, the median strength is 0.8% of the fuels covered.

This means, for example, that an electric utility with a 0.8% EERS is obligated to save 0.8% of its electricity sales through efficiency programmes.[6] Some states have targets of closer to 3%, such as Massachusetts and Rhode Island. However, when state EERSs are weighted by total final energy use in the United States, the national EERS strength level is only 0.1%. This is a result of the relatively large proportion of energy use in the United States that is not covered by obligations, either because it is being consumed in states without obligations or by end-uses such as transport that do not feature in these programmes.

Figure 2.10 Coverage of energy utility obligations, 2016



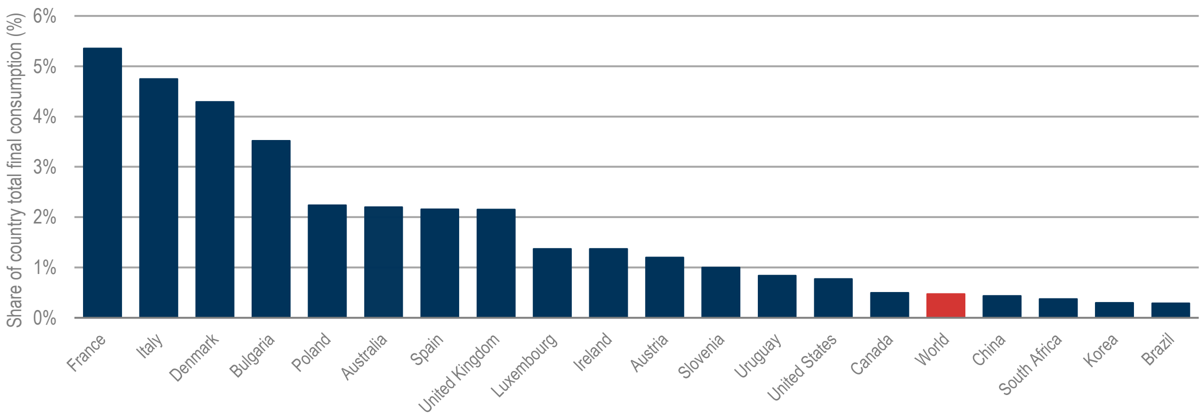
Note: For Denmark the target presented has been reduced as a result of evaluation evidence presented by the Danish Energy Agency. For Bulgaria the target presented has been reduced to reflect persistent under-achievement of targets by obligated parties.

Sources: IEA (2017d), *Market-Based Instruments for Energy Efficiency,* www.iea.org/publications/insights/insightpublications/MarketBased_Instruments_for_Energy_Efficiency.pdf; ATEE (2017), *Snapshot of Energy Efficiency Obligation Schemes in Europe: 2017 Update*, http://atee.fr/sites/default/files/part_6_2017_snapshot_of_eeos_in_europe.pdf; ACEEE (2016a), *The 2016 State Energy Efficiency Scorecard,* http://aceee.org/sites/default/files/publications/researchreports/u1606.pdf; US EIA (2017), *State Profiles and Energy Estimates*, www.eia.gov/state/seds/; DOIS Australia (2016), *Energy in Australia,* http://industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Energy-in-Australia.aspx.

The impact of over a decade of energy efficiency obligations has increased year-on-year, not just because of increases in coverage and strength, but also because of the long-lived nature of many energy efficiency measures. For example, a more efficient refrigerator bought in 2005 as a result of an incentive delivered through an obligation programme will deliver savings for its whole lifetime. In 2016, energy savings due to obligations put in place since 2005 are estimated to equal 1% or more of national energy consumption in a dozen countries (Figure 2.11), with the highest savings levels occurring in France (5.4%), Italy (4.8%) and Denmark (4.3%). It is important to note that the method for calculating the savings attributable to obligation policies varies between programmes, meaning that caution should be taken when comparing them.

[6] Obligations are typically based on the previous year's sales.

Figure 2.11 Energy savings in 2016 from utility obligations in operation since 2005, as a percentage of national final energy consumption



Sources: IEA (2017d), *Market Based Instruments for Energy Efficiency,*www.iea.org/publications/insights/insightpublications/MarketBased_Instruments_for_Energy_Efficiency.pdf; ATEE (2017), *Snapshot of Energy Efficiency Obligation Schemes in Europe: 2017 Update*, http://atee.fr/sites/default/files/part_6_2017_snapshot_of_eeos_in_europe.pdf; ACEEE (2016b), *State and Local Policy Database,* http://database.aceee.org/state-scorecard-rank; US EIA (2017), *State Profiles and Energy Estimates*, www.eia.gov/state/seds/; DOIS Australia (2016), *Energy in Australia,* http://industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Energy-in-Australia.aspx; Ontario Energy Board and IESO (2017), *Ontario Energy Report*, http://www.ontarioenergyreport.ca/pdfs/5806_IESO_OntarioEnergyReportQ42016_Electricity_EN_FA.pdf.

Key policy announcements in 2016

Several countries have announced new policies or implemented elements of previously adopted policies to promote energy efficiency since *EEMR 2016*. Examples include the Pan-Canadian Framework on Clean Growth and Climate Change, the European Commission's recast EED, fuel efficiency standards in India and Mexico's Energy Transition Law.

Argentina

The Ministry of Energy and Minerals launched a behavioural programme for public buildings (similar to the Guide of Good Practices for the Responsible Use of Energy) at the end of 2016. The programme issued guidelines for responsible energy use, including adjusting thermostats and lighting schedules. The second phase will assign an energy manager to each public building. A Diploma in Energy Management programme was also introduced (Ministry of Energy and Minerals, Argentina, 2017).

Brazil

Energy efficiency plays a key role in Brazil's NDC commitment to reduce GHG emissions by 37% by 2025 compared with 2005. This involves a 10% energy efficiency improvement target for 2030 and a new National Energy Efficiency Action Plan (Federative Republic of Brazil, 2015). The most common incandescent lightbulbs were banned in June 2016 to pave the way for their replacement by light-emitting diode (LED) bulbs (INMETRO, 2016).

Canada

In December 2016, the Pan-Canadian Framework on Clean Growth and Climate Change was announced, which aims to facilitate co-ordination by the federal, provincial and territorial governments (Government of Canada, 2017). Also in 2016, energy performance standards were tightened for 20 product categories (NRCAN, 2016) and energy efficiency programmes for the industry sector were launched in Manitoba, Ontario, Saskatchewan and Toronto (IEA, 2017c).

China

In June 2016 the Chinese government launched the Leading Efficiency Programme (LEP), an energy labelling initiative. The first phase covers televisions, variable-speed drives for air conditioners, and refrigerators. To qualify, products must be made and sold in mainland China (CLASP, 2016).

European Union

The European Commission's proposed update to the EED extends the energy savings target from 20% of projected primary energy by 2020 to 30% by 2030. Another requirement is for energy utilities to save 1.5% per year by deploying energy-efficient technologies and management strategies, or for member states to come up with alternative measures. The update is part of a package of measures that also includes dedicated measures for buildings, products (Ecodesign), and energy efficiency financing (a new Smart Financing for Smart Buildings programme) (European Commission, 2017).

Germany

A National Top Runner Initiative for residential appliances was launched under the National Energy Efficiency Action Plan in 2016 (Federal Ministry for Economic Affairs and Energy, Germany, 2017). Germany also launched a programme to fund smart grid pilot projects; a programme to reduce commercial and industrial waste heat; an incentive programme for the industry and services sectors to encourage energy efficiency improvements at the system level (IEA, 2017c) and a green paper on energy efficiency (Box 2.3).

Box 2.3 German green paper on energy efficiency

Policy makers are starting to consider the interactions of energy efficiency, renewable energy and power market policy; particularly in countries with ambitious energy efficiency and emissions reduction targets. One such country is Germany, which is pursuing policies that reduce primary energy demand, increase renewable energy supply and improve overall system efficiency. To advance these considerations, in September 2016 Germany released a Green Paper on Energy Efficiency that focussed on how efficiency and renewable energy can be further cost-effectively enhanced in all sectors. The paper was based on three principles:

- Reducing demand in all sectors ("Energy Efficiency First"). Increasing investment in energy efficiency technologies to halve energy demand by 2050 and using renewable energy to cover remaining demand.
- Direct use of renewable energy. Increasing the use of renewable energy, such as solar thermal, geothermal, waste heat and bioenergy for heating, building air conditioning and hot water.
- Renewable power is used efficiently for heat, transport and industry ("sector coupling"). The demand for energy that remains, despite efficiency measures and direct use of renewable energy, is covered by power from the wind and sun, primarily in technologies that replace fossil fuels with a small amount of power, or convert power into other energy sources such as hydrogen.

These principles also underpin Germany's market design reform strategy "Power 2030", with the overall aim of expanding the efficient use of renewable energy in the transport, heat and industry sectors.

Source: Federal Ministry for Economic Affairs and Energy (2016), Green Paper on Energy Efficiency: Discussion Paper of the Federal Ministry of Economic Affairs and Energy

India

The first phase of new fuel economy standards for LDVs in India, originally scheduled to start in 2016, took effect in 2017. Combined with the second phase, which begins in 2022, the standards are expected to avoid 50 million tonnes of CO_2 that would otherwise have been emitted in 2030 (ICCT, 2017). Also in 2016, the second cycle of India's Perform, Achieve, Trade energy efficiency programme for industry was launched, increasing the coverage to about half of industry energy use. By 2019, the programme aims to reduce industry energy use by 4% compared with 2014. Firms can comply with the targets by achieving their own energy savings or, from 2017, by purchasing energy savings certificates on the open market (Ministry of Power, India, 2017).

Mexico

At the end of 2015, Mexico published an Energy Transition Law that defines a transition strategy for the deployment of clean energy and energy efficiency in the power generation sector (Official Journal of the Federation, 2015). The strategy sets a goal of reducing final energy intensity at an average annual rate of 1.9% between 2016 and 2030 and 3.7% between 2031 and 2050 (Official Journal of the Federation, 2016). A roadmap describes the overall and sector-specific actions required to meet the goal (Secretariat of Energy, Mexico, 2017). The government also issued more stringent MEPS for LED lightbulbs in January 2017 (CONUEE, 2017).

United States

Many states made important progress on policies that promote energy efficiency in 2016. Two examples are California and Illinois.

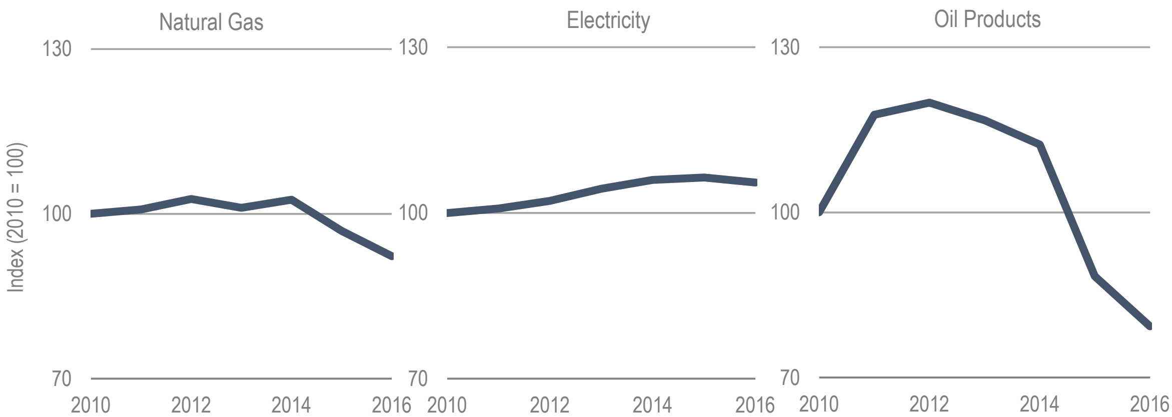
In **California**, the government started to implement two key laws related to energy efficiency – the Clean Energy and Pollution Reduction Act and State Assembly Bill 802 (AB 802). The Act requires savings of electricity and natural gas to double by 2030 (compared with 2015 levels). AB 802 complements the Act by establishing a buildings energy-use benchmarking and disclosure programme. This will expand consumer access to energy data and ensure that more buildings comply with efficiency standards (CEC, 2017).

In **Illinois**, the Future Energy Jobs Bill was signed into law in December 2016 and took effect in June 2017. It increases energy savings obligations for the state's largest utilities. For example, the electricity distribution company serving the Chicago area must achieve cumulative energy savings of 21.5% by 2030 (2012 baseline). The law also doubles the spending cap on utilities' energy efficiency programmes from 2% of revenue to 4%, and creates incentives for utilities to implement the programme. Importantly, it also allows utilities to include programme costs in their tariff schedules – previously efficiency was paid for separately. Building efficiency into tariffs makes it more of a "core" utility business model (MEEA, 2017; Illinois General Assembly, 2017).

Energy prices declined or remained steady

In 2016, in most countries and for most forms of energy, retail prices declined (Figure 2.12). Natural gas prices dropped 5 percentage points in 2016 after falling 6 percentage points in 2015; prices are expected to continue to weaken further in 2017 due to shale gas production in the United States and LNG exports from Australia (IEA, 2017e). Electricity prices remained stable or declined slightly, and composite prices for oil products dropped 9 percentage points in 2016 after a 20 percentage point fall in 2015.

Figure 2.12 Indices of average residential retail energy prices in OECD countries, 2010-16



Source: IEA (2017f), *Energy Prices and Taxes*, Q1, (database), www.iea.org/statistics/topics/pricesandtaxes/.

The response to price changes varies between countries. Since the sharp drop in oil prices in 2014, residential transport fuel use[7] has decreased in some countries – notably in Japan (3%) – and remained flat in others, including France, the United Kingdom and Mexico. In others, however, it has increased. In the United States, where fuel taxes are low and retail prices dropped by more than 30%, there has been a 6% increase in gasoline consumption since 2014. Since 2014, fuel prices have dropped by a quarter in China and fuel consumption has increased by 12%, with people buying larger vehicles, driving more kilometres with fewer passengers and taking less public transport.

The recent slump in oil prices underscores the long-run importance of vehicle standards

The role of vehicle standards in promoting efficiency gains becomes increasingly important as fuel prices for personal transport fall, as demand for mobility increases, and as consumer preferences shift towards larger vehicles (SUVs, pick-up trucks and so-called cross-overs). In Japan, for example, SUV sales are increasing, but LDV fuel economy standards have strengthened by 33% since 2000, building upon regulations first put in place in 1979 (first target in 1985). Fuel economy labelling has also been mandatory since 2000. Current fuel economy standards have a target to be achieved by vehicles sold from 2020 (following 2010 and 2015 targets). Fuel consumption declined for all vehicle segments between 2000 and 2016 (GFEI, 2017). The cumulative effect of progressively tightening standards has resulted in significant energy and income savings. While prices at the pump increased by more than 80% in Japan between 2000 and 2016, and average annual expenditures on gas went up by 40%, bills would likely have risen another 30% without fuel economy standards. IEA decomposition analysis shows efficiency reduced average spending at the pump by USD 170 per capita in 2016 (Figure 2.14). In total, efficiency saved car owners in Japan USD 22 billion in 2016 and reduced total passenger vehicle energy use 25%, or 750 PJ, which is equivalent to the combined personal vehicle energy use of the Netherlands and Sweden.

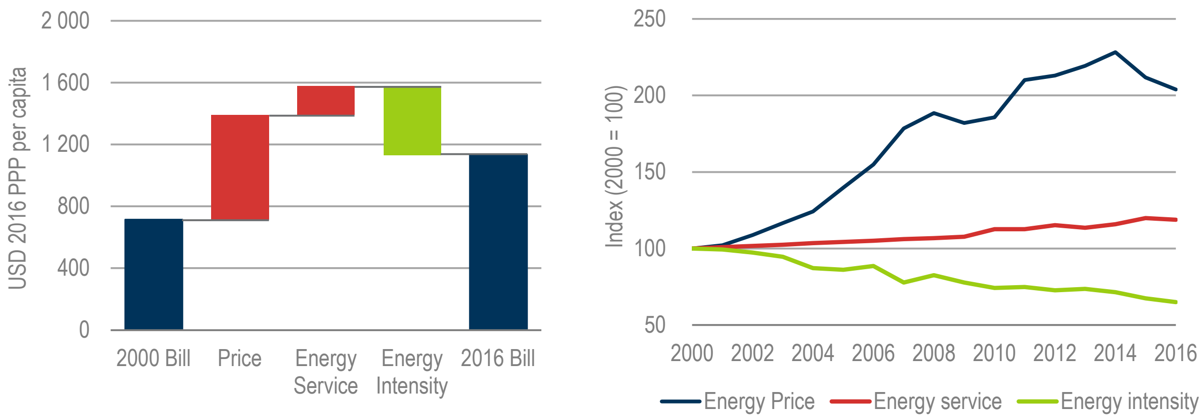
Efficiency continues to save residential customers money on energy even as prices drop. Savings tend to be higher in developed countries that have made more progress on efficiency policy and where fuel taxes are higher, but savings are noticeable even in large developing economies such as China and Mexico, where energy services are growing quickly.

[7] Including gasoline and diesel fuel use for passenger cars and two- and three-wheeled vehicles.

Efficiency continues to have a real impact on household energy bills

Despite recent decreases in energy prices, improvements in household energy efficiency continued in 2016. For example, in Germany, even though residential energy prices have fallen since 2014, the intensity of household energy consumption[8] continued to improve in line with the trend since 2000 (Figure 2.13).

Figure 2.13 Decomposition of household energy bills in Germany, 2000-16



Notes: 2016 energy use data estimated. Household energy includes expenditure for electricity and gas consumption.

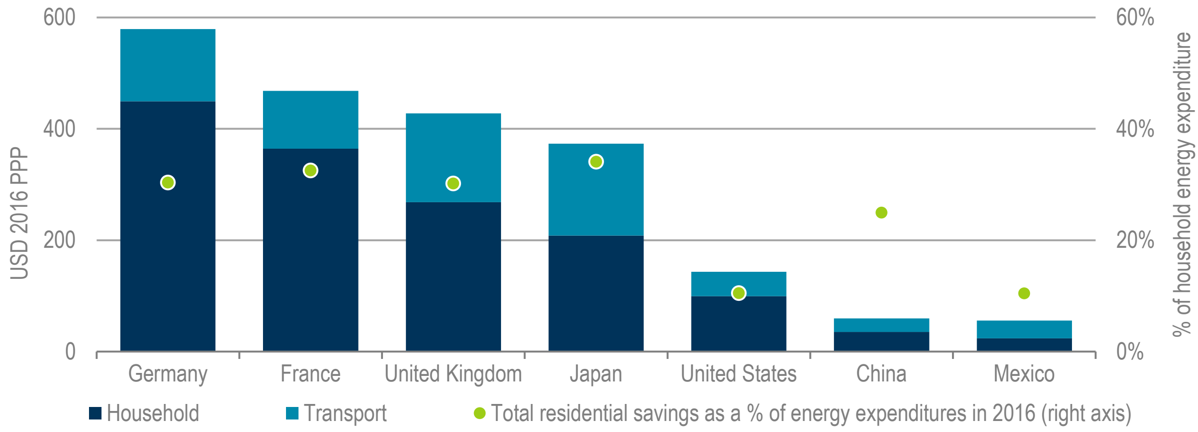
Without efficiency gains since 2000, average household expenditures on electricity and gas in Germany would have been USD 450 per capita, or 27%, higher in 2016. This increases to USD 580 per capita and 30% higher when the cost of personal transport is included. The proportion of household income spent on energy has risen since 2000. Households in Germany spent 7.0% of disposable income on energy bills in 2016, up 1.4 percentage points from 2000; however, in the absence of efficiency this would have been as high as 9%. Efficiency saved German households USD 45 billion in 2016 and reduced total household energy use by over 1 000 PJ, equivalent to half the total household energy use of Korea.

Savings on household energy expenditure due to efficiency vary significantly by country (Figure 2.14), but tend to be higher in countries with longer-established efficiency policy and higher energy prices. For example, France, Germany and the United States have comparable EPPI scores (5.6 to 6.6) yet absolute bill savings due to efficiency gains since 2000 are much lower in the United States, where energy prices are half those in Germany and almost 60% of those in France. The average household in the United States also consumes 20% more energy per year than in Germany, and 30% more than in France. Even in emerging economies where demand for energy services is growing, efficient gains are still avoiding additional household energy expenditure. Despite average residential energy prices in China being about a third lower than in the United States, households avoided an additional 25% of annual energy expenditure. In Mexico, 10% of additional expenditure was avoided. Household bill savings are calculated net of the policy costs incurred by bill payers due to energy company obligations.[9]

[8] Household energy use includes electricity and heating fuel consumption. It does not include transport fuel.

[9] These costs are estimated to equal 1% of residential energy bills in France and 2% of residential energy bills in the United States.

Figure 2.14 Total average residential savings per capita on energy expenditure in 2016 due to efficiency gains since 2000



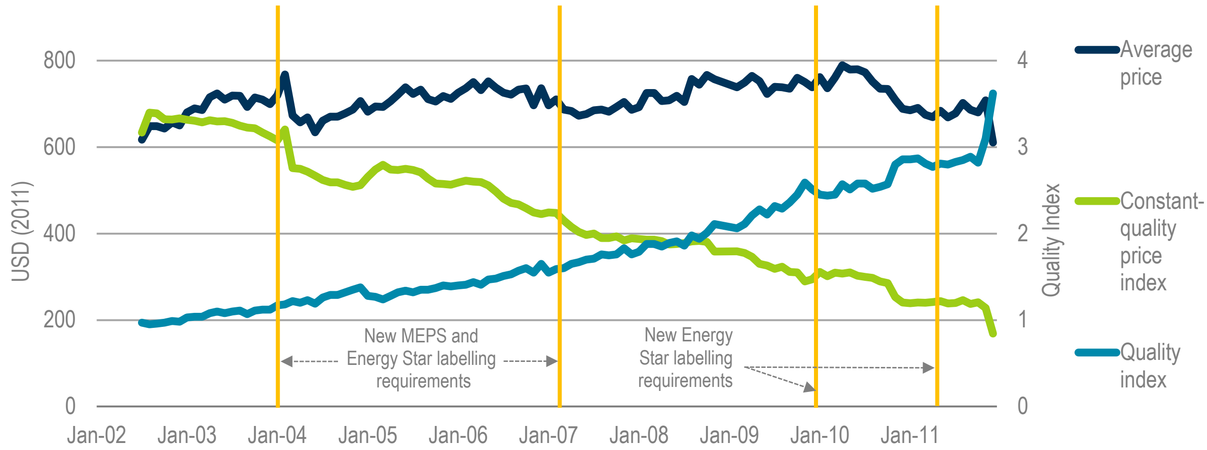
Note: 2016 energy use data estimated. Household energy includes expenditure for electricity and gas consumption.

Importantly, while household bills have come down, this has not been accompanied by an increase in the costs to consumers of energy-using products and equipment. Product prices have tended to decline in real terms at the same time as becoming more efficient, driven by policy. Studies in Australia, the European Union, Sweden and the United Kingdom have all observed this trend (IEA TCP-4E, 2016a). A recent study of standards and labelling programmes in the United States drew similar conclusions for quality-adjusted product prices (Box 2.4).

Box 2.4 Efficiency standards get customers more for their money

Recent research suggests that more stringent energy efficiency policies result in consumers getting better quality appliances without paying more. Brucal and Roberts (2017) analysed how implementation of more stringent MEPS and product labelling in the United States affected the quality and price of refrigerators and clothes washers between 2001 and 2011. Prices for regulated clothes washers fluctuated after standards were implemented, but were not higher in 2011 than in 2000 (dark-blue line in Figure 2.15). At the same time, clothes washer quality improved four-fold (light-blue line). If product quality is held constant, prices dropped considerably (green line). This means that if a clothes washer first sold in 2001 was instead first sold in 2011 without any updates, it would cost about USD 450 less. Changes in product prices and quality were similar for refrigerators. The research also showed that while room air conditioners were not regulated as strongly as other appliances studied, their quality may have benefited from standards because some innovations developed for regulated products may have been applied to room air conditioners in order to exploit economies of scale. Innovation costs were spread across more product categories, helping keep prices down across the board.

Figure 2.15 Clothes washer price and quality changes in response to efficiency standards



Notes: The figure shows the average market average price (dark-blue line), the quality-index (light-blue line) and constant-quality price index (CQPI, green line) for regulated washing machines. Vertical lines indicate periods of either new (more stringent) MEPS or Energy Star labels.

Source: Brucal and Roberts (2017), "Do energy efficiency standards hurt consumers? Evidence from house household appliance sales".

Technology that drives efficiency: Household connected devices

The number of installed connected devices may triple by 2020

The exponential growth in connected devices is a global technology trend that needs more attention from policy makers. These new sources of energy use require new efficiency strategies, and the fact that these devices can communicate with one another is creating opportunities for energy services and energy savings through more accurate, real-time control of energy consumption across end-uses. Their penetration is growing quickly. Gartner, a research firm, estimates that 4 billion household connected devices were installed worldwide in total by the end of 2016, and expects 1 billion more installations in 2017 (Gartner, 2017).[10] The types and volume of connected devices available are expanding rapidly, enabling new services that may become as common as smartphones are today. These services may enhance quality of life, but smart devices are not necessarily energy efficient. Connected devices form one component of the broad technology trend of digitalization, which impacts the entire energy system and is an emerging area of the focus for the IEA.

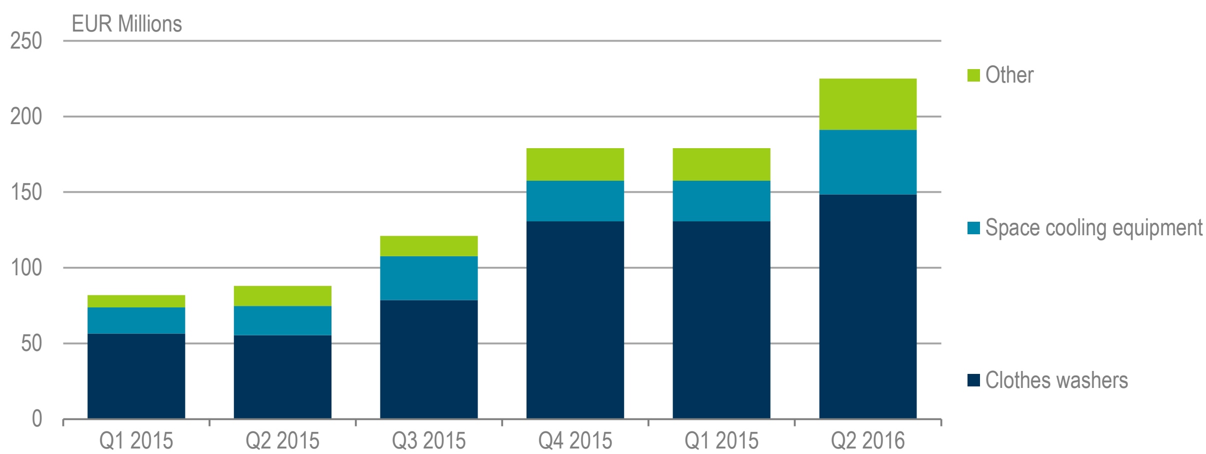
There has long been a degree of connectivity among household devices, such as electronic thermostats with programmable settings that control home temperature. The advent of low-cost electronics and sensors is enabling "smartness" to be added to many connected devices, meaning they can process input from internal sensors and adjust their functioning. For example, smart washing machines can sense the type and size of laundry load and adjust cycle time, water quantity and temperature accordingly. Until recently, such devices typically remained isolated, with the smartness limited to direct user input and pre-programmed responses at the time of

[10] Includes devices installed in 2016 and devices installed in previous years.

manufacture. However, many new devices that communicate with one another and with the outside world are now being developed and sold.

These devices can be grouped in three categories: lighting, appliances and home automation. **Smart lighting** is currently dominated by smart LED lightbulbs that can sense motion and be controlled directly or automatically via an app. **Smart appliances** – such as refrigerators and clothes washers, heating and cooling equipment, as well as consumer electronics – feature sensors and actuators that can optimise product maintenance and energy use, as well as other functions. An **actuator** is a mechanism that triggers a device in response to a sensor, for example turning on an outdoor light in response to a motion sensor. The popularity of smart appliances is growing quickly (Figure 2.16). **Home automation,** which uses connected devices to manage home security, comfort and energy use, requires gateways, actuators and sensors. A **gateway** is a hardware device that connects with and can be used to control smart devices within the home. It may also connect to the cloud. A **home energy management system (HEMS)** controls and records energy use through the gateway with user input via an app. **Sensors** include plug-in and battery-powered sensors for home security, comfort and energy management. The connected home usually starts with the purchase of a gateway, and grows as consumers purchase smart devices over time.

Figure 2.16 Sales value of large smart home appliances in the European Union, 2015-16



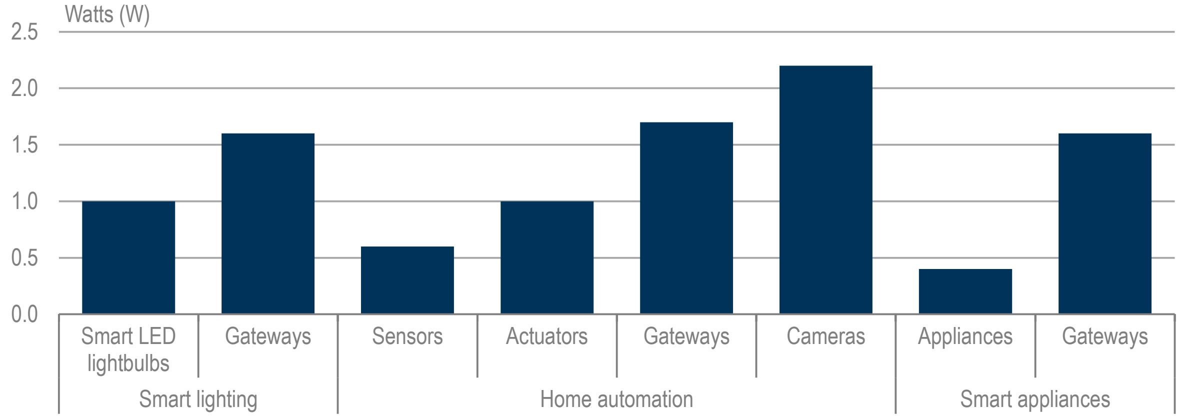
Note: "Other" includes tumble dryers, dishwashers, and cooking equipment.

Source: CECED (2016), *Home Appliance Europe 2015/2016*, www.ceced.eu/HA2025_report/assets/HA2025_report.pdf.

