CHAPTER 4

ENERGY EFFICIENCY

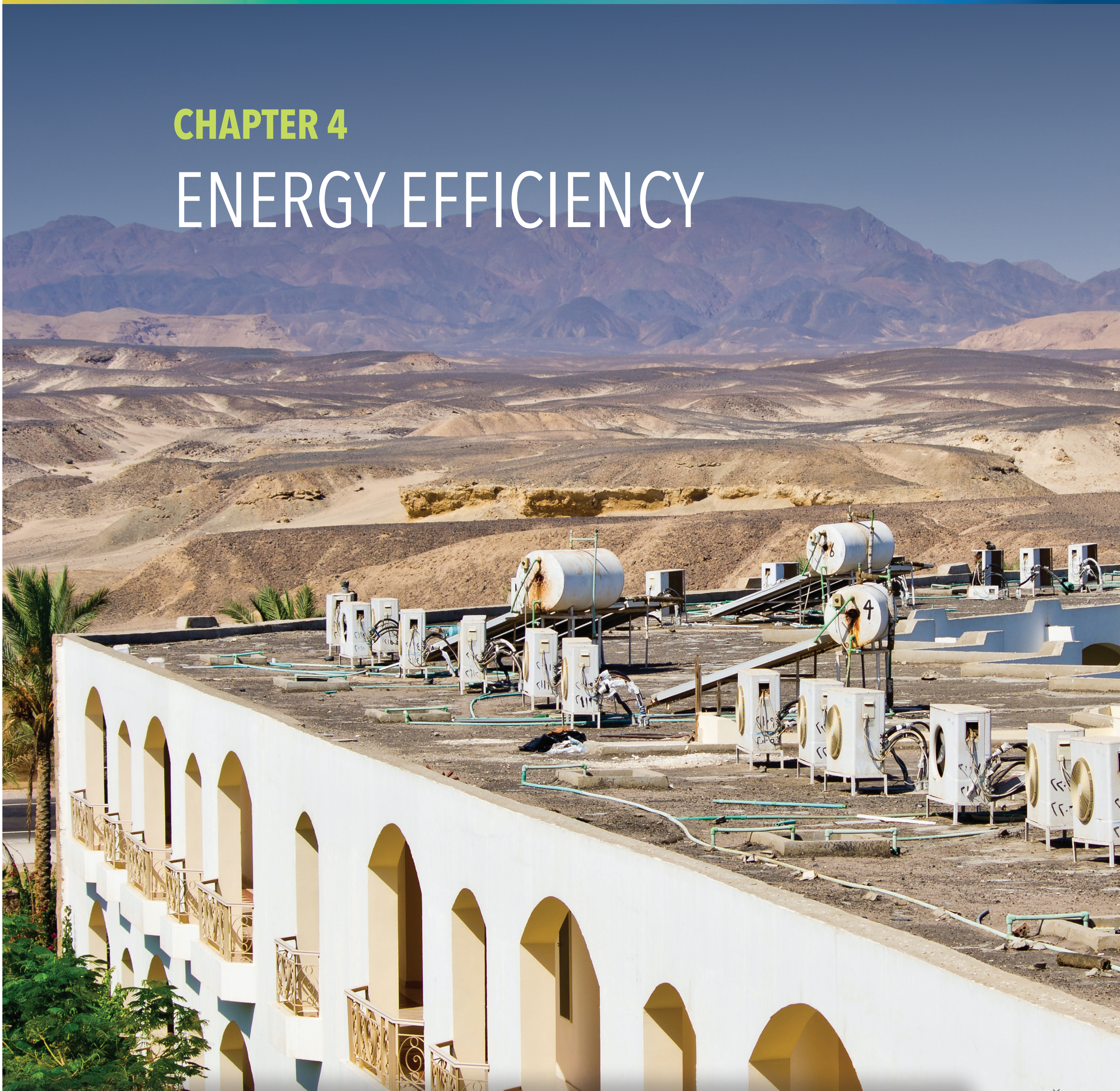


Photo: Shutterstock

MAIN MESSAGES

- **Global trend:** Rates of improvement in global primary energy intensity—defined as the percentage drop in global total primary energy supply per unit of gross domestic product (GDP)—were more sustained in 2010-2016 than they had been in 1990-2010.[31] Global primary energy intensity in 2016 was 5.1 megajoules per U.S. dollar (MJ/USD) (2011 purchasing power parity [PPP]), a 2.5% improvement from 2015. This continued a trend of sustained improvement, though the 2016 rate was a drop from the 2.9% observed in 2015.

- **2030 target:** Improvements in energy intensity are not in line with Sustainable Development Goal (SDG) target 7.3. The average annual rate of improvement[32] in global primary energy intensity between 2010 and 2016 was 2.3%. This is better than the rate of 1.3% between 1990 and 2010, but still behind the SDG target 7.3 of 2.6%, which represents a doubling of the historic trend. Annual improvements will now need to average over 2.7% until 2030 to meet SDG target 7.3. This additional progress is unchanged since 2015, although estimates for trends in 2017 and 2018 show further deterioration in the rate of global primary energy intensity improvement.

- **Regional highlights:** Energy intensity improvements were largest in Asia. Between 2010 and 2016, primary energy intensity in Eastern and Southeastern Asia improved by an annual average rate of 3.4%. Similarly, in Central and Southern Asia, the average annual improvement of 2.5% between 2010 and 2016 was above the global average and greater than historic trends. A key factor contributing to this is an increase in energy efficiency driven by concerted policy efforts and economic growth. Rates of improvement are just below the global average in Oceania, and Northern America and Europe, with improvement rates lagging in Latin America and Africa, where absolute levels of energy intensity are less than the global average, reflecting differences in economic structure, energy supply, and access.

- **Top 20 countries:** The annual improvement of primary energy intensity accelerated in 16 of the 20 countries with the largest total primary energy supply in the world. In 9 of these countries, improvement rates exceeded the global average, with China seeing the greatest improvement with an average annual rate of 4.7% between 2010 and 2016. This is linked to greater efforts to improve energy efficiency, such as the introduction of extensive codes, standards, and obligations that have placed more stringent performance requirements on energy-using appliances, vehicles, and companies.

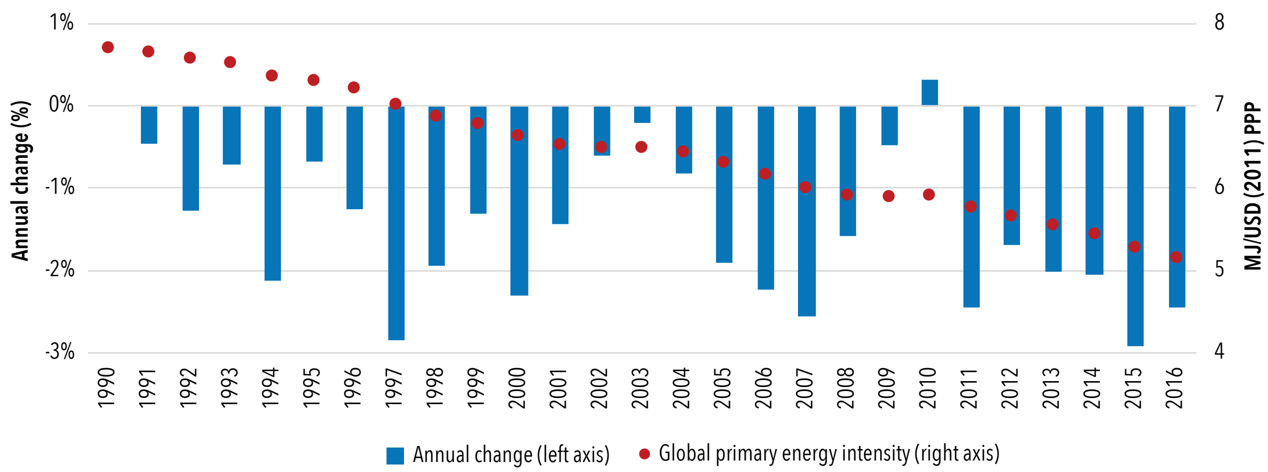
- **End-use trends:** Energy intensity across the major end-use sectors continued to improve, although rates were variable. Between 2010 and 2016 energy intensity in the industry sector improved by an average annual rate of 2.7%, aided by technology improvements and policies supporting energy efficiency in large economies, particularly China. This rate was the highest of any of the major subsectors analyzed. While the introduction of passenger car fuel efficiency standards has driven improvements in passenger transport energy intensity, rates were slowest in freight transport, where fuel efficiency standards have only recently been introduced in some countries.

