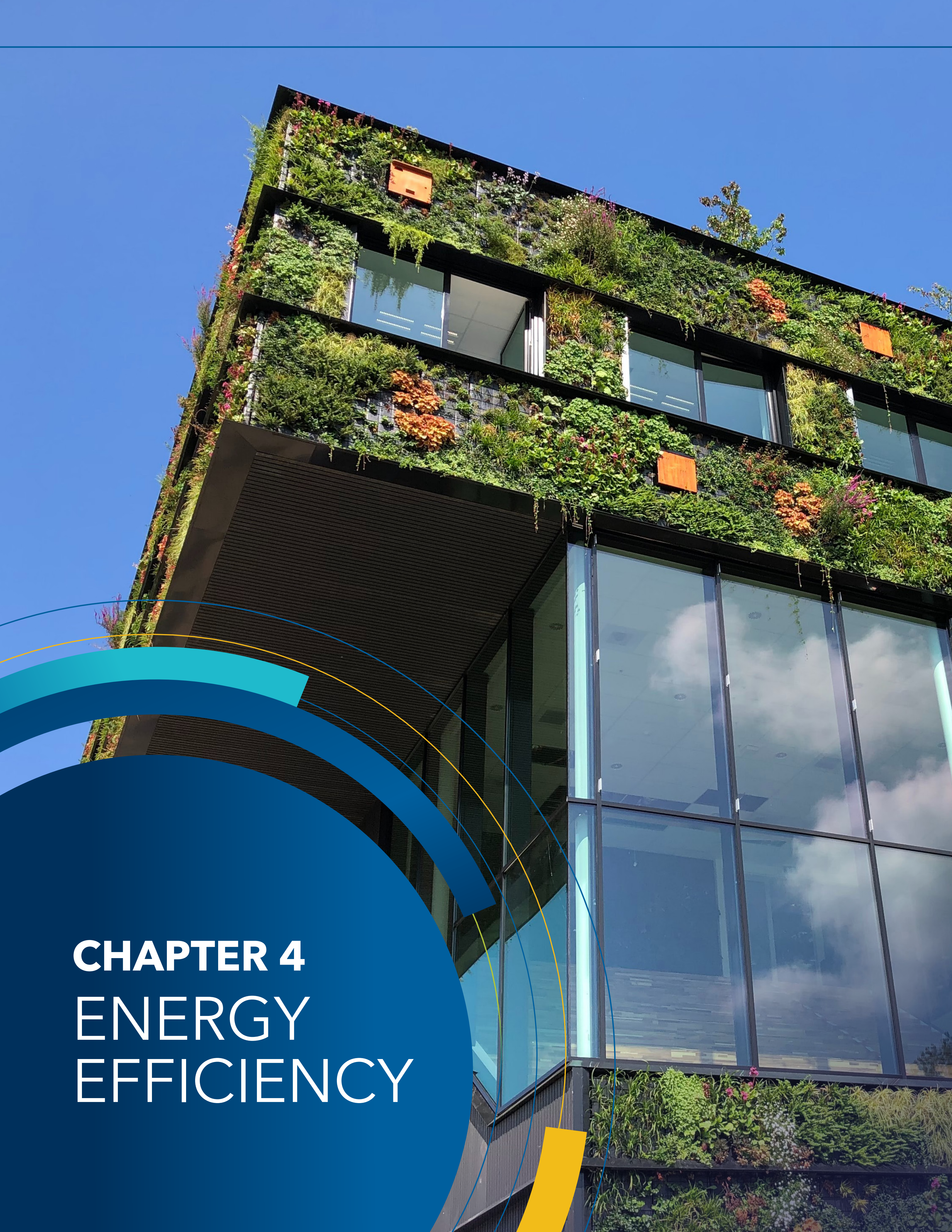

CHAPTER 4
ENERGY EFFICIENCY

MAIN MESSAGES

- **Global trend:** The rate of improvement in primary energy intensity—defined as the percentage decrease in the ratio of total energy supply per unit of gross domestic product (GDP)—has slowed in recent years. Worldwide, primary energy intensity[1] was 4.69 megajoules (MJ) per U.S. dollar in 2019, a 1.5 percent improvement from 2018. This was the second-lowest rate of improvement[2] since the global financial crisis, but still higher than the rate in the previous year.
- **2030 target:** Energy intensity improvements continue to remain below the target set under the United Nations Sustainable Development Goals (SDGs) for 2030. Between 2010 and 2019, the average annual rate of improvement in global energy intensity was 1.9 percent. Although better than the rate of 1.2 percent between 1990 and 2010, it is well below the SDG 7.3 target of 2.6 percent.[3] Annual improvement through 2030 must now average 3.2 percent to meet the target of SDG 7.3. While early estimates for 2020 point to a substantial decrease in intensity improvement as a result of the COVID-19 crisis, the outlook for 2021 suggests a return to the average rate of improvement during the previous decade. Making energy efficiency measures a priority in policy and investment over the coming years can help the world achieve SDG 7.3, promote economic development, improve health and wellbeing, and ensure universal access to clean, efficient energy.
- **Regional highlights:** Eastern Asia and South-eastern Asia was the only region that overachieved the target of SDG 7.3 between 2010 and 2019, with energy intensity improving by an annual average rate of 2.7 percent driven by strong economic growth and significant progress on energy efficiency. Nonetheless, average annual improvement rates in Oceania (2.2 percent), Northern America and Europe and Central Asia and Southern Asia (2.0 percent) were also above the global average and historical trends. The lowest rates of improvement were achieved in Latin America and the Caribbean (0.6 percent), followed by Western Asia and Northern Africa (1.2 percent) and Sub-Saharan Africa (1.3 percent). Data on absolute energy intensity reveal wide regional differences. For example, energy intensity in Sub-Saharan Africa is almost double the level in Latin America and the Caribbean. These variations mirror differences in economic structure, energy supply, and access to energy, rather than in energy efficiency.
