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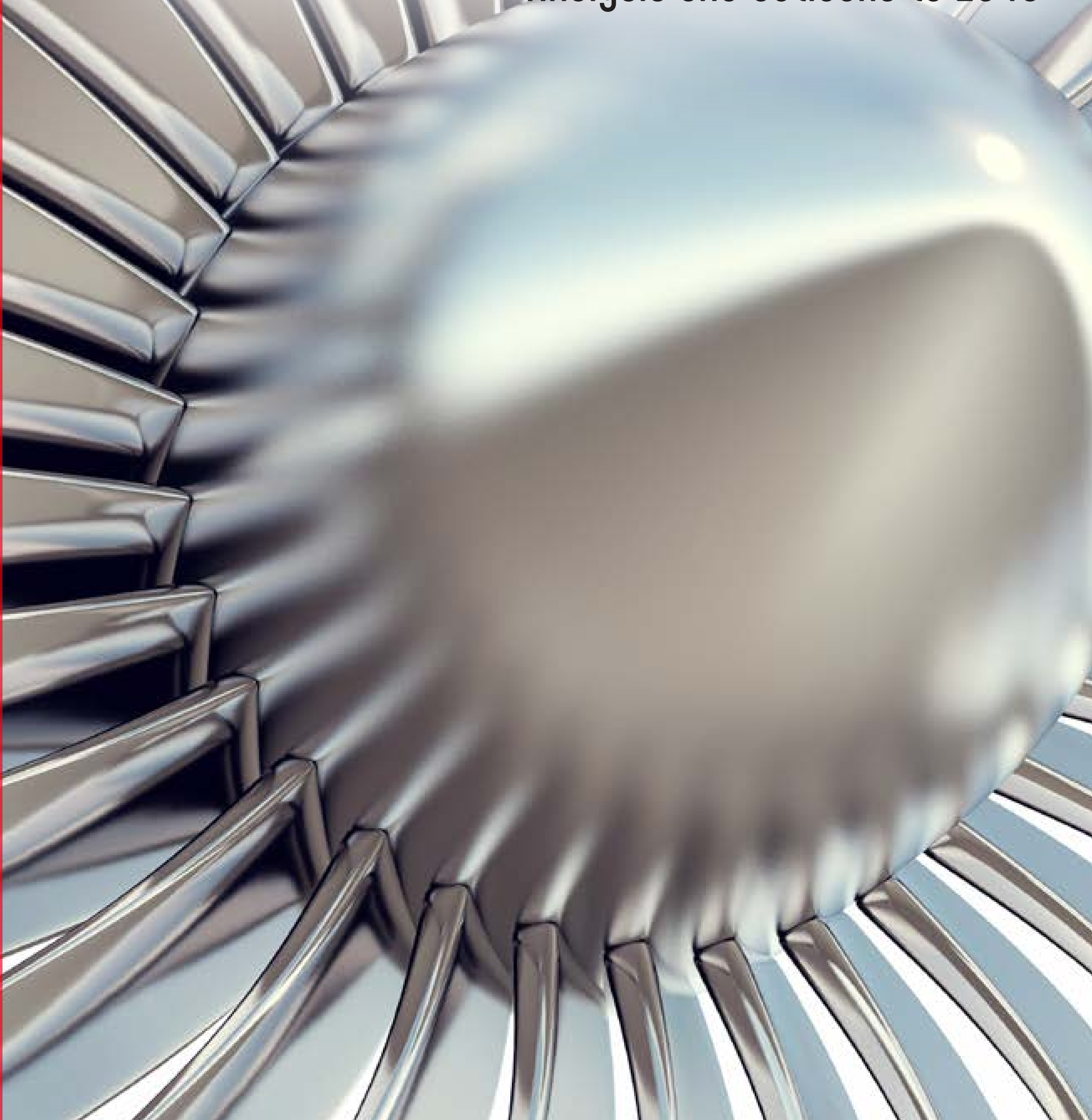
ENERGY EFFICIENCY 2018

Analysis and outlooks to 2040



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INTERNATIONAL ENERGY AGENCY

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FOREWORD

It is becoming increasingly clear that energy efficiency can bring many significant economic and environmental benefits. Yet it is also clear that huge energy efficiency potential remains untapped. While energy efficiency is improving, its impact on global energy use is being overwhelmed by increasing economic activity across all sectors. In 2017, global energy demand and emissions increased noticeably, breaking from recent trends. Energy efficiency is bringing benefits, but it could be doing much more.

Energy Efficiency 2018 is the annual global tracker of energy efficiency trends and indicators. This year's report is the most comprehensive analysis of current and future energy efficiency trends produced by the International Energy Agency (IEA). It incorporates a new Efficient World Scenario based on analysis from the IEA *World Energy Outlook*. This scenario answers the question of what would happen if countries realised all the available cost-effective energy efficiency potential between now and 2040.

The Efficient World Scenario shows that there is significant potential to broaden and deepen global efforts on energy efficiency, unlocking multiple benefits across all end-use sectors. The size of the global economy could double between now and 2040 with only a marginal increase in energy demand. I find it particularly encouraging that energy efficiency alone could cause greenhouse gas emissions to peak before 2020, a key target of the Paris Agreement on climate change. It is also notable that the Efficient World Scenario charts a path to full achievement of the target for energy efficiency included in the United Nations Sustainable Development Goals. This is particularly timely given the UN General Assembly's intention to conduct a high-level, mid-decade review of the UN Decade of Sustainable Energy for All. Substantial gains are also possible in the major emerging economies that will shape the future of the global energy system and are the focus of the IEA Energy Efficiency in Emerging Economies (E4) Programme.

Energy efficiency is at the heart of the modernisation agenda at the IEA. Our expanding work in bringing together policy makers and practitioners from across the globe is deepening our collective understanding of energy efficiency and best practice policy. I know from my discussions with governments around the world that awareness of the importance of energy efficiency is greater than ever. This is particularly true in major emerging economies. At the same, this report shows clearly that policies could be much stronger – and need to be stronger if we are to realise the substantial gains that are available. In recognising this, I reconfirm the IEA's commitment to improving global understanding of energy efficiency and the policies required to enhance it.

I hope this report will serve as a valuable resource and reference point for energy efficiency policy makers and practitioners. By providing analysis, policy guidance and facilitating exchange of best practice, the IEA aims to work closely with all actors to create a more energy efficient and prosperous future.

Dr. Fatih Birol

Executive Director

International Energy Agency

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EXECUTIVE SUMMARY

Growth in energy demand is accelerating despite progress on energy efficiency

Global energy demand grew by 2% in 2017 after two years of low growth. An increase in energy-using activities across many countries, regions and sectors outweighed ongoing progress on energy efficiency. Global energy intensity fell by 1.7% in 2017, the smallest annual improvement this decade.

However, demand would be much higher if not for progress on energy efficiency. Since 2000, improvements in energy efficiency in the world's major economies offset more than one-third of the increase in energy-using activities. Most of these savings were achieved in the industry and buildings sectors. Globally, efficiency gains since 2000 prevented 12% more energy use in 2017.

Energy efficiency alone can deliver substantial economic, environmental and social benefits

The potential for enhancing energy efficiency is clearly demonstrated by the Efficient World Scenario (EWS) developed by the IEA *World Energy Outlook*. This scenario shows what would result if all available energy efficiency measures were implemented between now and 2040. All these measures are cost-effective, based on energy saving alone, and use technologies that are readily available today.

The EWS could result in lower emissions in 2040 compared with today, despite a doubling in the size of global economy. While global gross domestic product (GDP) could double by 2040, the EWS shows the potential for efficiency alone to limit the increase in primary energy demand to levels only marginally higher than those today. This would result in a peak in energy-related greenhouse gas emissions before 2020, which would subsequently fall by 12% in 2040 compared with today. Energy efficiency could provide more than 40% of the abatement required by 2040 to be in line with the Paris Agreement, a task made all the more urgent considering the growth in emissions in 2017 and the rapid decarbonisation required to limit the impacts of climate change. Energy efficiency, combined with renewable energy and other measures, is therefore indispensable to achieving global climate targets.

The EWS would also help to achieve the UN Sustainable Development Goals (SDGs) and create multiple benefits for economies, households and the environment. The annual rate of global energy intensity improvement will exceed 3%, well above the 2030 energy efficiency target (SDG Target 7.3). Efficiency gains will also reduce coal, oil and gas imports, enhancing energy security. For example, the joint fossil fuel import bill of the People's Republic of China (hereafter "China") and India in 2040 could fall by nearly USD 500 billion (United States dollars). Families could benefit from over USD 550 billion in avoided energy spending in their cars and homes. The EWS would also cut key air pollutants such as sulphur dioxide, nitrogen oxides and particulate matter by one third compared with today. In particular, more efficient cooking could help reduce premature deaths from household air pollution by almost 1 million per year in 2040.

Enabling energy efficiency investment at scale is critical

All investment opportunities in the EWS are highly cost-effective and would bring significant economic benefits. The adoption of efficient technologies in the EWS requires average annual investment to double between now and 2025, and then to double again after 2025. This investment pays back on average by a factor of three, based on energy savings alone.

Global investment in energy efficiency is not on track to achieve the scale required in the EWS. Across all sectors, energy efficiency investment grew by just 3% to USD 236 billion in 2017. Spending grew in Europe, the largest investor, but fell slightly in China and the United States. Globally, investment growth slowed in all sectors. The buildings sector remains the largest recipient, accounting for nearly 60% of total efficiency investment, a similar share as in 2016.

New financing mechanisms are vital to delivering the investment opportunity in the EWS. Most energy efficiency investments continue to be self-financed, for example through homeowners' personal savings or companies' own balance sheets. These types of finance are unlikely to deliver the required investment growth on their own. To build confidence and capacity to encourage wider investment, policies are needed that support alternative finance mechanisms and business models such as energy service companies (ESCOs), green banks and green bonds. These mechanisms are growing, with the ESCO market increasing by 8% to nearly USD 29 billion in 2017 and green bonds issued primarily for energy efficiency tripling.

Policy efforts to boost energy efficiency are slowing

Current rates of progress in implementing energy efficiency policies will not be sufficient to realise the potential benefits presented by the EWS. Implementation of energy efficiency policy has slowed, putting the recent gains from energy efficiency at risk. The percentage of global energy use covered by mandatory energy efficiency policies and regulations increased from 32% in 2016 to 34% in 2017. Virtually all of this increase was due to replacement of vehicles, appliances and equipment with new stock subject to existing energy efficiency policies rather than the introduction of new policies.

Achieving the EWS would also require an increase in the strength of mandatory energy efficiency policies, which increased only marginally in 2017. Most of the overall growth in policy strength occurred in the transport sector, where standards for commercial and passenger vehicles were tightened in several countries and regions, including Canada, the European Union, India, Japan, Korea and the United States. Increases in policy strength in the buildings and industry sectors were minimal. Similarly, progress in implementing other types of efficiency policy, such as incentives and market-based instruments, was only marginal in 2017.

Efficiency gains in emerging economies are central to realising the Efficient World Scenario

Efficiency gains will reduce the impact of growing levels of activity on energy demand in emerging economies, where energy intensity can be halved. The IEA is working closely with the six major emerging economies of Brazil, China, India, Indonesia, Mexico and South Africa to build capacity and implement measures to enhance energy efficiency. Energy demand in these six countries has grown rapidly since 2000, to collectively become one-third of the global total. In the EWS, the economies of these countries could more than double for only a 24% increase in primary energy demand. Over 40% of the energy savings would be obtained in the industry sector, with the remainder split evenly between transport and buildings.

Efficiency policies have been important in delivering benefits in these emerging economies, but coverage varies. In 2017, nearly 46% of total final energy use in the six major emerging economies was covered by mandatory energy efficiency policies, although policy strength varies. However, without China, which has the highest coverage globally, average coverage in these economies is below 20%. Information and capacity building measures are becoming more widespread and other policies, including market-based instruments and incentives, are also present to differing degrees.

Government policy is key to unlocking the potential of the Efficient World Scenario

The EWS shows that energy efficiency could deliver significant economic, social and environmental benefits, but only if governments take greater policy action. The EWS implies reaching high levels of efficiency in many areas, but also acknowledges that ramp up and stock replacement takes time. However, the scale up in policy action must start immediately and there are good examples of policies in all end-use sectors that can form the basis for greater action. Regulatory measures will continue to be important but so will many other policies and supporting measures, including incentives for companies and individuals to reach greater levels of efficiency and initiatives that improve the availability of information on energy efficiency.

Current transport efficiency policy lays the foundation for the Efficient World Scenario

In transport, the EWS highlights the opportunity to accelerate the historic rate of efficiency improvement so that total energy demand remains flat, despite doubling activity levels. Transport is the sector with the largest global energy savings potential, whereas it has made the least efficiency progress since 2000 compared with buildings and industry. The key actions to realise this potential are improving vehicle fuel efficiency and increasing the adoption of electric vehicles (EVs). Fuel efficiency standards are the central policy that has enabled transport efficiency gains to date. Without them, road transport would be using an additional 1.2 million barrels of oil per day (mb/d). However, another 2.2 mb/d would be saved if all standards were as good as the best in class.

The EWS shows that efficiency levels for passenger cars could be much higher. Recent policy progress has resulted in four out of five cars sold today being covered by efficiency standards. However, there is potential for policies to expand and strengthen to make the average 2040 car as efficient as today's best hybrids. The EWS also implies that EVs could represent over 40% of the global passenger car fleet by 2040, meaning that policies to encourage adoption will be vital.

Trucks could provide over 40% of potential energy savings in the EWS for road transport, but achieving this will require a significant step up from current trends. Trucks account for around 40% of total road transport fuel consumption, with this share growing due to rising activity and a slower rate of efficiency improvement. This is linked to the fact that few countries have policies in place for truck fuel efficiency. Current and planned policies lay the foundation for future gains, but there is scope for both policy coverage and stringency to rise.

The EWS also demonstrates the importance of non-road transport (aviation, rail and shipping), with new policies creating opportunities for future efficiency gains. In shipping, meeting international emissions targets will require increased efficiency levels. In aviation, emissions trading schemes and targets have been established to support continued efficiency gains. Innovations in aviation management and technology, as well as improved flight routing, are also contributing to ongoing efficiency gains.

Buildings are becoming more efficient, but policy needs to be comprehensive

In the buildings sector, the EWS highlights the opportunity to improve efficiency per unit of floor area by nearly 40% compared with current levels. Using existing technologies, global building stock in 2040 could be 60% larger than today (in floor area) for no increase in overall energy demand. These gains will only be achieved with policy action that applies to all buildings, new and existing.

Building codes and appliance standards have been key policy measures, preventing 10% more energy use by buildings in 2017. However, policy coverage is variable. Two out of three countries lack mandatory building energy codes and 60% of the energy use for appliances is not covered by standards. To fund more efficient new buildings and upgrade existing stock, it will be vital to unlock new sources of finance, building on recent innovations.

Industry requires a greater focus on less energy-intensive sectors

In the industry sector, the amount of value-added produced for each unit of energy could nearly double by 2040. Important technologies contributing to these gains in energy efficiency are motor-driven systems and electric heat pumps for low-temperature process heat. Standards for electric motors have already contributed to efficiency gains, but if all countries had implemented and strengthened standards for electric motors at the same time as the fastest movers, today's global industrial electricity use could have been 16% lower.

The bulk of the potential energy savings in industry are in less energy-intensive manufacturing sectors, which could reduce their energy intensity by more than 40% by 2040. To achieve this reduction, policies will be required to engage a large number of energy users across a range of sectors, along with appropriate regulatory support. Policies that encourage the adoption of energy management systems and other incentive- and information-based measures will be essential, along with innovative financing mechanisms and business models, such as ESCOs.

The IEA Efficient World Strategy

The IEA Efficient World Strategy identifies the policies and actions required to deliver available energy efficiency gains, but how policies are designed and implemented is crucial. Policy needs to be tailored, dynamic and supported. Governments can maximise the effectiveness of energy efficiency policy by enacting ambitious measures, with appropriate follow-up and enforcement. Governments also have a role in ensuring market readiness to deliver efficiency improvements, and in evolving measures, using monitoring and evaluation, to increase ambition as technology develops and costs fall.

The key components of the IEA's Efficient World Strategy are summarised as follows:

Sector	Opportunity in the EWS	Government policy actions
Transport	• Energy demand could stay flat, despite doubling activity levels. • Passenger cars and trucks offer two-thirds of potential savings.	• Improve coverage and strength of transport policies for cars and trucks and non-road modes. • Provide incentives to support uptake and sustainable use of efficient vehicles.
Buildings	• Building space could increase by 60% for no additional energy use. • Space heating, cooling and water heating offer 60% of potential savings.	• Put in place comprehensive efficiency policies, targeting both new and existing building stock and appliances. • Incentives to encourage consumers to adopt high efficiency appliances and undertake deep energy retrofits.
Industry	• Value-added per unit of energy could double. • Less energy-intensive industry offers 70% of potential savings.	• Expanded and strengthened standards for key industrial equipment, including electric heat pumps and motors. • Incentives to encourage the adoption of energy management systems.
Investment	• Investment must immediately double, and double again after 2025. • Transport sector presents largest investment opportunity.	• Build scale and momentum in financing using programmes and incentives to increase activity. • Market-based instruments to encourage investment and business model innovation.

1. GLOBAL TRENDS AND OUTLOOK

Highlights

- **Global energy demand rose by 1.9% in 2017 – the fastest annual increase since 2010.** The forces driving energy demand, led by strong economic growth, outpaced progress on energy efficiency. As a result energy intensity – primary energy use per unit of gross domestic product (GDP) – fell by just 1.7% in 2017, the slowest rate of improvement since 2010.
- **Without energy efficiency progress, increased economic activity would have had a greater impact on the global energy system.** Efficiency improvements made since 2000 prevented 12% additional energy use in 2017. Efficiency gains also prevented 12% more greenhouse gas emissions and 20% more fossil fuel imports, including over USD 30 billion (United States dollars) in avoided oil imports in IEA countries.
- **Implementation of energy efficiency policy has slowed, putting at risk the recent gains from energy efficiency.** The International Energy Agency (IEA) tracks three types of energy efficiency policy: mandatory codes and standards; market-based instruments; and incentives. In 2017, 34% of global energy use was covered by mandatory energy efficiency policies, but progress implementing new policies was slow for a second year running. Utility obligation programmes remained largely unchanged in 2017. Spending on energy efficiency incentives in 16 major economies was estimated to be around USD 27 billion.
- **There is still huge potential for energy efficiency gains, as set out in the IEA Efficient World Scenario.** Since 2000, primary energy demand has grown by 39% and the global economy has grown by nearly 85%. In the Efficient World Scenario, which assumes the adoption of all cost-effective energy efficiency opportunities between now and 2040, the global economy doubles but there would be only a marginal increase in primary energy demand. On average, investments in the Efficient World Scenario pay back by a factor of three over the life of the measures.
- **The Efficient World Scenario can deliver a peak in energy-related greenhouse gas emissions before 2020**. Emissions would subsequently fall to levels 12% lower than today, providing over 40% of the abatement required to be in line with objectives in the Paris Agreement. Energy efficiency, combined with renewable energy and other measures, is therefore indispensable to achieving global climate targets. The Efficient World Scenario would also see reductions in air pollution, lower household spending on energy, enhanced energy security and many other benefits.
- **The IEA's Efficient World Strategy identifies the policies and actions required to deliver the available energy efficiency gains.** In transport, energy demand could stay flat despite doubling activity levels, with key measures that strengthen fuel efficiency and incentivise electrification. Total buildings energy use could also stay flat, despite 60% more building space, with the help of stronger and broader building codes and appliance standards. Industry could produce nearly twice as much value for each unit of energy use. Gains in light industry represent 70% of the energy savings, boosted by measures such as standards for industrial equipment and incentives to increase adoption of energy management systems.

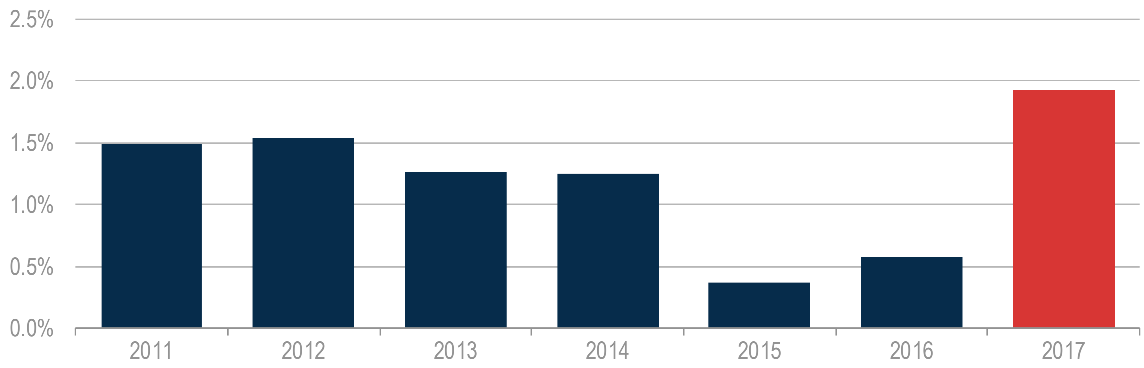
Trends in energy demand and intensity

Demand rose in 2017 as intensity gains slowed

Global primary energy demand[1] rose by 1.9% in 2017, the largest annual increase since 2010 and well above those in 2015 and 2016 (Figure 1.1). Most of the increase came from emerging economies, where demand increased by 2.7%, or 9.2 exajoules (EJ) compared with 0.7% (1.5 EJ) in advanced economies. Growth in emerging economies' energy demand was significant as it followed two years in which growth was less than 1%. This rise was due in large part to a 2.6% increase in energy demand in the People's Republic of China (hereafter "China") compared with a 1.1% fall in 2016 (Figure 1.2). Chinese primary energy demand rose as energy-intensive production in sectors such as steel manufacturing ramped up following two years of slow growth, increasing demand for fuels such as electricity and coal (IEA, 2018a).

In India, primary demand increased 4.1%, above the five-year average annual rate of 3.2% since 2012 but less than the ten-year average rate of 4.7% since 2007. Indian demand for oil continued to be strong because of air and road transport use (IEA, 2018a), while coal use grew by 3.8%, mainly for power generation (IEA, 2018b). The 0.7% growth in advanced economies' energy demand in 2017 represented the largest increase since 2010. In the European Union, a 1.5% increase in demand continued an upwards trend observed since 2015, corresponding to stronger economic growth over this period. In the United States, demand fell by 0.6%, continuing a downwards trend since 2015 due mainly to changes in the energy fuel mix, with gas replacing coal for higher efficiency power generation and industrial applications. US coal use decreased for the fourth consecutive year (IEA, 2018a).

Figure 1.1 Change in global primary energy demand



Sources: Adapted from IEA (forthcoming), *World Energy Outlook 2018*; IEA (2018c) *World Energy Balances 2018* (database).

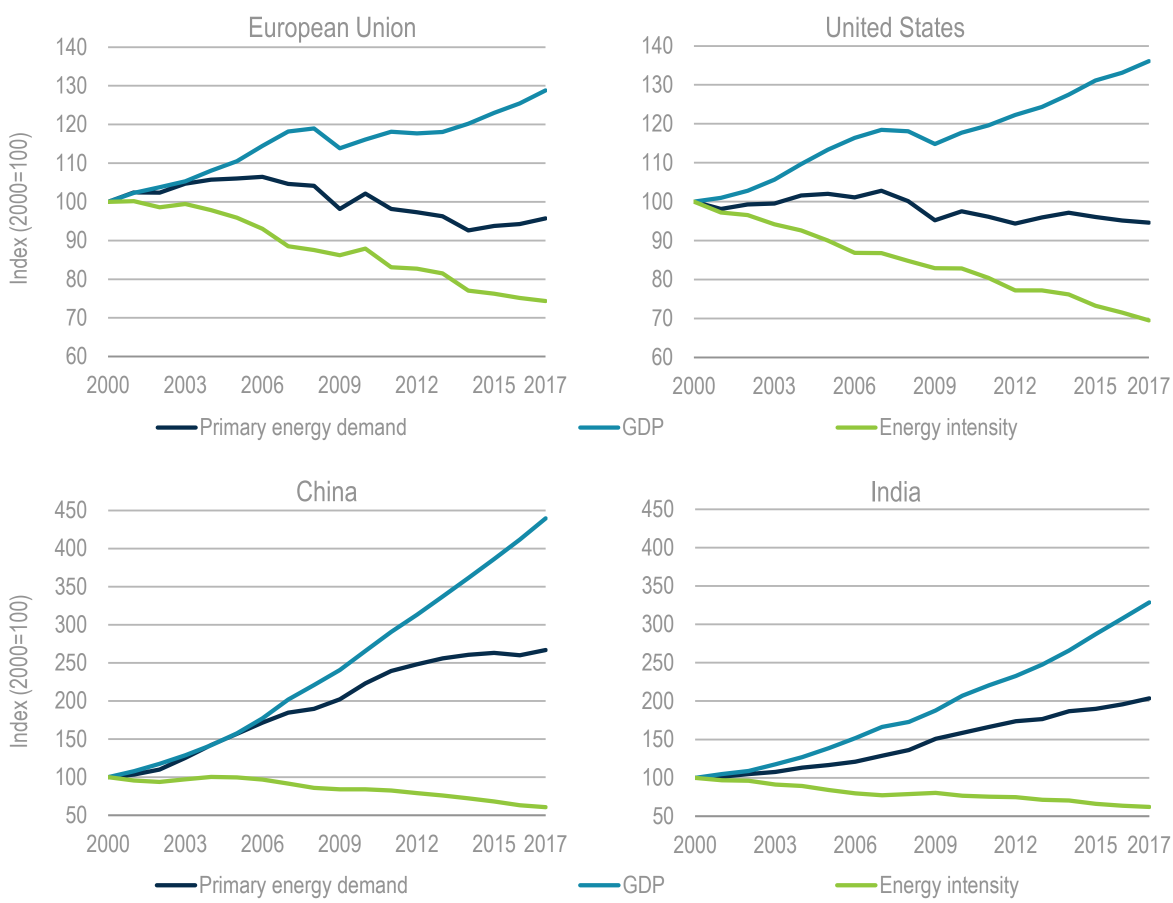
[1] Also referred to as total primary energy supply (TPES). All primary energy demand (TPES) and final energy use (TFC) data for 2017 are preliminary.

Box 1.1 What is energy intensity and how does it relate to energy efficiency?

Energy intensity is a measure of the amount of energy used to produce a unit of output. The energy intensity indicator used in this report is primary energy demand per unit of global GDP, i.e. the amount of energy the global economy uses (before it is converted into end-use fuels such as electricity and gasoline) to produce one unit of economic output.

Changes in global primary energy intensity are not solely an indication of energy efficiency improvements. They are also influenced by factors such as the movement of economic activity away from energy-intensive heavy industries towards less energy-intensive service sectors. Decomposition analysis, as detailed later in this chapter, is used to determine changes in energy efficiency more accurately.

Figure 1.2 Primary energy demand, GDP and energy intensity in selected economies, 2000-17



Note: For the European Union and the United States, the left axis ranges from 60 to 140; For China and India, the left axis ranges from 50 to 450. Primary energy intensity is calculated as primary energy demand per USD 1 000 of GDP in 2017 prices at purchasing power parity.

Sources: Adapted from IEA (forthcoming), *World Energy Outlook 2018*; IEA (2018c) *World Energy Balances 2018* (database).

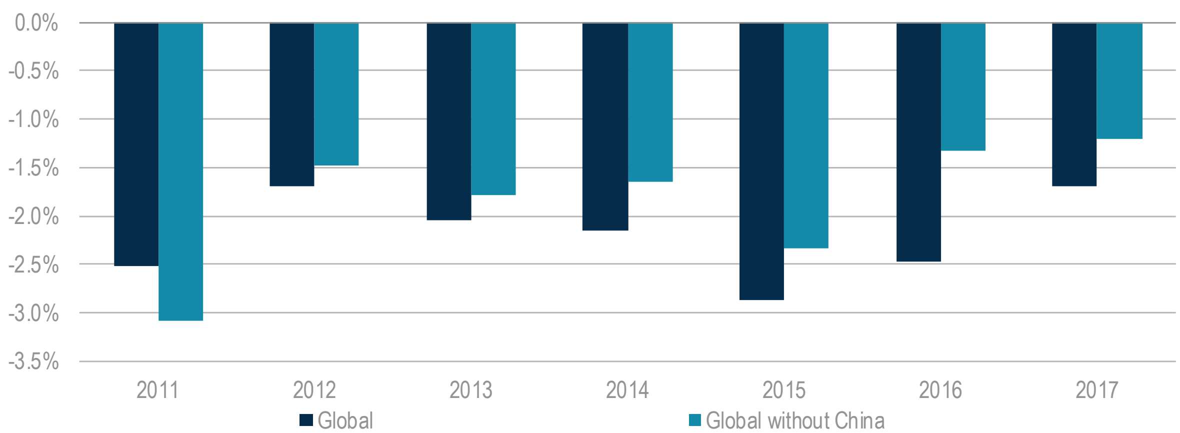
Several factors contributed to the rebound in global energy demand in 2017. Global economic growth rose from 3.1% in 2016 to 3.7% in 2017. Economic growth increased in all major economies in

2017. The Chinese economy grew by 6.8% in 2017, slightly up on 2016. Unlike in 2015 and 2016, the Chinese iron and steel sector had a greater impact on economic growth. In 2017, Chinese steel production rose by 3% after a decline in 2015 and almost no increase in 2016. The energy-intensive nature of steel production in China meant that increased production will have contributed to the observed growth in primary energy demand.

Economic growth in the United States was 2.3% in 2017, up from 1.5%, and the European Union's economy grew by 2.6% in 2017, up from 2%. In Japan, economic growth of 1.7% corresponded to a 0.4% rise in energy demand (the first increase in energy use since 2013), while Brazil's economy expanded by 1% following two years of contraction, which increased energy demand by 1.4% after two years of declining demand.

The combination of increased economic and energy demand growth resulted in global primary energy intensity falling by only 1.7% in 2017, the slowest rate of decline since 2010 (Figure 1.3). This slowdown would have even bigger had it not been for a faster decline in China, which was responsible for around one-third of the global fall in intensity. Chinese energy intensity fell by 3.9% compared with around 1.2% in the rest of the world. While annual improvements in global energy intensity since 2011 have averaged 2.2%, almost double the rate of improvement between 2001 and 2010, this report shows that global energy intensity could improve by closer to 3% per year. The 2017 rate of 1.7% suggests the world is still falling short in achieving its energy efficiency potential.

Figure 1.3 Changes in global primary energy intensity



Note: Primary energy intensity is calculated as primary energy demand per USD 1 000 of GDP in 2017 prices at purchasing power parity.

Sources: Adapted from IEA (forthcoming), *World Energy Outlook 2018*; IEA (2018c) *World Energy Balances 2018* (database).

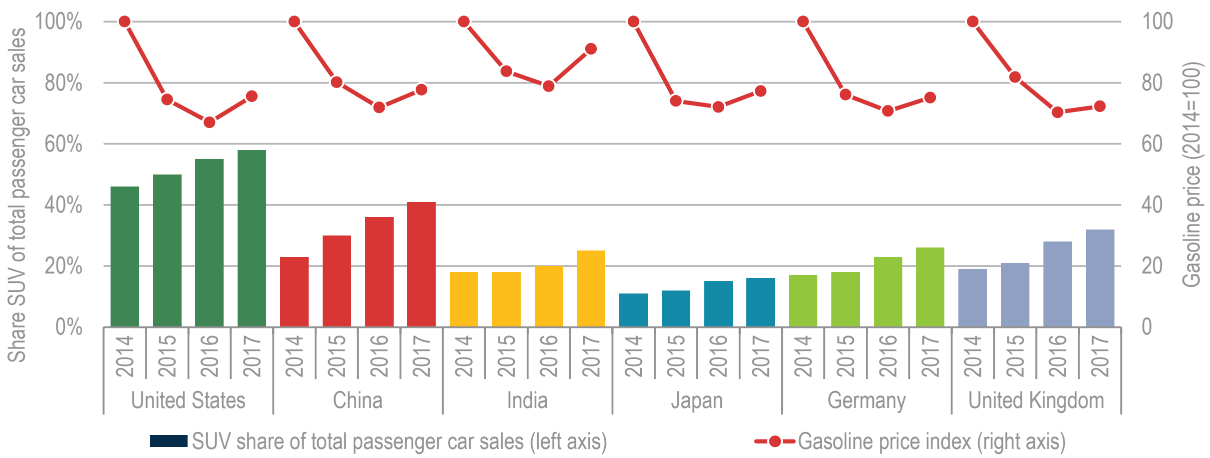
Gains in energy efficiency were not sufficient to curb demand growth

Oil use increased, despite a small rebound in oil prices

Oil demand increased from 96.2 to 97.8 million barrels of oil per day (mb/d) in 2017, despite a rebound in end-user oil prices in most major markets (IEA, 2018d). Most of the increase in demand came from the road transport sector, which accounts for about 50% of global final oil consumption and 22% of final energy consumption (IEA, 2018c). Aviation also contributed significantly to the overall growth in oil demand in 2017. Passenger kilometres flown increased by 7.6% to 7.7 trillion revenue passenger kilometres (RPK), with the number of passengers reaching a record 4.1 billion (ICAO, 2018).

The continuing rise in transport oil demand was driven by economic growth, particularly in emerging economies, which boosted demand for mobility. Compounding this was an increase in the sales of larger vehicles. The share of sport utility vehicles (SUVs) in passenger vehicle sales has been rising steadily in all major markets in recent years (Figure 1.4); globally, the share rose from 30% in 2014 to 41% in 2017.[2]

Figure 1.4 The share of SUVs in total new passenger vehicle sales, 2014-17



Sources: IEA analysis based on IHS Markit (2018), *Polk* (database); IEA (2018e), *Energy Prices and Taxes* (database).

Oil price increases in the second half of 2017 are not expected to have dampened demand significantly because income growth is continuing to support strong demand for mobility, particularly in emerging markets. In addition, demand for diesel and other oil products used by industry is likely to have remained strong through to the end of 2017, in line with economic growth (IEA, 2018f).

Although motorists may change their driving habits if recent oil price rises continue, purchases of larger and thirstier vehicles over the last few years will continue to influence oil demand for many years, given that the average life expectancy of a new car is now around 15 years.

Weather influenced energy demand in certain countries

In certain regions, unusually drier, hotter or colder weather boosted demand for energy in 2017. Drought in Europe – particularly Southern Europe – sharply reduced the availability of hydropower, which was replaced by sources of energy such as coal and natural gas, the supply of which involves more own-use of energy (IEA, 2018f). In addition, electricity demand for air conditioning rose because of hotter weather than usual. Europe experienced a 16% increase in cooling degree days – a measure of the need for air conditioning (Eurostat, 2018).

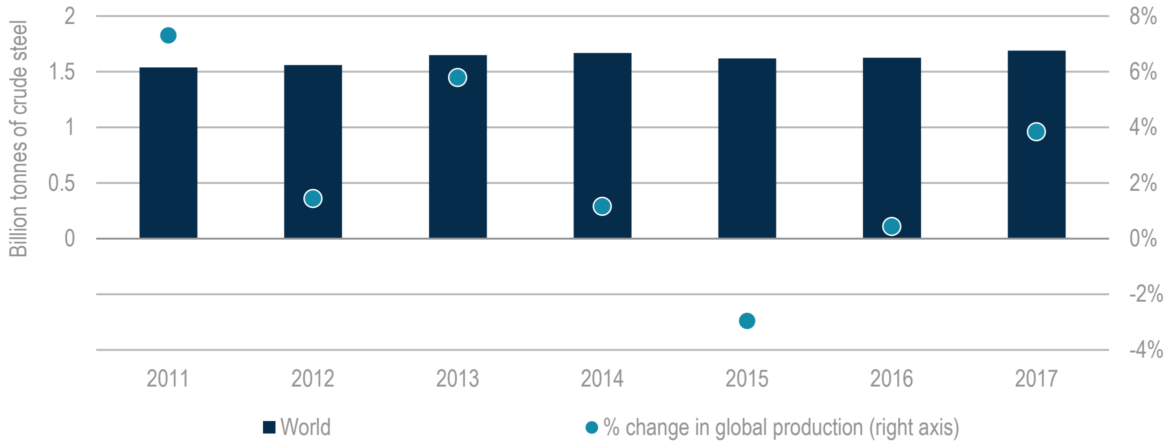
[2] IEA analysis based on IHS Markit (2018).

Warmer weather also boosted energy use in China – the world's second-largest consumer of energy for air conditioning. In the summer of 2017, the number of cooling degree days was around 4% higher than in 2016, contributing to an estimated 10% increase in space cooling energy demand.[3] Later in the year, a particularly cold start to the winter heating season led to a surge in demand for gas in the residential sector, forcing the authorities to re-authorise temporarily the use of coal-fired heating to stave off gas shortages (IEA, 2018f).

Increased industrial production in energy-intensive sectors also boosted energy demand

Preliminary data for 2017 suggest that output increased in some of the most energy-intensive sectors of the economy, tempering the downward trend in energy intensity. In particular, global crude steel production, which is responsible for over 5% of global energy use, increased by 4%. In 2016 steel production growth was almost flat and it fell in 2015 (Figure 1.5).

Figure 1.5 World steel production



Source: World Steel Association (2018), *Global Interactive Map*.

Improved energy efficiency prevented an even bigger increase in energy demand

Three main factors affect yearly changes in final energy use:[4]

- Activity effects: whether factors that drive energy-using activities, such as industry value-added, tonne or passenger kilometres travelled and population, increased or decreased, many of which are linked to changes in economic output.
- Structural effects: whether there were changes in the type of energy-using activities, such as the share of activity across various economic sectors, appliance ownership, number of buildings and floor area, and the share of different transport modes.
- Efficiency effects: whether the energy used per unit of activity increased or decreased.

[3] Based on NCAR (2004), Community Climate System Model, Version 3.0, www.cesm.ucar.edu/models/ccsm3.0/; NCAR (2012), GIS Program Climate Change Scenarios, Version 2.0, www.gisclimatechange.org; NOAA (2018), Global Summary of the Day (GSOD) 1990-2017, https://data.noaa.gov/dataset/dataset/global-surface-summary-of-the-day-gsod; CIESIN (2017), Gridded Population of the World, Version 4 (GPWv4): Population Count Adjusted to Match 2015 Revision of UN WPP Country Totals, Revision 10, https://doi.org/10.7927/H4JQ0XZW.

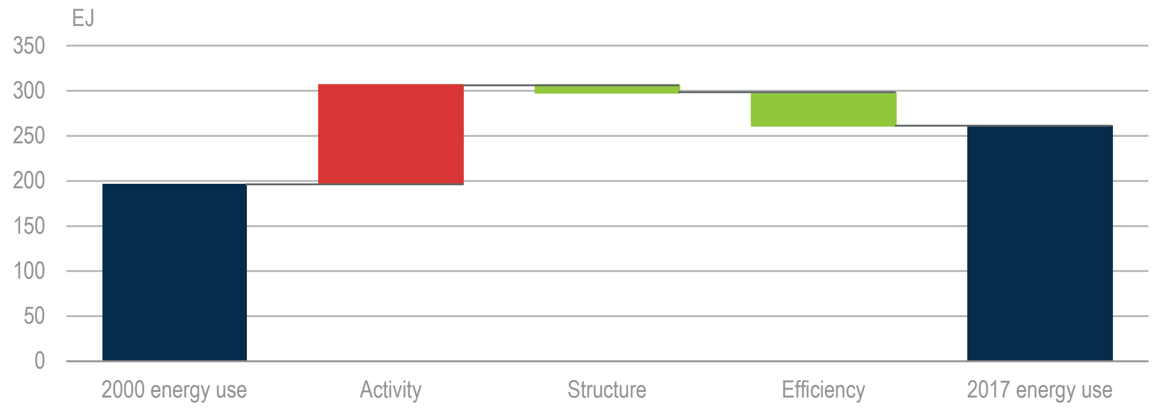
[4] Also referred to as total final consumption (TFC).

Since 2000, energy efficiency has increased by 15% in IEA countries and other major economies[5] and by just over 1% in 2017. There was a net increase in energy use, however, because activity increased by 5%. Structural changes also boosted total final energy consumption by 0.3%, the first time this has been observed since 2011.

Decomposition analysis examines the factors influencing energy use, including energy efficiency. The analysis here draws on the *IEA Energy Efficiency Indicators Database*[6] and additional data from the *IEA World Energy Balances*, IEA models and other public sources. Continued efforts to improve data quality and availability are essential to improve decomposition analysis and evidence-based policy development more broadly.

Decomposition analysis shows that energy efficiency offset one-third of the impact of increased activity on final energy use in IEA countries and other major economies in 2017 (Figure 1.6).[7] If no efficiency improvements had occurred, energy use would have increased by 65% instead of one-third.

Figure 1.6 Decomposition of final energy use in IEA countries and other major economies



Note: Countries covered are IEA countries plus China, India, Brazil, Indonesia, Russian Federation, South Africa and Argentina. "Energy use" covers the residential, industry and services, passenger and freight transport sectors. It excludes non-energy use (i.e. feedstocks), energy supply and US freight transport (see Chapter 2).

Sources: Adapted from IEA (2018g), *Energy Efficiency Indicators 2018* (database); IEA (2018c) *World Energy Balances 2018* (database); IEA (2018h), *Energy Technology Perspectives* (Buildings model); IEA (2018i), *Mobility Model* (database); Timmer et al. (2015), *World Input Output Database* (database); IBGE (2018), *Quarterly National Accounts* (database); National Bureau of Statistics of China (2018), *National Accounts* (database); Reserve Bank of India (2018), *The India KLEMS Database* (database); Statistics Indonesia (2018), *Gross Domestic Product* (database); INEGI (2018), *GDP - Activity of Goods and Services* (database); StatsSA (2018), *Gross Domestic Product (GDP), 4th Quarter 2017* (database); Quantec (2018), *Industry Service – RSA Standard Industry – Input Structure at basic prices* (database); INDEC, Republica Argentina (2018), *Macroeconomic aggregates (GDP)* (database); World KLEMS Data (2018), *Russia* (database).

The importance of energy efficiency improvements to reducing the impact of rising economic activity on final energy use has been steady since 2000. Between 2000 and 2017, efficiency gains saved an

[5] The analysis is limited to IEA countries plus Argentina, Brazil, China, India, Indonesia, the Russian Federation and South Africa, because complete energy data for all countries is not available for 2017.

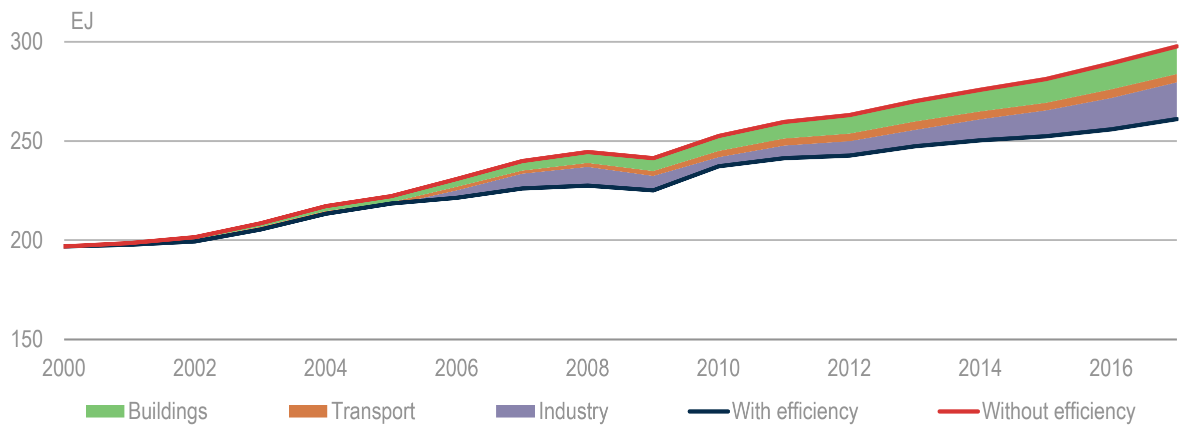
[6] Further information can be found at www.iea.org/statistics/efficiency/ and the Energy Efficiency Indicators report series, available from https://webstore.iea.org/statistics-data.

[7] For information about the methodology used in the decomposition analysis, please refer to www.iea.org/efficiency2018/data.

additional 37 EJ of final energy use in IEA countries and other major economies – equivalent to the final energy use of Japan and India combined. Efficiency gains in the industry sector contributed the most energy savings (19 EJ), followed by buildings (14 EJ) and transport (4 EJ) (Figure 1.7). Globally, it is estimated that energy efficiency improvements since 2000 prevented 12% more energy use in 2017.[8]

Structural changes in the industrial and service sectors also continue to drive down the overall energy intensity of the global economy, as the relative contribution of less energy-intensive services and light manufacturing rises. However, almost all of this impact continues to be offset by structural changes on the consumption side of the economy, including the adoption by households of larger vehicles and an increase in the average size of dwellings (see Chapters 2 and 3). In total these structural effects have offset just under 10% of the activity effect on energy consumption.

Figure 1.7 Energy use in IEA countries and other major economies with and without energy savings from efficiency improvements, by sector, 2000-17



Notes: Left axis starts at 150 EJ. Countries covered are IEA countries plus China, India, Brazil, Indonesia, Russian Federation, South Africa and Argentina. "Energy use" excludes non-energy use (i.e. feedstocks), energy supply and US freight transport (see Chapter 2).

Sources: Adapted from IEA (2018g), *Energy Efficiency Indicators 2018* (database); IEA (2018c) *World Energy Balances 2018* (database); IEA (2018h), *Energy Technology Perspectives* (Buildings model); IEA (2018i), *Mobility Model* (database); Timmer et al. (2015), World Input Output Database (database); IBGE (2018), *Quarterly National Accounts* (database); National Bureau of Statistics of China (2018), *National Accounts* (database); Reserve Bank of India (2018), *The India KLEMS Database* (database); Statistics Indonesia (2018), *Gross Domestic Product* (database); INEGI (2018), *GDP - Activity of Goods and Services* (database); StatsSA (2018), *Gross Domestic Product (GDP), 4th Quarter 2017* (database); Quantec (2018), *Industry Service – RSA Standard Industry – Input Structure at basic prices* (database); INDEC, Republica Argentina (2018), *Macroeconomic aggregates (GDP)* (database); World KLEMS Data (2018), *Russia* (database).

Outlook for energy efficiency and demand

The direction of global energy demand will hinge critically on how quickly technologies more efficient than those available today are developed, commercialised and used. The world could make vast improvements to efficiency now, however, by adopting technologies already widely available. Government policies can play a vital role in increasing the uptake of currently available technologies,

[8] Global energy savings are a combination of improvements in the IEA countries and other major economies analysed, plus the rest of the world, which represents 25% 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 the other major economies, to gains in intensity observed in these other countries.

as well as in accelerating the development of future technologies. More rigorous policies could exploit more of the enormous potential that already exists for using energy less wastefully, bringing sizeable energy savings, reductions in greenhouse gas (GHG) and local air pollution, and other benefits.

The IEA analyses the outlook for global energy markets in its annual *World Energy Outlook (WEO)*. The report adopts a scenario approach. The central scenario, known as the New Policies Scenario, takes into account existing energy policies and announced policy intentions, including nationally determined commitments (NDCs) under the Paris Agreement on climate change, where they are judged to be credible (IEA, 2017a). The Current Policies Scenario takes into account only policies that have already been adopted. It can therefore be considered a baseline or business-as-usual scenario.

In 2012, *WEO* presented for the first time the results of the Efficient World Scenario (IEA, 2012). This scenario quantifies the likely effects of putting in place policies to realise the potential of all known energy efficiency measures that are already economically viable. For this report, the IEA has updated the scenario with projections to 2040 in order to assess the scope for and implications of maximising energy efficiency (Box 1.2).

Box 1.2 Methodology and assumptions in the Efficient World Scenario

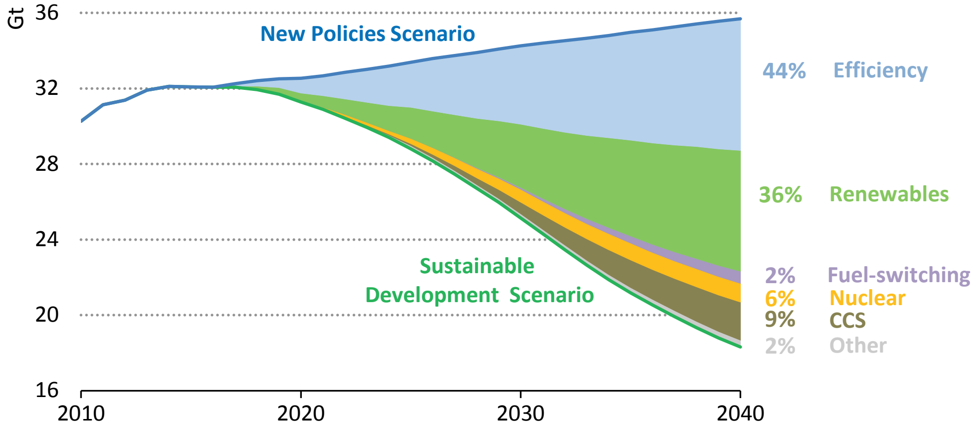
The IEA produces projections of energy markets for the *WEO* using its World Energy Model (WEM), a partial equilibrium model covering all fuels and regions that replicates how global energy markets function over the medium to long term. The Efficient World Scenario in *Energy Efficiency 2018* is based on the core assumption that policies are put in place to allow the market to realise the potential of all known energy efficiency measures that are economically viable. The sectors included in this analysis are: industry, transport and buildings (both residential and non-residential). The electricity generation industry and supply side measures – such as renewables and carbon capture storage – are not considered.

The efficiency measures included in the Efficient World Scenario for this update are based on all the energy efficiency measures that are in the Sustainable Development Scenario of *WEO 2017,* with the exception of electricity generation changes. In practice, it is unlikely that every measure that could maximise energy efficiency would be taken. The Efficient World Scenario may still be conservative, however, because it does not include the potential for technological advances between now and 2040 that could reduce the cost of enhancing energy efficiency or result in new ways to improve efficiency.

In determining which energy efficiency measures are economically viable, payback periods have been chosen in line with the literature and in consultation with experts. In some cases, these periods are longer than those required today by some lending institutions, households or companies, but they are always shorter than the technical lifetime of the individual assets. Furthermore, the benefits of increased efficiency only include the value of the energy savings to the bill payer, and do not assume any change in the value of carbon taxes. The value of other benefits, such as improved air quality and the social cost of carbon, are not included in the economic choice. Including these other benefits would increase the cost-effectiveness of the efficiency options chosen.

Realising the Efficient World Scenario would have benefits beyond energy savings, from reducing household and industry energy bills to improving air quality. The scenario demonstrates that while efficiency can make large cuts in GHG emissions, it would not be sufficient on its own to stabilise emissions at a level consistent with limiting the average global temperature rise to 2˚C or below, as envisaged by the Paris Agreement. Instead, energy efficiency's contribution to limiting climate change will be strongest as part of a package of measures, including increasing the supply of renewable energy. *WEO 2017* has shown that when combined with other measures, efficiency will realise over 40% of the carbon emissions reductions required to meet global climate change mitigation goals, the largest single contribution (Figure 1.8) (IEA, 2017a).

Figure 1.8 Global carbon dioxide (CO_2) emissions reductions in the WEO 2017 New Policies and Sustainable Development Scenarios



Improving energy efficiency, as in the EWS, will reduce energy consumption, which in turn may improve air quality and lower adverse health impacts. To obtain an insight into the impact of energy use on air pollutants, the outputs of the WEM model have been coupled with the Greenhouse Gas – Air Pollution Interactions and Synergies (GAINS) model developed by the International Institute of Applied Systems Analysis (IIASA).

Realising the existing efficiency potential would deliver huge cuts in energy demand

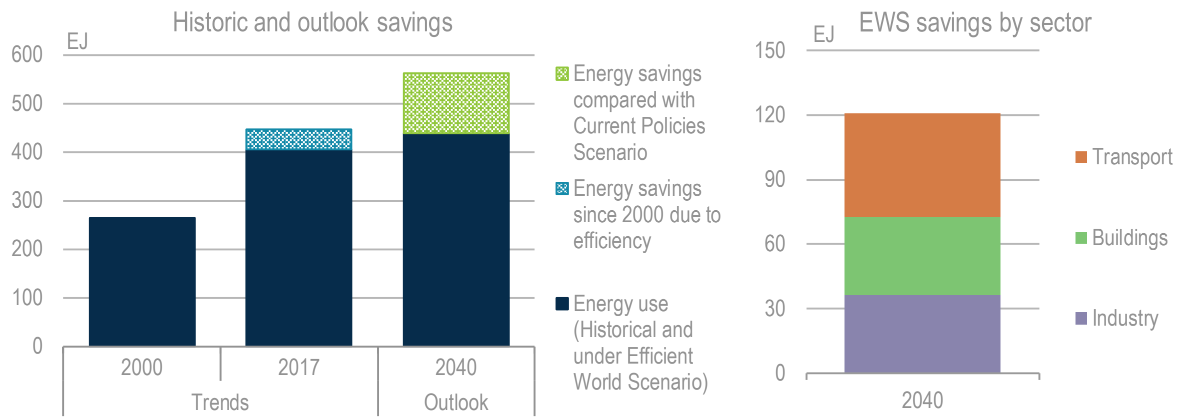
In the New Policies Scenario (NPS), primary energy demand rises to 736 EJ in 2040 – around 72 EJ (9%) less than in the Current Policies Scenario – while final energy consumption is around 40 EJ lower.[9] In the Efficient World Scenario (EWS), the energy savings are much bigger: primary demand grows half as much as in the NPS, to just 625 EJ in 2040 – only 7% higher than 2017 levels, 15% less than in the NPS and 23% less than in the Current Policies Scenario. The bulk of these energy savings are in the form of oil, coal and gas, leading to large reductions in GHG emissions and air pollution (see next section).

The additional energy savings in final energy consumption in the EWS, above those in the NPS, are, unsurprisingly, of a similar proportion, reaching 16% in 2040 (22% compared with the Current Policies Scenario) (Figure 1.9). Most of the savings are achieved in the transport sector, where energy use falls 22% compared with the NPS (30% compared with the Current Policies Scenario) thanks to a large reduction in oil consumption spurred by a combination of more efficient internal combustion engines and increased penetration of electric vehicles (EVs).[10]

[9] The results for the Current and New Policies Scenarios are from *WEO 2017*.

[10] Updated EV cost assumptions are a major reason for the large increase in potential transport sector energy savings depicted in this version of the Efficient World Scenario compared with the 2012 exercise.