The rapid growth of connected devices comes with a hidden energy price tag

In addition to the energy used to perform the device's primary function, such as to heat the home or wash clothes, power consumption by connected devices includes the energy used by the network infrastructure (including routers, switches and data centres), the energy used by the connected device to monitor and process information from internal sensors, and the energy used to maintain the device's connection to the wider network, commonly referred to as networked standby. **Networked standby** is also often a connected device's biggest draw on power. Average standby power for a subset of household connected devices is shown below (Figure 2.17). Worldwide network-related standby energy use for this subset alone could grow 20% per year to 46 TWh by 2025 (IEA TCP-4E, 2016).

Figure 2.17 Average standby power of household connected devices per unit



Source: IEA 4E-TCP (2016), *Energy Efficiency of the Internet of Things*, http://edna.iea-4e.org/tasks/task2.

There are currently mandatory energy performance standards or energy labels aimed at limiting network standby energy in the European Union, India, Korea, Mexico and the United States, including limits on standby power use, standby power requirements for connected devices labelled as energy-efficient, and functional requirements, such as mandatory product inclusion of use modes that minimise standby power use. Voluntary policy initiatives include manufacturer agreements limiting standby power use of specific products (e.g. set-top boxes and network equipment), and voluntary energy labelling schemes that include standby power limits (e.g. Energy Star in the United States and e-Standby in Korea).

Connected devices could enhance the efficiency of efficient homes but are largely immature technologies with savings driven by consumer behaviour

Connected devices enable many new sources of savings at the device, household and grid levels (Table 2.4). Smart devices ideally improve the efficiency of homes that are already efficient – it is important to not view them as high-tech substitutes for conventional measures that improve the efficiency of the building stock, such as air sealing and insulation, which are required to fully capitalise on the benefits of smart devices. Further, most smart technologies are immature, with reported savings that have not undergone rigorous third-party evaluation, or have not been verified beyond pilots.[11] The main risk is that energy savings enabled by most connected devices are driven by user behaviour, which may not align with efficiency.

[11] The energy impacts of in-home displays and load disaggregation have been verified through several evaluations. Savings from smart thermostats have also been assessed, but outcomes are mixed – they can sometimes result in energy increases, depending on user behaviour.

Table 2.4 Examples of energy efficiency enabled by household connected devices

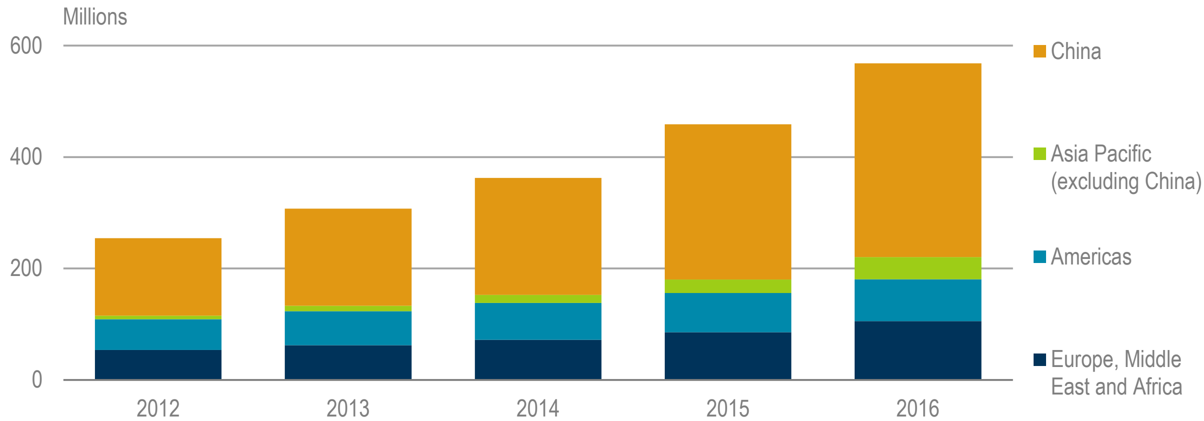
Level	Source of efficiency
Device	**Energy use optimisation**. Connectivity increases the opportunities for device optimisation by: (1) increasing energy use **awareness** by consumers, allowing them to modify use patterns; (2) improving the likelihood of appropriate product **set-up**: even though little quantitative evidence is currently available, the operational mode advised by smart set-up routines is expected to be more energy-efficient than the setting the end-user would choose manually; and (3) providing manufacturers with better **feedback** on consumer behaviour to design products that consume less energy, and develop household-specific optimisation software.
Household	**In-home displays (IHDs)** provide real-time household energy use data to consumers via an app or standalone display. They can enhance the efficiency of device-level energy use by giving consumers direct feedback on product and household energy use, and can stimulate householders to use appliances and equipment more efficiently. There are over 25 years of direct feedback pilots, and the results strongly suggest that customers reduce energy use in response to feedback. One metastudy found average annual household energy savings of 7%, although savings can erode as householders become less motivated. **HEMS** often incorporate in-home displays.
	Smart thermostats use machine learning to automatically adjust room temperature in response to occupant behaviour and input, and ambient conditions such as humidity. Users can control smart thermostats remotely though an app.
Grid	**Smart meters** are electronic measurement devices used by utilities to monitor customers' energy use and manage the grid. Smart meters do not directly result in energy savings but enhance or enable other savings opportunities by measuring household electricity use frequently enough (typically every 15 minutes or hourly) for household occupants (or devices) to respond in real time. Smart meter data can also be used to validate efficiency project savings. Smart meter deployments accelerated quickly in recent years (Figure 2.18).
	Time-variant pricing, such as time-of-use (TOU) tariffs, can enhance energy savings by connected devices. Time-variant pricing evaluations generally show peak electricity demand savings due to load-shifting, but not efficiency effects. For example, a key finding of TOU pilots in California was that residential customers respond to TOU price signals during evening hours. The pilot tested eight TOU rates around the state, with peak kW savings levels ranging from 2.7% to 6.1%. Potential energy savings benefits are indirect – some industry stakeholders believe adoption of smart devices will accelerate if there are more specific retail energy price signals to which the technology can respond. TOU tariffs require a smart meter to measure when consumers are using electricity and provide them with accurate bills.
	Load disaggregation technology analyses household smart meter data by breaking down household electricity use to the device level. Load disaggregation is sometimes used for targeted marketing of efficiency and demand response (DR) programmes. Utilities may market specific appliances, such as efficient air conditioners, to homes with high peak demand, or the data can be used to develop whole home efficiency reports (HERs). A HER compares the energy use of a home with historical and peer home energy use. Evaluations show that homes with higher energy use are motivated to reduce energy use when provided with a HER. En masse, this can have a substantial impact. Under the HER programme run by Commonwealth Edison, the electricity utility serving the Chicago area, 1.7 million participants received a HER in 2016, resulting in average annual energy savings per home of 1.5%. Global spending on load disaggregation-enabled programmes has grown exponentially in the last ten years to over USD 50 billion in 2016.

Sources: IEA TCP-4E (2016b), *Energy Efficiency of the Internet of Things*, http://edna.iea-4e.org/tasks/task2; CDA (2016), *CDA Voluntary Principles for Energy Efficient Connected Devices,* http://cda.iea-4e.org/cda-principles; CLASP (2008), *Techno Economic Analysis for Labeling of Set Top Boxes in India*, http://clasp.ngo/en/Resources/Resources/PublicationLibrary/2008/Techno-economic-analysis-for-STB-labels-in-India.aspx; Faruqui, Sergici and Sharif (2009), "The impact of informational feedback on energy consumption – A survey of the experimental evidence"; Edison Electric Institute (2016), *Smart Meters and Smart Meter Systems: A Metering Industry Perspective*, www.eei.org/issuesandpolicy/grid-enhancements/documents/smartmeters.pdf; The Edison Foundation (2016), *Electric Company Smart Meter Deployments: Foundation for A Smart Grid*, The Edison Foundation, Washington DC, www.edisonfoundation.net/iei/publications/Documents/Final%20Electric%20Company%20Smart%20Meter%20Deployments-%20Foundation%20for%20A%20Smart%20Energy%20Grid.pdf; Brattle Group (2017), *The Value of TOU Tariffs in Great Britain: Insights for Decision Makers,* Nexant (2017), *California Statewide Opt-in Time-of-Use Pricing Pilot, Interim Evaluation;* Bloomberg New Energy Finance (2015); Navigant (2016), *ComEd Home Energy Report Program Evaluation Report, Final,* http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY8_Evaluation_Reports_Final/ComEd_Home_Energy_Report_Opower_PY8_Evaluation_Report_2016-12-22_Final.pdf; IEA analysis of Bloomberg New Energy Finance (2015), *Energy Smart Technologies – Research Note*.

Smart meters installations are quickly accelerating

Global contracted installations of smart meters grew 22% annually from 2012 to nearly 570 million units in 2016 (Figure 2.18). Smart meters are an important precursor to smart homes because they can enable customers and smart devices to adjust energy use in response to changes in energy prices in real time. There is, however, considerable diversity in meter technology and functionality that could limit their role in optimising home energy use. In some cases, a HEMS may not be able to access smart meter data if the meter is incompatible with the HEMS communication protocol (e.g., ZigBee or ZWave).

Figure 2.18 Global contracted installations of electricity smart meters



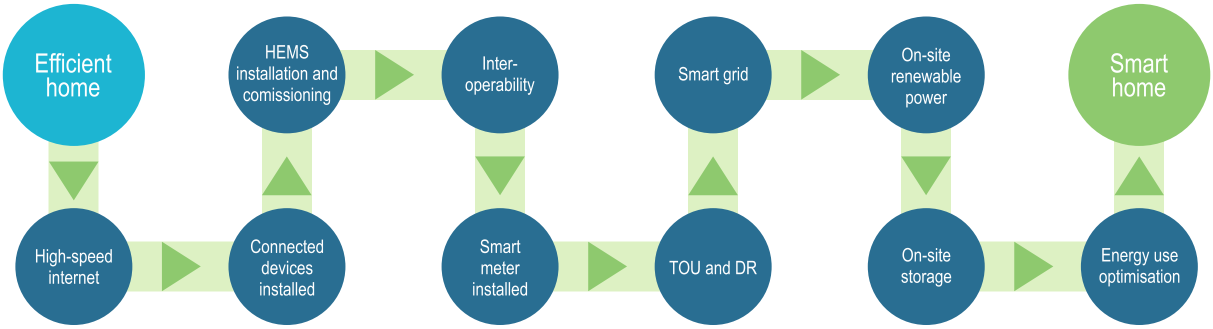
Sources: Bloomberg New Energy Finance (2016), *Smart-meter factpack 2016;* US ITC (2014), *Global Market for Smart Electricity Meters: Government Policies Driving Strong Growth,* www.usitc.gov/publications/332/id-037smart_meters_final.pdf.

Smart home technology exists but there are many barriers to market growth

A smart home embodies all the technology and functionality discussed above, and may also integrate on-site renewable generation and storage (in batteries or electric vehicles). It is characterised by the control, automation and optimisation of home energy use, water use, comfort and security. Control may be exerted by home occupants, grid operators (e.g., for demand response) or a third party (e.g., an energy services company). There are at least 11 preconditions for a smart home, starting with an efficient home with high-speed Internet access (Figure 2.19). While some these conditions may be adopted in different orders of priority by individual households, the scale of potential energy benefits increases as more of the preconditions are fulfilled.

While the technology exists for creating smart homes, it has not been taken up on a large scale anywhere. This is because of the high installation and operation cost, lack of time-variant pricing and smart grid infrastructure, privacy and security issues, market fragmentation, and lack of interoperability. **Interoperability** is the ability of smart devices to communicate with one another, with the HEMS and smart meter, with the cloud, and with product manufacturers and grid operators. Policy makers and industry have not developed interoperability standards that satisfy the technical requirements for smart homes and allay stakeholder concerns about data privacy and data ownership. **Blockchain** may help accelerate adoption of smart home technology by providing a secure platform for peer-to-peer energy trading and a low-cost method of validating energy savings.

Figure 2.19 Smart home preconditions



Sources: IEA 4E-TCP (2015), *Connected Devices Alliance: Technical Report on Progress with International Initiatives on Networked Devices*, www.iea-4e.org/files/otherfiles/0000/0353/CDA_TECHNICAL_REPORT_201115.pdf; Buildings Performance Institute Europe (BPIE) (2017), *Is Europe Ready for the Smart Buildings Revolution?*

Household connected devices may enable significant improvements in system efficiency, but policy makers should be careful to also account for their energy costs. Further, it is very challenging for policy makers to keep track of the diversity of smart technologies and their evolving markets. Recognising this fact, the G20 Network Devices Task Group, which consists of industry and government representatives, developed the **Connected Devices Alliance (CDA) Voluntary Principles for Energy-Efficient Connected Devices**. These principles provide guidance on the key features of energy-efficient connected devices and encourage a common global framework for the development of government policies and measures.[12]

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[12] The CDA Voluntary Principles for Energy Efficient Connected Devices are available on http://cda.iea-4e.org/cda-principles

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3. ENERGY EFFICIENCY IN KEY SECTORS

Highlights

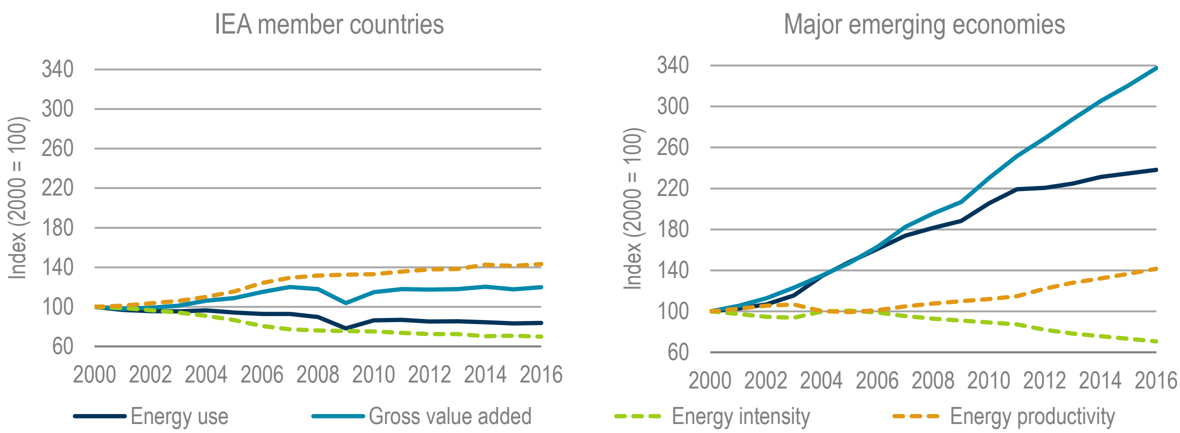
- **The energy intensity of industry, the sector in focus for this year's report, fell by nearly 20% between 2000 and 2016.** Improvements in China, home to the world's largest industry sector, accelerated after 2006, primarily as a result of energy efficiency policies. Globally, industry continues to produce more gross value added (GVA) per unit of energy consumed.
- **In some energy-intensive industry sectors, improvements in energy efficiency have come about mainly as a result of the addition of new production capacity using more modern technology, rather than upgrades to existing plants**. This is highlighted by primary aluminium smelting and cement manufacturing, where new and more efficient production capacity has been built in China and India in recent years. Energy efficiency gains in these sectors can help reduce the impact of volatile energy prices on competitiveness.
- **The application of energy management systems, which provide a structure to monitor energy use and identify opportunities to improve efficiency, is growing**. The number of certificates for ISO 50001 – a global standard for energy management created in 2011 – grew to nearly 12 000 in 2015; 85% of which were in Europe. Energy management systems can yield significant benefits. Early evidence suggests that companies that implement ISO 50001 or similar standards can achieve energy and financial savings of over 10%, alongside benefits such as improved management of other production inputs.
- **Progress in improving energy efficiency in buildings continues to be made thanks to policy action and technological advances**. Policies to date have focused primarily on the building envelope, rather than heating and cooling equipment. Space cooling is the fastest growing use of electricity in buildings and policy coverage is weakest where it is growing most rapidly.
- **There is considerable potential for appliance, equipment and lighting standards to achieve further energy savings.** Efficiency improvements of 10% to 20% are possible in most countries from products that are already commercially available. There is strong global momentum towards more efficient lighting. Switching from halogen to light-emitting diode (LED) lighting can yield energy savings of 75%. By 2022, 90% of indoor lighting worldwide is expected to be provided by compact fluorescent lamps (CFLs) and LEDs.
- **Fuel efficiency standards for trucks, which represent 43% of total oil consumption for road transport, have come on the radar for policy makers.** In 2016, only 16% of the energy use of trucks worldwide was covered by mandatory efficiency policies. Fuel economy standards are in place in only four countries – Japan, China, the United States and Canada. The European Union, India, Korea and Mexico are expected to introduce standards in the coming years.
- **Worldwide sales of electric vehicles, which are much more efficient than internal combustion engine vehicles, grew by 40% in 2016.** However, with falling gasoline prices, sales of less efficient large passenger vehicles, especially SUVs, increased across all major vehicle markets, dampening the global rate of improvement in fuel efficiency.

Industry

Industrial energy intensity continues to improve

Between 2000 and 2016, energy intensity – final energy consumption per unit of gross value added (GVA)[1] – in the manufacturing sectors ("industry") decreased by 30% in both IEA member countries and major emerging economies. However, improvements in emerging economies were most evident after 2006, largely as a result of industry programmes in China. At the same time, energy productivity – GVA per unit of final energy consumption – increased by over 40% in both country groupings (Figure 3.1). As absolute industrial energy intensity remains higher in the emerging economies, which have a greater share of global industry GVA, the overall improvement for the two country groupings combined is only 20%.

Figure 3.1 Industrial energy intensity and productivity trends 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, manufacture of coke and refined petroleum products and construction. Energy use related to blast furnaces, coke ovens and petrochemicals feedstocks are included. Major emerging economies covers Brazil, China, India, Indonesia, Mexico and the Russian Federation (hereafter, "Russia").

Source: Adapted from IEA (2017a), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/.

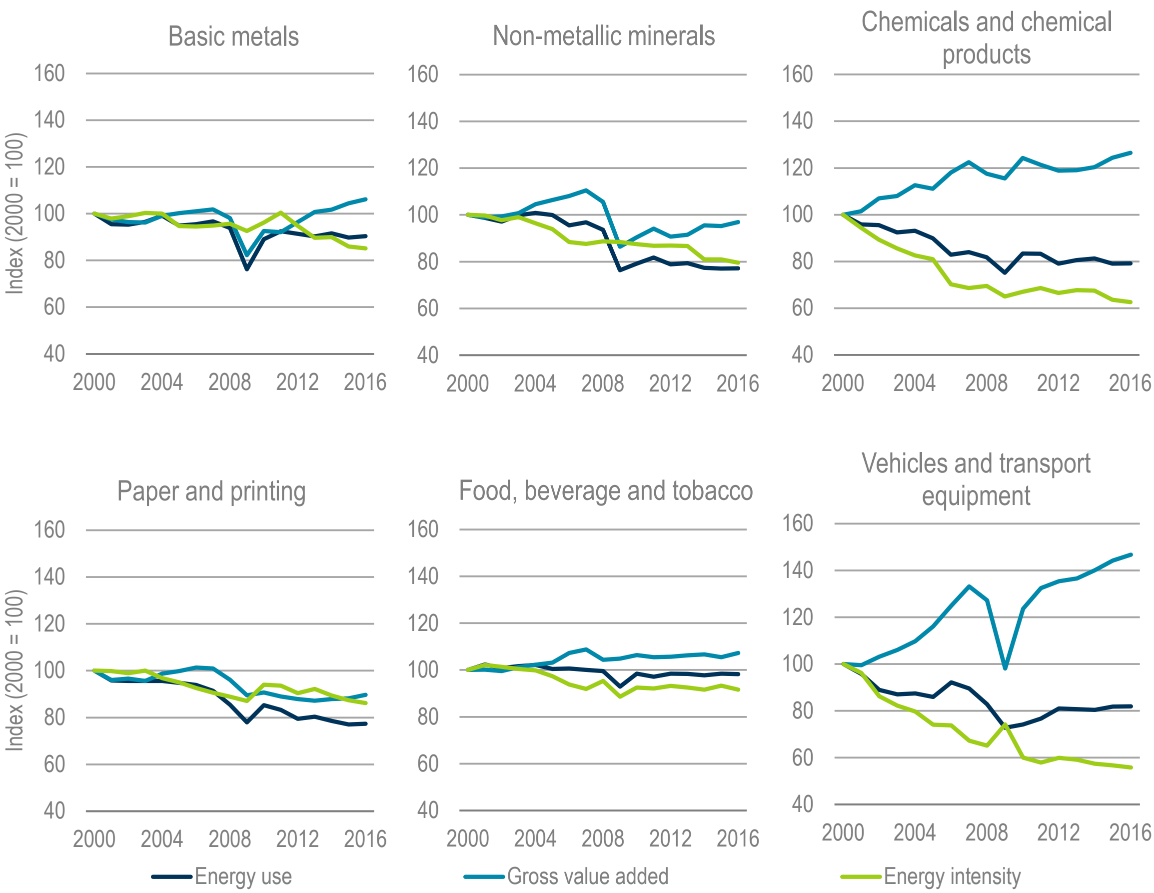
In IEA member countries, energy intensity has improved in all major industry sub-sectors, although trends are not uniform (Figure 3.2). For basic metals manufacturing, which includes iron and steel and aluminium manufacturing (Box 3.1), GVA has recovered since the global financial crisis. In 2016, final energy use was 10% lower than in 2000 and intensity 15% lower. Energy intensity fell by 20% in non-metallic minerals, which primarily covers cement manufacturing, and by 14% in paper and printing, which is dominated by pulp and paper manufacturing. There is less variation in the food, beverage and tobacco sub-sector, where energy intensity dropped by 8% between 2000 and 2016.

Energy intensity improvements were largest in the chemicals and vehicles sub-sectors, where there has been a clear divergence between energy use and GVA. This may reflect ongoing technological improvements, such as automation and the use of industrial robots, and strong demand for outputs, particularly plastics and vehicles. Globally, vehicles manufacturing is the largest user of industrial robots, which improve the sector's energy productivity through greater automation of production. In

[1] Gross value added refers to value of the goods produced by the industry sector

2015, the global supply of industrial robots was 50% higher to the vehicles manufacturing industry than to the second largest sector (electronics manufacturing). Deployment of industrial robots is also evident in the metals and chemicals manufacturing sub-sectors, which are the third- and fourth-largest sectors for deployment, globally (IFR, 2016).

Figure 3.2 Energy intensity by industry sub-sector in IEA member countries, 2000-16



Source: Adapted from IEA (2017a), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/.

Box 3.1 Energy efficiency of aluminium smelting improves as a result of new production capacity

In some energy-intensive industries, advances in energy efficiency are driven more by investment in new facilities – and, to a lesser extent, technology upgrades and closure of older facilities – than by performance improvements in existing facilities or government policy. An example of this is primary aluminium production. Due to the electricity-intensive nature of aluminium smelting and the ease with which it can be traded between markets, the location of new production is heavily influenced by the long-term availability of low cost electricity.

Production in China and countries in the Gulf Cooperation Council (GCC)[2] has increased significantly, while production in North America and Europe has declined or remained unchanged (Table 3.1). In the GCC countries, growth has resulted from the abundance of long-term, low-cost natural gas in the region, which is used for electricity generation. In China, production growth reflects the availability of coal-fired power generation and significant investment in aluminium smelting (and other stages of the aluminium supply chain) to meet growing domestic demand.

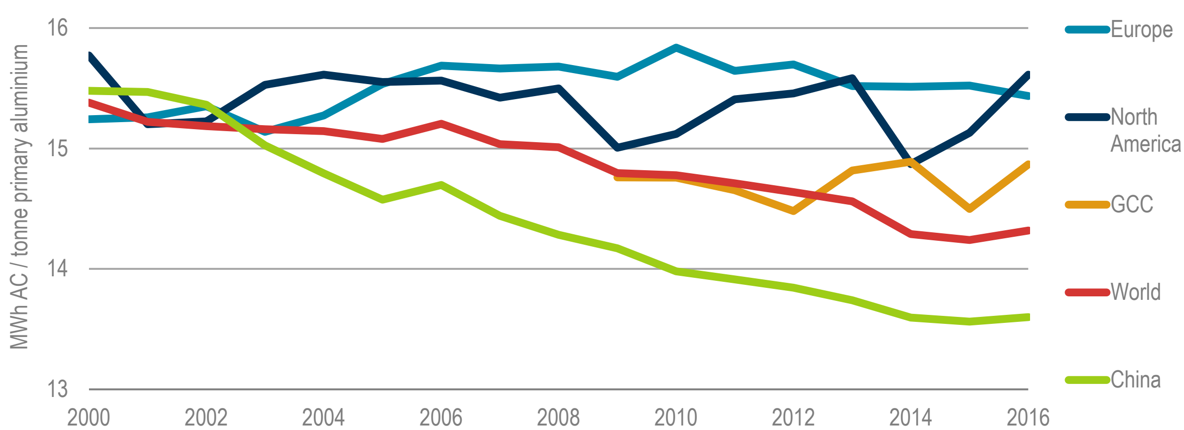
Table 3.1 Average annual change in primary aluminium production

	World	North America	Europe	China	GCC
2000-09	4.8%	-2.6%	0.5%	19.3%	N/A
2010-16	5.6%	-2.5%	-0.6%	10.6%	11.4%

Source: Adapted from International Aluminium Institute (2017), *Primary Aluminium Production* (database), www.world-aluminium.org/statistics/.

The substantial increase in primary aluminium production in China and the GCC countries since 2000 has coincided with a marked improvement in the global energy intensity of the sub-sector, which decreased by 6.9% between 2000 and 2016 (Figure 3.3). Over the same period, energy intensity of the sub-sector increased by 1.3% in Europe, decreased by 1.0% in North America and decreased by 12.1% in China.

Figure 3.3 Energy intensity of aluminium smelting, 2000-16



Source: Adapted from International Aluminium Institute (2017), *Primary Aluminium Production* (database), www.world-aluminium.org/statistics/.

Industry energy intensity is influenced by numerous factors

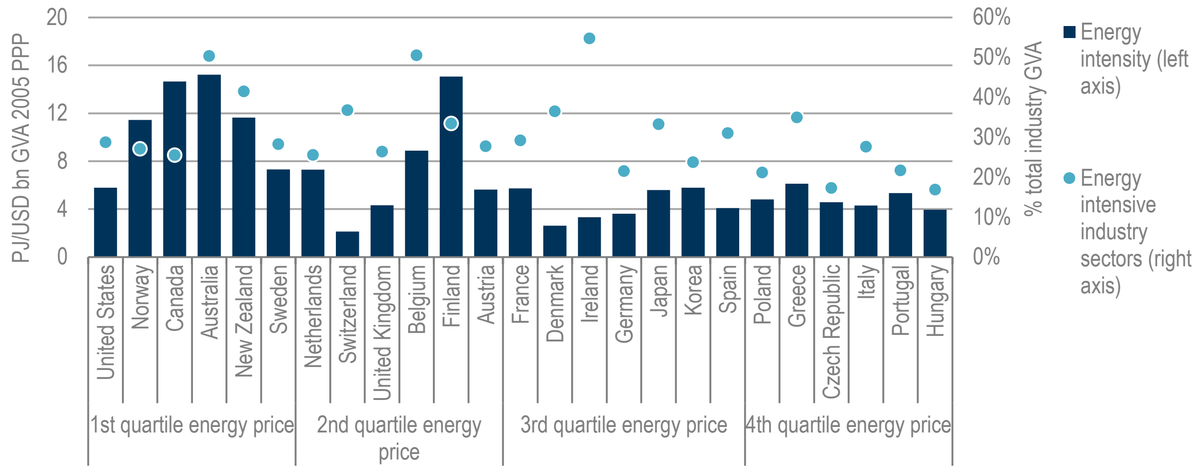
Overall industry energy intensity is influenced by several factors, particularly energy prices and activity levels in energy-intensive sub-sectors (Figure 3.4). IEA member countries with high energy prices (fourth quartile in Figure 3.4) have energy intensities 56% lower on average than countries with lower prices (first quartile in Figure 3.4). While this highlights the tendency of higher energy

[2] GCC (Gulf Cooperation Council) includes Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates, with Kuwait the only non-primary aluminium producing country.

prices to foster industry efficiency, it also shows that countries with cheap energy are favoured locations for energy-intensive sub-sectors. On average, the contribution of energy-intensive sub-sectors to total industry GVA was 44% higher in countries with lower energy prices than in countries with higher prices.

Ireland and Belgium have the highest contribution from energy-intensive sub-sectors to overall industry GVA. This is due to the chemicals manufacturing sub-sector, which contributes 50% of industry GVA in Ireland and 30% in Belgium. However, overall industry energy intensity in these countries remains low, due to the fact that the services sector dominates overall economic output. In Ireland, GVA from the services sector is four times greater than industry and it is nearly six times greater in Belgium.

Figure 3.4 Industry energy intensity and contribution to industry gross value added from energy-intensive sub-sectors by IEA member country, grouped by energy price, 2015



Note: Energy-intensive sub-sectors are basic metals manufacturing, non-metallic minerals manufacturing, paper and printing and chemicals and chemical products manufacturing.

Sources: Adapted from IEA (2017a), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/; IEA (2017b), *World Energy Balances*, www.iea.org/statistics; and IEA (2017c), *Energy Prices and Taxes*, Q1, (database), www.iea.org/statistics.