- **Electricity supply trends:** The average efficiency of electricity generation from fossil fuels is nearly 40% due to more efficient gas-fired generation and the construction of highly efficient coal-fired generation in China and India. Electricity transmission and distribution losses are also falling in many major producing countries, reflecting the increasing rates of electrification and modernization of supply infrastructure.

ARE WE ON TRACK?

Global primary energy intensity—total primary energy supply per unit of GDP (in USD 2011 PPP)—improved by 2.5% in 2016 to 5.13 MJ/USD (2011 PPP) (figure 4.1).

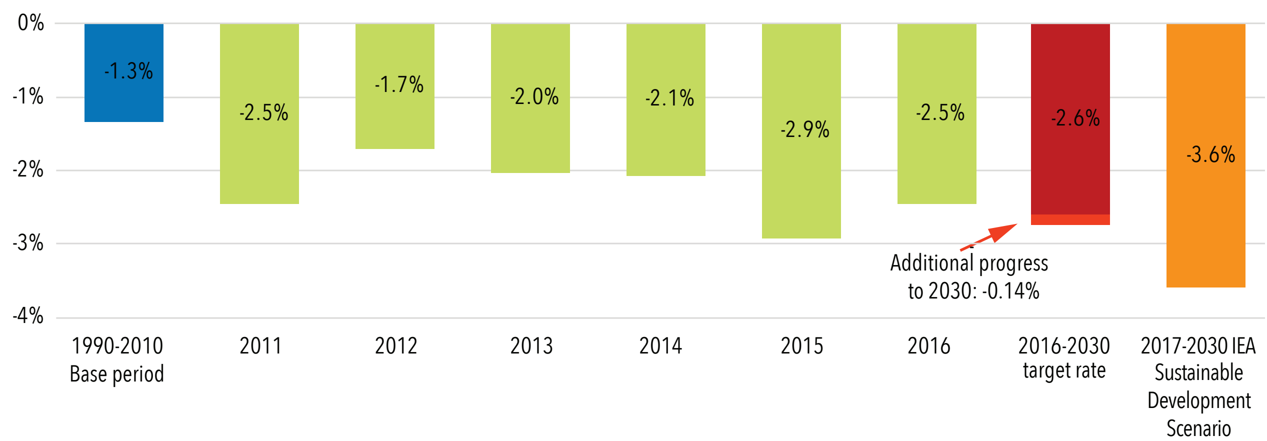
FIGURE 4.1 • GLOBAL PRIMARY ENERGY INTENSITY AND ITS ANNUAL CHANGE, 1990-2016



Source: IEA, UNSD, and WDI.

The 2.5% rate of improvement was less than in 2015, but consistent with the step up in rates of improvement seen since 2010 (figure 4.2). The average rate of progress since 2010 is still lagging behind what is needed to meet the SDG target 7.3 rate, which is now 2.74%.

FIGURE 4.2 • GROWTH RATE OF PRIMARY ENERGY INTENSITY BY PERIOD, AND TARGET RATE FOR 2016-2030



Source: IEA, UNSD, and WDI.

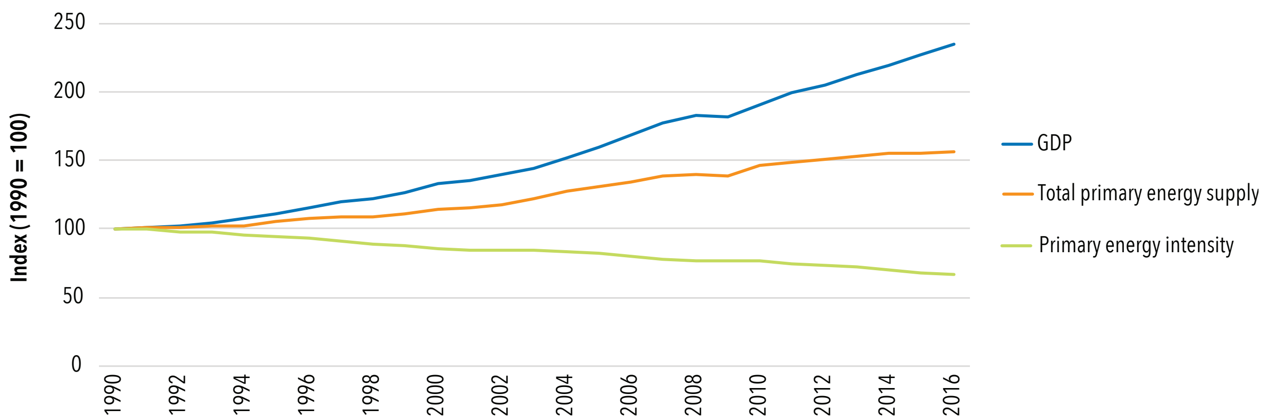
LOOKING BEYOND THE MAIN INDICATORS

COMPONENT TRENDS

The impact of improvements in primary energy intensity, the global proxy for improvements in energy efficiency, is revealed by trends in its underlying components (figure 4.3). Since 1990, global GDP has more than doubled. However, total primary energy supply at a global level increased by just over 50%, with growth slowing markedly in 2015 and 2016, after rising steadily after 2010.

The difference in growth rates for global GDP and total primary energy supply is reflected by consistent improvements in global primary energy intensity, which fell by over 30% between 1990 and 2016. Since 2010, global primary energy intensity fell by 10%, a slightly higher rate than that observed between 2000 and 2010. These improvements are impacting global emissions (box 4.1), but recent estimates show that they are not being sustained at the same rate (box 4.2).

FIGURE 4.3 • TRENDS IN UNDERLYING COMPONENTS OF GLOBAL PRIMARY ENERGY INTENSITY, 1990-2016



Source: IEA, UNSD, and WDI.

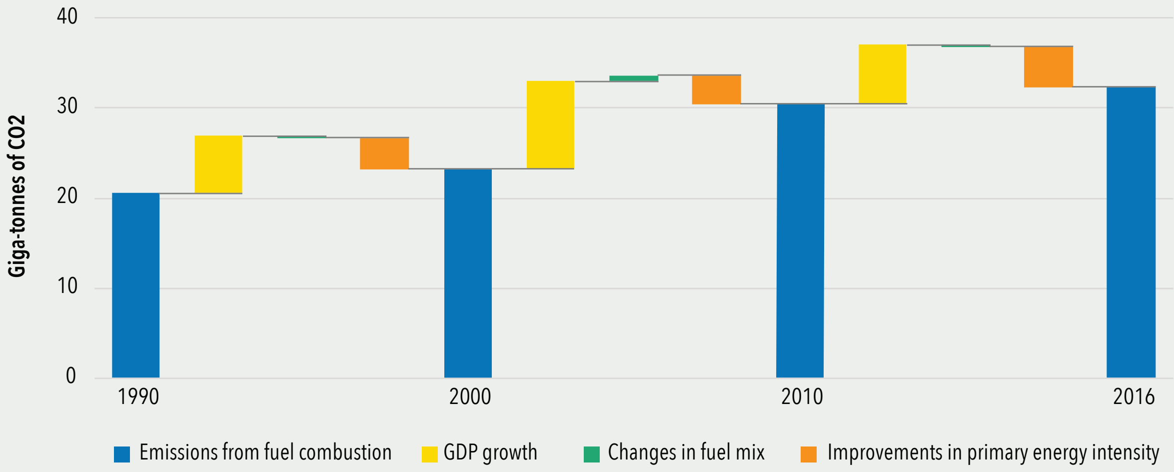
BOX 4.1 • WHAT IS THE IMPACT OF IMPROVEMENTS IN PRIMARY ENERGY INTENSITY ON EMISSIONS?

Improvements in global primary energy intensity are critical to limiting energy-related emissions resulting from fuel combustion. Decomposition analysis undertaken by the International Energy Agency highlights the effects on energy-related emissions of several key factors: gross domestic product (GDP) growth, changes in the global primary fuel mix, and improvements in primary energy intensity (figure B4.1.1).

GDP growth places upward pressure on emissions and since 1990 its total impact was equivalent to over 20 gigatonnes of additional carbon dioxide (CO2) emissions in 2016. Changes in the global primary fuel mix, defined as CO2 emissions per unit of total primary energy supply, can have a varying impact. Shifts toward the use of more emissions-intensive fuels, such as coal and oil, put upward pressure on emissions, whereas movement toward less emissions-intensive fuels, particularly gas and renewables, have the opposite effect. Since 1990 the impact of changes in the global fuel mix has been minimal, although between 2010 and 2016, fuel mix changes avoided nearly 300 million tonnes of CO2 emissions.