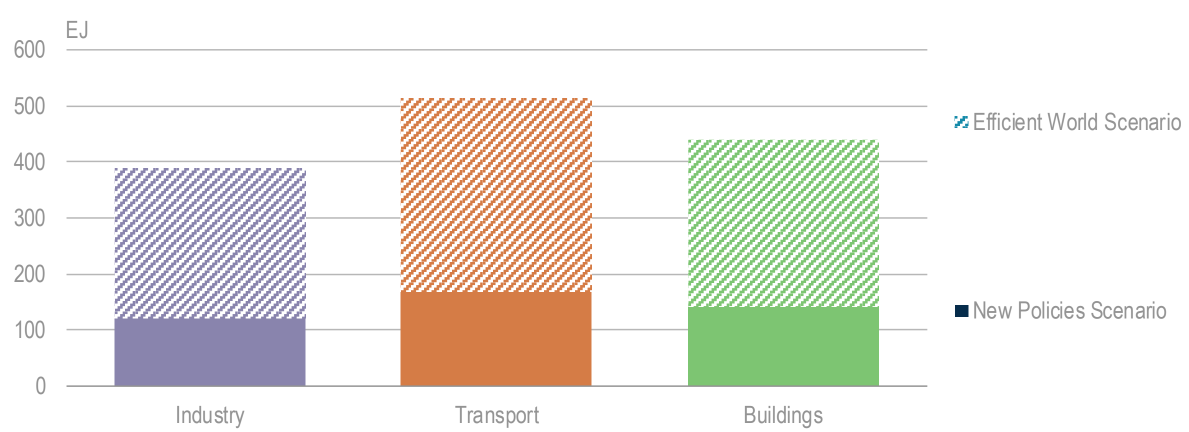
Figure 1.9 Global energy use and savings by scenario



Note: One-third of the energy savings in 2040 are the result of current and planned policy settings (New Policies Scenario) and two-thirds from measures contained in the Efficient World Scenario. "Energy use" includes non-energy use (i.e. feedstocks), excludes energy supply.

Industry remains the largest energy-consuming sector in 2040 in the EWS, which foresees industry value-added nearly doubling between 2017 and 2040. Even so, industry's energy use is expected to fall by 15% compared with the New Policies Scenario. Industrial gas and coal consumption fall the most, due to increased use of electric arc furnaces for metals recycling. Electricity use also falls sharply, with the introduction of highly efficient electric heat pumps for process heating applications. Efficiency measures in residential and non-residential buildings yield energy savings of a similar magnitude to those in industry.

Figure 1.10 Global cumulative energy savings in the New Policies and Efficient World Scenarios compared with the Current Policies Scenario

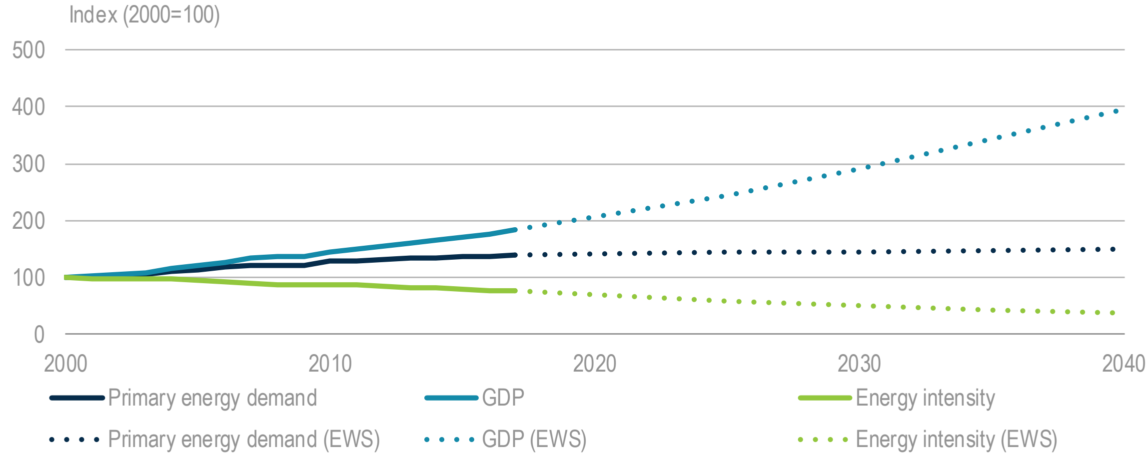


The cumulative energy savings by 2040 in the EWS are significant. Compared with the Current Policies Scenario, total savings by 2040 are 390 EJ in industry, 513 EJ in transport and 440 EJ in buildings. Across all sectors, around one-third of these savings are achieved in the New Policies Scenario (Figure 1.10). The order of these potential energy savings is in direct contrast to the historical trends observed since 2000, where transport has made the least efficiency progress compared with buildings and industry (Figure 1.7).

In an energy-efficient world, energy intensity could be halved from today's levels by 2040

Global primary energy intensity falls at an average rate of around 3% per year by 2040 in the EWS, with energy demand increasing marginally by only around 7% despite economic output doubling. As a result, intensity in 2040 is just half that of today (Figure 1.11).

Figure 1.11 Global primary energy demand, GDP and intensity, historically and in the EWS, 2000-40



Sources: Adapted from IEA (forthcoming), *World Energy Outlook 2018*; IEA (2018b) *World Energy Balances 2018* (database).

Table 1.1 World energy demand by fuel and scenario (EJ)

			New Policies Scenario			Efficient World Scenario			NPS - EWS	
	2000	**2016e**	**2025**	**2040**	**Annual growth 2016-40**	**2025**	**2040**	**Annual growth 2016-40**	**2016-40**	**2016-40**
Primary energy demand	**420**	**576**	**636**	**736**	**1.0%**	**604**	**625**	**0.3%**	**111**	**15%**
Coal	97	157	161	164	0.2%	146	131	-0.8%	33	20%
Oil	154	184	194	202	0.4%	185	160	-0.6%	42	21%
Gas	87	126	144	182	1.6%	141	162	1.1%	20	11%
Final energy use	**295**	**397**	**447**	**522**	**1.1%**	**426**	**438**	**0.4%**	**84**	**16%**
Electricity	46	74	90	121	2.1%	87	113	1.8%	8	7%

Notes: Annual growth refers to the compound average annual growth rate; NPS = New Policies Scenario; EWS = Efficient World Scenario. Further data from the Efficient World Scenario can be found at found at www.iea.org/efficiency2018/data.

The brisk decline in energy intensity manifests in different ways across end-use sectors. In the transport sector, passenger vehicles consume nearly 50% less fuel per vehicle kilometre (vkm) travelled in 2040 compared with today, road freight vehicles use 47% less fuel per tonne kilometre moved (tkm) and commercial aircraft consume 55% less fuel measured on a revenue-passenger kilometre basis. In industry, the amount of value produced per unit of energy use nearly doubles and the energy needed to produce a unit of crude steel falls 25% by 2040, thanks largely to increases in recycling rates. In the buildings sector, residential floor space is 28% less energy-intensive in 2040 compared with today as a result of drops in energy intensity in new buildings of 84% for space heating and 47% for cooling. Non-residential buildings become 37% less energy-intensive.

Total primary energy demand in 2040 is 15% lower in the EWS than the NPS, and the mix of fuels that supply energy will change. Demand for coal and oil, which rises in the NPS, is around 20% lower in the EWS in 2040 (Table 1.1). Gas consumption still rises in the EWS but is 10% lower than in the New Policies Scenario. Despite a switch towards more electric vehicles and heat pumps in the Efficient World Scenario, annual electricity use in 2040 will be 7% lower than in the New Policies Scenario.

Exploiting opportunities to improve energy efficiency would be highly cost-effective

The total global annual investment[11] needed to achieve the energy savings envisioned in the EWS averages around USD 584 billion a year between 2017 and 2025, increasing to USD 1.3 trillion between 2026 and 2040, as more expensive options are taken up in later years. Nonetheless, the initial cost of investment throughout the entire projection period is more than offset by the fuel cost savings that would flow. Each dollar spent to make the world's vehicles, buildings, appliances and equipment more efficient pays back on average by a factor of three through lower fuel bills (see Chapter 5 for a detailed analysis of current and future energy efficiency investment).

The impacts of energy efficiency

The energy savings brought about by energy efficiency improvements yield a range of benefits, including lower GHG emissions and air pollution, increased household purchasing power through reduced spending on energy, enhanced energy security through reduced imports and expanded access to modern energy services (Box 1.4). The magnitude of the savings achieved in the EWS would make the climate change targets under the Paris Agreement and the UN Sustainable Development Goals (SDGs) much more achievable (Box 1.3).

Box 1.3 Energy efficiency and the Sustainable Development Goals

Sustainable Development Goal 7 (SDG 7) is to "ensure access to affordable, reliable, sustainable and modern energy for all" (United Nations, 2018). The third of this goal's three targets (SDG 7.3) is to double the global rate of energy efficiency improvement by 2030.[12] The indicator used to measure progress is the same as the one used in this report to measure yearly changes in global energy intensity: primary energy use per unit of GDP.

The IEA's most recent status report has shown that current and planned policies (those included in the New Policies Scenario) are not enough to reach the SDG 7.3 target. Achieving the target requires an average annual improvement rate in global energy intensity of around 2.7% between 2015 and 2030, whereas the measures in the New Policies Scenario are only expected to result in a 2.4% improvement rate (IEA, 2018j). Global energy intensity improved by only 1.7% in 2017, casting further doubt on global efforts to achieve SDG 7.3 without rapidly scaling up policy action.

[11] Investment here refers to *incremental* investments in energy efficiency measures, rather than the total cost of such measures. Incremental investment in energy efficiency is the additional cost of energy efficient goods and services compared with goods and services of average efficiency. Further information about energy efficiency investment can be found in Chapter 5.

[12] The IEA provides annual country-by-country data on access to electricity and clean cooking (SDG 7.1) and is the main source for tracking progress towards meeting the targets to increase the share of renewable energy in the global energy mix (SDG 7.2) and double the rate of energy efficiency improvement (SDG 7.3).

Under the Efficient World Scenario, global energy intensity improves at an average rate of 3.1% per year,[13] above the rate required to achieve SDG 7.3, which shows that this target is achievable with stronger policy action, even using only technologies that are currently available. This finding is particularly timely given the UN General Assembly's intention to conduct a high-level, mid-decade review of the UN's Decade of Sustainable Energy for All (2014-24).

Energy efficiency is central to achieving other SDGs beyond SDG 7.3. For example, universal energy access (SDG 7.1) is made much more possible by achieving SDG 7.3, as a more efficient use of the world's energy resources will help more people gain access to modern energy services. Achieving SDG 7.3 also supports the pursuit of many non-energy related SDGs, including taking urgent action to combat climate change (SDG 13), reducing premature deaths and illnesses from energy-related air pollution (SDG 3.9) and improving household incomes (SDG 8).

Energy-related GHG emissions are rising again and aggressive efficiency improvements will be crucial to limit global warming

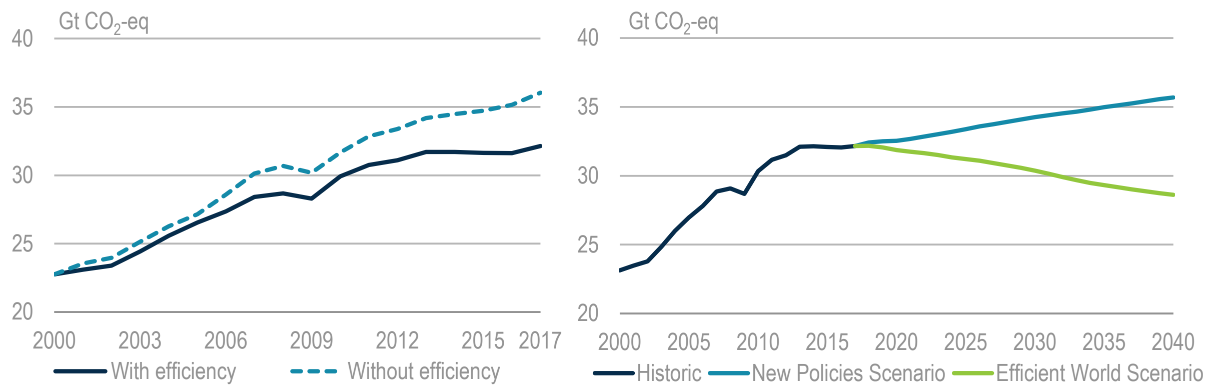
Energy efficiency will need to play a central role in tackling climate change, a task made all the more urgent by the recent rise in emissions and the limited time to achieve mitigation targets, as outlined by the recent Intergovernmental Panel on Climate Change (IPCC) special report on Global Warming of 1.5°C. Energy efficiency is one of the key ways the world can meet energy service demand with lower energy use, which is crucial in most of the IPCC GHG emissions pathways limiting global warming to 1.5°C (IPCC, 2018).

Energy-related GHG emissions increased by 1.4% to over 32.5 gigatonnes of CO_2 equivalent (Gt CO_2-eq) in 2017 – the first increase since 2014, after strong global economic growth led to greater use of emissions-intensive fuels. At the same time, efficiency helped to constrain the recent growth in emissions: had efficiency not improved since 2000, emissions would have been nearly 4 Gt CO_2-eq, or 12%, higher in 2017 (Figure 1.12).

Implementing the actions of the EWS from today would ensure that energy-related GHG emissions peak and begin to decline before 2020. By 2040, these cost-effective actions would reduce annual energy-related emissions by 3.5 Gt CO_2-eq (12%) on 2017 levels, delivering over 40% of the abatement required to be in line with the Paris Agreement. Energy efficiency, combined with renewable energy and other measures, is therefore indispensable to achieving global climate targets.

[13] Calculated as the average annual rate of intensity improvement between 2017 and 2030.

Figure 1.12 Energy-related GHG emissions, with and without efficiency, 2000-17 (left) and in the NPS and EWS, 2000-40 (right)



Note: Left axis starts at 20 Gt CO_2-eq.

Sources: Adapted from IEA (2018g), *Energy Efficiency Indicators 2018* (database); IEA (2018c) *World Energy Balances 2018* (database); IEA (2018h), *Energy Technology Perspectives* (Buildings model); IEA (2018i), *Mobility Model* (database); Timmer et al. (2015), *World Input Output Database* (database); IBGE (2018), *Quarterly National Accounts* (database); National Bureau of Statistics of China (2018), *National Accounts* (database); Reserve Bank of India (2018), *The India KLEMS Database* (database); Statistics Indonesia (2018), *Gross Domestic Product* (database); INEGI (2018), *GDP - Activity of Goods and Services* (database); StatsSA (2018), *Gross Domestic Product (GDP), 4th Quarter 2017* (database); Quantec (2018), *Industry Service – RSA Standard Industry – Input Structure at basic prices* (database); INDEC, Republica Argentina (2018), *Macroeconomic aggregates (GDP)* (database); World KLEMS Data (2018), *Russia* (database); IEA (2018k), *CO_2 emissions from Fuel Combustion* (database).

Efficiency reduces air pollution and associated premature deaths

Another major benefit of future efficiency improvements would be better indoor and outdoor air quality. Scaling up energy efficiency action to levels modelled in the EWS would deliver large reductions in emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and fine particulate matter ($PM_{2.5}$). SO_2 emissions in 2040 would be 42% lower than 2015 levels, due to cuts in oil use in transport, and coal use in the buildings and industry sectors. NO_x emissions would be 29% lower, driven primarily by the transport sector, where emissions would be 39% lower than 2015 levels. $PM_{2.5}$ emissions would be 15% lower, as less coal is combusted for heating and power and less gasoline and diesel are consumed by vehicles.

Yearly, almost 3 million people die prematurely from a range of causes linked to poor outdoor air quality, including cancer, respiratory illnesses and heart disease (IEA, 2017a). The efficiency measures in the EWS limit the growth in premature deaths by reducing concentrations of energy-related particulate pollution in outdoor air. Poor indoor air quality currently leads to around 2.7 million premature deaths per year. Under the EWS, these fall to under 1.9 million in 2040, around one-third lower than 2015 levels. Indoor air quality could be improved by using more efficient biomass cookers, which could reduce premature deaths by around 400 000 per year by 2040. Households switching from biomass to LPG or electric cooking would gain further benefit.

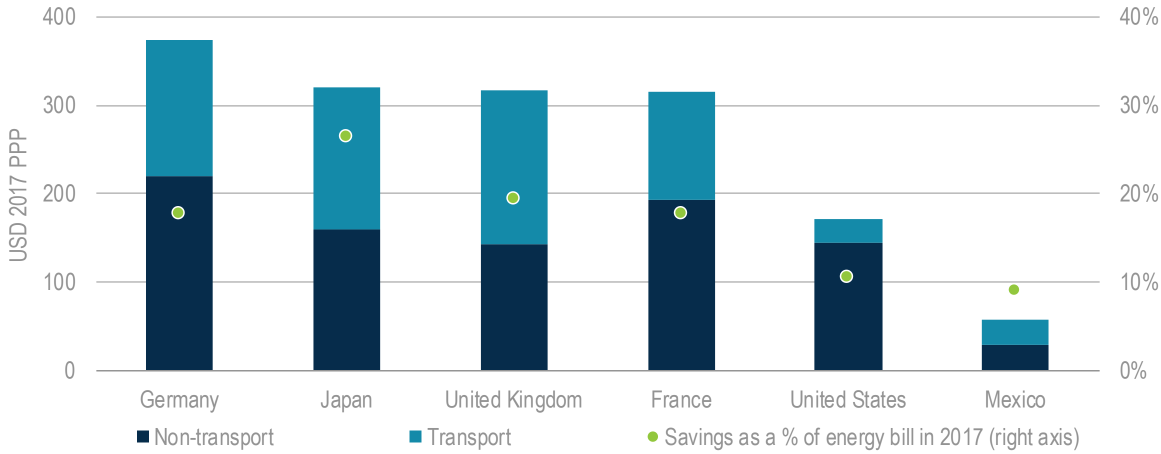
Efficiency reduces the impact of energy bills on household budgets

In 2017, household energy expenditure increased in several countries. In the United Kingdom, for example, energy's share of total expenditure increased from 4.9% in 2016 to 5.3% in 2017. The rise in expenditure would have been worse were it not for energy efficiency improvements. In 2017, the cumulative efficiency improvements made since 2000 saved UK households over USD 300 on average, around 20% of their yearly energy expenditure (Figure 1.13). German households saved an average of over USD 370 per household due to energy efficiency, primarily from reductions in gas use. Japanese households were on average USD 300 better off, with benefits attributable to energy savings made equally between transport and non-transport energy consumption. These savings meant that Japanese energy bills were 26% lower than they would have been without efficiency.

If the world was to implement the cost-effective energy efficiency opportunities available today, in 2040 households globally could save USD 201 billion in avoided expenditure on fuels such as electricity and gas, and USD 365 billion in avoided expenditure on transport fuels. Together, this is more than the amount spent on tourism in 2017 by the world's four highest-spending countries – China, Germany, the United States and the United Kingdom.

The financial savings resulting from efficiency under the EWS, combined with projected lower energy prices, create conditions in which households may paradoxically have incentives to consume more energy, a phenomenon known as the "rebound effect". However, in cases where spending on energy increases access to vital energy services that improve households' quality of life, some rebound in energy use is not necessarily negative. In addition, the extent to which rebound has negative impacts – such as increased GHG emissions – depends on other factors, such as the energy supply mix at the time.

Figure 1.13 Average household savings per capita on energy expenditure in 2017 due to efficiency gains since 2000

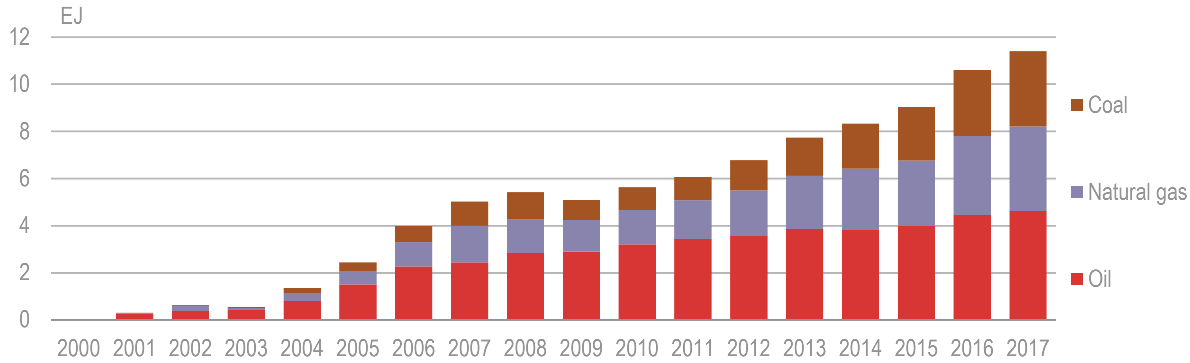


Sources: Adapted from IEA (2018g), *Energy Efficiency Indicators 2018* (database); IEA (2018b) *World Energy Balances 2018* (database); IEA (2018h), *Energy Technology Perspectives* (Buildings model); IEA (2018i), *Mobility Model* (database); IEA (2018e), *World Energy Prices 2018* (database).

Efficiency increases energy security by reducing fossil fuel imports

By reducing overall energy needs, improved energy efficiency helps reduce the dependence of net importing countries on coal, oil and gas imports, enhancing their energy security. In IEA countries and other major economies, efficiency gains since 2000 avoided the need for over 11 EJ or 20% more fossil fuel imports in 2017, of which avoided oil imports in IEA countries alone were worth over USD 30 billion (Figure 1.14). Lower imports also bring broader macroeconomic benefits, including an improved balance of payments and increased competitiveness.

Figure 1.14 Reduction in fossil energy imports in IEA countries and major emerging economies due to efficiency improvements since 2000 by fuel

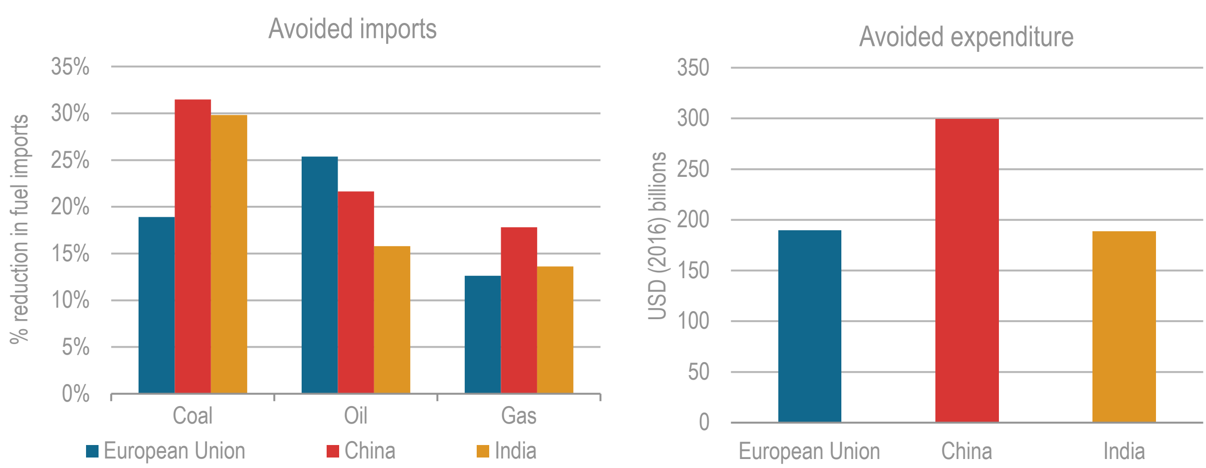


Note: Countries covered are IEA countries plus China, India, Brazil, Indonesia, Russian Federation, South Africa and Argentina.

Sources: Adapted from IEA (2018g), *Energy Efficiency Indicators 2018* (database); IEA (2018c) *World Energy Balances 2018* (database); IEA (2018h), *Energy Technology Perspectives* (Buildings model); IEA (2018i), *Mobility Model* (database); Timmer et al. (2015), *World Input Output Database* (database); IBGE (2018), *Quarterly National Accounts* (database); National Bureau of Statistics of China (2018), *National Accounts* (database); Reserve Bank of India (2018), *The India KLEMS Database* (database); Statistics Indonesia (2018), *Gross Domestic Product* (database); INEGI (2018), *GDP - Activity of Goods and Services* (database); StatsSA (2018), *Gross Domestic Product (GDP), 4th Quarter 2017* (database); Quantec (2018), *Industry Service – RSA Standard Industry – Input Structure at basic prices* (database); INDEC, Republica Argentina (2018), Macroeconomic aggregates (GDP) (database); World KLEMS Data (2018), *Russia* (database).

IEA countries represented nearly three-quarters of total import savings, with over 30% of these savings in the form of natural gas, because of major efficiency improvements in space heating and industrial processes and growth in the share of natural gas in the electricity generation mix. In several countries – including France, Italy and Spain – reductions in gas imports thanks to efficiency were particularly important in 2017, when gas demand for power generation was high (IEA, 2018d). Without the efficiency improvements made since 2000, gas imports in 2017 would have been higher in Spain (10%), Italy (14%) and France (15%), placing additional stress on gas infrastructure.

Figure 1.15 Avoided imports (left) and reduction in fossil-fuel net-import bills (right) for selected energy importing countries and regions in the Efficient World Scenario compared with the New Policies Scenario in 2040

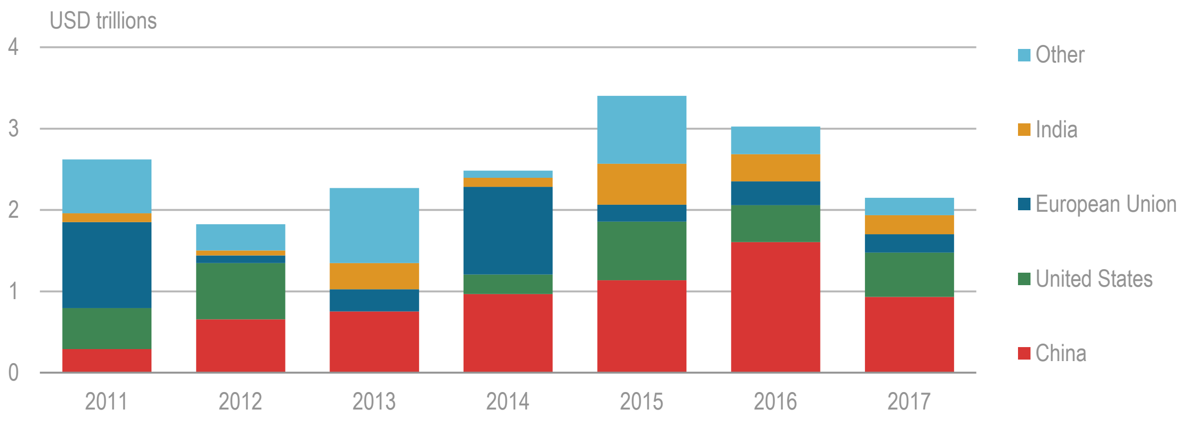


In the EWS, net fossil fuel imports decrease in some of the world's major energy importing economies (Figure 1.15). For the European Union in the EWS, fossil fuel imports are reduced from levels in the New Policies Scenario (NPS) to the value of nearly USD 200 billion, which includes savings of 49 billion cubic metres (bcm) of gas. Chinese gas imports are also around 50 bcm less in the EWS than the NPS and China's coal imports are over 30% lower, equivalent to 31 million tonnes of coal equivalent (Mtce). India's energy import savings of USD 189 billion in the EWS compared with the NPS accrue primarily from a reduction in coal imports: Efficiency improvements mean India avoids the need for 100 Mtce of imported coal.

Efficiency delivers an energy productivity bonus

The "energy productivity bonus" – 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 – provides an indication of the value of energy efficiency gains. In 2017, the global energy productivity bonus amounted to around USD 2 trillion, down from USD 3 trillion in 2016. At over USD 930 billion, China's energy productivity bonus was the largest of any single country, yet was 42% lower than 2016 (Figure 1.16). In the EWS, the GDP generated per unit of energy consumed is 18% higher than the NPS in 2040.

Figure 1.16 Energy productivity bonus, by country, 2011-17



Sources: Adapted from IEA (forthcoming), *World Energy Outlook 2018*; IEA (2018c) *World Energy Balances 2018* (database).

The historical and future benefits from energy efficiency (Table 1.2) are substantial, but represent just a selection of the multiple benefits derived from improvements in energy efficiency (Box 1.4).

Box 1.4 The multiple benefits of energy efficiency: a growing body of evidence

Evidence of the multiple benefits of energy efficiency continues to mount. In early 2018, the IEA held a workshop titled *Beyond Energy Savings: The Multiple Benefits of Energy Efficiency*, to examine recent research. Among the benefits discussed were those concerning the macro economy and public health, for which there is a growing body of literature.

While the health benefits from energy efficiency's impact on air pollution are widely known, recent studies on the link between noise pollution and health[14] suggest that energy-efficient building materials that also reduce exposure to noise pollution (such as double- or triple-glazed windows), could have further benefits for health. This would be an interesting topic for future scientific study.

A range of direct and indirect economic benefits can flow from improving energy efficiency, including for employment, productivity, and the incomes of individuals and businesses. In the US, the energy efficiency sector now reportedly employs nearly 2.25 million people, twice as many workers as all fossil fuel sectors combined. In 2017, the sector recorded a net increase of 67 000 jobs, making it the fastest growing job sector in the entire US energy industry (EFI and NASEO, 2018).

Increased energy efficiency can also improve access to energy. Particularly in developing countries, where large parts of the population continue to lack access to energy services, efficiency can help increase energy access by ensuring a greater level of energy service per unit of energy consumed. For example, compared with the New Policies Scenario, in 2040 it is estimated that 765 million more people would gain access to clean cooking facilities if the measures in the Efficient World Scenario were implemented.

Table 1.2 Summary of impacts in 2040 resulting from efficiency measures under the Efficient World Scenario

Aspect	Impact of scaled-up efficiency
Greenhouse gas emissions	Energy-related greenhouse gas emissions 12% lower than 2017 levels.
Health	SO_2 emissions 42% lower, NO_x emissions 29% lower, and $PM_{2.5}$ emissions 15% lower than 2015 levels. This could reduce premature deaths related to indoor air pollution by around one-third compared with current levels.
Household expenditure	Globally, households could save USD 365 billion on transport-related energy costs and USD 201 billion on non-transport-related energy costs under the EWS compared with the NPS.
Energy security	Large reductions in net fossil fuel import bills in key energy importing countries such as China (USD 300 billion), the European Union (USD 190 billion) and India (USD 189 billion), under the EWS compared with the NPS.

Trends in efficiency policy

Global policy settings leave many opportunities untapped and could be scaled up

By enacting policies, governments have a vital role to play in accelerating the adoption of energy-efficient appliances, equipment, buildings and vehicles across all end-use sectors. The *Energy Efficiency* Market Report tracks worldwide progress in implementing three types of policy:

- Mandatory policies and regulations with minimum energy efficiency performance requirements.

[14] For example, Clark et al. (2017) *Association of Long-Term Exposure to Transportation Noise and Traffic-Related Air Pollution with the Incidence of Diabetes: A Prospective Cohort Study*, www.ncbi.nlm.nih.gov/pmc/articles/PMC5783665/.

These include mandatory minimum energy performance standards (MEPS) for appliances and equipment, mandatory building codes, fuel economy standards and targets for industry.[15] For these policies, progress is measured using the Efficiency Policy Progress Index (EPPI). The EPPI measures the percentage of energy use covered by mandatory polices, combined with the increase in policy strength since 2000.[16]

- Energy utility obligation programmes. Also known as energy efficiency resource standards in the United States, obligation programmes require energy companies to achieve an energy efficiency target – typically a set amount of energy savings. Policy progress is measured by monitoring changes in policy coverage (the share of total final energy consumption supplied by obligated parties); and policy strength (the share of total final energy consumption required to be saved under the obligations in a given year). Obligations are not included in the EPPI.
- Incentives. These include policies put in place to encourage the take-up of energy-efficient technologies and behaviour through financial or fiscal rewards, including grants and subsidies, tax relief, equity finance, loans and debt finance, guarantees, on-bill finance and other incentives.[17]
- In 2017, progress in increasing the coverage of mandatory energy efficiency policies slowed – particularly the coverage of new policies – but the strength of these policies increased at a faster rate than in 2016 (Box 1.5). The coverage and strength of energy utility obligation programmes remained largely unchanged. Data gathered for the first time by the IEA also show that while some of the world's largest energy-consuming countries provide a range of different incentives for energy efficiency, the total value of these incentives remains far below subsidies for energy consumption.

Box 1.5 Defining and measuring policy coverage and strength

Policy coverage refers to the share of total final energy use by equipment and appliances that are subject to a policy or regulation. For example, if a country adopts new MEPS for specific types of refrigerator, the policy coverage is the amount of energy used by the regulated refrigerators, divided by the total amount of energy used by all refrigerators in a given year.

For a given end-use, once a policy is in place—irrespective of the strength of the policy—the end-use is considered to be "covered" by policy. Coverage of mandatory policies and regulations can be increased by modifying the scope of existing policies, introducing new policies or by replacing existing energy-using stock that was not subject to mandatory policies when it was brought into use. This last factor means that policy coverage grows automatically each year as the stock of energy-using appliances, equipment and vehicles is replaced progressively by new stock subject to the policy.

In the case of energy utility obligation programmes, policy coverage is calculated as the share of total final energy consumption supplied in aggregate by the energy companies that are required to meet the obligation.

Policy strength is defined as the extent to which a policy increases the amount of energy saved over time. For mandatory policies, we measure it by comparing the current policy requirement with the

[15] Other mandatory policies, such as mandatory product labelling, mandatory energy/emissions reporting or audits, and emissions trading schemes, are not included.

[16] Detailed information about how the EPPI is calculated can be found at www.iea.org/efficiency2018/data.

[17] Policies such as taxes, which discourage energy inefficiency through financial penalties, are not included.

requirement in 2000. For example, if the maximum permitted energy use for a refrigerator was 1 000 kWh per year in 2000 (based on a given set of operating conditions) and a new standard in 2010 lowered this to 750 kWh, the strength improvement is 25%. If the standard was lowered again in 2015 to 600 kWh, policy strength is 40%. If no policy was in place in 2000, the most efficient model available before the introduction of the policy is used as the baseline.

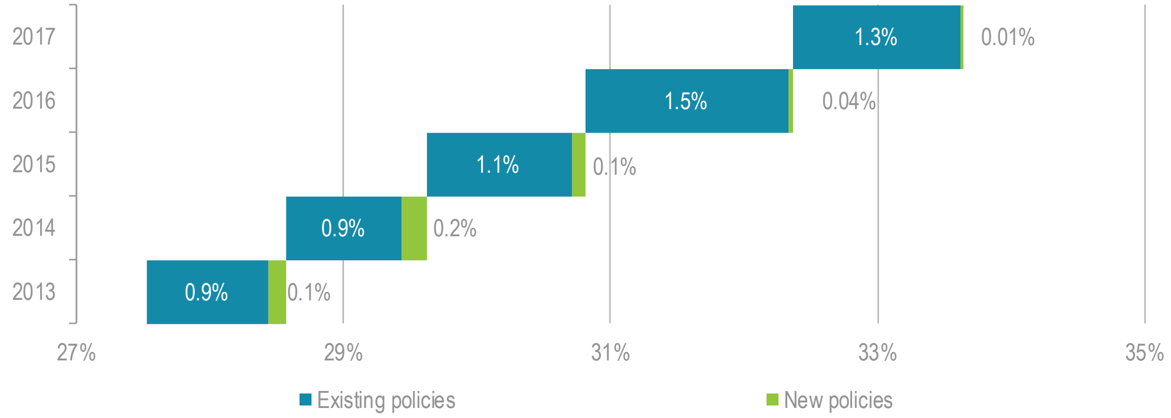
For utility obligation programmes, policy strength is the share of total final energy consumption required to be saved under the obligation in a given year. The policy coverage and strength analysis includes five energy types: electricity, coal, natural gas, oil and biomass.

The global coverage of mandatory policies rose in 2017

The percentage of global energy use covered by mandatory policies and regulations increased from 32% in 2016 to 34% in 2017.[18] As was the case in 2016, 99% of this increase was driven by replacements of vehicles, appliances and equipment with new stock subject to existing energy efficiency policies (Box 1.6); the remaining 1% was down to an extension of standards to new categories of energy-using equipment (Figure 1.17). The share of new policies in the increase in policy coverage has been falling in recent years.

With over 60% of its energy use covered by mandatory policies and regulation, China was again responsible for a large proportion of the global growth in policy coverage. The proportion of global energy use covered by Chinese mandatory policies and regulations increased from 13.5% to 13.9%. This increase was entirely due to stock turnover rather than new policies. New policies that increased coverage included passenger vehicle standards in India and appliance regulations in Peru, Singapore and Zimbabwe.

Figure 1.17 Annual additions to the percentage of global energy use covered by mandatory energy efficiency polices and regulations, owing to new and existing policies

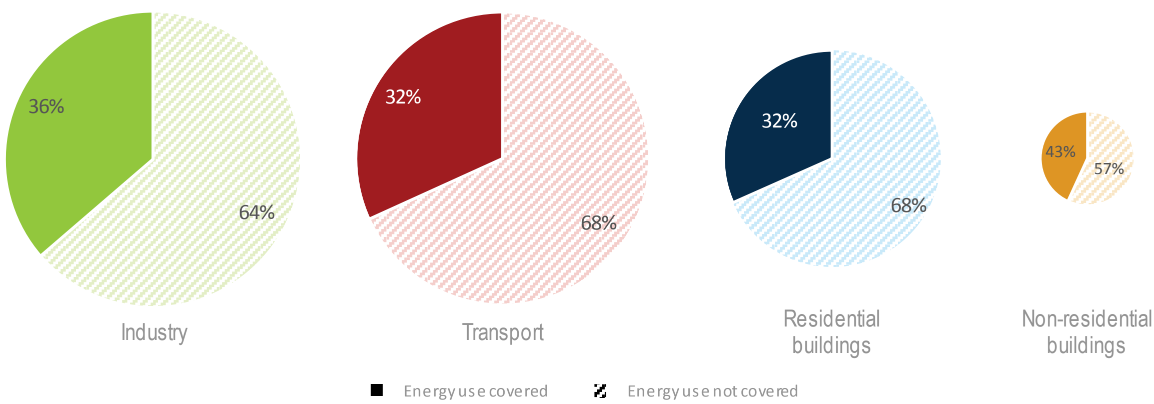


Note: Horizontal axis starts at 27%, showing that pre-2013 policies covered over 27% of global energy use.

[18] The estimates of policy coverage presented here differ from *Energy Efficiency 2017* (IEA, 2017b) due to revisions to data for the buildings sector and revised data for total final energy consumption in the industry sector, where blast furnace energy consumption is now counted as an industrial sector end-use rather than a non-energy use.

Policy coverage in 2017 was highest in non-residential buildings, at 43%, noting that the *amount* of energy used in non-residential buildings is the lowest of the four sectors examined (Figure 1.18). At 32%, policy coverage in the residential buildings sector appears low because much of the energy use in that sector is for domestic cooking using biomass, which is completely unregulated by mandatory policies. Mandatory policies covered 36% of industry consumption, but the amount of energy use covered was higher than in any other sector because industry was the leading energy-consuming sector. Coverage remained lowest in the transport sector at 32%, but the increase of 2.4 percentage points was the largest of any sector in 2017 and the largest single-year increase ever experienced in the sector – the result of an increase in the coverage of vehicle fuel economy standards, notably in the European Union, Canada, China, and India, as well as record vehicle sales (see Chapter 2).

Figure 1.18 Share of global final energy consumption covered by mandatory policies, by sector



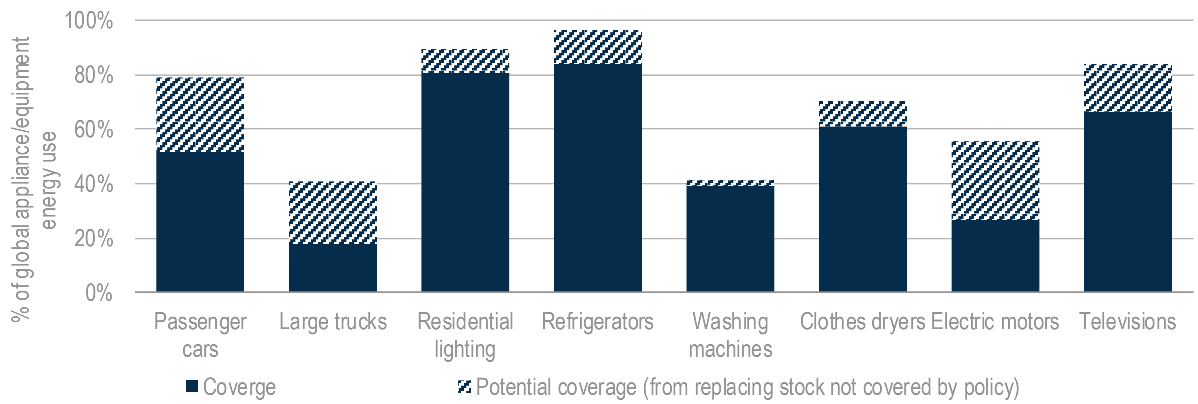
Notes: The size of pie charts is approximately proportionate to total final consumption in each sector.

Box 1.6 Increasing mandatory policy coverage by replacing stock

One way of increasing mandatory policy coverage is by replacing the stock of appliances, equipment and vehicles not subject to efficiency performance requirements under mandatory policies, with stock that is subject to such requirements. For some end-uses, renewing the stock could significantly increase mandatory policy coverage. For example, mandatory policy coverage of passenger cars could be increased from 52% to nearly 80% simply by replacing ageing vehicles not covered by mandatory policy. Similarly, replacing ageing trucks with newer stock, covered by mandatory policy, would more than double the policy coverage of large trucks from 18% to over 40%. For these end-uses, policymakers could consider measures to accelerate adoption of more efficient stock alongside mandatory policies.

In contrast, less than 40% of washing machine energy use is covered by mandatory policy. Coverage would only increase by 3% if ageing stock was replaced, indicating that most washing machines in countries with mandatory policies are already subject to those policies. Increasing global policy coverage further would require new mandatory policies that cover more products in more markets (Figure 1.19).

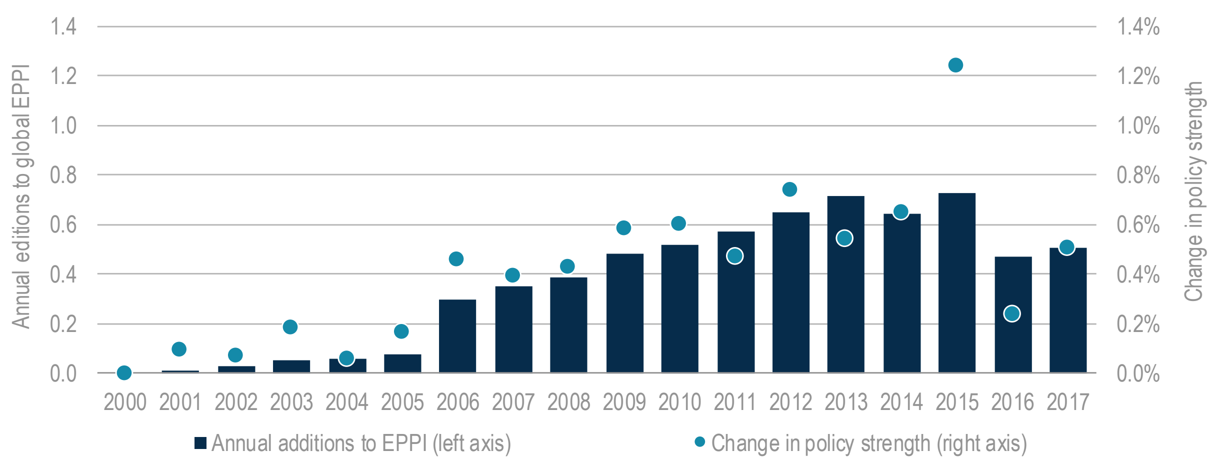
Figure 1.19 Mandatory policy coverage and potential coverage from replacing stock not covered by policy in 2017 for select appliances and equipment



The strength of mandatory policies increased but overall progress was still slower than recent years

Since 2011, the strength of mandatory policies has increased at an average rate of 0.6% annually, double the rate of increase observed during the previous decade (Figure 1.20). This suggests that countries are increasingly recognising the need for policies that are not only broad in coverage, but also *effective*. The strength of mandatory policies increased by 0.5% in 2017, below the annual average trend of around 0.6% observed since 2011 but above the 0.2% rise in 2016, which may have been an outlier, following a large increase in mandatory policy strength in 2015.

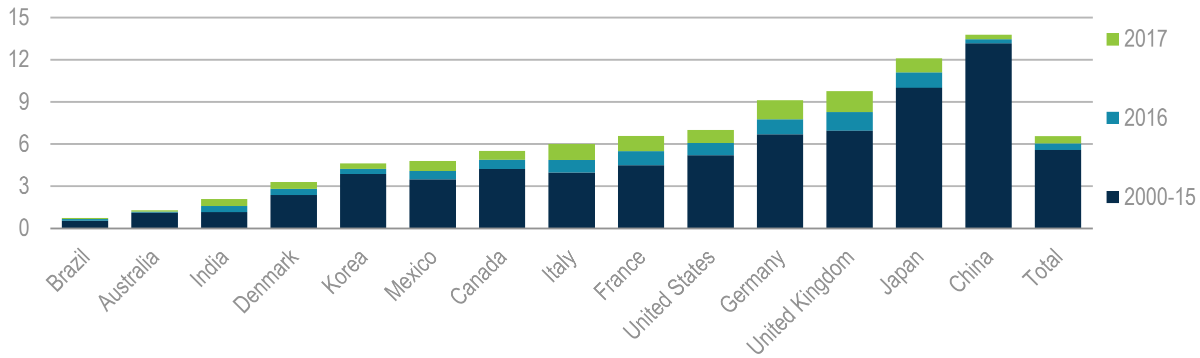
Figure 1.20 Efficiency Policy Progress Index (EPPI) and annual changes in mandatory policy strength, 2000-17



Most increases in policy strength occurred in the transport sector, where fuel economy standards for commercial and passenger vehicles were strengthened in several countries and regions, including Canada, the European Union, India, Japan and Korea. In the United States, a new set of vehicle emissions standards came into force in 2017, strengthening energy efficiency requirements for passenger vehicles. Minimal increases in policy strength occurred in the buildings and industry sectors. The main changes were a strengthening of standards for water heating technologies in the buildings sector in Europe and Korea, tighter standards for industrial electric motors in Chinese Taipei and Saudi Arabia, and an update of the Perform, Achieve and Trade (PAT) programme in the industrial sector in India.

The combined changes in the coverage and strength of mandatory policies resulted in a 0.51 increase in the Efficiency Policy Progress Index (EPPI) – the main IEA indicator of global progress on mandatory energy efficiency policy.[19] This increase was close to that in 2016, but around one-quarter lower than the average annual rate of growth in the five years to 2015 (Figure 1.20). The recent slowdown in growth of the global EPPI is due to a lack of both new mandatory policies and updates to existing mandatory policies. It may have repercussions for achieving future energy efficiency gains, given the central role that such policies have played in improving efficiency in the past.

Figure 1.21 Efficiency Policy Progress Index in selected countries and globally by period



The biggest increases in the EPPI in 2017 occurred in Europe, notably in France, Germany, Italy and the United Kingdom, where updated EU codes and standards for transport and buildings came into effect, increasing policy strength (Figure 1.21). China's EPPI increased only marginally, in part because of new standards for passenger and light commercial vehicles. Nonetheless, China remains ahead of all other leading energy-consuming countries, with most of its policy progress since 2000 having been achieved before 2016.

Strength and coverage of energy utility obligations was largely unchanged

"Market-based instruments" include energy utility obligation programmes (with or without "white certificate" trading), auctions, and other policies that specify an efficiency outcome (e.g. an energy savings target), without prescribing the delivery mechanisms and the technologies to be used. The main market-based instrument tracked by the IEA is energy utility obligation programmes.

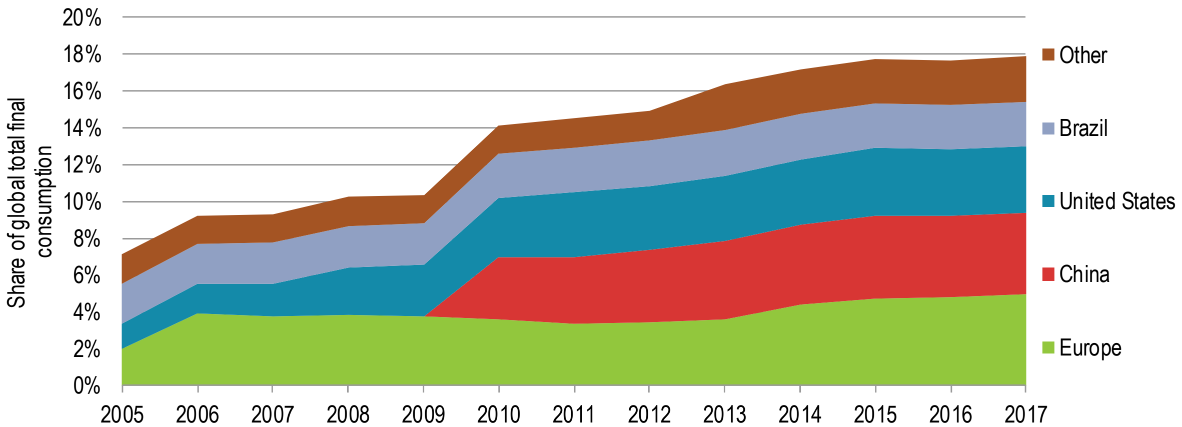
As in 2016, there was little change in the coverage and strength of energy utility obligation programmes in most countries in 2017.[20] In 2017, 47 obligation programmes were in operation,

[19] The EPPI combines the percentage of energy demand covered by mandatory polices and regulations with the increase in policy strength since 2000. For any given country or region, a 1-point increase in the EPPI means the global stock of energy-using vehicles, buildings and equipment is 1% more efficient than in 2000. An explanation of how the EPPI is calculated can be found at www.iea.org/efficiency2018/data.

[20] Energy utility obligations analysed here include both federal and state/provincial programmes.

spread over 21 countries in Africa, Asia, Australia, Europe, North America and South America. The majority were concentrated in Australia, Europe and North America and more than half in the United States. New utility obligations were introduced in Greece and Latvia. In the first half of 2018, a 26th US obligation programme was launched, in the state of New Hampshire, and New Jersey established targets for a programme that will begin in 2019.

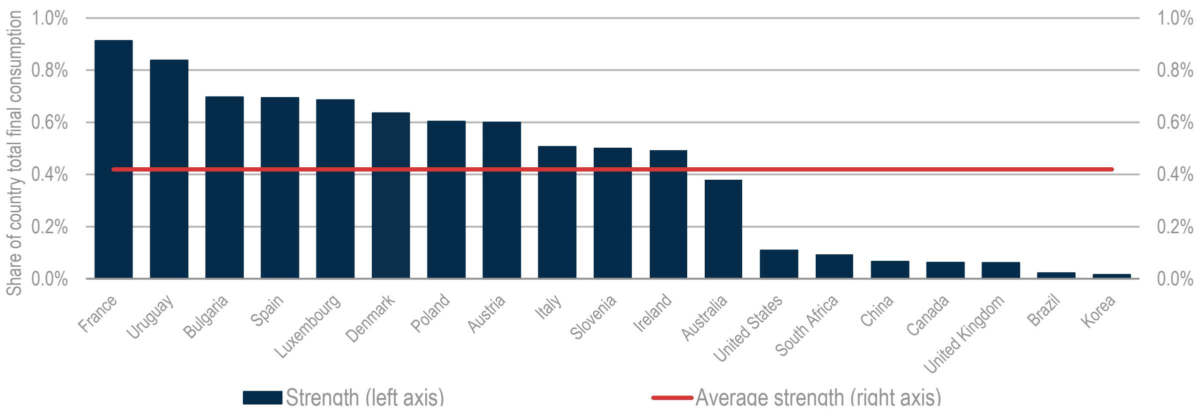
Figure 1.22 Coverage of energy utility obligations, by country/region



Sources: IEA (2017b) *Energy Efficiency Obligation:* South Africa*;* ACEEE (2017) *The 2017 State Energy Efficiency Scorecard;* ANEEL (2016) Legislação Correlata; ATEE (2017), *Snapshot of Energy Efficiency Obligations Schemes in Europe: 2017 update*; China Electricity Council (2017) *Development and Reform Regulations (2017) No 1690*; Korea Legislation Research Institute (2016) *Energy Use Rationalization Act.*

Over half of the programmes operating around the world have not changed since 2014. Just under 18% of global final energy use was covered by obligation programmes in 2017, a level that has been steady since 2015 (Figure 1.22).

Figure 1.23 Strength of utility obligations in operation since 2005

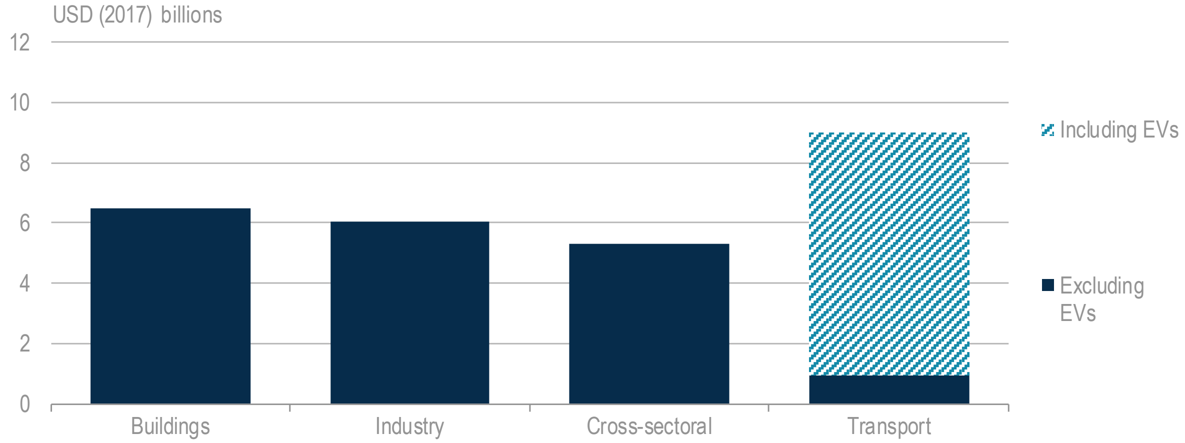


Note: The method for calculating the savings attributable to obligation policies varies between programmes, meaning that caution should be taken when comparing them. Data include both federal and state/provincial energy utility obligations, depending on the country.