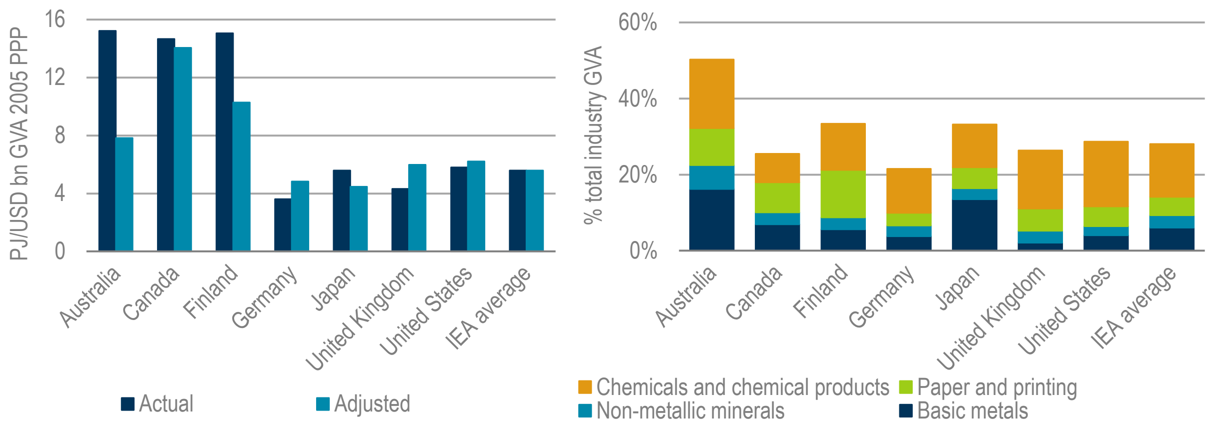
The energy intensities in Figure 3.4 do not account for differences in industry structure, particularly the contribution to total industry GVA from energy-intensive sub-sectors. To account for these differences, energy intensity can be adjusted to reflect differences in industry structure[3] (Figure 3.5). Adjustment lowers the energy intensities for industry in Australia and Finland, reflecting the contributions to GVA from their basic metals manufacturing and paper and printing sub-sectors, which are both above the IEA average. Unadjusted Japanese intensity is at the IEA average. After adjustment it is lowered, reflecting the contribution from basic metals manufacturing, which is also higher than the IEA average.

Paper and printing, particularly pulp and paper manufacturing, has a noticeable impact on industry energy intensity. IEA member countries with the highest contribution from the paper and printing sub-sector are Finland (12%), Australia (10%) and Canada (8%), all of which have high energy

[3] Adjusted energy intensity is a reflection of how much energy each industry sub-sector in a specific country would notionally consume to produce the same GVA as the sub-sector average across all IEA member countries

intensities. Despite its energy intensity, in many IEA countries, pulp and paper manufacturing has low emissions intensity, as biomass waste streams such as wood shavings, bark or black liquor[4] are used as input fuel for on-site electricity and thermal energy generation.

Figure 3.5 Adjusted industry energy intensity (left) and contribution of energy-intensive sub-sectors to industry GVA (right) in selected IEA member countries, 2015



Source: Adapted from IEA (2017a), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/.

Energy intensity and efficiency varies within industry sub-sectors

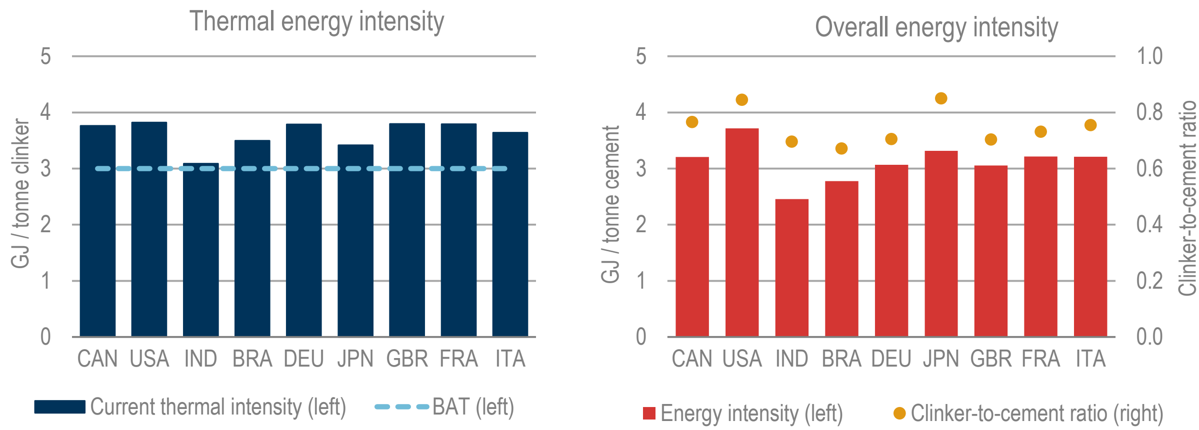
Even within an industry sub-sector with a single output, energy efficiency varies among countries and firms. An example is cement manufacturing – the most significant component of the non-metallic minerals manufacturing sub-sector – which has a noticeable presence in all major economies.

Most of the energy used in cement manufacturing is for the production of heat (up to 1 450°C) to make clinker, the major component of cement. The thermal energy intensity of cement production is affected by the fuels combusted, the age and type of the kilns, and the amount of pre-heating. The distance between current thermal energy intensity in several major economies and the intensity possible using best available technology (BAT) illustrates the potential energy savings in the sub-sector (Figure 3.6). India is closest to BAT due to a combination of new, more efficient, production capacity being recently added and the use of locally sourced raw materials, with lower moisture content. In the other countries, where the distance to BAT is greater, deploying BAT would save over 20% of current thermal energy consumption. Improvements to thermal energy intensity in cement production are challenging, however, due to the time and capital expenditure needed to upgrade kilns.

Variation is also seen in the overall energy intensity of cement production. A key factor influencing overall energy intensity is the amount of clinker included in the final cement mix, represented by the clinker-to-cement ratio (Figure 3.6). In the countries analysed, Brazil has the lowest clinker-to-cement ratio – about 20% lower than the United States, contributing to its overall energy intensity being 25% lower. Thermal energy demand of cement manufacturing can be decreased by reducing the clinker-to-cement ratio. However, the degree to which the clinker-to-cement ratio can be lowered depends on the availability and quality of substitutes, and any regulatory or technical requirements for specific cement applications.

[4] Black liquor is an aqueous solution of sulfate chemicals used in the pulping process and lignin and hemicellulose residues extracted from wood.

Figure 3.6 Energy intensity of cement production, 2014



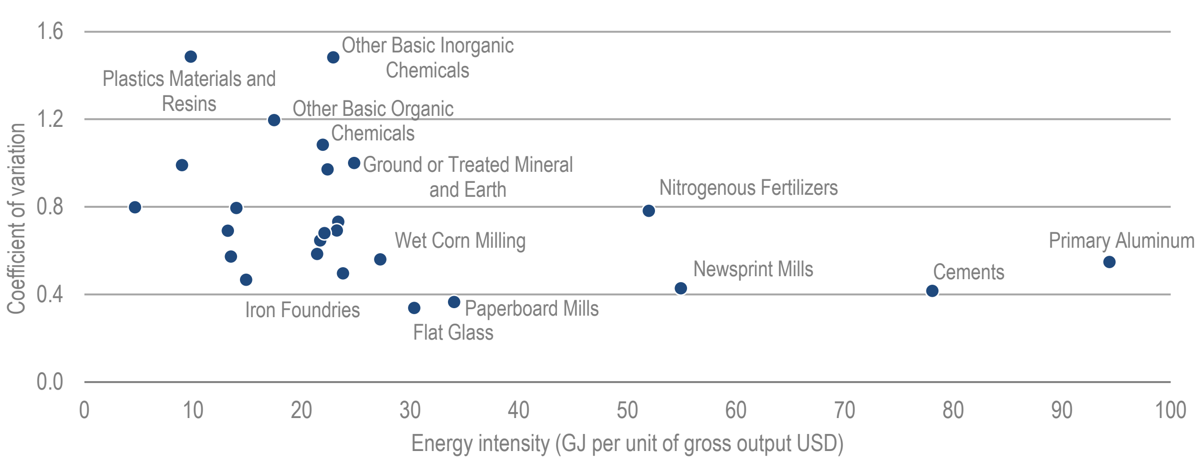
Note: BAT considered as dry-process kiln with pre-calciner and 6 stage cyclone pre-heater at 3 GJ/tonne clinker.

Sources: Adapted from WBCSD Cement Sustainability Initiative (2017), *Global Cement Database on CO_2 and Energy Information* (database), www.wbcsdcement.org/index.php/key-issues/climate-protection/gnr-database.

Box 3.2 Variation in energy intensity is greater among firms in less energy-intensive sub-sectors

Even within narrowly defined industry sub-sectors, energy use and performance can differ according to factors such as product mix, input quality or weather. Boyd et al. (2011) examined the distributions of plant-level energy use per dollar value of total output in more than two dozen energy-intensive, trade-exposed manufacturing sub-sectors in the United States (Figure 3.7). More energy-intensive sub-sectors such as cement and aluminium tended to have lower variation in energy intensity, perhaps because standardised production methods, competitive markets and the greater contribution of energy to overall production costs, lead producers to be more cost-efficient. Larger variation was observed in less energy-intensive sub-sectors such as plastics and chemicals, which may reflect greater diversity in products and plant size, as well the lower driver for energy efficiency, due to energy representing a smaller component of the total cost of production.

Figure 3.7 Variation of energy intensity within industry sub-sectors in the United States

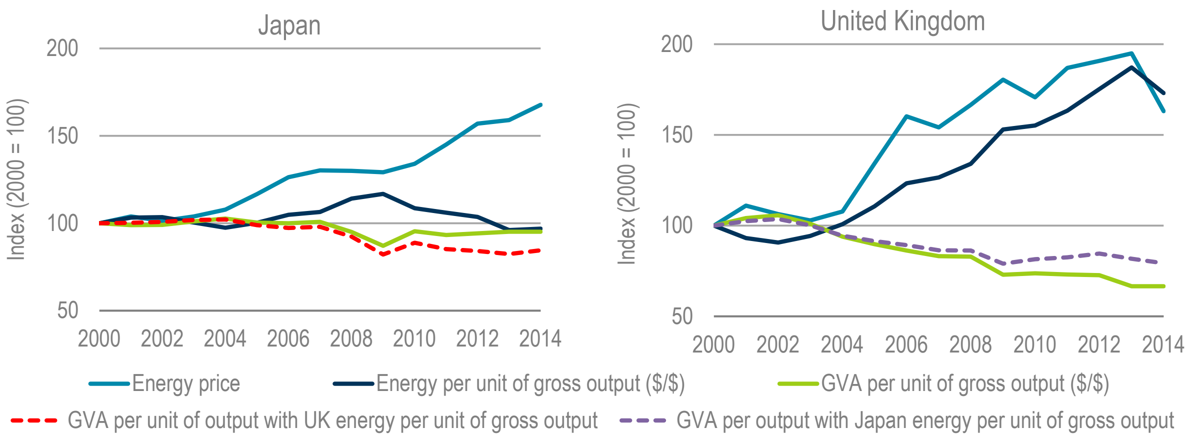


Source: Boyd et al. (2011), *Preliminary Analysis of the Distributions of Carbon and Energy Intensity for 27 Energy Intensive Trade Exposed Industrial Sectors*.

Energy efficiency reduces the negative impact of energy prices on competitiveness

Many factors contribute to the competitiveness of industries, but in energy-intensive industry sub-sectors, energy efficiency reduces the impact of rising and volatile energy prices on GVA and overall competitiveness. For energy-intensive industrial processes, where there are often few low-cost alternatives to existing fuel sources, energy efficiency provides an economic means of reducing the impact of volatile energy prices. An illustration of the impact of improvements in efficiency in response to rising and volatile energy prices is provided through a comparison of trends in energy price, energy per unit of gross economic output[5] (as a dollar-to-dollar ratio) and GVA per unit of gross economic output (as a dollar-to-dollar ratio) in the non-metallic minerals manufacturing sub-sector in Japan and the United Kingdom (Figure 3.8).

Figure 3.8 Impact of increasing energy price for the non-metallic minerals manufacturing sub-sector in Japan and the United Kingdom, 2000-14



Note: Energy price is the weighted average price for the non-metallic minerals manufacturing sectors in Japan and the United Kingdom in 2014 national currency.

Sources: Adapted from IEA (2017c), *Energy Prices and Taxes*, Q1, (database), www.iea.org/statistics; and Timmer et al. (2015), *World Input Output Database* (database), www.wiod.org/.

Between 2000 and 2014 in Japan there was a clear divergence between energy price, which increased by 68%, and energy per unit of gross economic output, which decreased by 3%. This coincided with a flattening in the trend for GVA per unit of gross output, which in 2014 was only 5% less than in 2000. In the United Kingdom, trends for energy price and energy per unit of gross output did not diverge. Energy price increased 63% and energy per unit of gross output increased by 73%, while GVA per unit of gross output fell by 33%. The reduction in energy per unit of gross output in Japan helped avoid a larger reduction in the GVA per unit of gross output, which would have negatively impacted overall competitiveness. The alternative is viewed for the United Kingdom.

The competitiveness impact of energy efficiency is further highlighted by the dashed lines in Figure 3.8. For Japan, the dashed line shows GVA per unit of gross output if, all other things being equal, energy per unit of gross output had followed the same trend as in the United Kingdom. This would have led to an 11% reduction in GVA in 2014. For the United Kingdom, the dashed line represents the

[5] Gross economic output represents the total economic activity associated with the production of new goods and services and is measured as the sum of intermediate consumption (production inputs) and GVA.

GVA per unit of gross output if, all other things being equal, energy per unit of gross output followed the same trend as Japan. This would have resulted in a 19% improvement in GVA above the levels observed in 2014. These hypothetical trends illustrate how energy efficiency, in the form of reductions in energy use per unit of gross economic output, can contribute to the competitiveness of industry sub-sectors, particularly those with higher energy intensity.

Several factors may have influenced the observed trends and it is difficult to identify a single explanation. Contributing factors include technology, with Japan's cement manufacturing sector having a large percentage of waste heat recovery, and policy, particularly the industry energy efficiency targets implemented in Japan after the Great East Japan earthquake (Chapter 1). The degree to which inefficient firms exited the market or reduced production following the global financial crisis may have also contributed. However, between 2008 and 2014 physical output of cement, the dominant product within non-metallic minerals manufacturing, fell by 8% in Japan and 11% in the United Kingdom. This would not appear substantial enough to create the difference in trends observed in Figure 3.8.

At a firm level, efficiency can improve competitiveness through increased profitability. A recent study by ClimateWorks Australia revealed that in some global industry sub-sectors, firms whose energy productivity (economic output per unit of energy use) was among the worst in their sector could achieve growth in annual profits of 2.2% to 13.8% by increasing energy efficiency to bring it into line with that of their best-performing peers (ClimateWorks Australia, 2016).

The use of energy management systems in industry is growing

An energy management system creates a structure to monitor energy consumption and improve energy efficiency in an industrial or commercial firm. The implementation of energy management systems is a key element of industry energy efficiency policy in many countries (Table 3.2). The ISO 50001 standard provides an internationally consistent benchmark for implementation and has aided policy makers by providing a means of verifying compliance.

Table 3.2 Examples of policies supporting implementation of energy management systems

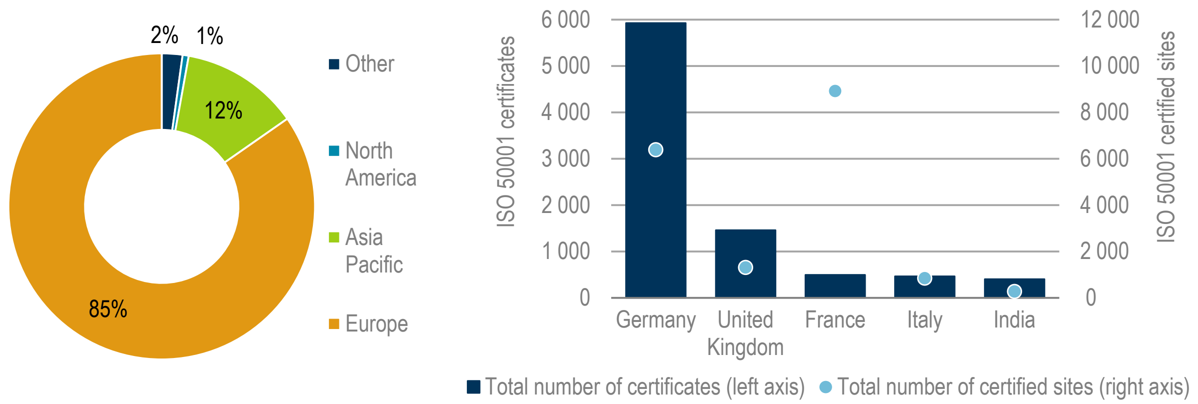
Country / Region	Policy	Description	Year implemented
European Union	Energy Efficiency Directive (EED)	Article 8 of the EED requires member states to ensure that large enterprises carry out regular energy audits. However, enterprises that have implemented an energy management system can be exempted from this obligation.	2012
United States	Superior Energy Performance (SEP) Program	To be SEP-certified, facilities implement ISO 50001 and an independent third party verifies energy performance improvement. The SEP certification emphasises measureable savings through a transparent process.	2012
China	Top 10 000 Enterprises programme	Enterprises are required to establish an energy management system following China's GB/T 23331 standard.	2011
Indonesia	Ministerial Regulation on Energy Management	Companies that use more than 6 000 tonnes of oil-equivalent (toe) per year are obliged to implement an energy management system, with ISO 50001 adopted as the Indonesian national standard.	2012

Germany	National Action Plan on Energy Efficiency	Large companies are required to implement an energy management system according to ISO 50001 to apply for energy and environmental tax exemptions.	2014
Portugal	Intensive Energy Consumption Management System (SGCIE)	Companies that use more than 500 toe per year are required to conduct periodic energy audits and develop Energy Consumption Rationalisation Plans that stipulate minimum energy efficiency objectives	2008

Sources: Adapted from European Commission (2016a), *Guidance note on Directive 2012/27/EU on Energy Efficiency*, http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52013SC0447; IIP (2017), *CN-3b: Top-10,000 Energy-Consuming Enterprises Program*, http://iepd.iipnetwork.org/policy/top-10000-energy-consuming-enterprises-program; CEM (2017a), *Energy Management Working Group: Members and Their Programs*, www.cleanenergyministerial.org/Our-Work/Initiatives/Energy-Management/Members-and-Their-Programs; Directorate General of Energy and Geology (2017), *SGCIE - background and objectives*, http://sgcie.publico.adene.pt/SGCIE/Paginas/Enquadramento.aspx

The number of ISO 50001 certifications is an indicator of attitudes towards energy management and the effectiveness of policies in driving uptake. The total number of certificates, globally, grew from 459 in 2011 to 11 985 in 2015. Europe has the largest proportion of certificates of any region, with 85% of the total (Figure 3.9). Germany has the largest number of certificates among European countries, although France has the largest number of certified sites, because certain certificates cover many sites. The dominance of Europe, and Germany in particular, in the number of ISO 50001 certificates is striking. Implementation of ISO 50001 in Germany is still voluntary but the tax incentives for certified companies are clearly a strong driver.

Figure 3.9 ISO 50001 certificates by region (left) and comparison of number of certificates and certified sites (right), 2011-15



Sources: Adapted from ISO (2016a), *ISO Survey*; and ISO (2016b), *ISO Survey of Certifications to Management System Standards* (database), http://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&viewType=1.

Among industry sub-sectors, basic metals and fabricated metal products had the largest number of ISO 50001 certificates in 2015, reflecting the energy-intensive nature of the sub-sector (Table 3.3). However, the less energy-intensive food, beverage and tobacco sub-sector had the second highest number of certificates, perhaps because there are many companies in the sub-sector and consumers in some markets are influenced by perceptions of sustainability.

While the number of ISO 50001 certificates reached 11 985 after five years, this is less than the uptake of other international management standards. ISO 9001 exceeded 220 000 certifications after five years[6] and ISO 14001 certifications reached nearly 65 000.[7] This may reflect a lack of sufficient market or policy incentives, but also the lack of uptake in China. In 2015, China had the largest number of ISO 9001 and 14001 certifications, with 28% and 36% of the respective totals. However, China's ISO 50001 certificates represented only 2% of the global total, because the government's industrial energy management policy is based on a different energy management standard (GB/T 23331).

Table 3.3 ISO 50001 certifications by industry sub-sector, 2015

Industry sector	Number of ISO 50001 certificates
Basic metal and fabricated metal products	919
Food products, beverage and tobacco	876
Rubber and plastic products	672
Chemicals, chemical products & fibres	583
Electrical and optical equipment	312

Sources: Adapted from ISO (2016a), *ISO Survey*; and ISO (2016b), *ISO Survey of Certifications to Management System Standards* (database), http://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&viewType=1.

Energy management systems produce real benefits for industry

The adoption of an energy management system, whether driven by policy or by a company's strategy, can lead to savings in energy and associated costs. Data on these benefits can be found in company case studies, although many relate to companies that have been using energy management systems for a short time.

Data contained in 42 ISO 50001 case studies from France, Germany, the United Kingdom and other countries show average annual energy savings of 26%.[8] Because of the variance in country, industrial sector and process there is a broad range with claimed savings extending to beyond 60% in a small number of cases. From a financial perspective, data from 75 ISO 50001 case studies show financial savings averaging around USD 1.2 million per year (Waide Strategic Efficiency, 2016; CEM, 2017b).

The reported energy and financial savings in the ISO 50001 case studies have not been verified and do not take account of the business-as-usual rate of energy performance improvement before implementation. Figure 3.10 presents the verified quarterly energy and cost savings for ten companies across various sectors that participated in the US Superior Energy Performance (SEP) programme, including the rate of energy performance improvement before implementation.

The verified results confirm the greater than business-as-usual benefits that companies obtained by implementing ISO 50001. Energy savings in the four quarters before implementation averaged 3.2% of total energy use. This increased to an average of 7.5% in the first four quarters after implementation and 14.2% in quarters five to seven. Similarly, cost savings averaged 3.0% in the four quarters before implementation but increased to 6.3% in the first four quarters after implementation

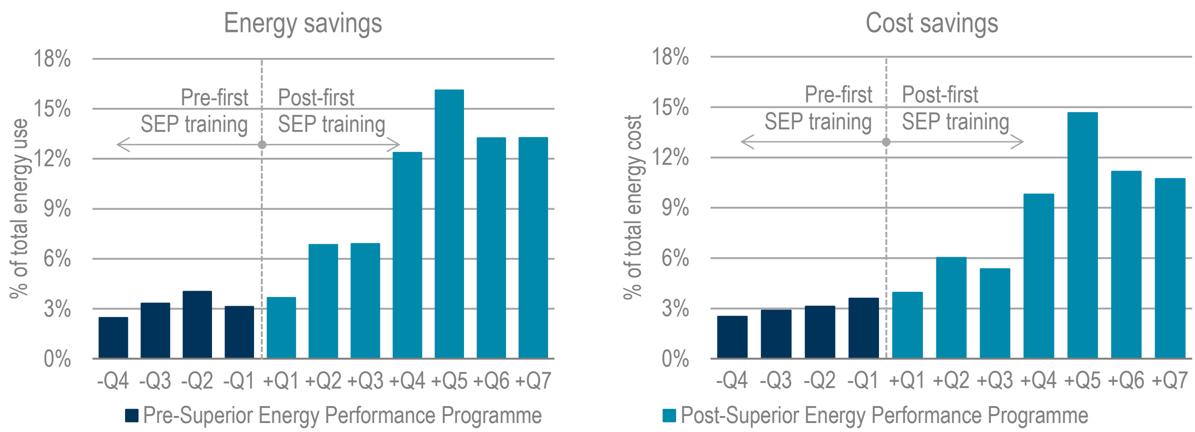
[6] ISO 9001 is the international standard that specifies requirements for a quality management system.

[7] ISO 14001 is the international standard that sets out the criteria for an environmental management system.

[8] Savings are reported for a range of end-uses from specific industrial processes to the entire company energy use.

and 12.2% in quarters five to seven. The gradual increase in savings after implementation reflects the time needed to fully implement an energy management system.

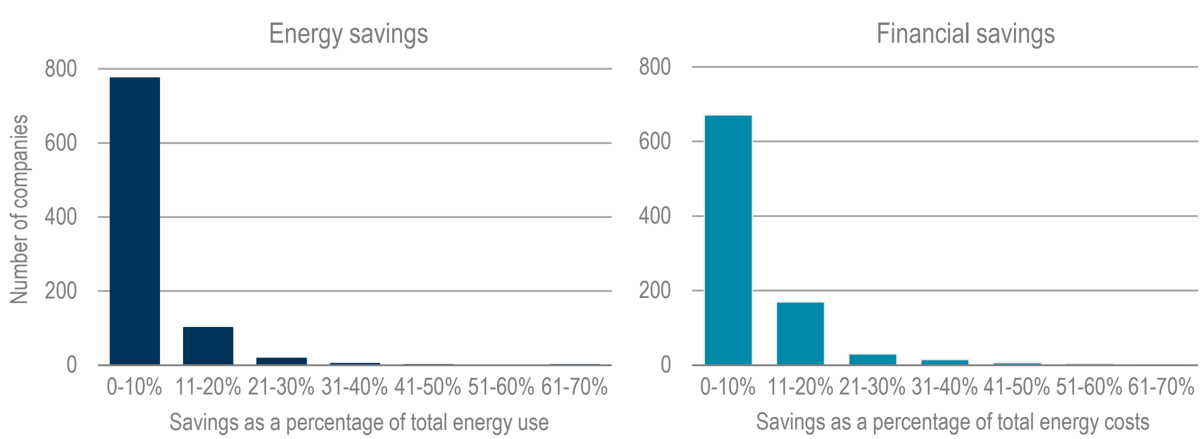
Figure 3.10 Verified average quarterly energy and associated cost savings from implementation of the ISO 50001 energy management system



Source: LBNL (2015a), *Development of an Enhanced Payback Function for the Superior Energy Performance Program*, http://aceee.org/files/proceedings/2015/data/papers/1-72.pdf.

Other forms of energy management are also providing energy savings and financial benefits to industry. Portugal's SGCIE Programme (Table 3.2) provides an example of government policy that has mandated energy management within industry but does not require implementation of ISO 50001. Among the 900 companies that have reported results as part of participation in SGCIE, average energy savings equivalent to 5.9% of total energy use have been reported, and average financial savings of 8.1% of total energy cost (Figure 3.11). In total, SGCIE companies have reported energy savings of 4.4 PJ per year and financial savings of over USD 56 million per year. As SGCIE applies to smaller companies (large industrial companies covered by the European Union Emissions Trading Scheme are exempt), the results are not directly comparable with the case studies from companies that implemented ISO 50001, given different company size and industry sectors.

Figure 3.11 Savings for companies participating in Portugal's SGCIE Programme



Source: Adapted from Directorate General of Energy and Geology (personal communication 22 May 2017).

Implementing an energy management system provides several benefits beyond energy and cost savings. These include improvements in staff skills, safety and the management of other production inputs, as well as reduced maintenance costs. Assessing the non-energy benefits of energy efficiency projects greatly enhances the case for implementation (Box 3.3).

Box 3.3 The multiple benefits of energy efficiency highlight its value to industry

Energy efficiency provides numerous benefits to companies, including improvements in worker comfort, product quality, overall flexibility and productivity, as well as reductions in maintenance cost, risk, production time and waste. However, translating these benefits into strategic and financial outcomes is challenging, so the full benefits of industrial energy efficiency are not fully recognised.

The value that energy efficiency can create is revealed in an energy efficiency audit of a Swiss surface treatment company, which was subsidised by the regional government in the canton of Vaud. The audit identified an opportunity to replace ageing rectifiers used for electronic galvanising with new rectifiers that had improved cooling and monitoring. Alongside energy cost savings there were numerous other benefits, including reductions in maintenance costs, cooling water use, rejection rate, legal and commercial risks, and increases in product quality, attractiveness and customer loyalty. By translating these benefits into financial outcomes, based on greater inflows from increased value and reduced costs from avoided outflows, the total value of the energy efficiency opportunity could be determined.

When energy savings alone were considered, the simple payback for energy efficiency measures was calculated at 6 years (internal rate of return of 6.9%). However, when the financial outcomes derived from the multiple benefits of the opportunity were considered, the simple payback reduced significantly to 0.85 years (internal rate of return of 118%)[9], greatly improving the case for implementation.

Source: Cooremans C., Eco'Diagnostic, Monney L., Greenwatt, Canton of Vaud Energy audit program, Presentation of 31 May 2016. www.vd.ch/fileadmin/user_upload/themes/environnement/energie/fichiers_pdf/EE_centre_de_profit_201606.pdf.

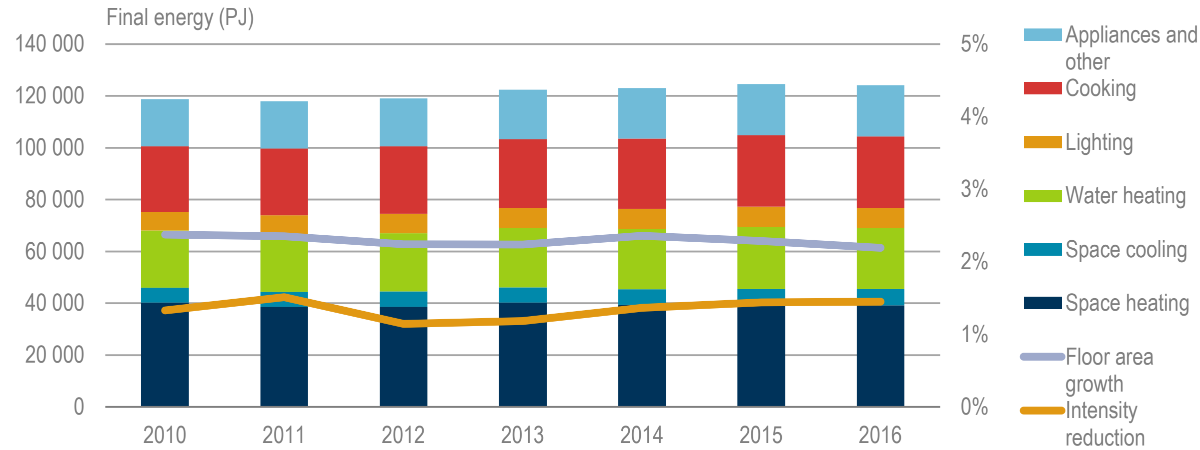
Buildings

The buildings sector is not on track to achieve global climate commitments, but progress is being made with global initiatives, policies and technologies. Annual net building-related GHG emissions peaked at 9.5 gigatonnes ($GtCO_2$-eq) in 2013 and decreased to 9.0 Gt in 2016. However, buildings final energy consumption grew steadily from 119 EJ in 2010 to 124 EJ in 2016 as a result of increasing floor area growth, which is outpacing energy intensity reduction (Figure 3.12).

Progress on energy efficiency policies for buildings continues to increase, though the share of progress on building envelopes by country varies compared with progress on heating, ventilation and air conditioning (HVAC) equipment. In some countries, such as Denmark and Germany, building envelope policy has been the key driver for policy progress, while in other countries, such as Japan and Korea, HVAC equipment has been a key driver (Figure 3.13). A combination of both envelope and equipment policies is critical for the transition to sustainable buildings. Highly efficient building envelopes enable the use of higher-efficiency equipment and energy sources, such as low-temperature waste heat, heat pumps and renewable energy.