Changes in primary energy intensity have done the most to offset the impact of GDP growth on energy-related CO2 emissions. Between 1990 and 2016, improvements in global primary energy intensity offset nearly half of the impact from GDP growth on emissions, resulting in the avoidance of nearly 11 billion tonnes of additional annual CO2 emissions.

FIGURE B4.1.1 • DECOMPOSITION OF GLOBAL ENERGY-RELATED CO2 EMISSIONS, 1990-2016

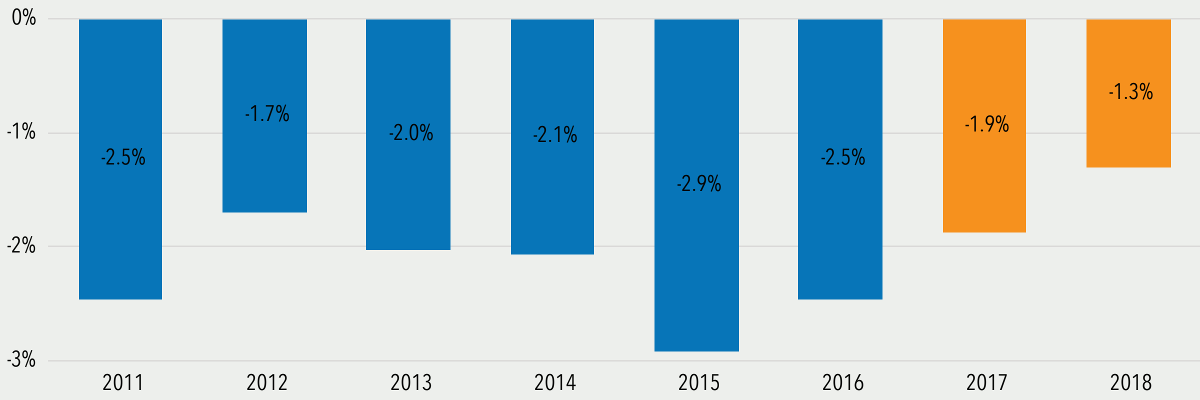


Source: IEA, UNSD, and WDI.

BOX 4.2 • ESTIMATES FOR 2017 AND 2018 INDICATE SLOWING RATES OF PRIMARY ENERGY INTENSITY IMPROVEMENT

Estimates from the International Energy Agency in its Global Energy and CO2 status report show that the slowing rate of global primary energy intensity improvement observed in 2016 continued into 2017 and 2018 (figure B4.2.1). Global primary energy intensity is estimated to have improved by 1.9% in 2017 and shrunk again in 2018 to just 1.3%.

FIGURE B4.2.1 • GROWTH RATE OF GLOBAL PRIMARY ENERGY INTENSITY, 2011-2018



Source: IEA 2019.

While it is estimated that efficiency continued to improve in 2017 and 2018, its impact has been overwhelmed by factors placing pressure on energy demand. These factors, linked to strong economic growth and low energy prices, have combined with a static energy efficiency policy landscape to shrink primary energy intensity improvements. Progress in implementing new energy efficiency policies or strengthening existing policies has been slow, limiting the ability of energy efficiency gains to offset the impact of economic growth on energy demand. Slowing rates of improvement mean that additional efforts will be required, on top of those already needed, to reach Sustainable Development Goal target 7.3.

Source: Further information available at www.iea.org/geco.

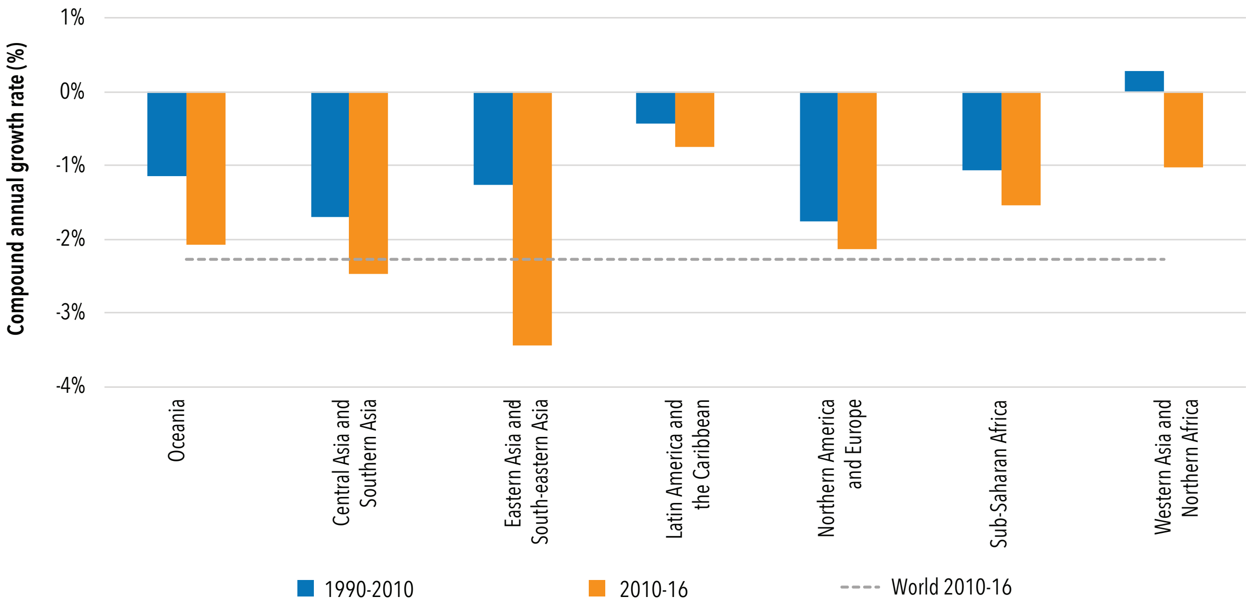
REGIONAL TRENDS

Primary energy intensity improvements have been variable across major regions (figure 4.4). Between 1990 and 2010 improvements were most apparent in Northern America and Europe, as well as Central and Southern Asia. This was linked to economic growth driven by less-energy-intensive service sectors, which benefited from advances in information and communication technologies.

Between 2010 and 2016, primary energy intensity improved across all major regions. Unlike in 1990-2010, improvements were most apparent in East and Southeastern Asia, exceeding the global average. The key factor behind this trend was China's improved primary energy intensity, which drove not only regional but also global trends. Progress was also apparent in Central and Southern Asia, which exceeded the global average rate of improvement. This was linked to strong improvements in India, which has become a growing factor in global trends.

Rates of improvement between 2010 and 2016 in Northern America and Europe, and Oceania, were just below the global average. The rates of improvement in other regions lagged further behind, although Latin America and the Caribbean, Western Asia, and Northern Africa had absolute primary energy intensities below the global average in 2016, reflecting differences in economic structure, energy supply, and access.

FIGURE 4.4 • GROWTH RATE OF PRIMARY ENERGY INTENSITY AT A REGIONAL LEVEL, 1990-2016



Source: IEA, UNSD, and WDI.

MAJOR COUNTRY TRENDS

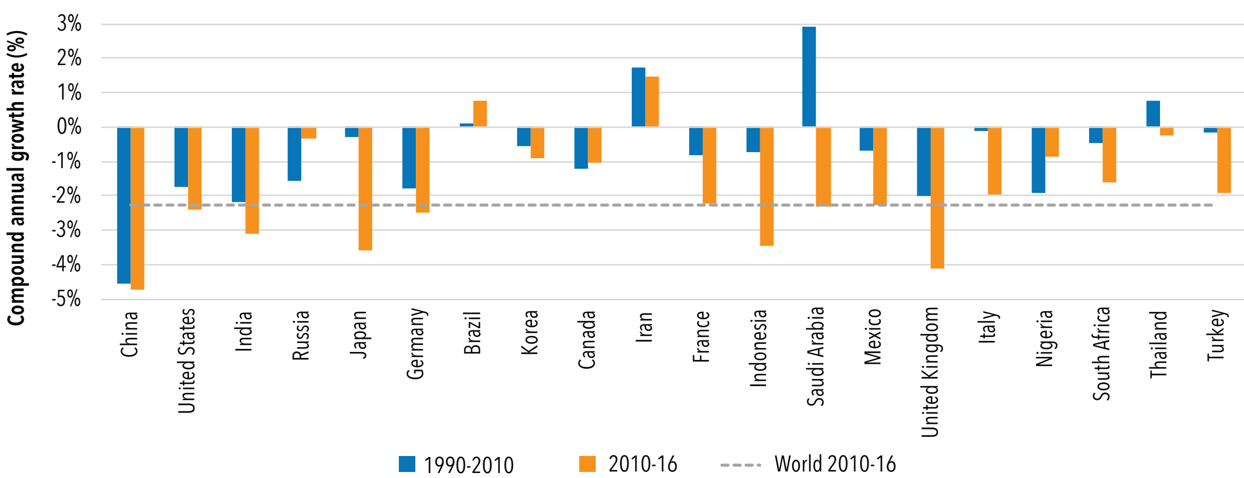
Rates of improvement in primary energy intensity in the 20 countries with the largest total primary energy supply will be central to realizing SDG target 7.3. Sixteen of these countries stepped up their rate of improvement between 2010 and 2016, with nine countries performing better than the global average (figure 4.5).