Sources: IEA (2017b) *Energy Efficiency Obligation:* South Africa*;* ACEEE (2017) *The 2017 State Energy Efficiency Scorecard;* ANEEL (2016) Legislação Correlata; ATEE (2017), *Snapshot of Energy Efficiency Obligations Schemes in Europe: 2017 update*; China Electricity Council (2017) *Development and Reform Regulations (2017) No 1690*; Korea Legislation Research Institute (2016) *Energy Use Rationalization Act.*

There was also little change in the strength of utility obligation programmes in 2017 although targets were increased in Ireland, Slovenia and in the US states of Maine, Ohio and Vermont. In 2018 targets were increased in Illinois and North Carolina. The total energy savings targeted under obligation programmes worldwide amounted to around 0.4% of all the final energy consumed in the countries with such programmes (Figure 1.23). The savings targets were highest in France, at 0.9% of national energy consumption, followed by Uruguay (0.8%), with Bulgaria, Spain, Luxembourg, Denmark, Poland and Austria all above 0.6%. Global cumulative savings achieved since 2005 amounted to around 1% of the final energy consumption of countries with obligations in 2017. The share was highest in France (6.2%), Italy (5.4%) and Denmark (4.9%).

Figure 1.24 National government incentives for energy efficiency in 2017, by sector, including and excluding incentives for electric vehicles



Note: Data obtained from surveys conducted with Australia, Austria, Brazil, China, Estonia, Germany, India, Ireland, Italy, Mexico, Norway, Portugal, Spain, Switzerland, the United Kingdom and the United States. In the case of China, 2016 efficiency incentives data are used as a proxy for 2017.

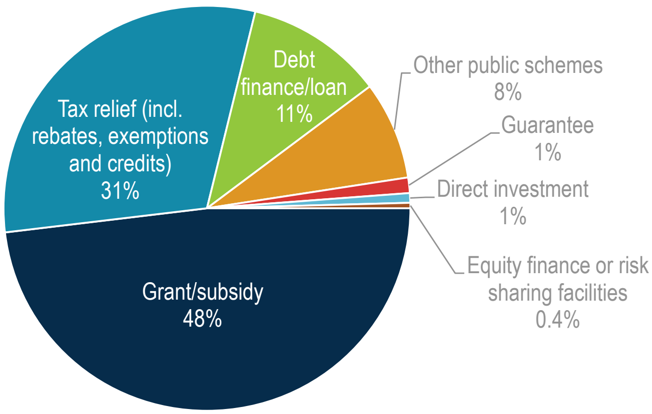
Government incentives for energy efficiency are small in comparison to other government spending

In 2017, national government incentives for energy efficiency in 16 of the world's major economies, which include tax relief, grants, subsidies, loans and rebates, amounted to USD 27 billion, including USD 8 billion in incentives for EVs. When EV incentives are included, the transport sector was the largest recipient of incentives, with around USD 9 billion. Excluding EV incentives, incentives were greatest in the buildings sector (USD 6.5 billion) followed by industry (USD 6 billion) (Figure 1.24).

National governments favour grants and subsidies

The largest share of total public spending on energy efficiency incentives in the countries surveyed – 48% – was in the form of grants and subsidies, followed by tax relief and credits (31%) (Figure 1.25). Italy, which provides generous tax breaks for upgrades to residential and non-residential buildings, accounted for much of this tax relief. In terms of the number of incentive programmes, grants and other types of direct subsidy were by far the most popular policy instrument, with nearly three times as many grant and subsidy programmes in place as the next most popular instrument – debt finance/loan arrangements. The strong preference for grants and direct subsidies may reflect the fact that policy makers are familiar with them and that they are easy to administer and communicate.

Figure 1.25 Government expenditure on incentives for energy efficiency by type of incentive



Note: Data obtained from surveys conducted with Australia, Austria, Brazil, China, Estonia, Germany, India, Ireland, Italy, Mexico, Norway, Portugal, Spain, Switzerland, the United Kingdom and the United States. In the case of China, data are for 2016.

Certain government incentives were successful in leveraging a significant amount of private finance, boosting the cost-effectiveness of those incentives. For example, loans provided by the German government for building rehabilitation under the CO_2 Building Modernisation Programme achieved a public-to-private finance leverage ratio of 1:20 between 2009 and 2017.[21]

Governments' spending on efficiency is relatively small

Public spending on efficiency incentives, while significant in absolute terms, represents a small share of total spending and of spending on other types of energy subsidy. For example, in the group of countries surveyed here, total spending on fossil fuel consumption subsidies amounted to USD 103 billion in 2016 according to the OECD-IEA fossil fuel subsidies database.[22]

Countries seeking to increase energy efficiency through incentives could improve the efficacy of their policies and rationalise government spending by re-allocating spending to efficiency from other subsidies that discourage the efficient use of energy. This has the potential to provide a policy "win-win" because energy efficiency and subsidy reform are mutually reinforcing. By raising end-user prices, subsidy reform can create a stronger case for energy efficiency and reduce payback times on energy-efficient equipment. In turn, efficiency improvements that result in energy savings can reduce the impact that higher energy prices, which can result from subsidy reform, have on household bills.

Key policy announcements in 2017

In addition to policies that entered into force in 2017, countries developed new policies that will be implemented in the coming years. Some of the notable policy announcements are listed below.[23]

[21] Source: Personal communication with the Federal Ministry of Economic Affairs and Energy of Germany.

[22] The fossil fuel subsidy data have been filtered for "consumer support estimates" only and therefore exclude subsidies for the production of fossil fuels. Fossil fuel subsidies for public transport and CO_2 tax relief for industries that commit to CO_2 reduction targets have been excluded as these could be considered efficiency incentives. Source: (For fossil fuel subsidies) OECD-IEA (2018), *Fossil Fuel Support Database*.

[23] Policy announcements listed in this section are not included in analysis of policy progress conducted above as they are yet to come into force.

European Union

In November 2016, the European Commission announced a Clean Energy Package, comprising eight proposals to facilitate the EU clean energy transition. The package included proposals to update the Energy Efficiency Directive (EED), the Energy Performance of Buildings Directive (EPBD) and several other measures. In June 2018, EU member states and the European Parliament agreed on a non-binding target of improving energy efficiency by 32.5% by 2030; the target will be reviewed in 2023.

The revised EPBD was agreed in May 2018 and entered into force on 9 July 2018 (EU 2018/844). Member states must establish long-term strategies to fully decarbonise and dramatically reduce the energy use of their entire stock of residential and non-residential buildings, supported by financing mechanisms. This implies all EU buildings must reach near zero energy performance levels by 2050. The directive also contains obligations on ”smart readiness”, which, among other measures, requires member states to include at least one EV charging point in all non-residential buildings with at least ten parking spaces. Energy-using equipment within buildings will be subject to tighter energy performance requirements under product standards contained in the EU Eco-Design Directive.

Canada

Implementation of the Pan-Canadian Framework on Clean Growth and Climate Change is continuing. The framework was developed to drive Canada towards its greenhouse gas emissions reduction targets under the Paris Agreement, with energy efficiency accounting for one-third of planned emissions reductions by 2030. Several efficiency measures are being developed through ongoing consultations. These include improving equipment regulations; promoting energy management in industry; improving the efficiency of government operations; deploying infrastructure for electric and alternative fuel vehicles; retrofitting existing buildings; and moving toward a "net-zero energy ready" building standard. Canadian provinces and territories have been joining efforts to advance the framework, including adopting Canada's Buildings Strategy and improving the energy performance of key heating technologies. These efforts could unlock significant efficiency gains, as building and space heating improvements could reduce building energy demand by over 14 million tonnes of oil equivalent (Mtoe) in 2050, with improvements to space heating energy efficiency accounting for over 70% of cumulative savings in the buildings sector to 2050 (IEA, 2018l).

India

An update to India's Energy Conservation Building Code (ECBC) was announced in May 2017. The model building code prescribes the energy performance standards for new commercial buildings and includes requirements for builders, designers and architects to integrate passive design principles and renewable energy sources into building designs. New buildings must demonstrate minimum energy savings of 25% to be code-compliant. Buildings that achieve energy savings of 35% will earn "ECBC Plus" status and those that achieve savings of 50% will reach "Super ECBC" status. The code will come into force upon adoption by the states.

Italy

The Italian government unveiled in November 2017 its National Energy Strategy – a ten-year plan covering a broad range of energy sector interventions. The strategy includes a target to reduce energy consumption by 30% by 2030. Specific measures include a strengthened tax deduction programme ("Ecobonus") for residential energy efficiency, loan guarantees and strengthened MEPS. In transport, the strategy calls for sustainable local mobility, including switching to more energy-efficient transport and smart mobility such as car sharing, as well as vehicle efficiency improvements and infrastructure to support intermodal freight transport. In addition, the country's white certificate scheme will be strengthened and streamlined, while a co-funding programme for energy audits and energy management systems will be introduced to support small and medium-sized businesses.

Malaysia

As part of its most recent five-year plan, the Malaysian government announced in 2016 the National Energy Efficiency Action Plan 2016-2025, containing a range of energy efficiency measures, with a focus on strengthening demand-side management (DSM). The proposed plan includes several sectoral targets, including the retrofit of 100 government buildings, a target of 100 companies to implement the ISO 50001 energy management system standard, the installation of 4 million smart meters in industry, an expansion of the coverage of MEPS for household appliances and increased sales of energy-efficient vehicles. It also includes a range of financing and funding mechanisms, as well as training initiatives and awareness raising campaigns. The Ministry of Energy, Green Technology and Water conducted stakeholder consultations on the plan in 2017.

Switzerland

On 1 November 2017, the Swiss government announced a new set of energy efficiency measures as part of its broader Energy Strategy 2050. Buildings sector measures include subsidies for energy-efficient retrofits in residential dwellings and tax incentives for building demolitions to encourage total rather than partial retrofits. In the transport sector, the strategy sets a target for 2020 of 95 grams of CO_2 per kilometre for passenger vehicle emissions standards and 147 grams of CO_2/km for passenger light-duty vehicles (cars and certain trucks). The strategy also extends the Swiss competitive energy efficiency tender programme.

United Kingdom

The UK government announced a new Clean Growth Strategy in late October 2017, with energy efficiency at its heart. It includes measures to improve the efficiency of commercial buildings and industry by at least 20% by 2030. GBP 3.6 billion (USD 4.6 billion) has been allocated for residential building upgrades through the Energy Company Obligation (ECO) programme. A GBP 184 million (British pounds) (USD 236 million) innovation fund will target low-carbon heating technologies, while GBP 255 million (USD 327 million) is being made available for public sector energy efficiency improvements.

United States

California announced changes to its building codes in March 2018 as part of efforts to move toward net zero energy residential buildings. Commencing in 2019, the codes require improvements in the thermal envelope of buildings, greater use of LED lighting, installation of solar photovoltaic systems in all new homes, and measures to encourage the use of "demand-responsive technologies", such as battery storage and heat pump water heaters. California, New York and Vermont are working with utilities and other partners on so-called pay-for-performance (P4P) pilot programmes, which allow savings from energy efficiency improvements to be monetised in real time, based on meter readings.

IEA Efficient World Strategy

The Efficient World Scenario (EWS) indicates key opportunities for efficiency improvements in all sectors. It is notable that the potential for future energy savings by sector rank in reverse order of where most progress has been since 2000. While transport has the largest potential savings in the EWS, recent efficiency gains have been less than industry and buildings. For industry, energy-intensive sectors have been key contributors to historic efficiency gains (see Chapter 4). However, the EWS highlights large savings potential in less energy-intensive industry. The EWS implies reaching high levels of efficiency in many areas, but also acknowledges that ramp up and stock replacement takes time. However, the scale up in policy action must start immediately if EWS is to be realised.

Effective policy action is key to unlocking the substantial energy savings and associated benefits in the EWS. There are a wide range of policy measures that governments can consider to reduce barriers that may prevent the potential of the EWS from being realised. All of these measures have been or are currently implemented in some form, providing a basis for further development. There is a full suite of policy types and mechanisms already proven to deliver the required market responses. However, greater reach, scale and pace will be required in the application of policy, and that is why exchange among countries and learning from best practice will be vital.

The EWS opportunities represent substantial energy savings and could be unlocked through targeted policy measures, combining regulation, incentives, market-based instruments, information and capacity building measures and other tools. These opportunities and the enabling policy measures constitute the IEA's Efficient World Strategy, which maps out the priority sectors, technologies and policy actions for achieving the full potential benefits of energy efficiency (Table 1.3).

The most effective policy strategies are those that:

- **enact** ambitious policies and measures with appropriate follow-up and enforcement
- **ensure** market readiness to deliver
- **evolve** policy measures, using data to increase ambition as technology develops and costs fall.

Government policy is also important in encouraging and facilitating new finance and business models for energy efficiency. Recent finance and business model innovation offer a glimpse of the potential, but investment needs to accelerate. The energy efficiency potential of the EWS represents a large volume of attractive investment opportunities that can stimulate growth and enhance competitiveness while delivering the overarching energy and climate benefits of an efficient world.

Table 1.3 Summary of the IEA Efficient World Strategy

Sector	Opportunity in the EWS	Key government policy measures
Transport	Global transport energy demand could stay flat between now and 2040, despite doubling activity levels. Key end-use opportunities: • Passenger cars – Average passenger car in 2040 could be as efficient as today's best hybrids and 40% of the global car fleet could be electric. • Trucks – Current and planned policies could see annual efficiency improvement rates grow to 1.5%, compared with less than 0.1% since 2000, but could be over 2.5% in the EWS. • Aviation and shipping – annual efficiency improvement rates could rise to 3%.	**Regulation:** • Increased coverage and strength of fuel economy standards for cars and trucks. • Continuation and development of global targets and measures for aviation and shipping. **Finance and incentives:** • Efficiency-based vehicle taxation. • Financial support for electrification of various transport modes. **Information and capacity building:** • Information to support efficient vehicle uptake and mode shift. • Training to support more efficient transport practices.
Buildings	Total energy use in buildings could stay flat between now and 2040, despite 60% growth in total building floor area. Key opportunities: • Buildings in 2040 could be nearly 40% more energy efficient than today. • Space heating – Energy efficiency could improve by 43% between now and 2040. • Water heating – Energy efficiency could improve by 43% between now and 2040, compared with 25% improvement since 2000. • Space cooling – Average air conditioner efficiency could double between now and 2040.	**Regulation:** • Increased coverage and strength of building energy codes and standards, for both new and existing buildings. • Expanded and strengthened standards for equipment and appliances, such as electric heat pumps and air conditioners. **Finance and incentives:** • Fiscal or financial incentives to encourage consumers to adopt high efficiency appliances and undertake deep energy retrofits. • Market-based instruments to encourage investment and business model innovation. **Information and capacity building:** • Improved quality and availability of energy performance information and tools. • Expanded professional training programmes and accreditation.
Industry	Industry could produce nearly twice as much value from each unit of energy use in 2040 compared with current levels. Key sub-sector opportunities: • Light industry – 70% of potential energy savings for industry in 2040, due to over 40% improvement in efficiency compared with 16% since 2000. • Iron and steel – 14% of potential energy savings for industry in 2040, due to 25% improvement in efficiency compared with 5% since 2000.	**Regulation:** • Expanded and strengthened standards for key industrial equipment, including electric heat pumps and motors. • Mandatory measures to increase scrap metal collection and recycling. **Finance and incentives:** • Appropriate incentives to encourage the adoption of energy management systems. • Financial or fiscal incentives to increase scrap metal collection and recycling. • Market-based instruments to encourage investment and business model innovation. **Information and capacity building:** • Mechanisms such as industry networks, training and case studies to enhance awareness and capacity.

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2. TRANSPORT

Highlights

- **Passenger transport energy use increased by 38% between 2000 and 2017.** This surge was driven by a rise in activity (passenger kilometres), particularly in emerging economies; by changing transport modes, specifically lower vehicle occupancy; and by an increasing share of larger cars, which pushed up energy use by 19%. Energy efficiency improvements since 2000 saved almost 5 EJ of additional energy use in 2017, equivalent to the energy used by nearly 120 million cars.

- **Mandatory fuel economy standards have been important in boosting the efficiency of road vehicles.** The introduction and strengthening of such standards since 2000 reduced the use of oil for transport in 2017 by nearly 1.2 million barrels of oil per day (mb/d). Another 2.2 mb/d would have been saved had the best-in-class standards been adopted worldwide over that period.

- **Freight transport fuel efficiency progress has been more limited.** Higher activity levels and shifts from rail to road freight increased energy use by 65% between 2000 and 2017. Vehicle efficiency improvements and shifts towards larger trucks, which carry more load per energy use, had a limited impact, offsetting demand growth by less than 1%.

- **Five countries – Canada, the People's Republic of China (hereafter "China"), India, Japan and the United States – have adopted fuel efficiency standards for heavy-duty vehicles (HDVs), which account for around 40% of total road transport fuel consumption.** Those standards covered nearly 50% of global HDV sales in 2017. The European Union has proposed a CO_2 emission standard for HDVs, which will deliver efficiency gains.

- **New policy measures are also creating opportunities to unlock efficiency gains in non-road transport modes.** In shipping, meeting recently adopted international emissions targets will require increased efficiency levels. Innovations in aviation management and technology, as well as improved flight routing, are also contributing to ongoing efficiency gains.

- **The Efficient World Scenario highlights the potential for transport energy demand to remain flat between now and 2040, despite doubling activity levels.** At an end-use level, the average passenger car could be as efficient as today's best hybrids and over 40% of the global car fleet could be electrified. The annual rate of efficiency improvement for trucks can rise to 1.5% with current and planned policies, but in the Efficient World Scenario, the annual improvement rate could be over 2.5%. Non-road transport (aviation and shipping) could see annual efficiency improvements of 3% between now and 2040.

- **Transport presents the largest opportunity for gains in the Efficient World Scenario, but potential will not be realised without policy action.** The IEA Efficient World Strategy lays out the enabling measures that will be needed to realise this opportunity. These include expanding and strengthening standards for cars and trucks; continuing and developing global targets and measures for aviation and shipping; incentives for electrification; and information to support efficient vehicle uptake and mode shift.

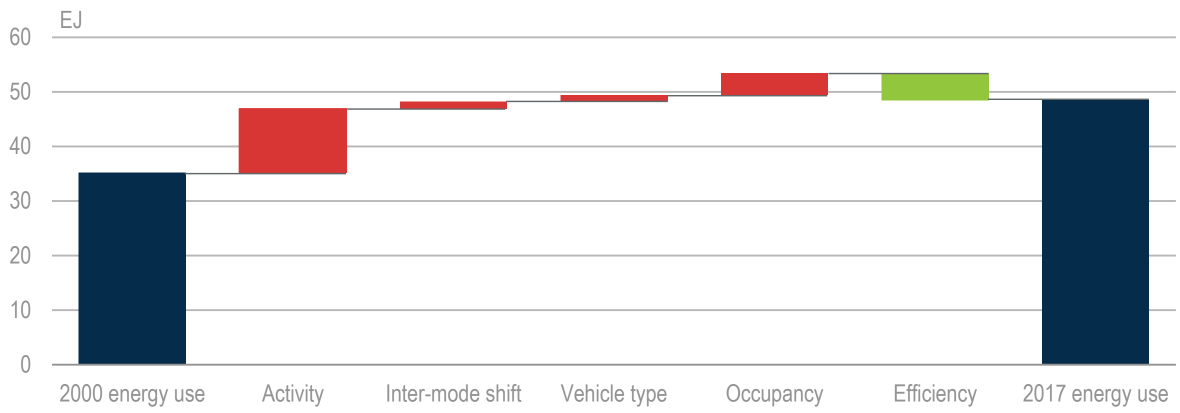
Transport energy efficiency trends and outlook

In 2017, final energy use[24] by the transport sector was around 29% of global final energy demand, representing an increase of 3.3% from 2016 and 45% between 2000 and 2017. This growth is largely due to a rise in the number of vehicles on the road as well as increasing demand for aviation and shipping. Global road vehicle sales increased by 3.1% from 2016 to 96.8 million new sales in 2017 (OICA, 2018). In 2017, a record 4.1 billion passengers travelled on flights, up 7.1% from 2016, and aviation passenger kilometres similarly rose by 7.6% (ICAO, 2018a).

Total final energy use in passenger transport increased by 38% globally between 2000 and 2017, primarily because of an increase in activity (i.e. passenger kilometres), notably in emerging economies such as Brazil, China, India and Indonesia. One-third of the growth in energy use came from lower vehicle occupancy, a shift away from public transport to cars (inter-mode shift) and an increasing share of larger cars (vehicle type) (Figure 2.1). [25]

Energy efficiency improvements since 2000 saved almost 5 EJ of additional energy use by passenger transport in 2017, equivalent to the energy used by nearly 120 million cars. The impact of energy efficiency would have been greater if not for the growing share of larger cars, such as SUVs and passenger light-trucks, which accounted for 9% of the increase in energy use between 2000 and 2017.

Figure 2.1 Decomposition of passenger transport final energy use, 2000-17



Note: Countries covered are IEA countries plus Argentina, Brazil, China, India, Indonesia, Russian Federation and South Africa. Passenger transport energy use includes passenger motor vehicles (including 2 and 3 wheelers), buses and, where data is available, rail, shipping and air transport (aviation).

Sources: Adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database); IEA (2018b), *Mobility Model* (database); IEA (2018c), *World Energy Balances 2018* (database).

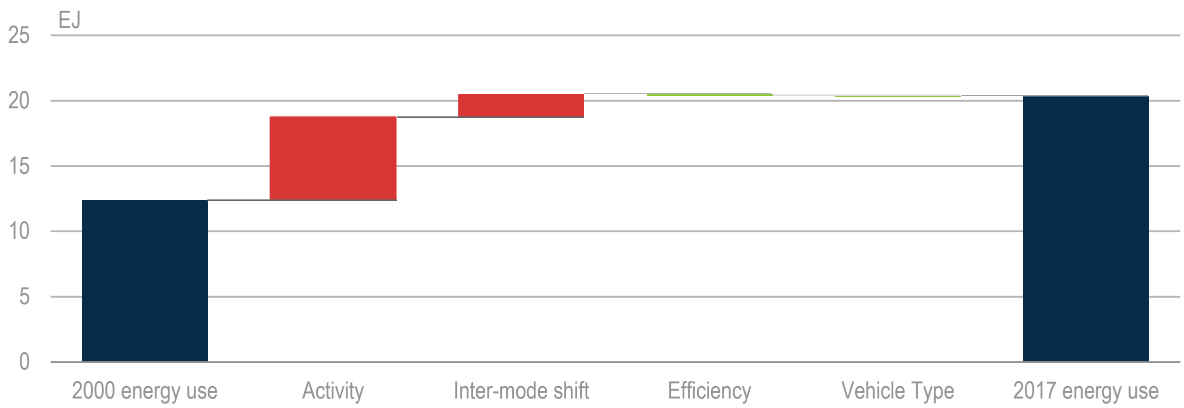
Freight transport (road, rail, maritime and air) covers around 40% of transport final energy consumption. Heavy-duty vehicles (HDVs) or trucks and buses account for almost one-third of global transport energy use and around 40% of total road fuel consumption. Freight transport represented around 20% of global oil demand in 2015 (IEA, 2017a).

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

[25] A shift from passenger cars to passenger light trucks, which includes sports utility vehicles (SUVs), multi-purpose vehicles (MPVs) and light trucks (less than 3.5 tonnes). Globally, 4 in 10 new cars sold is an SUV, a share which continues to increase, as noted in Chapter 1.

In freight transport, higher activity levels and shifts from rail to road freight increased energy use by 65% between 2000 and 2017 (Figure 2.2). Vehicle efficiency improvements and shifts towards larger trucks[26] which carry more load (vehicle type) had a limited impact, offsetting growth in energy demand by less than 1%. Freight transport's share of energy use relative to passenger transport's share increased by 7%, partially due to the difference in efficiency progress.

Figure 2.2 Decomposition of freight transport final energy use, 2000-17



Note: Countries covered are IEA members (excluding the United States) plus China, India, Brazil, Indonesia, Russian Federation, South Africa and Argentina. Freight transport energy use includes medium- and heavy-duty freight trucks, commercial 3 and 4 wheelers, light commercial vehicles and, where data is available, rail, shipping and air transport (aviation). The data for freight road tonne-kilometres and energy consumption in the United States have been revised for years 2008-11 and 2000-15 respectively, leading to a significant increase in the intensity of freight road transport compared with the previous values for the same years and a decrease in energy saving coming from this sector. Therefore, this data has been excluded. Load factors (tonne kilometres per vehicle kilometre) are not available.

Sources: Adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database); IEA (2018b), *Mobility Model* (database); IEA (2018c), *World Energy Balances 2018* (database).

Transport can accelerate towards an efficient world

Upward pressure on transport energy use has limited the impact of recent energy efficiency gains. However, the Efficient World Scenario (EWS) suggests that transport energy demand could remain flat between now and 2040, despite doubling activity levels. Passenger transport energy efficiency could improve by 2.8% per year to 2040. The historic trend since 2000 is 0.5% per year, but recently implemented and planned policies could raise this to 2%. The rate of improvement in the EWS could result in the average passenger car in 2040 being as efficient as today's best hybrids.

For trucks, implemented and planned policies could see the annual efficiency improvement rate increase to 1.5%, compared with less than 0.1% since 2000. However, the EWS sees the annual rate rise to over 2.5% (Figure 2.3). Over half of the cost-effective efficiency improvement in passenger and freight transport could come from cars and vans, followed by trucks (Figure 2.4).

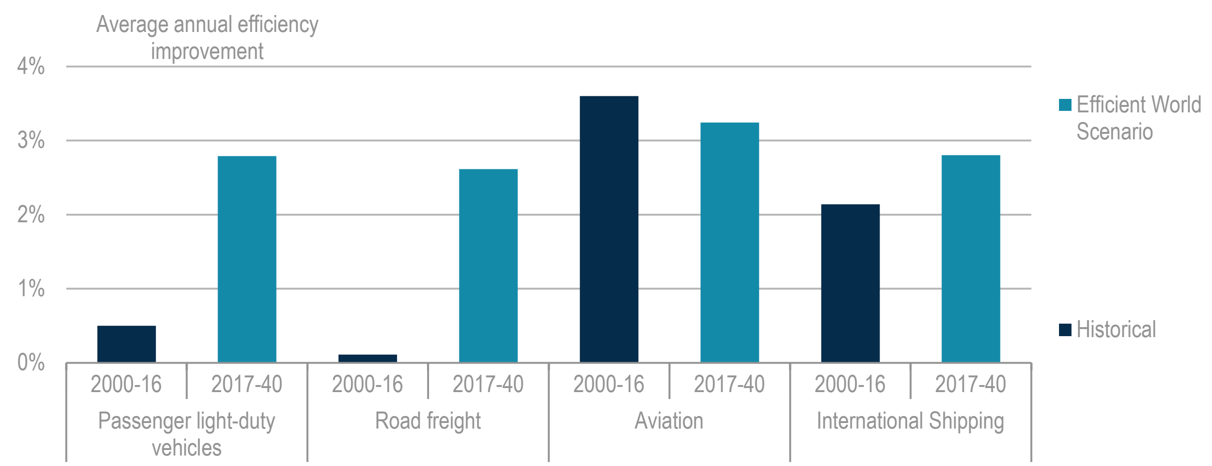
The policies that could achieve these increases in efficiency are likely to include a mix of new and more stringent fuel economy standards, continued use of efficiency-based vehicle taxation (i.e.

[26] Trucks include both medium freight trucks and heavy freight trucks. Unlike passenger cars, shifts toward larger trucks are typically more efficient as they carry a larger quantity of goods.

registration and circulation taxes), and support for electrification of various transport modes. Policies aimed at improving transport efficiency could also address behavioural trends that are pushing up energy use, such as lower vehicle occupancy and movements away from public transport, though these trends are not explicitly modelled in the EWS.

Energy efficiency improvements in aviation and shipping have historically been higher than in passenger and freight transport, although there is evidence of a slowdown in recent years. For example, aviation energy efficiency, measured as energy use per revenue passenger kilometre, has improved 3.6% per year on average between 2000 and 2016, although keeping up with this trend may be challenging, as the improvement rate from 2015 to 2016 has fallen to 1.6%. The EWS suggests there is significant cost-effective potential for improvements in aviation efficiency, especially in new aircraft and logistics, as discussed in the special focus section at the end of this chapter. Similarly, the energy efficiency improvement rate in shipping has slowed recently, with only a 1.5% improvement from 2015 to 2016 (compared with an average improvement of 2.1% between 2000 and 2016). Significant potential exists to increase this rate of improvement cost-effectively. Several policies have been put into place in recent years to tap into this potential, though more concrete measures need to be developed to match the set ambitions.[27]

Figure 2.3 Historical efficiency improvements and future projections for passenger and freight transport, 2000-40



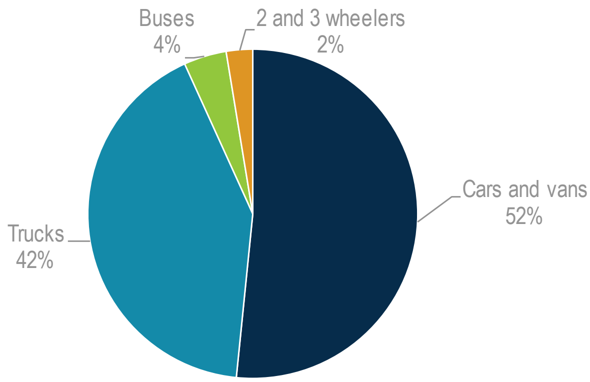
Notes: Passenger light-duty vehicles efficiency is per vehicle kilometre (vkm), road freight and shipping are per tonne-kilometre (tkm) and aviation per revenue passenger kilometre (rpk). International shipping is based on the 2000-15 historical trend in tkm.

Sources: Adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database); IEA (2018b), IEA *Mobility Model* (database).

In terms of relevance, cars and vans represent more than half of the additional cost-effective efficiency potential in the road transport sector in the EWS compared with the NPS, and trucks represent another 42% (Figure 2.4).

[27] In April 2018, the International Maritime Organisation (IMO) agreed on a strategy to cut the shipping industry's greenhouse gas (GHG) emissions in half by 2050. The Energy Efficiency Design Index (EEDI), in force since 2013, is contributing to this effort (IMO, 2018a; IMO, 2018b). Another regulation that will affect the shipping industry is the low sulphur in oil regulation that starts in 2020 (IMO, 2016).

Figure 2.4 Energy savings potential for road transport in the EWS compared with NPS, 2040



There is significant investment potential in transport efficiency

There are many ways of investing in energy-efficient transport, covering different vehicle modes and geographical scopes. In general, investments in energy-efficient transport can be grouped into three categories:

- Improve: Increasing the efficiency of existing technologies, for example enhancing internal combustion engines, improving tyres and reducing vehicle weight.
- Switch: Switching to more efficient technologies, such as electric powertrains.
- Avoid-shift: Shifting mobility towards less energy-intensive modes, such as from cars to trains, and shortening distances travelled for key activities, such as work, shopping and leisure, through urban planning or densification of cities.

Due to data availability constraints, the EWS focuses only on the first two categories for passenger transport. For freight transport, all three options have been included, including shifts towards larger truck types that could transport goods with a lower energy intensity (e.g. from medium freight trucks to heavy freight trucks), though excluding urban planning.

Transport is the sector that presents the largest opportunity to increase energy efficiency investment. In the EWS, achieving the full, cost-effective potential of energy efficiency improvements to 2040 would require 50% more investment than in the NPS. Investment in electric vehicles (EVs) accelerates during the latter part of the EWS (2026-40), as the shift toward electric mobility takes hold and prices begin to fall.

Energy efficiency investment in non-car transport modes (including two- and three-wheelers, buses, trucks, ships and planes) could grow by 65% between 2025 and 2040 relative to NPS levels, compared with only 10% between 2017 and 2025. This is because it is expected to take longer for the electrification of non-car modes to start to grow significantly.

Transport energy efficiency policy

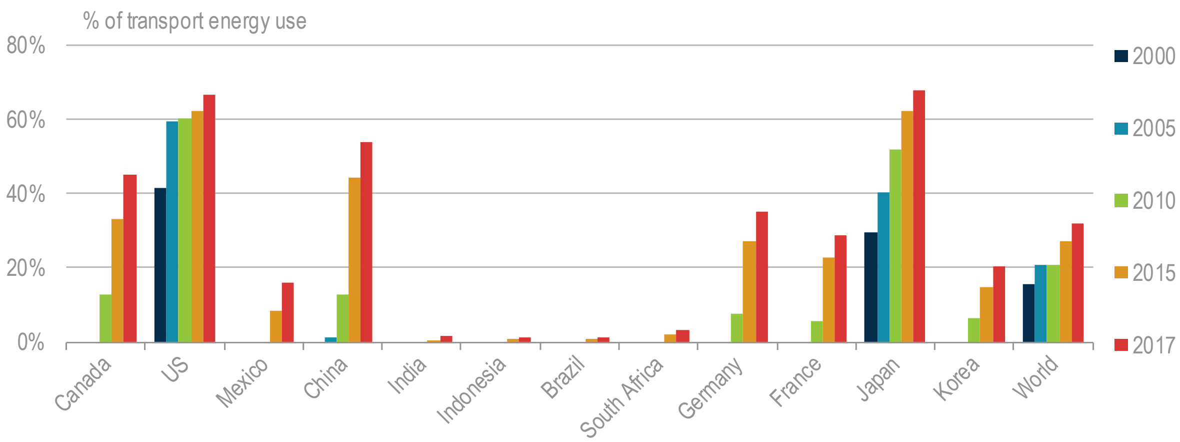
Transport policy has enabled various efficiency improvements at a time of rapidly growing demand for transport services. Average car fuel economy improvements in key markets would have stagnated during the past 15 years without the implementation and regular updating of fuel economy standards or efficiency-based vehicle taxation, such as registration and circulation taxes (IEA, 2016; GFEI, 2017). In more recent years, however, countries with existing fuel economy standards experienced a slowdown in overall efficiency improvement due to a shift towards larger cars and shifting market shares from diesel to gasoline cars.

Policy coverage has grown rapidly during record car sales

The global fleet of road and non-road vehicles is increasingly covered by efficiency standards. The combination of new policies and the purchase of vehicles covered by existing policies determines what share of the vehicle stock is subject to mandatory fuel economy standards. The growth of the vehicle market in China, Europe and the United States enabled policy coverage to increase by 2.4 percentage points to 32% in 2017 (Figure 2.5). This is the largest annual growth in policy coverage in the transport sector in the past three years. Nevertheless, mandatory energy efficiency policy coverage in transport remains lower than that in buildings and industry.

In regard to trucks, only five countries have implemented fuel economy standards: Canada, China, India, Japan and the United States. These countries accounted for nearly 50% of global HDV sales in 2017. Japan and the United States have the broadest policy coverage, due to the early introduction of fuel economy standards, but China and Europe are quickly catching up. Several emerging economies do not yet have fuel economy standards in place for either cars or trucks.

Figure 2.5 Mandatory policy coverage of transport energy use for select countries, 2017



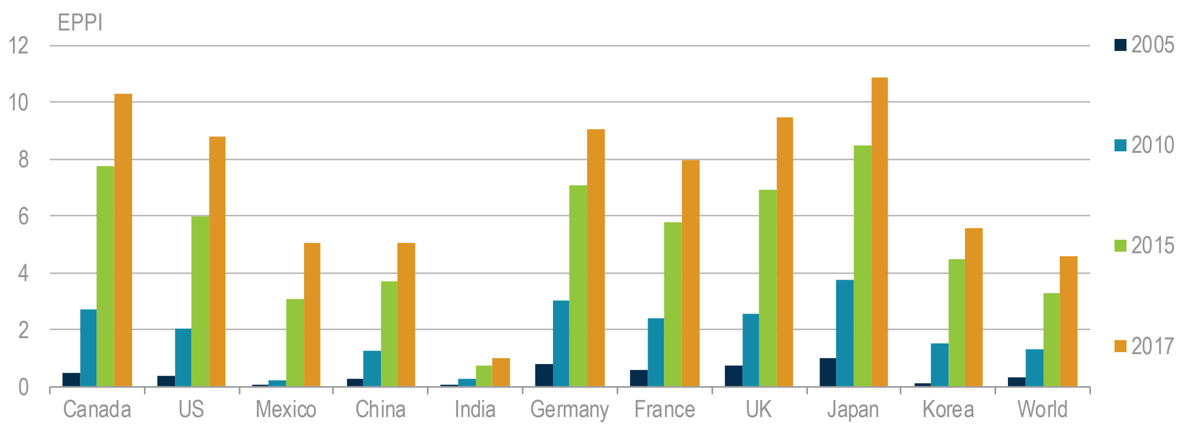
Sources: Analysis based on energy data from IEA (2017a) *Energy Technology Perspectives*; IEA (2018b), IEA *Mobility Model* (database); IEA (2017c) *World Energy Outlook*. Analysis based on policy data from IEA (2018d), *Energy Efficiency Policy and Measures Database 2018*; Odyssee-Mure (2018) (Mure database); Delgado and Rodriguez (2018), *CO_2 emissions and fuel consumption standards for heavy-duty vehicles in the European Union;* and ICCT (2018a), *TransportPolicy.Net* (database).

Policy stringency improving especially for passenger cars and trucks

The IEA Efficiency Policy Progress Index (EPPI) tracks the coverage and stringency of fuel efficiency policies. For each EPPI point, the vehicle stock is 1% more efficient than in 2000 based on policy targets. Most countries work with corporate average fuel economy (CAFE) standards, where the fuel efficiency of the average sales per manufacturer has to be better than a certain threshold[28]. As a result, actual average efficiency levels of the vehicle stock closely follow stringency levels.[29]

Efficiency policy progress has historically been slower in transport than in other sectors. Unlike in other sectors, however, growth of the EPPI score for transport has risen, from an annual average of 0.4 points between 2010 and 2016 to 0.7 points from 2016 to 2017, after numerous new regulations came into force (Figure 2.6). As with policy coverage, the largest contributions to policy stringency are from cars and passenger light trucks in China, Europe and the United States. The United States is growing the fastest, at 1.5 points in 2017, following the kick-off of the 2017-25 phase of the CAFE standards and phase 2 (2018-27) of HDV fuel economy regulations. Despite new policy announcements for shipping and aviation, these non-road vehicle modes are not expected to make substantial contributions to the EPPI score until the mid- to late-2020s.

Figure 2.6 Efficiency Policy Progress Index for transport end-uses by key region, 2000-17



Note: World includes all countries beyond the list of countries in this graph.

Sources: Analysis based on energy data from IEA (2017a), *Energy Technology Perspectives*; IEA (2017), *World Energy Outlook;* IEA (2018b), IEA *Mobility Model* (database). Analysis based on policy data from IEA (2018j), *Policy and Measures Energy Efficiency Database 2018*; Odyssee-Mure (2018), Mure Database, accessed 9 July 2018; Delgado and Rodriguez (2018), *CO_2 Emissions and Fuel Consumption Standards for Heavy-Duty Vehicles in the European Union*; and ICCT (2018a), *TransportPolicy.Net* (database).

Significant energy savings realised from transport policies, but steep road ahead

Policy coverage and stringency improvements for light-duty vehicles have been central to efficiency progress to date, though differences in efficiency levels between vehicle markets indicates there is still untapped potential (IEA, 2016). Existing fuel economy standards[30] since 2000 saved nearly 1.2 million barrels of oil a day (mb/d)[31] by 2017, equal to almost 95% of global oil demand growth

[28] The fuel efficiency of individual cars can be worse than the threshold level, as long as it is compensated by enough cars that are better than the threshold level.

[29] Most equipment and appliance standards regulate the minimum performance level per product, which is not directly linked to the market average efficiency.

[30] Freezing fuel economy levels at the first year a fuel economy standard has been implemented from 2000.

[31] Relative to 2.5 mb/d, starting from the first fuel economy standards (United States in 1978 and Japan in 1979).

between 2016 and 2017 (IEA, 2018e). Implementing the best-performing standards[32] in terms of relative improvement (from a 2000 baseline) globally could have saved another 2.2 mb/d, which would have tripled the achieved savings. The majority of the potential savings would have come from North America (Canada and the United States) and the major emerging economies (Brazil, China, India, Indonesia, Mexico and South Africa), each representing one-third of the potential savings.

Figure 2.7 Historical and future change in global passenger car energy use without standards and if best-in-class fuel economy standards had been implemented, 2000-17 and 2017-40

Note: Passenger car standards are based on the Japanese standard, while passenger light trucks and light-commercial vehicles standards are based on the United States regulation.

Sources: Analysis based on IEA (2018b), *Mobility Model* (database) and ICCT (2018a), *TransportPolicy.Net* (database).

Nearly all existing fuel economy standards for light-duty vehicles focus on new vehicle sales and target yearly improvement rates of 1.2 to 6.6%.[33] On the basis of existing stock, these stringency levels translate to an improvement rate of around 2% per year. In the EWS, unlocking the full potential of cost-effective energy efficiency opportunities enables an average improvement of 2.8% per year based on stock, meaning that policy strength could be increased by at least 40%, while achieving full policy coverage.

Fuel economy standards have been successful in improving the energy efficiency of new passenger vehicles, but the opportunities available today based on current technologies suggest that the efficiency of the global car fleet could cost-effectively double by 2040. This means that the average car globally would be as efficient as a today's best hybrid vehicles. In the EWS, 43% of the passenger car fleet would be electric by 2040, compared with 14% in the NPS.

[32] Japanese fuel economy standards for passenger cars and United States fuel economy standards for passenger light trucks and light-commercial vehicles.

[33] Annualised improvement rate from 2016 baseline until the end of the policy timeframe, which is different for each country.

Four key kinds of policy action could be considered to realise the full potential for energy efficiency within the EWS:

- Setting stringent fuel-economy and emissions standards on a timeline that allows automakers, component suppliers and their upstream providers to adapt new models and production lines.
- Kick-starting markets by mandating a specified percentage of low-emissions vehicles in public procurement to create economies of scale, targeting key cost drivers (e.g. batteries) and vehicle types (e.g. buses and cars).
- Establishing new financing mechanisms that take advantage of lower operating costs to reduce upfront cost barriers.
- Exploring opportunities to implement technology-neutral, alternative taxation systems, such as activity-based taxation, to provide more direct links with infrastructure utilisation and local air pollution challenges while providing stable tax income for governments.

New policies will drive transport efficiency policy coverage and progress

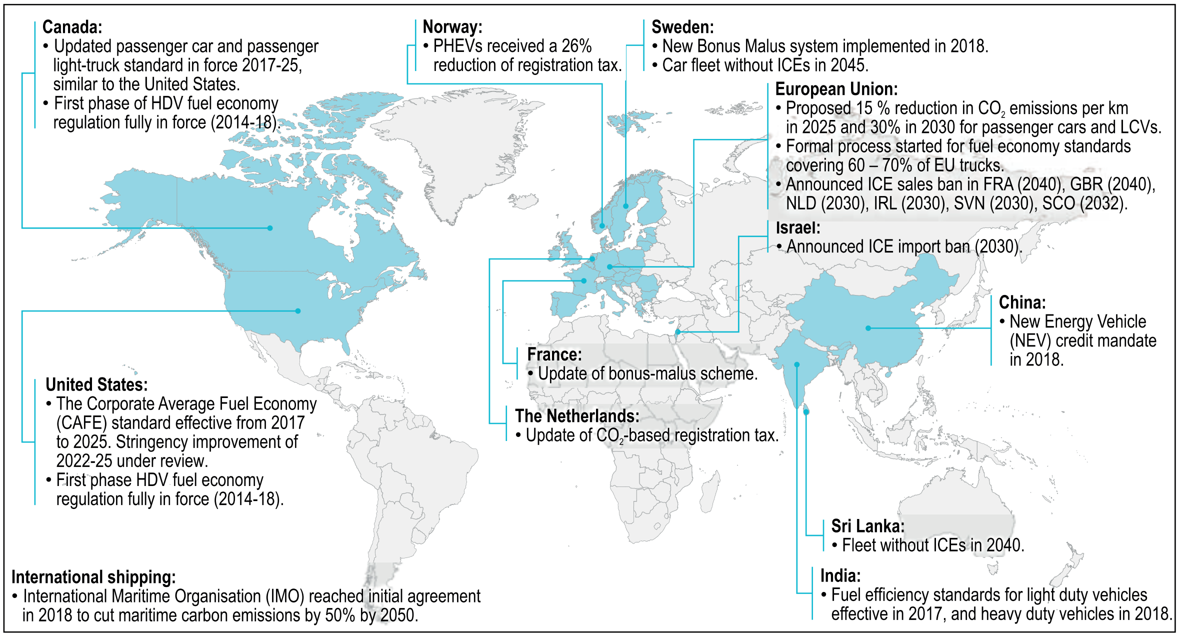
In 2017, several key countries and regions proposed, enacted or updated new policy measures for various vehicle modes in order to set transport energy efficiency on a path toward the full potential represented in the EWS (Figure 2.8). These measures have increased policy coverage, the share of transport energy use covered by an energy efficiency policy, and policy stringency. Some significant examples of mandatory fuel efficiency standards, captured in the EPPI results above, are discussed in the section below. While these new or proposed measures will move us forward, further improvement in coverage and stringency is required to realise the full energy efficiency potential available in the transport sector.

India's passenger car fuel economy standards take effect

In 2017 there were 3.5 million new car sales in India, making it the fifth-largest new passenger vehicle market globally after China, the United States, Japan and Germany (IHS Markit, 2018). India's first fuel efficiency standard became effective from April 2017, meaning manufacturers must meet average new-car fleet targets of 130 gCO_2/km (or 10% more efficient than Mexico's current standard). In 2022 the stringency of this standard will increase by 13% (similar to China's standard in 2020) (ICCT, 2018a). Updated and improved test procedures will be introduced from 2023 (Dinodia et al, 2018).[34]

[34] The Indian standard currently uses the New European Drive Cycle (NEDC), which is less representative of real-world driving conditions. From 2023, a Real Driving Emissions (RDE) testing programme will be introduced to help ensure that on-road emissions match laboratory certification conditions, notably with respect to NO_x emissions from diesel cars.

Figure 2.8 Overview of key new or updated national or supranational transport energy efficiency policies, 2017-18



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Note: ICE = internal combustion engine; GHG = greenhouse gas; HDV = heavy-duty vehicle; PHEV = plug-in hybrid electric vehicle. LCV = light-commercial vehicle.

Sources: Canada: ICCT (2018b); Norway: IEA (2018f); Sweden: IEA (2018f); European Union: EC (2018a,b), IEA (2018g); Israel: Times of Israel (2018); France: Government of France (2018); United States: ICCT (2018d, 2018f); China: ICCT (2018e); Netherlands: Dutch Tax Authority (2018a, 2018b); Sri Lanka: IEA (2018g); International shipping: IMO (2018a, 2018b), IMO (2016); India: Garg and Sharpe (2017), ICCT (2017a), ICCT (2018c).

European Union proposes a CO_2 standard update for light-duty vehicles

In November 2017, the European Commission proposed an update of the CO_2 emissions standards for new cars and light commercial vehicles, targeting a 15% reduction in vehicle CO_2 emissions by 2025 and a 30% reduction by 2030 (EC, 2018b). The updated standards also require the use of a more stringent testing procedure, in force for new car models from September 2017 and for all new car registrations from September 2018.[35] In addition, the proposed regulation outlines a vision that includes specific production shares and incentives for low- and zero-emissions vehicles. Manufacturers achieving a share of low- and zero-emissions vehicles higher than a proposed threshold will be rewarded in the form of a less strict overall CO_2 target.

The European Parliament has recently voted for a more stringent proposal than that put forward by the European Commission, targeting a 20% reduction in CO_2 emissions for new cars and vans by 2025 and a 40% reduction by 2030 (European Parliament, 2018). The European Council has since agreed

[35] The updated standards use the more stringent Worldwide Harmonised Light Vehicle Test Procedure (WLTP) to replace the NEDC as test cycle for the current target of 95 grammes of CO_2 per kilometre (gCO_2/km) for cars and 147 gCO_2/km for LCVs for 2020/2021. The WLTP aims to reflect real-world driving conditions more accurately than the NEDC, which increasingly underestimated real-world fuel consumption and emissions (Tietge et al., 2017). The WLTP came into force for newly introduced car models from 1 September 2017 and covers all new car registrations from 1 September 2018 (WLTPfacts, 2018).

on a middle-ground CO_2 emissions reduction target of 15% for new cars and vans by 2025, and 2030 reduction targets of 35% for new cars and 30% for new vans (Dieselnet, 2018). Negotiations between the European Commission, Parliament and Council to finalise the standard started in October 2018.

Heavy-duty vehicle regulations are expanding to India and the European Union

India introduced new fuel efficiency standards for commercial HDVs (including buses) in August 2017, with the first phase taking effect in April 2018 and the second in April 2021. The standard is a minimum performance regulation applying to all trucks and buses over 12 tonnes, accounting for 60% of Indian HDV fuel use (Garg and Sharpe, 2017). In contrast with existing US and Canadian standards that apply to each manufacturer's sales-weighted average, every truck is required to meet the target.

In May 2018, the European Commission submitted a proposal for a CO_2 emissions performance standard for new HDVs (EC, 2018a). The target currently covers four groups of trucks, representing 65% to 70% of CO_2 emissions by HDVs in the European Union (EC, 2018a). The proposed standards target a 15% reduction in CO_2 emissions of new HDVs by 2025 compared with a 2019 baseline, and 30% by 2030, with a review of the targets in 2022 (EC, 2018a). The targets apply to each manufacturer on a sales-weighted basis across all truck sub-groups in order to allow manufacturers to cost-optimise the balance of savings among their HDV fleet.

Compared with the other standards, the relative savings target is higher than India, Japan and China, but lower than the United States and Canada relative to their respective baselines (Delgado and Rodriguez, 2018). However, as the average fuel economy of trucks in Europe was 14-22% better than the United States in 2016, the standard would be the most stringent to date (IEA, 2017a). In the United States and Canada, the HDV fuel efficiency standard concluded its first phase in 2017 (increasing from a 2010 baseline). Its stringency remains stable until 2021 then increases further until 2027 with a 2017 baseline.

China boosts fuel economy improvement with extensive support for EVs

New transport efficiency policies take effect in China in 2018, complementing the government's already ambitious fuel economy standard 5.0 L/100km by 2020 (IEA, 2017b). The New Energy Vehicle (NEV) credit mandate sets minimum production requirements for a range of electric vehicles, including plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) (MIIT, 2017; ICCT, 2018b). In addition, some flexibility is offered through a credit trading mechanism.

China's national Electric Vehicle Subsidy Programme was amended to push manufacturers towards producing electric vehicles with ranges that are more comparable to conventional cars, as well as batteries with higher energy densities.[36]

[36] China's national Electric Vehicle Subsidy Programme grants subsidies for the purchase of electric cars. The level of subsidy allocated depends on three characteristics: the vehicle range in kilometres (km); energy efficiency in kilowatt-hours per 100 km (kWh/100 km); and battery pack energy density in Watt-hour per kilogram (Wh/kg). In February 2018, the programme was amended, lowering the subsidy level for PHEVs and low-range BEVs (less than 300 km), and increasing the levels for long-range BEVs (more than 300 km). This means that those EV models that are subject to the largest cost increment with respect to combustion engine vehicles receive larger subsidies (MIIT, 2017). These changes are intended to push car manufacturers to invest in electric cars with ranges closer to those of ICE cars (IEA, 2018g).

Standards under scrutiny in the United States

In April 2018, the US Environmental Protection Agency (EPA) announced a change in greenhouse gas (GHG) emissions standards for new light-duty vehicles sold in the United States between 2022 and 2025 (US EPA, 2018). This decision followed a planned mid-term evaluation of the standards, in which the EPA determined that the standards set during the previous administration were too stringent in light of recent trends in the penetration of fuel efficiency technologies and fuel price developments (US EPA, 2018). In addition, in August 2018, new details were released that propose a freeze of the model year (MY) 2020 standards between 2021 and 2026 instead of an increase (US EPA, 2018a).

California, which was granted a waiver by the EPA to implement its GHG emissions standards in 2009 (Federal Register, 2009), has announced its intention to maintain its more stringent rules even if federal standards are rolled back (Davenport and Tabuchi, 2018). However, the federal government is considering a withdrawal of this waiver (NHTSA, 2018).

These announcements do not directly affect the most recent fuel economy standards, which came into effect in 2017 for light-duty vehicles.

International Maritime Organisation greenhouse gas strategy 2050

In April 2018, the International Maritime Organisation (IMO) adopted its first strategy to reduce GHG emissions from ships (IMO, 2018a). To meet the IMO targets, the shipping industry will need to adopt energy efficiency measures and low-carbon fuels much faster than it has done to date. The transition to low-carbon fuels is more challenging in the shipping industry than in other sectors, because opportunities for electrification are limited and low-carbon fuels are costly. Due to the international character of the sector, transitions to certain low-carbon fuels may also require global changes in refuelling infrastructure. As a result, efficiency improvements are likely to be the primary driver of GHG reductions, at least in the short to medium term, representing up to two-thirds of the potential (IEA, 2017c). There is significant scope to improve technical and operational energy efficiency, both in new ships and by retrofitting existing ships. For new ships, the efficiency improvement potential is about 50-60% compared with the IMO’s energy efficiency design index baseline (average efficiency design for ships between 1999 and 2009) (IEA, 2017c).

Transportation energy efficiency technology

Diesel on its way out?

Diesel vehicles are still the largest contributor to global passenger vehicle fuel efficiency improvements, as they generally have better fuel economy than gasoline vehicles and are sold in larger quantities than electric vehicles. However, diesel car sales have dropped in all core markets, a trend that is inflected by the fact that diesel vehicles emit pollutants (NO_x and particulate matter) at levels that exceed regulatory limits.[37] Several governments and manufacturers have announced plans to move away from internal combustion engine vehicles (diesel and gasoline) and towards alternative electric and hybrid vehicles (Table 2.1). Eleven countries, representing 8% of global passenger car sales, have announced scheduled bans on non-electrified vehicles, and 19 cities have announced impositions on sales or access restrictions on combustion engine vehicles (IEA, 2018h).

[37] IEA analysis based on IHS Markit (2018).

Many diesel bans first focus on older diesel cars to ensure a gradual transition. In efficiency terms, for cars of comparable size and power, the advantage of diesel over petrol vehicles is still a significant 1.5 L/100km (IHS Markit, 2018).

In addition to specific bans on internal combustion engines, by 2017 nearly all car manufacturers had included or expanded plans for electric cars within their strategies, showing a strong commitment to develop alternative powertrains (IEA, 2018g; IEA, 2017a). Between 2016 and 2017, the range of cumulative car manufacturer targets for electric vehicle deployment in 2025 increased from 42-70 million to 47-101 million electric cars[38] on the road. Meeting the most ambitious of these announced targets aligns with the EWS trajectory.