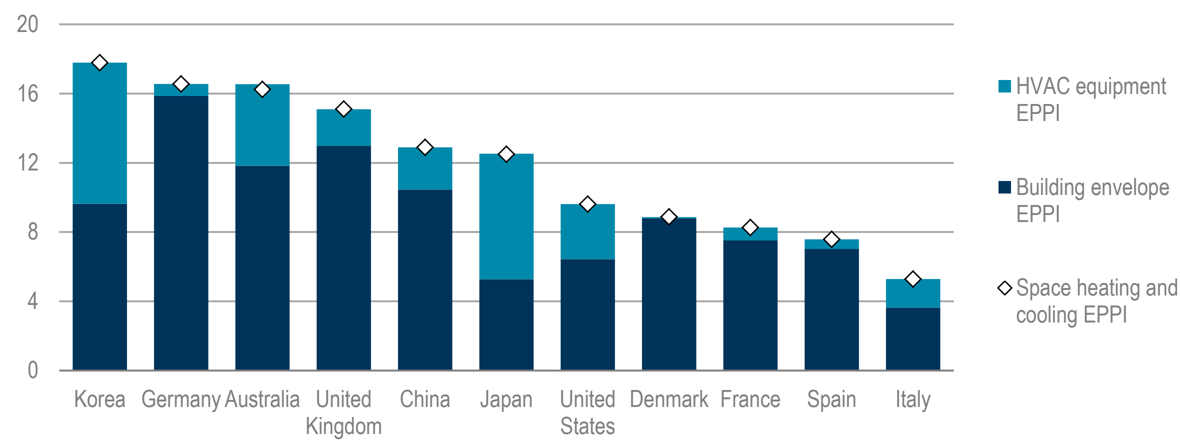
[9] Calculated with a discount rate of 6%. Financial savings from lower rejection rates and reduced risk have not been included.

Figure 3.12 Buildings sector energy consumption, energy intensity and floor area (2010-16)



Source: Adapted from IEA (2017d), *Energy Technology Perspectives 2017*.

Figure 3.13 Share of space heating and cooling efficiency policy progress since 2000 from building envelopes vs. HVAC equipment



Source: Adapted from IEA (2017e), *Efficiency Policy Progress Index* (database).

Energy efficiency in buildings is being delivered through policy

Building codes are creating market confidence in several parts of the world for new buildings that are energy-efficient. Mexico took two major steps in the last year, including publishing the first national building energy efficiency code in collaboration with the International Code Council, and launching a building energy code roadmap that provides national targets in three-year increments to 2050. California is leading the way in the United States, with the latest 2016 Building Energy Efficiency Standards estimated to exceed the energy savings of the 2015 International Energy Conservation Code (CEC, 2017). On 19 June 2017, India released a much anticipated update to the Energy Conservation Building Code, a national model code that can be adopted and enforced by state and local governments to improve the efficiency of non-residential buildings (BEE, 2017).

Appliance, equipment and lighting standards can lead to additional energy savings in buildings. Last year, the IEA Energy Efficient End-Use Equipment Technology Collaboration Programme (IEA 4E-TCP) reported energy savings of 16% to 26% over the past 10 years for major household appliances. The programme has now identified that further efficiency improvements of 10-20% are available in most countries from products already being sold in the market, including energy savings of over 75% by switching from halogen lighting to LED lighting. IEA 4E-TCP estimates that the market for efficient lighting will continue to grow and that 90% of all indoor lighting will be efficient (CFLs and LEDs) by 2022, due to a combination of improved policy and decreasing cost of efficient lighting (IEA 4E-TCP, unpublished). In Chile, the refrigerator market has shifted from 15% energy efficiency label A or better in 2007 to nearly 90%, a case of policy success, but one that now requires a policy update to continue to shift the market to more efficient refrigerators (FCH, 2016).

Energy efficiency in buildings is being delivered through technology

Meters and controls are connecting buildings with big data. The IEA Energy in Buildings and Communities Technology Collaboration Programme (IEA EBC-TCP) has initiated research projects to better understand how buildings use energy, including EBC Annex 70 Energy Epidemiology and EBC Annex 71 Building Energy Performance Assessment Based on In-situ Measurements (IEA EBC-TCP, 2017). These two projects are looking at how detailed building energy use data can be used to make policy and building operation decisions that increase efficiency. This approach is enabled by increasing digitalization and the ability to capture and analyse large data sets.

Increasing the efficiency of water heaters raises different issues for policy makers in different regions, due to variations in consumer hot water use, environmental conditions and energy infrastructure impact. More energy can be saved by switching between types of water heater than by increasing the efficiency of each equipment type; heat pumps enable energy savings of 60% to 85% compared with typical instantaneous and storage heaters. Japan's Top Runner programme and Australia's white certificate schemes have enabled the water heating markets in both countries to have increasing sales of highly efficient heat pumps, with over 500 000 heat pump water heaters sold in Japan alone each year (IEA 4E-TCP, 2017).

Heat pumps are increasingly being recognised as a solution for many building energy needs. For years, less sophisticated heat pumps did not efficiently operate in cold climates. New findings from the IEA Heat Pumping Technologies Technology Collaboration Programme (IEA HPT-TCP) Annex 41 show that cold climate heat pumps are being introduced to the market that can operate much more efficiently with a heating capacity output higher than 70% in temperatures of -25°C (IEA HPT-TCP, 2017). Cold climate heat pumps could shift significant portions of global heating energy use away from less efficient electric and fuel heating systems in mixed and cold climates. In district energy systems, large-scale heat pumps are improving the efficiency of space heating, water heating, cooling and refrigeration. Heat pumps are an increasingly cost-effective way to meet both energy efficiency targets and countries' emissions reductions targets. This is leading to new combined approaches to policy thinking, such as the EU heating and cooling strategy (European Commission, 2016b).

Energy efficiency in buildings is key to global goals

Two key international agreements – the Paris climate change agreement and the Montreal Protocol on ozone depletion – are targeting energy efficiency in buildings as a means to achieve broader goals. The result could be a significant boost for energy efficiency efforts worldwide. The launch of the Global Alliance for Buildings and Construction (GABC) at the COP21 climate summit in 2015 and the Kigali Amendment to the Montreal Protocol in 2016 have motivated funders and other interested parties to support efforts to increase energy efficiency. Energy efficiency efforts are being added to the existing Montreal Protocol network due to the Kigali Amendment to reduce the use of ozone-depleting hydrofluorocarbons for cooling, the fastest growing end-use in buildings (Box 3.4).

Box 3.4 Space cooling and the Kigali Amendment to the Montreal Protocol

The Kigali Amendment to the Montreal Protocol provides an international platform not only to phase out ozone-depleting HFCs but also to increase air conditioner efficiency. As a result of the amendment, government funding to the Multilateral Fund (MLF) for the Implementation of the Montreal Protocol has increased. Funding has also been provided by private philanthropists to create the Kigali Cooling Efficiency Program.

These resources will enable work in developing countries towards policies that could include accelerated minimum energy performance standards (MEPS), harmonisation of standards, increased "cooling access" and reduction in the energy needed for mechanical air conditioning. In the long term, the efficiency of air conditioner technology is expected to improve through more efficient equipment (accounting for 75-85% of energy savings potential) and more efficient refrigerants (accounting for 15-25% of the energy savings potential) (LBNL, 2015b; US DOE, 2016).

The GABC has brought together 24 countries and 72 non-state organisations to work towards a global buildings and construction sector that is low-carbon, energy-efficient and resilient. GABC partners are supporting global efforts on awareness, education, policy, finance, data and market transformation. GABC is tracking global actions in the buildings sector, including the 88 buildings-related NDCs pledged under the Paris Agreement, as well as 3 000 city-level commitments and 500 private sector actions for the building sector that have been registered with the United Nations Framework Convention on Climate Change (GABC, 2017). Companies have increased their support for energy efficiency awareness, capacity building, financing models and policies through private initiatives like the Amplify initiative (Box 3.5).

Box 3.5 Companies boost energy efficiency in buildings through the Amplify initiative

The World Business Council for Sustainable Development (WBCSD) leads the global Energy Efficiency in Buildings (EEB) Amplify initiative. This private sector-led initiative aims to achieve substantial reductions in building energy consumption globally. It brings together local building companies and city officials to develop a common understanding of market barriers and develop action plans to unlock investments in energy efficiency city-wide. The initiative sets up local platforms that act as catalysts for change in four main areas: (1) awareness of the benefits of energy efficiency (i.e. the business case); (2) the need for proper skills and collaboration throughout the value chain; (3) adequate financing models; (4) the need for consistent and long-term policy frameworks (i.e. regulations and incentives).

In 2017, EEB Amplify is being rolled out in Europe in partnership with the European Climate Knowledge and Innovation Community (Climate-KIC), with initial engagements in Switzerland (Zurich), the United Kingdom (Birmingham), Romania (Bucharest) and France (city to be confirmed); and in the United States in partnership with the U.S. Green Building Council (Phoenix and Brooklyn).

Source: WBCSD (2017), *Energy Efficiency in Buildings*, www.wbcsd.org/Projects/Energy-Efficiency-in-Buildings.

Transport

Transport was responsible for 28% of global final energy consumption in 2016 (IEA, 2017f). More than 90% of transport energy use depends on oil products, which means that efficiency improvements can significantly reduce emissions of pollutants and GHGs. Light-duty vehicles (LDVs, passenger cars, passenger light-trucks and light commercial vehicles) have attracted most of the attention from policy makers, while other transport modes are lagging. As of 2016, only four countries had fuel economy standards for heavy-duty vehicles (HDVs). The LDV market is experiencing a diverging trend. Sales of very efficient vehicles such as battery electric vehicles (BEVs) are surging, but more fuel-intensive light trucks (SUVs, vans and pick-up trucks) are also gaining popularity (GFEI, 2017; EEA, 2017; US EPA, 2017).

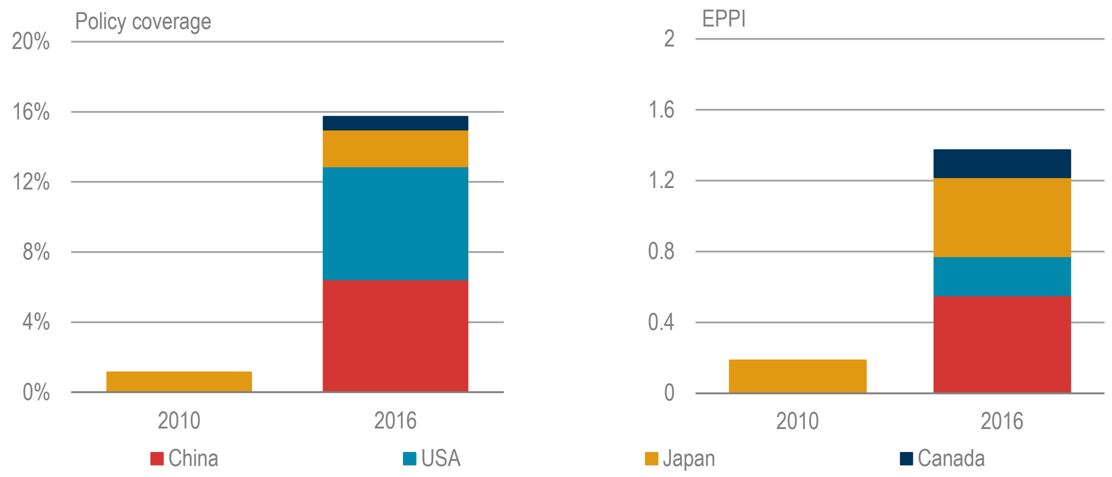
Heavy-duty vehicle policy progress

In recent decades, the main focus of fuel economy regulations has been on LDVs. Yet heavy-duty vehicles represented nearly 43% of road oil consumption and one-fifth of total oil consumption in 2015 (IEA, 2017f). Between 2000 and 2015, road freight oil demand grew by 50% to 17 million barrels per day. This growth represents more than one-third of total oil demand growth. The amount of goods transported by HDVs grew by 65% and truck sales increased by 60% between 2000 and 2015 (IEA, 2017f). The magnitude of HDV energy demand within the transport sector and fast energy demand growth mean that it is urgent to use policy and technology to improve HDVs' energy efficiency (IEA, 2017f; IEA, 2017g).

During the last ten years, policy makers have begun to try to limit HDV fuel consumption through regulations (Figure 3.14). Policy coverage of mandatory HDV fuel economy standards is rapidly growing. Coverage of global HDV energy use has increased from less than 1% in 2010 to 16% in 2016 (Figure 3.14). However, this coverage is still low given that more than 55% of LDV stock was covered by mandatory standards in the most recent year. Fuel economy standards in Canada, China, Japan and the United States are leading the way to a more fuel efficient HDV fleet (IEA, 2017e). China is the only country that had reached a second phase of HDV fuel economy regulations by 2016 (having implemented Phase 2 in 2014), rapidly strengthening minimum performance levels.

In the past two years, growth of policy coverage has been caused solely by stock turnover. Four other jurisdictions – the European Union, India, Korea and Mexico – are at various stages of developing HDV standards, with planned implementation dates around 2020. The inclusion of these countries and regions would represent another 20% of global HDV sales, further speeding up policy coverage growth. The United States and China have also announced HDV standard updates around 2020. Given this progress, HDVs' score on the IEA Efficiency Policy Progress Index, which tracks the coverage and strength of mandatory policies, is expected to keep growing over the coming decades.

Figure 3.14 Evolution of mandatory efficiency policy coverage progress for HDVs, 2010-16



Note: HDV data only include medium-freight trucks and heavy-freight trucks.

Sources: ICCT and DieselNet (2017), *Transportpolicy.net*, www.transportpolicy.net; and IEA (2017f), *Mobility Model,* www.iea.org/etp/etpmodel/transport.

Besides fuel economy standards, other policy types have aimed to improve HDV energy efficiency (Table 3.4). The European Union has no HDV fuel economy regulations yet but does have the highest fuel taxes in the world, and around half of its member countries have deployed road tolls. Countries that do have fuel economy standards have low fuel taxes and no national road pricing schemes for trucks, highlighting a differentiation in policy strategy. However, the growing number of countries with HDV fuel economy standards indicates a widening policy approach. It is difficult to measure and compare the effectiveness of these policy types. In 2016, trucks in Europe were 14 to 22% more efficient per tonne-kilometre (tkm) than those in China and the United States (IEA, 2017g). On a smaller scale, scrappage programmes aim to speed up stock turnover. Only a few countries have deployed these programmes, and in most cases only for a few years, indicating limited impact on the market. A majority of HDV markets have some type of voluntary green freight programmes in place.

Table 3.4 Specifications of implemented national truck energy efficiency policies

Country	Fuel economy standard	Strength increase per year	Fuel tax rate (diesel)	National road pricing schemes for trucks	Scrappage programme	Green freight programmes
Japan	2005-15	0.8-1.0%	Low / intermediate		2009-10	Green Freight Asia 2013
Canada	2014-17	1.5-6.3%	Low / intermediate			SmartWay 2013
United States	2014-17 2018-27	0.5-4.0% 0.9-2.8%	Low / intermediate			SmartWay 2004
China	2014-19 2021-	3.6-4.9% 2.4-4.4%	Low / intermediate		2009-10	China Green Freight Initiative 2012; GFA 2013

European Union*	2020-	High	AUT (2004), BEL (2016/1995), BGR (2004), CZE (2007), DNK (1995), DEU (1995/2005), HUN (2013), LUX (1995/2008), POL (2011), ROM (2002), SVK (2013), NLD (1995), CHE (2001)	ESP (2012-16)	EcoStars 2009; Lean and Green 2008; Objective CO_2; FRET 21 2010
Mexico	2020-	Low / intermediate		2003-18	Transporte Limpio
Korea	2020-	Low / intermediate			Green and Smart Transport Partnership
India	2020-	Intermediate subsidies			GFA 2014
Australia and New Zealand		Low / intermediate	NZL (1977)		AUS (Ecostation 2009)
Brazil		Low / intermediate			Brazilian Green Logistics Program

*The EED (2012) includes mandatory energy audits for large enterprises by internationally recognised standards.

Sources: IEA and CEM (2017), *Global EV Outlook 2017;* and ICCT and DieselNet (2017), *Transportpolicy.net* (database), www.transportpolicy.net.

Trends for electric vehicles and light trucks are diverging

The global vehicle market reached record sales in 2016, with around 93 million newly registered vehicles, of which approximately 90 million are light-duty vehicles (LDVs) (OICA, 2017). The dynamic global LDV market shows competing trends that an increasing amount of electric vehicles are sold along with more fuel-demanding light-duty trucks. As an important indicator to track fuel economy progress, the Global Fuel Economy Initiative (GFEI) target is 2.8% improvement per year in average fuel economy of newly registered vehicles, but over the past two years, improvement has been only 1.1% per year, though the improvement rate is increasing in emerging economies (GFEI, 2017). Three factors have affected recent trends in global average LDV fuel economy:

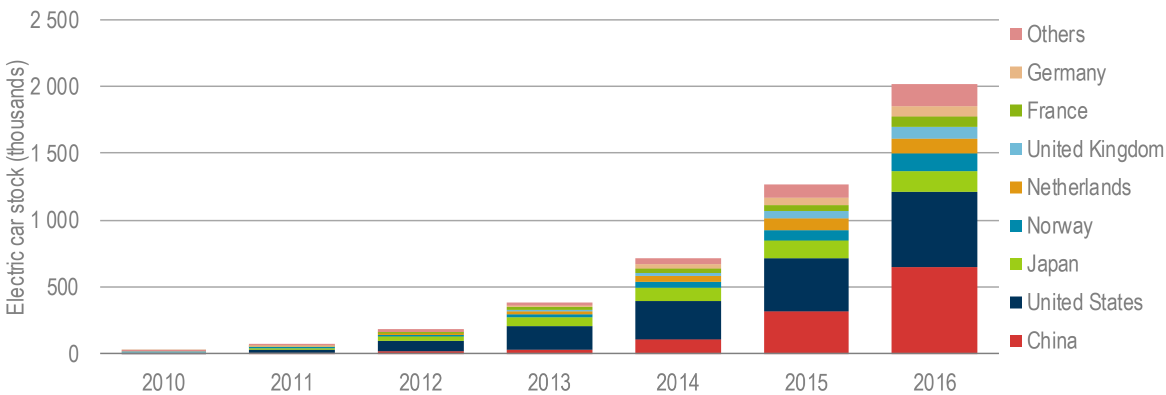
- a continued surge in electric vehicle sales;
- a larger share of light trucks (pick-up trucks, SUVs) in new LDV registrations in key markets;
- Faster growth of new LDVs in less efficient vehicle markets compared with more efficient markets.

Electric vehicle sales grew by 40% in 2016, down from 70% growth in 2015 (Figure 3.15).[10] There are now more than 2 million electric vehicles worldwide, but this still represents less than 0.2% of the 1.2 billion LDVs on the road (IEA and CEM, 2017). The electric vehicle market is diversifying and

[10] Electric vehicles refers to battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).

maturing quickly. Since 2010, the number of available electric vehicle models has increased almost five-fold (MarkLines, 2017). Only 40% of the LDV size classes had an electric vehicle model available in 2010, while in 2015 all size classes had at least one model available. Electric vehicles are much more efficient than diesel or gasoline alternatives, but are not yet at a scale to have a significant influence on global LDV fuel economy. However, recent announcements from Norway, France and the United Kingdom to phase out sales of new gasoline or diesel LDVs, as well as announcements that China, India and the Netherlands are considering similar measures, highlights the movement towards electric mobility.

Figure 3.15 Development of global electric light-duty vehicle stock, 2010-16



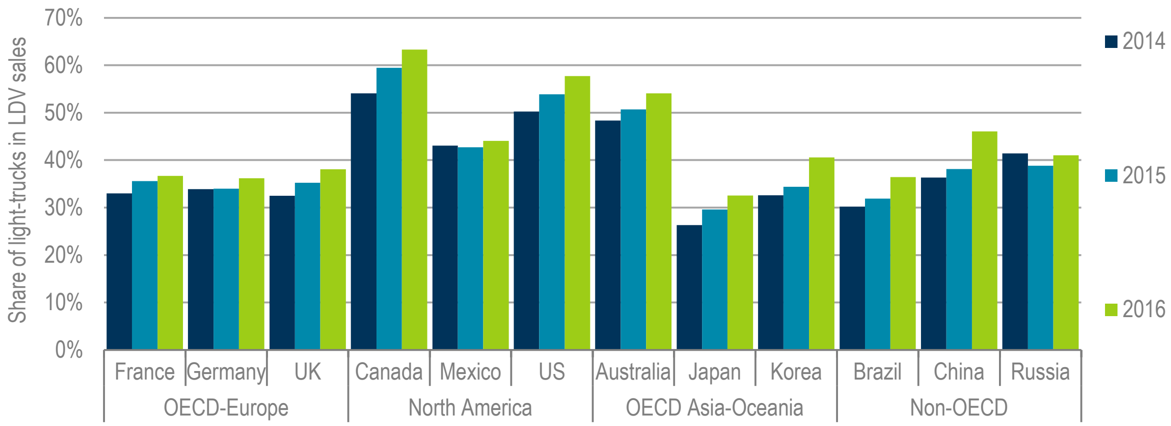
Source: IEA and CEM (2017), *Global EV Outlook 2017,* www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf.

Alongside rapidly increasing sales of electric vehicles, light trucks are gaining popularity over smaller passenger cars. Light trucks, which are still mainly gasoline- or diesel-driven, include vans, SUVs and pick-ups. Their share of all major vehicle markets grew in 2016 (Figure 3.16). China's light truck market share even grew by more than a quarter during this two-year period, heading towards 50% of the LDV market. Light trucks' share of LDV sales is highest in Canada and the United States, almost double their share of major European vehicle markets. New research on the United States LDV market shows that rising income, falling fuel prices and declining unemployment rates go along with a higher market share for light trucks (Schoettle and Sivak, 2017). If current economic growth and falling unemployment continues, shares of light trucks are expected to continue growing.

Between 2010 and 2015, LDV sales grew faster in markets with lower average vehicle efficiencies. LDV sales in the more efficient European Union LDV market were almost the same in 2015 as they were in 2010, while U.S. sales grew from 11 million to more than 16 million during the same period (GFEI, 2017). China's dominant position among emerging markets was emphasised by growth of more than 20% between 2013 and 2015, while LDV markets shrank in Brazil, Indonesia and Russia (GFEI, 2017).

Current LDV fuel economy standards are improving efficiencies of new sales, but not fast enough to stay on track to meet long-term LDV efficiency targets. The diverging vehicle preference trend provides a test for the success and impact of electric vehicles and the robustness of fuel economy policies to account for changing consumer preferences.

Figure 3.16 Market shift towards light trucks (vans, SUVs, pick-ups) in key markets, 2014-16



Source: Adapted from IHS Markit (2016), *Vehicle Registrations and Other Characteristics at Model Level*; and Marklines (2017), *Connect to the Global Automotive Industry* (database), www.marklines.com/portal_top_en.html.

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4. ENERGY EFFICIENCY INVESTMENT, FINANCE AND MARKETS

Highlights

- **Global investment in energy efficiency increased by 9% to USD 231 billion in 2016, maintaining the upward trend of recent years.** At 24%, the rate of growth was strongest in China, though Europe is still responsible for the largest share of investment worldwide (30%).

- **Among end-use sectors, buildings still dominate global energy efficiency investment, accounting for 58% in 2016.** Incremental investment of USD 133 billion made up one-third of energy efficiency spending in buildings. Most investment in the sector, which grew 12% in 2016, goes to building envelopes, appliances and lighting. The biggest increase in 2016 went to lighting, as switching from inefficient incandescent and halogen lighting to compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs) continued.

- **Issuance of green bonds for energy efficiency investments worldwide more than doubled in 2016 to USD 18 billion**. France remains the largest source of global issuance for energy efficiency, with Chinese issuance growing rapidly after entering the green bond market in late 2015. Private banks and green banks – public or private institutions that work with private lenders to leverage investments for low-carbon projects – are also playing a role in funding energy efficiency.

- **The global energy service company (ESCO) market expanded by 12% to USD 26.8 billion in 2016.** China has by far the largest market, making up over half of global revenues, thanks to strong government incentives, with the United States representing a further quarter. Over 1 million people are now employed by ESCOs around the world.

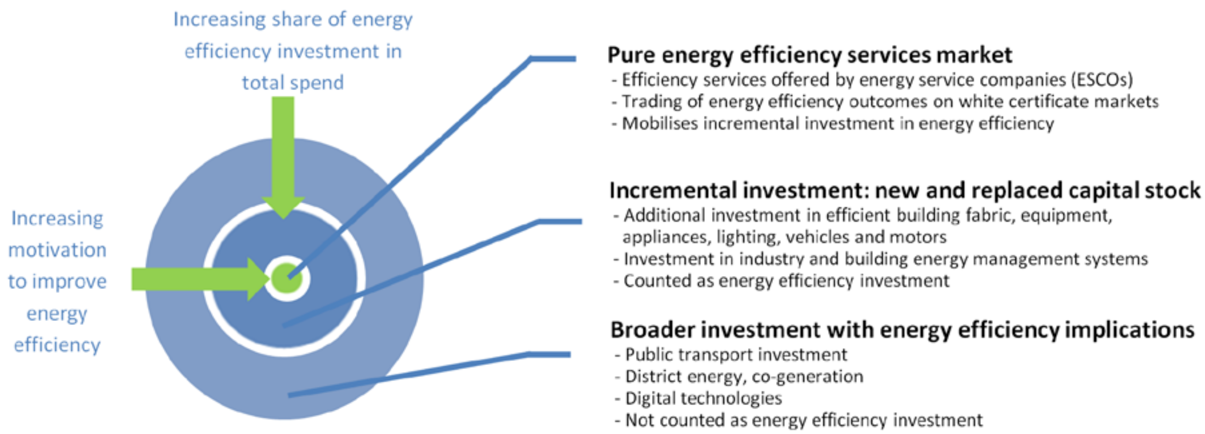
- **Energy efficiency has become a highly valuable and tradeable commodity in several countries.** In 2016, changes in policy substantially increased the market value of energy savings in France and Italy, the world's two biggest markets, where savings in the form of white certificates are traded. The Italian white certificate price went up by 150% between early 2016 and mid-2017 and the French price doubled from mid-2016 to mid-2017.

- **Measures to enhance energy efficiency, in the form of electricity demand savings, are increasing their participation in auctions to provide future capacity in wholesale electricity markets.** In 2016 and early 2017, a record amount of demand savings from energy efficiency, totalling more than 4 gigawatts (GW), was accepted in the two biggest electrical capacity auctions in the United States. Digital technology is expected to increase the ability for energy efficiency to participate in electricity markets.

Introduction

Millions of consumers and businesses across all sectors of the economy invest in measures that improve energy efficiency. In most cases, energy efficiency is just one of many characteristics of an investment, so the proportion of the investment dedicated to improving efficiency needs to be calculated with reference to the cost of a less efficient alternative. For example, if the price of a less efficient refrigerator is USD 400 and the price of a more efficient equivalent is USD 450, the incremental investment in energy efficiency would be measured as USD 50. It is the sum of these incremental investments that the IEA defines as energy efficiency investment (Figure 4.1). Broader systemic investment that also affects the energy efficiency of the economy, such as improvements to public transport, is not included in the data. Pure investment in energy efficiency services, for example through energy service companies (ESCOs), makes up a small proportion of the overall market and is a subset of the estimate of incremental investment.

Figure 4.1 Elements of the energy efficiency market



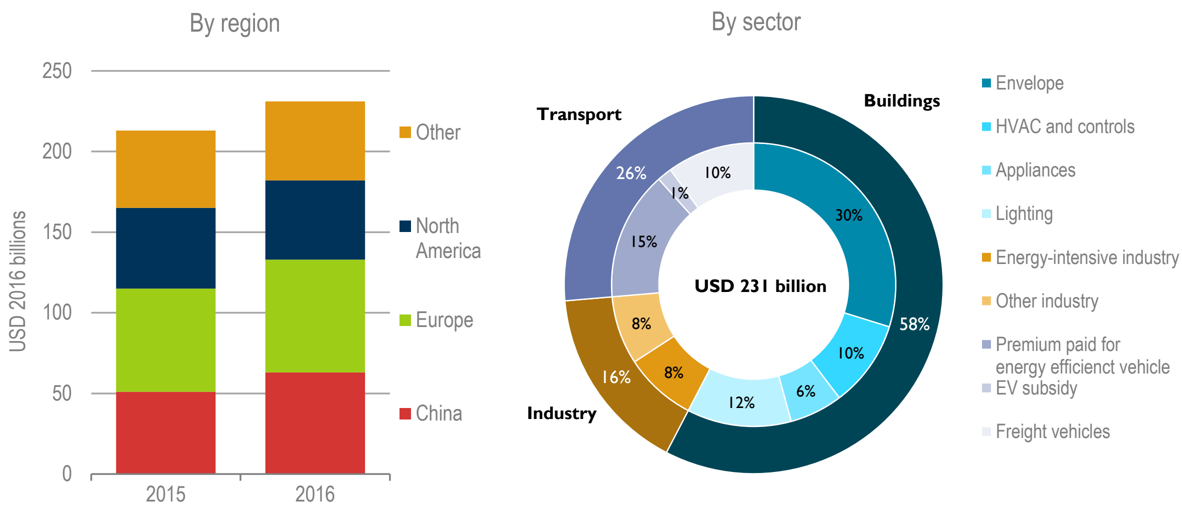
Energy efficiency investment grew in 2016

In 2016, global investment in energy efficiency increased by 9% to USD 231 billion (Figure 4.2).[1] This increase coincided with a slowdown in investment on the supply side of the energy system. Energy efficiency investment now represents 13.6% of the USD 1.7 trillion invested across the entire energy market (IEA, 2017a).

China accounted for most of the investment growth in 2016, with a 24% increase from 2015. Investment increased by 10% in the European Union and decreased by 2% in the United States. This decrease was largely due to a decrease in investment in the United States transport sector – lower international oil prices were especially pronounced in the United States, making the investment in fuel efficient vehicles less attractive (IEA, 2017a). At a sectoral level, transport accounted for 26% of incremental energy efficiency investment in 2016, industry 16% and buildings 58% (Figure 4.2).

[1] Global energy efficiency investment is presented in real USD (2016), converted at market exchange rates. A methodological improvement has led to a downward revision of the estimate for energy efficiency investment for freight transport in 2015. As such, the estimate of energy efficiency investment, published in the *Energy Efficiency Market Report 2016*, has been updated to USD (2016) 213 billion.