China has the largest total primary energy supply in the world and the fastest rate of primary energy intensity improvement in the countries analyzed. This is in part linked to China's modernizing economy and changing structure, where more activity is being undertaken in the less-energy-intensive manufacturing and service sectors. The other important driver has been the Chinese government's efforts to implement policies to drive improvements in energy efficiency, including codes and standards for appliances, buildings, and vehicles, and mandatory energy efficiency improvement targets for China's most energy-intensive companies.

India and Indonesia are two other major emerging economies that showed strong rates of improvement in primary energy intensity between 2010 and 2016. In both countries, economic growth, driven by less-energy-intensive manufacturing and service sectors, combined with increased energy efficiency to produce this result. Similar trends are also observed in Japan and the United Kingdom, which have long implemented energy efficiency policies. Brazil and Iran are the two major energy-consuming countries where primary energy intensity is worsening. This is linked to stagnant economic conditions in both countries, which have sizeable energy-intensive industry sectors.

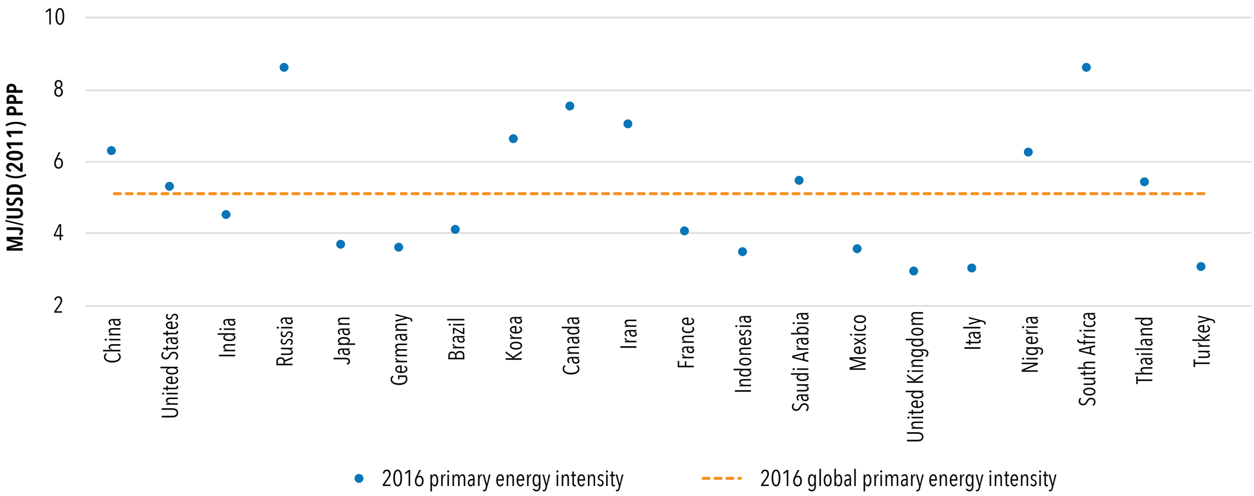
While primary energy intensity is improving in the majority of the world's largest energy-using countries, half of these countries still have absolute levels of energy intensity that are higher than the global average (figure 4.6). Higher primary energy intensity is often due to factors other than levels of energy efficiency. These include the presence of energy-intensive sectors such as iron and steel, cement, aluminum, and pulp and paper manufacturing; climatic factors that increase demand for space heating or cooling; and the fuel mix associated with electricity generation, particularly the presence of fuels that have higher thermal losses.

FIGURE 4.5 • GROWTH RATE OF PRIMARY ENERGY INTENSITY IN THE 20 COUNTRIES WITH THE LARGEST TOTAL PRIMARY ENERGY SUPPLY, 1990-2016



Source: IEA, UNSD, and WDI.
Note: Countries along x-axis ordered by total primary energy supply.

FIGURE 4.6 • PRIMARY ENERGY INTENSITY IN THE 20 COUNTRIES WITH THE LARGEST TOTAL PRIMARY ENERGY SUPPLY, 2016



Source: IEA, UNSD, and WDI.
Note: Countries along x-axis ordered by total primary energy supply.

END-USE TRENDS

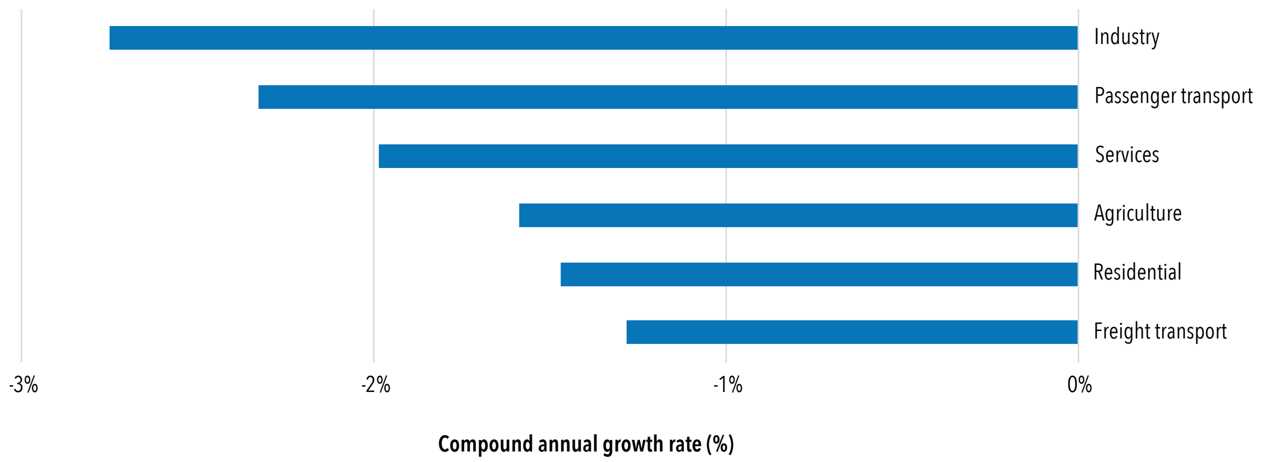
At an end-use level, the rate of improvement in energy intensity since 2010 is greatest in the industry, passenger transport, and service sectors (figure 4.7). Continuing productivity gains within the global industry sector, due to increasing output driven by technological advances, is reflected in an average annual improvement rate of 2.7%. Advances in information and communication technologies, which also drive productivity gains in the global services sector, have combined with improvements in the efficiency of commercial buildings to produce a 2% rate of improvement.

Rates of improvement in the energy intensity of the residential and agricultural sectors are both over 1%. Greater rates of improvement in the residential sector will be important to realizing SDG target 7.3, particularly as living standards and demand for energy services rise, emphasizing the importance of residential building codes and appliance standards.

In passenger transport, the average annual rate of improvement in energy intensity was over 2%. An important factor behind this was passenger car fuel efficiency standards in major markets; these standards helped limit increases in energy use between 2010 and 2016, despite a 30% increase in activity (as measured in passenger-kilometers). Cars are the largest component of the passenger transport sector and while there has been improvement, it is still short of what is required to reach SDG target 7.3 and other global targets (box 4.4).

The limited application of fuel economy standards for trucks is reflected by the low rate of energy intensity improvement in the freight transport sector. Fuel economy standards for trucks have been implemented in five countries (Japan, the United States, Canada, China, and India), and their implementation is planned throughout the European Union. This change to the policy landscape will contribute to greater improvement in the energy intensity of freight transport in the future.

FIGURE 4.7 • GROWTH RATE OF ENERGY INTENSITY BY SECTOR, 2010-2016



Source: IEA, UNSD, and WDI.
Note: Energy intensity of freight transport is defined as final energy use per tonne-kilometer; for passenger transport it is final energy use per passenger-kilometer; for residential it is final energy use per square meter of floor area; and in the services, industry, and agriculture sectors, energy intensity is defined as final energy use per unit of gross value added (in USD 2011 PPP).