Table 2.1 Announcements by car manufacturers related to curbing or halting production of internal combustion engine cars

Manufacturer	2017 sales (millions)	Planned policies
Toyota	8.0	Stop selling diesel cars in Europe by the end of 2018.
Fiat Chrysler	4.1	Phase out diesel across its model line-up as of 2022.
Honda	3.7	Discontinue production and sales of a flagship diesel-powered vehicle in Europe.
Peugeot (PSA)	3.2	All vehicles are electrified with HEV and PHEV in 2025 for global market.
Chongqing Changan	2.6	All vehicles are electrified with HEV and PHEV in 2025 for Chinese market.
Beijing Automotive Industry Holding (BAIC)	2.0	All vehicles are electrified with HEV and PHEV in 2025 for Chinese market.
Mazda	1.1	All vehicles are electrified with HEV, PHEV and BEV in 2030.
Subaru	1.0	Withdraw diesel car production and sales by FY 2020.
Jaguar Land Rover	0.6	All vehicles are electrified with HEV and PHEV in 2020 for global market.
Volvo	0.5	Stop developing diesel engine, all vehicles are electrified with HEV and PHEV in 2025 for global market.
Porsche	0.2	No diesel units in production; focus on optimised gasoline, HEVs, PHEVs and BEVs.

Sources: Campbell (2018) for Fiat Chrysler; Nikkei (2017a) for Honda; Porsche (2018) for Porsche; Nikkei (2017b) for Subaru; Toyota Europe (2018) for Toyota; Reuters (2017a) for Volvo; Reuters (2017b) for BAIC, Reuters (2017c) for Chongqing Changan, Jaguar Land Rover (2017) for Jaguar Land Rover; Automotive News (2018) for PSA; CNET (2018) for Mazda; New registrations (sales) from IHS Markit (2018).

Multi-modal electrification is becoming more of a reality

Most of the interest in electric vehicles focuses on passenger cars. However, other modes are gaining increasing amounts of attention. Electric two-wheelers are already mainstream and cost-competitive with comparable ICE versions in China. Other markets such as Europe are also starting to embrace them (IEA, 2018g).

Truck and bus manufacturers are also announcing changes. With over 370 000 electric buses on the road, China covers more than 95% of the global electric bus market (IEA, 2018g). China's largest bus manufacturers, BYD and Yutong, are becoming increasingly active on the global market. Various

[38] Battery-electric vehicles and plug-in hybrid electric vehicles.

manufacturers in Europe (Volvo, Solaris, VDL, Ebusco and Linkker) and North America (Proterra) are catching up, with a range of models.

Medium and heavy freight trucks have been more challenging to electrify due to the required battery size and weight. However, various truck manufacturers have announced electric models (IEA, 2018g). The highest feasibility is for inner-city trucks that would have to deal with increasingly stringent air pollution standards and more start-stop movements. The news in November 2017 of the Tesla Semi, a heavy freight truck, sparked announcements by Daimler, Renault and Nikola[39] that they were developing similar electric trucks (IEA, 2018i). Another option, the construction of overhead lines on key highways, is being piloted in Germany and Sweden (IEA, 2017a; IEA, 2018g).

Transportation energy efficiency price drivers

The cost of the most efficient vehicles differs across countries

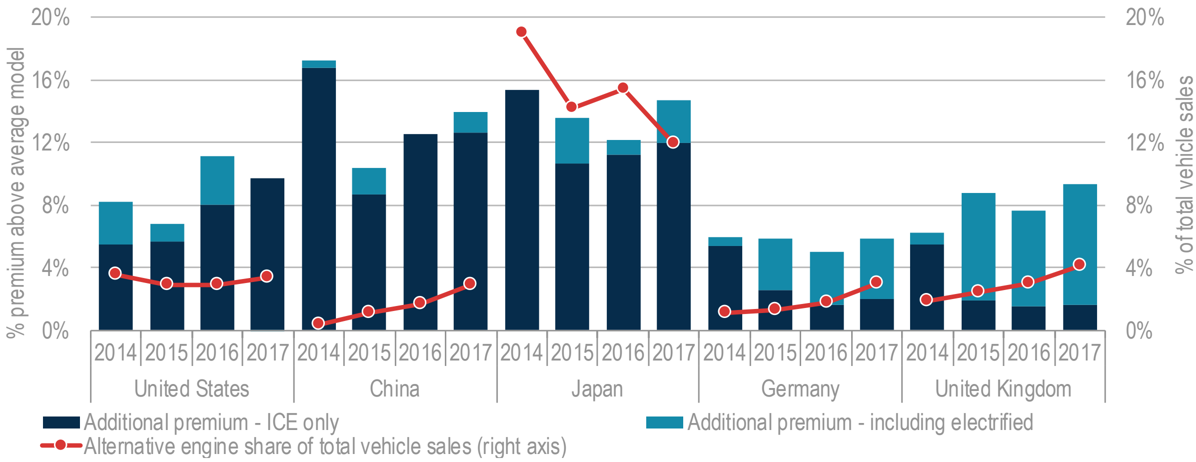
The additional cost of an energy efficient vehicle compared with a conventional vehicle of similar size and power differs considerably between countries (Figure 2.9). China, Japan and the United States are dominated by gasoline cars, whereas Europe has a higher share of diesel cars. Japan, one of the most technologically advanced markets for cars, has the highest share of alternative powertrains, making it more expensive to buy the most efficient version within each vehicle class. In China, where vehicles are less expensive than in Europe and the United States, additional energy-efficient technologies cost a higher percentage of the purchase price. In Europe, diesel vehicles offer a cost-competitive option to improve energy efficiency. This effect is less pronounced in the United States where diesel is less prominent, leading to higher premiums. However, the lower average efficiency of gasoline cars results in a lower premium to buy an efficient gasoline vehicle compared with Japan, where average vehicle efficiency is higher.

The price premium for energy-efficient vehicles increased or was stable for most countries between 2014 and 2017. This premium refers to the additional cost required to purchase a car that is in the top 25% most efficient, compared with a vehicle of average efficiency. This includes EVs. The primary reason behind the observed price premium trend is the increasing penetration of more complex and expensive powertrains such as hybrids, plug-in hybrids and battery electric vehicles. Economies of scale and integrated design for these alternative engine vehicles (e.g. reducing the weight of the car body) are necessary to bring prices down to the levels of efficient ICE cars.

Electric vehicles currently require a considerably higher price premium than other efficient vehicles, though this gap has narrowed over the past four years, partly because battery prices are falling (IEA, 2018g). In the United States, electric vehicles are often large and marketed in more expensive segments, commanding higher premiums. In Europe, particularly in France and the United Kingdom, electric cars are aimed more towards city use and less luxurious segments, and thus command less of a premium. The electric vehicle market is still in the early stages of development in many countries, so these decreasing price trends are still preliminary. In China, where growth in electric vehicle sales has been unprecedented, a clear trend in premiums is yet to emerge because the market is changing rapidly. Currently, electric vehicles cost 250% more than comparable vehicles before government subsidies, which reduce the premium to similar magnitudes as in other countries.

[39] Fuel cell range extender.

Figure 2.9 Additional premiums to purchase energy efficient or electrified cars and light commercial vehicles



Source: IEA analysis based on IHS Markit (2018).

Notes: This figure shows the additional costs, as a percentage of the purchase price, required to buy an energy efficient vehicle over a vehicle of similar size and power. It also shows the share of new car sales which are a hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs) or battery electric vehicles (BEVs). A purchase of an energy efficient vehicle here refers to the additional cost required to purchase a vehicle within the top 25th percentile of a given size and power segment, it includes electric vehicles. These percentage premiums are averaged per country, year and weighted by the registrations in each size and power segment.

Consumers have long been prepared to pay more to purchase a diesel vehicle with the promise of better fuel efficiency and lower fuel costs than a gasoline alternative. New hybrid and electric vehicles similarly have a higher upfront purchase price and have even lower running costs. Governments can give consumers incentives to switch from diesel to hybrid and electric vehicles by introducing CO_2-based registration taxes, such as the bonus-malus scheme in France and Sweden, and updated CO_2-based private and company car taxes in the Netherlands (Government of France, 2018; IEA, 2018f; Dutch Tax Authority, 2018a, 2018b). In the past decade, diesel fuel in Europe has been taxed on average 25% less than gasoline per litre. In Europe alone, EUR 25 billion (Euros) (USD 29 billion) in annual tax revenues could be generated by equalising gasoline and diesel fuel taxes – more than double the global government incentives given to electric vehicles in 2017 (see Chapter 1).

Pump prices up since the second half of 2017

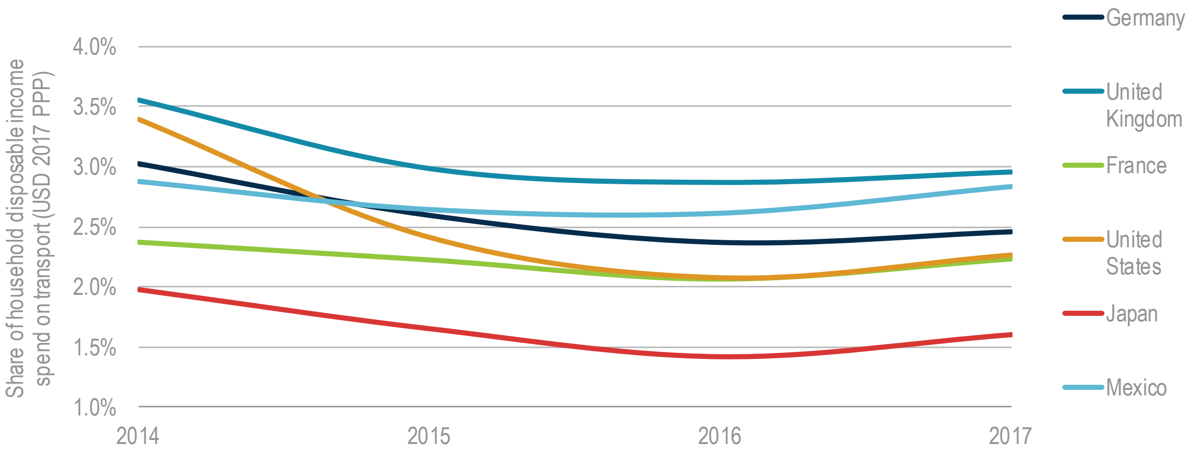
After more than two years of low prices, the crude oil price increased by more than 30% during the second half of 2017 (IEA, 2018e).[40] During the same period, prices at the pump grew between 5-11% in Europe and 9-15% in North America, with further growth in the first half of 2018. Historically, such price growth has increased uptake of energy-efficient vehicles and reduced overall driving mileages (Sorrell, Dimitropoulos and Sommerville, 2009; Brons et al., 2008; Burke and Nishitateno, 2013). However, the effects of less efficient vehicles purchased during past low oil prices will be locked in

[40] Based on Brent oil prices.

for many years. In addition, as more electric vehicles enter the market, the attention paid to the price associated with charging is increasing (Box 2.1).

After three years of decline, household income spent on vehicle refuelling increased between 2016 and 2017 (Figure 2.10), despite growing shares of electric mobility and strong economic growth in most countries. The response to the rising oil price highlights the risk of locking in higher fuel expenditure if consumers chose to buy a less efficient vehicle when oil prices are low.

Figure 2.10 Income spent on car refuelling in selected countries, 2013-17



Note: 2017 energy use is estimated. Income is spread over the entire population. For vehicle owners, expenditure is 40-100% higher.

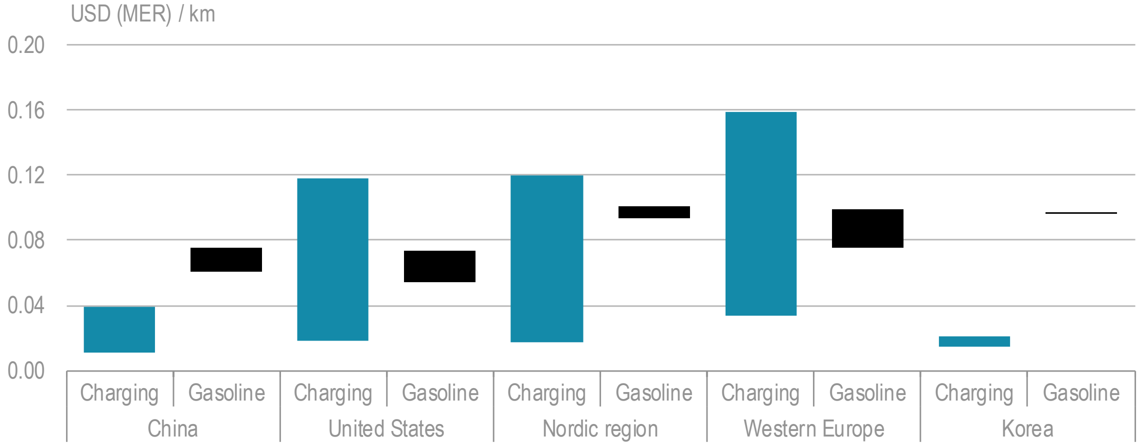
Sources: IEA analysis based on IEA (2018b), *Mobility Model*; IEA (2018h), *World Energy Prices 2018* (database), IEA (2018c), *World Energy Balances 2018* (database), OECD.STAT.

Box 2.1 Range of refuelling prices of electric cars compared with gasoline

The refuelling market for electric vehicles is diversified as many players try to enter the market. In 2015, Europe alone already had more than 300 different types of contracts and charging cards, with large price differences between various charging options (Figure 2.11) (Hubject, 2015). The IEA *Nordic EV Outlook 2018* highlighted the fact that charging tariffs can be two to three times higher for fast charging than for private charging (IEA, 2018f). Similar patterns were found for the US charging market (RMI, 2017).

In the current transport refuelling market, gasoline and diesel are sold per litre (with a stable energy content). As electricity can be refuelled in more locations (home, work, on-street), and electricity prices change over the course of a day, a range of business models are being tested. Hence, in per-kilometre terms, charging tariffs can be 85% cheaper or up to 60% more expensive than gasoline.

Figure 2.11 Variability of vehicle recharging tariffs for key regions, 2017



Note: Charging prices include private charging with embedded payback of charging equipment, publicly accessible slow charging and publicly accessible fast charging. Free charging is excluded. Prices are in USD at market exchange rates based on period average exchange rates from OECD.stat (OECD, 2018). The gasoline price is based on premium unleaded 95 RON and regular unleaded gasoline (Korea) converted by the average fuel economy of the World Light-Duty Test Cycle (WLTC) and an ICE vehicle. In Europe, the variability is driven by monthly averages of all available countries in 2017. In the United States, the price range is determined on a weekly basis for key regions set by the Energy Information Administration. In China, gasoline variability is based on weekly gasoline prices in Beijing in 2016 (latest available). Public fast charging in China has a maximum tariff and a variable electricity price depending on the time of the day. The Korean government has set a cap of KRW 173.8 (Korean won) per kWh for fast charging. Western Europe is represented by various charging point operators in Austria, Belgium and the Netherlands. The gap in fuel economy is based on IHS Markit (2018), comparing the average fuel economy of new electric cars and non-electric cars in 2017.

Sources: IEA (2018h); EIA (2018); FastNed (2018); IEA (2018f); BNEF (2017); Flowcharging (2018); IEA HEV TCP (2017); Xcharge (personal communication, 27 March 2018).

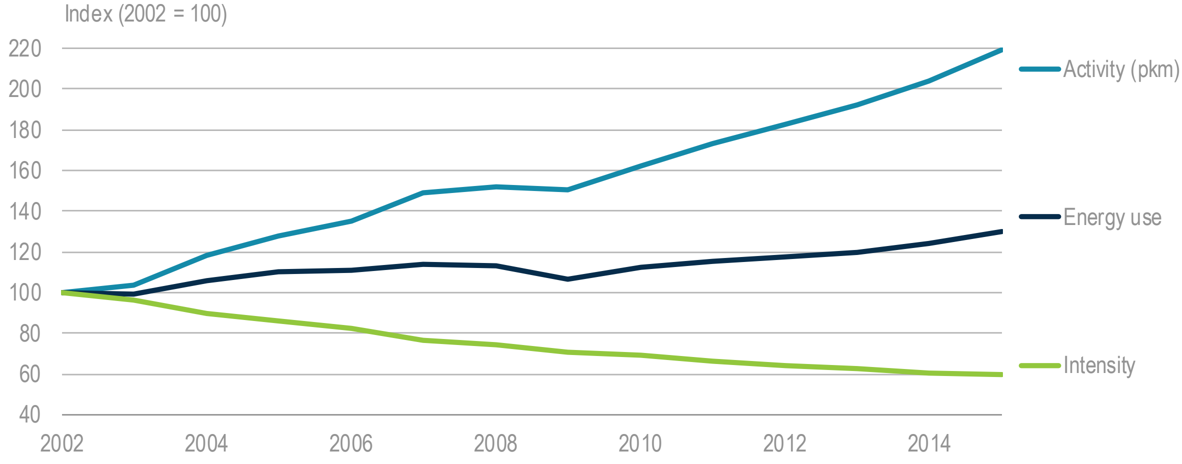
Special focus: Aviation

Aviation efficiency has improved but future gains will be more challenging

Demand for air transport has grown considerably, reflecting the increasingly global nature of business and leisure travel. Demand is projected to increase by 3.8% annually and reach 17 trillion passenger kilometres by 2040, more than triple that in 2010 (IEA, 2017c). As jet fuel represents around 30% of aviation operating costs, improved energy efficiency has long been pursued as means of improving profitability (Lee et al., 2001). Between 2000 and 2017, aviation energy use per passenger kilometre improved by an average annual rate of 3.7%, mostly because the average number of passengers per flight increased, influenced by the rise of low-cost airlines that use newer, more efficient aircraft and provide more budget travel options. Without these improvements, observed demand growth would have resulted in an additional 68% energy use in 2017, equivalent to total fuel demand of international shipping.

In the EWS, aviation energy efficiency increases by one-third between now and 2040. Historically, efficiency has been increased through technological advances in jet engines, improved aerodynamics and more passengers per flight. Sustaining historical improvement rates will be challenging, however. The largest potential efficiency gains can be obtained by completely redesigning aircraft. Considering the long lead times and investment required, such measures are unlikely to be realised before 2030. Radically different engine technologies (such as electric motors or fuel cells) are also unlikely to be feasible in the near future (Sarlioglu and Morris, 2015).

Figure 2.12 Indexed aviation energy intensity trends, 2002-15



Sources: IEA (2018c); ICAO (2018d).

Note: Includes both domestic and international aviation. Year 2002 values are as follows, Total Final Energy Consumption 9.3 EJ, pkm 3025 billion, Intensity 3.1 MJ/pkm.

In the short term, a series of incremental efficiency improvements are possible, in the range of 10% to 30% (Schafer et al., 2015), which will contribute to realising the potential gains in the EWS. Business-as-usual improvements linked to the adoption of a new generation of aircraft, such as the Airbus A320 NEO and the Boeing 737 MAX, could improve fuel efficiency by 15%. More ambitious measures could unlock greater efficiency gains in the short term, including early adoption of new aircraft or retrofitting new engines to existing aircraft.

The largest influence on aviation efficiency in recent years, in terms of energy per passenger kilometre, has been the increase in the number of passengers per flight. Many new aircraft have considerable flexibility regarding passenger numbers. For example, the Airbus A380, the largest commercial passenger aircraft in the world, can in theory accommodate 868 passengers in an economy class set-up (Airbus, 2018), but the provision of business and first-class seating options reduces the average real capacity to about 500 seats (SeatGuru, 2018).

Operational improvements such as better aeroplane routing can also reduce energy use (Box 2.2). It is typically more efficient to break up very long-haul flights (around 10 000 km) into separate legs (e.g. 2 x 5 000 km) to reduce the weight of the fuel carried per flight (Green, 2006). Other possible operational changes include electric aircraft taxiing, as currently an estimated 6% of fuel is burnt on the ground at airports (Greener by Design, 2017), and giving pilots incentives to adopt more efficient behaviours (Dobruszkes and Givoni, 2013). Emerging technology options, such as engine retrofits, could enhance efficiency further.

Box 2.2 Shortening flight distances through better routing

The European IRIS project is a new technology for the routing of aircraft that uses satellites for air traffic management to complement traditional radio transmission. Currently, aircraft have to fly over "checkpoints" to interact with ground-based radio transmissions. This means flights often are not able to take the shortest route between airports, adding an average 42 km to the distance of each flight. By using satellite navigation, IRIS will be better able to route flights and manage congestion in the skies.

These routing improvements are projected to reduce fuel use by 5% to 10% for a typical European journey (SESAR, 2015).

A similar scheme to improve aircraft routing was introduced in 2018 by ENAV, the Italian agency overseeing flight routing. It frees aircraft flying above 9 000 m to take a more efficient route than normal, saving an estimated 22.8 km per flight and a total of 37 000 tonnes of fuel and 116 000 tonnes of CO_2 in 2017 (ENAV, 2018).

Current policies and developments

Energy efficiency policy for aviation is complicated by its international nature, as most aircraft cross several regional and national jurisdictions. However, several national and international policies have been recently introduced, with the aim of providing incentives for investment in energy efficiency and emissions reduction.

Emissions trading

The European Union Emissions Trading System (EU ETS), along with smaller trading schemes that operate in Korea and Shanghai, covers emissions from aviation. In Europe, the ETS operates as a "cap-and-trade" system: any emissions above a level equal to 95% of 2004-06 historical aviation emissions have to be compensated for by purchasing and trading CO_2 emissions allowances (EC, 2008). The system is limited to flights within Europe, to facilitate implementation of the International Civil Aviation Organization's (ICAO) CORSIA programme for flights beyond Europe (EC, 2018c).

CORSIA

The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), overseen by ICAO, was agreed in October 2013 with the goal of ensuring carbon-neutral aviation growth post-2020. The scheme aims for emissions growth post-2020 to be offset via a global market-based measure. This allows flexibility to reduce emissions by improving efficiency, using sustainable fuels and purchasing emissions allowances. As of January 2018, 73 countries were participating in the scheme, accounting for 76% of international aviation passenger kilometres (ICAO, 2018b).

Under CORSIA, countries with small national carriers (less than 0.5% of 2018 total passenger kilometre market share) are excluded. As a result, all traffic to and from these countries is not covered by CORSIA and emissions are therefore not offset. As CORSIA oversees international aviation, domestic flights are also exempt, which represent around 40% of aviation fuel consumption (Sheelhasse et al., 2018).

CORSIA and EU ETS only target carbon emissions. Other GHGs emitted by aeroplanes at high altitudes, such as NO_x and water vapour, are not covered. While the effects of these gases are not fully understood, these other aviation emissions are estimated to have two to four times the warming potential of CO_2 (IPCC, 2007; Jardine, 2005).

ICAO Fuel Consumption Standards

In 2017, ICAO ratified CO_2 emissions standards on aeroplanes to be enforced by national aviation authorities. The standards limit the emissions of new aircraft; if they are not met, planes will have to be modified accordingly (ICAO, 2017). The standards include separate targets for aircraft certified before 2020 and those certified after, and flexibility based on the mass of the aircraft. It is estimated the standards will require new aircraft entering service after 2028 to be on average 4% more fuel efficient than in 2015 (ICCT, 2017b).

Fuel, departure and ticket taxes

Taxation measures are also used by governments to provide incentives for more efficient behaviour in aviation, although most aviation fuel is not taxed (OECD, 2017; Keen and Strand, 2007; ICAO, 2018c).

Departure and ticket taxes, which are targeted at aviation activity, are widely applied. In some cases, taxes have been used to specifically target modal shift. In Norway for example, a "green" levy has been in place since 1995 that imposes a charge on flight tickets for which there is an alternative rail service.

Efficiency gains from switching to high speed rail

High-speed rail is currently more than 11 times more energy-efficient on a passenger kilometre basis than aviation (IEA, 2018b). While aviation is the fastest form of transport between destinations, consumers can spend a significant amount of time travelling to and from airports, which are typically outside cities, including passing through lengthy security measures. This means that for short flight distances, high-speed rail is a comparable and more energy efficient travel option in terms of both cost and duration, with trips typically ranging between two and five hours (UIC, 2018a).

High-speed rail has reduced aviation activity on certain routes in China, Europe, Japan and Korea. Air traffic dropped 56% between Paris and London and 58% between Brussels and London when the Eurostar was introduced (Dobruszkes and Givoni, 2013). China, which has made high-speed rail a key policy priority in the past decade, has already built more than 20 000 km of high-speed rail infrastructure, accounting for around 65% of the existing global high-speed rail network (UIC, 2018b; IEA and UIC, 2017). This has contributed to reductions in various flight routes. For example, air traffic between Guangzhou and Wuhan reduced by 48% in the years after the HSR line was opened for the public (Lee, Yoo and Jung, 2012).

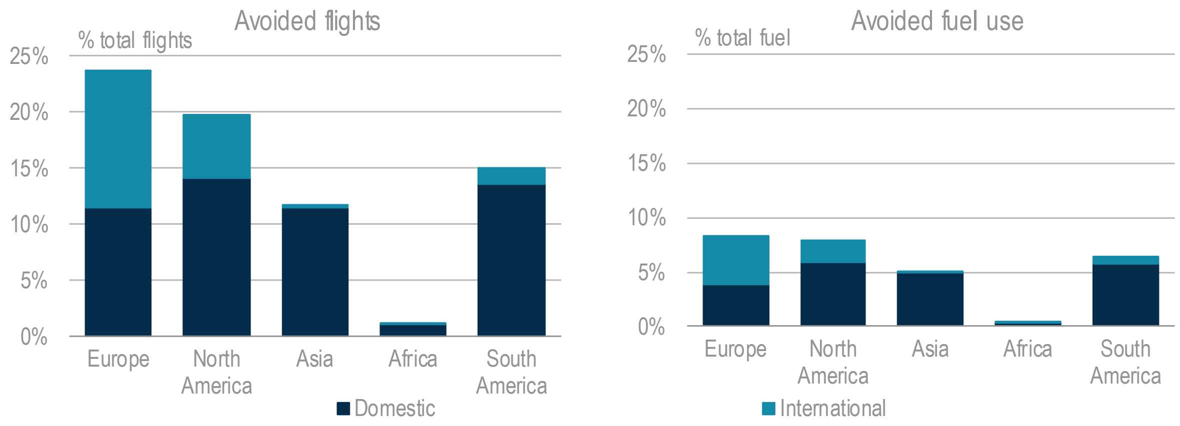
Currently 18% of all commercial passenger flights are time competitive[41] with HSR, connect sufficiently large cities[42] and do not cross mountain ranges or bodies of water.[43] On these routes, which account for around 6.5% of aviation energy use, switching to high-speed rail could be a viable and more energy-efficient alternative (Figure 2.13). Further analysis of the potential for high speed rail will be presented in the forthcoming IEA *Future of Rail* publication.

[41] Assumed travel time includes travel time to airports/stations and security checks of 210 minutes for flights and 80 minutes for HSR.

[42] Airport throughput of more than 1 000 000 passengers per year.

[43] IEA analysis using OAG (2018).

Figure 2.13 Potential to avoid flights and aviation fuel through high speed rail



Source: IEA analysis based on OAG (2018).

Note: Flights do not cross bodies of water or mountain ranges. Average train speed is set at 250 km/h. Additional travel time for airports is 210 and 80 minutes for HSR. Airports have a throughput of at least 1 million passenger per year.

An efficient world strategy for transport

Overall opportunity	Global transport energy demand could stay flat between now and 2040, despite doubling activity levels.
Sub-sector opportunities	**Passenger cars:** • Offers more than half of the potential energy savings in road transport in 2040.[44] • Energy efficiency could improve by 2.8% per year to 2040. The historic trend since 2000 is 0.5% per year, but recently implemented and planned policies could raise this to 2%. • The average passenger car in 2040 could be as efficient as today's best hybrids and 40% of the global car fleet could be electric. **Trucks:** • Trucks represent 42% of the potential energy savings in road transport in 2040. • Recently implemented and planned policies could see the annual efficiency improvement rate increase to 1.5%, compared with the historic trend of less than 0.1%. • The EWS sees the annual improvement rate raised to over 2.5% through policies being strengthened and more widely applied. **Aviation and shipping:** • Non-road transport (aviation, shipping and rail) represents one-third of total transport sector energy savings potential in 2040. • Efficiency improvement rates in aviation and shipping could grow to 3% per annum, double the rates achieved in 2016.
Policy measures to enable efficiency gains	**Regulation:** • Expanded and strengthened fuel economy standards for cars and trucks can continue to deliver efficiency gains. • Continuation and development of global targets and measures for aviation and shipping. **Finance and incentives:** • Efficiency-based vehicle taxation. • Financial support for electrification of various transport modes. • Consider market-based instruments to increase investment and business model innovation, although application to date has been limited. **Information and capacity building:** • Information to support efficient vehicle uptake and mode shift (e.g. labels, web-based resources and vehicle/trip comparison tools). • Training to support more efficient transport practices.

[44] Energy savings in 2040 are calculated with respect to the New Policies Scenario (NPS).

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3. BUILDINGS AND APPLIANCES

Highlights

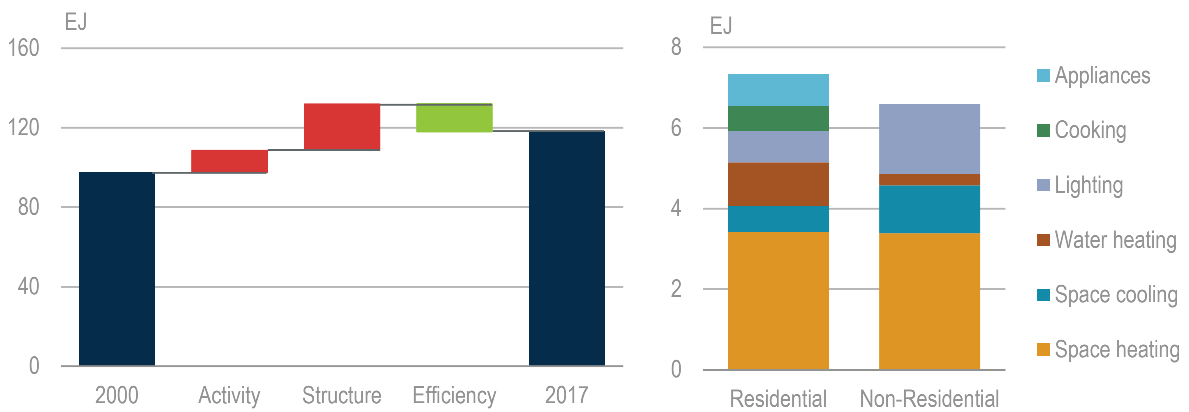
- **Energy use in the buildings sector continues to climb, but without energy efficiency improvements since 2000, energy use would have been 12% higher in 2017.** Final energy use in buildings and appliances rose by 21% between 2000 and 2017 to reach 120 exajoule (EJ). Energy savings of 14 EJ have been achieved since 2000, thanks to expanded energy efficiency policy coverage, technology improvements and investment trends. These are impressive savings given the level of economic expansion, population and floor area growth during this period.
- **Building codes and appliance standards have been key policy measures, preventing additional buildings energy use.** Globally, 34% of building energy consumption was covered by mandatory energy efficiency policies in 2017, 32% in residential and 43% in non-residential buildings. At the end-use level, lighting and cooling are leading the way with mandatory policy coverage near 80%, although stringency varies.
- **The Efficient World Scenario highlights the potential for global building energy demand to remain flat between now and 2040, despite total building floor area growing by 60%.** Buildings in 2040 could be nearly 40% more energy efficient than today. Space heating offers over a quarter of the potential energy savings. Water heating efficiency could also improve by 43% and improvements in space cooling, which is the fastest growing source of building energy demand, could see air conditioner efficiency double.
- **The IEA Efficient World Strategy lays out the policy measures that can enable potential efficiency gains for buildings and appliances to be realised.** While many countries have already implemented building energy codes and standards, delivering the Efficient World Scenario would require them to be strengthened and expanded to cover new and existing buildings. Similarly, minimum energy performance standards (MEPS) for key equipment and appliances, such as electric heat pumps and air conditioners, will also need to be strengthened and expanded. Incentives can also be used to encourage adoption of high efficiency appliances and building retrofits. These can be complemented by improvements in the quality and availability of energy performance information and tools.
- **Space cooling is a major driver of building energy demand and will require policy attention to realise efficiency gains.** Some energy savings are already being delivered by more efficient cooling equipment and through passive cooling technologies and design, but more can be done globally by bringing MEPS closer to best available technology to avoid locking in inefficient cooling systems.
- **In the Efficient World Scenario, annual investment in efficient buildings and appliances rises from USD 140 billion (United States dollars) in 2017, to an average of USD 220 billion up to 2025, and then to USD 360 billion to 2040.** Delivering the additional investment, particularly for buildings, will require finance and business model innovation to attract greater levels of third-party financing. Market-based instruments, including obligation and white certificate schemes, can also enable competition among market actors to deliver innovative financial solutions.

Energy efficiency trends and outlook for buildings and appliances

In 2017, buildings and appliances were responsible for around 30% of global final energy use. Building energy use increased 0.8% from 2016 and rose 20% between 2000 and 2017. This growth was primarily driven by structural factors such as increases in floor area, occupancy and access to services along with increases in activity, including changes in population, climate and the use of appliances (Figure 3.1).

Structure and activity are interlinked. Growing populations and changing economic conditions result in more floor area, buildings and appliances. Since 2000, global energy consumption in buildings has decoupled from the growth in floor space and economic output. This shows that people and businesses are able to make use of energy services more efficiently and at greater value than ever before. Energy use per floor area, an indicator of energy efficiency, has improved each year since 2000 at an average annual rate of 1.6%, while floor area increased by 3% per year.

Figure 3.1 Decomposition of buildings global final energy use, 2000-17 (left) and end-use contribution to efficiency savings in residential and non-residential buildings, 2000-17 (right)



Note: Non-residential buildings in this analysis exclude other non-core buildings services (e.g. business services, computers, data centres), which are included in the industry and services decomposition analysis in Chapter 4.

Sources: Adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database) and IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

In 2017, residential buildings consumed more than three times the energy consumed by end-uses in non-residential buildings. However, growth in non-residential energy consumption since 2000 has outpaced the residential sector by a factor of two, mainly because of significant structural impacts, namely economic growth. Energy intensity per floor area has improved by 1.7% a year on average since 2000 in residential buildings and 1.6% in non-residential buildings.

The two fastest-growing end-uses in buildings are space cooling and appliances. Energy consumption for space cooling has nearly doubled since 2000, driven largely by increased penetration of cooling equipment. Energy intensity per floor area in the residential sector increased by over 80% since 2000. Energy consumption by appliances has grown by 58% since 2000. Space heating, water heating, lighting and cooking have also experienced improvements of more than 20% in energy intensity per floor area since 2000.

Global growth in energy use in buildings has been largely driven by the major emerging economies – Brazil, the People's Republic of China (hereafter "China"), India, Indonesia, Mexico and South Africa –

on average experiencing a 43% increase in buildings energy use alongside an increase in total floor area of 22% since 2010. China and India have experienced rapid increases in energy use for space cooling, doubling since 2010. Space cooling energy intensity per floor area increased by 71% in China and 42% in India. This trend is also seen in Southeast Asia, where space cooling energy use increased by 66% and space cooling energy intensity per floor area has grown by 35% since 2010.

Energy efficiency has reduced global buildings and appliances energy use

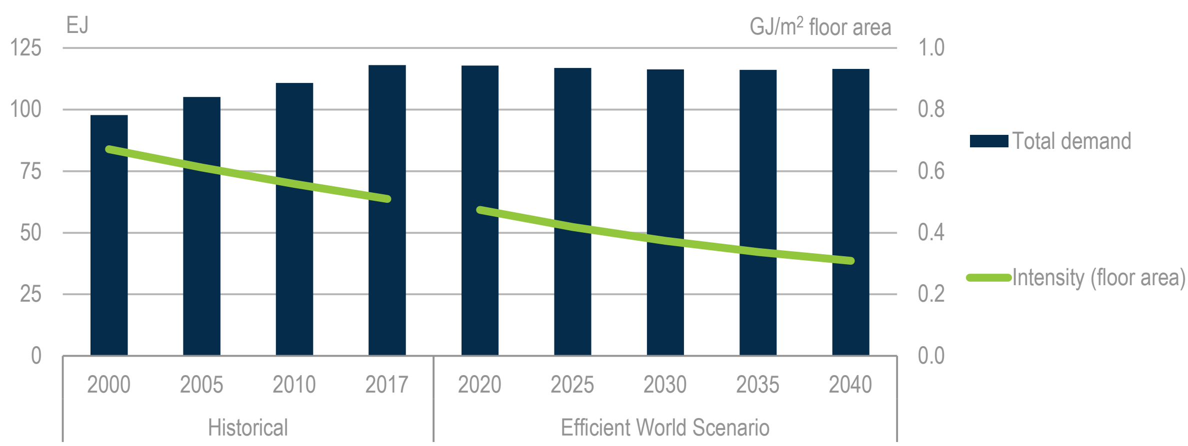
Energy efficiency improvements have saved almost 14 EJ of additional energy use in buildings and appliances since 2000, equivalent to the total energy consumption of Brazil. Without these improvements, global building energy use would have risen by an additional 12%. These savings have come from both the residential and non-residential sector, with space heating comprising a significant amount of the energy savings in both sectors (Figure 3.1). In the non-residential sector, about one quarter of the savings have come from lighting improvements.

Despite these impressive savings, considerable potential for cost-effective energy efficiency was not achieved between 2000 and 2017. For example, if the least efficient refrigerators in the world (around 30% of the stock) had been subject to minimum standards and reached the efficiency of the global average (a 30% reduction in energy consumption), around 170 petajoule (PJ) of energy would have been saved in 2017.

An efficient world requires increasing the pace of building and appliance improvements

Cost-effective opportunities for continued improvement in building and appliance energy efficiency are significant. The Efficient World Scenario (EWS) suggests that the average building in 2040 could be 39% more efficient per floor area than current buildings, resulting in a 1.3% decrease in energy use compared with current levels. This improvement would require energy intensity (energy use per floor area) to improve, on average, by 2.2% per year between now and 2040, a slight step-up from the average annual rate of 1.6% since 2000 (Figure 3.2).

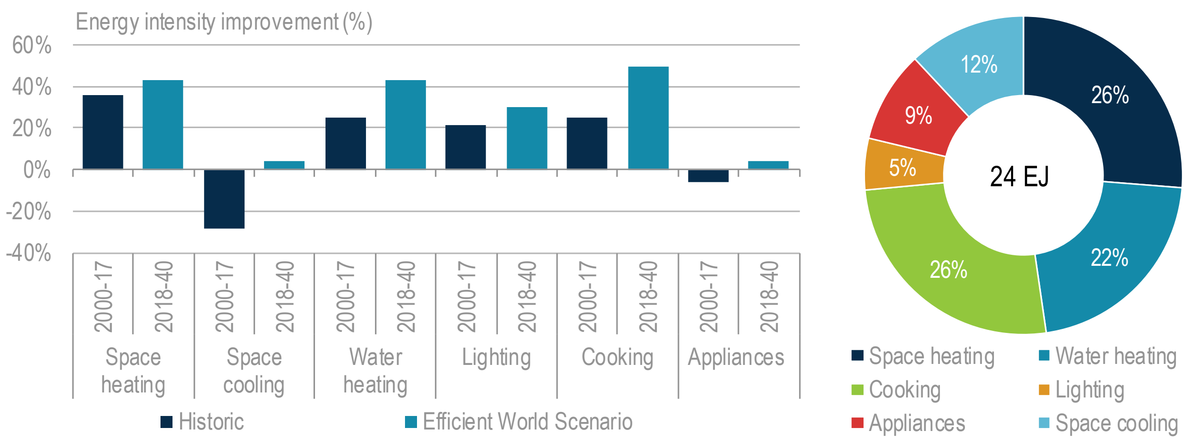
Figure 3.2 Buildings energy use and energy intensity, 2000-40



Sources: Historical data adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database) and IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

These opportunities will largely come by increasing efficiency in cooking, space and water heating, which together could deliver 24 EJ of energy savings to 2040 (Figure 3.3). A worsening in space cooling and appliance energy intensity since 2000 is due to increased equipment and appliance use, particularly in emerging economies, as opposed to equipment and appliances becoming less efficient. In the EWS, space cooling and appliances could each achieve energy intensity improvements of 4%, even with increasing access to space cooling and greater appliance ownership.

Figure 3.3 Buildings sector global change in energy intensity (per floor area), 2000-40 (left) and end-use contribution to total energy savings in the EWS to 2040 (right)

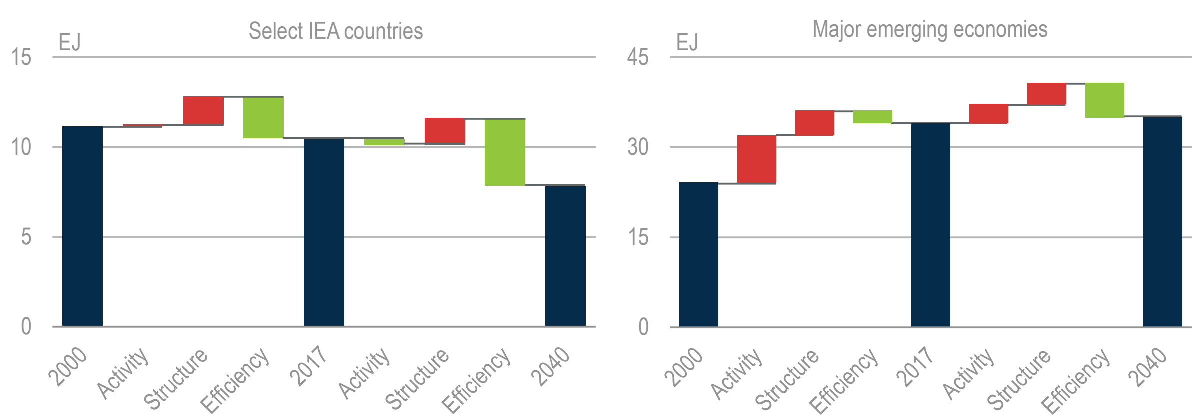


Note: Energy savings in the EWS are determined with respect to the New Policies Scenario.

Sources: Historical data adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database) and IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

The majority of energy savings in the EWS come from extending and strengthening heating and cooling measures. For space heating, if all countries were to achieve best practice market averages (such as in Japan and Scandinavia), global heating energy consumption could be cut in half, helping to achieve nearly half of the total building energy intensity improvements in the EWS. The EWS implies a doubling of total efficiency by 2040, which in some countries leads to an absolute reduction in building energy use and in others, limits energy use growth to just above current levels (Figure 3.4).

Figure 3.4 Buildings energy use decomposition in selected countries, global, 2000-40



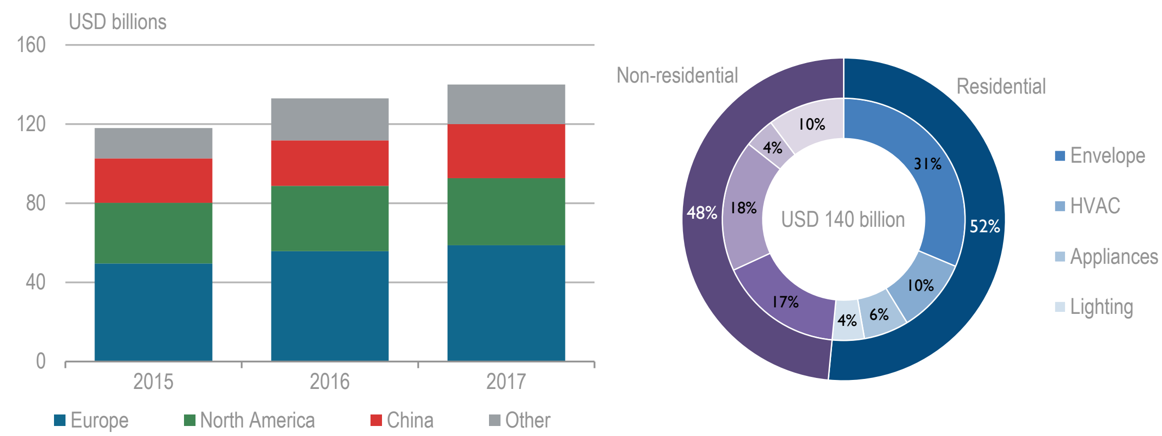
Notes: Select IEA countries are Canada, France, Japan and the United Kingdom. The major emerging economies are Brazil, China, India, Indonesia, Mexico, and South Africa. Activity includes changes in population, climate and the use of buildings and appliances. Structure includes increases in floor area, occupancy and access to services.

Sources: Historical data adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database) and IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

Energy efficiency investment in buildings and appliances

Total incremental spending on energy efficiency investments for buildings increased by 3%[45] in 2017 to USD 140 billion (Figure 3.5).[46] Energy efficiency investment growth only slightly outpaced total investment in building construction and renovation, which grew by 2.5% to USD 5 trillion in 2017. The growth rate of energy efficiency investment as a share of total investment has slowed from the 6-11% annual growth rates observed from 2014 to 2016.

Figure 3.5 Buildings incremental investment by region, 2015-17 (left) and by sector and end-use (right)



Note: Total energy efficiency spending is the expenditure on products and services that deliver energy efficiency in a building. Incremental energy efficiency investment is additional cost compared with a baseline or business-as-usual expenditure.

Investment in energy efficiency can deliver significant economic benefits

Achieving all of the cost-effective potential for improving building and appliance efficiency in the EWS presents a significant investment opportunity for governments and energy service companies worldwide. Under the EWS incremental investment rises from USD 140 billion to nearly USD 220 billion between now and 2025, 25% above levels already expected in the NPS (Figure 3.6). The average annual investment will need to keep growing to over USD 360 billion between 2026 and 2040, an extra USD 130 billion above what is expected in the NPS.

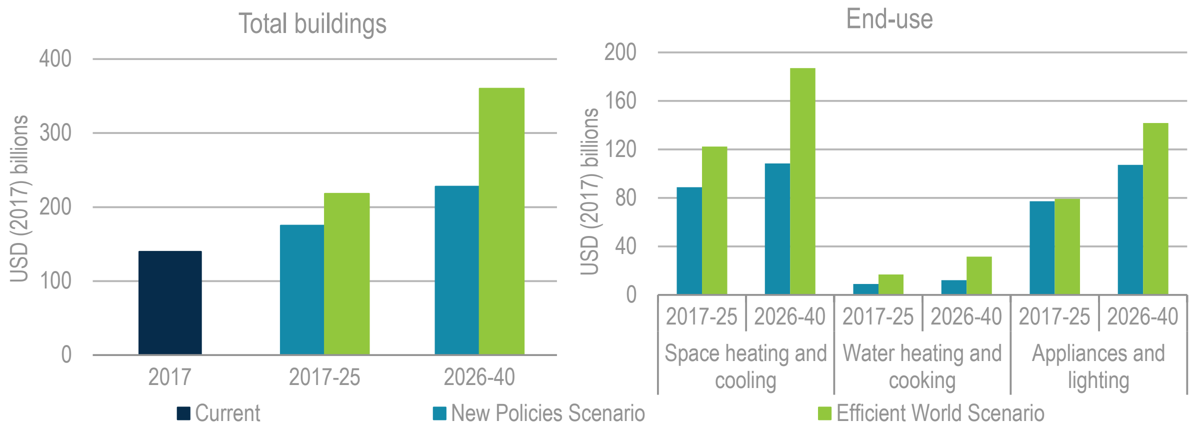
Space heating and cooling represent more than half of the average annual investment required in the EWS, with appliances and lighting responsible for nearly 40%. Much of the space heating and cooling investment is devoted to improving building envelopes, thus reducing the need for heating and cooling. Such measures require investments larger than those for appliances and lighting, which are typically based on many smaller investments by individual consumers. Investment levels in the New

[45] Inflation adjusted to 2017 US dollars.

[46] Incremental spending on energy efficiency investments represents the additional cost for products and services that deliver energy efficiency in a building compared with a baseline or business-as-usual expenditure. This is different from total investments in energy efficiency, which reflect the full cost of energy efficiency improvements (i.e. the total cost incurred by the building or appliance owner, including expenditure otherwise required to meet a code or standard). In 2017, total investment in energy efficiency was USD 423 billion, or three times the amount of incremental investment, which is a more accurate reflection of the total size of the investment opportunity achieved by energy services companies and the total amount of out-of-pocket expenditure for building owners and property developers.

Policies Scenario for appliances and lighting are close to those in the EWS, due to the strengthening of existing standards, particularly for lighting, towards high efficiency LEDs. These are conservatively high estimates of investment requirements; innovation and economies of scale are likely to reduce the cost of the additional efficiency.

Figure 3.6 Average annual energy efficiency investment in buildings, in total (left) and by end-use (right), 2017-40



One factor favouring greater levels of investment is the replicable and scalable nature of building energy efficiency projects that have predictable returns, and can be aggregated to appeal to third-party financiers. As detailed in Chapter 5 (Box 5.2), much of the existing finance and business model innovation for energy efficiency is linked to buildings, providing the basis for further innovation and investment growth.

Market-based instruments, such as white certificate and obligation schemes, are policy measures that can drive increased investment and business model innovation. The amount of investment generated by MBIs has increased six-fold over the last ten years, with most countries with MBIs in place achieving public/private leverage rates of up to 200% (i.e. every one dollar of public investment triggers up to two dollars of private sector investment) (IEA, 2017). There is also some evidence of business model innovation in both white certificate and obligation schemes. For example, Energy Services Companies (ESCOs) have been engaged in white certificates markets, such as those in Italy, France and Australia, driving innovation in the delivery of energy savings from measures including lighting and HVAC upgrades.

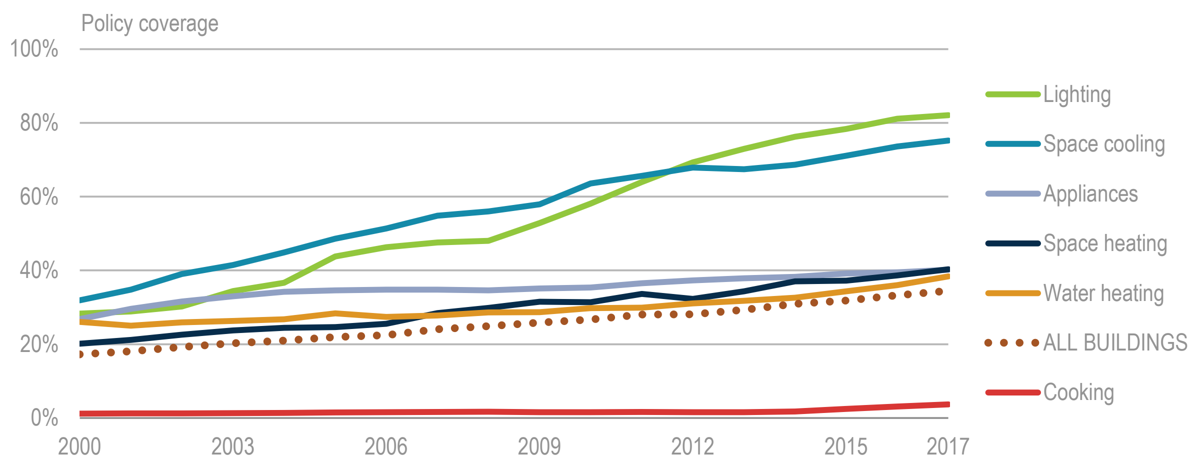
New approaches are also are being introduced in the United States to achieve energy efficiency at scale in the buildings sector. For example, in California, energy efficiency policies have mandated that at least 60% of the savings achieved in obligation schemes needs to be delivered by third-party service providers. This has spurred new approaches, including pay-for-performance programmes, which when coupled with private financing instruments, such as the PACE programme (see chapter 5), are able to drive innovation and lower costs for energy efficiency service delivery.

Energy efficency policy for buildings and appliances

Energy efficiency policy coverage for buildings and appliances continues to climb

Globally, 34% of building energy consumption was covered[47] by mandatory energy efficiency policies (e.g. codes and standards) in 2017 – more than 32% of residential and 43% of non-residential buildings energy use. At the end-use level, lighting and cooling are leading the way with mandatory policy coverage around 80%. Recent increases in coverage in space cooling have come from countries such as Jordan and Peru that introduced new standards and labelling programmes effective in 2017. Cooking is the lowest covered end-use due to the unregulated nature of traditional biomass. Only 4% of global cooking energy use is covered by mandatory policies (Figure 3.7).

Figure 3.7 Global energy efficiency policy coverage of buildings end-uses, 2000-17



Note: This policy coverage is for both the residential and non-residential segments of the buildings and appliances sector.

Energy efficiency policy strength has made limited progress

To generate efficiency gains, governments have not only introduced and increased the coverage of mandatory policies, but also improved the performance levels or strength of these policies. The Efficiency Policy Progress Index (EPPI), the IEA's integrated metric capturing changes in policy coverage and strength, indicates that efficiency improvements in residential end-uses since 2000 have been limited (Figure 3.8).

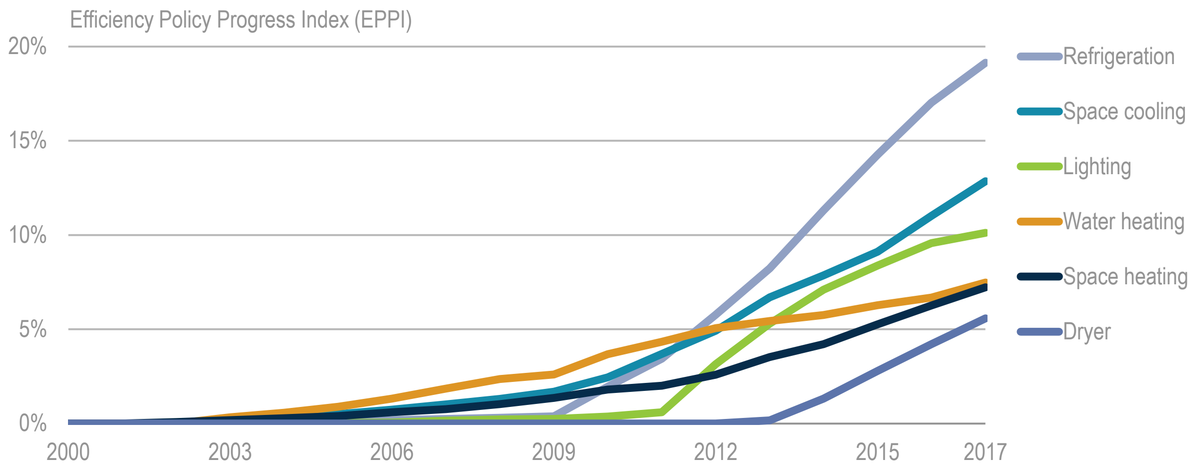
Refrigeration and space cooling have shown the largest policy progress, through a combination of growing policy coverage and increasing strength in some countries. The European Union, India and the United States regularly revise performance requirements for products, which continuously improve the strength of these policies.

Lighting has also shown strong progress, a result of substantial efficiency improvement programmes coupled with mandatory programmes to phase out inefficient technologies. Most of the rapid

[47] See Box 1.5 in Chapter 1 for explanation of energy efficiency policy coverage and strength.

increases since 2010 have been the result of widespread implementation of MEPS in major emerging economies, particularly China.

Figure 3.8 Global residential policy coverage and strength progress by end-use, 2000-17



Note: See Chapter 1 for a description of the Efficiency Policy Progress Index (EPPI).