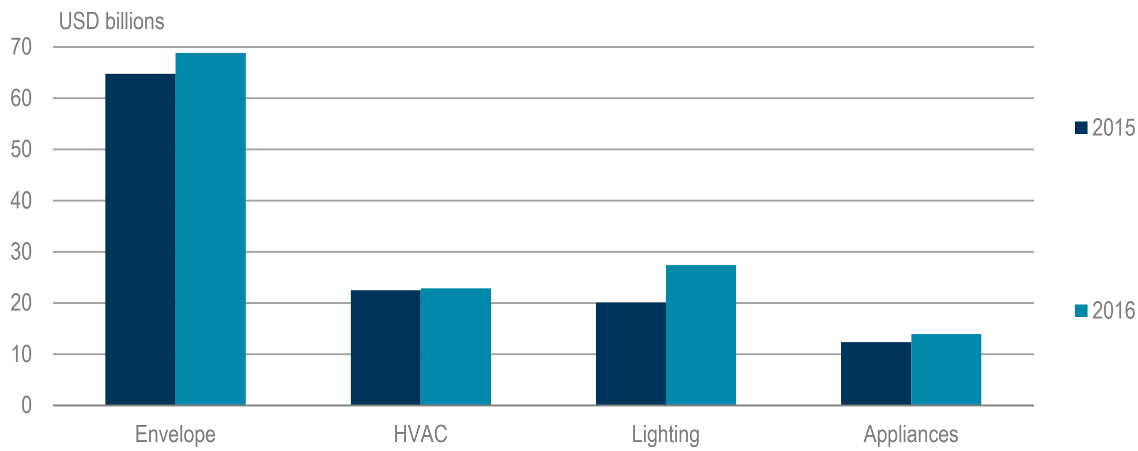
Figure 4.2 Energy efficiency investment by region and sector



Sources: IEA Energy Efficiency Investment Database; Navigant Research (2016), *Energy Efficiency Buildings Global Outlook* (database), www.navigantresearch.com; CEE (2016), *CEE Annual Industry Report*; IHS Markit (2016), *Vehicle Registrations and Other Characteristics at Model Level*; Marklines (2017), *Connect to the Global Automotive Industry*; and IEA 4E-TCP[2] (unpublished), *Phase-out of Inefficient Lighting: A Global Market Move*.

Over the past three years, energy efficiency investment in the buildings sector increased steadily, growing by 8% in 2015 and 12% in 2016 (Figure 4.3). Only a small share of the spending on new buildings is considered energy efficiency investment, as the majority is considered an autonomous improvement. However, three-quarters of spending on existing building energy efficiency retrofits was considered energy efficiency investment in 2016.

Figure 4.3 Incremental energy efficiency investment in buildings, 2015-16



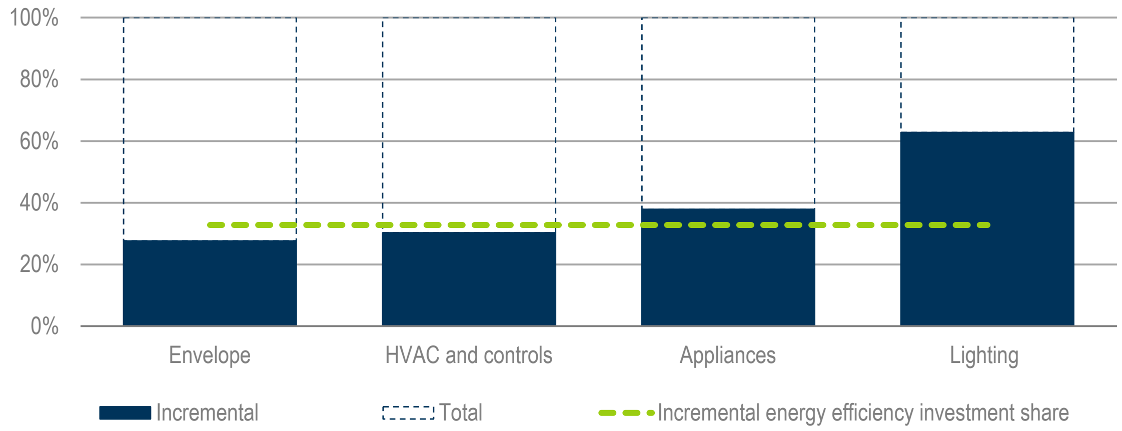
Sources: IEA Energy Efficiency Investment Database; Navigant Research (2016), *Energy Efficiency Buildings Global Outlook* (database), www.navigantresearch.com; CEE (2016), *CEE Annual Industry Report*; and IEA 4E-TCP (unpublished), *Phase-out of Inefficient Lighting: A Global Market Move*.

[2] Technology Collaboration Programme on Efficient Electrical End-Use Equipment.

The largest investment increase was in the lighting sub-sector (light bulbs, luminaires and light fixtures), where incremental investment increased by one-third. The ongoing transition from incandescent and halogen lamps to efficient light bulbs and luminaires, mainly LEDs, has contributed to this growth in global investment. In emerging economies, higher rates of appliance ownership and the spread of mandatory energy efficiency standards and policies are combining to increase investment in efficiency.

Incremental energy efficiency investment in buildings was USD 133 billion in 2016, one-third of the USD 406 billion in total energy efficiency spending on projects in the sector. Lighting had the highest incremental investment as a share of total energy efficiency spending, with just over 60%. In each of the other building sub-sectors, incremental investment is less than 40% of total energy efficiency spending (Figure 4.4).

Figure 4.4 Share of incremental energy efficiency investment in the buildings sector, 2016



Sources: IEA Energy Efficiency Investment Database; Navigant Research (2016), *Energy Efficiency Buildings Global Outlook* (database), www.navigantresearch.com; CEE (2016), *CEE Annual Industry Report*; and IEA 4E-TCP (unpublished), *Phase-out of Inefficient Lighting: A Global Market Move*.

Energy efficiency investment in the transport sector grew by 5% in 2016. A key component of this is electric vehicle (EV) sales, which grew by 40% in 2016. However, this growth was largely led by China, with passenger vehicle sales (as a whole) declining in several key markets, including Japan and the United States. Policy incentives are a key driver of EV investment, with the ongoing advancement of technology and performance also contributing (IEA, 2017a). Investment in the industry sector grew by 5%, without as much regional variation.

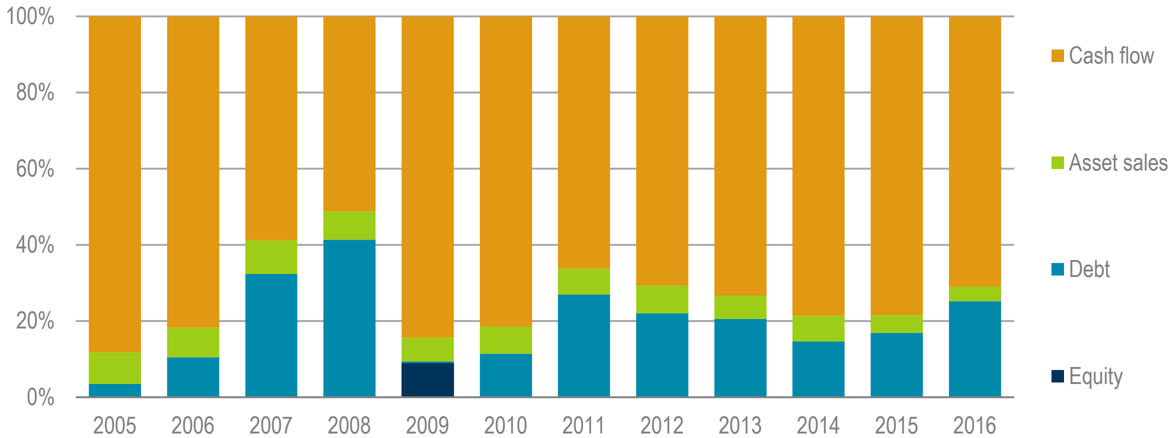
Energy efficency investment is mainly self-financed

Energy efficiency investment in residential buildings and light-duty vehicles is largely financed by household income, savings and personal loans from commercial banks (OECD, 2017). In the non-residential sector, which includes freight transport, industry[3] and commercial buildings (which could include commercially owned, multi-family dwellings), companies finance their activities primarily through cash flow from business operations. Debt issuance, equity issuance and asset sales are also

[3] Industry covers manufacturing (ISIC divisions 10-18, 20-23, and 25-32) and excludes mining and quarrying, manufacture of coke and refined petroleum products, and construction.

contributing sources of finance. Such activities include investment in energy efficiency measures. Figure 4.5 shows the sources of finance for listed companies engaged in energy efficiency in the non-residential sector.

Figure 4.5 Sources of finance for business activities, including energy efficiency, in the non-residential sector, 2005-16



Note: Cash flow reflects total cash flow less dividend payments, debt reflects total debt issuance less repayments and equity reflects total equity issuance less share buybacks. Data calculated from the cash flow statements of approximately 7 500 listed companies globally with over 80% of revenue attributed to any of the industry, freight, or non-residential buildings sectors.

Source: Adapted from Bloomberg LP (2017), *Bloomberg Terminal* (database).

Cash flow, derived from business operations, is the largest source of finance for companies engaged in business activities, including energy efficiency, in the non-residential sector. The proportion of debt as a source of finance decreased sharply in the wake of the global financial crisis, probably because of debt repayment in 2009. However, debt's role has increased since then due to the availability of low-cost capital.

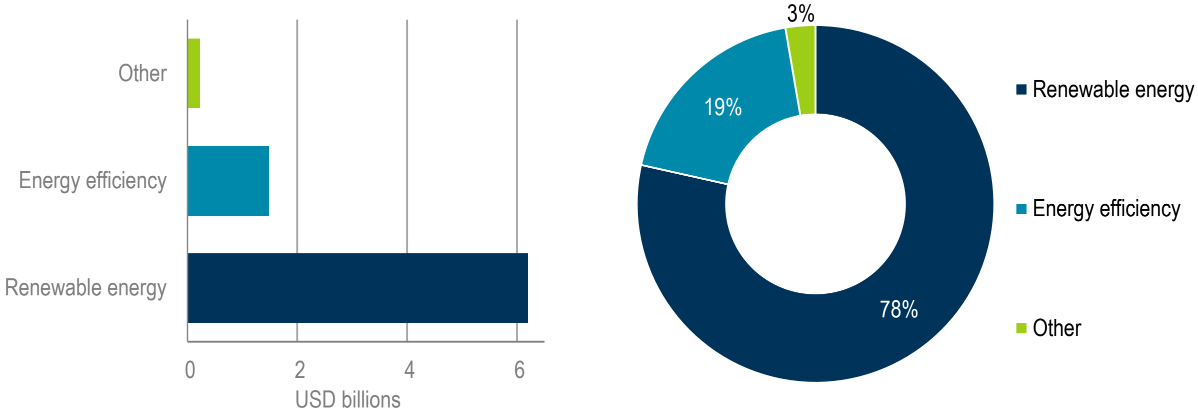
Historically, there has not been enough information on the potential risks associated with energy efficiency finance. The absence of formalised financing structures has led to a lack of understanding among interested parties, creating uncertainty and adding to the perceived risk of debt financing for energy efficiency. However, debt instruments provided by green banks and the growing green bond market are improving transparency and creating new opportunities for financing energy efficiency investment.

Banks are dedicating funds to energy efficiency

Green banks are playing an increasingly important role in funding energy efficiency and clean energy projects. These banks can be public, quasi-public or private institutions and work with private lenders to leverage investments for low-carbon projects (Coalition for Green Capital, 2017). The first green bank, the Connecticut Green Bank, was established in 2011, followed closely by the UK Green Investment Bank. Since then several green investment entities have been created on the national and regional level, including the Green Finance Organisation of Japan, the Clean Energy Finance Corporation of Australia and the New York Green Bank.

By the end of 2016, green banks had invested USD 7.9 billion (Figure 4.6), leveraging 2.25 times as much investment from the private sector (Green Bank Network, 2017). Of this, 19% went to energy efficiency, with low-carbon transport, such as electric vehicles, included as part of the 3% of "other" investment. This result reflects in part the ongoing preference for energy efficiency in the non-residential sector to be financed through end-users' own funds rather than through debt. However, there are also several barriers to investment in energy efficiency such as project size and complexity. There are currently several international initiatives seeking to address these barriers and increase the flow of finance to energy efficiency, notably the recently published G20 Energy Efficiency Finance Toolkit.

Figure 4.6 Green bank network investments, 2011-2016



Source: Adapted from Green Banks Network (2017), *Impact*.[4]

In addition to green banks, some traditional banks have started to show greater levels of interest in funding energy efficiency. In 2017, 122 banks from 42 countries, the majority of which were from the private sector, signed the G20 Bank Statement on Energy Efficiency. They agreed to acknowledge that they are uniquely placed to channel finance to activities that promote energy efficiency, to increase the awareness and potential for energy efficiency upgrades and to further incorporate energy efficiency into all applicable projects (G20 Energy Efficiency Finance Task Group, 2017).

Box 4.1 Initiatives to encourage debt finance for energy-efficient households

Several initiatives in Europe and North America offer rebates and lower interest rates on mortgages for energy-efficient buildings. One example is the Energy Efficient Mortgages Action Plan (EeMAP), a project coordinated by the European Mortgage Federation (EMF-ECBC), which has received funding under the EU Horizon 2020 programme to create a private bank financing mechanism to increase energy-efficient investment in EU residential buildings. The project will define a standardised approach for mortgage lenders in the European Union to offer households the possibility of a preferential interest rate and/or additional funds in return for measurable energy efficiency improvement in their property.

The initiative hinges on two key assumptions. First, that an energy-efficient property has a higher value. Second, that borrowers will have more disposable income due to savings on their energy bills as a result of the energy efficiency improvements, and will therefore be less likely to default on their payments (EMF-ECBC, 2016). Increased property value and a lower chance of default make the loan less risky, so these loans could be subject to less stringent capital requirements.

[4] Data for Green Banks Network (2017) accounts for 6 green entities: Australia Clean Energy Finance Corporation, Malaysia Green Technology Corporation, Connecticut Green Bank, NY Green Bank, Green Finance Organization (Japan), UK Green Investment Bank.

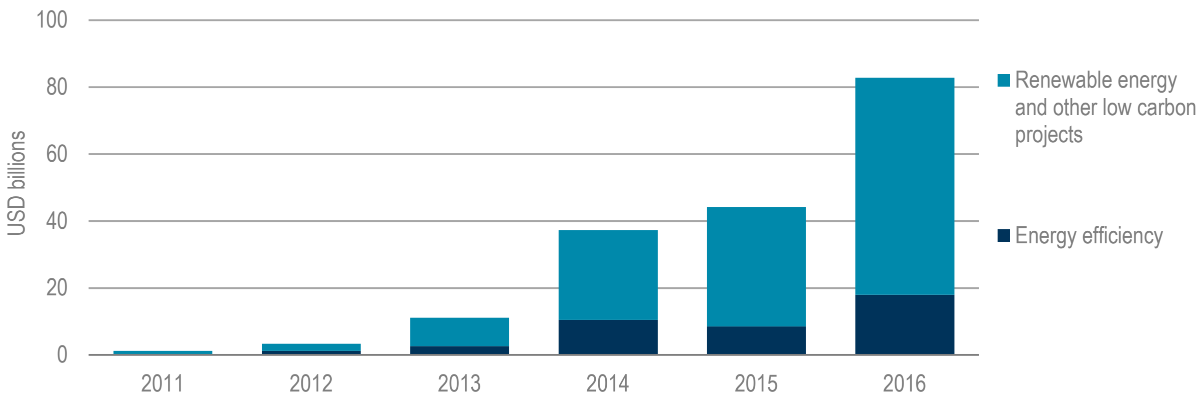
EeMAP looks to build on existing EU-wide energy performance certificates and combine these with additional indicators to provide robust, investment-grade data on building performance. Creating a standardised process for assessing and issuing energy-efficient loans could be a key way not only to unlock debt finance for energy efficiency, but also to create a strong framework to standardise, aggregate and securitise projects. The EeMAP consortium estimates that the project could unlock energy savings of 88 GWh per year, based on upgrades to 35 000 homes that achieve average energy savings of 15%.

Source: Adapted from EMF-ECBC (personal communication 1 August 2017 – preliminary estimates conducted by the EeMAP consortium).

Green bonds for energy efficiency doubled in 2016

Since development banks first issued bonds with a green label in 2007, the market has expanded rapidly. Between 2015 and 2016, the amount of green bond issuance allocated to energy efficiency more than doubled, from USD 8.5 billion to USD 18 billion, to reach 22% of the green bond market (Figure 4.7).[5] This increase offset the decline in 2015. It is important to note that a portion of green bond issuance is dedicated to refinancing existing debt.

Figure 4.7 Certified green bond issuance, 2011-16



Source: Adapted from Climate Bonds Initiative (2016), *China Green Bond Market 2016,* www.climatebonds.net/files/files/SotM-2016-Final-WEB-A4.pdf.

The increase in green bond issuance was driven to a large extent by China, which joined the market in late 2015 after the People's Bank of China introduced regulations. These regulations made China the first country in the world to publish official national standards for the issuance of green bonds.[6]

Even though green bonds dedicated solely to energy efficiency projects represent only 7% of the total issuance to date, 57% of the total issuance has some proportion dedicated to energy efficiency investments. One reason for this is that energy efficiency is embedded as a component of the majority of projects.

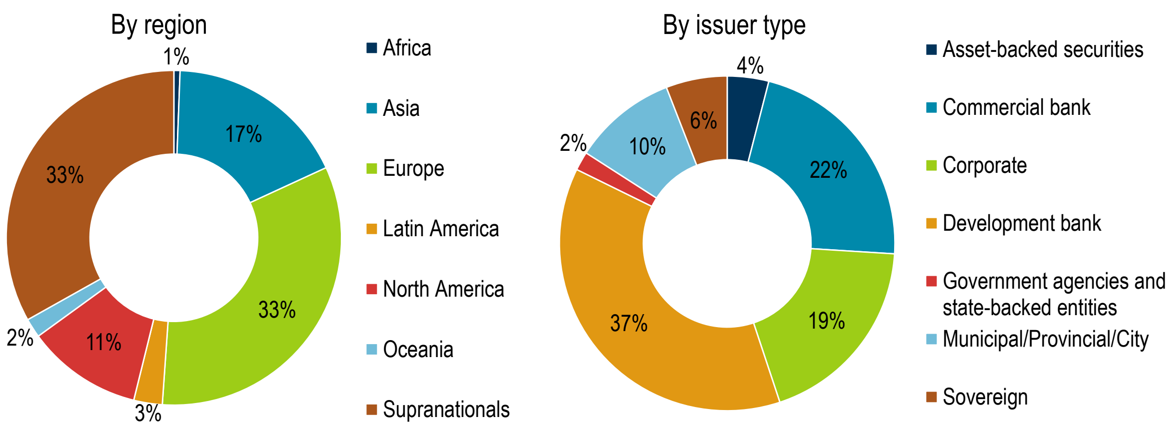
To date, supranationals – entities comprised of several national governments – and issuers within Europe are each responsible for one-third of green bond issuance that includes energy efficiency

[5] Climate Bonds Initiative (personal communication 6 July 2017).

[6] Climate Bonds Initiative (personal communication 6 July 2017).

(Figure 4.8). Issuers from Asia have only captured 17% of the global market so far, but China is already the second-largest country for energy efficiency issuance (13%) behind France (15%), illustrating its rapid growth since 2015. One contributing factor to France's share in the market is the Energy Transition for Green Growth Law that was introduced in 2015. The law encourages dedicated funding for low-carbon infrastructure, creating a stable political context for such development. Importantly, an article in the law requires asset owners to disclose how they manage climate risks.

Figure 4.8 Issuance of green bonds that include energy efficiency by region and issuer type, 2007-16



Note: Supranational refers to entities comprised of multiple national governments.
Source: Climate Bonds Initiative (personal communication 6 July 2017).

Development banks have been the main issuers of green bonds, reflecting ongoing promotion of low-carbon economic development. There has been greater corporate issuance for building energy efficiency projects in Europe than in North America, where the majority of building energy efficiency issuance has been from municipalities, provinces or cities.

There is potential for growth for other forms of issuance, particularly in the form of asset-backed securities, in which finance is provided for an aggregation of energy efficiency projects, backed by the projects' forecast returns, which form a single securitised asset. Aggregation creates a larger single investment opportunity, making it more suitable and attractive for debt financing. To date, asset-backed securities represent only 4% of the total issuance for green bonds that include energy efficiency projects (Box 4.2), while the share of asset-backed securities in the total green bond market is 10%.

There is potential for green bonds issued specifically for energy efficiency to increase across all sectors. Continued growth will require internationally agreed standards that that can be understood by financial institutions so they are better able to assess potential risks and returns.

Box 4.2 Green bond issuance as asset-backed securities by Renovate America

Renovate America's Home Energy Renovation Opportunity (HERO) programme has issued more than USD 2 billion in securitised green bonds for energy efficiency and small-scale renewables since its inaugural bond in 2014. The programme, which has been made possible by the Property Assessed Clean Energy (PACE) legislation, has partnered with local governments to provide financing for home improvement projects, tied to property taxation. This has enabled loan repayments to be made through voluntary property tax assessments, and has enabled Renovate America to issue its green bonds as asset-backed securities.

Starting in 2017, the PACE model of securitised bonds for energy-efficient homes is being implemented in Europe, starting in Spain and France (PACENation, 2017). There are also plans to apply the model in South Africa.

On-bill financing assists low-income households to invest in energy efficiency

There is opportunity for substantial energy savings in buildings occupied by renters or low-income households. However, many tenants do not meet typical requirements for loans to finance energy efficiency upgrades, especially since such upgrades may be considered financially risky by some banks. This hurdle can be overcome by distribution utilities, which serve all customers, regardless of income, credit history or tenancy status, and can provide finance to homes using "on-bill financing."

On-bill financing is already being implemented by some utilities, to assist low-income households to overcome the financial barriers to energy efficiency. Customers can accept a tariff that then allows the utility to invest in cost-effective energy efficiency upgrades. Through subsequent bills, the utility can recover the costs of the upgrades via a charge that is less than the estimated savings from the upgrade. The utility's investment is tied to the electricity meter at the building, so if a customer leaves, the cost recovery is passed on to the new tenant. This can create a challenge for on-bill financing: although the new tenant benefits from the upgrade, they are required to continue paying the charge on their utility bill, regardless of their desire for the upgrade.

This type of on-bill finance is now offered by 12 utilities in the United States, most of which had previously offered on-bill loan programmes. However those programmes did not reach low-income market segments (Energy Efficiency Institute, n.d.). To date, utility commissions in four US states have approved on-bill financing, some of which have service areas recognised for persistent poverty. Altogether, utilities in these states have reported making more than 2 000 investments, totalling over USD 20 million, with only 0.1% of charges uncollected.

Box 4.3 On-bill financing by Energy Efficiency Services Limited

Energy Efficiency Services Limited (EESL) is a state-owned Indian ESCO that carries out a range of energy efficiency projects, using on-bill financing to recoup the upfront capital investment. The main focus of EESL has been lighting. Through its programme Unnat Jyoti by Affordable LEDs for ALL (UJALA, which means light in Hindi), EESL provides LED light bulbs to end-users, saving nearly 31 000 kilowatt hours (kWh) per year and reducing peak demand and emissions. EESL has invested USD 178 million, which is recovered through charges on electricity bills, facilitating access to the technology for low-income clients.[7]

Since the inception of the UJALA programme in 2014 EESL has grown substantially and increased LED distribution by a factor of 27 (Table 4.1). EESL is now using on-bill financing to accelerate the deployment of other energy-efficient appliances within the residential sector, such as air conditioners and electric fans. It was also recently announced that EESL will undertake the procurement of 10 000 electric vehicles to replace petrol and diesel-powered vehicles used by the Indian government.

[7] Energy Efficiency Services Limited (personal communication 2 June 2017).

Table 4.1 EESL UJALA programme performance, 2014-17

Financial year	EESL total revenue (USD millions)	UJALA revenue (USD millions)	Lighting fixtures distributed (millions)
2016-17	188.8	140.3	129.2
2015-16	110.1	96.7	80.2
2014-15	10.9	2.1	4.7

Source: Energy Efficiency Services Limited (personal communication 10 July 2017).

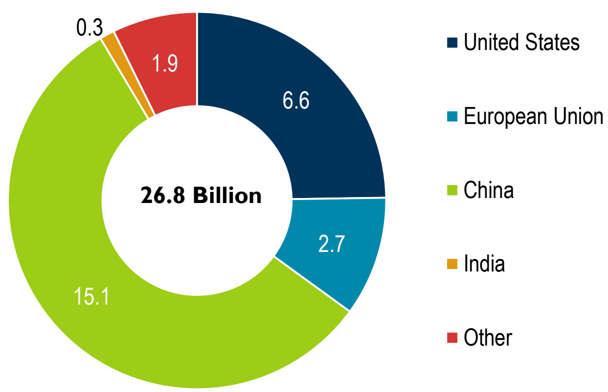
The pure energy efficiency market continues to expand

The pure energy efficiency market plays a relatively small role in energy efficiency investment but is the only area where units of energy efficiency are bought and sold directly. The main actors are energy service companies (ESCOs) and energy utilities, obligated to deliver energy efficiency by policy makers. In white certificate markets energy savings generated by ESCOs and other utilities can be traded. With digitalisation, the energy sector is becoming more easily able to measure energy efficiency impacts at a granular level, meaning that the value of efficiency to electricity system operators is starting to be rewarded in more markets, particularly in the United States.

The global ESCO market grew in 2016, led by China's industry sector

Total ESCO revenues reached USD 26.7 billion in 2016 (Figure 4.9), up 11% from USD 24 billion in 2015. ESCOs provide efficiency upgrades and services through mechanisms such as energy performance contracts (EPCs), which guarantee either energy or monetary savings. China has the world's largest ESCO market, with revenue over USD 15.1 billion in 2016. The United States is second at USD 6.6 billion, with the European Union market worth USD 2.7 billion. ESCOs are also significant employers. More than 1 million people are employed in the global ESCO market (Table 4.2).

Figure 4.9 ESCO revenue by region, 2016



Notes: ESCO revenues for the United States are estimated to have grown by 6% in 2016. For China, the value of EPCs signed each year was spread over four years and summed for 2016 in order to make ESCO revenues comparable with the method used for the United States and the European Union. However, cash flow may not be even over the term of an EPC, which can vary between five and 20 years, and 80% of the revenue is usually earned within the first three years (Zhao personal communication 16 May 2016).

Sources: Adapted from EMCA (2015), ESCO Development in China – Drivers and Barriers; JRC (2014), ESCO Market Report for Non-European Countries 2013; JRC (2017), Energy Service Companies in the EU: Status Review and Recommendations for Further Market Development with a Focus on Energy Performance Contracting; Navigant Research (2015), Energy Service Company Market Overview: Expanding ESCO Opportunities in the United States and Europe; and Zhao (personal communication 16 May 2016).

Table 4.2 ESCO Jobs in China, the United States and the European Union

Region	ESCO employment
China	652 000
United States	387 000
European Union	100 000

Note: The employment number for the European Union is estimated from the average annual ESCO revenue growth since 2010.

Sources: Cambridge Econometrics (2015), *Assessing the Employment and Social Impact of Energy Efficiency*; US DOE (2017), *Energy and Employment Report*; and EMCA (personal communication 17 July 2017).

Box 4.4 Innovative models for ESCO financing

There are many forms of financing employed by ESCOs. One common model uses an EPC, where the energy user enters into an agreement with an ESCO that then provides the technology and guarantees performance and energy savings. In this model, the customer can self-finance the project or have the ESCO fund the project using its own resources. In both cases, the customer or the ESCO may enter into a direct loan agreement with a third-party lender to secure financing for the project. Securing loans from third parties is easier for large industrial customers or utility-sized ESCOs than for smaller ESCOs, who often struggle in this regard.

One innovative model designed to meet that challenge was implemented in Ireland and won the Environmental Finance Energy Efficiency Deal of the year for 2017. Urban Volt, a LED lighting firm (in this instance acting as the ESCO) teamed up with SUSI Partners, a specialist energy efficiency fund (Figure 4.10). EUR 30 million was made available in funding over a two-year period to Urban Volt to install energy efficiency lighting free of charge for small businesses, which is paid back through the savings achieved. Urban Volt was responsible for bundling these smaller projects to achieve sufficient investment volumes. SUSI Partners would then buy the projects, taking over the credit risk of the customer defaulting. This model frees up cash flow for the ESCO to develop new projects, reduces their credit risk and enables start-ups and smaller firms to access capital.

Figure 4.10 ESCO finance model

Source: SUSI Partners (personal communication 7 July 2017).

Policy-enabled markets drive energy efficiency investment

Energy efficiency is rarely traded as a commodity. Where it is traded, it is usually the result of government regulations to create a market for efficiency outcomes, such as energy savings, carbon dioxide emissions reductions, or electricity system adequacy (the ability of the power system to match the evolution in electricity demand). Obligations on energy companies to achieve energy savings targets among end-users have become more popular among policy makers over the last decade, with programmes now in operation in 46 countries and states (see Chapter 2) (IEA, 2017b). Some of these programmes allow compliance to be traded between obligated parties in the form of a unit of energy savings, encapsulated in an energy efficiency certificate, also known as a white certificate. In a small number of cases, energy companies may also fulfil their obligations by buying white certificates from other parties.

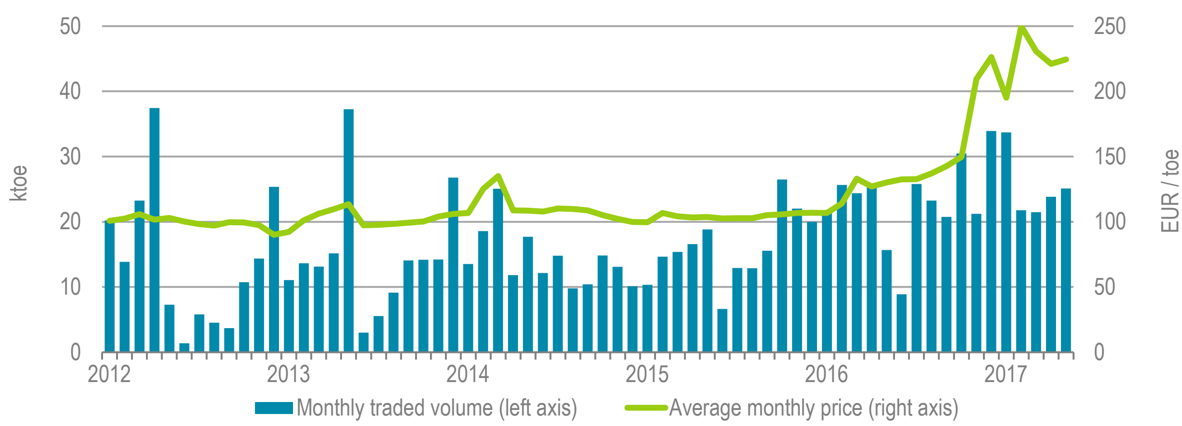
White certificate markets, in which obligated utilities, ESCOs and other certified organisations can trade the achievement of energy savings, operate in France, Italy, Poland and the Australian states of New South Wales and Victoria. Trading between obligated parties is also allowed under the Indian Perform, Achieve, Trade (PAT) programme, where certificates are generated through over-compliance with targets. Auctions for energy savings are in place in Portugal and Switzerland, while pilots are being run in Germany and the United Kingdom, where the focus is on peak time electricity savings as an alternative to paying for supply-side capacity. In the United States, some capacity market auctions allow energy efficiency resources to compete against supply-side resources for the provision of electricity system adequacy.