BOX 4.3 • TRACKING PASSENGER CAR FUEL EFFICIENCY THROUGH THE GLOBAL FUEL ECONOMY INITIATIVE

The Global Fuel Economy Initiative (GFEI) is a partnership between the International Energy Agency, UN Environment, International Transport Forum, International Council on Clean Transportation, and University of California–Davis, and is coordinated by the FIA Foundation. One of the stated targets of the GFEI is a 50% reduction in the fuel economy (in liters per 100 kilometers [km]) of newly sold passenger cars globally by 2030, compared with a 2005 baseline.

In the recent benchmarking report for the GFEI, the global average fuel economy of passenger cars in 2017 was estimated at 7.2 liters of gasoline equivalent (Lge) per 100 km. The annual rate of improvement between 2015 and 2017 was 1.4%. This was a slowdown compared with the 1.7% observed between 2005 and 2015, and only a third of the 3.7% now required to meet the 2030 GFEI target. Rates of improvement vary widely across countries and regions, depending on fuel prices and development status (table B4.3.1).

There are a number of factors contributing to the slowing rate of improvement in fuel economy. Growth in the market for large, relatively inefficient vehicles, such as sport utility vehicles, grew 11 percentage points between 2014 and 2017, slowing the rate of improvement in fuel economy. Another factor is the rapid decline of diesel car sales, most notably in Europe. While of benefit to air quality, this has impacted improvements in fuel economy, as diesel vehicles are generally more efficient than equivalent gasoline vehicles. Most diesel cars have been replaced by gasoline vehicles, though the market share of electrified vehicles is rapidly growing in several markets.

Fuel economy policies also affect improvement rates. In countries with fuel economy standards or purchase incentives, the rate of improvement was 60% faster than countries without such policies. While historic policy settings did not lead to improvement rates required for the GFEI target, most of the existing standards imply improvement rates that would allow countries to meet the 2030 GFEI target, although only the European Union has set an explicit fuel efficiency target for 2030. Fuel economy policies and incentives also have a significant impact on the adoption of electrified vehicles.

A step-up in policy action will be central to realizing the GFEI target. Critical steps include an increase in the coverage and strength of vehicle fuel economy standards and the tightening of rules for fuel economy testing and on-road compliance. Long-term commitments and targets supported by incentives will also be important to drive greater levels of investment.

TABLE B4.3.1 • PROGRESS IN AVERAGE FUEL ECONOMY IMPROVEMENT IN DIFFERENT REGIONS

<table>
<tr><th colspan="3"></th><th>2005</th><th>2010</th><th>2015</th><th>2017</th><th>2030</th></tr>
<tr><td rowspan="3">Advanced
(Gasoline price ≥ USD 1/L)</td><td colspan="2">average fuel economy (Lge/100km)</td><td>7.4</td><td>6.5</td><td>5.8</td><td>5.8</td><td rowspan="12">4.4</td></tr>
<tr><td colspan="2" rowspan="2">annual improvement rate (% per year)</td><td></td><td>-2.4%</td><td>-2.5%</td><td>-0.1%</td></tr>
<tr><td colspan="4">-2.0%</td></tr>
<tr><td rowspan="3">Advanced
(Gasoline price < USD 1/L)</td><td colspan="2">average fuel economy (Lge/100km)</td><td>11.0</td><td>9.5</td><td>8.6</td><td>8.6</td></tr>
<tr><td colspan="2" rowspan="2">annual improvement rate (% per year)</td><td></td><td>-2.9%</td><td>-1.9%</td><td>-0.4%</td></tr>
<tr><td colspan="4">-2.0%</td></tr>
<tr><td rowspan="3">Emerging</td><td colspan="2">average fuel economy (Lge/100km)</td><td>8.6</td><td>8.5</td><td>7.8</td><td>7.5</td></tr>
<tr><td colspan="2" rowspan="2">annual improvement rate (% per year)</td><td></td><td>-0.2%</td><td>-1.6%</td><td>-2.3%</td></tr>
<tr><td colspan="4">-1.2%</td></tr>
<tr><td rowspan="3">Global average</td><td colspan="2">average fuel economy (Lge/100km)</td><td>8.8</td><td>8.0</td><td>7.4</td><td>7.2</td></tr>
<tr><td colspan="2" rowspan="2">annual improvement rate (% per year)</td><td></td><td>-2.0%</td><td>-1.5%</td><td>-1.4%</td></tr>
<tr><td colspan="4">-1.7%</td></tr>
<tr><td rowspan="2">GFEI target</td><td rowspan="2">Required annual improvement rate (% per year)</td><td>2005 base year</td><td colspan="5">-2.8%</td></tr>
<tr><td>2017 base year</td><td colspan="3"></td><td colspan="2">-3.7%</td></tr>
</table>

Source: IEA elaboration and enhancement for broader coverage of IHS Markit database (IHS Markit 2018).
Note: Further information available at https://www.globalfueleconomy.org/.

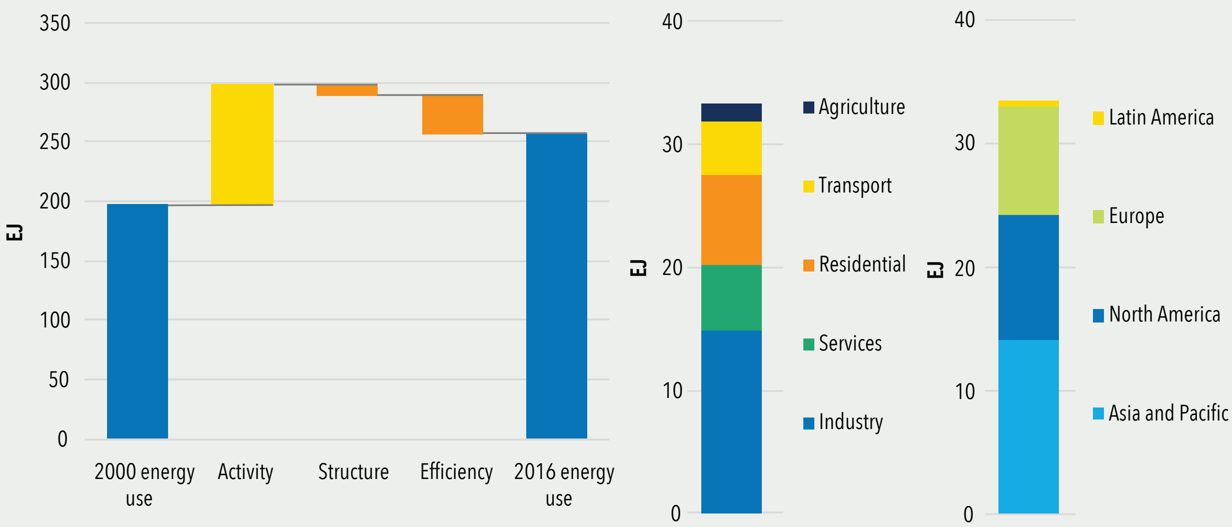
BOX 4.4 • DETERMINING SECTORAL AND REGIONAL CONTRIBUTIONS TO ENERGY SAVINGS

Improvements in energy intensity are not due solely to energy efficiency. Activity levels across energy-using sectors and structural changes also have an impact. Decomposition analysis allows the influence of activity levels, structural change, and energy efficiency improvements in final energy use to be determined. In the process, it is possible to analyze sectoral and regional contributions to efficiency gains (figure B4.4.1).

The factors that influence levels of activity include gross value added in the industry and service sectors, passenger- and tonne-kilometers in transport, and changes in population and climate in the residential sector. These factors all drive demand for energy services and put upward pressure on final energy use. Structural effects can have varying impacts on energy use. A shift of economic activity away from energy-intensive sectors, such as iron and steel and cement manufacturing, toward less-energy-intensive manufacturing or service sectors puts downward pressure on energy use. In the residential sector, increasing levels of appliance ownership and floor area put upward pressure on energy use. Similarly, in transport, shifts to less efficient transport modes and falling vehicle occupancy rates place pressure on energy demand. Separating structural effects from changes in activity allows for the impact of energy efficiency on final energy use to be analyzed.

Decomposition analysis shows that improvements in efficiency between 2000 and 2016 resulted in the avoidance of over 33 exajoules (EJ) of additional final energy use for the economies analyzed, nearly equivalent to the final energy use of India and Japan combined. These gains were complemented by structural effects due to shifts in economic activity toward less-energy-intensive sectors, which avoided an additional 10 EJ of energy use. However, these factors were more than offset by increasing levels of activity across all energy-using sectors. Activity effects are most apparent in the industry and service sectors, where increases in gross value added continued to put pressure on energy use.