Targeted policy action is required to achieve the potential of the Efficient World Scenario

While policy coverage and, to a lesser extent policy strength, have been improving since 2000, concerted effort is needed to broaden and deepen efficiency policies to achieve the full opportunity available in the EWS. By 2040, most buildings will need to be either highly efficient new buildings or have deep energy retrofits. Globally, this means energy intensity per floor area will have to improve at an average annual rate of 2.2%, up from 1.6% per year since 2000.

Exemplary policy available to accelerate towards the Efficient World Scenario

Building energy codes are particularly important to keep efficiency improvements on track to achieve the potential in the EWS. Several countries have enacted new or updated existing policies that could be adapted by others (Box 3.1). For example, a key policy under development in India will establish the first national model building energy code for residential buildings. Other successful strategies have involved establishing energy efficiency targets and making commitments to low-carbon growth, including new requirements for near or net zero carbon buildings in Canada, Europe and Scotland.

Some of these policies explicitly require the use of smart building technologies and renewable energy, such as in California and Europe. Other policies target existing buildings, such as the requirements to improve the energy performance of rental properties in the United Kingdom and the United States. New information and decision-making tools, such as Building Passports in Europe, are also being introduced to encourage building owners and operators to invest in building energy performance.

More than 80 countries have introduced MEPS, to successfully raise the energy efficiency of products placed on their markets. Successful strategies have included explicit mechanisms to ensure continuous improvement, as well harmonising standards with neighbouring countries, which shares the regulatory effort and makes programmes more effective. Considering lifecycle and societal benefits is also important when setting the appropriate level of ambition for MEPS policies.

Box 3.1 New and evolving policies in building energy performance

Policies continue to spark ideas for energy efficiency

India took a large step forward in the last year with its first model building energy code for residential buildings. The Energy Conservation Building Code for Residential Buildings, available for review and public comment through 2018, has been developed to enable simple enforcement while improving occupant thermal comfort and enabling the use of passive systems (BEEP India 2018, BEE 2018).

New York City has proposed the first city regulations to require existing buildings to curtail their emissions, with a goal of reducing emissions by 80% by 2050. The policy would include annual penalties for exceeding fossil fuel usage limits, and is expected to deliver 17 000 building retrofit jobs if it is enacted (NYC, 2017).

Building passports record information on components and operations of a building over its lifetime. The Global Alliance for Buildings and Construction, through its workgroup on Building Measurement, Data and Information, has identified building passports as a high-priority tool for improving material sourcing, building design, operation and decision making (GABC, 2018). Building passports can enable financing of both construction and renovation projects (EeMAP, 2018) and can help building owners make better renovation decisions (BPIE, 2016).

The Pan-Canadian Framework on Clean Growth and Climate outlines **Canada**'s commitments to improved energy efficiency and low-carbon economic growth. The framework establishes end-use targets and provides roadmaps, such as the roadmap for energy-efficient equipment in the building sector (EMMC, 2018).

Scotland has developed its first energy strategy (Scottish Government, 2017), which set targets for Scotland's Energy Efficiency Programme to transform buildings to be near zero carbon by 2050 (Scottish Government, 2018).

In the **United Kingdom**, all new rentals must now achieve a minimum energy performance rating of E, and there are aspirations to eventually raise the minimum rating to C, with A being the most efficient grade achievable (Government of the United Kingdom, 2018).

In **Boulder, Colorado,** updates to the housing code require multifamily building owners to meet a basic energy efficiency standard as of December 31 2018, by earning 100 points on an efficiency checklist before they can rent apartments (City of Boulder, 2018).

Colombia has just announced a "Return and Save" programme to replace 1 million refrigerators within five years by reducing value-added tax on the most efficient refrigerators from 19% to 5% while recycling old refrigerators and disposing of their refrigerant (in keeping with the country's commitments under the Montreal Protocol on substances that deplete the ozone layer). The policy is expected to bring in money for the government, with the tax revenue reduction offset by the reduction in energy subsidies and creation of 2 000 direct and 10 000 indirect jobs (MINMINAS, 2018).

Evolution of existing policies are providing lessons for continuous improvement

In **California**, as of May 2018, the 2019 Building Energy Efficiency Standards will be the first code in the United States to require solar photovoltaic systems on new homes. The code also targets energy efficiency, including 30% reduction in energy use for non-residential buildings (California Energy Commission, 2018).

Canada, which also has a continuous improvement process, is guided by the target of achieving "Net Zero Energy Ready" buildings by 2030. The National Energy Code of Canada for Buildings 2017 pushes towards that target with energy savings of 10% over the 2011 version (NRCan, 2018a; NRCan 2018b).

The **European Commission** revised its Energy Performance of Buildings Directive (EPBD) in 2017 (European Commission, 2018) so that member states must comply by 2020 with measures that require national strategies to decarbonise buildings, encourage smart building technologies and increase the rate of building renovation to deliver increased performance. These revised regulations require buildings to have very low energy demand met by renewable energy (net-zero energy).

France, which historically has offered tax credits and loans for energy efficiency renovations (Ministère de la Transition écologique et solidaire, 2018), updated its policies to strive for new buildings to be nearly zero energy in compliance with RT 2012 (Thermal Regulation 2012), which is designed to limit the energy intensity of new buildings to a maximum of 50 kWh/m^2 per year (Les Economies d'énergie dans le bâtiment, 2018).

Australia and **New Zealand** have recently announced a further strengthening of their MEPS for refrigerators (E3, 2017). MEPS were first implemented in 1999 (2002 for New Zealand) and upgraded in 2005. Such evolution of existing policies is key to delivering an efficient world.

Similarly, the **European Commission** has been improving its mandatory MEPS and labelling programmes and has finalised proposals to increase MEPS for refrigerators, external power supplies, servers and other equipment (European Commission, 2017). Improvements include the development of a central registration database, which will enable regulators to better track the market and provide information to consumers.

In **Italy**, fiscal incentives for building renovations can enable tax deductions of up to 85% for more comprehensive projects or 50% for a range of eligible technologies such as windows and heating systems. The reward for building owners has been two-fold: improvement in energy efficiency and reduction in personal or corporate income taxes. While the state receives less tax revenue related to sales of efficient building equipment, the policy will result in a net increase in tax revenue of around EUR 8.8 billion over its lifetime thanks to projected increases in value-added tax and income tax (ENEA, 2017).

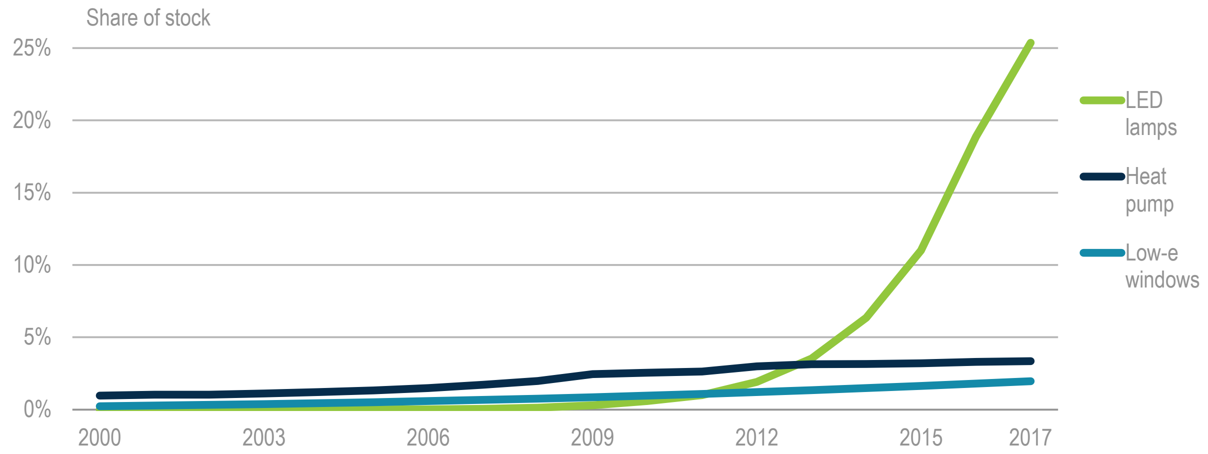
Energy efficient technology for buildings and appliances

Technologies are constantly evolving in energy performance, costs and market availability. Key technologies that are proven to deliver energy efficiency in buildings include insulation, LED lighting, heat pumps, and low-emissivity windows. While insulation is now commonly installed to comply with building energy codes, most buildings are not insulated well enough to perform at levels possible in the EWS. LED lamps are starting to make major inroads into lighting markets in many regions, and now account for more than 25% of installed lighting due to a near tripling share of new LED sales in the last three years (Figure 3.9).

Sales of low emissivity or “low-e” windows have been steadily increasing to reach over 20% of global sales, including more than 80% of the residential window market in the United States (Selkowitz, 2014), but account for only 2% of the global stock of installed windows. Heat pumps, which can offer significant energy efficiency compared with combustion or electric resistance heating, also have a very low global share of the stock for heating, at 3%. High potential therefore exists for heating and cooling energy savings if sales of these technologies were to increase.

Heat pump technology could save energy in multiple end-uses with the aid of the Comfort and Climate Box, an international project being researched through the IEA Technology Collaboration Programmes (TCPs), based on goals set out in Mission Innovation Challenge 7 on Affordable Heating and Cooling of Buildings (Mission Innovation, 2017).

Figure 3.9 Share of stock in buildings for key energy efficient technologies



Sources: Adapted from IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/) and Selkowitz (2014).

The digital revolution offers promise and prospects for buildings technology

Digitalisation is occurring across many segments of the building lifecycle, including through the use of building information modelling (BIM) during design, construction and operation. New information technology could be used to support the use of building energy or renovation passports for reporting and decision making for energy use in buildings (EeMAP, 2018).

Digitalisation would also enhance the effectiveness of building energy management systems (BEMS). BEMS enhance the control and monitoring of energy use in buildings, allowing for load management and communication with suppliers. The enhanced application of BEMS will contribute to realising the potential efficiency gains in the EWS, and allow buildings to make a larger contribution to demand-side response programmes. Demand-side response by consumers and end-use equipment enables more efficient operation of the electric grid by reducing or shifting electricity usage during peak periods in response to time-based rates or other forms of incentives. The market for demand response is still immature, however, and business models for accessing this potential grid benefit are still to be developed and commercialised.

Governments are beginning to introduce policy measures to encourage readiness for demand response, such as:

- Demand response capability label for air conditioners in Australia (Energy Rating, 2018).
- Smart-Grid-Ready heat pump label in Germany (TGA News, 2012).
- Energy rating label in Korea, requiring high-rating air conditioners to be controllable.
- ENERGY STAR connected functionality in the United States for thermostats, air conditioners, refrigerators, freezers, clothes washers, dryers and lighting (ENERGY STAR, 2018).

The US Department of Energy is supporting research to use digitalisation in grid-interactive buildings to increase energy efficiency and enable consumption to respond to grid conditions (US DOE, 2018). The European Commission also introduced a “smart readiness indicator” as part of its revised Energy Performance of Buildings Directive (European Commission, 2018). The indicator is intended to make building energy smartness more understandable and useful for building users, owners and tenants by raising awareness of the benefits of smart technologies and ICT in buildings (VITO NV, 2018).

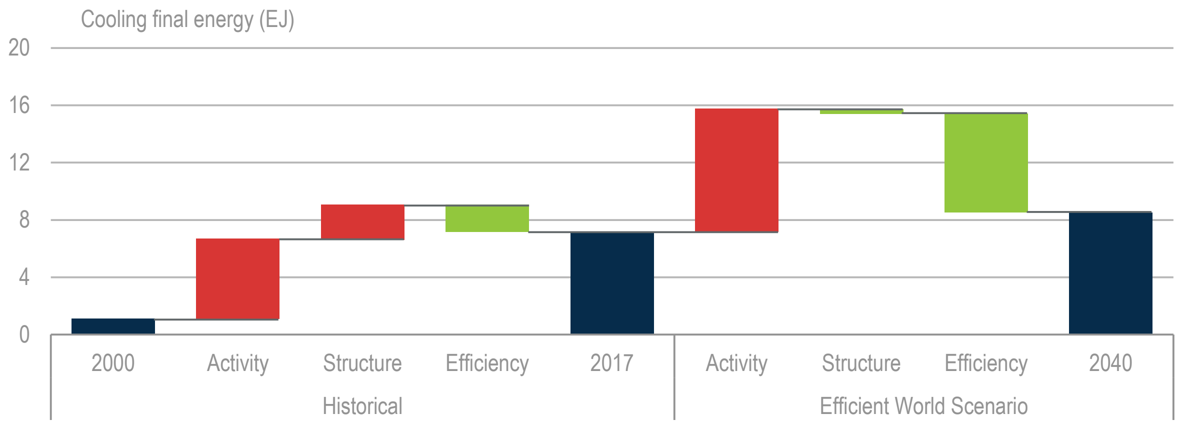
Special focus: Cooling

Historically, space cooling energy use has been a very small portion of global energy use. As economies become wealthier, however, the demand for cooling is increasing. At the same time, global temperatures continue to rise and the demand for comfort increases. That means space cooling policy choices in the near-term will have a significant impact on the electricity grid.

Cooling is the fastest growing energy end-use in buildings

Cooling energy use in buildings has more than doubled since 2000, from 3.6 EJ to 7 EJ, making it the fastest growing end-use in buildings, led by a combination of warmer temperatures[48] and increased activity due to population and economic growth. Without efficiency gains, space cooling energy use would more than double between now and 2040 due to increased activity and use of air conditioning. In the EWS, energy efficiency for cooling offsets much of the climate, activity and structure impacts to limit cooling energy growth between now and 2040 to 19% (Figure 3.10).

Figure 3.10 Decomposition of global buildings cooling energy use, 2000-40



Note: Non-residential buildings in this analysis exclude other non-core buildings services (such as computers and data centres), which are included in the industry and services decomposition analysis in Chapter 4.

Sources: Historical data adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database) and IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

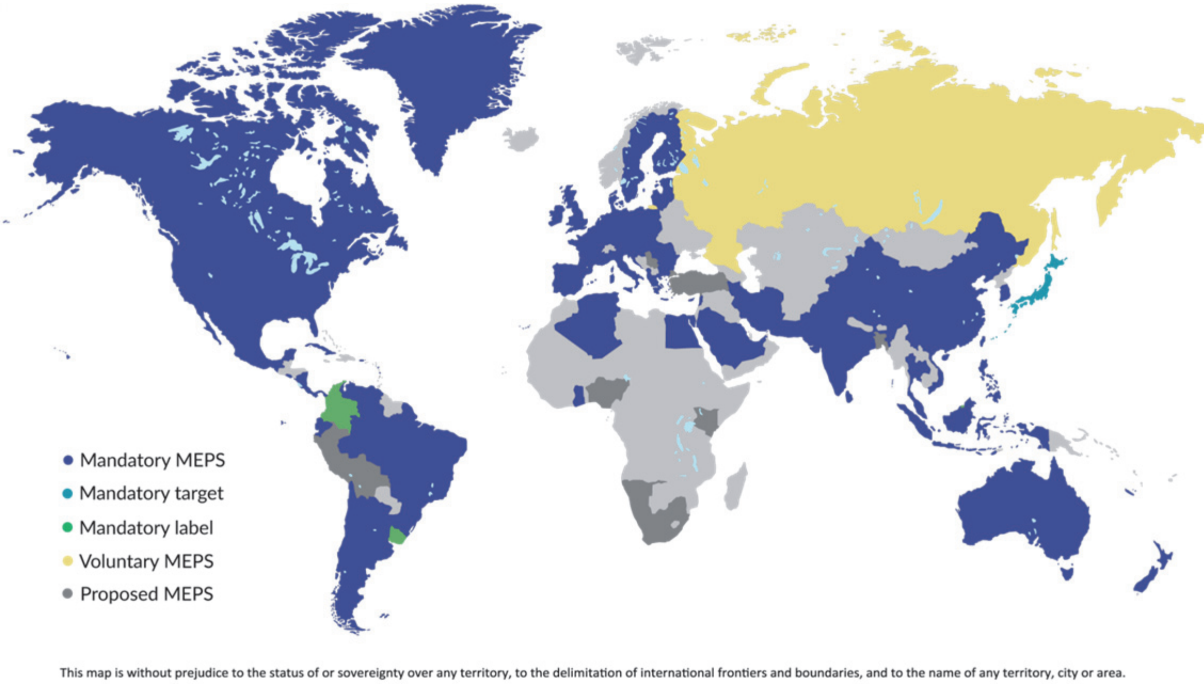
Improvements in cooling technology performance are the primary source of energy efficiency gains (accounting for over 90% of the change), underlining the impact that MEPs can have in curtailing energy demand for space cooling. The majority of the technology improvements (60%) are in developed countries that already have significant cooling energy consumption. These savings can help to offset much of the total growth for cooling due to the increase in cooling equipment ownership in the major emerging economies – Brazil, China, India, Indonesia and Mexico).

[48] As indicated by the increase in population-weighted cooling degree days.

Cooling equipment policy coverage is expanding, but policy strength needs improvement

While most of the countries that have high penetration of air conditioning do have mandatory energy efficiency policies for cooling equipment, some hot countries still lack these key policies and cooling equipment policy strength has only incrementally improved in 25 years (Map 3.1).

Map 3.1 Cooling equipment policy coverage, 2017



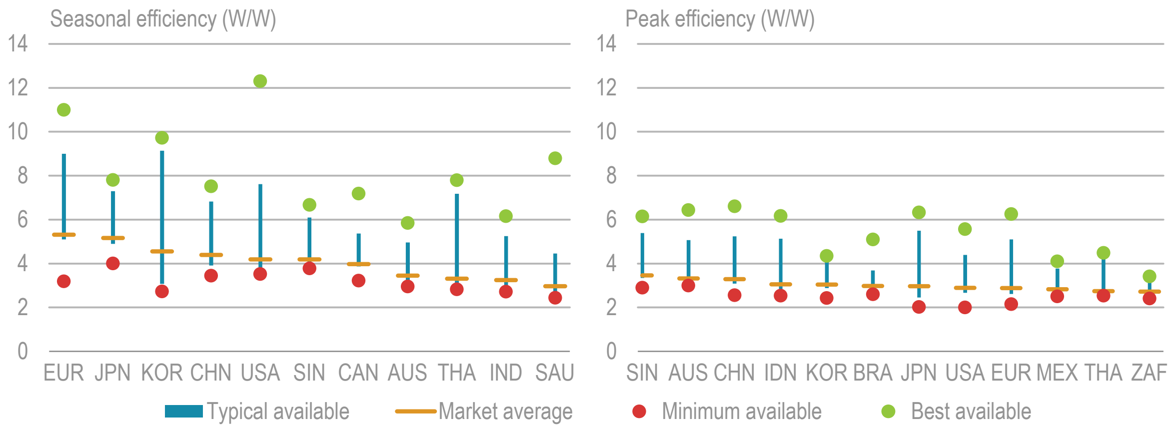
Note: Map shows one policy per country based on the strongest policy, e.g. the European Union has mandatory MEPS and labelling, but only mandatory MEPS are shown.

Source: IEA (2018b), *Global Exchange on Efficiency: Cooling*.

There is significant scope to raise minimum energy performance standards

While the efficiency of best available air conditioning technology has continued to improve, there is significant potential to close the gap between the best available technology and the market average (Figure 3.11). In the EWS, average air conditioner efficiency could double, which is possible with current technology. Global best available air conditioning equipment is up to five times more energy-efficient than the least efficient equipment currently available, based on the seasonal energy efficiency ratio (SEER), which reflects the average annual energy efficiency of cooling equipment. It is twice as efficient as the market average based on the energy efficiency ratio (EER), which better reflects the operational efficiencies of air conditioners during peak demand. A strong MEPS policy would be adjusted over time, for both EER and SEER metrics, to narrow these gaps between minimum available and best available technology.

Figure 3.11 Energy efficiency performance for small cooling equipment by country, 2018



Note: Seasonal efficiency is typically reported as SEER and peak efficiency is typically reported as EER. EER and SEER values for each country are not always comparable due to different testing procedures to determine the efficiency ratios.

Source: IEA (2018b), *Global Exchange on Efficiency: Cooling*.

There are different types of commercial cooling equipment that can provide similar levels of service. However, the efficiency of these systems can vary greatly. As with other appliances, it is important that policy, which may seek to regulate performance of commercial cooling equipment, considers the energy being used to provide the service, as opposed to developing regulations for each specific technology. Such an approach encourages the market to move to the most efficient means of delivering cooling, as opposed to driving greater levels of efficiency in a particular technology.

Improving cooling technology through research and development

Public support for cooling-related research is needed to ensure the development and deployment of energy-efficient air conditioning equipment, as well as efficient building solutions (Box 3.2). Many countries contribute to such efforts through the IEA TCPs for District Heating and Cooling, Heat Pumping Technologies, Solar Heating and Cooling and for Energy Efficient End-Use Equipment.

Box 3.2 New technologies will shape the energy needed to achieve cooling comfort

Current research on cooling will help markets evolve. Researchers at the University of Colorado in Boulder are working on a plastic film technology that can cool without consuming energy or water. The thin film can reflect solar heat gain while allowing heat rejection in the form of infrared thermal radiation (Service, 2017). At ETH Zurich researchers are studying a three-layer membrane that can be used as a “passive cooling curtain” in hot and dry climates. This technology allows evaporation of water from the middle “water-attracting” layer through holes in the outer “water-repellent” layers, resulting in heat extraction from the air and passive cooling of the space without the use of energy (Schlaefli, 2017).

In Barcelona, researchers at the Institute of Advanced Architecture of Catalonia are developing passive cooling options, including technologies that imitate the human body by regulating temperature through transpiration and devices that enable shading by tilting closed when liquid is evaporated by solar heat (IAAC, 2017). Several other research and development projects are focusing on personal comfort rather than air temperatures within buildings. These technologies, including robots, clothing and chairs, work on the premise that reducing the temperature in a small area can save significant energy compared with cooling an entire building (Bonnington, 2018; Octocool, 2018; CBE, 2017).

An efficient world strategy for buildings

Overall opportunity	Total energy use in buildings could stay flat between now and 2040, even though total building floor area grows by 60%, as a result of buildings being nearly 40% more energy efficient compared with current levels.
End-use opportunities	**Space heating:** • Over a quarter of potential energy savings in the EWS in 2040.[49] • Energy efficiency could improve by 43% between now and 2040, compared with 38% improvement since 2000. New net-zero energy buildings by 2020 in advanced economies and by 2030 in emerging economies. • Key measures include more efficient heating equipment (e.g. increased deployment of heat pumps) and improved buildings insulation and windows to reduce heating demand. **Water heating:** • Over 20% of the potential energy savings in the EWS in 2040. • Energy efficiency could improve by 43% between now and 2040, compared with 25% improvement since 2000. • Key measures include improved efficiency for water heating equipment (e.g. increased deployment of heat pumps). **Space cooling:** • Over a quarter of the potential building energy savings for the major emerging economies in the EWS and 12% of global energy savings potential. • Key measures include high efficiency air conditioners and controls, and improved building insulation and windows to reduce cooling demand. • Average air conditioner efficiency could double, which is possible with current technology.
Policy measures to enable efficiency gains	**Regulation:** • Increase coverage and strength of building energy codes and standards, for both new and existing buildings. • Increase coverage and strength of standards for key building equipment and appliances, such as electric heat pumps and air conditioners. **Finance and incentives:** • Appropriate fiscal or financial incentives to encourage consumers to adopt high efficiency appliances and undertake deep energy retrofits. • Market-based instruments, including obligation and white certificate schemes, can encourage business model innovation and increased investment. **Information and capacity building:** • Improved quality and availability of energy performance information and labelling for buildings and components. • Expanded professional training programmes and accreditation for designers, suppliers, installers and auditors

[49] Energy savings in 2040 are calculated with respect to the New Policies Scenario (NPS).

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4. INDUSTRY

Highlights

- **Growing industrial activity continues to push up energy use in the sector, which rose by nearly 2% in 2017.** However, energy efficiency has prevented an even greater increase in energy use. Without the efficiency improvements that have been made in the industry and service sectors of IEA countries and other major economies since 2000, energy use in 2017 would have been 20% higher. The People's Republic of China (hereafter "China") has been responsible for nearly one-third of these efficiency savings. Structural change – the movement of activity towards less energy-intensive industry and service sectors – has offset just over a quarter of the impact on energy use from rising activity levels.

- **Just over 35% of global industrial energy use was covered by mandatory energy efficiency policies in 2017.** Coverage is highest in China, India and Japan. Policy progress has slowed substantially in recent years because few major new policies have been implemented. The performance of electric motors is currently regulated in many major economies, with over one-quarter of global electric motor energy use covered by mandatory energy efficiency policies. If all motors in these countries were replaced by motors meeting the standard, policy coverage would rise to 55%.

- **The Efficient World Scenario identifies the potential for industry to produce nearly twice as much value per unit of energy use in 2040, compared with current levels.** Overall manufacturing energy intensity could improve by 44% between now and 2040. Less energy-intensive sectors, such as food, beverage and textile manufacturing, represent 70% of the potential energy savings for industry in 2040, due to efficiency improving by over 40%, compared with 16% since 2000. Energy efficiency in iron and steel manufacturing could improve by 25%, compared with 5% since 2000, as a result of increased metals recycling.

- **The IEA Efficient World Strategy highlights that a range of policy measures can enable greater industrial energy efficiency gains.** Expanded and strengthened standards for key industrial equipment, particularly heat pumps and electric motors, will drive efficiency gains in less energy-intensive industry. There will also be a role for appropriate incentive and finance measures, which increase the adoption of energy management systems, as well as information, training and capacity building programmes.

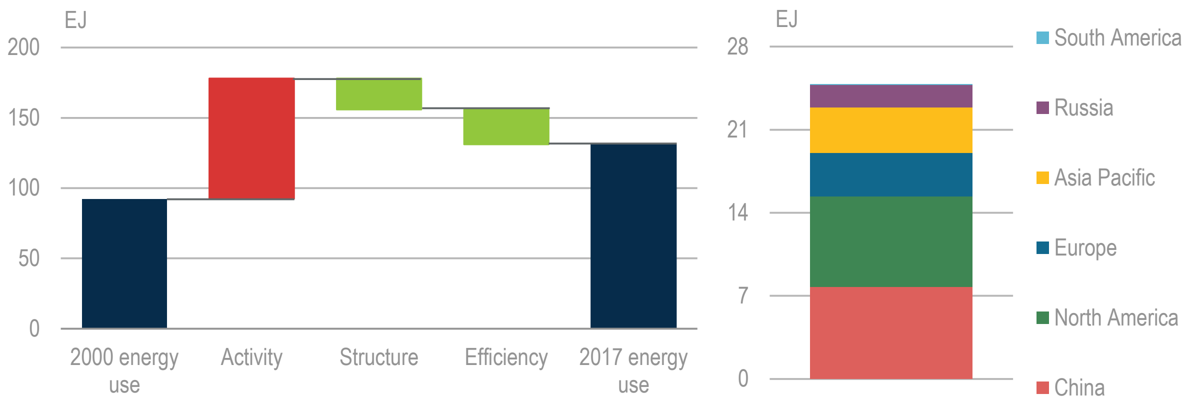
- **Recycling of scrap metal presents a vital opportunity to realise efficiency gains in metals manufacturing.** The production of metals like iron, steel, aluminium and copper from scrap is 60-90% less energy-intensive than production through primary routes. Governments can encourage metal recycling through regulatory instruments, subsidies, tax policies, direct provision of recycling services and information to improve recycling practices.

- **In the Efficient World Scenario, industrial energy efficiency investment increases from USD 35 billion (United States dollars) in 2017 to an average of USD 51 billion up to 2025, and USD 126 billion to 2040.** Increased third-party financing will be required to realise these investment levels, with market-based instruments a potential vehicle to encourage business model innovation.

Industrial energy efficiency trends and outlook

The combination of improved energy efficiency and changes in economic structure has offset more than half of the impact on final energy use of increased economic activity in the industry and service sectors in IEA countries and other major economies (Figure 4.1). A near doubling in activity, driven overwhelmingly by China and India, continues to push up energy use. Structurally, the movement of economic activity away from energy-intensive industrial sectors, such as metals, cement and pulp and paper manufacturing, towards less energy-intensive manufacturing and the service sectors has offset around just over a quarter of the impact from rising activity. Such structural change, which has long been apparent in developed economies, is now very evident in emerging economies. China was responsible for over 40% of the energy savings resulting from structural change, with non-OECD economies accounting for two-thirds.

Figure 4.1 Decomposition of energy use in the industry and service sectors (left) and the regional contribution to observed efficiency savings (right) in IEA countries and other major economies, 2000-17



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. Excludes non-energy use (i.e. feedstocks). Service sectors include ISIC divisions 33-99, excluding transportation. Countries covered are IEA countries plus Argentina, Brazil, China, India, Indonesia, Russian Federation and South Africa.

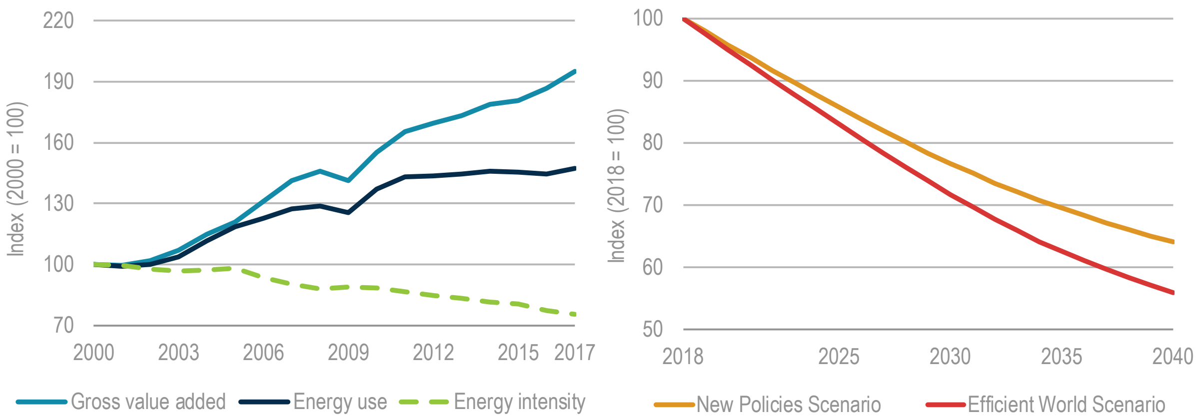
Sources: Adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database); IEA (2018b), *World Energy Balances 2018* (database); Timmer, M. P. et al. (2015), *World Input Output Database* (database); IBGE (2018), *Quarterly National Accounts* (database); National Bureau of Statistics of China (2018), *National Accounts* (database); RBI (2018), *The India KLEMS Database* (database); Statistics Indonesia (2018), *Gross Domestic Product* (database); INEGI (2018), *GDP – Activity of Goods and Services* (database); StatsSA (2018), *Gross Domestic Product (GDP), 4th Quarter 2017* (database); Quantec (2018), *Industry Service – RSA Standard Industry – Input Structure at basic prices* (database); INDEC (2018), *Macroeconomic aggregates (GDP)* (database); World KLEMS Data (2018), *Russia* (database).

Without improvements in energy efficiency since 2000, an additional 25 EJ (20%) of energy use would have been required in the industry and service sectors. This equivalent to the total final energy use of India and would have resulted in additional greenhouse gas (GHG) emissions of 2.4 gigatonnes of carbon dioxide (CO_2) equivalent (Gt CO_2-eq). The impact of improved energy efficiency is over 10% larger than the impact of structural change. Just under one-third of the efficiency savings in the industry and service sectors took place in China, where efficiency improved rapidly after strong policies were put in place and new production facilities were installed in energy-intensive sectors. At a sectoral level, energy-intensive manufacturing contributed around 40% to efficiency savings. Efficiency has particularly improved in cement and chemicals manufacturing, owing in part to the construction of new facilities in China and India.

Manufacturing energy intensity has fallen, but a faster rate may be possible

The energy intensity[50] of the manufacturing industries in IEA countries and other major economies has fallen by 25% since 2000 (Figure 4.2). This improvement is responsible for a marked flattening of growth in energy use in recent years, although it is estimated that energy use grew by around 2% in 2017, reversing the trend of preceding years.

Figure 4.2 Energy intensity trends for the manufacturing industries in IEA countries and other major economies, 2000-17 (left) and energy intensity outlooks, 2018-40 (right)



Notes: Includes ISIC divisions 10-18, 20-23 and 25-32 and excludes mining and quarrying, manufacture of coke and refined petroleum products and construction. Excludes non-energy use (i.e. feedstocks). Countries covered for trends from 2000-17 are IEA members plus Argentina, Brazil, China, India, Indonesia, Russian Federation and South Africa. Industry energy intensity in the NPS and EWS is calculated on the basis of energy use per unit of gross value added (GVA), measured on a purchasing power parity basis in 2016 US dollars.

Sources: Adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database); IEA (2018b), *World Energy Balances 2018* (database); Timmer, M. P. et al. (2015), *World Input Output Database* (database); IBGE (2018), *Quarterly National Accounts* (database); National Bureau of Statistics of China (2018), *National Accounts* (database); RBI (2018), *The India KLEMS Database* (database); Statistics Indonesia (2018), *Gross Domestic Product* (database); INEGI (2018), *GDP – Activity of Goods and Services* (database); StatsSA (2018), *National Accounts and Supply and Use Tables* (database); INDEC (2018), *Macroeconomic aggregates (GDP)* (database); World KLEMS Data (2018), *Russia* (database).

In the New Policies Scenario (NPS) the energy intensity[51] of the manufacturing industries improves by 36% between now and 2040, a rate 20% higher than the average annual intensity improvement in the countries analysed in Figure 4.2 since 2000.The Efficient World Scenario (EWS) shows that even greater gains are possible. Manufacturing industries could produce nearly twice as much gross value-added from each unit of energy use, resulting in an energy intensity improvement of 44%, and the use of 15% less energy than in the NPS.

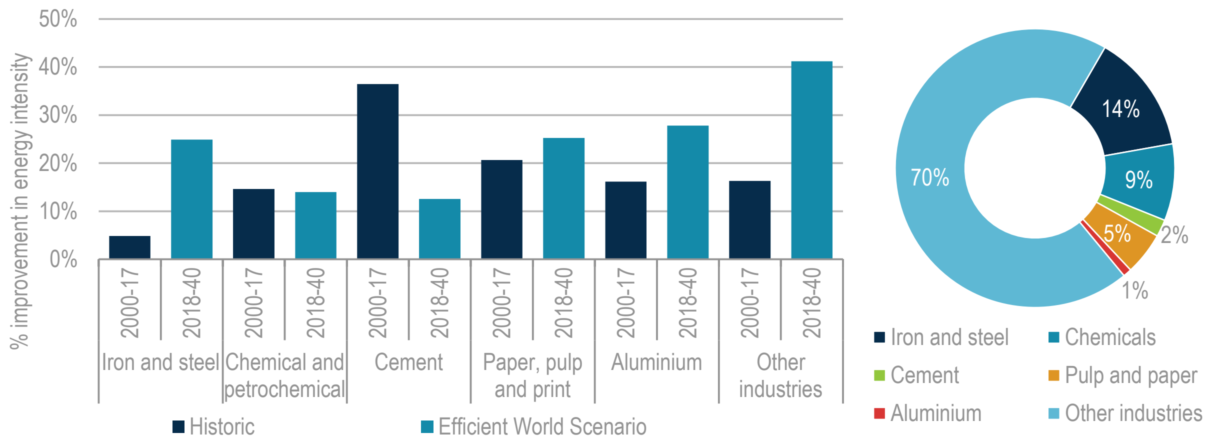
At the sub-sector level, the EWS shows that energy intensity – energy use per unit of GVA – could improve by 41% in the less energy-intensive manufacturing sectors such as food, beverage, automotive and textiles manufacturing, encapsulated within “other industries” (Figure 4.3). Efficiency gains in these sectors represent the majority (70%) of energy savings in the EWS compared with the NPS. Between 2000 and 2017, energy intensity improved by 16% in this aggregated sector,

[50] Energy use per unit of gross value added (GVA), measured on a purchasing power parity basis in 2010 US dollars.

[51] Energy use per unit of gross value added (GVA), measured on a purchasing power parity basis in 2016 US dollars.

so a substantial increase is required to achieve EWS levels. Two major opportunities to achieve this increase are deploying high-efficiency electric heat pumps to replace gas, coal or oil boilers for the generation of low-temperature heat (less than 100°C), and improving the efficiency of electric motor-driven systems. In the EWS, there are twice as many electric heat pumps for process heating compared with the NPS.

Figure 4.3 Percentage improvement in energy intensity by industry sub-sector, historically and in the EWS (left) and sub-sector contribution to total energy savings in the EWS to 2040 (right)



Note: Energy savings in the EWS are determined with respect to the New Policies Scenario.

The EWS shows that energy intensity[52] in the iron and steel manufacturing sector could fall by 25% by 2040 (after having fallen by 5% since 2000) and in the aluminium manufacturing sector by 28% (16% since 2000). In addition to efficiency improvements in primary metals production, a key contributor will be an increase in the recycling of scrap metal to produce new metals, as discussed later in this chapter. In pulp and paper manufacturing, increased levels of paper and cardboard recycling could combine with process and equipment level efficiency gains to deliver improvements in energy intensity of 25% by 2040, compared with improvements of just over 20% since 2000.

Energy intensity in chemicals and petrochemicals manufacturing could fall by 14% by 2040 in the EWS. Petrochemicals are set to account for over a third of the growth in oil demand to 2030, and nearly half to 2050, ahead of trucks, aviation and shipping. Efficiency gains, including improvements in process heating and motor-driven systems, will contribute to limiting the impact on energy use from continuing growth in demand for petrochemical products. Energy efficiency can combine with other measures including carbon capture, utilisation and storage (CCUS), coal to gas feedstock shifts and increased recycling, to reduce CO_2 emissions and other environmental impacts from petrochemicals production (IEA, 2018c).

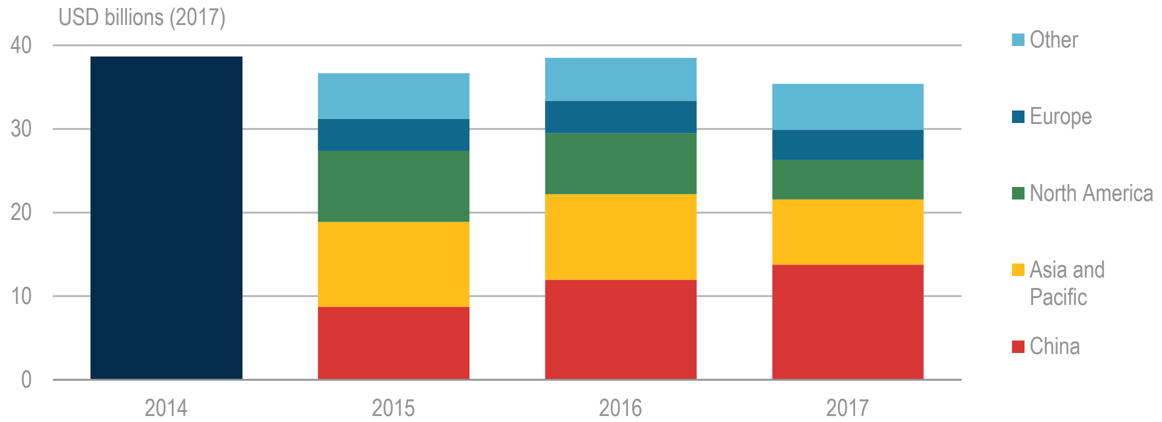
[52] Energy intensity in iron and steel manufacturing is presented as energy use per tonne of steel; for aluminium it is energy use per tonne of aluminium; for chemicals it is energy use per tonne of chemical product, averaged across the five products that are explicitly modelled: ethylene, propylene, BTX aromatics, ammonia and methanol; for pulp and paper it is energy use per tonne of paper production; and for cement it is energy use per tonne of cement production.

The energy intensity of cement manufacturing has improved considerably since 2000 as a result of new and highly efficient production in China and India. Further improvements of 13% by 2040 are also possible in the EWS. A key measure that will contribute to this decline is a reduction in the clinker-to-cement ratio. Clinker is the major component of cement and its production is responsible for the largest proportion of energy use in the manufacturing process. The clinker-to-cement ratio has a significant impact on energy intensity. As detailed in *Energy Efficiency 2017*, there is scope for the ratio to be lowered.

Industrial energy efficiency investment

Global investment in industrial energy efficiency fell 8% between 2016 and 2017 to USD 35 billion (Figure 4.4). China has grown to become the largest source of industrial energy efficiency investment, with just under 40% of the global total.

Figure 4.4 Global investment in industrial energy efficiency, 2014-17



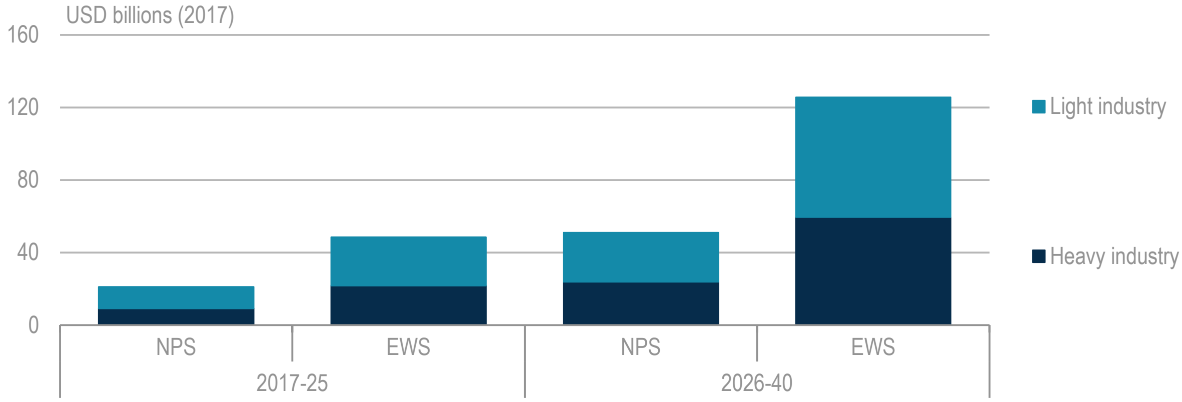
The majority of investment in industrial energy efficiency continues to be made by companies investing their own funds, referred to as on-balance sheet finance (IEA, 2017). As a result, energy efficiency investments compete for capital with other business improvement projects, and high return expectations create a competitive environment for funding.

Fluctuations in energy prices also affect the number and type of energy efficiency measures adopted by industry. As financial return calculations are still largely based on energy savings alone, higher energy prices improve the economic return on efficiency measures, increasing competitiveness against other projects seeking capital within a company. There is some correlation between trends for industrial energy prices and levels of energy intensity.

Other forms of finance are needed to increase industrial energy efficiency investment

To realise the benefits in the EWS, industrial energy efficiency investment must increase to an average annual rate of USD 51 billion from 2017 to 2025, and then to USD 126 billion a year from 2026 to 2040 (Figure 4.5). Light industry, which corresponds to the "other industries" in Figure 4.3 and includes sectors like food, beverage and textiles manufacturing, provides more of the additional energy savings in the EWS and is the focus of much of the additional investment.

Figure 4.5 Average annual industrial energy efficiency investment in the NPS and EWS, 2017-40



An important part of increasing industrial energy efficiency investment in order to capture the EWS potential will be diversifying the sources of finance. The growing availability of innovative finance for energy efficiency, discussed in Chapter 5, has not yet affected industry in a major way. Industrial efficiency projects are sometimes seen as tailored, complex and risky. At the same time, important elements of industrial efficiency, such as heat pumps, more efficient electric motors and variable-speed drives, are relatively simple and replicable, and therefore well suited to alternative sources of finance and business models. The potential involvement of green banks and energy savings insurance (see Chapter 5) will be valuable in reducing this risk and increasing the knowledge of private sector financiers about industrial energy efficiency.

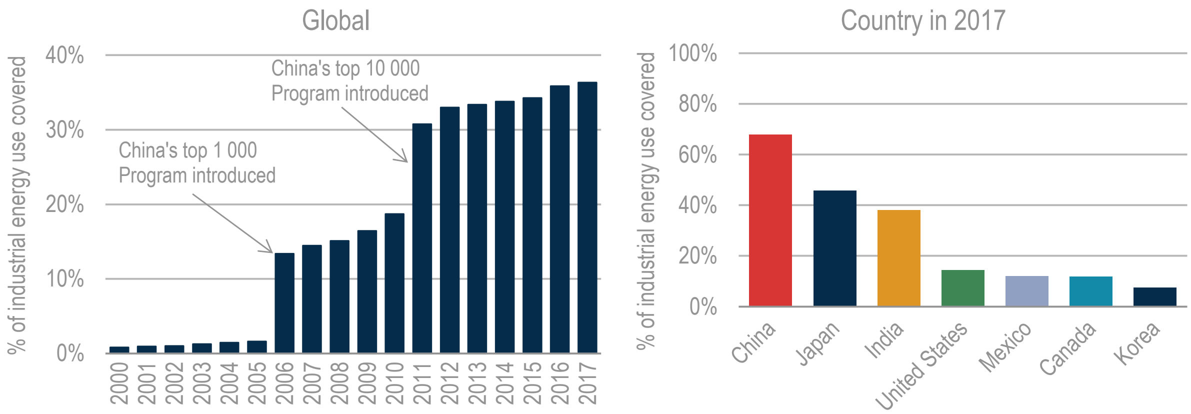
Industrial energy efficiency policy

The amount of global industrial energy use covered[53] by mandatory efficiency codes and standards increased by 0.5 percentage points in 2017 to reach 36% (Figure 4.6). The bulk of policy coverage results from the implementation of mandatory industrial energy efficiency policies in China, India and Japan, along with countries that have long had MEPS for electric motors. Stock turnover rather than new policies is the main reason for the recent incremental progression in coverage.

Due to the size of its industry sector, China's mandatory industrial energy efficiency policies are the bedrock of global coverage. China's policies began with the implementation of the Top 1 000 Programme in 2006 and transitioned to the Top 10 000 Programme, which established mandatory energy intensity improvement targets for the largest energy-consuming enterprises within China. Targets were set at the national level and then passed down to regional and local levels, where they were instituted in individual companies. China will maintain energy intensity improvement targets for industry but will mandate separate requirements for the top 100, 1 000 and 10 000 energy consumers. The policy is being progressively implemented, with full implementation expected in the second half of 2018.

[53] See Box 1.5 in Chapter 1 for explanation of energy efficiency policy coverage and strength.

Figure 4.6 Industrial energy use covered by mandatory energy efficiency policies, globally, 2000-17 (left) and by country in 2017 (right)



Japan has implemented mandatory energy efficiency targets since 2009 through an amendment to its Act on the Rational Use of Energy. Targets take the form of performance benchmarks, which are applied to the steel, cement, pulp and paper and chemicals manufacturing sectors, as well as to electricity generation and oil refining. Benchmarks are defined according to the performance of the top 10% to 20% of companies within each industry sub-sector. Companies are required to meet performance targets based on these benchmarks in five years. Companies are also required to improve energy intensity by at least 1% per year and report annually on progress towards achieving the benchmarking indicator. The policy currently covers just over 60% of energy use in the Japanese industry and service sectors, but extension of the benchmarking policy to capture some public sector buildings and facilities is being considered. This would increase the coverage of the policy to 70%. The combination of benchmarks and the required 1% improvement rate has led to the manufacturing industries in Japan improving energy intensity at a rate of 1.4% per year (Ministry of Economy, Trade and Industry, Japan, 2018, personal communication).

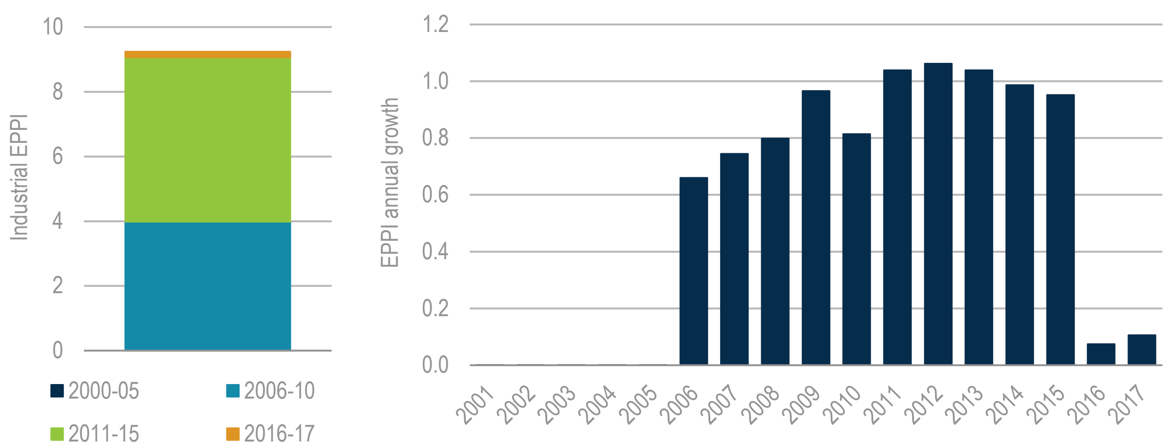
In India, the Perform, Achieve and Trade (PAT) scheme has entered its second cycle. PAT sets mandatory energy intensity improvement targets for designated consumers (DCs) in energy-intensive sectors. Unlike other mandatory policies, PAT provides an incentive for DCs that exceed targets by allowing them to generate energy saving certificates (ESCerts) that can be traded with other DCs that were not able to meet the energy intensity target. At the end of the first PAT cycle, there were 12 trading periods between 26 September and 12 December 2017. After a slow start to ESCert trading, certificate price declines encouraged a late surge in activity, resulting in USD 3.82 million worth of trading by the end of the period.

In the second PAT cycle, the policy was expanded to cover 11 economic sectors with a 30% increase in the number of DCs, covering 58% of industrial energy use in India. The national target to be achieved over the second cycle corresponds to nearly 4% of the annual energy consumption in the manufacturing sectors covered, notable given that the EWS identifies potential savings of around 1% of global manufacturing energy use over the same period. The third PAT cycle came into effect on 1 April 2017, covering 116 DCs with a combined annual energy consumption of 116 Mtoe, of which 24 Mtoe is in thermal power plants. The combined energy reduction target over the three years of the third PAT cycle is 1.01 Mtoe (BEE, 2018).

The progression of industrial efficiency policy is slowing

The introduction and strengthening of mandatory industrial energy efficiency policies and MEPS for industrial equipment, particularly electric motors, has resulted in the global industry sector reaching a score of 9.2 in 2017 on the Efficiency Policy Progress Index (EPPI) (Figure 4.7). The industry EPPI grew by 0.1 points in 2017, 40% more than 2016, but well below the average annual rate of increase of 1.0 between 2011 and 2015, the period of highest progress since 2000. This result reflects a fairly static picture for industrial energy efficiency policy progress in 2017. No major new policies were implemented, and progress was driven by stock turnover, particularly electric motors.

Figure 4.7 Industrial EPPI in 2017 (left) and annual additions to industrial EPPI, 2001-17



Note: See Chapter 1 for a description of the Efficiency Policy Progress Index (EPPI).

Industrial energy efficiency policy must progress to unlock greater efficiency gains

Mandatory policies have succeeded in increasing industrial energy efficiency and will contribute to realising potential efficiency gains in the EWS. MEPS are not widely applied to industrial equipment, aside from electric motors, with existing policies implemented with varying levels of stringency, suggesting the potential to both expand and strengthen such policies. In the EWS, there are twice as many electric heat pumps for process heating in 2040 compared with the NPS. Achieving this deployment could be facilitated by mandatory policy, including standards that push the market towards higher efficiency equipment.

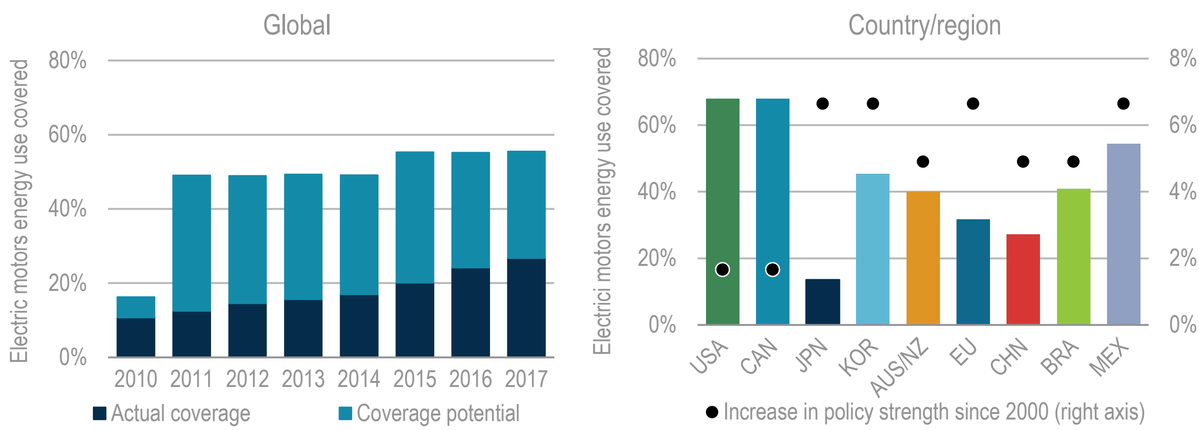
Progress in reducing industrial energy intensity in the short term will also be aided by the maintenance of existing mandatory programmes in China and India, which will continue to be responsible for the largest share of growth in global industry energy demand. The continuation and expansion of these policies provides these countries with a level of assurance that efficiency improvements will continue. Similar expansion plans for the Japanese industry benchmarking policy also signal that policy settings will be in place to increase efficiency in industry and services.

Mandatory policies are currently complemented by other measures that incentivise greater levels of energy efficiency and provide relevant information to energy users and this will need to continue to realise opportunities in the EWS. As discussed later in this chapter, these include incentives, which encourage the adoption of energy management systems or energy efficiency targets, and information sharing and other resources that improve knowledge and skills relating to energy management and efficiency. Industrial energy efficiency policy should also be developed with the aim of facilitating greater levels of third-party finance, which is needed to reach investment levels required by the EWS. Introducing market-based instruments such as white certificate schemes, which in Europe have been successful in unlocking energy efficiency potential within industry, and supporting development of an energy service company (ESCO) market, can contribute to achievement of such objectives.

Policies for electric motor-driven systems

The amount of energy use associated with the operation of industrial electric motors that are subject to MEPS increased to 27% in 2017. Across those countries with MEPS, if all motors were replaced by motors meeting the standard, policy coverage would rise to 55% (Figure 4.8). The addition of MEPS for electric motors at the IE3 level[54] in Japan and Saudi Arabia level in 2015, and in Chinese Taipei in 2017, have pushed this coverage potential slightly higher in recent years. The United States and Canada implemented MEPS at the IE2 level in 1997, the first countries to do so, which have been strengthened to the IE3 level. If all countries had implemented and strengthened MEPS for electric motors to the IE3 level at the same time, it is estimated that global industrial electricity use in 2017 could have been 16% lower.