Prices in the Italian white certificate market have risen steeply

Italy's white certificate programme has been operating since 2005. It requires electricity and gas distributors with more than 50 000 clients to meet their energy saving obligations either by generating and submitting their own white certificates through the implementation of energy efficiency projects, or by buying white certificates from other parties.[8] Each white certificate is equivalent to 1 tonne of oil-equivalent (toe) and almost all sectors can generate certificates. Between the start of 2005 and the end of May 2017, over 47 million white certificates were issued, with around one-third of certificates generated by non-obligated parties (GME, 2017).

The market in Italy was stable between 2009 and 2015, with the price of certificates rarely moving outside of the EUR 90 to EUR 110 range. Policy makers made small annual adjustments to the programme rules, which broadly maintained equilibrium in the market. During 2016, however, the price rose steeply to reach EUR 200 by the end of the year and during 2017 the price has been volatile, rising to a monthly high of EUR 250 (Figure 4.11).

Figure 4.11 Trends in the Italian white certificate market, 2012-17



Note: Monthly prices are expressed as a weighted average across certificate types (I, II, II-CAR, III and V).

Source: Adapted from GME (2017), *Energy Efficiency Certificates – Sessions* (database), www.mercatoelettrico.org.

[8] Other parties include other distributors, ESCOs and companies or organisations with a certified energy manager or ISO 50001-certified management system.

The increase in price was caused by a number of factors, most notably changes in the methodology for the generation of white certificates. These changes included updates to additionality criteria, making it less likely that some industrial projects qualify for certificates, and removing the multiplier applied to longer-lived projects (while increasing the number of years for which certificates can be generated by projects), reducing the average number of certificates issued per project. The publication of draft rules around these changes in 2016 led to a sharp increase in the price of allowances as obligated parties sought to hedge against the risk of future supply shortages; the rule changes came on top of an extended period of five to six years in which the number of certificates generated has remained fairly constant, indicating that the market might not find it easy to react quickly to a tightening in programme rules. Some factors point to an increase in supply over the next year, as eligibility rules for standard projects become clearer and the first metered projects that fall under new requirements for baseline measurement (involving one year of daily measurements) are completed. However, it remains to be seen how the energy efficiency sector as a whole will react to the current high prices in terms of bringing forward more supply of efficiency projects.

Prices in the French white certificate market have rebounded

France's white certificate programme has been in operation since 2006. It requires over 2 000 energy suppliers[9] to submit white certificates equivalent to their energy savings obligations, which are based on their energy sales. The current obligation period stretches from 2015 to 2017. It targets lifetime final energy savings of 700 TWh[10] (covered by classic certificates) and, from 2016, an additional 150 TWh in savings from fuel-poor households (covered by fuel poverty energy saving certificates). Obligated suppliers may generate certificates themselves, by implementing energy efficiency measures and programmes, or may purchase certificates on the open market. Suppliers may also delegate their obligations to other obligated parties or ESCOs and can "buy out" by paying a penalty of 20 EUR/MWh if other options become too expensive. To date, the vast majority of certificates have been generated by suppliers' own actions, with less than 2% of certificates being traded on the spot market.

The market price of classic certificates in France fell throughout the first half of the current compliance period, from 3.15 EUR/MWh in January 2015 to 1.40 EUR/MWh in August 2016. Since July 2016, however, when the market opened for fuel poverty energy savings certificates (which have been trading at a price of 4.40-5.15 EUR/MWh), the price of classic certificates has risen again to EUR 3.10 (Figure 4.12). Fuel poverty energy savings certificates can be submitted by an energy supplier as compliance with either their classic or fuel poverty obligations. The introduction of the fuel poverty obligation has reduced the supply of classic certificates, given that those that qualify can command a higher price in the fuel poverty market.

Despite having similar functions, the price of French and Italian white certificates cannot be directly compared. This is because Italian certificates reflect annual savings, whereas French certificates reflect cumulative savings over a project's entire life.

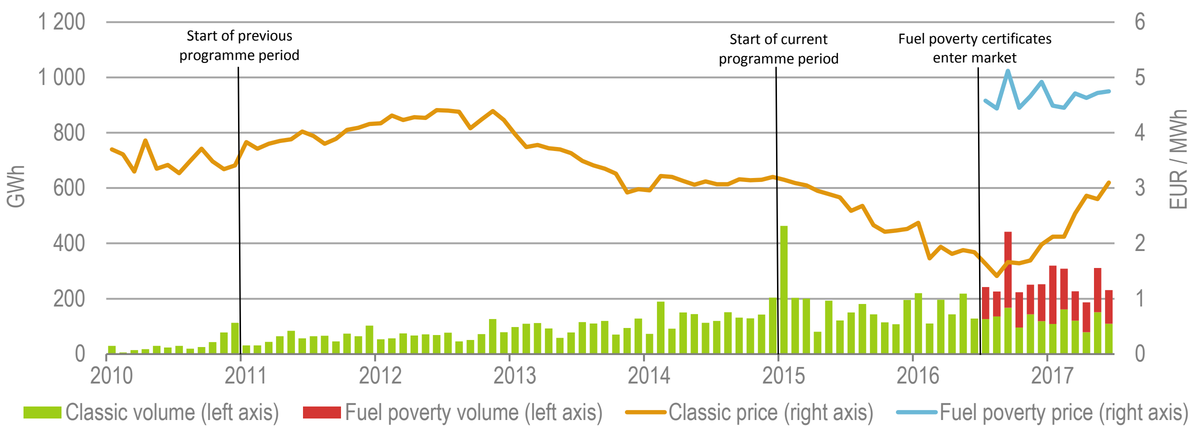
In November 2016, targets for the 2018-20 phase of the French white certificate programme were announced. Ambition has been raised to 1 200 TWh for classic certificates and 400 TWh for fuel

[9] Obligated energy suppliers include electricity, gas, and district heating and cooling suppliers with sales of more than 400 GWh per year, liquid petroleum gas suppliers with sales of over 100 GWh per year and distributors of automotive fuels.

[10] Lifetime savings are discounted at a rate of 4% per year, with the cumulative savings generated by a project denominated in what is termed as "KWh cumac", with each unit qualifying for a white certificate.

poverty certificates. This increased ambition – allied with new efforts on monitoring and verification, and the removal of the ability to claim certificates for work co-funded through tax credits – is likely to put upward pressure on certificate prices, as certificates can be interchanged between phases.

Figure 4.12 Trends in the French white certificate market, 2010-17



Source: Adapted from EMMY (2017), *Rating of kWh.*

India's Perform, Achieve, Trade (PAT) programme is entering its second cycle

The PAT programme in India is a mandatory, multi-phase, market-based trading instrument. The programme sets energy efficiency standards in energy-intensive sectors ("designated consumers", or DCs). The first cycle, 2012-15, successfully reduced the energy consumption of more than 400 energy-intensive enterprises by 5.3%, surpassing the 4.1% target (Table 4.2). The targets were based on annual specific energy consumption for each DC in 2010 (the baseline year) and adjusted to account for factors such as product mix, capacity utilisation, change in fuel quality, import/export of power, and other factors.[11] The majority of the DCs implemented low-cost measures, such as changes to process control and the installation of variable speed drives on electric motors, which were financed through DCs' own resources. In the cement industry, for example, common measures included the installation of waste heat recovery systems and vertical rolling mills. In the iron and steel sector, measures included the installation of top recovery turbines and adoption of a coke dry quenching process.

The trading of energy saving certificates (ESCerts) is central to the PAT programme and serves as an incentive to reach, or even surpass, the targets. The ESCerts, equivalent to 1 toe of energy savings, are based on quantified energy savings verified by an accredited energy auditor. The certificates are awarded after a DC surpasses its target and can then be sold to another DC that has failed to achieve its target, the price for which is determined through supply and demand. The ESCerts can also be banked for DCs to use towards meeting future targets in the next PAT cycle as the programme continues. Starting in 2017, demand for ESCerts is expected to be low, given that about 3.8 million ESCerts have been issued, of which about 1.5 million will be absorbed by DCs who are falling short of targets.

[11] India Bureau of Energy Efficiency (personal communications 4 June 2017).

If a DC has not met its target and fails to purchase sufficient ESCerts to compensate for its shortfall, it will be subject to a financial penalty. For the second PAT cycle (2016-19), the baseline is the assessment year of the first PAT cycle, i.e. 2014-15. Coverage is being expanded to include more DCs and sectors, bringing the total to 621 DCs from 11 sectors. As the low-cost measures start to be implemented, additional financial support is expected to encourage DCs to invest in higher-cost energy efficiency measures with longer payback periods.

Table 4.3 Targets and achievements in the first cycle of the PAT programme (2012-15)

Sector	Target (million toe)	Achievements (million toe)	% above target	% over achievement	Number of ESCerts (millions)
Power (thermal)	3.21	3.06	-5%	-5%	3.8
Iron and steel	1.49	2.10	29%	41%	
Cement	0.82	1.44	43%	76%	
Aluminium	0.46	0.73	38%	59%	
Fertiliser	0.49	0.83	42%	73%	
Paper and pulp	0.12	0.26	54%	117%	
Textile	0.07	0.12	45%	71%	
Chlor-alkali	0.05	0.13	58%	100%	
Total industry	**6.68**	**8.67**	**23%**	**30%**	

Source: BEE (personal communications 4 June 2017).

A growing amount of energy efficiency is being accepted in capacity auctions

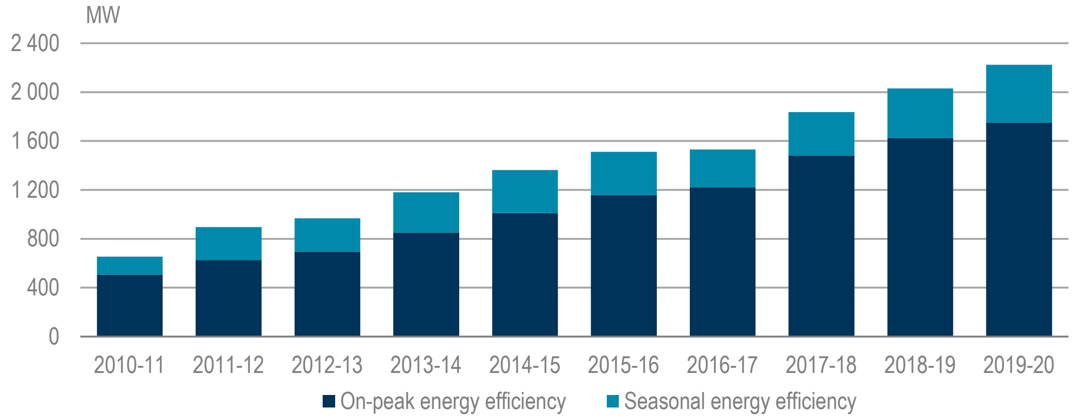
Electricity market operators need to ensure that there is sufficient capacity available to meet expected future demand and sometimes do this through auction processes, known as capacity auctions. These allow third parties to offer electricity supply capacity at a certain price (bids) or, as is becoming more common, offer capacity in the form of demand reductions.

In some of the electricity capacity auctions in the United States, which are based on projections for how much electricity demand will need to be met a few years ahead, bids can comprise not only energy resources that meet demand, but also energy efficiency measures that reduce demand. The auctions held by the New England Independent System Operator (ISO-NE) and by PJM (which covers the mid-Atlantic region and parts of the Midwest) have received significant bids from companies promising to deliver load reductions at peak hours through energy efficiency.

Bids in these auctions can comprise different types of demand-side measures. Energy efficiency measures such as building refurbishments, which deliver reductions in energy consumption throughout the year, including during peak hours, differ from demand-side response measures, which can be called upon to deliver energy savings at peak, either by shifting consumption to other parts of the day, or by reducing consumption for a specified period.

In the ISO-NE capacity market, over 2 200 MW of efficiency resources cleared the recent auction for delivery in 2019/20 (Figure 4.13). This was more than triple the amount cleared for delivery in 2010/11 and represented 6% of the total capacity cleared.

Figure 4.13 Energy efficiency savings accepted in the ISO-NE capacity market



Note: On-peak energy efficiency includes measures that will provide demand reduction during peak hours (1pm to 5pm) on working days between June and August, and during peak hours (5pm to 7pm) on working days in December and January. Seasonal energy efficiency includes resources that are defined by weather conditions (cold winter days, hot spells in the summer).

Source: Liu (2017), "Demand response and energy efficiency in the capacity resource procurement: Case studies of forward capacity markets in ISO New England, PJM and Great Britain".

The amount of energy efficiency clearing PJM auctions has also increased. In the 2017 PJM auction for delivery in 2020/21, 2 240 MW of energy efficiency capacity was offered, with 1 710 MW clearing (UtilityDive, 2017). This was the largest amount to clear, representing a 13% increase on the 2016 auction and more than triple the amount cleared in 2009. Enabling capacity market bids that comprise efficiency measures recognises the value of efficiency to electricity system adequacy, providing incentives for further investments and value to rate payers.

While the amount of energy efficiency currently clearing capacity markets is small compared with conventional electricity supply, the deployment of digital technology, particularly smart meters (see Chapter 2), may allow for efficiency to make a greater contribution. Drawing on real-time energy use data captured by smart meters, digital platforms can be developed to quantify the time and location of potential energy efficiency resources, so that the demand savings generated can be aggregated and can deliver capacity to the electricity grid.

This new approach is being implemented by Pacific Gas and Electric in California through a pay-for-performance residential pilot, in which utilities procure demand savings from aggregators who source energy efficiency from residential consumers with an installed smart meter. Utilities who procure savings enter into savings purchase agreements with aggregators, and pay for savings as they are delivered. Other states have committed to pilots using similar strategies, including Illinois, Massachusetts, New York and Oregon.

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5. ENERGY EFFICIENCY IN INDONESIA

Highlights

- **Indonesia is the largest energy consumer in Southeast Asia, accounting for over 36% of the region's primary energy demand.** Between 2000 and 2015, Indonesia's gross domestic product (GDP) doubled and its demand for electricity increased 150%. Economic growth is set to drive up Indonesia's energy needs. It is projected that electricity generation capacity will need to increase by 4.1 gigawatts (GW) per year to 2030, with 50% coming from coal-fired power plants. Efficiency will be essential to avoid unnecessary energy use and expenditure and reduce emissions.

- **Effective implementation and enforcement of current energy efficiency policies are projected to deliver a 2% reduction in energy use by 2025.** Enhancements to existing policies, and planned policies that have not yet been implemented, could achieve a further 4.5% reduction against a scenario with no policy change. However, beyond this there remains scope for greater savings.

- **Significant electricity savings are possible from improvements in the energy efficiency of lighting.** Switching to compact fluorescent lamps (CFLs) over the last decade with the help of government programmes saved Indonesian consumers USD 3.3 billion on their electricity bills in 2016. Light-emitting diodes (LEDs), which are even more efficient, are now taking a growing market share, reaching 30% of all lightbulb sales in 2016. If the current rate of LED uptake continues, Indonesian consumers could save nearly USD 560 million per year by 2030.

- **The take-up of more efficient space cooling technologies could save Indonesian consumers nearly USD 690 million per year by 2030.** Demand for space cooling is growing quickly and is likely to double between 2016 and 2020. Minimum energy performance standards (MEPS) for air conditioners were put in place in 2016, but current levels are not having a substantial effect on the market. If Indonesia accelerated the implementation of regional targets for space cooling energy efficiency, it could avoid 32 PJ of electricity consumption by 2030.

- **There is considerable potential to save energy in Indonesia's transport sector through increased uptake of electric motorcycles.** Two-wheelers are the leading form of passenger transport in Indonesia, with 80 million in use. If the penetration of more efficient electric two-wheelers was boosted to match the current level in China, Indonesia's spending on oil imports would be cut by USD 800 million in 2030. Local air pollution would also be reduced.

- **The introduction of fuel efficiency standards for heavy-duty vehicles (HDVs) – medium and large freight trucks – will also produce significant savings**. HDVs currently account for 40% of the country's total road transport energy use and it is projected that HDV fuel demand will grow 70% between 2015 and 2030. If Indonesia introduced HDV fuel efficiency standards that improved efficiency at the same rate as in China, USD 630 million in oil imports could be avoided in 2030 alone. Together with the increased uptake of electric motorcycles, savings in 2030 of over 75 000 barrels of oil per day could be achieved, equivalent to 13% of Indonesia's current net oil imports.

Introduction

This chapter examines Indonesia's progress in increasing energy efficiency and the vast potential for future energy savings from improved efficiency. As well as analysing changes in energy intensity and the impact of efficiency on energy demand, the chapter investigates how policies that improve lighting can increase energy efficiency. It also examines the energy savings and other benefits that can be achieved by improving the efficiency of space cooling and electric motors and by encouraging the adoption of electric motorbikes.[1]

The significance of Indonesia

The importance of Indonesia to global energy markets continues to grow. Indonesia remains the largest energy consumer in Southeast Asia, making up over 36% of the region's energy demand and consuming nearly as much energy as Thailand, Malaysia and Singapore combined. Rapid economic growth has brought a sharp rise in electricity demand. Between 2000 and 2015, Indonesia's GDP doubled and its demand for electricity increased by 150% (IEA, 2016a).[2]

Indonesia's population in 2016 was 261 million, with 54% living in urban areas, up from 46% a decade ago (World Bank, 2017). However, per-capita electricity consumption in 2014 (814 kilowatt hours [kWh]) was only about one quarter of the global average (3 030 kWh) (IEA, 2016a). Around 23 million people, or 8.9% of the population, still do not have access to electricity, mostly on small islands and in remote areas (Anditya, 2017), and 38% do not have access to clean cooking technology (IEA, 2016b).

Indonesia's strong economic growth is expected to continue, increasing electricity consumption to 491 terawatt hours (TWh) by 2030. It is projected that electricity generation capacity will need to increase by 4.1 gigawatts (GW) per year, with 50% of the new installed capacity being coal power plants (IEA, 2016b).[3] As GDP increases, demand for greater levels of comfort and personal mobility will continue to drive up demand for energy. In 2014, the government set a target of reducing energy intensity by 1% per year to 2025 by implementing economy-wide energy efficiency measures (Government of Indonesia, 2014), and decreasing total final consumption (TFC) by 17% by 2025 (Government of Indonesia, 2017). Indonesia's progress in developing and implementing effective policy has been limited. Effective enforcement of current policies is expected to reduce energy consumption by at least 2% below forecasts in the Indonesian National Energy Plan (NEP) by 2025. Enhancements to existing policies and planned policies that have not yet been implemented could achieve a further 4.5% reduction.

Improving the effectiveness and expanding the scope of energy efficiency policies in Indonesia is critical to ensuring continued access to secure, affordable and reliable energy.

[1] This publication reflects the views of the International Energy Agency (IEA) Secretariat but does not necessarily reflect those of the government of Indonesia.

[2] GDP at purchasing power parity.

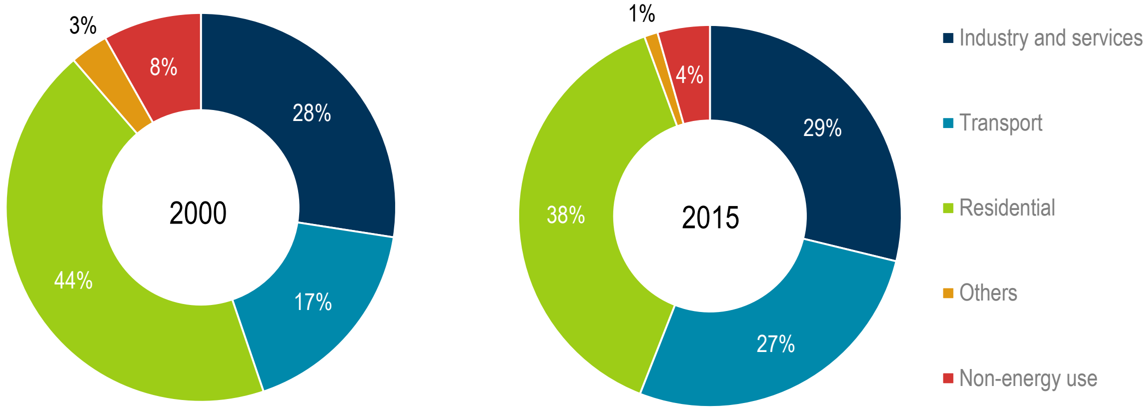
[3] The New Policies Scenario of the *World Energy Outlook 2016* (*WEO 2016*) takes account of broad policy commitments and plans that have been announced by countries, including national pledges to reduce GHG emissions and plans to phase out fossil-energy subsidies, even if the measures to implement these commitments have yet to be identified or announced.

Indonesian energy use and intensity

Indonesia, a net energy exporter, is the fifth-largest coal producer in the world, the seventh-largest exporter of liquefied natural gas (LNG) and the fifth-largest producer of biodiesel (IEA, 2016a). Production and export of coal has grown exponentially since 2002 (IEA, 2016a). Imports of oil and oil products have risen significantly since 2004, when Indonesia switched from being a net oil exporter to importer, due in part to a decline in domestic oil production since 2000. Indonesia is now the world's third-largest net importer of oil products and the tenth-largest in terms of electricity generation using oil (IEA, 2016a).

Between 2000 and 2015, energy use (total final consumption) grew by 36%, with oil (39%) and biomass (35%), the dominant sources. Indonesia's largest consuming sectors in 2015 were the residential sector (38%) and industry and services (29%), followed by transport (27%) (Figure 5.1).

Figure 5.1 Indonesian final energy use by sector, 2000 and 2015



Source: Adapted from IEA (2017a), *World Energy Balances 2017*, www.iea.org/statistics.

Growth in energy use in Indonesia has not coincided with a worsening of energy intensity, largely because of structural changes in the economy and natural efficiency gains due to new investment in the industrial sector. Between 2000 and 2015, GDP doubled, but energy demand (total primary energy supply, TPES) only rose by 45%, meaning that energy intensity improved (i.e. decreased) by 33%. Other major emerging economies have experienced a similar trend: energy intensity improved by 31% in India and 33% in China over the same period, whereas the energy intensity improvement observed in OECD countries was only 24% and globally 21% over the same period.

Future trends in energy intensity and energy demand

IEA modelling projects that energy demand in Indonesia will be fuelled by rapid increases in energy consumption in industry (to 33% of energy use in 2030) and transport (29% of energy use in 2030). Shares of energy demand (TPES) by fuel type are not projected to change significantly, with a strong reliance on coal (29%) and oil (28%) in 2030 (IEA, 2016b).[4]

[4] Projected energy demand is from IEA's *World Energy Outlook 2016* – New Policies Scenario.

Coal is projected to continue to dominate power generation, with more than 50% of the fuel mix, followed by gas (24%) and renewable energy (20%) (IEA, 2016b). Industry's growing share of energy consumption stems in part from the Indonesia Industrial Development Masterplan (Rencana Induk Pembangunan Industri Nasional, RIPIN), under which Indonesia plans for the industrial sector to account for 30% of GDP by 2035, up from 21% in 2015 (Ministry of Industry, 2015).

Transport is the third-largest end-use of energy in Indonesia. Its share is projected to rise at 3% per year on average from 1 850 PJ in 2015 to 2 800 PJ in 2030. Between 2015 and 2030, passenger vehicle numbers are projected to increase from 8 million to over 20 million, and two-wheeler stock from 80 million to nearly 100 million (IEA, 2017b).

Table 5.1 Indonesian GDP, population, energy use and electricity production, 2030

	GDP (USD millions)	Population (million)	Final energy consumption (EJ)	Electricity production (TWh)
Base year (2015)	2.8	257.6	6.8	233.9
Projection (2030)	6.2	295.5	9.4	491.8
Average annual growth	5.3%	0.9%	2.2%	5.1%

Note: Projections based on the *World Energy Outlook 2016* New Policies Scenario

Sources: Adapted from IEA (2016b), *World Energy Outlook 2016* and IEA (2017c), *World Energy Balances 2017*, www.iea.org/statistics.

Rising energy demand and falling subsidies have increased energy retail prices, especially for electricity (Box 5.1). The average cost of electricity production per kilowatt hour (kWh) increased from USD 0.072 in 2003 to USD 0.095 in 2015 and the average electricity tariff increased from USD 0.065/kWh to USD 0.08/kWh over the same period (MEMR, 2016a). Coupled with the gradual removal of fuel subsidies, the cost of energy for electricity and transport is a domestic political and economic concern, making cost reductions through energy efficiency measures all the more important for Indonesia.

Box 5.1 Energy subsidies in Indonesia

Indonesia has recently begun to make major progress in the removal of energy subsidies for both transport fuels and electricity supply. In 2015, government subsidies for gasoline were abolished and those for diesel were fixed at 1 000 Indonesian rupiah (IDR)/litre (USD 0.07). Diesel subsidies were reduced again in 2016 to 500 IDR/L (USD 0.04). In 2015 alone, removal of subsidies generated savings of IDR 120 trillion to the government (USD 9 billion) (IEA, 2017d). These savings are equivalent to 8% of state revenues for 2015 (IEA, 2017d; Ministry of Finance, 2016a; MEMR, 2016b). Reducing or abolishing subsidies incentivises transport users to switch to more efficient vehicles, with the abolition of gasoline subsidies reducing the average payback period for more efficient gasoline vehicles by 30% (to around two years). The Indonesian government reviews subsidy levels every three months based on international fuel prices, so further efficiency benefits could be obtained if subsidies continue to be reduced or abolished in the long term. However in the first quarter of 2017, the international oil price rose, and the government of Indonesia did not raise the prices of gasoline and diesel (MEMR, 2017).

Electricity subsidies are also undergoing a planned phase-out, with household electricity subsidies being removed from higher-income households, and targeted instead towards the two lowest consumption classes in Indonesia, the 450 volt-amperes (VA) and 900-VA connection classes. Due to the enactment of these reforms, in 2013, the cost of subsidies fell by two-thirds from 2014 to 2016, saving the Indonesian government USD 5.6 billion. A survey conducted by Indonesia's National Team for the Acceleration of Poverty Reduction (TNPK2) and the state-owned utility (Perusahaan Listrik Negara, PLN), found that only 17% of customers currently accessing the 900-VA connection class are actually eligible to receive the subsidies. This suggests that the electricity subsidies could be targeted even more effectively. In 2016 the government approved plans to remove subsidies for better-off customers using the 900-VA connection class (IEA, 2017d). In January 2017, the government applied a tariff adjustment, raising the price of electricity for 900-VA connection class customers who were no longer eligible to receive the subsidy. Reducing these subsidies further will not only reduce government expenditure, which could then be used to scale up energy access, but it could also incentivise the use of more efficient end-use appliances in the residential sector.

A critical role for energy efficiency

Only 16% of Indonesian energy use is covered by mandatory energy efficiency policies such as MEPS or labelling (IEA, 2017e).[5] In 2016, Indonesia's mandatory energy efficiency policies comprised MEPS and labelling for both CFLs[6] and air conditioners[7] and a requirement for industrial companies using more than 0.25 PJ per year to implement energy management programmes and report their energy consumption.[8] While this figure is 11% higher than the average for the Association of Southeast Asian Nations (ASEAN), there are still substantial opportunities to improve energy efficiency by increasing the stringency of current measures and enhancing compliance with them. The majority of the 16% coverage (14.7%) is due to Government Regulation No. 70/2009 on industrial energy management, however compliance with this policy is not yet comprehensive. Non-mandatory measures currently in place in Indonesia include incentivising a domestic market for energy service companies. Opportunities for further savings outlined in this chapter include mandating MEPS for LEDs, improving the stringency of MEPS for air conditioning, encouraging the uptake of electric two-wheelers, improving compliance with existing industry policies, and mandating MEPS for electric motors.

Exploiting its high potential to improve energy efficiency could bring Indonesia numerous benefits, such as greater competitiveness, job creation and better energy security. Growth in energy use would slow down, reducing the need for new coal-fired power plants and making it easier to achieve the goal of extending access to those without electricity.

The 2014 National Energy Policy (Kebijakan Energi Nasional, KEN) and the 2017 National Energy Plan (Rencana Umum Energi Nasional, RUEN) outlined Indonesia's goals of reducing energy intensity by 1% annually to 2025 and achieving an average saving of 17% in energy use across the industry, transport, residential and services sectors (Government of Indonesia, 2014; Government of Indonesia, 2017).

Achieving the 17% target would stimulate economic growth, and consumers, businesses and the public sector would benefit from substantial energy savings – a cumulative total of 11 300 PJ by 2025

[5] Following a review of global energy efficiency policies in place, Indonesia's policy coverage has increased from just over 1% in the IEA *Energy Efficiency Market Report 2016* to 16% in this year's edition. This is due to the inclusion of Ministerial Regulation 14/2012 on Energy Management, covering large energy users using greater than 6 000 toe. It is important to note that policy coverage does not take into account the level of enforcement of these policies.

[6] Ministry of Energy and Mineral Resources Regulation No. 18/2014.

[7] Ministry of Energy and Mineral Resources Regulation No. 7/2015.

[8] Government Regulation No. 70/2009 requires companies using more than 6000 tonnes of oil equivalent (0.25 PJ).

against current business-as-usual forecasts in the NEP. Annual energy savings for Indonesian consumers will reach around 2 200 PJ by 2025. It has been estimated that meeting the government's 2025 energy intensity target would avoid the equivalent of 20 coal-fired power stations (Karali et al., 2015), greatly reducing the need to invest in new generation and improving the reliability of electricity supply. Savings just from avoided investment in coal-fired power stations would be USD 10 billion.

As well as generating savings, achieving the energy efficiency target would avoid GHG emissions of 341 million tonnes of CO_2-equivalent ($MtCO_2$-eq) between 2017 and 2025, with savings in 2025 alone totalling 57 $MtCO_2$-eq (Government of Indonesia, 2016). This would help Indonesia meet its NDC under the Paris climate agreement, which includes a target of reducing emissions by 29% by 2030 (Government of Indonesia, 2016).