FIGURE B4.4.1 • DECOMPOSITION OF FINAL ENERGY USE IN MAJOR ECONOMIES, 2000-2016 (LEFT) AND SECTORAL AND REGIONAL CONTRIBUTIONS TO EFFICIENCY GAINS (RIGHT)



Source: IEA 2018.
Note: Countries covered are IEA members plus China, India, Brazil, Indonesia, Russia, South Africa, and Argentina, covering around 75% of global energy use.

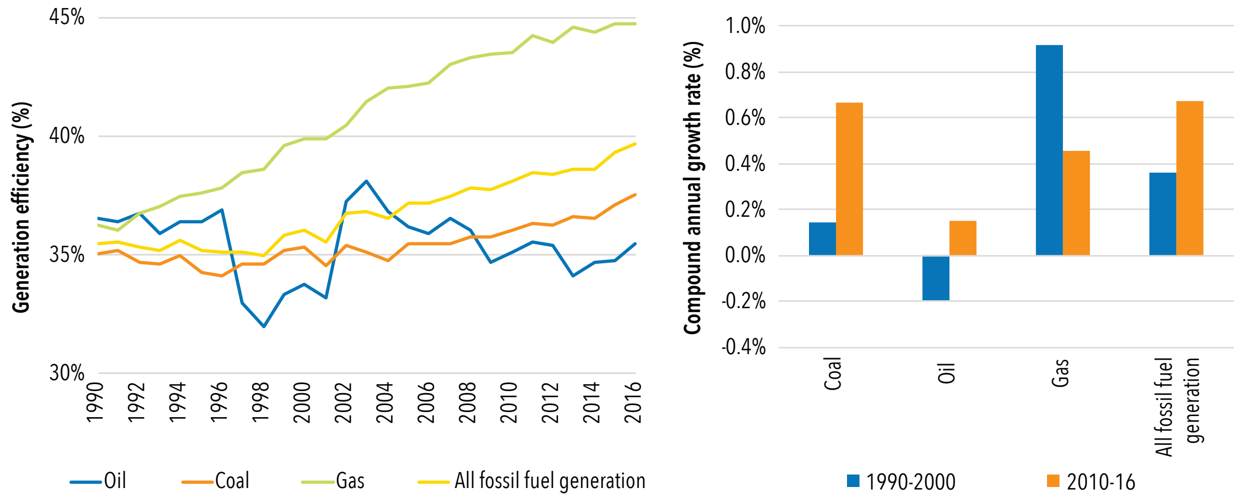
The industry sector made the largest contribution to efficiency gains in the major economies analyzed, followed by the residential, service, and transport sectors. Savings were driven by China, where government policy and new production capacity improved energy efficiency. The influence of China is also apparent in the regional contribution to efficiency gains. The Asia and Pacific region was responsible for over 40% of the energy savings from efficiency improvements in the major economies analyzed. Just over 10 EJ of energy savings were obtained from efficiency gains in Northern America, with the influence of the United States, which has an extended history of policy driven action on energy efficiency, the major factor behind this result.

TRENDS IN THE EFFICIENCY OF ELECTRICITY SUPPLY

The rate of improvement in global primary energy intensity is influenced by changes in the efficiency of electricity supply. These include improvements in the efficiency of fossil fuel generation and reductions in transmission and distribution losses. The efficiency of fossil fuel electricity generation increased at a steady rate in 2000-2016, reaching nearly 40% (figure 4.8), after showing flat rates of improvement in 1990-2010. Two factors behind this trend were a growing share of more efficient gas-fired generation and the improved efficiency of coal-fired generation.

While the rate of improvement in the efficiency of gas-fired generation slowed, total efficiency levels climbed to nearly 45%, reflecting the presence of more efficient technologies such as combined-cycle gas turbines. The share of gas in total fossil fuel electricity generation rose to over 35%. Construction of new, more efficient, supercritical and ultra-supercritical coal-fired power generation in economies with growing electricity demand, specifically China and India, were reflected in the rising efficiency of overall coal-fired generation, which improved at an average annual rate of nearly 0.7% between 2010 and 2016, the fastest rate observed.

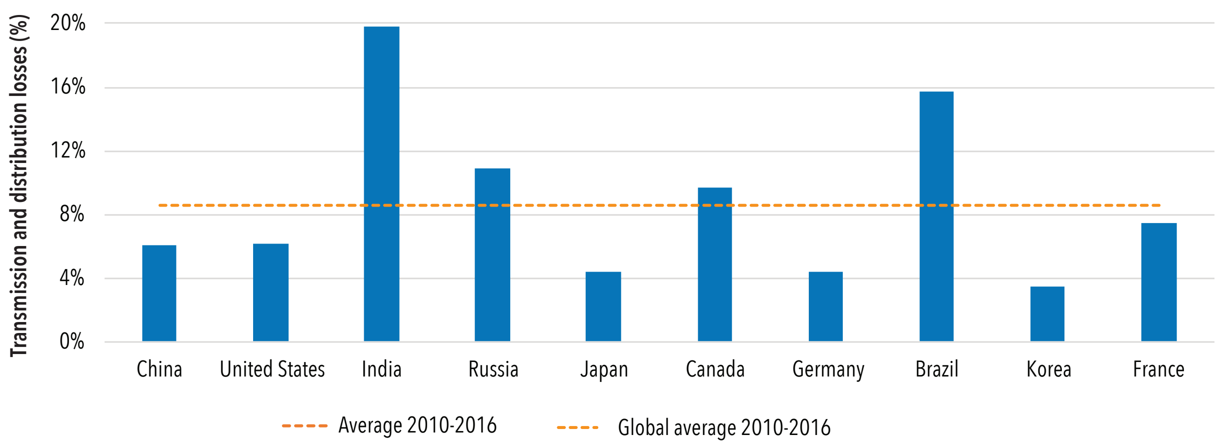
FIGURE 4.8 • TRENDS IN THE EFFICIENCY OF GLOBAL FOSSIL FUEL ELECTRICITY GENERATION (LEFT) AND RATE OF IMPROVEMENT (RIGHT), BY FUEL TYPE, 1990-2016



Source: IEA, UNSD, and WDI.

Increasing levels of energy access and electrification are resulting in the modernization of electricity networks in the world's largest electricity-producing countries. This in turn reduces transmission and distribution losses, which contribute to supply-side efficiency gains. These improvements saw losses in China fall to nearly 5% in 2016. However, in India, losses are still above the global average, reflecting the ongoing modernization of electricity networks (figure 4.9). In other countries with established electricity networks and full access, losses are typically below the global average.

FIGURE 4.9 • TRANSMISSION AND DISTRIBUTION LOSSES FOR THE WORLD'S 10 LARGEST ELECTRICITY PRODUCERS, 2016



Source: IEA, UNSD, and WDI.
Note: Countries along x-axis ordered by electricity production.

POLICY RECOMMENDATIONS AND CONCLUSIONS

The accelerated improvement of global primary energy intensity observed in 2010-2016 was linked to greater energy efficiency in large energy-using countries and regions. China, India, Japan, and Northern America and Europe all stepped up or maintained their policy ambitions regarding energy efficiency. The policy approaches adopted in these countries and regions provide examples to others regarding measures that can drive the efficiency gains needed to meet SDG target 7.3.