Figure 4.8 Global policy coverage and potential for electric motors, 2010-17 (left) and major country/region coverage and increase in policy strength since 2000 (right).



Note: Energy use captures all electric motor sizes, with MEPS applying to just medium sized motors (0.75-375kW).

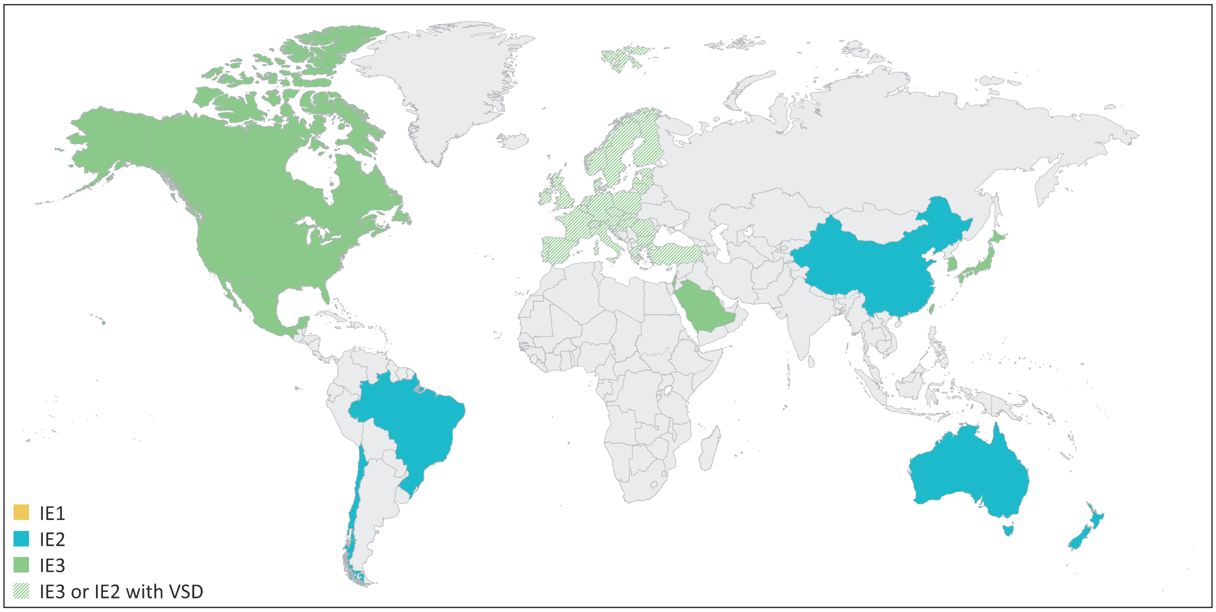
The European Union introduced MEPS at the IE2 level in 2011, so coverage has not yet reached levels in other countries and regions. These MEPS have now been strengthened to the IE3 level, or IE2 with a variable speed drive, so the European Union is now equal with Japan, Korea and Mexico, which have all introduced MEPS since 2000 and increased stringency to the IE3 level (Map 4.1). The increase in policy strength is consistent across Australia/New Zealand,[55] Brazil and China, with MEPS still at the IE2 level, although Brazil will transition to IE3 in 2019 (Box 6.2), with Australia/New

[54] 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 IE4, IE4 being the most efficient, with future efficiency improvements leading to additional classes.

[55] MEPS for electric motors in Australia and New Zealand are based on the same standard (AS/NZS 1359.5:2004.

Zealand and China also expected to move to IE3 soon. India implemented performance standards at the IE2 level in early 2018, although these are not yet mandatory.

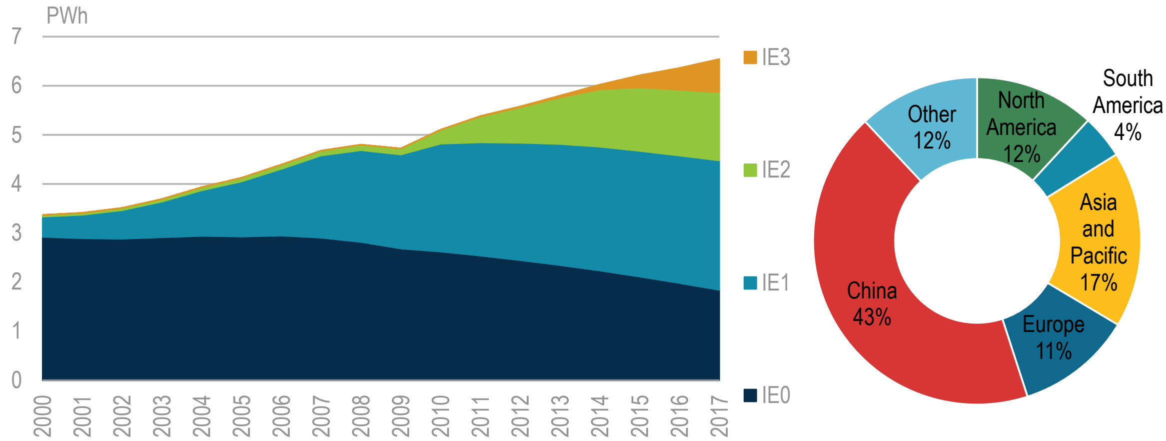
Map 4.1 Countries with MEPS for electric motors, by strength level



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Nearly 30% of electric motor energy use globally in 2017 was associated with unregulated electric motors, classified as IE0 (Figure 4.9). This is due to the operation of motors that fall outside the coverage of standards, the continuing operation of unregulated motors in economies where MEPS have been implemented or motors operating in countries without any MEPS. Motors at the IE1 level cover 40% of global electric motor energy use, with IE2 and IE3 motors taking an increasing share. China was responsible for nearly 45% of electric motor energy use globally in 2017, covering 40% of motors operating at the IE0 efficiency level and 30% at the IE1 level.

Figure 4.9 Energy consumption of electric motor systems by efficiency level, 2000-17 (left) and regional breakdown of electric motor energy use in 2017 (right)



Measures and policies to improve efficiency need to go beyond the electric motor unit and consider the wider system

There is cost-effective potential for the efficiency of motor-driven systems to increase by 35% between 2017 and 2040 (Table 4.1). To achieve such an increase, the majority of motors' energy use in 2040 will need to come from the super-premium efficiency IE4 level, with the remainder at IE3 level. However, the wider motor-driven system presents greater opportunities for efficiency gains than just the motor unit. Potential comes from the increased application of variable speed drives (VSDs), improvements in the design, selection and operation of end-use devices and efficiency gains across the wider motor-driven system. VSDs are a common feature of new, high-efficiency electric motors but can also be retrofitted to existing electric motors, representing one of the most cost-effective efficiency measures.

Table 4.1 Efficiency improvement indicators for electric motor-driven systems, 2017-40

		New Policies Scenario					Efficient World Scenario				
	2017	2020	2025	2030	2035	2040	2020	2025	2030	2035	2040
Efficiency improvement	100	102	106	109	111	114	105	114	122	129	135

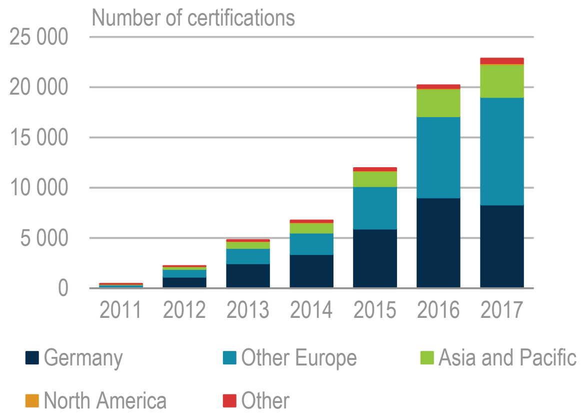
Improving the efficiency of end-use devices such as pumps, fans and compressors may be aided by standards, which have been implemented in a small number of large energy-using countries, although many remain voluntary (CLASP, 2018; IEA-4E, 2016; IEA-4E, 2018). End-use device inefficiencies are also linked to poor design of the motor-driven system, particularly over-sizing of the electric motor and end-use device, which leads to wasted energy use. This can be reduced by improving information and skills for the design and installation of motor-driven systems; implementing design standards; and including energy performance incentives in contracts for design and installation of motor-driven systems. This will be important given the large potential in the EWS for energy savings in less energy-intensive manufacturing sectors, in which operations can be more variable and diffuse.

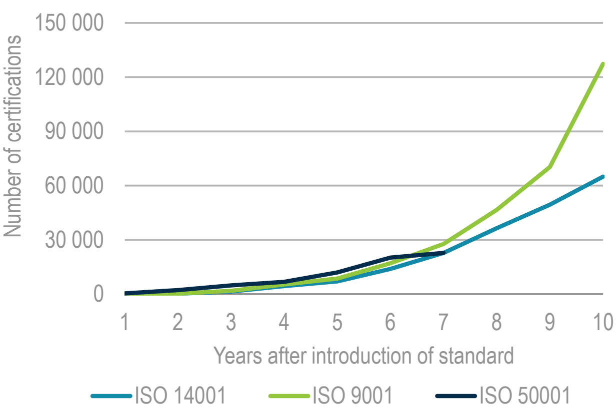
Energy management systems for industrial energy efficiency

Measures that enhance the efficiency of the entire motor-driven system are aided by the implementation of an energy management system. An energy management system is a collection of procedures and practices to ensure the systematic planning, analysis, control, monitoring and improvement of energy use and efficiency. Energy management systems are effective in developing better practices across large parts of industry that may not have the expertise or incentive to focus on efficiency as much as energy-intensive sectors.

ISO 50001 is the global energy management standard. By the end of 2017 the number of certifications to ISO 50001 had reached nearly 23 000, a 13% increase from 2016 (Figure 4.10). This was a marked slowdown in the growth of total certifications observed in previous years. The major factor that contributed to the slowdown in 2017 was the 8% reduction in German certifications, although the continuation of favourable tax incentives (Box 4.1) has seen Germany maintain its place as the country with by far the most certifications. The ISO 50001 standard has been going through a review, which may have contributed to the observed slowdown in the growth of certifications. The updated standard (ISO 50001:2018) has now been published.

Figure 4.10 ISO 50001 certifications 2011-17 (left) and certification progress compared with other management standards (right)





Sources: Adapted from ISO (2018), *ISO Survey of certifications to management system standards* (database); just-style (2001), *ISO 9000 simplified*; Thandapani, D. et al. (2011), *ISO 9001:2000 based quality management system via ABET based accreditation*; ISO (2000), *The ISO Survey of ISO 9000 and ISO 14000 Certificates, Tenth cycle: Up to and Including 31 December 2000.*

The growth of certifications in the first seven years of ISO 50001 is similar to that of other management standards, namely ISO 14001 and ISO 9001.[56] However, ten years after their introduction, there were over 60 000 ISO 14001 certifications and over 120 000 ISO 9001 certifications. Whether ISO 50001 certifications follow a similar path to that of other standards will depend on how many Chinese companies adopt the standard. China is responsible for the largest percentage of ISO 9001 and ISO 14001 certifications, while at the end of 2017 they represented just 8.5% of total ISO 50001 certifications. However, in 2016, the number of ISO 50001 certifications in China nearly tripled, and in 2017 the number of certifications grew by over 40%, making China the fourth highest globally and the largest outside Europe. There is also a Chinese national energy management standard (GB/T 23331), to which there were in total 2 552 certifications by the end of 2017 (CNCA, 2018).

Box 4.1 German tax incentives for ISO 50001

German companies that implement an energy management system can claim relief from the country's renewable energy surcharge (Special Equalisation Scheme) or the energy and electricity tax (energy and electricity tax cap). The standard renewable energy surcharge is 0.068 EUR (Euros)/kWh. A company that operates in a designated energy-intensive sector, meets specified electricity use criteria and has a recognised energy or environmental management system in place is able to apply for the Special Equalisation Scheme, under which it pays no more than 20% of the renewable energy surcharge. By the end of 2017 over 2 000 companies had claimed the incentive, worth around EUR 5 billion.

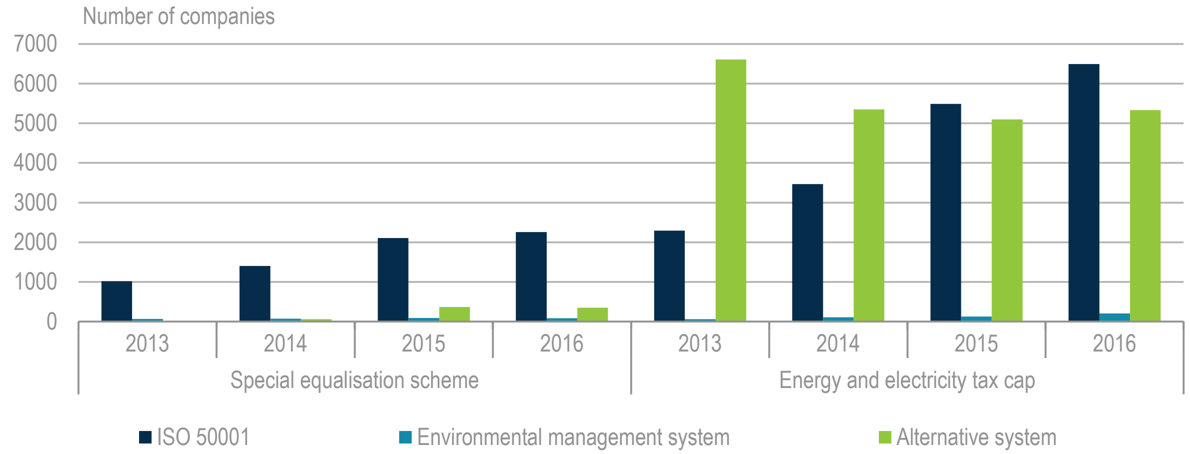
In Germany natural gas for industry is taxed at 5.5 EUR/MWh and electricity at 20.5 EUR/MWh. Companies in the manufacturing, energy, mining, water supply and building sectors can apply for a 90% refund of the energy and electricity tax, provided that the industries agree to a collective energy intensity reduction target of 1.35% per year and that companies implement an energy or environmental

[56] ISO 9001 is the international standard that specifies requirements for a quality management system. ISO 14001 is the international standard that sets out the criteria for an environmental management system.

management system. By the end of 2017, around 4 800 companies had qualified for relief from the energy tax and around 9 400 for the electricity tax, worth in total around EUR 2 billion.

ISO 50001 certification is the main method of meeting the energy management requirement, although other systems are used by small and medium-sized enterprises (Figure 4.11). Sectors qualifying for the energy and electricity tax cap are achieving energy intensity reductions of around 3% per year, compared with the target of 1.35%.

Figure 4.11 Type of action undertaken by German companies obtaining incentives through the special equalisation scheme and energy and electricity tax cap, 2013-16



Source: German Federal Ministry of Economics and Technology, personal communication 28 June 2018.

To increase uptake of energy management systems, it is vital to enhance understanding of the benefits obtained. As highlighted in *Energy Efficiency 2017*, early evidence suggests companies that implement an energy management system achieve a rapid improvement in energy and cost savings. Much of this improvement results from better identification, assessment and implementation of opportunities to replace existing technology with efficient alternatives or enhance industrial process control. There is also evidence that energy management systems unlock additional energy and cost savings that are not linked to specific technology or control interventions (Box 4.2).

Box 4.2 Energy management system unique savings

The United Nations Industrial Development Organisation (UNIDO) works with companies in developing economies to implement energy management systems in line with ISO 50001. Data from nine of these companies reveals that on top of savings resulting from the implementation of efficiency projects, they achieved additional "energy management system unique" savings, linked to improvements in staff awareness of energy efficiency; energy management capability; daily routine operations; and staff accountability. Following the implementation of an energy management system in these nine companies, projects were implemented that led to electricity savings of over 26 GWh. However, there were also an additional 8 GWh of "energy management system unique" savings, which accounted for between 1% and 19% of total electricity use in the companies analysed and 12% to 80% of the total savings.

Source: UNIDO, personal communication, 21 June 2018.

A variety of policy measures are used to increase uptake of energy management systems

Several types of policy measures have been implemented to promote the uptake of energy management systems. The ability for certification to be used as a means of confirming and tracking compliance has led to ISO 50001 becoming central to many policies. In North America, energy management programmes centre on voluntary arrangements that provide information and assistance to companies. The main example is the Superior Energy Performance (SEP) Program in the United States, which recognises companies that implement the ISO 50001 standard and achieve verified energy performance improvements. The SEP Program is complemented by a new voluntary support measure (50001 Ready), which is aimed at guiding small and medium-sized enterprises (SMEs) through the process of implementing ISO 50001.

In Europe, regulatory measures are coupled with incentives to adopt energy management systems through Articles 7 and 8 of the EU Energy Efficiency Directive (EED). Member states can meet elements of these requirements through means such as voluntary agreements, which involve companies agreeing to take steps to improve efficiency in exchange for fiscal or legal incentives. Measures can include putting in place an energy management system, with ISO 50001 included in current or previous voluntary agreements in Denmark, Ireland and Sweden (IEA, 2018d). Article 8 of the EED requires EU member states to ensure that companies that do not meet the definition of an SME undertake an energy audit at least once every four years. In many EU member states, exemptions to this requirement are provided to companies that have implemented a recognised energy management system, such as ISO 50001.

Measures to increase the adoption of energy management systems will be vital to realising efficiency gains within industry, particularly in less energy-intensive manufacturing sectors where there is a large amount of potential for efficiency gains in the EWS. Incentives are currently the preferred means of promoting implementation of energy management systems, although success varies. While an energy management system ensures that a company has the systems and processes to improve efficiency, it does not guarantee a certain rate of improvement. This relies on the company implementing identified energy efficiency opportunities and improving operating practices. Therefore, incentives can be coupled with a target to achieve an agreed rate of energy efficiency improvement, which will provide a greater degree of certainty that incentives will lead to efficiency gains. Targets are part of policies in Germany (at a sectoral level) and the United States.

Learning energy efficiency networks are also being used to improve understanding of energy management systems and how they can be successfully implemented. Networks bring together companies from the same sector, region, supply chain or corporate group to share experiences and build capacity to collectively improve energy efficiency. Participation can also be encouraged through use of incentives. In Switzerland, companies that agree to join a network and meet energy and emissions reduction targets are exempted from CO_2 taxes (IPEEC, 2017). Networks have also become a key policy in Germany, which has a goal of establishing 500 networks by 2020. Mexico has also established networks to promote the adoption of energy management systems (Box 6.6).

Digital technology, particularly improved energy metering, monitoring and process control systems, will continue to make energy management systems more effective. Data is central to the effective implementation of an energy management system, with digital innovation allowing for real-time and automated data collection and analysis. Digital innovation will continue to unlock opportunities to realise the benefits highlighted by the EWS, but vigilance and action from policy makers is required.

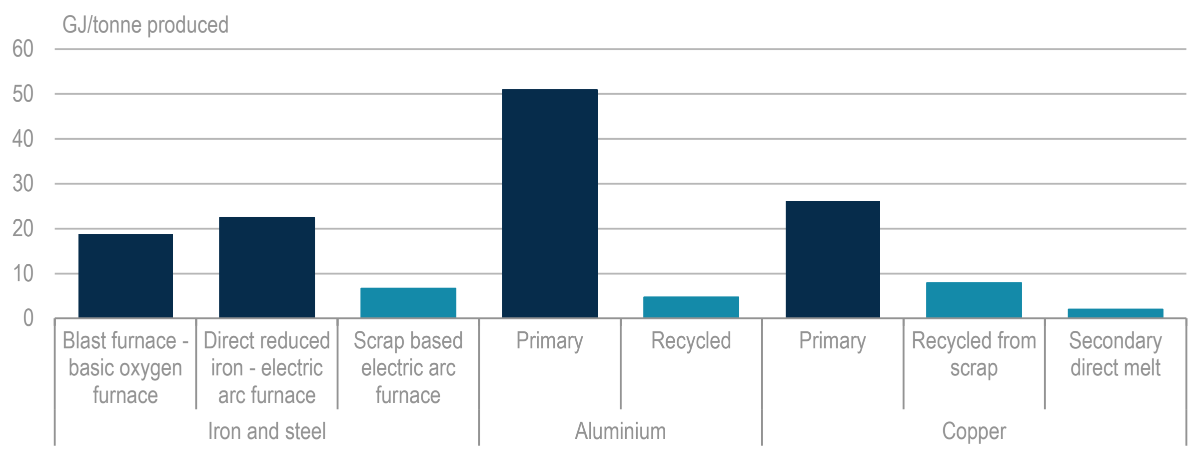
Key actions include facilitating adoption of digital technologies by SMEs that lack technical skills or other resources; developing a clear evidence base to communicate the value proposition of energy management systems and digital technology; and considering ways to reduce any privacy or cyber-security risks (IEA, 2018d).

Special focus: Metals recycling

The production of metals such as iron, steel, aluminium and copper from recycled scrap presents a significant opportunity for energy efficiency. Metals manufacturing is responsible for over a quarter of global industrial energy use, with primary metals manufacturing, in which metals are produced from mineral ores, the largest proportion. Recycling, also referred to as secondary production, is far less energy-intensive than primary production and is therefore an important component of the EWS. Crude steel production in an electric arc furnace using scrap is 60% to 70% less energy-intensive than primary production. Similarly, aluminium recycling, where scrap is re-melted and re-cast, is over 90% less energy-intensive. Recycled copper, in which scrap metal is also re-melted and re-cast, is 70% less energy-intensive than primary production (Figure 4.12).

The main factor limiting the growth of metals recycling is the quality and availability of scrap metal. Scrap is collected and recycled within industrial processes, referred to as new scrap, and at the end-of-life of infrastructure, vehicles and consumer appliances, referred to as post-consumer scrap. Many metal applications have long lifetimes, so a lot of metal is not available for recycling and is still in productive use. If the cost of collecting, sorting and recycling scrap is high, a business case for recycling may also be difficult to develop.

Figure 4.12 Energy intensity of primary and recycled metal production of steel, aluminium and copper



Notes: Primary aluminium refers to the production of aluminium ingots from alumina via an electrolytic process in molten solution (Hall Héroult process). Recycled aluminium production refers to the production of aluminium ingots from the refining of old and new scrap and metal dross and re-melting of new and sorted old scrap. Primary copper production refers to the production of copper cathode from copper ore. Recycled copper production refers to the production of cathode copper metal from scrap, secondary direct melt refers to the production of copper billets from copper cathode and ingot.

Sources: Adapted from World Steel Association (2018), *Energy Use in the Steel Industry*; World Aluminium (2018), *Primary Aluminium Smelting Energy Intensity* (database); European Aluminium (2013), *Environmental Profile Report for the European Aluminium Industry*; The Aluminium Association (2013), *The Environmental Footprint of Semi-Finished Aluminium Products in North America*; International Copper Association (personal communication 12 September 2018).

Although data on rates of metal recycling are limited, global estimates show that recycling rates vary across the three major metals. Steel has the highest percentage, owing to its high volumes in large infrastructure, favourable characteristics and established market (Table 4.2). Recycling rates for copper are lower than for the other metals analysed, due to in part its use in smaller and more distributed consumer appliances. Post-consumer scrap represents a varying percentage of total metals recycling, from as high as 70% for steel to as low as 35% for copper, highlighting the potential to increase collection rates.

Table 4.2 Recycling rates for iron and steel, aluminium and copper

Metal	End-of-life recycling rate	Amount of post-consumer scrap in total recycling
Iron and steel	50-90%	50-70%
Aluminium	60-95% (average 70%)	60%
Copper	40-50%	35-50%

Notes: The end-of-life recycling rate is recycled end-of-life metal as a percentage of end-of-life metal products. End-of-life recycling refers to functional recycling and includes recycling as a pure metal (e.g. copper) and as an alloy (e.g. brass). Post-consumer scrap is metal in products that have reached their end-of-life.

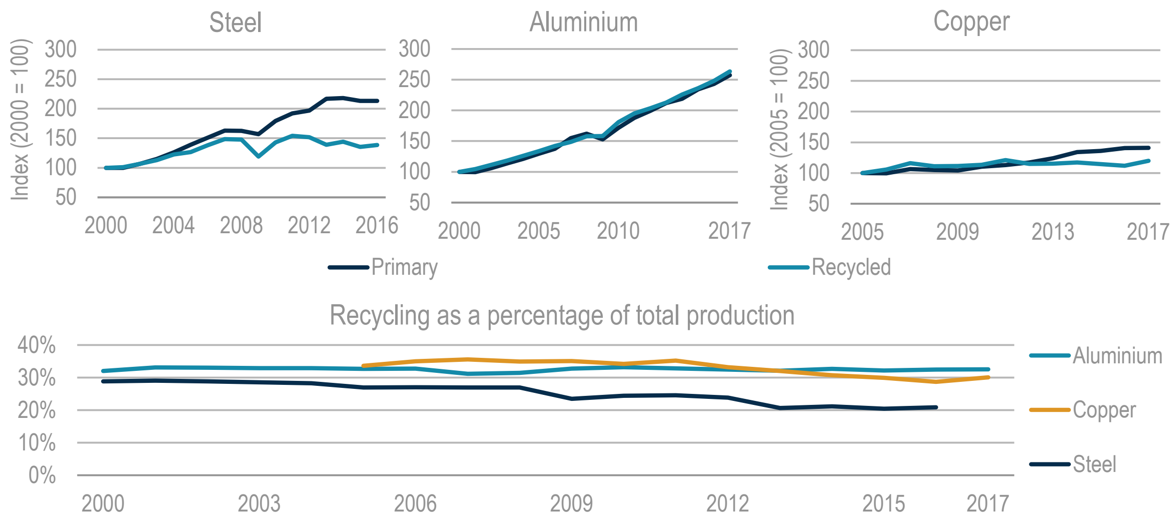
Sources: UNEP (2011), *Recycling Rates of Metals: A Status Report*; Bertram et.al. (2017), *A Regionally-Linked, Dynamic Material Flow Modelling Tool for Rolled, Extruded and Cast Aluminium Products*; World Aluminium (2016), *Global Aluminium Cycle 2016.*

Global trends for steel, aluminium and copper recycling are variable (Figure 4.13). Since 2000, production of crude steel from scrap through an electric arc furnace has risen by around 50%. However, primary production of steel has doubled, because demand for steel in China outpaced the availability of scrap. Conversely in regions like Europe and North America, scrap availability was higher but demand for crude steel was lower, creating a mismatch between scrap supply and crude steel demand. As a result, crude steel produced from scrap through an electric arc furnace has fallen to just over 20% of the global total. Depending on scrap availability and prices, some primary steel production routes incorporate recycled metal, so increased primary production does contribute to increases in steel recycling.

To reach the levels in the EWS by 2040, electric arc furnaces will need to be used for half of global steel production – both-scrap based production and direct reduced iron. Steel produced through electric arc furnaces, including direct reduced iron, represented just over a quarter of global crude steel production in 2017 (World Steel Association, 2017).

Global aluminium production has grown strongly since 2000, reflecting strong demand from emerging economies, particularly China. Recycled aluminium production has risen at a similar rate, with its percentage of total production fairly flat at just over 30% due to limited scrap availability. This percentage increases to over 60% in the EWS, which will be challenging to achieve given that demand for aluminium will continue to grow and the desire for applications with longer lifetimes will continue to limit scrap availability. Copper recycling has been reasonably flat compared with the other metals analysed. After peaking in 2011, recycling as a percentage of total production fell, as a result of reduced activity in Europe and lower copper prices, which impacted the business case for recycling. In 2017, recycling was estimated to represent just over 30% of global production.

Figure 4.13 Global primary and recycled metal production trends



Notes: Steel recycling reflects production from electric furnaces minus the production of direct reduced iron as a percentage of total crude steel production. Aluminium recycling reflects recycled metal as a percentage of total aluminium supply. Copper recycling reflects production of cathode copper metal from scrap plus the production of copper billets from copper cathode and ingot in secondary direct melt, as a percentage of total copper supply.

Sources: World Steel Association (2017), *Steel Statistical Yearbook 2017*; World Steel Association (2010), *Steel Statistical Yearbook 2010*; World Aluminium (2017), *Global Mass Flow Model*; ICSG (2018), *Annual Recyclables Survey 2018*.

There are numerous forms of policy support designed to increase the amount of scrap metal available and improve the business case for recycling, although the majority are designed for recycling in general (Table 4.3). Financial assistance, in the form of grants or loans to recycling facilities, is widely used to expand recycling. Private financing, other than typical company loans, is not a major contributor. Taxation measures that encourage recycling are the most common forms of policy support. In several countries, tax credits are provided to companies that recycle. Landfill taxes, which are intended to discourage landfilling of wastes in support of recycling, are the most common form of support.

The provision of recycling services, typically by local governments, has made it much easier for consumers to recycle, although the extent to which this benefits metals recycling is less than that for plastics and paper. Extended Producer Responsibility (EPR) programmes, where manufacturers become financially responsible for the management of end-of-life products, can create incentives for the design of products that are recyclable at low cost. Such policies are often applicable to electronics manufacturers, facilitating copper recycling, and vehicle manufacturers, aiding aluminium recycling. The long-lived nature of steel, its extended supply chain and use in large-scale infrastructure as opposed to consumer products has meant that collection rates for scrap steel have not benefitted from EPR to the same extent.

Current policy settings are not increasing recycling rates enough to unlock the efficiency gains possible in the EWS. There are opportunities to develop policies that are more targeted towards increasing scrap metal collection and recycling, as many current policies focus on recycling in general. Tax-based incentives are the most common policy tool, but still rely on voluntary decisions by companies or consumers. Well-enforced policies that encourage or mandate metals recycling, such as EPR or landfill bans, are the strongest tool to increase scrap collection.

The energy efficiency benefits from metals recycling also fit with the broader objective of resource efficiency. In addition to energy efficiency, resource efficiency refers to material efficiency through the improved design and construction of infrastructure, equipment and consumer appliances, such that fewer raw materials are required. Resource efficiency is becoming a central component of EU Policy Frameworks, specifically the EU Action Plan for a Circular Economy, which was adopted in 2016 with over half of the initiatives in the plan already delivered (European Commission, 2018b).

Table 4.3 Policy support measures that extend to metals recycling

Policy/support category	Type of support	Example of policy/support
Financial assistance for recycling facilities	Grants	New South Wales, Australia: The Major Resource Recovery Infrastructure programme provides grants to fund major resource recovery facilities.
	Debt finance from public banks	EU: Over 5% of transactions in the European Fund for Strategic Investments managed by the European Investment Bank have a resource efficiency element.
Favourable tax treatment for recycling facilities	Corporate tax provisions for small businesses	North Carolina, United States: If a business purchases or constructs facilities or equipment for recycling or resource recovery, it may be entitled to special corporate state income tax treatment.
	Recycling specific tax credits	Mexico City: Tax credits are available to corporations that recycle or reprocess solid waste.
	Accelerated depreciation for recycling facilities	United States: The RISE Program in the United States entitles domestic recycling companies to write-off 50% of an asset's value in the first year of operation.
	Value added tax credits	South Korea: Tax credit for scrap metal collectors that acquire scrap from individuals or public organisations.
Measures to encourage individuals and organisations to recycle	Bans of landfilling of certain wastes	EU: Proposal in the EU Action Plan for a Circular Economy to ban landfilling of separately collected waste.
	Taxes on landfill waste	Many countries and regions have implemented landfill taxes, which are assessed by weight or type of waste.
	Provision of recycling services by local government	EU: The EU waste framework directive requires the member states to provide for the collection of recyclable wastes including paper, plastic, glass and metal.
	Extended product responsibility (EPR)	Requirements for manufacturers to collect old products once usable life is over. By 2013, there were nearly 400 EPR systems in operation globally, with nearly 50% covering electronics and vehicles/automotive products (including batteries).

Sources: OECD (2017), *Working Part on Resource Productivity and Waste: Mapping Support for Primary and Secondary Metal Production*; OECD (2016), *Extended Producer Responsibility, Guidance for efficiency waste management: Policy highlights*; NSW Office of Environment and Heritage (2018), *Waste Less Recycle More Initiative grant programs*; European Commission (2018a) *Environment and Resource Efficiency*; KPMG (2017), *The KPMG Green Tax Index*; State of North Carolina (2018), *Tax Provision Information*; Institute of Scrap Recycling Industries (2018), *Rise FAQs*; KPMG (2013), *The KPMG Green Tax Index 2013*; European Commission (2018b), *Circular Economy: Implementation of the Circular Economy Action Plan*; EUR-Lex (2018), *Directive 2008/98/EC of the European Parliament and of the Council of 19 Dec 2008 on Waste and Repealing Certain Directives*.

An efficient world strategy for industry

Overall opportunity	Industry could produce nearly twice as much value from each unit of energy use in 2040 compared with current levels.
Sub-sector opportunities	**Less energy-intensive/light industry:** • Represents 70% of potential energy savings for industry in the EWS.[57] • Energy efficiency could improve by over 40% between now and 2040, compared with 16% improvement since 2000. • Key technologies are motor-driven systems and electric heat pumps for process heating. • In the EWS, there are twice as many electric heat pumps for process heating and the majority of electric motors are at today's highest efficiency standard. **Iron and steel:** • Represents 14% of the potential energy savings for industry in the EWS. • Energy efficiency could improve by 25% between now and 2040, compared with 5% improvement since 2000. • Key measure is increased metals recycling. • In 2040, electric arc furnaces are used for half of global steel production. **Chemicals and petrochemicals:** • Represents nearly 10% of the potential energy savings for industry in the EWS. • Energy efficiency could improve by nearly 15% between now and 2040, a similar rate to that achieved since 2000. • Energy efficiency can combine with CCUS, fuel switching and increased recycling to limit the impact from the continuing growth in demand for petrochemicals (IEA, 2018c).
Policy measures to enable efficiency gains	**Regulation:** • Increased coverage and strength of minimum energy performance standards for key industrial equipment, including electric heat pumps, motors and other end-use devices. • Mandatory measures to increase scrap metal collection and recycling (can also drive increased recycling and efficiency gains for other metals manufacturing including aluminium and copper). **Finance and incentives:** • Appropriate incentives to encourage the adoption of energy management systems, such as fiscal incentives or links to environmental regulation. • Financial or fiscal incentives to encourage increased scrap metal collection and recycling. • Market-based instruments, including obligation and white certificate schemes, to encourage business model innovation and increased investment. **Information and capacity building:** • Mechanisms such as industry networks, training and case studies to enhance awareness and capacity.

[57] Energy savings and heat pump deployment in 2040 are calculated with respect to the New Policies Scenario (NPS).

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5. INVESTMENT, FINANCE AND BUSINESS MODELS

Highlights

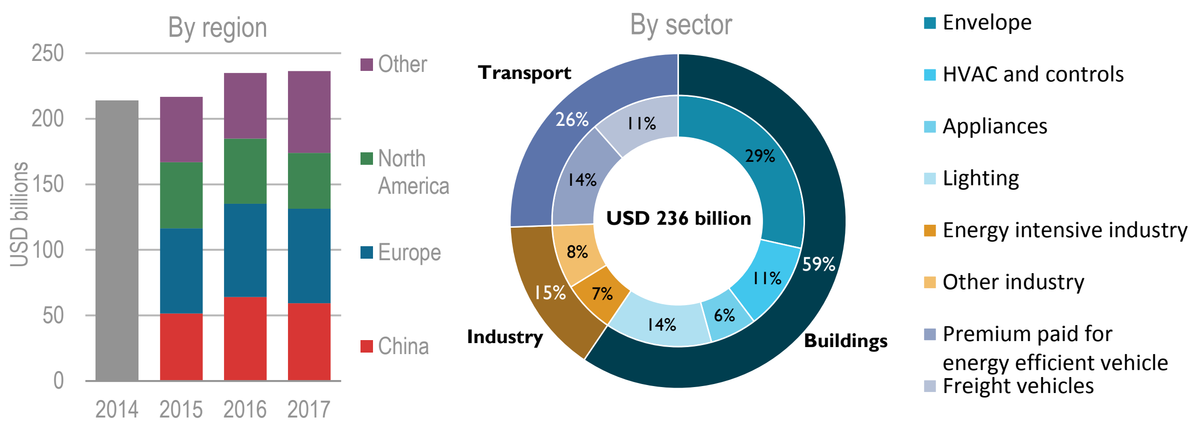
- **Global investment in energy efficiency grew by 3% to USD 236 billion (United States dollars) in 2017**. Europe remains the largest source of investment, rising by 1%, while investment fell slightly in the United States and the People's Republic of China (hereafter "China"). Investment growth slowed in all sectors. Buildings still receive the largest share of efficiency investment, at 59% of the total – a similar share as in 2016.
- **To realise the Efficient World Scenario (EWS), energy efficiency investment needs to grow significantly**. Average annual investment in the EWS needs to grow to over USD 584 billion between now and 2025, and then to nearly USD 1.3 trillion per year between 2026 and 2040. All investments required for the EWS are cost-effective, paying back on energy savings alone by an average factor of three over the life of the measure.
- **In the EWS, transport accounts for the largest share of investment, due to investment in fuel efficiency and electric vehicles.** Cumulative transport investment in the EWS is 51% higher than in the New Policies Scenario (NPS). Investment in buildings, including spending on building envelopes and efficient appliances, would need to be 48% above NPS levels. While industry is the smallest component of total investment in the EWS, cumulative investment in industry by 2040 would still need to be nearly 1.5 times above NPS levels.
- **To reach the investment levels needed to realise the EWS, more diverse finance sources and business models are necessary.** Energy service companies (ESCOs), which design, install and can finance energy efficiency projects, are an example of a relatively mature energy efficiency business model. The global ESCO market grew by 8% to USD 28.6 billion in 2017. A number of other finance and business model innovations, including green bonds and repayment mechanisms, are also continuing to develop.
- **Green banks are a growing source of private finance for energy efficiency projects.** From 2012 to 2017, the share of energy efficiency and low-emissions transport in total green bank investment grew over 50%, though funding dipped slightly in 2017.
- **In 2017, bonds issued for energy efficiency rose from 18% to 29% of the total green bond market of USD 161 billion, equalling the issuance of bonds dedicated to renewable energy for the first time.** Together with other innovative finance models, such as Property Assessed Clean Energy (PACE) loans (largely in the residential sector), green bonds are boosting the amount of third-party finance available for energy efficiency.
- **Mobilising the large amount of additional investment required in the Efficient World Scenario will benefit from a supportive policy environment.** Market-based instruments, including obligation schemes and auctions, have been shown to encourage investment and business model innovation. These measures, coupled with improvements in the quality and availability of information, can reduce the risk profile of energy efficiency, thereby building investor confidence and understanding.

Energy efficiency investment trends and outlook

Investment growth slowed in 2017

Global energy efficiency investment grew marginally in 2017, up by 3% to USD 236 billion (Figure 5.1). Europe continues to see the most energy efficiency investment at USD 75 billion, 32% of the global total. North America accounted for 18% of investment, at USD 42 billion, a drop from 20% in 2016, and China's share of total investment was 27%, up from 25% in 2016.

Figure 5.1 Energy efficiency investment by sector and region



Note: HVAC = heating, ventilation and air conditioning.

Sources: Includes inputs from Navigant Research (2016); IHS Markit (2018).

The buildings sector continues to dominate energy efficiency investment, reaching USD 140 billion (59%) of the global total in 2017, a 3% increase from 2016. Transport sector investment grew the most, up by 11% to USD 60 billion, just over a quarter of the global total. Industry sector investment fell by 8% to USD 35 billion in 2017. Further analysis of sub-sector investment trends is presented in Chapters 2, 3 and 4.

Box 5.1 Estimating global energy efficiency investment

As in *World Energy Investment 2017*, *World Energy Investment 2018* and other recent IEA reports, an energy efficiency investment is defined here as incremental spending on new energy efficient equipment or the full cost of refurbishments that reduce energy use. This includes both private investment and funds invested through government incentives. The intention is to capture spending that leads to reduced energy consumption. Under conventional accounting, part of the spending would be categorised as consumption rather than investment.

In the buildings sector, the incremental investment for new or renovated buildings is the change in cost for services (design, delivery and installation) and products (lighting, appliances, equipment and materials) that increase energy efficiency, beyond the investment required for the minimum performance legally allowed. For building types and products that do not have efficiency requirements, this cost is the incremental spending on energy efficient services and products beyond what would have otherwise been spent, which in some cases is no spending. For the incremental investment in buildings achieved due to the improvement in energy efficiency policies, this cost is the incremental spending required to achieve the new energy performance requirements beyond the previous level to which the market had already adapted.

In the transport sector, it is assumed that the buyer of an efficient vehicle would have otherwise chosen a less efficient model of similar size and power; the incremental expenditure is calculated for each country as the additional price paid for the 25% most efficient cars sold in each size and power class, compared with the average price in that class. Spending on infrastructure to support shifts to more efficient transport modes, such as public transport or cycle paths, is not included. For the industry sector, the incremental investment is calculated based on the average technology efficiency in the prior year plus the spending on energy management systems that improves system-wide efficiencies.

The Efficient World Scenario investment methodology is similar but calculates the cost increment of an efficiency improvement against a reference technology. For example, the reference technology for refrigerators is a 2016 A++ model and future electricity savings and cost increments are calculated relative to that model. In transport, the cost increment of an efficient vehicle is calculated against an average gasoline car and multiplied by the volume of sales.

Energy efficiency investment increases substantially in the Efficient World Scenario

Delivering the potential of the Efficient World Scenario (EWS) will require significant growth in energy efficiency investment (Table 5.1). Average annual investment must grow to USD 584 billion between now and 2025, and then to nearly USD 1.3 trillion per year between 2026 and 2040.

Table 5.1 Energy efficiency investment needs to meet the EWS, 2017-40

	Annual average 2017-2025 (USD billions)	Annual average 2026-2040 (USD billions)	Cumulative 2017-2040 (USD billions)
New Policies Scenario	437	790	15 780
Efficient World Scenario	584	1 284	24 514

At the sectoral level, the largest contributor to total investment to realise the EWS needs to be the transport sector, due to greater investment required in fuel efficiency and electric vehicles (Figure 5.2). Cumulative transport investment to 2040 in the EWS is 51% higher than in the New Policies Scenario (NPS). Investment in buildings, which includes spending on building envelopes and efficient appliances, would need to be 48% above levels in the NPS. At 10%, the industry sector is the smallest component of total cumulative investment in the EWS to 2040. However, cumulative investment to 2040 for industry will need to be nearly 1.5 times above NPS levels, the largest investment growth between the NPS and the EWS.

In the EWS, the contribution of each country and region to the necessary total investment varies by sector (Figure 5.3). Because it has a large industry sector, China is responsible for 30% of industry investment by 2040, most of it to increase the deployment of electric heat pumps and improve the efficiency of motor-driven systems in less energy-intensive industry sectors. In the buildings sector, Europe covers 30% of total global investment, due to increased retrofits for older building stock and the deployment of electric heat pumps for space heating. An increase in the penetration of electric vehicles in China's passenger car fleet, from current levels of around 0.4% to over 60% in 2040, requires China's share of cumulative transport sector investment in the EWS to rise over 20%.

Figure 5.2 Cumulative energy efficiency investment in the EWS by sector (left) and compared with the NPS (right), 2017-40

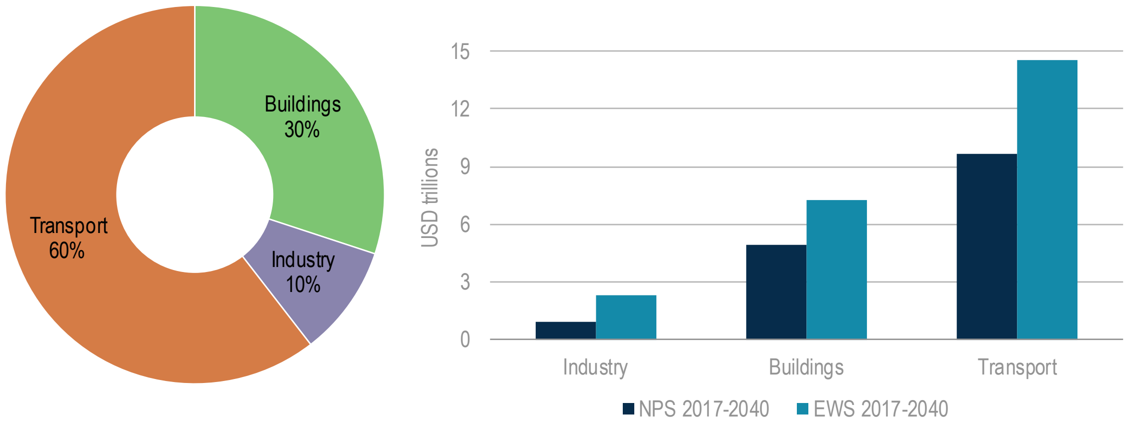
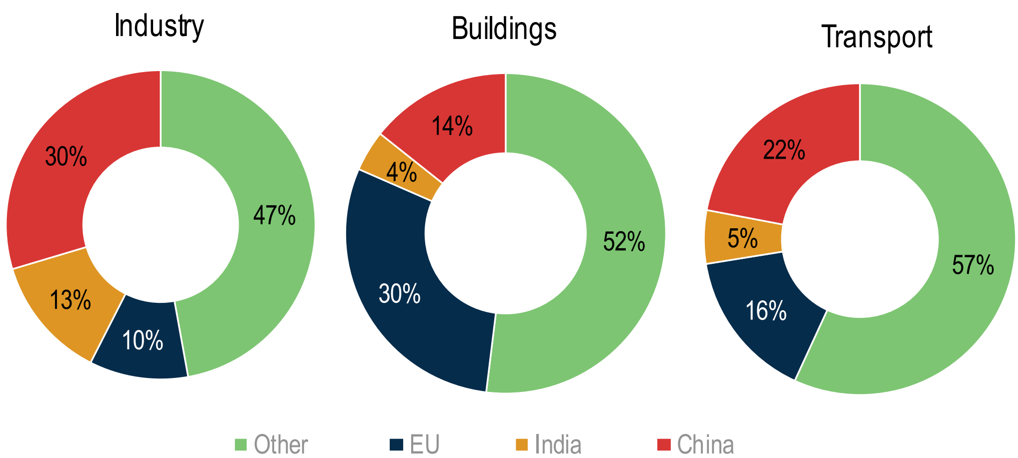


Figure 5.3 Cumulative energy efficiency investment in the EWS by sector and region



Note: *Other* includes North America, Southeast Asia, Africa, the Middle East, South America, and Asia Pacific (not including China).

All energy efficiency investments required to achieve the EWS are cost-effective. Across all sectors, each dollar spent on improving energy efficiency pays back on average by a factor of 3 over the life of the measure, as a result of lower energy expenditure. For transport, efficiency pays back by a factor of more than 2. In buildings, efficiency investment pays back by a factor of 2.4 and for electric motor-driven systems it is nearly a factor of 7. This is based on energy savings only and does not include the numerous other benefits of energy efficiency, many of which deliver additional financial returns.

Investment across the entire global energy system is experiencing a shift. In 2017, investment in electricity supply fell by 6% to USD 750 billion, but outpaced investment in oil and gas supply, at USD 716 billion (IEA, 2018).

At present, most energy efficiency investment comes from energy users through their savings or loans (known as "on balance sheet" investment). However, it is unlikely such sources can deliver the increases in investment required to achieve efficiency's full potential. At the same time, attracting finance from alternative sources can be difficult. Energy efficiency investments take place on a smaller scale than other energy investments, face a lack of technical understanding and a perception that they are risky. To encourage the flow of investment to the opportunities available in energy efficiency, it is therefore vital to focus on the possibilities that new business models offer.

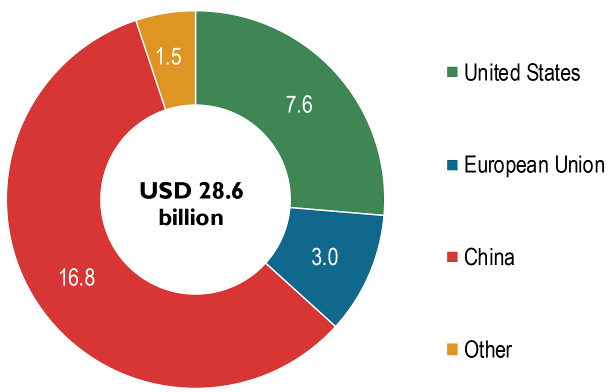
If the potential of the EWS is to be realised, governments will need to consider how policy environments can be developed to encourage greater levels of finance and business model innovation. Although they are at varying stages of development, sources of finance and business models exist that are designed to de-risk energy efficiency projects and encourage greater investment. Some of these are described in the remainder of this chapter.

Energy efficiency business models

Energy service companies are at the heart of innovative business models for efficiency

Energy service companies (ESCOs) design, install, and in some cases, finance energy efficiency projects through a contractual agreement with the energy-using customer, usually using an energy performance contract (EPC). EPCs incentivise ESCOs to identify and implement energy efficiency opportunities, the financial returns from which are subsequently shared with the customer. Under many EPCs, the ESCO can also provide ongoing operation and maintenance services for energy efficiency projects, further reducing the risk to the customer.[58]

Figure 5.4 ESCO revenue by region, 2017



Sources: Adapted from IEA data and JRC (2017), *Energy Service Companies in the EU: Status Review and Recommendations for Further Market Development with a Focus on Energy Performance Contracting*.

The value of the global ESCO market grew by 8% to USD 28.6 billion in 2017 (Figure 5.4). China's ESCO market continues to underpin the global market, growing 11% to nearly USD 17 billion in 2017. This rapid growth was fostered by favourable policies such as tax incentives and accounting systems that have accommodated ESCO projects. Some of these policies have now been withdrawn, but early evidence shows that the impact of this withdrawal on the Chinese ESCO market has not been

[58] This section draws on new data collected through an IEA survey of 19 ESCO industry associations, covering markets in Europe, North and South America, Asia and Pacific and Africa.

substantial, reflecting its maturity and centrality to the implementation of efficiency measures. In the United States, where ESCOs have been operating for well over 30 years, the market grew to just over USD 7.5 billion in 2017. The European ESCO market represents 10% of the global total.

ESCO projects are generating energy and financial savings

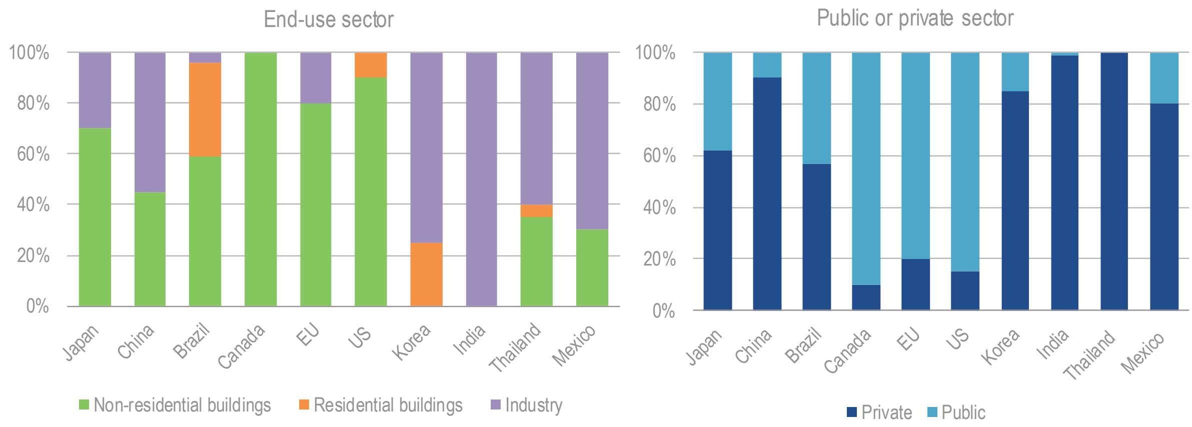
On average, ESCO projects deliver energy savings of about 25%. However, there are notable differences in ESCO markets among countries and regions, particularly in terms of the sectors where savings are achieved (Figure 5.5).

The majority of ESCO projects take place in the non-residential buildings sector, followed by industry, while transport projects remain scarce. The prominence of the non-residential buildings sector reflects the availability of low-risk efficiency opportunities that are easily implemented and scaled up, such as lighting replacements, building envelope improvements and heating, ventilation and air conditioning (HVAC) upgrades. The extended tenure of non-residential buildings also makes the sector an attractive prospect for ESCOs, given the preference of ESCOs in many regions for long-term contracts. By contrast, the residential sector is often seen as less attractive due to its diffuse and heterogeneous nature.

ESCO activity in industry varies significantly between countries (Figure 5.5). In the majority of Asian markets, industry is the dominant sector for ESCOs, due to favourable policies. In North America and Europe, industry plays a marginal role in the ESCO market. Industry in these regions prefers to use internal expertise to implement efficiency measures and favours projects with very short payback periods, which are not as attractive for ESCOs seeking long-term contracts.

In most regions, the majority of projects are undertaken in the private sector. In North America, however, ESCO projects are overwhelmingly undertaken within the public sector. Government policy has a major influence on these trends. In China, policies provide incentives for ESCO engagement in the private sector and restrict the degree to which the public sector can engage with ESCOs. In North America, public sector asset owners are able to obtain debt on favourable terms, which can then be used to finance ESCO contracts more readily.

Figure 5.5 ESCO market activity by country and sector, 2017



In all regions, government policy has a major impact on ESCO activity. Policies that encourage ESCO engagement, allow relevant accounting practices and enable the acquisition of third-party finance, have been proven to expand the market and de-risk projects. In the United States, EPCs can be structured as operating leases, which are not counted on an organisation's balance sheet under the US Generally Accepted Accounting Principles (GAAP). In 2017, the European Commission issued a statement clarifying the terms under which an EPC can be accounted for off-balance sheet, through the framework of the ESA2010 European System of Accounts (EC, 2017). It is hoped that these measures will stimulate the ESCO market, as similar measures have in the United States, and increase energy efficiency investment.

Energy savings insurance can further reduce risk associated with ESCO projects

The ESCO market is not immune to the issue of uncertainty associated with the performance of efficiency projects, which inhibits greater levels of third-party finance. To reduce this uncertainty, a small number of financial institutions and private companies are now offering energy savings insurance (ESI) (Box 5.2).

Two types of ESI are being offered, technical and credit.[59] Technical insurance covers the ESCO or technology provider if promised energy savings are not achieved, assuming the technical risk associated with the efficiency project. Credit insurance guarantees that repayments to the ESCO will continue if a customer defaults.