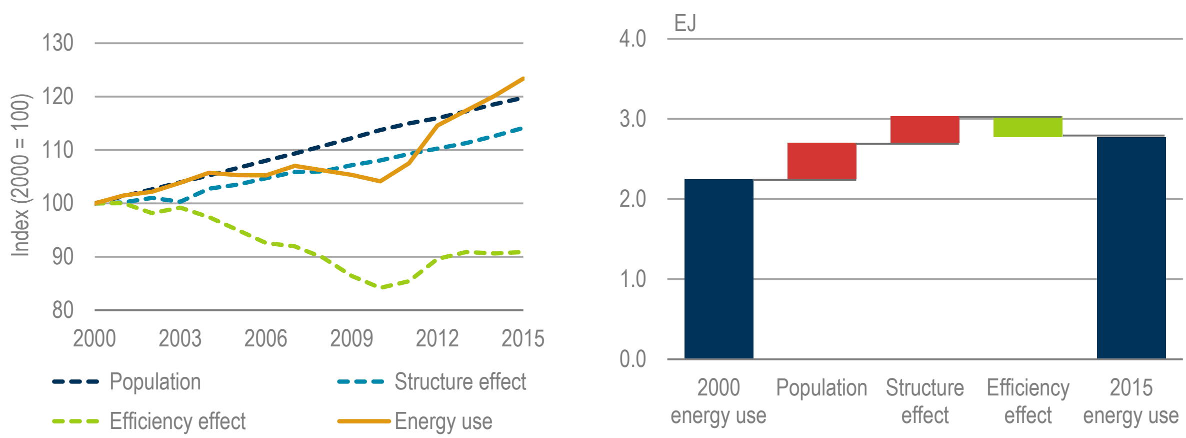
The remainder of this chapter explores energy use and energy intensity changes in the residential, transport and industry sectors. It then presents a series of energy efficiency success stories and opportunities for potential energy savings to 2030.

Residential sector

In 2015, the energy intensity of the Indonesian residential sector (energy use per capita) was 13% less than the global average, 7% higher than China and 68% higher than in India. The residential sector's share of total energy use (total final consumption) fell from 44% in 2000 to 38% in 2015. Decomposition analysis (see Annex 1) has been used to explain the factors that have influenced energy use within the residential sector in Indonesia since 2000.

Since 2000, residential energy demand in Indonesia has risen by 35%, because of increases in population, in the number of dwellings and their floor area, and in appliance ownership. Improvements in energy efficiency, as represented by the efficiency effect (Figure 5.2), were responsible for offsetting just over 30% of the increase in demand for residential energy services, resulting in a 24% overall increase in energy use since 2000.

Figure 5.2 Decomposition of Indonesian residential sector final energy use, 2000-15



Note: Structure effect includes number of dwellings, residential floor area and appliance ownership per capita.

Source: Adapted from IEA (2017a), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/.

Most energy use in the residential sector is for cooking (77%), where the predominant fuel is biomass, followed by liquefied petroleum gas (LPG) and electricity. Alongside the use of efficient lighting products, three factors improved energy efficiency in the residential sector between 2000 and 2015. First, the transition from kerosene to LPG cookstoves was aided by a programme implemented between 2007 and 2015 by Pertamina, the state-owned oil and natural gas company. The programme distributed 55 million LPG packages to households and 2.3 million to home-based businesses, reducing kerosene consumption by 91%, or 331 PJ, saving USD 14.7 billion in government subsidies for kerosene (Pertamina, 2016). However government LPG subsidies increased from 2008 to 2015, so the overall saving was only USD 1.7 billion (Ministry of Finance, 2016b). Secondly, since 2007 the widespread switch to CFLs from incandescent lamps has driven up efficiency improvements in the residential sector. Lastly, the share of households with access to electricity increased from 52% to 91% between 2000 and 2016, reducing the use of less efficient fuel sources (Anditya, 2017).

These efficiency improvements from switching cooking fuels and using more efficient lighting fixtures contributed to a 2.4% decrease in overall residential energy use per capita between 2000 and 2015. By comparison, over the same period, residential energy use per capita increased by 3.6% in China and 8.2% in India.

The following sections highlight success stories and opportunities for further energy savings in the residential sector.

Lighting the path to energy efficiency

From incandescents to compact fluorescent lamps

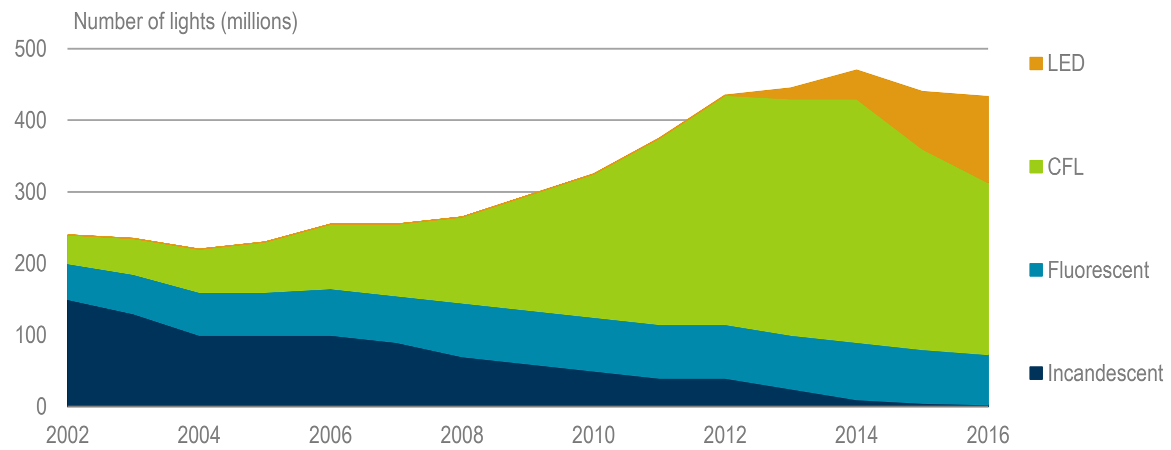
Indonesia kick-started the domestic market for CFLs through a distribution programme in 2007, followed with CFL labelling in 2011.[9] The government could replicate this experience to achieve a successful transition from CFLs to LED lighting.

Indonesia's move to CFLs started as a response to increases in the price of oil, which was being used for a large amount of electricity generation, and the consequent increase in the burden of energy subsidies on public expenditure. The government instructed the state-owned electricity company, PLN, to distribute 50 million CFLs with a focus on areas serviced by diesel power generation. The programme allowed households to exchange three incandescent lamps for three free CFLs between 2008 and 2009, and saved 4.6 TWh in electricity consumption in 2009 alone. The cost of the CFL distribution programme was USD 86.6 million but the net saving for PLN through savings in the cost of fuel, after lost electricity sales, was USD 163.6 million for 2009 (Antara News, 2008).

Supported by the 2011 MEPS and labelling of CFLs, public awareness of lighting energy efficiency grew. With a low price of USD 1-3 per CFL, sales doubled from 100 million in 2007 to 200 million in 2010 (Figure 5.3). Lighting energy intensity greatly improved over this period and partially offset increases in the demand for lighting services due to greater use in households and an increased number of households (Figure 5.4). In 2016, 98% of Indonesian households with electricity access had at least one CFL lamp installed (Manoppo, 2017).

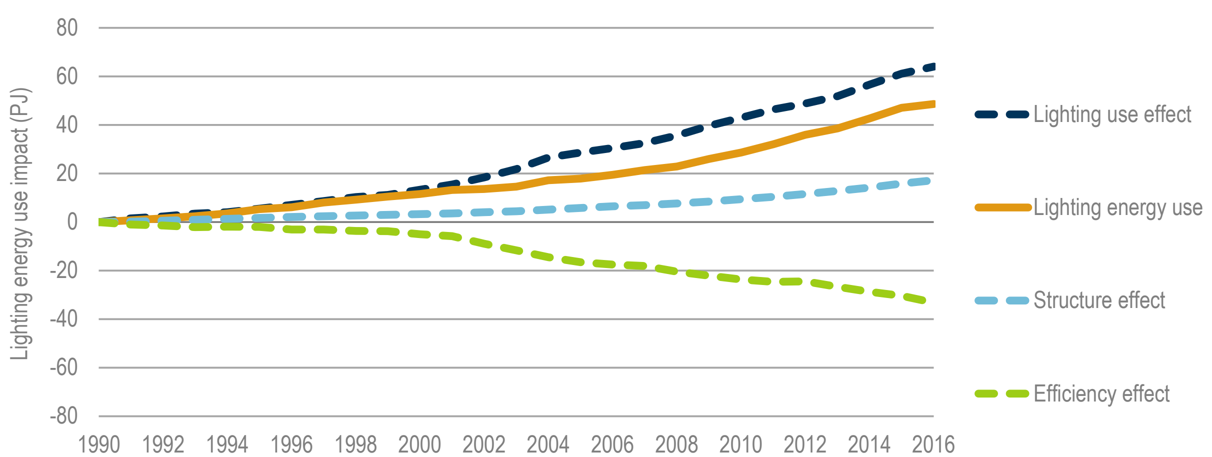
[9] Ministry of Energy and Mineral Resources Regulation No. 6/2011.

Figure 5.3 Indonesian lighting sales, by type, 2002-16



Source: Adapted from Manoppo (2017), Facts and Figures on Indonesia Efficient Lamps.

Figure 5.4 Decomposition of lighting energy use in Indonesia, 1990-2016



Note: Structure effect includes population and number of dwellings and residential floor area per capita.
Source: Adapted from IEA (2016a), *Key World Energy Statistics*.

New regulations in 2014 required every lighting product on the market to be tested in a government-approved facility,[10] however ensuring compliance with these requirements is still a challenge. Only 18 of 35 companies were complying with the regulation in late 2016, covering just 27% of the market (76 million out of 280 million CFL sales). Of the products that have been tested, 45% received the highest rating of four-stars, 7% received three stars, 40% two stars and 8% one star (EBTKE, 2016).

Indonesia has shown that a successful distribution campaign can kick-start demand for more efficient products. However, the lack of penalties for non-compliant products reduces the effectiveness with which MEPS and labelling regulations drive the market for more efficient products. Learning from this experience could improve the transition to LEDs, delivering greater

[10] Ministry of Energy and Mineral Resources Regulation No. 18/2014.

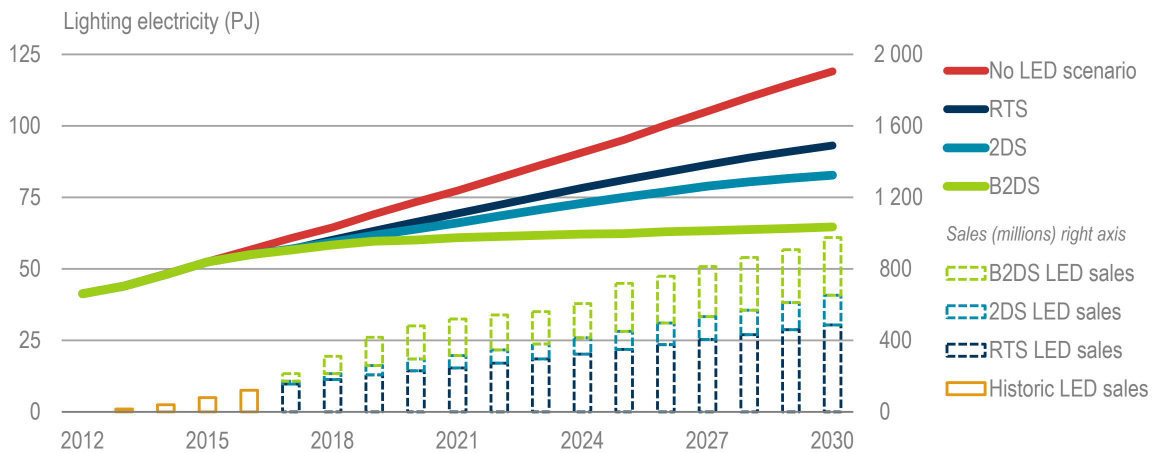
benefits to Indonesia's economy and energy consumers, and making it easier for local manufacturers of efficient LEDs to compete for market share.

From CFLs to LEDs: Achieving future energy savings

The sale of LEDs in Indonesia has grown rapidly, reaching a 30% market share of all new lamp sales in 2016. Despite this growth, prices remain high: around USD 9 for a 7-watt LED versus USD 2.50 for the most efficient CFL with the same lumen output and from the same brand. Indonesia does not have any standards or labels for LEDs, risking less efficient imported LEDs taking market share.

The switch to LEDs in Indonesia saved 2 PJ from 2013 to 2016. If the uptake of LEDs continues at business-as-usual rates (Figure 5.5), annual savings by 2030 would be 26 PJ or USD 558 million, compared with a scenario in which no LEDs are in use.[11] If greater deployment was achieved, annual savings would more than double, reaching 54 PJ by 2030,[12] or nearly USD 1.2 billion in savings for electricity consumers based on the current average electricity price (IEA, 2017e).

Figure 5.5 Projection of energy savings from increased LED sales in Indonesia, 2012-30



Note: RTS refers to the Reference Technology Scenario, 2DS refers to the 2°C Scenario[13] and B2DS refers to the Below 2° Scenario.
Source: Adapted from IEA (2017e), *Energy Technology Perspectives 2017*.

Indonesia can draw on the experience of India's UJALA programme (Chapter 4), which is on target to install 770 million LEDs by 2019 (EESL and IEA, 2017). This programme has been designed and implemented by Energy Efficiency Services Limited (EESL) a publicly owned energy services company (ESCO). It has replaced over 250 million low-efficiency lamps with LEDs, without the need for any subsidies, using a bulk procurement programme. The programme allows customers to pay 20% of the purchase price of the new LED upfront, and the remainder in equal monthly instalments.

In addition to large energy and cost savings for consumers, the UJALA programme demonstrates the multiple benefits that can be achieved through a zero-subsidy programme, including for local LED

[11] Savings calculated using the IEA *Energy Technology Perspectives* Reference Technology Scenario (RTS), which provides a baseline scenario that takes into account existing energy- and climate-related commitments by countries.

[12] Savings calculated using the IEA *Energy Technology Perspectives* Beyond 2°C Scenario (B2DS), which models a rapid decarbonisation pathway in line with international policy goals.

[13] Savings calculated using the IEA 2° Scenario (2DS), which models an energy system deployment pathway and an emissions trajectory consistent with at least a 50% chance of limiting the average global temperature increase to 2°C.

manufacturers. Importantly, the programme set a minimum performance level for the LEDs it procured of four to five stars (the two highest categories on India's energy rating label). It also required manufacturers to guarantee LEDs for a minimum of three years, ensuring that the programme installed only high-quality bulbs (EESL and IEA, 2017).

Implementing a similar bulk procurement and zero-subsidy distribution programme in Indonesia would not only avoid additional energy costs for consumers but could also enable domestic manufacturers of high-efficiency LEDs to lower production costs and increase market share. Even without a programme such as UJALA, the introduction of MEPS and labelling for LEDs to filter out inefficient products would allow domestic manufacturers of high-quality LEDs to compete for market share without being undercut by cheaper, less efficient imports that do not meet requirements.

Encouraging the uptake of LEDs in Indonesia would require the reduction of import tariffs on LED components. This is an example of where improved understanding and collaboration between several government ministries would be required in order to realise the potential financial and energy savings.

Achieving energy efficiency by accelerating air conditioner standards

Indonesia implemented its first air conditioner MEPS in 2016, with a performance standard of 2.5 Energy Efficiency Rating (EER). When these standards were set, quality market data were not available. As a result, the MEPS were set at the lower end of the market, so this is not likely to lead to significant energy savings (Letschert, V. et al., unpublished). Indonesia also created a one- to four-star energy label in 2016. Again, the lack of data affected implementation of the policy: the performance levels set do not allow for products on the market to be sufficiently distributed between categories, so the label does not help consumers choose higher performing products. However, the setting of these initial MEPS and label categories has created an important regulatory infrastructure that will enable Indonesia to improve upon these standards in the future.

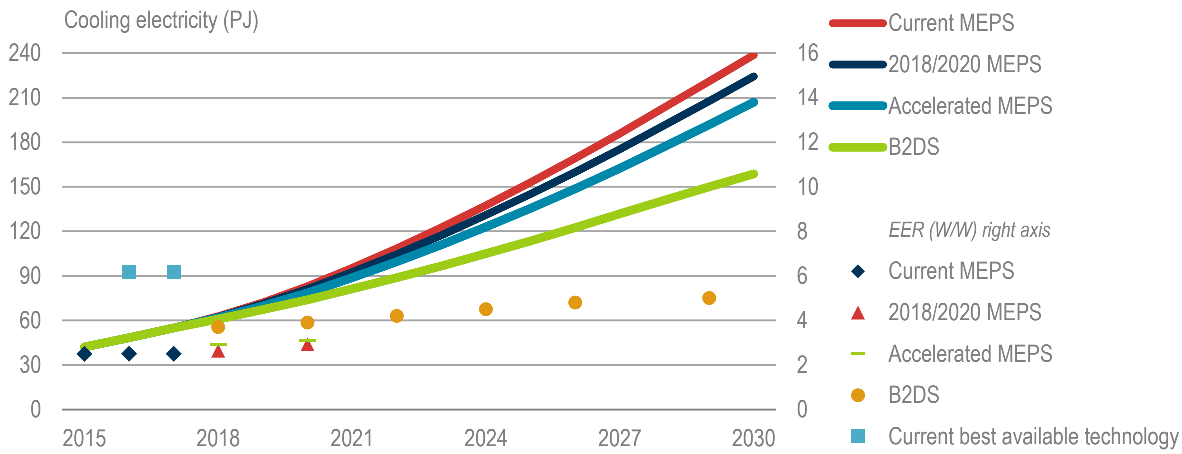
Indonesia now has access to better quality air conditioner market data, including 2016 Indonesia air conditioner registration figures and some other market statistics.[14] These numbers show that the least efficient import is 2.53 EER (labelled 1-star) while the least efficient locally produced air conditioner is 2.65 EER (labelled 2-star). The air conditioner MEPS currently provide an opportunity for less efficient imports to compete for market share against local manufacturers, who are already manufacturing higher-efficiency air conditioners. The data show that 80% of the air conditioners available in the Indonesian market achieve the highest star rating (4-star), as opposed to 15% to 30% in more effective labelling policies globally (Letschert, V. et al., unpublished).

Regional efforts to improve air conditioner MEPS, conducted through the ASEAN Standards Harmonization Initiative for Energy Efficiency (SHINE), aim to have each country in the ASEAN region achieve at least 2.9 EER by 2020 (ASEAN SHINE, 2017). Adopting this specification would lead to annual energy savings of 14.5 PJ by 2030 and USD 313 million in savings to the consumer, compared with a scenario in which the current MEPS level is maintained (Figure 5.6). If Indonesia accelerated the implementation of the ASEAN SHINE MEPS early in 2018 and then increased this minimum to 3.1 EER in 2020 (accelerated MEPS scenario), annual energy savings by 2030 would be 32 PJ with USD 686 million in savings to the consumer (Figure 5.6).

[14] Data collected with support from Lawrence Berkeley National Laboratory (LBNL).

If Indonesia were to implement even more ambitious air conditioner MEPS in line with the B2DS, increasing minimum performance to 3.7 EER in 2018 and 5.0 EER in 2028, annual savings by 2030 would be 80 PJ and USD 1.7 billion (Figure 5.6). These savings are significant and these MEPS are still well below the standard met by the best available technology in Indonesia of 6.2 EER.

Figure 5.6 Projected impact of air conditioner MEPS, 2015-30



Note: The Energy Efficiency Rating (EER) is measured on a watt per watt (W/W) basis.

Sources: Adapted from IEA (2017e), Energy Technology Perspectives 2017 and United for Efficiency (forthcoming), Accelerating the Global Adoption of Energy Efficient Electric Motors and Motor Systems.

Increasing the MEPS level would enhance the ability of domestic manufacturers of efficient products to compete for market share. Indonesian manufacturers also have the potential to develop energy-efficient products to meet the demand for low-power air conditioners for Indonesian households with small electrical connections (900-VA access). Producing efficient air conditioners for this specific market could increase the market share for Indonesian manufacturers, as few imported products meet the low-power constraints and this market sector is likely to be less attractive to large international companies.

Harmonising efficiency standards with the wider region would enable domestically produced air conditioner models to meet the MEPS of neighbouring countries, in particular those who are seeking to meet or exceed the ASEAN SHINE efficiency targets. This could provide the domestic manufacturing industry with greater export opportunities. Thailand has demonstrated how effective the implementation of more ambitious MEPS can be for boosting the domestic air conditioner manufacturing industry and driving export growth (Hengrasmee, unpublished).

Beyond standards for efficient lighting and air conditioners, the potential to use standards to boost efficiency and save energy in whole buildings has been exploited by the cities of Jakarta and Bandung through “green building” codes (Box 5.2).

Box 5.2 Building codes in Jakarta and Bandung

Alongside national energy efficiency standards for individual building components, the cities of Jakarta and Bandung have developed and implemented local whole-building green building codes that include energy efficiency requirements. Both cities have mandatory requirements for large buildings, while Bandung also has building code requirements that incorporate energy performance and incentives for small buildings.

Currently 412 of 508 local jurisdictions in Indonesia have some form of building regulation in place, which provides an important regulatory framework that could enable the inclusion of future energy efficiency requirements. In addition, the Ministry of Public Works and Housing has developed a policy for green buildings, with a 2015 decree that requires buildings of more than 500 m^2 to meet minimum energy performance requirements.

Jakarta was the first city in Indonesia to develop and implement a green building code for large buildings. The code, which includes checklists and forms on the city website, is for green design, construction and operation, with reporting required every five years to obtain an extension on the building occupancy permit. However enforcement is a challenge and compliance issues need to be addressed.

Bandung was the second city in Indonesia to develop a green building code. Launched in 2016, the Bandung green building code goes a few steps further than the Jakarta code by being applicable to all buildings, with mandatory measures for large buildings and voluntary measures for all other buildings to achieve 1-star level compliance. The Bandung code also includes additional sustainability measures to achieve 2- and 3-star level compliance, with the opportunity to receive financial incentives. In addition, Bandung has implemented two innovative green building code policies, providing online tools for reporting and a sampling verification procedure.

Jakarta and Bandung's green building codes have created the basic framework, tools and policy understanding that can encourage more widespread adoption and enforcement of energy efficiency requirements for buildings across Indonesia. With the support of the city's leaders, Bandung has been able to demonstrate to Indonesia the next step in improving building code development and implementation across all buildings.

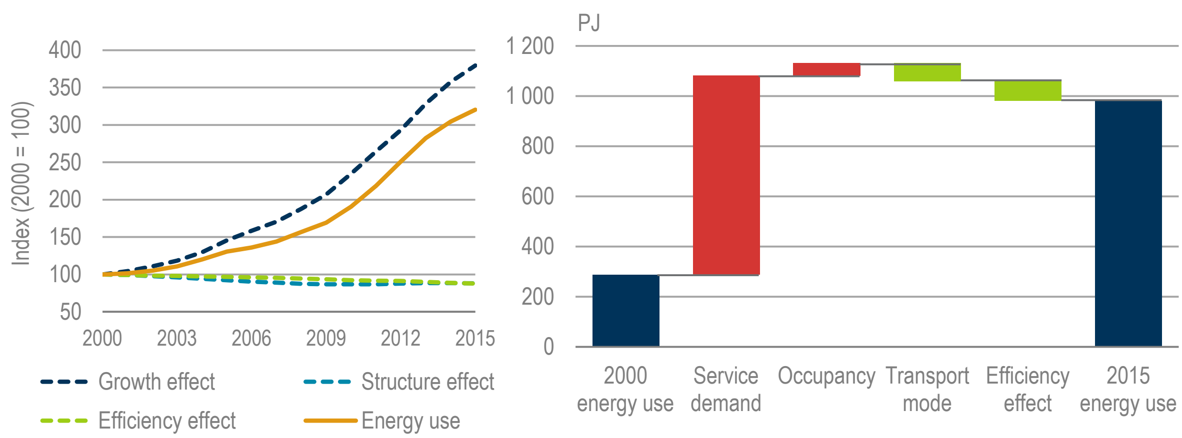
Transport sector

The largest increase in demand for energy from 2000 to 2015 in Indonesia was in the transport sector. Decomposition analysis is again used to understand the factors that have influenced this change (Figure 5.7).

In passenger transport, energy service demand has increased nearly four-fold between 2000 and 2015, driven primarily (84%) by an increase in the distance travelled per passenger. Around 6% of the growth in service demand has been offset by changes in transport mode, primarily from the increased share in the total passenger transport fleet of two-wheelers. Sales of two-wheelers have been increasing at an annual rate of 14.4% (Indonesia Motorcycle Industry Association, 2016). Although there has been a lack of fuel economy standards, the uptake of new, more efficient passenger vehicles has contributed to an efficiency effect that offset 9% of the growth in service demand.

Energy intensity in the Indonesian passenger transport sector is heavily influenced by the use of two-wheelers, which represent 85% of the total vehicle stock and account for just over 23% of total transport sector energy use. In comparison, two-wheelers are responsible for only 6.6% of transport energy use in China and 10.9% in India (IEA, 2017b). Passenger cars account for less than 22% of total energy use, with light commercial trucks representing 27% of fuel use. While the use of two-wheelers in Indonesia (measured in vehicle-kilometres) grew nearly nine-fold between 2000 and 2015, the energy intensity of this mode of transport improved by 12.5%, reflecting the efficiency benefits of the purchase of new stock.

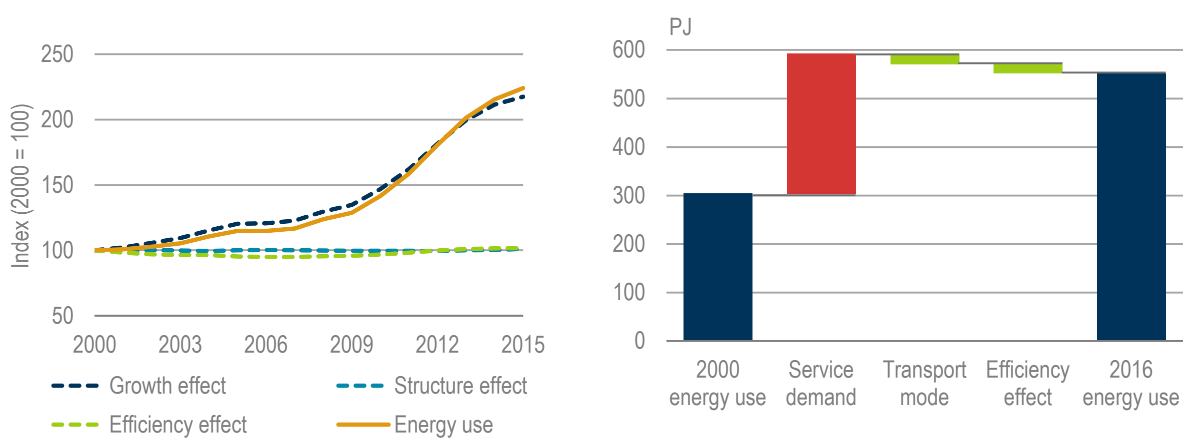
Figure 5.7 Decomposition of Indonesian passenger transport final energy use, 2000-15



Source: Adapted from IEA (2017a), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/.

Within the freight transport sector, the growth effect doubled between 2000 and 2015, reflecting increased demand for freight services in line with economic growth (Figure 5.8). Again, the impact of energy efficiency in offsetting the growth effect was limited, due to the absence of heavy-duty vehicle fuel efficiency standards, which are also lacking in many other countries (IEA, 2017e). The energy intensity of light trucks improved by 4% between 2000 and 2015, with medium and heavy trucks improving by 7% and 8% respectively over the same period.

Figure 5.8 Decomposition of Indonesian freight transport final energy use, 2000-15



Source: Adapted from IEA (2017a), *Energy Efficiency Indicators* (database), www.iea.org/statistics/topics/energyefficiency/.

The increase in demand for transport services in Indonesia has been facilitated by the improvement and expansion of transport infrastructure across the country, especially airports, and the growth of low-cost airlines. From 2015 to 2016, the number of airline passengers increased 10.5%, to 95.2 million. Train passengers increased by 8% to 351.8 million (Statistics Indonesia, 2017). The Bus Rapid Transit (BRT) system in Jakarta also increased passenger numbers, from 102.3 million in 2015 to 123.7 million in 2016, an increase of 20% in just one year.[15]

Indonesia on the move

Energy demand for transport in 2015 constituted 29% (1 850 PJ) of energy use in Indonesia and is projected to increase to 2 800 PJ in 2030 (IEA, 2017b). Transport fuels have been largely imported since Indonesia switched from being a net oil exporter to a net oil importer in 2004. Improving the energy efficiency of transport offers Indonesia the opportunity to avoid expenditure on imported oil, improve the balance of trade and improve energy security. Three activities that could deliver substantial savings include accelerating the uptake of electric two-wheelers to replace conventional motorcycles, promoting and expanding the use of public transport, and implementing fuel efficiency standards for heavy-duty vehicles.

The rise of the electric two-wheeler

Two-wheelers[16] are the most popular mode of personal transport across Indonesia, especially in cities. There are currently 80 million motorcycles[17] on the road in Indonesia and they consume 23% of all transport fuels, totalling 470 PJ in 2015.

Average annual sales have totalled 6.5 million units from 2005 to 2015, compared with car sales of 0.8 million (Indonesia Motorcycle Industry Association, 2016; Association of Indonesia Automotive Industries, 2017). As the economy and population continue to grow and despite the development of public transport options, the motorcycle is expected to remain the preferred mode of transport for many Indonesians. The Indonesia National Energy Plan (NEP) target includes 184 million motorcycles on the road by 2030, including electric two-wheelers (Government of Indonesia, 2017). IEA modelling, which factors in different economic growth and stock turnovers, projects that the number of motorcycles will reach nearly 100 million by 2030 (IEA 2017b). As of 2016, sales of electric two-wheelers in Indonesia were negligible, but the NEP target would see 800 000 in use by 2020, 2.1 million by 2025 and 4 million by 2030 (Government of Indonesia, 2017).