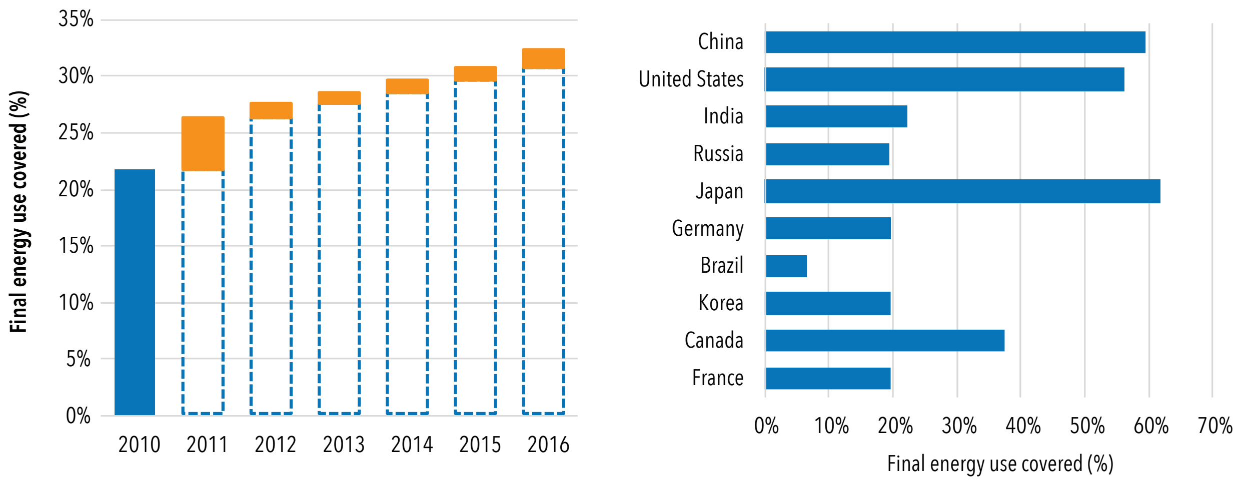
ENERGY EFFICIENCY POLICY

There are three broad types of energy efficiency policy that are used by governments to drive progress:

- *Regulation*—mandatory requirements to improve energy efficiency or to meet specified targets or standards, which include minimum energy performance standards for appliances and equipment, vehicle fuel efficiency standards, building codes, and mandatory energy efficiency improvement targets for industrial firms or sectors;
- *Incentives*—fiscal or financial incentives to energy consumers to improve efficiency; and
- *Information*—labels, websites, training, and capacity building regarding the performance of products or ways to improve energy efficiency.

The scope of energy efficiency regulations at a global and national level is reflected by the percentage of final energy use that is covered by mandatory efficiency codes and standards (figure 4.10). This metric reflects the energy use of appliances, equipment, and vehicles that were required to comply with minimum energy performance standards before being sold; the energy use of buildings that were constructed or renovated in accordance with a mandatory building energy code; and the energy use of industrial firms or sectors that are required by law to meet energy efficiency improvement targets.

FIGURE 4.10 • INCREMENTAL GROWTH IN ENERGY USE COVERED BY MANDATORY EFFICIENCY POLICIES GLOBALLY, 2010-2016 (LEFT), AND COVERAGE IN THE 10 COUNTRIES WITH THE HIGHEST TOTAL PRIMARY ENERGY SUPPLY (RIGHT)

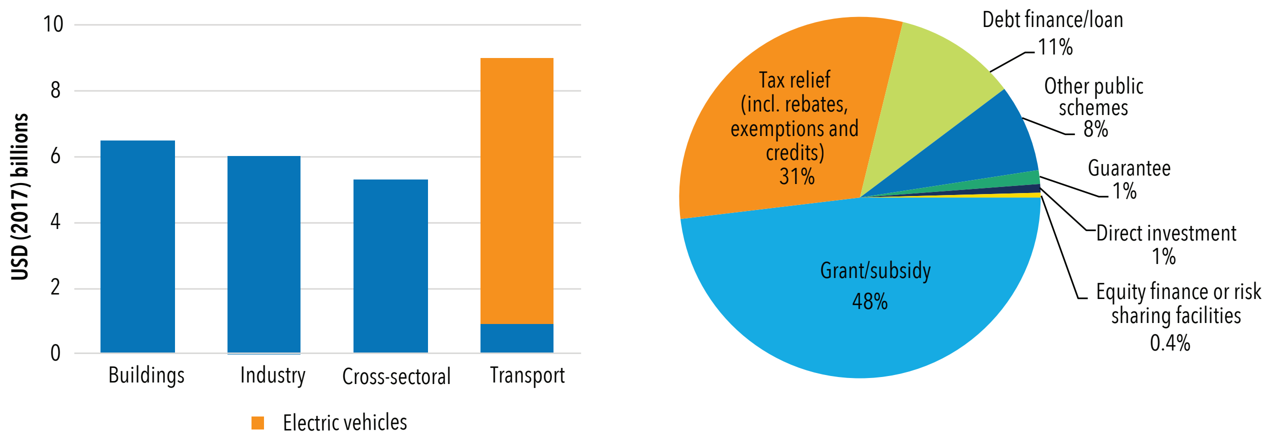


Source: IEA 2018.

In 2016, over 32% of global final energy use was covered by mandatory energy efficiency policies. Coverage rose consistently after a marked increase in 2011 following the implementation of new measures in China. This growth reflects the replacement of old energy-using equipment, appliances, and vehicles with new models. The influence of new policies on coverage growth was minimal after 2012, reflecting a slowdown in the implementation of new mandatory policies; practically all growth in 2016 was due to existing policies.

Fiscal and financial incentives to improve energy efficiency are policy tools being used by governments to complement direct regulation and encourage greater levels of efficiency. In 2017, incentives for energy efficiency in 16 of the world's major economies amounted to $27 billion (figure 4.11). These incentives included grants, subsidies, tax relief, loans, and rebates, with the transport sector being the largest single recipient, thanks to $8 billion in incentives for the adoption of electric vehicles.

FIGURE 4.11 • NATIONAL GOVERNMENT INCENTIVES FOR ENERGY EFFICIENCY BY SECTOR (LEFT) AND TYPE (RIGHT), 2017



Source: IEA 2018.
Note: Countries covered are Australia, Austria, Brazil, China, Estonia, Germany, India, Ireland, Italy, Mexico, Norway, Portugal, Spain, Switzerland, the United Kingdom, and the United States. For China, incentives data for 2016 are used as a proxy for 2017.

Grants, subsidies, and tax relief represent nearly 80% of the energy efficiency incentives in the countries analyzed. Grants and subsidies are used to effectively lower the capital cost of more energy efficient appliances or equipment, making their purchase more appealing to consumers. Fiscal incentives in the form of tax relief are intended to appeal to consumers, particularly businesses, by lowering their tax bills. Although other forms of incentives based on debt or loan finance are less prominent, there are a growing number of governments that use these incentives to reduce the risk associated with energy efficiency projects, thereby encouraging complementary private sector investment.

Financial incentives for energy efficiency are often provided through market-based instruments, in which a government uses regulation to specify a desired outcome, typically energy savings, and then establishes a framework for market actors to deliver the outcome. The most common market-based instruments are:

- Obligation schemes, such as white certificate programs or energy efficiency resource standards, where energy suppliers or utilities are required to deliver a specified amount of savings; and
- Auctions, where companies or service providers bid for government funds to support the implementation of energy efficiency measures.

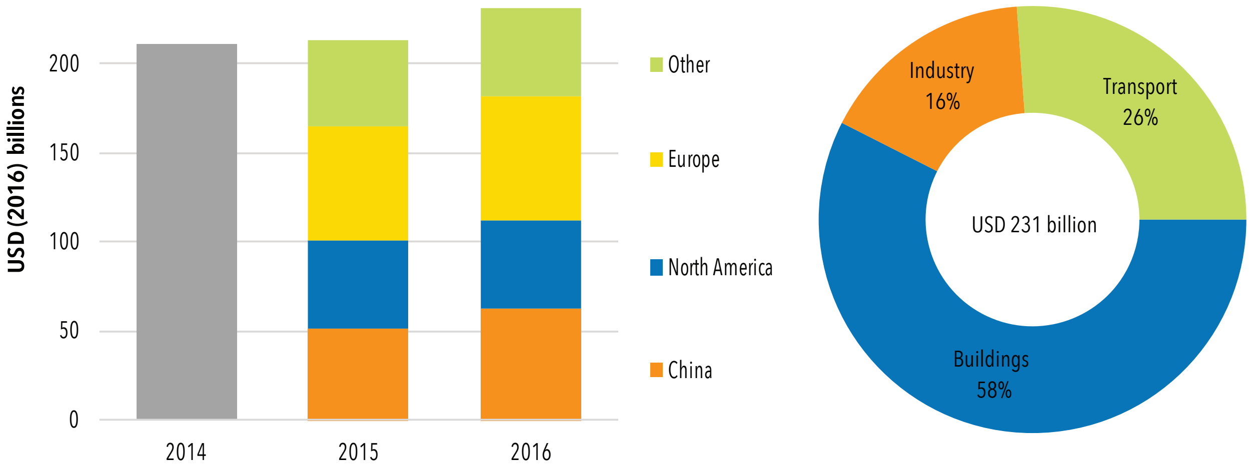
Between 2005 and 2016, the number of market-based instruments in operation quadrupled globally (IEA 2016), reflecting how these measures leverage market forces to deliver energy efficiency.