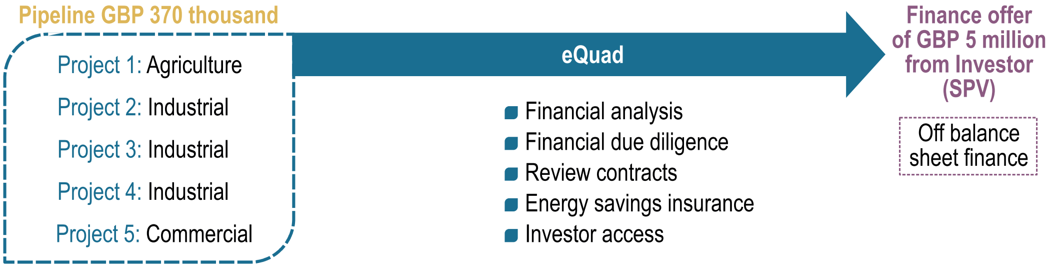
Box 5.2 Linking investors and insurers to energy efficiency projects

Proven Lighting, an Irish company, has been providing LED lighting to industrial customers for about ten years. Recently it decided to move to a Lighting-as-a-Service (LaaS) business model, in which it is responsible for the financing, technology acquisition, installation and maintenance of its LED projects. The customer has no up-front cost but makes periodic payments to Proven Lighting once the project is installed.

Proven Lighting developed a pipeline of five projects in the industry, commercial and agriculture sectors worth GBP 370 000 (British pounds) (USD 480 000). The company considered a bank loan to finance the pipeline, but since this would be treated as an on-balance sheet asset, it would severely limit Proven Lighting's ability to take on additional projects. Furthermore, having the loan on its books made any future deals a risky prospect. To avoid these credit risks, Proven Lighting aimed to finance its project pipeline off-balance sheet. The company used eQuad, an online platform created and managed by Joule Assets, where investors can review and select renewable energy and energy efficiency projects to finance. To secure financing through eQuad, Joule Assets arranged for the project pipeline to receive financial analysis and due diligence, and facilitated a partnership with an insurance firm to provide the project with energy savings insurance to reduce its risk profile in the eyes of prospective financiers (Figure 5.6).

[59] Both of these can be applied to the different models for ESCO contracts and financing, including the most common models: guaranteed savings and shared shavings. In the guaranteed savings model, the ESCO assures a level of energy savings and the customer is typically responsible for securing finance. In the shared savings model, the ESCO generally secures the financing and the customer and ESCO "share" the financial savings. The shared savings model lends itself more readily to securitisation, a mechanism that aggregates debt and turns it into tradeable packages (securities).

Figure 5.6 The eQuad project development pipeline



Through eQuad, within the first week of sending out its portfolio, Proven Lighting was matched with an investor. The firm worked with Joule Assets to structure a GBP 5 million (USD 6.5 million) Special Purpose Vehicle (SPV), fully owned by the investor. The payback time for each investment within the pipeline was less than two years.

The SPV arranged the necessary finance for Proven Lighting to cover the upfront capital and ongoing maintenance costs of their initial pipeline, while enabling a steady stream of capital for future projects on an as-needs basis. This allows Proven Lighting to better market its LaaS business model and to increase their sales output. The deal with eQuad enabled Proven Lighting to roll out their LaaS solution more quickly. From start (preparing the project business models through eQuad) to finish (deal closure with the fund), the process took less than three months.

Source: Joule Assets (personal communication 20 July 2018).

Energy efficiency finance

Energy efficiency financing by green banks is increasing

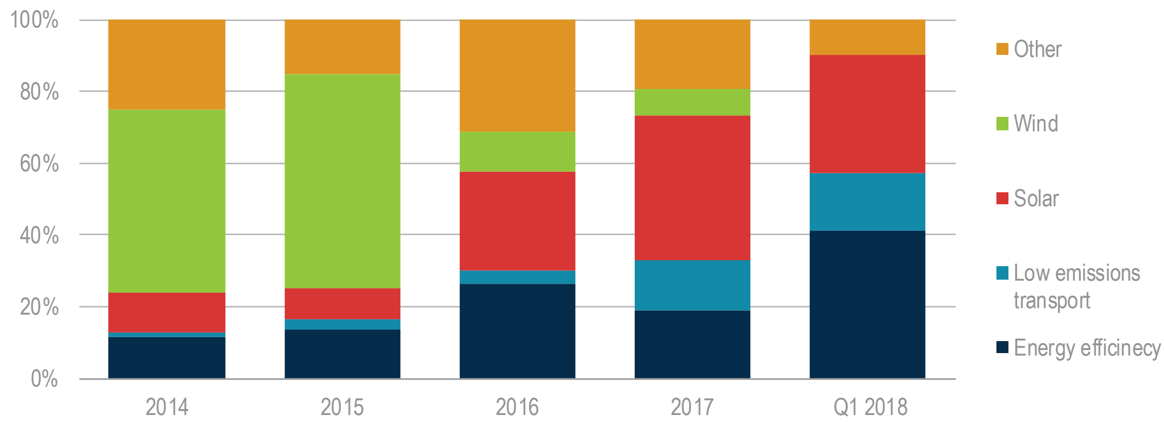
The role of green banks in providing energy efficiency finance has increased significantly in the past two years. Green banks are established by national or regional governments to provide finance and leverage private investment for projects that will benefit the environment and are commercially viable but struggle to attract finance (Green Banks Network, 2018). They can be public, quasi-public or private institutions with a mandate from a public authority to ensure the scope of their activities. Most green banks invest public funds in projects alongside private capital. The first, the Connecticut Green Bank, was established in 2011. At least nine green banks now operate at the regional, national and international levels, of which six are members of the Green Bank Network.

Investments analysed in this section refer to those made by members of the Green Bank Network.[60] To date, these six banks have committed to invest over USD 10 billion across a variety of sectors, including energy efficiency (Green Bank Network, 2018). However, green banks currently represent a small portion of institutional financing of energy efficiency projects. Other financial institutions with remits that extend beyond clean energy and energy efficiency (such as KfW, European Bank for Reconstruction and Development, the European Investment Bank and the World Bank) also invest in energy efficiency projects.

[60] The Green Bank Network includes the Clean Energy Finance Corporation (Australia), the Malaysia Green Technology Corporation, Connecticut Green Bank, New York Green Bank, Green Finance Organisation (Japan) and the Green Investment Group (United Kingdom).

The share of total green bank investment for energy efficiency and low-emissions transport is increasing (Figure 5.7). Energy efficiency investment reached USD 430 million in 2017, of which the buildings sector received 81%. The majority of this finance has been loans to small and medium-sized enterprises (SMEs) for building and equipment upgrades, plus new construction of energy-efficient single-family homes. In the first quarter of 2018, energy efficiency was the largest sector for new green bank investment, as a result of an investment made by Australia's Clean Energy Finance Corporation (Box 5.3).

Figure 5.7 Annual allocation of green bank investment, 2014-Q1 2018



Notes: Covers six entities — Clean Energy Finance Corporation (Australia), the Malaysian Green Technology Corporation, Connecticut Green Bank, New York Green Bank, Green Finance Organisation (Japan) and the Green Investment Group (United Kingdom). While other financial institutions focus on green finance, these six fit the Green Bank Network's definition of what constitutes a green bank. Transactions occurring in 2018 reflect closings that finalised by the date of the individual green banks' latest public report release. These dates differ by bank. Projects in the "other" category include waste-to-energy investments, energy storage, geothermal, and smart grid technology.

Source: Green Bank Network (2018).

Box 5.3 CEFC: A major player in energy efficiency finance among green banks

The Clean Energy Finance Corporation (CEFC) is a significant player in green bank investment. Owned by the Australian government, the CEFC represents nearly 50% of global investment by green banks. It is responsible for almost all the investment by green banks in low-emissions transport, for the increased share of solar in green bank investment since 2016 and for the increase in energy efficiency investment in 2018.

For its Energy Efficient Asset Finance programmes, the CEFC has partnered with private-sector banks, specifically the Australia New Zealand Banking Group, the National Australia Bank, Westpac and the Commonwealth Bank, leading to a reduction in finance rates for customers. The CEFC has committed AUD 770 million (Australian dollars) to the programme, which allows banks to offer a discount of 0.7 percentage points on the standard asset finance rate for loans of up to AUD 5 million if energy efficiency requirements are met. The CEFC funds have a term of 11.5 years and an interest rate of 3.1%.

Source: Green Bank Network (personal communication, 7 July 2018).

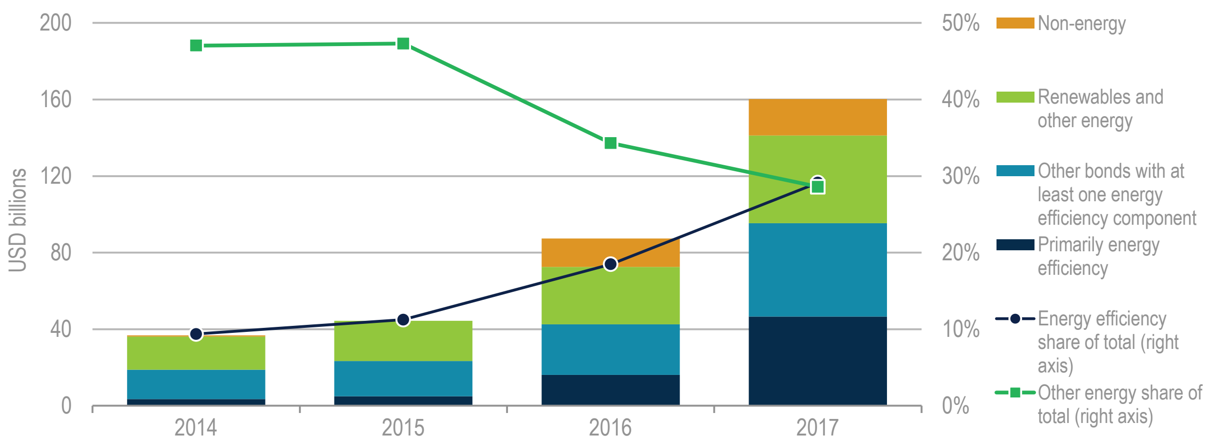
As more private financiers work with green banks to finance energy efficiency and other clean energy projects, knowledge of the risk profile grows and financiers become more willing to invest in these projects even without the presence of a green bank. This trend has been observed with investment in wind energy, which has become a less dominant focus of green bank funds, as the role of green banks has been overtaken by private financing. However, energy efficiency investment has not yet reached this point.

Policy plays a critical role in supporting the involvement of green banks. While public funds form the basis of green bank investment, finance is typically provided through loans. Governments achieve a return on investment, reducing the long-term impact on public budgets.

Energy efficiency surpasses renewable energy in green bond issuance

As issuance of green bonds continues to grow, so does energy efficiency's share of the disclosed uses of the funds raised.[61] Green bonds – bonds created to specifically fund clean energy and environmental projects – can provide investors with more transparency and greater certainty that they are investing in specific green projects or activities. Green bonds can also provide a lower-cost source of financing, or refinancing, than traditional bank loans.

Figure 5.8 Global green bond issuance by use of proceeds, 2014-17



Notes: Green bonds included are those labelled under the Climate Bonds Taxonomy and Certification Scheme. Allocation by energy end-use follows Climate Bonds Initiative conventions. "Non-energy" includes uses such as forestry and climate adaptation projects. "Other energy share of total" includes both non-energy and renewable energy bonds.

Source: Climate Bonds Initiative (2018).

The value of green bonds issued primarily for energy efficiency tripled from USD 16 billion in 2016 to USD 47 billion in 2017, outpacing green bonds dedicated to renewable and other energy sources

[61] Green bonds cover: corporate bonds, asset-back securities, supranational, sub-sovereign and agency (SSA) bonds, municipal bonds, project bonds, sovereign bonds and financial sector bonds. In this report, only green bonds labelled to provide transparency to investors are discussed; unlabelled climate-aligned bonds are excluded. The market for climate-aligned bonds is estimated at USD 674 billion in 2017 (Climate Bonds Initiative, 2017). Additionally, some regions have or are developing their own standards. For example, China has a separate standard that does not always align with international green bond standards.

(USD 46 billion) for the first time.[62] Fannie Mae's Green Mortgage-Backed Securities (MBS) account for nearly 60% of green bonds issued primarily for energy efficiency (Figure 5.8).

In addition, green bonds recording energy efficiency as a component of their use of proceeds (although sometimes a very small component) represent an additional USD 49 billion, or 30% of the total, up from USD 26 billion in 2016. Definitions of energy efficiency content vary, however, so it is difficult to identify the underlying drivers for these trends.

Repayment schemes for energy efficiency finance are expanding

Another form of energy efficiency financing that has grown rapidly in recent years is repayment programmes operated by public-backed bodies or utilities. The best-known examples are the Property Assessed Clean Energy (PACE) programmes in the United States, in which property owners can obtain funds to finance energy efficiency measures. Repayment of funds is then made through charges attached to property tax bills. Other programmes, mostly managed by utilities, use energy bills as the repayment mechanism, referred to as on-bill financing.

PACE programmes support deployment of a range of renewable energy, energy efficiency and water conservation projects. Funding provided through a PACE programme can cover the total costs of a variety of measures, including technologies such as ventilation, lighting, water pumping, electric motors, solar panels and insulation. PACE programmes are now active or under development in 26 US jurisdictions, with enabling legislation enacted in 34.

By mid-2018, nearly USD 5.9 billion in energy efficiency measures had been funded through PACE programmes in the United States (Figure 5.9). There are two types of PACE programmes; residential (R-PACE) and commercial (C-PACE). Nearly 90% of investment has been in the residential sector. However, the cumulative amount invested through C-PACE programmes increased 75% in 2017. The vast majority of projects are in California, the first US state to enact enabling legislation.

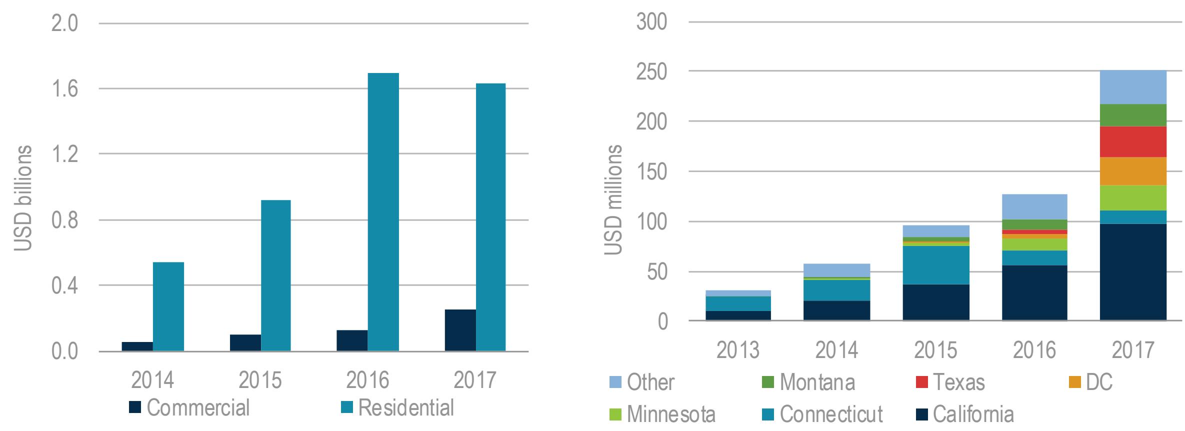
Several factors have contributed to the recent growth of PACE programmes. Funding provided through PACE programmes is repaid annually along with other property taxes, on the same bill, which simplifies repayment. PACE funding is also preferable to a standard bank loan, particularly for low-income property owners. Funding is offered at a lower interest rate for a period of 15 to 30 years, whereas standard bank loans, with higher interest rates, usually do not exceed 5 to 7 years.

Similar PACE projects can also be aggregated by funding bodies – a process known as securitisation – and refinanced through the growing green bond market. Refinancing allows funding bodies to free up capital, creating space to support more efficiency measures. During the first half of 2018, USD 5 billion of PACE projects had been securitised through the green bond market, nearly 85% of the total value of PACE projects (Figure 5.10). Three main financing bodies are responsible for securitising PACE projects in the United States: Renovate America, Ygrene and Renew Financial.

[62] While it can be difficult to assess the percentage of a green bond's proceeds that will be dedicated to energy efficiency, this section follows the Climate Bonds Initiative conventions for allocation by energy end-use. Green bonds for which the use of proceeds is allocated to energy efficiency include those that specifically target energy efficiency applications in accordance with the Climate Bonds Standard, as well as green bonds for all property assessed clean energy (PACE) asset-backed securities (ABS), rooftop solar photovoltaic (PV) ABS (which reduce energy imports to a building) and issuances from corporate and public entities in the utilities, property, transport infrastructure sectors. A change in methodology from 2016 to 2017 accounts for the large difference in multilateral development banks' share of energy efficiency green bond issuance. Due to greater clarity in bond disclosure, in 2016 a larger portion of development bank issuance was considered as energy efficiency, whereas in 2017 a smaller portion is attributed in energy efficiency issuance.

Securitisation of commercial (C-PACE) projects also increased in 2017 and 2018, with the first two C-PACE securitisations completed.

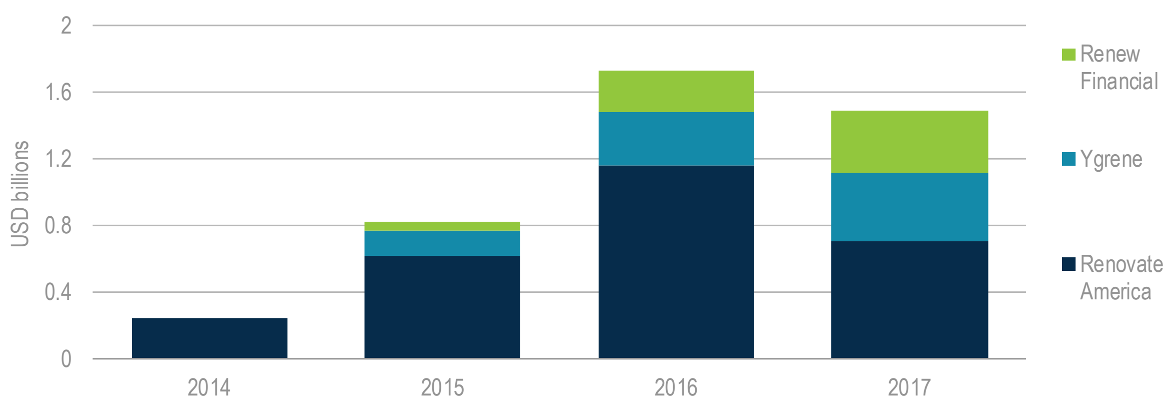
Figure 5.9 PACE loans by sector (left) and annual C-PACE loans by US state (right), 2013-17



Source: PACENation (2018).

Following its success in the United States, the PACE model is expanding to other regions. In Australia, a funding programme modelled on PACE, Environmental Upgrade Agreements, has funded projects worth more than USD 60 million. In the Canadian province of Alberta, the PACEAlberta Programme is under development. In Europe, a EuroPACE Programme pilot is under development in Spain (PACENation, 2018).

Figure 5.10 PACE securitisations by year and issuer, 2014-17



Source: PACENation (2018).

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6. ENERGY EFFICIENCY IN EMERGING ECONOMIES

Highlights

- **Efficiency gains since 2000 in the six major emerging economies – Brazil, the People's Republic of China (hereafter "China"), India, Indonesia, Mexico and South Africa – saved 13 exajoule (EJ) or 10% more final energy use in 2017.** China is the overwhelming force behind these gains, representing nearly 80% of the total energy savings across all six economies.

- **Nearly 46% of final energy use in the six economies is covered by mandatory energy efficiency policies, driven by policy in China.** Coverage is highest in non-residential buildings and industry, due to building codes in all six economies and industry policies in China and India. Mandatory measures are complemented by market-based instruments, including utility obligations in China, public funding of energy service companies in India, and information exchange, including energy efficiency networks in Mexico.

- **The IEA Efficient World Scenario highlights that, on average, energy intensity in the six economies could fall by 50% between now and 2040.** Since 2000, primary energy demand in the six economies has more than doubled. However, the economies of these six countries could be more than 2.5 times larger in 2040 than today, for only 25% more energy demand. The six economies would still represent nearly 40% of global energy demand in 2040, compared with one-third at present.

- **Potential efficiency improvements in the Efficient World Scenario would save nearly USD 147 billion (United States dollars) in household energy expenditure and 3.4 Gt CO_2-eq of emissions in 2040.** Emissions savings are nearly half the total avoidable global emissions in the Efficient World Scenario. Efficiency gains correspond to the saving of almost 32 EJ of final energy use, split across industry (41%), transport (30%) and buildings (28%).

- **As the climate warms and living standards improve, the six economies will dominate global space cooling demand.** Minimum Energy Performance Standards (MEPS) for air conditioners have been implemented or proposed in all six economies. Strengthening them will contribute to realising potential efficiency gains. In India, where space cooling energy demand in the EWS quadruples between now and 2040, MEPS have been strengthened.

- **Potential efficiency gains for the industry sector are greatest in less energy-intensive manufacturing sectors.** Key measures to unlock this potential include deploying electric heat pumps and improving the efficiency of motor-driven systems. Mandatory energy efficiency improvement targets imposed on companies and industry sectors in China and India create a basis for ongoing efficiency improvements.

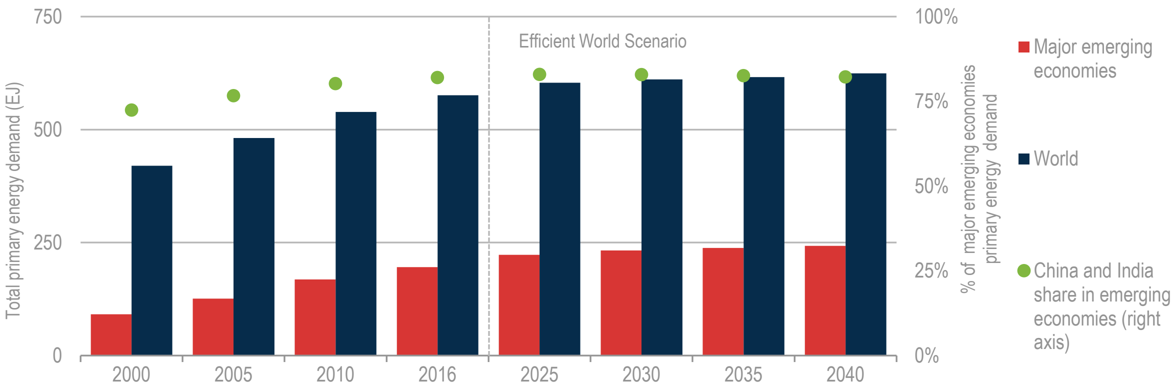
- **Improvements in passenger vehicle and road freight fuel efficiency will make the largest contributions to transport efficiency gains in the six economies.** China and India are leading the way with the implementation of fuel efficiency standards for passenger cars and trucks. There are opportunities in all six countries to increase adoption of electric vehicles.

Energy demand and efficiency trends in the major emerging economies

The six major emerging economies – Brazil, China, India, Indonesia, Mexico and South Africa – account for one-third of global primary energy demand, equivalent to the energy demand of all of Europe and the United States combined. Under the IEA New Policies Scenario (NPS), total energy demand in these countries could increase by 45% between now and 2040. However, the IEA Efficient World Scenario (EWS) shows that the increased adoption of cost-effective energy efficiency measures could limit this rise to 24%, with the six countries representing nearly 40% of global energy demand in 2040 (Figure 6.1). China and India are the main sources of energy demand growth, representing nearly 82% of demand among the six countries in 2040.

The IEA supports these six economies efforts to capture the benefits of energy efficiency through the Energy Efficiency in Emerging Economies (E4) Programme. The E4 Programme started in 2014 and is continuing as part of the IEA Clean Energy Transitions Programme (Box 6.1). Analysis in this chapter is informed by data collected in partnership with the six countries and outputs from the EWS.

Figure 6.1 Primary energy demand, globally and for the six major emerging economies in the Efficient World Scenario, 2000-40



Source: Adapted from IEA (2018a), *World Energy Balances 2018* (database).

Box 6.1 The Energy Efficiency in Emerging Economies (E4) Programme

The IEA Energy Efficiency in Emerging Economies (E4) Programme supports the governments of the major emerging economies in scaling up energy efficiency to reap the social and economic development benefits it brings, while at the same time meeting climate and clean energy transition goals. Activities range from data gathering and analysis to policy design and implementation support.

Over the past five years, the E4 Programme has built on a range of activities in collaboration with the major emerging economies. Highlights from the programme include:

- Brazil – sharing experience on market-based mechanisms for improving energy efficiency.
- China – analysing the strong progress China has made on energy efficiency, sharing analytical methodologies with China and sharing the results with others.
- India – evaluating the social and economic benefits of the national roll-out of LED lighting to demonstrate the social and economic benefits of energy efficiency.

- Indonesia – assessing the potential energy savings from Indonesia's existing portfolio of measures against its national target.
- South Africa – assessing the cost-effective potential for energy efficiency in support of the National Energy Efficiency Strategy.
- Mexico – collaborating with the Energy Ministry in its work to pull together the many initiatives in the buildings sector to develop a roadmap to achieve more efficient buildings with a particular emphasis on cooling.
- Southeast Asia and Latin America – building regional communities of practice amongst officials focusing on policy opportunities and tracking progress of energy efficiency measures.

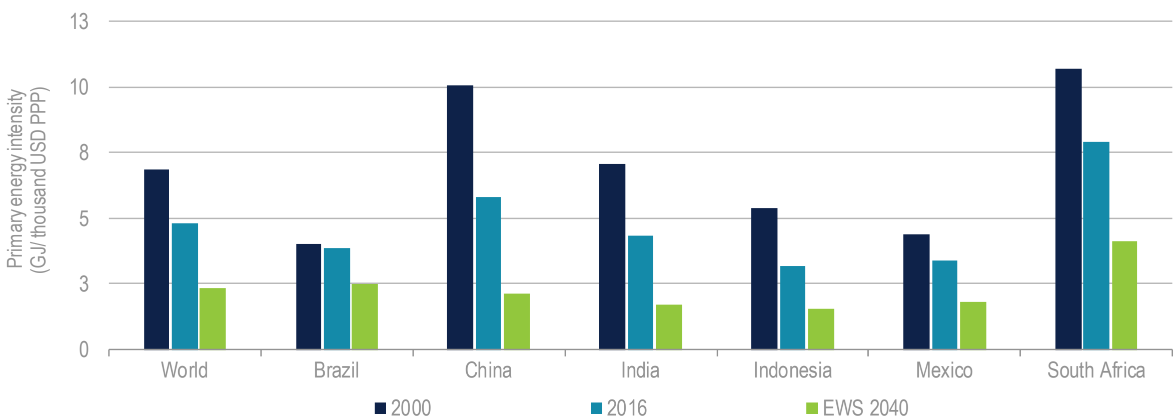
As the E4 Programme has evolved, exchange among countries has become a more central element. Countries are keen to learn from each other, and the IEA facilitates exchange of experience and information among the emerging economies, but also across IEA countries and beyond.

A key pillar of the E4 Programme is training and capacity building for energy efficiency policy makers. Intensive training courses develop the knowledge and skills of policy makers in all aspects of energy efficiency. More than 1000 officials from over 90 countries have been trained to date. Through this training the IEA is building a global community of practice of policy makers, with a common understanding of best practice in energy efficiency policy.

The Efficient World Scenario provides the E4 Programme with clear direction for the future by prioritising cost-effective energy efficiency measures for each partner country.

The E4 Programme is part of the IEA's Clean Energy Transitions Programme, which supports emerging economies in all aspects of clean energy. This programme draws on data, modelling and policy analysis, with a focus on implementation and impact. It leverages the IEA's position as a global clean energy hub to build the global knowledge base and capacity for delivering clean energy outcomes, with energy efficiency to the fore. More information about the E4 Programme can be found at www.iea.org/topics/energyefficiency/e4/.

Figure 6.2 Primary energy intensity in the six major emerging economies



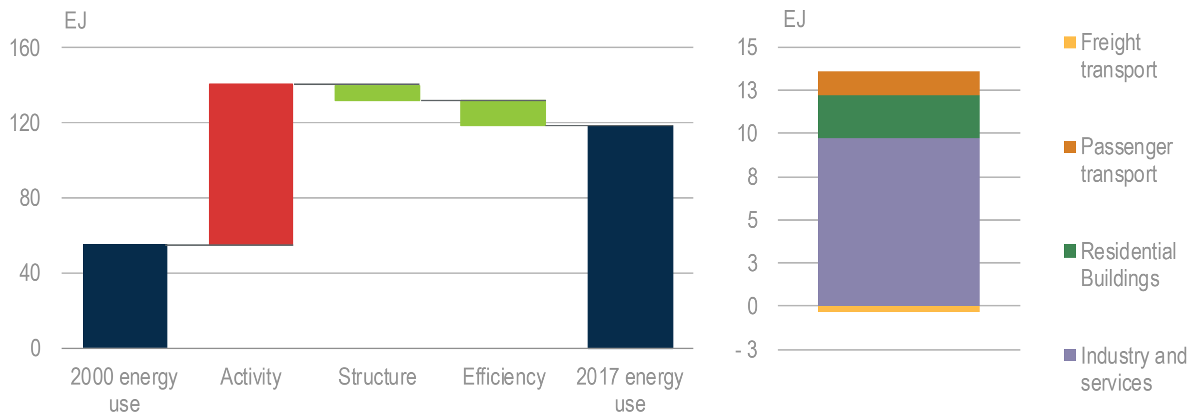
Primary energy intensity – primary energy demand per unit of GDP – varies across the six economies depending on the size and make-up of each country's industry sector and each country's level of economic development (Figure 6.2). Since 2000, primary energy intensity has improved in all six economies, by a total of 29%.

The EWS shows that primary energy intensity could decline substantially by 2040. China and India have the greatest potential for improvement. Their combined primary energy intensity could fall by more than 60% compared with 2016, while the average intensity across all six economies could decline by over 50%.

Efficiency has saved a considerable amount of additional energy use in the major emerging economies

Efficiency gains since 2000 in the six economies saved an additional 10% final energy use in 2017, equivalent to the total energy use of Germany (Figure 6.3). Nearly 75% of the efficiency gains were obtained in the industry and service sectors, particularly in China, which was responsible for 80% of total industry savings. Efficiency gains were smallest in passenger and freight transport, where only China, India and Mexico have implemented fuel efficiency standards.

Figure 6.3 Decomposition of the six major emerging economies' final energy use, 2000-17 (left) and sectoral contribution to efficiency gains (right)



Notes: "Energy use" covers the residential, industry and services, passenger and freight transport sectors. It excludes non-energy use (i.e. feedstocks) and energy supply. Buildings analysis based on IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

Sources: Adapted from IEA (2018a), *World Energy Balances 2018* (database); IEA (2018b), *Mobility Model* (database); Timmer, M. P. et al. (2015), *World Input Output Database* (database); IBGE (2018), *Quarterly National Accounts* (database); National Bureau of Statistics of China (2018), *National Accounts* (database); Reserve Bank of India (2018), *The India KLEMS Database* (database); Statistics Indonesia (2018), *Gross Domestic Product* (database); INEGI (2018), *GDP – Activity of Goods and Services* (database); StatsSA (2018), *Gross Domestic Product (GDP), 4th Quarter 2017* (database); Quantec (2018), *Industry Service – RSA Standard Industry – Input Structure at basic prices* (database).

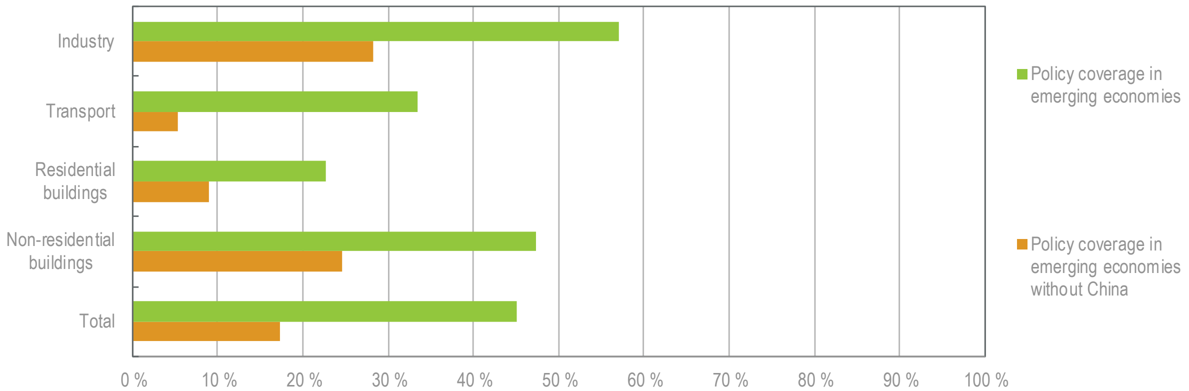
Structural economic effects are also becoming more apparent in the six economies, notably the movement of economic output from energy-intensive industry sectors to less intensive manufacturing and service sectors. However, most of the impact of these changes was offset by other structural effects that increased energy use, including shifts in transport modes, reduced vehicle occupancy and increased appliance ownership and building floor area. The net result is that structural change as a whole led to the saving of 6% more energy use in 2017.

Policy coverage in the major emerging economies countries has potential to grow

In 2017 nearly 46% of final energy use in the six economies was covered by mandatory energy efficiency policies (Figure 6.4). However, coverage varies widely by country and the overall average is influenced by China, where mandatory energy efficiency policies are used extensively. Without

China, average policy coverage is below 20%. Coverage across the six economies is most substantial in the non-residential buildings and industry sectors, at nearly 50% and 60% respectively. Coverage is high in non-residential buildings because of codes in all six countries and rapid new construction rates. For industry, China's Top 10 000 Programme and India's Perform, Achieve and Trade (PAT) scheme form the basis of policy coverage. These programmes set mandatory efficiency improvement targets for energy-intensive industry sectors and companies.

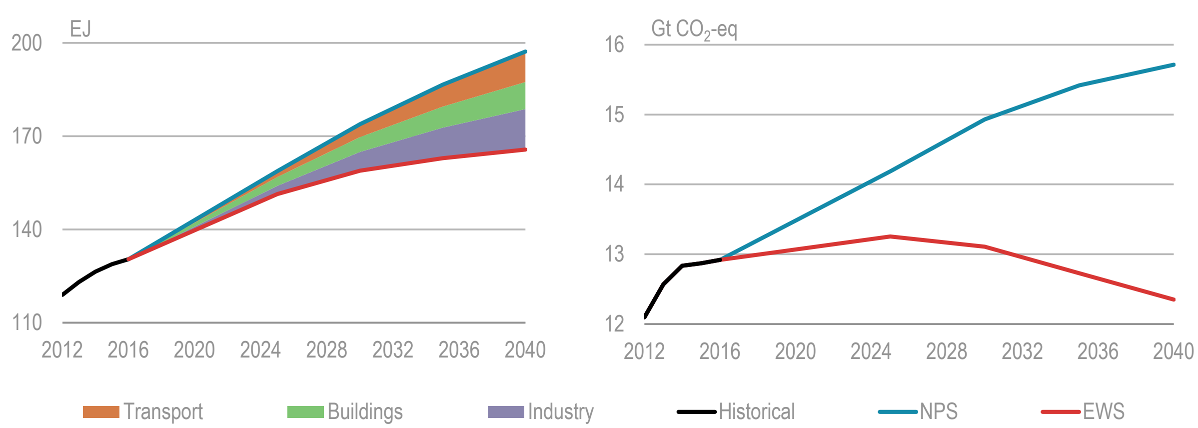
Figure 6.4 Mandatory policy coverage in major emerging economies



Policy coverage is lower in the residential buildings and transport sectors. However, the recent addition of passenger car and truck fuel efficiency standards in China will boost coverage as new vehicles replace stock purchased before standards were introduced. In residential buildings, the variable presence of appliance standards and building codes keeps coverage below 25%.

Major emerging economies can obtain substantial benefits from energy efficiency

Figure 6.5 Total final energy use and emissions in the NPS and EWS for major emerging economies, 2012-40



Note: "Energy use" includes non-energy use (i.e. feedstocks), excludes energy supply.

The EWS shows that the six economies could gain significant benefits by maximising economically viable energy efficiency measures. By 2040, the six economies could collectively save over 46 EJ (1101 Mtoe) of additional primary energy demand compared with the NPS, equivalent to the current energy demand of Japan, Germany and France combined. This corresponds to the saving of almost

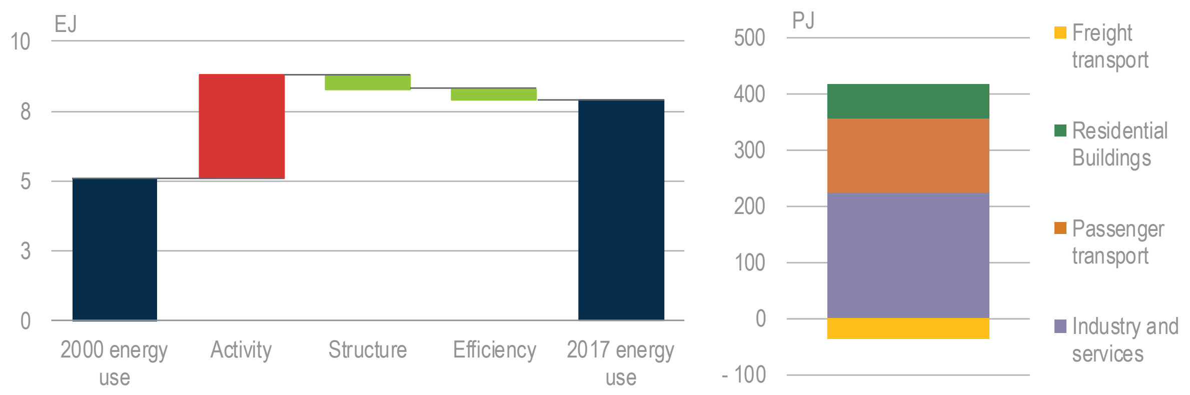
32 EJ of additional final energy use, split across industry (41%), transport (30%) and buildings (28%). Additional household expenditure on energy of nearly USD 147 billion would also be saved by 2040, and emissions of nearly 3.4 Gt CO_2-eq prevented. These emissions savings are nearly half of the total global emissions prevented in the EWS by 2040 (Figure 6.5). If the efficiency potential of the EWS is captured, energy-related emissions would peak by 2025 and decline thereafter.

The remainder of this chapter presents the efficiency trends and outlooks in each of the six major emerging economies analysed. Policy measures that have been implemented or could unlock the benefits in the EWS are also highlighted, presenting an Efficient World Strategy for the six countries.

Brazil

Efficiency trends and outlook

Figure 6.6 Decomposition of Brazilian final energy use, 2000-17 (left) and sectoral contribution to efficiency gains (right)



Notes: "Energy use" covers the residential, industry and services, passenger and freight transport sectors. It excludes non-energy use (i.e. feedstocks) and energy supply. Buildings analysis based on IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

Sources: Adapted from IEA (2018a), *World Energy Balances* (database); IEA (2018b), *Mobility Model* (database); IBGE (2018), *Quarterly National Accounts* (database).

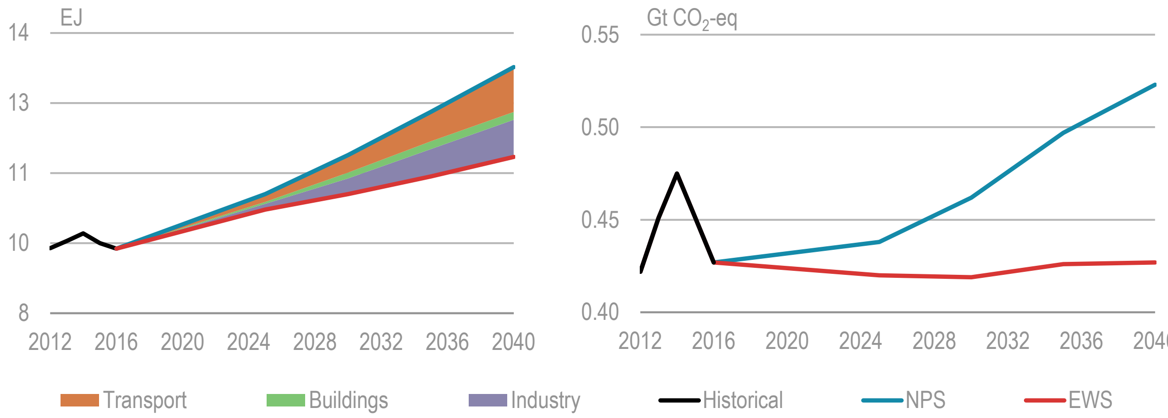
Improvements in energy efficiency in Brazil since 2000 saved 5% more energy use in 2017, with the industry and service sectors contributing to almost 60% of the total energy use saved (Figure 6.6). Efficiency gains also saved 4% more coal and gas imports and prevented over 15 Mt CO_2-eq of additional emissions. This is notable given that Brazil is one of the least carbon-intensive economies in the world due to its use of hydro for electricity and biofuels in transport.

Increased economic activity between 2000 and 2017 would have pushed up energy use by 73% but was offset by structural changes in Brazil's economy and improvements in efficiency. The majority (63%) of the activity growth took place in industry and services, where gross value added (GVA) grew by 85%.

Structural changes – notably the movement of activity from energy-intensive industry sectors to less-intensive manufacturing and service sectors – reduced the impact of activity growth on energy use by 14%. This reduction would have reached 23%, however, if energy use had not been pushed up by structural changes in the residential buildings and transport sectors, including increased appliance ownership, shifts to less efficient modes of transport, and decreasing vehicle occupancy levels.

Since 2000, Brazil's primary energy demand has grown by over 52%. The EWS shows that adopting cost-effective energy efficiency measures could limit growth to 22% above current levels, saving nearly 2 EJ of additional final energy use by 2040 compared with the NPS (Figure 6.7), equivalent to the primary energy demand of Belgium. Emissions would remain the same in 2040 as current levels. Up to USD 9 billion would be saved in annual household expenditure on energy.

Figure 6.7 Total final consumption and emissions in the NPS and EWS for Brazil, 2012-40



Note: "Energy use" includes non-energy use (i.e. feedstocks), excludes energy supply.

The largest opportunities for energy savings in the EWS compared with the NPS come from transport (49% of savings in 2040) and industry (42%). Passenger cars offer the largest opportunity for efficiency gains in transport between now and 2040, as a result of the average fuel efficiency of passenger cars improving by 27% and the share of electric vehicles in the national fleet rising from 0% to 31%.

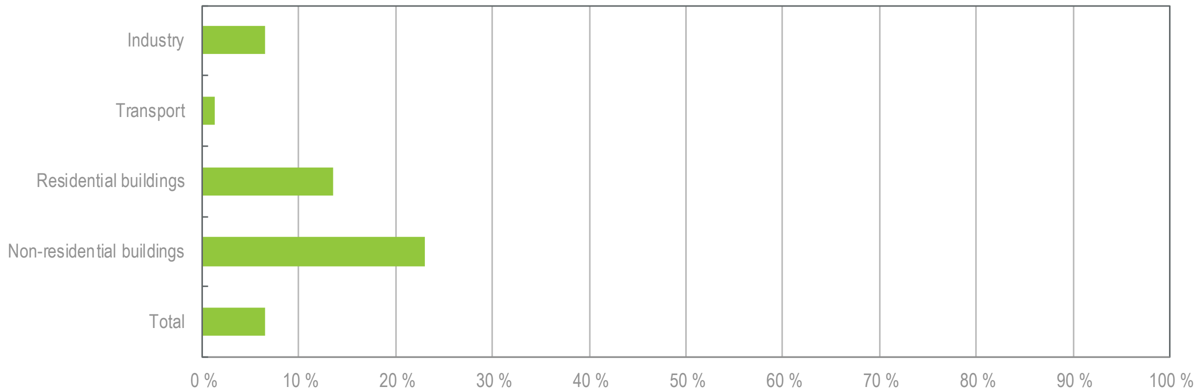
In industry, opportunities for efficiency gains in the EWS are prominent in the pulp and paper and iron and steel manufacturing sectors. Energy use per tonne of production could be reduced by around 40% in both pulp and paper and iron and steel between now and 2040. In iron and steel manufacturing, an important contributor to potential efficiency gains will be an increase in metals recycling, specifically the production of crude steel in an electric arc furnace from metal scrap.

Policy trends and future opportunities

In 2017, 6% of final energy use in Brazil was covered by mandatory energy efficiency policies (Figure 6.8). At a sectoral level, the introduction of building codes and appliance standards has resulted in policy coverage of 14% in residential buildings and 23% in non-residential buildings. In industry, policy coverage has grown to nearly 7% because of the phased introduction of MEPS for electric motors. Further stock turnover could increase coverage to around 15%. In transport, coverage is minimal because there are no mandatory fuel economy standards for cars and trucks.

Brazil adopted new standards for ceiling fans in 2017, which are expected to save nearly 760 GWh by 2030 and prevent emissions of over 440 t CO_2-eq (INMETRO, 2013). The Ministry of Mines and Energy held a public consultation in late 2017 on proposals to strengthen MEPS for refrigerators, freezers, air conditioning and distribution transformers.

Figure 6.8 Energy use covered by mandatory energy efficiency policies in Brazil



Brazil supports energy efficiency through a combination of standards for appliances and lighting, the Energy Efficiency Obligation Programme for electricity distributors (PEE), the National Energy Conservation Programme (PROCEL) and the National Programme for Energy Efficient Use of Petroleum and Natural Gas Derivatives (CONPET). PROCEL was previously funded by a combination of the Global Reversion Reserve (Reserva Global de Reversão, or RGR)[63] (Falcão, 2014) and dedicated funds from the PEE. It is currently funded solely through a mandatory allocation (20%) of dedicated energy efficiency funds from distribution companies under the PEE. In 2017, the total funding amounted to USD 4.6 million (PROCEL, 2018), compared with USD 61 million in 2011 (Falcão, 2014).

Recent energy efficiency programmes are guided by the 2011 national energy efficiency plan (Plano Nacional de Eficiência Energética), which sets a goal of reducing electricity consumption by 10% by 2030 compared with the growth projected in the National Energy Plan 2030 (PNE, 2030). This is equivalent to cumulative energy savings of 107 TWh from 2010 to 2030 (MME, 2011), about one-third of the cumulative savings possible in the EWS in 2030 compared with the NPS.

In the EWS, the potential for energy savings is highest in the transport sector. The average fuel efficiency of passenger vehicles is nearly 24% lower in Brazil than in the European Union because Brazil has not implemented fuel efficiency standards for passenger cars or trucks. If Brazil had adopted fuel efficiency standards for passenger cars as stringent as Japan's, it would have obtained fuel savings of nearly 85 000 barrels of oil equivalent (BOE) per day in 2017, equivalent to 7% of all its transport sector energy consumption. In 2017, however, the passing of law No. 13.576 created the National Biofuels Policy (RenovaBio), which aims to reduce greenhouse gas emissions and improve the life cycle energy efficiency of biofuels. This is an important development because biofuels are central to transport in Brazil.

In the industry sector, Brazil has introduced MEPS for electric motors and will soon strengthen them to the IE3 level, on par with the most stringent policies globally (Box 6.2). Measures aimed at increasing the adoption of energy management systems, which are key to unlocking gains across the wider motor-driven system, present an opportunity for further savings.

[63] The RGR (Global Reversion Fund) is a fund established in 1957 to support rural electrification and other investments in electricity infrastructure in Brazil. Through 2013, a portion of the fund supported the PROCEL programme, after which the legal mandate for the fund shifted away from PROCEL to other priorities.

Brazil will need to increase metals recycling to realise potential efficiency gains in the EWS. In 2016, just over 20% of Brazil's crude steel was produced via metals recycling (scrap-based electric arc furnace production). This compares favourably with China (6%) but is lower than the European Union (39%) and North America (58%) (World Steel Association, 2017). Higher percentages in other regions reflect greater availability of scrap metal. As scrap availability increases, it will be vital to put measures in place that ensure high scrap collection rates and hence maximise the efficiency gains from metals recycling.

In the buildings sector, space cooling will be the key contributor to future energy use. In the NPS, space cooling nearly quadruples by 2040 compared with current levels. The EWS demonstrates opportunities to limit this increase, although demand would still triple. Maintaining and strengthening building codes and standards for space cooling equipment are key policy mechanisms to realise these opportunities. Space cooling efficiency gains will also be important in managing peak and overall electricity demand, thereby reducing pressure on Brazil's electricity network.

Box 6.2 Brazil will adopt IE3 motor standards

Brazil has historically been a major exporter of electric motors. The establishment of domestic energy performance standards in importing countries and regions such as the United States and the European Union has prepared Brazilian manufacturers for the introduction of domestic standards. MEPS for specific ranges of industrial motors were implemented at the IE2 level in 2009. MEPS for electric motors at the IE3 level were announced in 2017 and will take full effect in 2019, elevating Brazil to the same levels as China, the European Union, Japan and North America.

The strengthening of MEPS is forecast to save over 11 TWh in electricity between 2019 and 2030, as well as USD 4.7 million in energy costs by 2020 and USD 172 million by 2050 (Sauer et. al., 2015). The more stringent standard could also increase industrial energy efficiency across Latin America, as Brazil exports 38% of its machinery to its neighbouring countries.

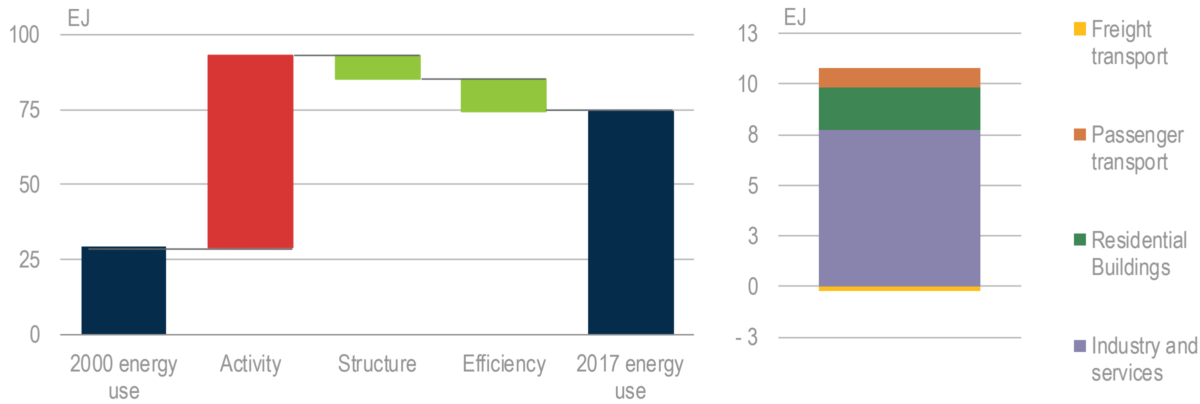
Sources: Adapted from Sauer, I. L. et al. (2015), *A Comparative Assessment of Brazilian Electric Motors Performance with Minimum Efficiency Standards*; MME (2017), *MME Sets New Efficiency Rules for Electric Motors and Ceiling Fans*; WITS (2018), *Brazil Product Exports and Imports 2016* (database).

China

Energy efficiency trends and outlook

China has made huge strides in energy efficiency. Without the energy efficiency improvements that have been made since 2000, China would have used 12% more energy in 2017 (Figure 6.9). Efficiency gains in China's industry and service sectors and residential sector saved more than 10 EJ in energy consumption in 2017, equivalent to the final energy consumption of Germany. Emissions of nearly 1.2 Gt CO_2-eq, equivalent to almost half those of the United States, have been prevented, as have nearly 10% additional fossil fuel imports.

Figure 6.9 Decomposition of Chinese energy use, 2000-17 (left) and sectoral contribution to efficiency gains (right)



Notes: "Energy use" covers the residential, industry and services, passenger and freight transport sectors. It excludes non-energy use (i.e. feedstocks) and energy supply. Buildings analysis based on IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

Sources: Adapted from IEA (2018a), *World Energy Balances* (database); IEA (2018b), *Mobility Model* (database); Timmer, M. P. et al. (2015), *World Input Output Database* (database); National Bureau of Statistics of China (2018), *National Accounts* (database).

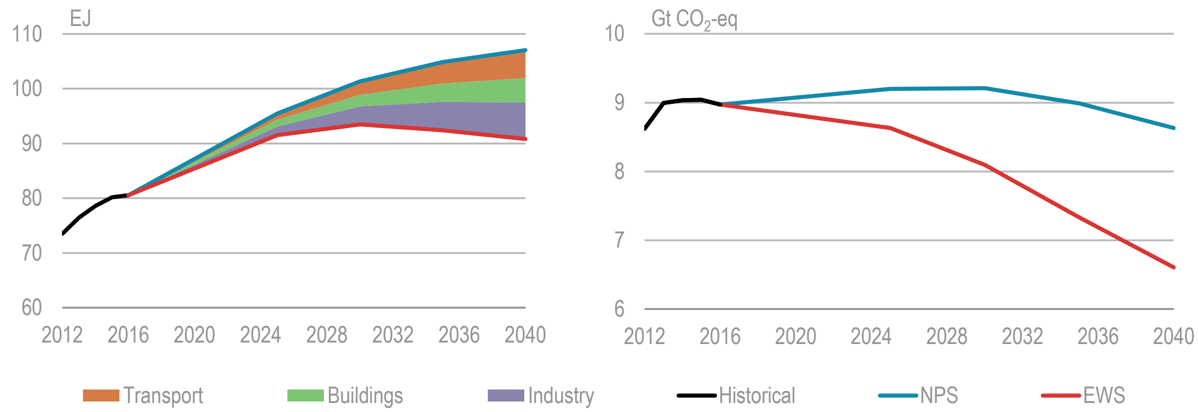
Increased economic activity between 2000 and 2017 in China would have more than tripled energy use without the impact of efficiency gains and structural change. Nearly 80% of this impact on energy use was due to the industry and service sectors, where massive increases in output have more than quadrupled GVA since 2000.

Structural changes in the economy, notably the movement of economic activity from energy-intensive industry sectors to less-intensive manufacturing and service sectors, reduced the impact of activity growth on energy use. However, factors that lowered energy use were in part offset – by 30% – by other structural changes that raised energy use in the residential and transport sectors, including increased appliance ownership, shifts to less efficient modes of transport, and decreasing vehicle occupancy. Overall, structural changes reduced the impact of activity growth on energy use by 12%.

Since 2000, China's primary energy demand has grown by over 160%. However, the adoption of all the cost-effective energy efficiency measures in the EWS could limit growth between now and 2040 to just 8%. This would save just over 16 EJ of additional final energy use compared with the NPS, equivalent to the current energy use of Germany and France combined (Figure 6.10). In the EWS, China's final energy use peaks by 2030 and starts to decline, with emissions falling to 26% below current levels, preventing over 2 Gt CO_2-eq of additional emissions in 2040 compared with the NPS, equivalent to nearly twice the emissions of Japan.