The manufacturing of electric two-wheelers in Indonesia has already started. In 2015, a state university in East Java started research and development into electric vehicles in conjunction with a local motorcycle manufacturer. The prototype of this research was tested on the road in November 2016, and the manufacturer now has advance orders for more than 35 000 units.[18] While this company is planning to start mass production and sales in 2018, another manufacturer from Central Java is hoping to start selling their 2 kW electric two-wheeler in mid-2017, with initial production of 100 units per month (Detik News, 2017a). The manufacturer claims that the price of domestically produced electric two-wheelers will be comparable with conventional motorcycles currently on the market. PLN is also testing imported electric two-wheelers in order to provide

[15] Institute for Transportation and Development Policy, personal communication 22 March 2017.

[16] Two-wheelers in the context of this chapter are defined as conventional (non-electric) motorcycles or mopeds, excluding electric bicycles.

[17] Incorporating stock turnover.

[18] "Sepuluh Nopember Institute of Technology" [Institut Teknologi Sepuluh Nopember] (personal communication 21 March 2017).

charging stations (Detik News, 2017b), of which the NEP requires there to be at least 1 000 in Indonesia by 2025 (Government of Indonesia, 2017).

If electric two-wheelers reach the levels of penetration forecast in the NEP (2.2%), annual energy savings of 10 PJ will be reached by 2030 compared with current IEA business as usual projections, equal to 0.5% of Indonesian transport energy use in 2015 (IEA, 2017b). However, the potential for energy savings is much higher. If Indonesia reached China's 2015 electric two-wheeler penetration level of 25% by 2030 (IEA and CEM, 2016), savings would be approximately 97 PJ in 2030, reducing oil import expenditure by USD 800 million (Figure 5.9).

Switching to electric two-wheelers at the more ambitious penetration rates will require approximately 67 PJ of additional primary energy demand.[19] Electric two-wheelers are around six times more efficient than the equivalent conventional two-wheeler,[20] so even when taking into consideration the prominence of coal-fired power generation in Indonesia, the switch will still result in a net primary energy savings of 30 PJ.

There are significant other benefits in switching to electric two-wheelers, including reducing tailpipe emissions and local air and noise pollution, especially given projected higher rates of motorbike and vehicle ownership. The impact of air pollution on health in Indonesia is substantial, with 56% of Indonesians exposed to higher than recommended levels of PM 2.5[21] and 20% exposed to more than 3.5 times the recommended World Health Organisation limit (IEA, 2016c). Total levels of improvements in air pollution and emissions will depend on the fuel source used to generate electricity, however as Indonesia moves towards more efficient primary energy generation and increases renewable electricity generation, energy savings and air pollution benefits resulting from a switch to electric two-wheelers will accelerate in scale.

Fuel efficiency standards for heavy duty vehicles

Medium and heavy freight trucks – referred to as heavy duty vehicles (HDVs) – were responsible for around 40% of Indonesia's total road transport energy use in 2015. Their energy use is expected to grow by 70% by 2030, increasing oil demand and required imports.

As in many countries, HDVs are not currently covered by mandatory fuel efficiency standards in Indonesia. Only Canada, China, Japan and the United States have introduced HDV efficiency standards and the European Union, India, Korea and Mexico are in the process of developing standards.

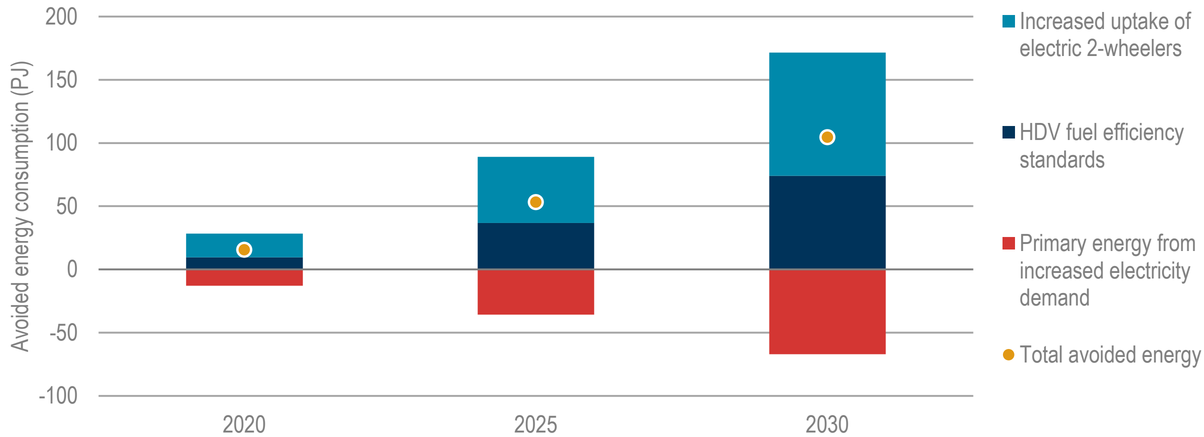
If Indonesia were to implement standards that drive the same relative improvement in HDV fuel efficiency as China, 75 PJ of energy use could be avoided by 2030, compared with current IEA business-as-usual projections, reducing oil import expenditure by USD 630 million (Figure 5.9). When combined with the increased uptake of electric two-wheelers, savings of 75 000 barrels of oil per day could be made in 2030, equivalent to 13% of Indonesia's current net oil imports. As with the uptake of electric two-wheelers, improved HDV fuel efficiency would reduce tailpipe emissions and local air pollution, lessening the impact on health from the expected increase in energy demand in the road transport sector.

[19] Adapted from IEA (2017b) *Mobility Model*, www.iea.org/etp/etpmodel/transport.

[20] Calculated using final energy consumption on the basis of tank/plug to wheel efficiency based on data provided by Gesits, personal communication 19 April 2017, and Walker and Roser (2015).

[21] PM 2.5 is particulate matter of less than 2.5 micrometers or less and can be dangerous to human health.

Figure 5.9 Avoided energy consumption from the introduction of HDV fuel efficiency standards and the increased uptake of electric two-wheelers compared with additional primary energy demand



Source: Adapted from IEA (2017b) *Mobility Model* (database and simulation model), www.iea.org/etp/etpmodel/transport.

Improving and expanding public transport

Over the last five years, Indonesia has greatly expanded its public transport system, mainly in the capital city of Jakarta and the surrounding area. These improvements have been driven by two presidential regulations[22] supporting mass transit and light rail projects. With a population of just over 10 million people in 2016 (UN DESA, 2016) and with millions commuting from the surrounding suburbs, Jakarta is facing a serious challenge in providing reliable public transport to reduce traffic congestion and air pollution. The population of Greater Jakarta, known as Jabodetabek (Jakarta-Bogor-Depok-Tangerang-Bekasi), is estimated to exceed 30 million. To address this challenge, Jakarta constructed a single-line bus rapid transit (BRT) system, called TransJakarta, which catered for 15.3 million passengers when it opened in 2004. The TransJakarta system has expanded rapidly: in 2016 there were 13 lines and 123.7 million passengers, representing growth of 18.6% annually.[23]

In addition to the BRT, there has been a substantial increase in the use of the state-owned metroline train system, the KRL Metroline, from 102.3 million passengers in 2004 to 280.6 million in 2016, an 8.8% annual growth rate (Figure 5.10). This has been achieved by increasing the number of trains, installing park-and-ride facilities for people outside Jakarta, and improved ticketing facilities. The total annual growth of the BRT and metroline systems reached 10.8% between 2004 and 2016.

According to the Greater Jakarta Transport Management Authority, the use of public transport in Jabodetabek accounted for 15% of the 40.5 million daily trips in 2015 but it is targeted to reach 60% by 2030.[24] Two public transport infrastructure projects are being developed in Greater Jakarta, mass rapid transport (MRT) and light rail transport (LRT) systems that are expected to be in use by 2019 and should carry 600 000 passengers per day. By 2019, according to company

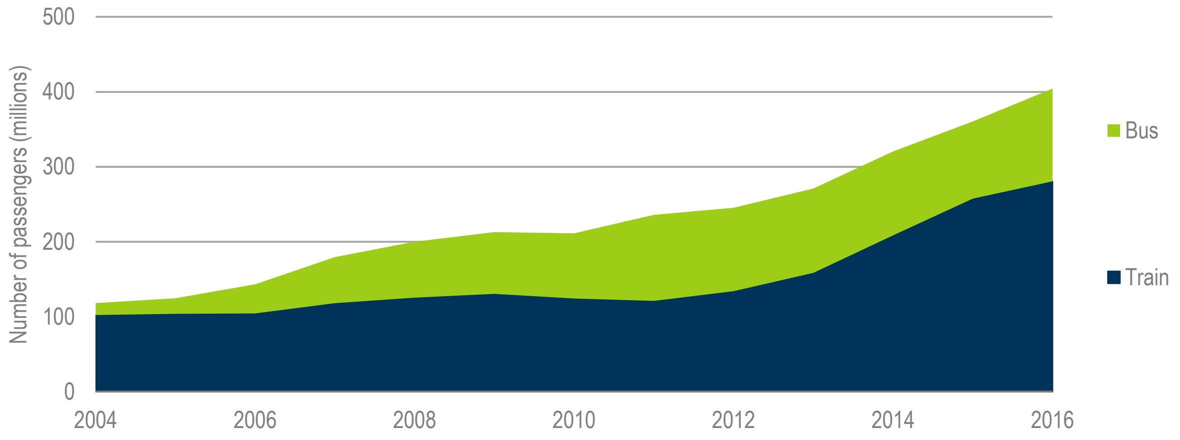
[22] Mass Rapid Transport Regulation No. 3/2016 and Light Rail Transport Regulation No. 98/2015.

[23] Institute for Transportation and Development Policy, personal communication 22 March 2017.

[24] Ministry of Transport Regulation No. 172/2015.

projections the KRL Metroline is forecast to carry around 1.2 million passengers per day (Greater Jakarta Railway, 2017) and TransJakarta is on track to carry 500 000 a day by 2017 (TransJakarta, 2017). If all of these targets are met by the end of 2019, public transport could service 2.3 million passengers per day compared with the current capacity of 1.1 million passengers.

Figure 5.10 Number of train and bus passengers in the Greater Jakarta Area, 2004-16



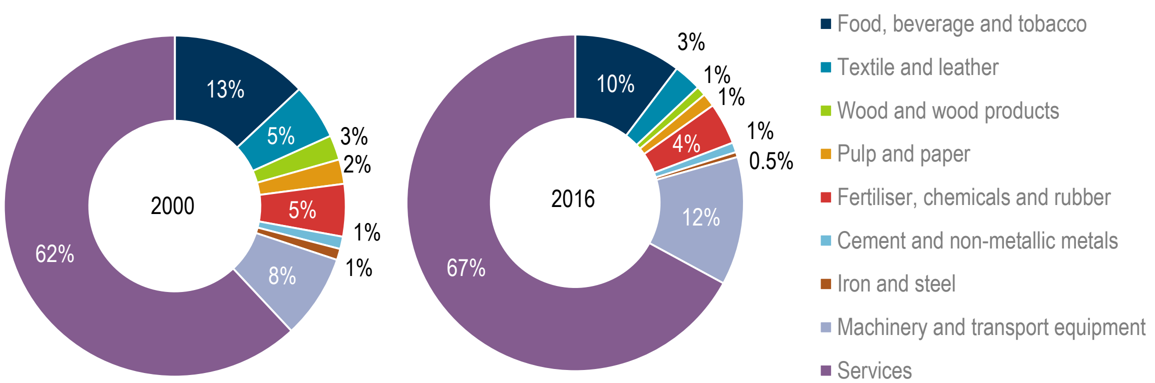
Sources: Adapted from Institute for Transportation and Development Policy (2017), personal communication, and Statistics Indonesia (2017).

Industry and services

Indonesia's industry and services sector more than doubled its economic output between 2000 and 2016, driven by growth in low energy intensity manufacturing and services (Figure 5.11). In the industry sector, the proportional contribution to overall GDP from energy intensive sub-sectors such as iron and steel, cement and pulp and paper decreased between 2000 and 2016. The largest industry sub-sectors contributing to overall GDP are both low energy intensity manufacturing sectors: machinery and transport equipment; and food, beverage and tobacco. While the contribution to GDP from food, beverage and tobacco manufacturing has slightly decreased, the contribution to GDP from transport and machinery equipment manufacturing quadrupled between 2000 and 2016, increasing its contribution to the GDP of the overall industry and services sector from 8% in 2000 to 12% in 2016. The sub-sector's growth has been driven by a 37% increase in foreign direct investment between 2010 and 2016 (Indonesia Investment Board, 2017).

Increased activity in the services sector has been driven by the information and communications services sub-sector. Its contribution to total GDP grew over seven-fold between 2000 and 2016 (Statistics Indonesia, 2017).

Figure 5.11 Breakdown of Indonesian industry and services sector GDP



Note: The industry and services sector is comprised of industry, services, agriculture and, where data is available, fishing activities.
Source: Adapted from Statistics Indonesia (2017).

Industrial energy efficiency is the key to meeting energy savings targets

To meet the energy intensity improvement target outlined in the NEP, the energy consumption of the industrial sector will need to be 17% lower than the Indonesian government's current business-as-usual projections. In order to achieve these savings, effective implementation of existing industrial energy efficiency policies is needed, as are additional policy measures, such as MEPS for industrial equipment and appliances (Box 5.3).

Government Regulation 70/2009 requires companies using more than 0.25 PJ annually to appoint an energy manager, conduct mandatory energy audits and report publicly on energy consumption. The regulation also allows for the establishment of fiscal incentives for the promotion of energy efficiency measures for industrial energy users, although these incentives are yet to be introduced. Companies consuming above this threshold represent around 60% of Indonesia's energy use in the industrial sector, although at present, only 120 of the estimated 600 to 700 companies who meet this threshold are reporting on their energy use. Ensuring compliance with all aspects of the regulation, as well as ensuring compliance by all companies who meet the threshold, remains a challenge. Through financing mechanisms, the establishment of ESCOs, the training of energy auditors, knowledge sharing, opportunity identification and effective use of penalties, compliance with this regulation can be improved.

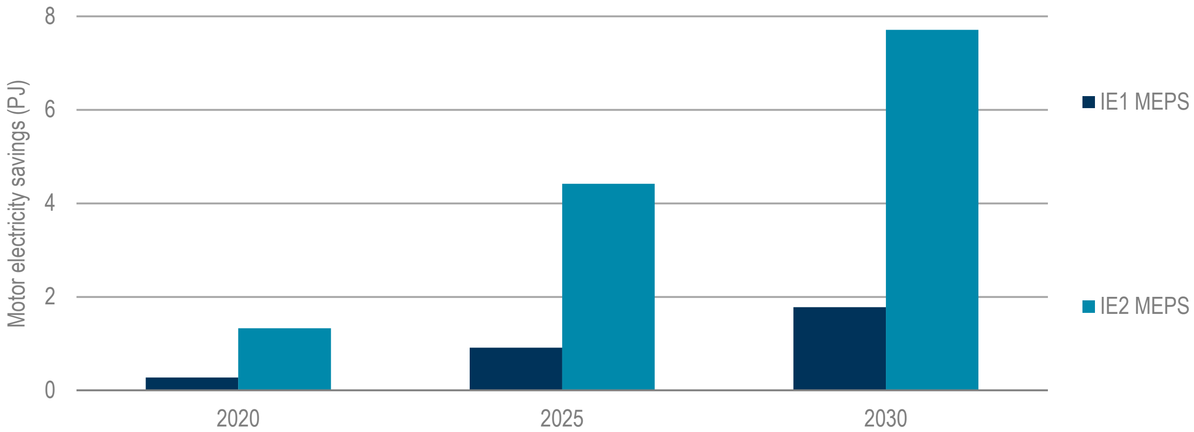
Box 5.3 Improving the efficiency of electric motors

In Indonesia, over 60% of electricity use in the industry sector is due to electric motor-driven systems and total consumption is set to rise in line with growth in industrial activity. There are currently no MEPS for electric motors in Indonesia and it is estimated that around 35% of the current motor stock are at an efficiency level equivalent to IE0[25] (ECN, 2016).

[25] MEPS for electric motors are based on the International Electrotechnical Commission standards for motor efficiency, divided into "IE" classes. Formal classifications range from IE1 to 1E4, with future efficiency improvements leading to additional classes.

Currently, Indonesia is preparing a MEPS and labelling programme for three-phase electric motors with capacity between 0.375 kW and 75 kW, which will start at the IE1 level.[26] If, as an alternative, Indonesia were to implement MEPS at an IE1 level for medium-sized motors ranging from 0.75 to 375 kW, which globally are responsible for the majority of motor electricity use, electricity savings within industry of 1.8 PJ could be achieved by 2030, compared with current IEA projections (IEA, 2016b). These savings are aided by a slightly accelerated turnover of existing motor stock. However, as IE2 motors represent only 4% of currently installed Indonesian motor stock (ECN, 2016), if MEPS were to be set at the higher IE2 level, the current level in China, annual motor electricity savings of 7.7 PJ could be achieved by 2030 (Figure 5.12).

Figure 5.12 Industrial motor electricity savings from implementation of IE1 and IE2 MEPS



Note: Motors electricity use as based on *World Energy Outlook 2016* New Policies Scenario and assuming 3 000 hours of annual operating time.

Sources: Adapted from ECN (2015), Energy Efficient Electric Motors and their Driven Systems, and IEA (2016b), World Energy Outlook 2016.

As electric motors are included in the ASEAN SHINE initiative, motor MEPS in Indonesia could be harmonised with other ASEAN countries. Harmonisation could extend to shared practices and facilities for product testing and monitoring, thereby reducing the resources required for appropriate monitoring, verification and enforcement.

There is a risk that MEPS may lead to an increase in the sale of cheaper second-hand motors that have undergone rewinding. If not conducted properly, rewinding can reduce motor efficiency. Supporting measures aimed at improving motor repair and rewinding practices, such as technical assistance programmes and information that enables informed decisions regarding the repair or replacement of motors, can mitigate this risk (Econoler, 2013; United for Efficiency, forthcoming).

To maximise the potential energy savings from regulating motors, the efficiency of the overall electric motor-driven system needs to be considered. Of future global energy savings from improvements to electric motors, 16% will be due to more efficient motor units, whereas almost 60% will be due to improvements in the broader motor-driven system (IEA, 2016b). Measures that cover motor-driven systems include energy management programmes (as outlined in Chapter 3), energy audit programmes, financial incentives and awareness-raising.

[26] EBTKE (personal communication of 9 June 2017).

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ANNEX 1: DECOMPOSITION ANALYSIS

Decomposition analysis provides a greater understanding of the impact of various factors on energy use. Analysis involves the decomposition of energy demand into three distinct factors:

- Growth – the change in the level of action that creates demand for energy.
- Structure – the mix of activities within an economy or sector.
- Efficiency – the amount of energy used per unit of activity. The term "efficiency effect" is used in this report to avoid confusion with the term "energy intensity".

Table A.1 Sectors and indicators included in the IEA decomposition analysis

Sector	Service/sub-sector	Growth	Structure	Efficiency effect
Residential	Space heating	Population	Floor area per population	Space heating energy* per floor area
	Water heating	Population	Occupied dwellings per population	Water heating energy per occupied dwellings
	Cooking	Population	Occupied dwellings per population	Cooking energy per occupied dwellings
	Space cooling	Population	Floor area per population	Space cooling energy* per floor area
	Lighting	Population	Floor area per population	Lighting energy per floor area
	Appliances	Population	Appliance stock per population	Appliances energy per appliance stock
Passenger transport**	Car; bus; rail; shipping	Passenger kilometre	Share of passenger kilometres by mode and persons per vehicle	Energy per vehicle kilometre
Freight transport	Truck; rail; domestic shipping	Tonne kilometre	Share of tonne kilometres by mode	Energy per tonne kilometre
Industry	Food, beverage and tobacco; paper, pulp and printing; chemicals and chemical products; non-metallic minerals; primary metals; metal products and equipment; motor vehicles and transport equipment; and other manufacturing	Value-added	Share of value-added	Energy per value-added
Services	Service	Value-added	Share of value-added	Energy per value-added
Other industries***	Agriculture and fishing; construction	Value-added	Share of value-added	Energy per value-added

* Adjusted for climate variation using heating and cooling degree-days.

** Changes in passenger vehicle size are not captured in the analysis.

*** Because they are energy producing sectors and outside the scope of this analysis, the following sectors are not included: mining and quarrying; fuel processing; and electricity; gas and water supply. "Other industries" are analysed only to a very limited extent.

The decomposition analysis presented in this report covers 75% of global energy use and includes all IEA member and association countries.

ANNEX 2: EFFICIENCY POLICY PROGRESS INDEX

The table below includes the list of metrics used by the IEA to determine the energy performance levels of each end-use in the EPPI.

Table A.2 Metrics used in the EPPI

Sector	End-use	Performance level metric
Buildings (residential/non-residential	Space heating and cooling	Increase in expected building performance per m^2 or weighted change in envelope U-value ($W/m^2/K$) based on standardised building configurations
		Increase in efficiency of heating system standards (boilers, furnaces, heaters)
		Increase in the energy efficiency ratio (EER) of space cooling equipment standards
	Water heating	Increase in minimum performance levels of water heating equipment
	Appliances	Increase in minimum performance levels
Transport	Light-duty vehicles and heavy-duty vehicles	Increase in vehicle fuel economy or emissions standards
		Increase in fuel economy or GHG standards for medium and heavy freight trucks
Industry	Motor-driven systems	Increase in minimum performance levels for electric motors based on IE level or average motor size
	Industry sector	Energy savings target from mandatory industry schemes weighted by consumption of the businesses that are included in the programme

The first version of the EPPI, launched in *EEMR 2016*, measured policy progress in 2015 relative to 2005. The updated EPPI now tracks policy progress on a rolling basis for each year from 2000 to 2016. Furthermore, measurements of coverage and strength have been integrated. This was done by combining data from three other IEA models into the EPPI model: the Energy Technology Perspectives buildings model, which tracks global energy use in buildings and industry, the Mobility Model (transport), which tracks global energy use for vehicles, and the World Energy Model, which tracks overall energy production and consumption for the *World Energy Outlook*. The specific EPPI modeling updates include:

- Resetting the baseline year from 2005 to 2000. This means that policy progress is measured relative to existing energy performance levels in 2000.
- Linking sales of equipment and vehicles for all years after 2000 to improvements in policy strength since 2000. This allows the IEA to track how much equipment is covered by stronger new policies as the stock turns over. The share of equipment in each model year after 2000 is multiplied by the strength in policy improvement relative to 2000. The result shows the impact of policy progress on the stock of each equipment or vehicle, in each year.

- Weighting policy progress by final energy consumption (TFC) share per country, sector and end-use, to aggregate progress and assess the relative importance of end-uses and sectors.

For example, if a country's minimum energy performance level for refrigerators was 500 kWh/unit in 2000, and new standards reduced minimum performance levels to 450 kWh/unit in 2001 then to 400 kWh/unit in 2003, the EPPI value for refrigerators in this country in 2016 are calculated as the share of refrigerators in the country manufactured in years (MY) 2001 to (MY) 2003 times 10% (the difference in annual energy use between a 500 kWh and a 450 kWh unit) and the share of post (MY) 2003 units in the 2015 stock times 20% improvement (the difference in annual energy use between a 500 kWh and a 400 kWh unit). The following figure and table below shows an EPPI calculation in further detail.

Figure A.1 Graphical overview of an EPPI calculation for example end-use

Table A.3 An EPPI calculation for an example end-use

End-use X	**Share of stock**				**Strength**			
Model year	**2000**	**2001**	**2002**	**2003**	**2000**	**2001**	**2002**	**2003**
2000	5.0%	4.8%	4.7%	4.5%	0.0%	0.0%	0.0%	0.0%
2001	0.0%	6.0%	5.9%	5.7%		10%	10%	10%
2002	0.0%	0.0%	4.0%	4.3%			10%	10%
2003	0.0%	0.0%	0.0%	6.5%				20%
EPPI	**2000**	= 5.0% × 0.0%						
	2001	= (4.8% × 0.0%) + (6.0% × 10%) = 0.6%						
	2002	= (4.7% × 0.0%) + (5.9% × 10%) + (4.5% × 10%) = 1.0%						
	2003	= (4.5% × 0.0%) + (5.7% × 10%) + (4.3% × 10%) + (6.5% × 20%) = 2.3%						

Note: The stock shares of each model year do not fully align with the presentation in Figure A.1, as stock shares per model year vary over time due to early retirement and changes in total stock

This approach enables the IEA to track the movement of minimum performance regulations compared with a given base year, taking stock turnover into account. Note that this analysis shows the movement of bottom-line performance and does not directly reflect the same movement of the market average unit energy consumption. The gap between the MEPS and the market average differs per end-use and per country.

GLOSSARY

Regional and country groupings

ASEAN

Cambodia, Thailand, Lao People's Democratic Republic, Malaysia, Brunei Darussalam, Indonesia, Myanmar, Philippines, Singapore, Viet Nam.

China

Refers to the People's Republic of China, including Hong Kong.

OECD

Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel,[1] Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

List of acronyms, abbreviations and units of measure

Acronyms and abbreviations

2DS	2°C Scenario
AB	Assembly Bill
app	application
ASEAN	Association of Southeast Asian Nations
AUS	Australia
AUT	Austria
B2DS	Below 2°C Scenario
BAT	best available technology
BCAP	Building Codes Assistance Project
BEE	Bureau of Energy Efficiency
BEL	Belgium
BEV	battery electric vehicle
BGR	Bulgaria
BPIE	Buildings Performance Institute Europe
BRT	bus rapid transit
CDA	Connected Devices Alliance
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
CEM	Clean Energy Ministerial

[1] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

CFL	compact fluorescent lamp
CHE	Switzerland
CHL	Chile
CO_2	carbon dioxide
COP	Conference of the Parties
CZE	Czech Republic
DCs	designated consumers
DEU	Germany
DNK	Denmark
US DOE	United States Department of Energy
DR	demand response
E4	Energy Efficiency in Emerging Economies
e-bike	electric motorbike/motorcycle
EBC-TCP	Energy in Buildings and Communities Technology Collaboration Programme
EBTKE	Directorate of Energy Conservation (Indonesia)
EC	European Commission
ECN	Energy Research Centre of the Netherlands
EEA	European Environment Agency
EEB	Energy Efficiency in Buildings
EED	Energy Efficiency Directive
EeMAP	Energy Efficient Mortgages Action Plan
EEMR	*Energy Efficiency Market Report*
EER	Energy Efficiency Rating
EERS	energy efficiency resource standard
EESL	Energy Efficiency Services Limited
EMCA	Energy Management Company Association (China)
EMF-ECBC	European Mortgage Federation
EMMY	Registre National des Certificats d’Economie d’Energie (France)
ENTSOG	European Network of Transmission System Operators for Gas
US EPA	United States Environmental Protection Agency
EPCs	energy performance contracts
EPPI	Efficiency Policy Progress Index
ESCerts	energy saving certificates
ESCO	energy service company
ESP	Spain
ETP	*Energy Technology Perspectives*
EU	European Union
EUR	euros
EV	electric vehicle
FIN	Finland

FRA	France
FYP	five-year plan
G20	Group of 20
GABC	Global Alliance for Buildings and Construction
GBPN	Global Buildings Performance Network
GBR	Great Britain
GCC	Gulf Cooperation Council
GDP	gross domestic product
GEF	Global Environment Facility
GFA	Global Freight Alliance
GFEI	Global Fuel Economy Initiative
GHGs	greenhouse gases
GME	Gestore Mercati Energetici (Italy)
GRC	Greece
GVA	gross value added
HDV	heavy-duty vehicle
HEMS	home energy management system
HER	home efficiency report
HFCs	hydrofluorocarbons
HPT-TCP	Heat Pumping Technologies Technology Collaboration Programme
HUN	Hungary
HVAC	heating, ventilation and air conditioning
ICCT	International Council on Clean Transportation
IDR	Indonesian rupiah
IFR	International Federation of Robotics
IEA	International Energy Agency
IEPD	Industrial Efficiency Policy Database
IHD	in-home display
ITA	Italy
ISO	International Organisation for Standardisation
ISO-NE	New England Independent System Operator
ISR	Israel
JPN	Japan
JRC	European Commission Joint Research Centre
KIC	Knowledge and Innovation Community
LBNL	Lawrence Berkley National Laboratory
LDV	light-duty vehicle
LED	light-emitting diode
LEP	Leading Efficiency Programme
LNG	liquefied natural gas

LPG	liquefied petroleum gas
LUX	Luxembourg
MEMR	Ministry of Energy, Mines and Resources (Indonesia)
MEPS	minimum energy performance standards
MLF	multilateral fund
MoMo	IEA Mobility Model
MY	manufacturing year
NEP	Indonesian National Energy Plan
NLD	Netherlands
NOR	Norway
NRCAN	Natural Resources Canada
NZL	New Zealand
OECD	Organisation for Economic Co-operation and Development
OICA	International Organization of Motor Vehicle Manufacturers
PACE	Property Assessed Clean Energy
PAMS	Policies and Measures Database
PAT	Perform, Achieve, Trade Programme
PLN	Perusahaan Listrik Negara (Indonesia)
PM	particulate matter
POL	Poland
PPP	purchasing power parity
PRT	Portugal
PUSDATIN	Centre for Data and Information Technology (Indonesia)
ROM	Romania
RTS	Reference Technology Scenario
SEP	Superior Energy Performance
SGCIE	Intensive Energy Consumption Management System
SHINE	Standards Harmonization Initiative for Energy Efficiency
SUV	sports utility vehicle
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
TCP-4E	Implementing Agreement for a Co-operative Programme on Efficient Electrical End-Use Equipment
TEPCO	Tokyo Electric Power Company
TFC	total final consumption
TOU	time of use
TPES	total primary energy supply
UJALA	Unnat Jyoti by Affordable LEDs for ALL
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America

USD	United States Dollars
WBCSD	World Business Council for Sustainable Development
Yr	year

Units of measure

°C	degree Celsius
b/d	barrel per day
bcm	billion cubic metres
bn	billion
EJ	exajoule
GW	gigawatt
GWh	gigawatt hour
$GtCO_2$-eq	gigatonne of carbon dioxide equivalent
K	kelvin
kW	kilowatt
kWh	kilowatt hour
mb/d	million barrels of oil per day
mcm	million cubic metres
$MtCO_2$-eq	million tonnes of carbon dioxide equivalent
Mtce	million tonnes of coal equivalent
Mtoe	million tonnes of oil equivalent
MW	megawatt
PJ	petajoule
tkm	tonne-kilometre
toe	tonne of oil equivalent
TWh	terawatt hour
W	watt

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Typeset in France, October 2017

Cover design: IEA. Photo credits: © Shutterstock

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

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Energy efficiency is central to all global energy transitions. It is the world's most available, secure and affordable energy resource and every government around the world has the power to further exploit efficiency for widespread benefit.

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