While regulation- and incentive-based policy measures compel or encourage greater action on energy efficiency, they do not ensure that consumers have the right information to make appropriate decisions. Information- and capacity-building measures are therefore an important complement to other energy efficiency policies. These measures include appliance and equipment labels that inform consumers of energy performance, performance rating tools, and case studies highlighting successful energy efficiency projects. Awareness-raising campaigns aimed at educating and empowering consumers to take action have also been successful in many countries (e.g., campaigns targeting women in developing countries).[33]

ENERGY EFFICIENCY INVESTMENT

In 2016, the incremental amount invested in more efficient buildings, appliances, vehicles, and industrial equipment totaled $231 billion, the majority of which was in the buildings sector (figure 4.12). The presence of low-cost and replicable energy efficiency measures, such as lighting upgrades and improvements to heating, ventilation, and air conditioning system performance, contributes to the buildings sector receiving the most incremental investment.

FIGURE 4.12 • ENERGY EFFICIENCY INVESTMENT BY REGION (LEFT) AND SECTOR (LEFT), 2016



Source: IEA 2017.

CONCLUSIONS

Even with sustained improvements in primary energy intensity since 2010, the average rate of improvement is still lagging behind SDG target 7.3. Improvements in 2016 were close to the target rate although a step down from 2015; estimates for 2017 and 2018 indicate that progress has continued to slow. There is still significant potential to cost-effectively improve energy efficiency—improvement in primary energy intensity could not only meet but even exceed SDG target 7.3 by 2030. Achieving this potential would generate benefits across the entire energy system and significantly improve energy access, since more efficient appliances and equipment reduce the amount and cost of the energy infrastructure required to provide access to modern energy services.

Government policy will continue to be central to global efforts to realize the benefits of improved energy efficiency. Supportive policy measures have been implemented in some form across advanced and major emerging economies, and will provide a basis for global expansion and development. Key actions include:

- Implementing and strengthening mandatory energy efficiency policies, which push appliances, equipment, and vehicles toward the best available technologies.

- Providing targeted and appropriate fiscal or financial incentives to encourage energy users to pursue greater levels of efficiency.
- Leveraging the power of the market, through implementation of market-based mechanisms, to deliver energy efficiency improvements at least cost.
- Providing targeted and high-quality information and capacity-building measures, to maximize market readiness to deliver higher levels of energy efficiency.

Government policy will also need to create an environment that is conducive to the development of new finance and business models, which are needed to raise levels of energy efficiency investment.

One factor that will have an increasing impact on energy efficiency across all sectors is the growth and application of digital technologies. Digitalization encapsulates an increase in the amount and accuracy of energy use data, an enhanced ability to conduct data analysis, and improvements in connectivity, which improve the interaction between consumers and devices, enabling greater control and flexibility of use.

Digitalization is creating new business models for the delivery of energy efficiency, which capture benefits not only for individual consumers but also the broader energy market. This is an active area of analysis that policy makers will need to continue to monitor, not only to establish frameworks that best capture the positive impacts, but to leverage the power of digitalization to improve the development, implementation, and enforcement of energy efficiency policies.

METHODOLOGY

Total primary energy supply (TPES) (in megajoules [MJ])	Equal to Total Energy Supply as defined by the International Recommendations for Energy Statistics (IRES), made up of production plus net imports minus international marine and aviation bunkers plus-stock changes. *Data sources*: Total energy supply is typically calculated in the making of national energy balances. Energy balances are compiled based on data collected for around 150 economies from the International Energy Agency (IEA) and for all countries in the world from the United Nations Statistics Division (UNSD).
Gross domestic product (GDP) (in USD 2011 purchasing power parity [PPP])	Sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. This is calculated without making deductions for the depreciation of fabricated assets or for depletion and degradation of natural resources. GDP is measured in USD 2011 PPP. Purchasing power parities (PPPs) are the rates of currency conversion that equalise the purchasing power of different currencies by eliminating the differences in price levels between countries. In their simplest form, PPPs are simply price relatives which show the ratio of the prices in national currencies of the same good or service in different countries. *Data source:* World Bank's World Development Indicators (WDI).
Primary energy intensity (in MJ/USD 2011 PPP)	$Primary\ Energy\ Intensity = \frac{TPES}{GDP}$ Ratio of TPES to GDP measured in MJ per USD 2011 PPP. Energy intensity indicates how much energy is used to produce one unit of economic output. A lower ratio indicates that less energy is used to produce one unit of economic output. Energy intensity is an imperfect indicator of energy efficiency as changes are impacted by other factors, particularly changes in the structure of economic activity.
Average annual rate of improvement in primary energy intensity (%)	Calculated using compound annual growth rate (CAGR). $CAGR = \left(\frac{PEI_{t2}}{PEI_{t1}}\right)^{\frac{1}{(t2-t1)}}$ -1 Where: $PEI_{t2}PEI_{t2}$ is primary energy intensity in year *t2* $PEI_{t1}PEI_{t1}$ is primary energy intensity in year *t1* Negative values represent decreases (or improvements) in energy intensity (less energy is used to produce one unit of economic output or per unit of activity), while positive numbers indicate increases in energy intensity (more energy is used to produce one unit of economic output or per unit of activity).
Total final energy consumption (TFEC) (in MJ)	Sum of energy consumption in different end-use sectors, excluding non-energy uses of fuels. TFEC is broken down into energy demand in the following sectors: industry, transport, residential, services, agriculture and others. It excludes international marine and aviation bunkers, except at the world level where international bunkers are included in the transport sector. *Data sources:* Energy balances from the IEA, supplemented by the UNSD for countries not covered by the IEA.
Value added (in USD 2011 PPP)	Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for the depreciation of fabricated assets or depletion and degradation of natural resources. The industrial origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. *Data source:* World Bank's World Development Indicators (WDI).

Industry energy intensity (in MJ/USD 2011 PPP)	$Industry\ energy\ intensity = \frac{Industrial\ TFEC}{Industrial\ value\ added}$ Ratio between industry TFEC and industry value added measured in MJ per USD 2011 PPP. Industry corresponds to ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37), non-fuel mining and construction. *Data sources:* Energy balances from the IEA and the UNSD and value added from the WDI.
Services energy intensity (in MJ/USD 2011 PPP)	$Services\ energy\ intensity = \frac{Services\ TFEC}{Services\ value\ added}$ Ratio between services TFEC and services value added measured in MJ per USD 2011 PPP. Services correspond to ISIC divisions 50-99. They include wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services. *Data sources:* Energy balances from the IEA and the UNSD and value added from the WDI.
Agriculture energy intensity (in MJ/USD 2011 PPP)	$Agriculture\ energy\ intensity = \frac{Agriculture\ TFEC}{Agriculture\ value\ added}$ Ratio between agriculture TFEC and agriculture value added measured in MJ per USD 2011 PPP. Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. *Data sources*: Energy balances from the IEA and the UNSD and value added from the WDI.
Passenger transport energy intensity (in MJ/passenger-kilometer [pkm])	$Passenger\ transport\ energy\ intensity = \frac{Passenger\ transport\ TFEC}{Passenger\text{-}kilometers}$ Ratio between passenger transport TFEC and passenger transport activity measured in MJ per passenger-kilometers. *Data source:* IEA Mobility Model.
Freight transport energy intensity (in MJ/tkm)	$Freight\ transport\ energy\ intensity = \frac{Freight\ transport\ TFEC}{Tonne\text{-}kilometers}$ Ratio between freight transport TFEC and activity measured in MJ per tonne-kilometers. *Data source:* IEA Mobility Model.
Residential energy intensity (in MJ/unit of floor area)	$Residential\ energy\ intensity = \frac{Residential\ TFEC}{Residential\ floor\ area}$ Ratio between residential TFEC and square meters of residential building floor area measured in MJ per m2. *Data source:* IEA Buildings Model.
Fossil fuel electricity generation efficiency (%)	$Generation\ efficiency = \frac{Electricity\ output}{Fuel\ input}$ Ratio of the electricity output from fossil fuel power generation (coal, oil, and gas) and the fossil fuel input to power generation. *Data source:* IEA Energy Balances.
Power transmission and distribution (T&D) losses (%)	$Power\ T\&D\ losses = \frac{Electricity\ \ transmission\ and\ distribution\ losses}{(Electricity\ output\ main + Electricity\ output\ CHP + Electricity\ imports)}(\%)$ Where: “electricity output main” is electricity output from main activity producer electricity plants; and “electricity output CHP” is electricity output from combined heat and power plants. *Data source*: IEA Energy Balances.

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ENDNOTES

31 Some of the analysis in this chapter is based on data and analysis in the report Energy Efficiency 2018 (IEA 2018).

32 Calculated as the compound average annual growth rate.

33 For more information, see http://genderandenvironment.org/resource/agent-energy-webinar-energy-efficiency-as-a-means-to-improve-womens-lives/.