The largest opportunities for energy savings in the EWS by 2040 are in industry (42%) and transport (31%). In industry, the less energy-intensive manufacturing sectors such as food, beverage and textile manufacturing can deliver the largest gains, reducing energy use per unit of GVA by nearly half between now and 2040. Key measures to realise these efficiency gains are the increased adoption of electric heat pumps for low-temperature process heating (less than 100°C) and improvements in the efficiency of motor-driven systems. Energy intensity in the iron and steel sector (energy use per tonne of steel production) could also fall by around 35% in the EWS, primarily as a result of increased metals recycling.

Figure 6.10 Total final energy use and emissions in the NPS and EWS for China, 2012-40



Note: "Energy use" includes non-energy use (i.e. feedstocks), excludes energy supply.

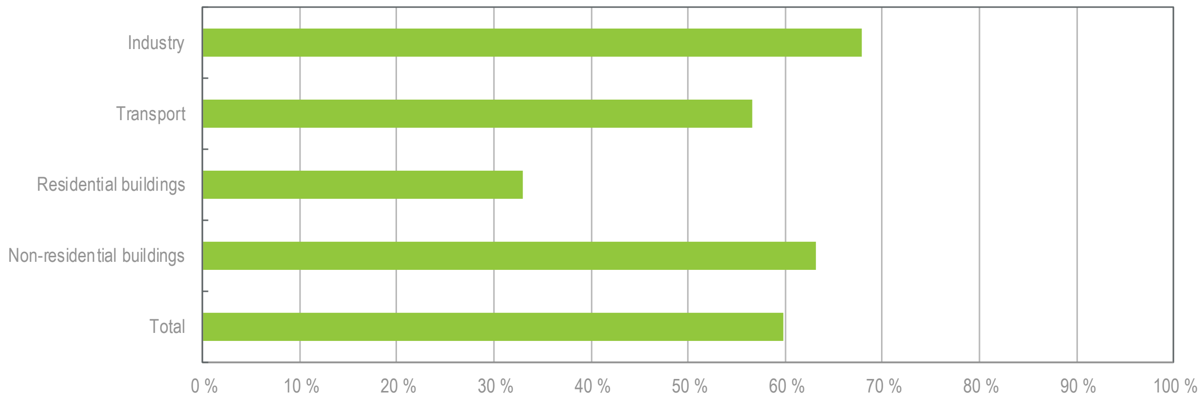
In the transport sector, improvements in passenger car fuel efficiency of nearly 60% between 2016 and 2040 represent the largest opportunity for savings. Fuel economy can be further improved, and electric vehicles' share of the total passenger car market could increase from 0.4% in 2016 to over 60% in 2040.

Policy trends and future opportunities

Around 60% of final energy use in China was covered by mandatory energy efficiency policies in 2017, the highest coverage globally (Figure 6.11). Policy coverage is highest in industry, at nearly 70%, because of the mandatory energy efficiency improvement targets introduced through the Top 1 000 and Top 10 000 Programmes.

Policy coverage for non-residential buildings (63%) and residential buildings (33%) reflects China's ambitious building codes and appliance standards. These have been crucial to counteract the increase in energy use resulting from rapid construction activity and higher rates of appliance ownership. The introduction of passenger car and truck fuel economy standards sees transport coverage reach 57%.

Figure 6.11 Energy use covered by mandatory energy efficiency policies in China



China's 13th Five-Year Plan set an interim target of reducing energy intensity by 15% between 2015 and 2020. Meeting this target would represent a 44% reduction in energy intensity between 2005 and 2020. In industry, which has the largest potential for savings in the EWS, China has an extensive mandatory policy in the form of the Top 10 000 Programme, which will be superseded by the recently announced 100, 1 000, 10 000 Programme. However, this policy is most applicable to energy-intensive industry sectors and does not have the same level of impact on less energy-intensive manufacturing sectors, where there are substantial opportunities to improve efficiency.

Improving the efficiency of motor-driven systems will be central to realising efficiency gains in less energy-intensive manufacturing. While China has implemented standards for electric motors, they are at the IE2 level – less stringent than in other large economies. The adoption of energy management systems will also push up efficiency across the entirety of motor-driven systems. By the end of 2017 there were nearly 4 500 energy management certifications under the ISO 50001 standard and China's national GB/T 23331 standard, combined. China is a global leader in other management system standards, with more than 130 000 ISO 9001 certifications and 350 000 ISO 14001 certifications by the end of 2016. Therefore, there are opportunities for policy to boost adoption of energy management systems to reach similar levels.

In transport, which represents over 30% of the energy savings potential in the EWS, China is already one of only five countries with fuel efficiency standards for both cars and trucks. The impact of these standards is still to be fully realised, as the average fuel efficiency of passenger cars is currently 27% worse than the European Union and 23% worse than Japan. Standards are also less stringent than in other major markets. If China had adopted fuel efficiency standards for passenger vehicles as stringent as those of Japan, it could have saved nearly half a million BOE per day in 2017.

MEPS continue to be a central energy efficiency policy for China, with new standards being introduced to cover additional appliances and equipment, including air purifiers, data centres and dust collectors (CNIS, 2016). Policy implementation is a priority: a new pilot survey will gather sales statistics on appliances and equipment to improve compliance and enforcement (NDRC, 2018). Other mandatory policies are also driving efficiency gains in China, including energy efficiency obligations

(EEOs) for utilities, which were renewed as part of the Guidance on Electricity DSM Regulations (NDRC, 2017a) (Box 6.3).[64]

Efforts in China will be central if the world is to realise the benefits described by the EWS. Ensuring compliance and enforcement of existing policies is crucial. In addition, thorough evaluation and assessment needs to become a higher priority, to inform future policy development.

Box 6.3 DSM – Implementing Energy Efficiency Obligations for Utilities

In 2017, China revised and renewed its national "Guidance on Electricity Demand-Side Management Regulations" [电力需求侧管理办法]. When the rule was issued in 2010, it was the first energy efficiency obligation (EEO) placed on the State Grid Corporation and the Southern Grid Company, which together cover the majority of the Chinese electricity market. According to the EEO, the utilities and their local subsidiaries were to achieve "energy savings of at least 0.3% compared with sales volumes from the previous year and a reduction of 0.3% in maximum load."

Between 2012 and 2016, the two grid companies exceeded their mandatory energy saving and peak capacity targets by significant amounts. The cumulative electricity savings target of 55 GWh was exceeded by 13 GWh and the peak capacity reduction target of around 13 GW was exceeded by around 4 GW.

Sources: NDRC (2010) *DSM Rule*; RAP (2012) *Best Practice in Designing and Implementing Energy Efficiency Obligation Schemes*. China Electricity Council (2017), *Development and Reform Commission: Deepen the structural reform of supply side and do a good job in power demand side management under the new situation*; NDRC (2017b), *DSM Rule (Revised)*.

India

Energy efficiency trends and outlook

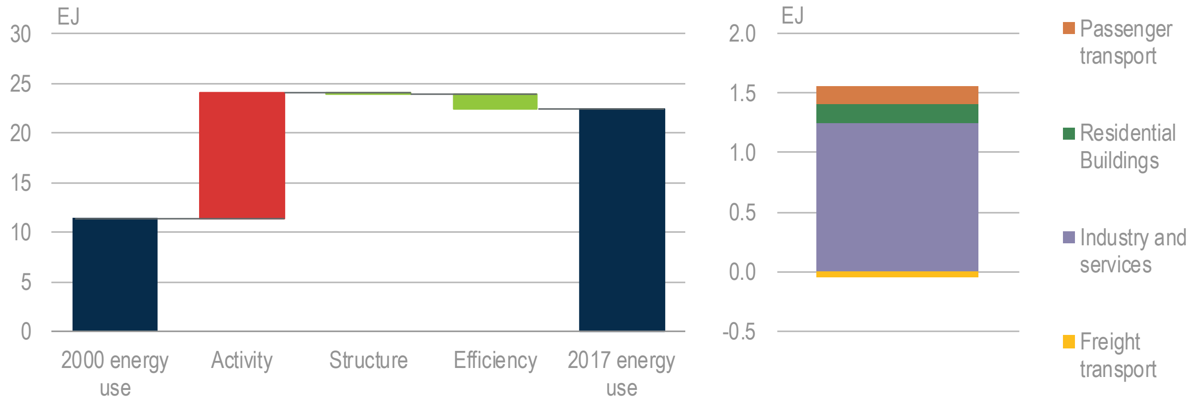
Energy efficiency improvements in India since 2000 avoided an additional 6% more energy use in 2017 (Figure 6.12). Efficiency gains were largely achieved through the industry and service sectors and residential buildings. Efficiency improvements also prevented nearly 145 Mt CO_2-eq in emissions and 5% more imports of fossil fuels in 2017.

Increased economic activity in India would have more than doubled energy use between 2000 and 2017 without the impact of efficiency gains and structural change. Nearly 70% of this impact on energy use was due to the industry and service sectors, where massive increases in output have more than tripled GVA since 2000.

Structural changes were responsible for avoiding 1% more energy use in 2017. These changes were due to the movement of economic activity from energy-intensive industry sectors to less-intensive manufacturing and service sectors. The impact of these changes was almost completely offset by structural changes that boosted energy use, specifically increases in residential building floor area and appliance ownership, shifts to less efficient modes of transport, and decreasing vehicle occupancy rates.

[64] The Guidance on Electricity DSM Regulation is governed by six central government agencies, with the National Development and Reform Commission (NDRC) as the lead agency.

Figure 6.12 Decomposition of Indian final energy use, 2000-17 (left) and sectoral contribution to efficiency gains (right)



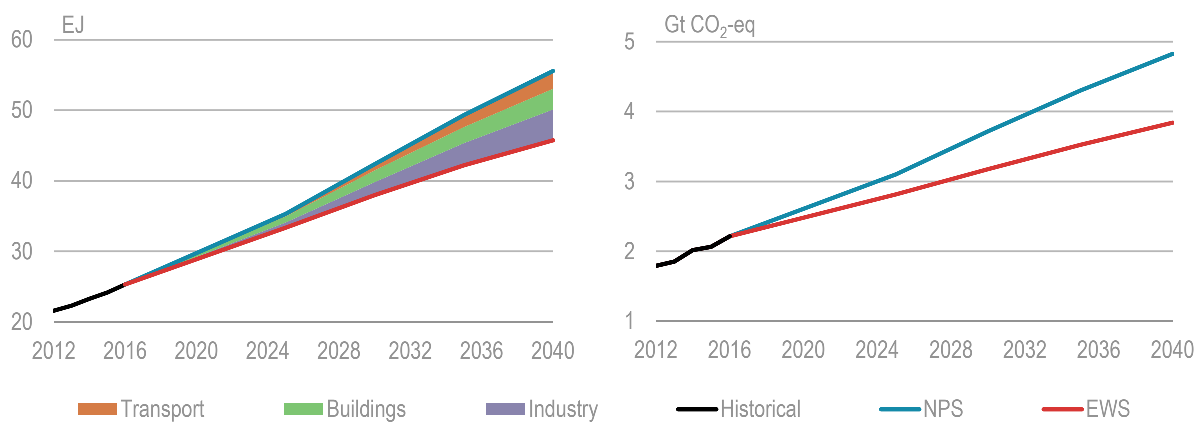
Notes: "Energy use" covers the residential, industry and services, passenger and freight transport sectors. It excludes non-energy use (i.e. feedstocks) and energy supply. Buildings analysis based on IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

Sources: Adapted from IEA (2018a), *World Energy Balances* (database); IEA (2018b), *Mobility Model* (database); Reserve Bank of India (2018), *The India KLEMS Database* (database).

Since 2000, India's primary energy demand has nearly doubled. However, in the EWS, adopting cost-effective energy efficiency measures could limit demand growth in 2040 to 82% above current levels, saving almost 10 EJ of additional final energy use by 2040 compared with the NPS. This equates to preventing nearly 985 Mt CO_2-eq in emissions, more than the emissions of Australia and Canada combined (Figure 6.13).

The largest opportunities for energy savings by 2040 in the EWS compared with the NPS are in industry (45%) and buildings (30%). In industry, the largest opportunity is in the less energy-intensive manufacturing sectors such as food, beverage and textile manufacturing. Energy intensity (energy use per unit of GVA) in these sectors more than halves by 2040 as electric heat pumps for low-temperature process heating are adopted more widely and motor-driven systems become more efficient. In the buildings sector, the largest energy savings come from space cooling (29%) and appliances (31%).

Figure 6.13 Total final energy use and emissions in the NPS and EWS for India, 2012-40



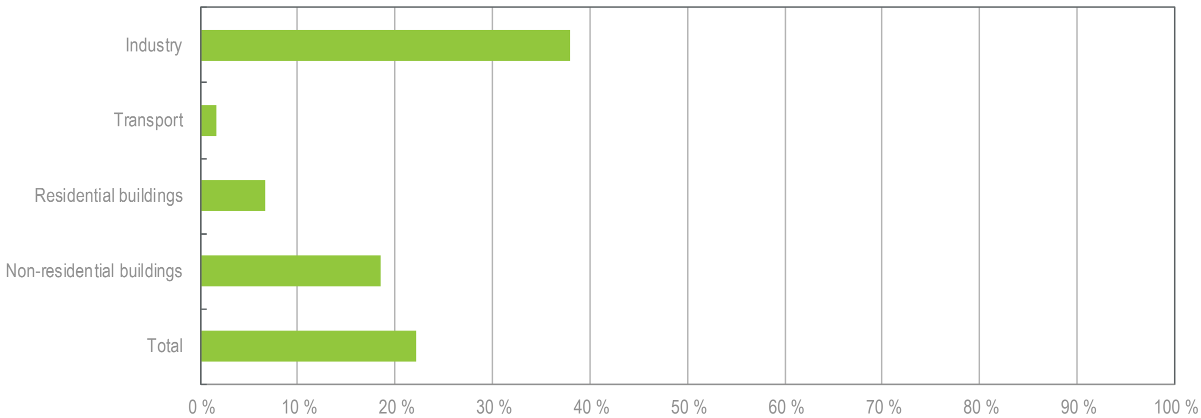
Note: "Energy use" includes non-energy use (i.e. feedstocks), excludes energy supply.

Policy trends and future opportunities

In 2017, 23% of India's energy use was covered by mandatory energy efficiency policies, with coverage highest in industry and non-residential buildings (Figure 6.14). In industry, the expanding Perform, Achieve and Trade (PAT) scheme is responsible for high coverage. In non-residential buildings, the adoption of appliance standards and state-based building bylaws, coupled with growing energy access and new construction, has resulted in policy coverage of nearly 20%.

Standards for consumer appliances lifted policy coverage in residential buildings to nearly 7% in 2017. In the transport sector, the implementation of passenger car fuel economy standards in 2017 will soon increase policy coverage, as new vehicles subject to the standards replace existing stock. This policy is forecast to prevent 50 Mt CO_2-eq of emissions in 2030, about 10% of the total emissions that could be prevented by 2030 in the EWS compared with the NPS. Ambitious plans have also been implemented to increase the penetration of electric vehicles (Box 6.4). Further gains are expected with the enforcement of fuel economy standards for heavy-duty vehicles in 2018. India is just the fifth country to implement such standards.

Figure 6.14 Mandatory policy coverage of different sectors in India



The Energy Conservation Act, enacted in 2001 and amended in 2010, provides the basis for India's energy efficiency policy framework. The Act is reinforced through the National Mission on Energy Efficiency, one of eight missions under the 2008 National Action Plan on Climate Change. The National Mission on Energy Efficiency is in the process of being converted to the Roadmap of Sustainable and Holistic Approach to National Energy Efficiency (ROSHANEE). The Bureau of Energy Efficiency (BEE), under the Ministry of Power, has also overseen revision and extension of important policies and programmes over the past year. This includes a revision of the Energy Conservation Building Code, further expansion of the BEE standards and labelling programme, the launch of the third and fourth cycles of the PAT scheme for industry, and the extension of fuel efficiency standards to commercial heavy-duty vehicles.

The PAT scheme is currently the key policy to drive efficiency gains in the industry sector, in which India has the largest potential for savings in the EWS. As with China's Top 10 000 Programme, the PAT scheme targets efficiency improvements in energy-intensive industry sectors, but also extends to less energy-intensive sectors, specifically textile manufacturing. Electric motor-driven systems could make an important contribution to efficiency gains. India has recently implemented performance standards for electric motors at the IE2 level. Unlike in other major economies, however, these standards are not mandatory.

Rising demand for space cooling will greatly increase energy use in India's buildings sector. In the EWS, space cooling energy demand could more than quadruple to 2040 as living standards improve and purchasing power rises. Stronger MEPS for air conditioners came into effect in January 2018, increasing the minimum ISEER requirement to 3.30 (2 stars) (Government of India, 2016).[65] A National Cooling Action Plan is also being developed, which considers refrigerant technology, thermal comfort, building design, and standards and labelling (Jaiswal, 2018). While recent action to strengthen performance standards for air conditioners will push the Indian market to greater levels of efficiency, the current market average performance is just 2% lower than the new standard level, which is nearly 46% lower than current best available technology (BAT) in the Indian market (IEA, 2018c).

Box 6.4 India's bulk procurement is changing the market for efficiency

Bulk procurement can expand markets for energy efficient products – and has been successfully doing so in India. The procurement of large quantities generates sufficient demand to achieve economies of scale, making efficient products available at or below cost of conventional products. The ability for one manufacturer to deliver products for bulk procurement encourages other manufacturers to follow suit.

Energy Efficiency Services Limited (EESL), an Indian state-owned "super" energy services company (ESCO), has radically pushed down the price of LEDs available in the market and helped to create local manufacturing jobs to meet the need for energy efficient lighting. LEDs now cost less than USD 1 (around INR 60), down 80% from the first round of procurement in 2014. Through its Unnati Jyoti by Affordable LEDs for ALL (UJALA) programme, EESL has replaced over 308 million lamps with LEDs, without the need for any subsidies.

EESL has been looking to replicate the success of this procurement model across different product categories, including air conditioners, electric fans, and electric vehicles. Through its first procurement round of air conditioners, the lowest-price bidder offered high-efficiency five-star air conditioners that can save 30-40% on the cooling electricity bill for INR 35 000, a cost only slightly higher than that of the cheapest air conditioners on the market. Prices are expected to fall further as more air conditioners are procured and product manufacturers exploit the economies of scale that bulk procurement can induce.

Bulk procurement does pose challenges, which include generating demand at sufficient scale, negotiating the right contractual conditions, and managing product performance. By meeting these challenges, companies involved in bulk procurement will continue to transform markets by improving access to more energy efficient products.

Sources: Sengupta, D. (2017), *Panasonic emerges as lowest bidder for EESL's super-efficient ACs*; IEA (2017), *Energy Efficiency 2017*, EESL and IEA (2017), *India's UJALA Story*.

Indonesia

Energy efficiency trends and outlook

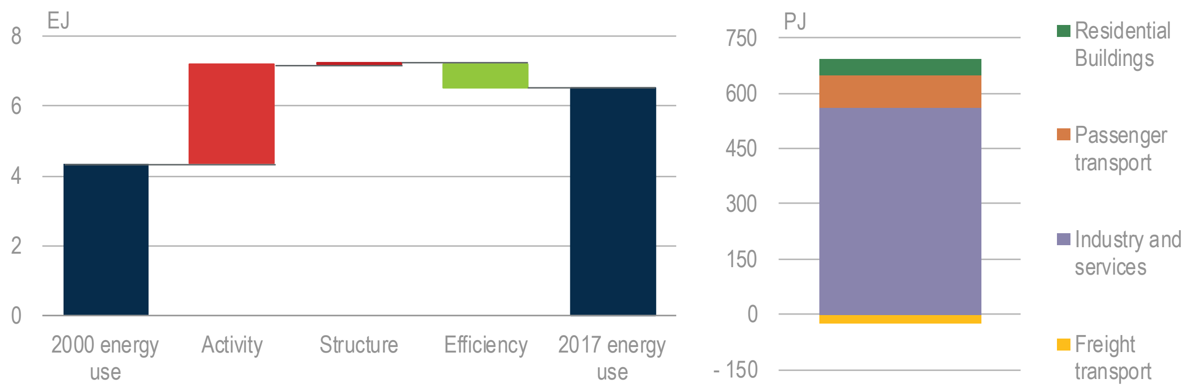
Energy efficiency improvements in Indonesia since 2000 have offset 23% of the impact of growing economic activity, preventing 9% more energy use in 2017 (Figure 6.15). The industry and service

[65] ISEER is the Indian Seasonal Energy Efficiency Ratio. It is calculated based on a bin temperature range of 24-43°C and 1600 cooling hours per annum (BEE, 2015).

sectors and passenger transport make the greatest contributions to overall efficiency gains. Efficiency improvements also prevented 65 Mt CO_2-eq in emissions in 2017 and reduced oil imports by 6%.

Without the impact of efficiency gains, increased economic activity would have lifted Indonesian energy use by nearly two-thirds between 2000 and 2017. Nearly 60% of this activity growth resulted from increased output in the industry and service sectors. Economic activity moved from energy-intensive industry sectors to less-intensive manufacturing and service sectors, and there was also a shift towards more efficient modes of transport, specifically motorbikes and scooters. However, all of these energy-saving effects were offset by structural changes that increased energy use, particularly increased appliance ownership and floor area in residential buildings.

Figure 6.15 Decomposition of Indonesian final energy use, 2000-17 (left) and sectoral contribution to efficiency gains (right)



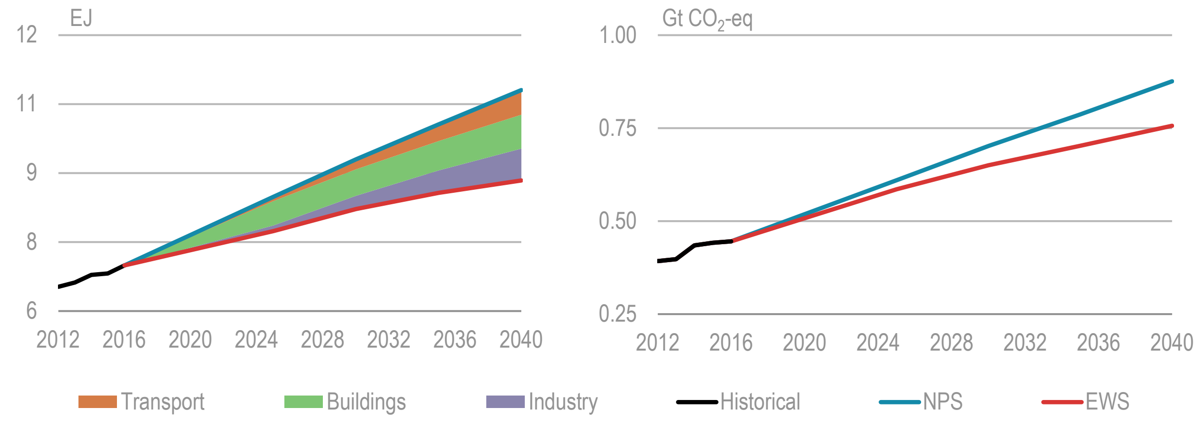
Notes: "Energy use" covers the residential, industry and services, passenger and freight transport sectors. It excludes non-energy use (i.e. feedstocks) and energy supply. Buildings analysis based on IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

Sources: Adapted from IEA (2018a), *World Energy Balances* (database); IEA (2018b), *Mobility Model* (database); Timmer, M. P. et al. (2015), *World Input Output Database* (database); Statistics Indonesia (2018), *Gross Domestic Product* (database).

Since 2000, primary energy demand in Indonesia has increased by 48%. However, the EWS shows that adopting cost-effective energy efficiency measures would limit the further increase in primary energy demand to 2040 to 50%, compared with a 75% increase in the NPS. This would avoid 2 EJ of additional energy use and 120 Mt CO_2-eq in emissions by 2040 compared with the NPS (Figure 6.16). Efficiency gains in the EWS would also save households USD 7 billion in 2040 due to reduced energy bills and provide 26 million more families with access to clean cooking.

The largest opportunities for energy savings in the EWS compared with the NPS come from buildings (38%) and industry (35%). Of the potential energy savings in buildings, one-third are due to efficiency gains in space cooling and another one-third to efficiency gains in appliances. In industry, efficiency gains in the less energy-intensive manufacturing sectors – including food, beverage, tobacco and textile manufacturing – could improve energy intensity (energy use per unit of GVA) by over 40% between now and 2040.

Figure 6.16 Total final energy use and emissions in the NPS and EWS for Indonesia, 2012-40



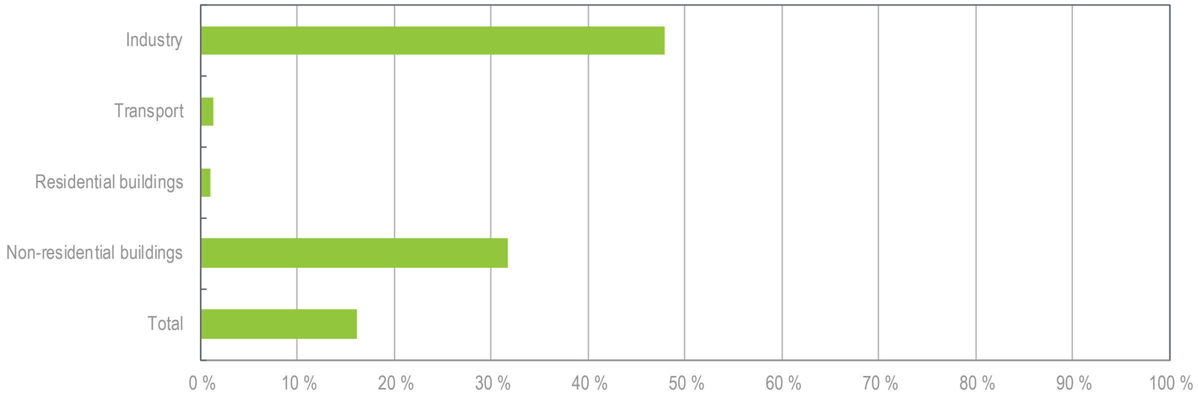
Note: "Energy use" includes non-energy use (i.e. feedstocks), excludes energy supply.

Policy trends and future opportunities

Around 16% of Indonesia's total energy use in 2017 was subject to mandatory energy efficiency policies (Figure 6.17). Industrial energy efficiency policy in Indonesia centres on government regulation 70/2009, which is responsible for the high coverage observed in 2017. The regulation requires all companies with an annual energy consumption exceeding 6 000 tonnes of oil equivalent (toe) to appoint an energy manager, develop an energy conservation plan, perform an energy audit and report energy consumption to government. Following concerns over its implementation, the regulation is currently under review.

Codes for large commercial buildings, implemented by local jurisdictions, are responsible for non-residential buildings coverage reaching 32%. Similar measures could be implemented for residential buildings, where the lack of codes, combined with lower appliance ownership, leads to low policy coverage. Transport has the lowest policy coverage, due to the continued absence of fuel efficiency standards for passenger cars and trucks.

Figure 6.17 Mandatory policy coverage of different sectors in Indonesia



Indonesia introduced a new MEPS and labelling system for residential air conditioning in late 2017. A minimum energy efficiency rating of 2.50 (EER measured on a watt per watt basis) is the new standard and ranks as one-star in the new four-star labelling scheme, where 3.05 EER is the current best performer. A progressive update of these MEPS is also planned that will raise the minimum value to 2.64 EER by August 2018 and 2.92 EER after July 2020 (MEMR, 2017). The current standard is 18% below the market average and 59% below BAT available in Indonesia, so there is scope for further strengthening of MEPS.

To unlock efficiency gains in the residential building sector, Indonesia is also removing electricity subsidies for 16.5 million customers, leaving 23.5 million customers in lower income brackets eligible for subsidies, and promoting adoption of efficient appliances (Box 6.5).

Efficiency gains in motor-driven systems are an important element of the EWS in Indonesia. Existing regulations are intended to push large industry towards more efficient practices. However, the absence of MEPS for electric motors means that the majority of units in Indonesia are operating at a level equivalent to IE0. If Indonesia were to introduce MEPS at the IE2 level, the same as in China but lower than in other regions, it could save nearly 8 PJ of industrial electricity use by 2030 (IEA, 2017).

Box 6.5 Increasing energy access via energy efficiency and renewable energy in Indonesia's Lampu Tenaga Surya Hemat Energi (LTSHE) Programme

Indonesia launched the Lampu Tenaga Surya Hemat Energi (LTSHE) Programme in 2017 as part of its pre-electrification programme in areas of low energy access. Each household was given four LED lamps together with a 20 Watt-peak solar photovoltaic (PV) module and a lithium battery that can last for 60 hours. The provinces targeted mostly have energy access significantly lower than in Java: Riau, Maluku, West Papua, Papua, and West Nusa Tenggara. The programme has reached about 79 564 homes in five provinces with spending of nearly USD 25 million and is aiming to reach 175 782 homes in 15 provinces by 2018.

The programme shows how energy efficiency can be integrated with renewable energy to facilitate energy access. Incandescent lamps of equivalent light output would need around 25 watts, requiring six to eight more solar PV modules of the same watt-peak power. The same battery would also be able to operate the lights for only around seven hours

Source: Adapted from ESDM (personal communication 29 June 2018).

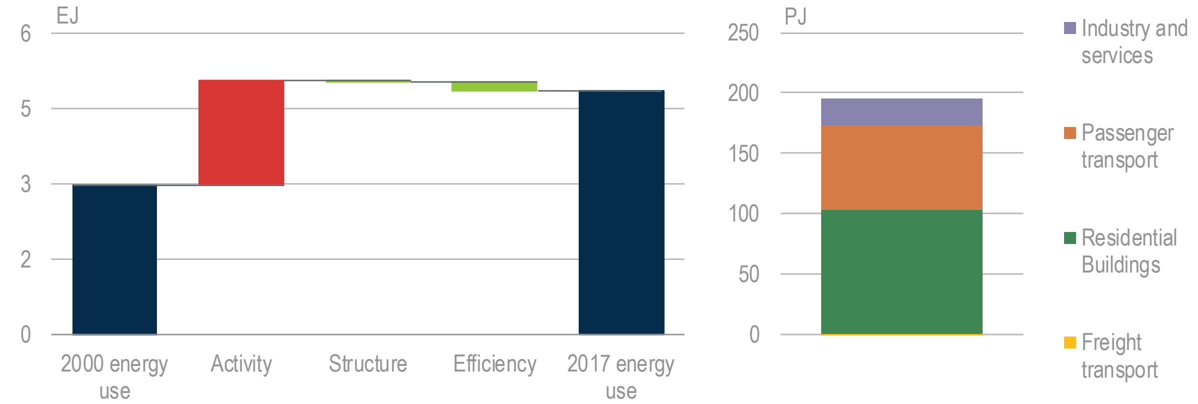
Mexico

Energy efficiency trends and outlook

Efficiency gains in Mexico since 2000 prevented 3% more energy use in 2017 (Figure 6.18). Over 59% of these savings have been achieved in the residential sector. Passenger transport is responsible for 40% of the savings and industry and services contribute around 12%, mostly in less energy-intensive manufacturing sectors. Efficiency gains also prevented 12 Mt CO_2-eq in emissions and 2% additional coal and gas imports.

Without the impact of efficiency gains and structural change, increased economic activity would have lifted Mexican energy use by 69% between 2000 and 2017. Passenger and freight transport were each responsible for one-third of the growth, while increased output in industry and services accounted for nearly 28%. Structural change has had little impact on energy use in Mexico. Movement of economic activity from energy-intensive industry sectors to less-intensive manufacturing and service sectors was almost entirely offset by structural effects that increase energy use. Specifically, Mexico experienced changes in transport modes and occupancy levels and increased appliance ownership and building floor area.

Figure 6.18 Decomposition of Mexican final energy use, 2000-17 (left) and sectoral contribution to efficiency gains (right)

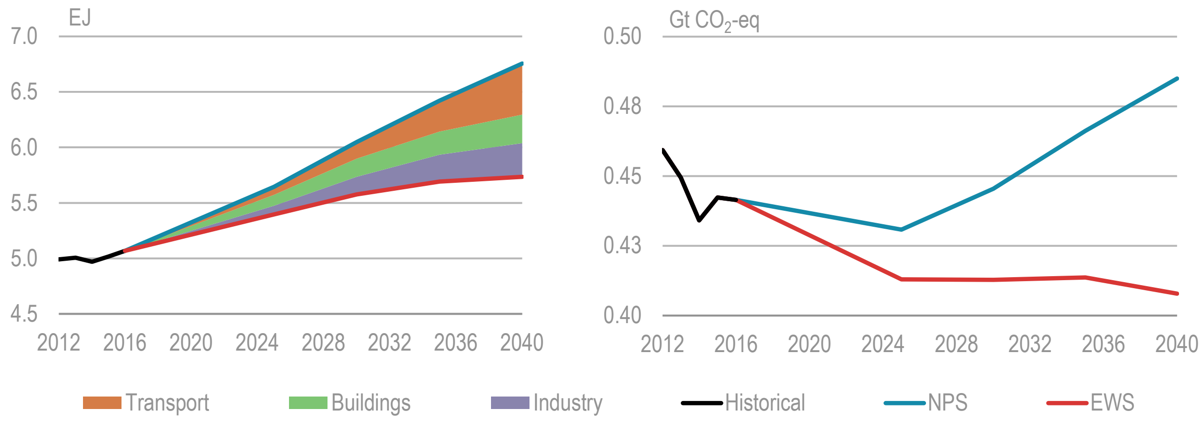


Notes: "Energy use" covers the residential, industry and services, passenger and freight transport sectors. It excludes non-energy use (i.e. feedstocks) and energy supply. Buildings analysis based on IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

Sources: Adapted from IEA (2018a), *World Energy Balances* (database); IEA (2018b), *Mobility Model* (database); Timmer, M. P. et al. (2015), *World Input Output Database* (database); INEGI (2018), *GDP – Activity of Goods and Services* (database).

Since 2000, primary energy demand in Mexico has increased by nearly 23%. However, the EWS shows that adopting cost-effective energy efficiency measures could contain the increase in energy demand to just 10% between now and 2040, avoiding 1 EJ of additional final energy use compared with the NPS (Figure 6.19). Emissions of over 77 Mt CO_2-eq could also be prevented in 2040, a drop of nearly 8% from current levels.

Figure 6.19 Total final energy use and emissions in the NPS and EWS for Mexico, 2012-40



Note: "Energy use" includes non-energy use (i.e. feedstocks), excludes energy supply.

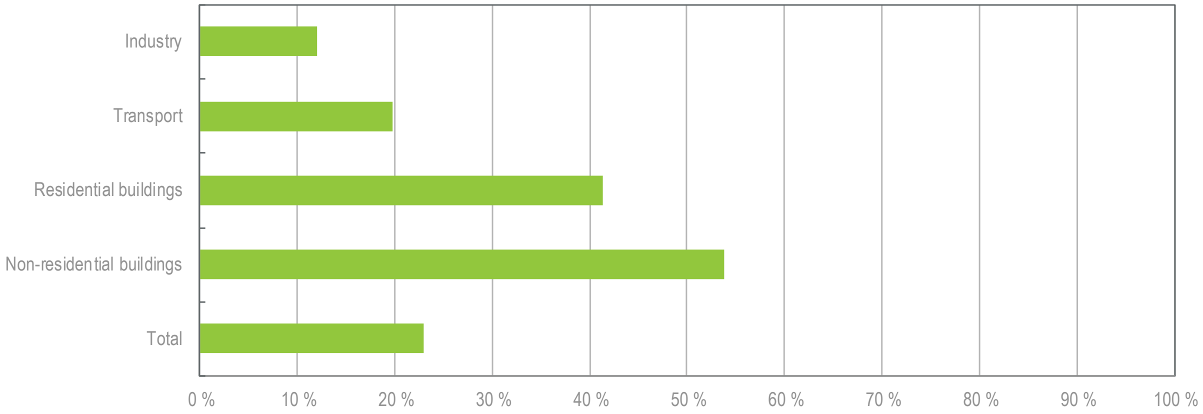
The largest opportunities for energy savings in the EWS in 2040 compared with the NPS come from transport followed by industry (30%) and buildings (25%). In the transport sector, efficiency could be improved by increasing the fuel efficiency of trucks and cars by over 35%. For industry, potential efficiency gains are greatest in the less energy-intensive manufacturing sectors, including food, beverage, tobacco and textile manufacturing, where energy intensity could improve by over 35% between now and 2040.

Policy trends and future opportunities

Around 23% of Mexico's final energy use in 2017 was covered by mandatory energy efficiency policies (Figure 6.20). Policy coverage is greatest in the buildings sector, with codes in place for both commercial and residential buildings. In industry, MEPS for electric motors, which were first implemented in 2006 and strengthened in 2008, result in coverage of around 12%.

In 2017, Mexico updated its model code for existing buildings in the residential sector and adopted a Roadmap for Building Energy Codes and Standards, which sets national targets in three-year increments to 2050 and lays out steps for municipalities to adopt its model code. Updated MEPS for commercial refrigerators, lighting and external power sources of less than 250 W were also introduced.

Figure 6.20 Mandatory policy coverage of different sectors in Mexico



In 2015, Mexico adopted its Energy Transition Law (Ley de Transición Energética), which charts a course for increasing the share of clean energy sources in the electricity system and advancing energy efficiency. As part of its strategy to implement the law, Mexico has set the goal of reducing the energy intensity of final consumption by almost 2% annually from 2016 to 2030. The annual target will increase to just under 4% from 2031 to 2050 (SENER, 2016). Mexico is also working to reach its target of reducing transport energy use per unit of GDP by 6% between 2015 and 2018.

In the transport sector, Mexico has benefited from the introduction of fuel efficiency standards for passenger cars, with the fuel efficiency of the country's passenger car fleet on a par with the global average. Efficiency gains in freight transport could be substantial in the EWS. Unlike other countries in North America, Mexico has not yet adopted fuel efficiency standards for trucks. In Mexico the average fuel efficiency of trucks is around 30% worse than China and 20% worse than the United States, both of which have introduced standards, indicating that the introduction of fuel efficiency standards for trucks could unlock efficiency gains.

Mexico has adopted MEPS for electric motors at the IE3 level, matching stringency levels across North America. These standards provide the starting point for increasing efficiency in less energy-intensive manufacturing sectors. Adopting energy management systems across motor-driven systems will also boost efficiency, with Mexico promoting uptake through learning energy efficiency networks (Box 6.6). While Mexico does not mandate industrial energy efficiency improvements, it has created a framework for voluntary agreements with industry. Such agreements, which have been implemented in Europe, provide incentives to industry for agreed improvements in energy efficiency. The first voluntary agreement was signed in December 2017.

Box 6.6 Learning energy efficiency networks get results in Mexico

Learning energy efficiency networks help companies and other actors to share experiences and knowledge, and build capacity to identify and undertake energy savings measures. In Mexico, the National Commission for the Efficient Use of Energy (CONUEE) established the National Programme for Energy Management Systems (PRONSAGEn) in 2014 with the support of the German Agency for International Co-operation (GIZ).

Learning networks were introduced in 2015 as part of Mexico's strategy to implement energy management systems in the public and private sector. By the end of 2017, 12 networks had been established, covering 95 entities across various industry sectors including refineries, dairy and food production, and public buildings. (CONUEE 2018). CONUEE developed free online materials to facilitate these networks, including training materials on implementing energy management systems, a manual on learning networks, reports documenting progress with learning networks, and directories with names and contact information of relevant experts.

There are signs that these measures are generating energy savings and financial savings. One of the first companies to join a learning network, Clariant, has benefited from energy savings of nearly 30% and developed strategies to replicate this success across its production facilities (energía a debate, 2018). Dow Chemical expects to reduce energy consumption by 18% over three years in participating facilities through its learning network in Mexico (Dow, 2017).

Learning networks are also changing company cultures and generating longer-term processes to manage energy use. Of the 11 companies that joined Mexico's first learning network, eight have chosen to continue the network beyond its initial timeframe using their own resources. The success of these networks has stimulated growth in learning networks not only in Mexico but also in Argentina, El Salvador and Nicaragua (SENER, 2018).

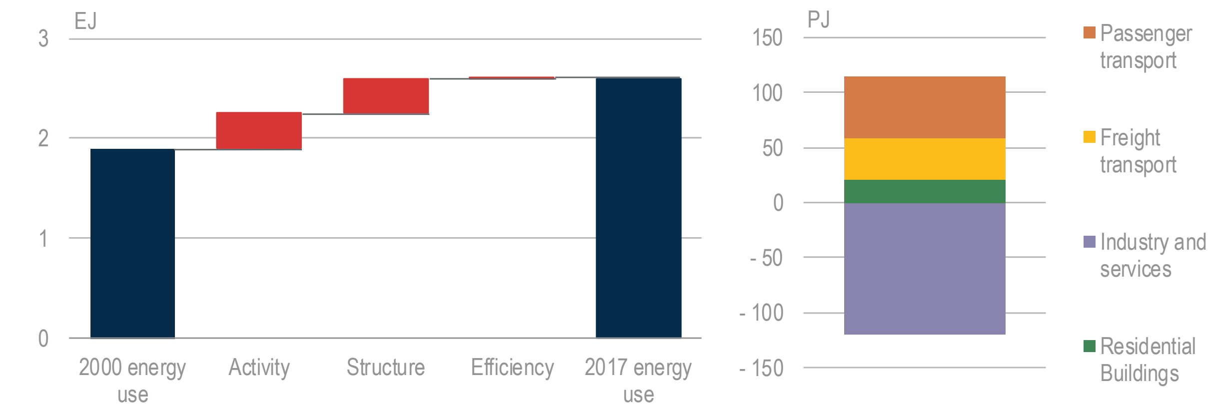
South Africa

Energy efficiency trends and outlook

Progress on energy efficiency in South Africa varies from sector to sector (Figure 6.21). Efficiency gains in transport and residential buildings since 2000 have been offset by worsening efficiency in industry and services. However, this trend appears to be reversing. Efficiency gains in the manufacturing industries since 2015 have prevented over 25 PJ of additional energy use.

Growing economic activity in South Africa has increased energy use by 19% since 2000. Activity growth was due to increased economic output from the industry and service sectors, where GVA has risen by 70% since 2000. However, a decrease in freight transport activity offset almost 50% of this activity growth in other sectors. Structural change resulted in 10% more energy use in 2017, largely because of changes in transport modes and vehicle occupancy levels. The movement of economic activity from energy-intensive industry sectors to less-intensive manufacturing and service sectors offset 56% of the impact of structural change in other sectors.

Figure 6.21 Decomposition of South African final energy use, 2000-17 (left) and sectoral contribution to efficiency gains (right)

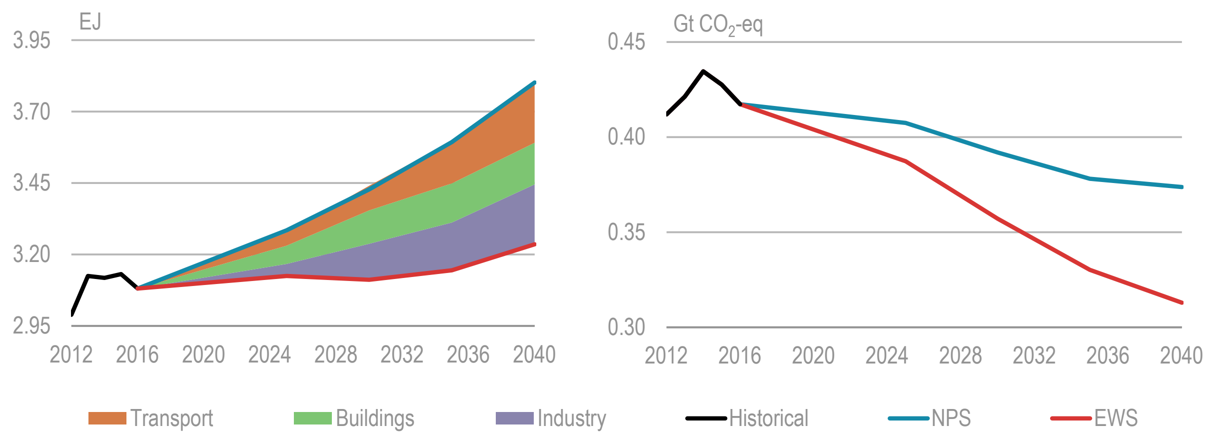


Notes: "Energy use" covers the residential, industry and services, passenger and freight transport sectors. It excludes non-energy use (i.e. feedstocks) and energy supply. Buildings analysis based on IEA *Energy Technology Perspectives* Buildings model (www.iea.org/etp/etpmodel/buildings/).

Sources: Adapted from IEA (2018a), *World Energy Balances* (database); IEA (2018b), *Mobility Model* (database); StatsSA (2018), *Gross Domestic Product (GDP), 4th Quarter 2017* (database); Quantec (2018), *Industry Service – RSA Standard Industry – Input Structure at basic prices* (database).

Since 2000, primary energy demand in South Africa has increased by nearly 30%. However, the EWS shows that adopting cost-effective energy efficiency measures could reduce primary energy demand by 4% between now and 2040, and save 566 PJ in additional final energy use compared with the NPS (Figure 6.22). Efficiency gains in the EWS could also save households USD 2 billion a year by 2040 and reduce emissions by 25% compared with current levels.

Figure 6.22 Total final energy use and emissions in the NPS and EWS for South Africa, 2012-40



Note: "Energy use" includes non-energy use (i.e. feedstocks), excludes energy supply.

The largest potential for efficiency gains in the EWS are in transport (37%) and industry (37%). In the transport sector, efficiency gains are possible across all sub-sectors. Fuel efficiency could improve by 29% for cars and 40% for trucks between now and 2040. In the industry sector, energy intensity in the less energy-intensive manufacturing sectors, including food, beverage and textile manufacturing, could improve by 40% between now and 2040 as more electric heat pumps are deployed and efficiency is improved in electric motor-driven systems.

Policy trends and future opportunities

Only 5% of South Africa's final energy use was covered by mandatory energy efficiency policies in 2017. Coverage was highest in the residential buildings sector, at 20%, due to codes and MEPS, which will be successively tightened (Box 6.7). MEPS for consumer appliances contribute to 5% coverage in the residential sector, which will grow as existing appliances are replaced with new stock that is compliant with existing standards. There was no policy coverage in the industry sector in 2017 as South Africa lacks MEPS for electric motors and mandatory efficiency improvement targets. South Africa has drafted its Post-2015 National Energy Efficiency Strategy (NEES) as part of its National Development Plan 2030 (Table 6.1).

Table 6.1. Post-2015 National Energy Efficiency Strategy of South Africa

Sector	Target	Planned policies
Industry and mining	15%	• Increased adoption of energy management systems by companies. • Introduction of MEPS for industrial electric motors as a package that includes tighter regulation of motor rewinding and differential import duties to reduce price differences between standard and premium efficiency motors. • Minimum design standards for industrial boilers.
Commercial and public	37%	• Successive tightening of building standards. • Mandatory display of energy performance certificates. • Green leases. • Municipal energy efficiency strategies.
Residential	33%	• Successive tightening of MEPs. • Endorsement labelling.
Agriculture	30%	• Awareness-raising campaigns. • Grants to support energy efficiency improvement.
Transport	39%	• Vehicle efficiency standards. • Corrective tax schemes to favour more efficient vehicles by taxation of low efficiency vehicles, as well as incentive schemes to trade in old inefficient vehicles. • Eco-driving as part of the curriculum of driving schools.
Economy-wide	29%	

Note: Targets refer to the reduction in energy use between 2015 and 2030.

Source: DOE South Africa (2016).

Implementing vehicle efficiency standards will be vital to unlock efficiency gains in the transport sector, which has the greatest opportunity for savings in the EWS. Even though average passenger car fuel efficiency in South Africa is 7% better than the global average, if South Africa had adopted fuel efficiency standards for passenger cars at the same stringency as that of Japan, fuel savings of nearly 20 000 BOE per day could have been achieved in 2017, equivalent to 6% of South Africa's transport energy consumption. Similarly, fuel efficiency for trucks is 4% higher than the global average but there are no mandatory fuel efficiency standards.

Implementing MEPS for electric motors, a policy planned for the industry and mining sectors, will be an important first step to unlocking greater efficiency gains. Complementing this with measures that extend to the wider motor-driven system and other industrial equipment, specifically the implementation of energy management systems, could enable further savings. Some South African companies have already experienced the benefits of energy management systems through involvement with the United Nations Industrial Development Organisation's Industrial Energy Efficiency Project (Hartzenberg, 2017). This and other initiatives, which are helping to foster an energy service company (ESCO) industry, have contributed to recent efficiency gains in the industry and service sectors.

Box 6.7 Advancing net zero energy buildings in South Africa

The Green Building Council (GBC) of South Africa has launched net zero building certification in 2017, as well as pilot projects in Cape Town and the provinces of Gauteng and Western Cape. This is another step towards South Africa's strong base of green buildings.

Certified green buildings already cover around 2.8 million square meters (GBCSA, 2016). In 2015, green projects achieved returns of 12.5% due to energy efficiency projects with payback periods from five to eight years (IFC, 2017). The Green Star building certification was launched by GBC in 2009. Certifications grew 2 000% in the first three years and 471% in the second three years, as perceptual, technical and financial barriers fell rapidly and market acceptance rose (WGBC, 2017).

A commitment from South Africa's Industrial Development Corporation (IDC) of USD 1.2 billion for green industries, and a EUR 120 million (USD 140 million) credit facility for renewable energy and energy efficiency projects, further expands the possibilities for net zero energy buildings.

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GLOSSARY

Regional and country groupings

ASEAN

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

Asia and Pacific

Australia, Bangladesh, Brunei, Cambodia, India, Indonesia, Japan, Korea, Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Viet Nam.

China

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

Latin America

Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela and other Latin American and Caribbean countries (Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), French Guyana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, St. Kitts and Nevis, Saint Lucia, Saint-Pierre et Miquelon, St. Vincent and the Grenadines, Suriname, and Turks and Caicos Islands).

OECD

Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel,[66] 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.

[66] 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.

List of acronyms, abbreviations and units of measure

Acronyms and abbreviations

AC	air conditioning
ACEEE	American Council for an Energy-Efficient Economy
AUD	Australian dollars
AUS	Australia
BAIC	Beijing Automotive Industry Holding
BAT	best available technology
BEE	Bureau of Energy Efficiency, India
BEEP	Energy Efficiency Project
BEMS	building energy management system
BEV	battery-electric vehicle
BIM	building information modelling
BRA	Brazil
CAAGR	compound annual average growth rate
CAFE	corporate average fuel economy
CAN	Canada
CCUS	carbon capture, utilisation and storage
CEFC	Clean Energy Finance Corporation (Australia)
CHN	People's Republic of China
CONPET	National Programme for Energy-Efficient Use of Petroleum and Natural Gas Derivatives (Brazil)
CONUEE	National Commission for the Efficient Use of Energy (Mexico)
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CPS	Current Policies Scenario
DSM	demand-side management
ECBC	Energy Conservation Building Code
ECO	Energy Company Obligation
EED	Energy Efficiency Directive
EEO	energy efficiency obligation
EESL	Energy Efficiency Services Limited

EFSI	European Fund for Strategic Investments
EER	energy efficiency ratio
EPA	Environmental Protection Agency
EPBD	Energy Performance of Buildings Directive
EPC	energy performance contract
EPPI	Efficiency Policy Progress Index
EPR	Extended Producer Responsibility
ESCO	energy service company
ESI	energy savings insurance
ETS	emissions trading system
EU	European Union
EUR	euros (defined as Europe in Figure 3.11)
EV	electric vehicle
EWS	Efficient World Scenario
GAAP	Generally Accepted Accounting Principles
GAINS	Greenhouse Gas – Air Pollution Interactions and Synergies
GBC	Green Building Council
GBP	British pounds
GHG	greenhouse gas
GDP	gross domestic product
GIZ	German Agency for International Co-operation
GVA	gross value added
HDV	heavy-duty vehicle
HEV	hybrid-electric vehicle
HVAC	heating, ventilation and air conditioning
ICAO	International Civil Aviation Organization
ICE	internal combustion engine
ICT	information and communication technology
IDC	Industrial Development Corporation
IDN	Indonesia
IEA	International Energy Agency
IIASA	International Institute of Applied Systems Analysis

ISEER	Indian Seasonal Energy Efficiency Ratio
IMO	International Maritime Organization
IND	India
INR	Indian rupees
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardization
JPN	Japan
KOR	Korea
LaaS	Lighting-as-a-Service
LED	light-emitting diode
LPG	liquefied petroleum gas
LTSHE	Lampu Tenaga Surya Hemat Energi
MBS	mortgage-backed securities
MEPS	minimum energy performance standards
MEX	Mexico
MY	model year
NEDC	New European Drive Cycle
NEES	National Energy Efficiency Strategy
NEV	New Energy Vehicle
NO_x	nitrogen oxides
NPS	New Policies Scenario
OECD	Organisation for Economic Co-operation and Development
PACE	Property Assessed Clean Energy
PAT	Perform, Achieve and Trade
PEE	Energy Efficiency Obligation Programme for Electricity Distributors
PEV	plug-in electric vehicle
PHEV	plug-in hybrid electric vehicle
PROCEL	National Energy Conservation Programme
PV	photovoltaic
ROSHANEE	Roadmap of Sustainable and Holistic Approach to National Energy Efficiency (India)
RPK	revenue passenger kilometres
SAU	Kingdom of Saudi Arabia

SDG	Sustainable Development Goal
SEER	seasonal energy efficiency ratio
SEP	Superior Energy Performance
SIN	Singapore
SME	small and medium-sized enterprises
SO_2	sulphur dioxide
SPV	special purpose vehicle
SUV	sport utility vehicle
TCP	Technology Collaboration Programme
TFC	total final consumption
THA	Thailand
TPES	total primary energy supply
UNIDO	United Nations Industrial Development Organization
UJALA	Unnati Jyoti by Affordable LEDs for All (India)
UK	United Kingdom
US	United States
USA	United States of America
USD	United States dollars
VSD	variable speed drive
WEM	World Energy Model
WEO	World Energy Outlook
WLTP	Worldwide Harmonised Light Vehicle Test Procedure
ZAF	Republic of South Africa

Units of measure

°C	degree Celsius
BOE	barrels of oil equivalent
EJ	exajoule (10^{18} joules)
GW	gigawatt
GWh	gigawatt hour
Gt CO_2-eq	gigatonnes of carbon dioxide equivalent (billion tonnes of carbon dioxide equivalent)
Gtoe	gigatonnes of oil equivalent (billion tonnes of oil equivalent)

km	kilometre
ktoe	kilotonnes of oil equivalent (thousand tonnes of oil equivalent)
kW	kilowatt
kWh	kilowatt hour
mb/d	million barrels per day
Mt CO_2-eq	million tonnes of carbon dioxide equivalent
Mtoe	megatonnes of oil equivalent (million tonnes of oil equivalent)
MW	megawatt (10^6 watt)
PJ	petajoule (10^{15} joules)
pkm	passenger-kilometre
TJ	terajoule (10^{12} joules)
tkm	tonne-kilometre
toe	tonne of oil equivalent
TWh	terawatt hour (10^{12} watt hours)
W	watt

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- What are current levels of investment in energy efficiency and by how much does investment need to increase in future to realise the opportunity of the Efficient World Scenario?
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