- **Trends in the top 20 energy consuming countries:** Comparing the periods 2000–10 and 2010–19, the annual rate of improvement in energy intensity increased in 13 of the 20 countries with the largest total energy supply in the world. However, less than half of the top energy consuming countries performed better than the global average. China continues to improve energy intensity at the fastest rate, at an annual average of 3.8 percent between 2010 and 2019, followed by the United Kingdom at 3.7 percent. Japan and Germany also continue to improve their energy intensity at rates beyond the SDG 7.3 target, thanks to decades of concerted effort toward energy efficiency and a shift in their economies toward producing high-value, low-energy goods and services. Indonesia is the only other emerging economy apart from China with an average energy intensity improvement rate above the SDG 7.3 target.

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1 Hereafter referred to as "energy intensity". See note to figure 4.8 for the definition of energy intensity by sector.

2 Calculated as a compound average annual growth rate.

3 Revisions of underlying statistical data and methodological improvements explain the slight changes in historical growth rates from previous editions. The SDG 7.3 target of improving energy intensity by 2.6 percent per year in 2010–30 remains the same, however.

- **End-use trends:** Compared with the previous decade, the rate of energy intensity improvement accelerated across all sectors over the 2010–19 period, with the exception of the residential buildings sector. The freight transport sector experienced the highest rate of energy intensity improvement, at 2.2 percent a year. Notable progress has also been made in the industry sector (2 percent), which spans a range of energy-intensive economic activities. This is a major enhancement since sectoral energy intensity had deteriorated in the preceding period. Sectoral improvement rates have been the lowest in the residential sector, where the rate of energy intensity improvement slowed from 1.9 percent in the previous period to 1.2 percent annually between 2010 and 2019.
- **Electricity supply trends:** The rising share of renewables in electricity generation improves supply efficiency by eliminating the losses incurred in the conversion of primary (nonrenewable) fuels into electricity. This relationship between efficient primary renewable electricity[4] and a decrease in energy intensity highlights the synergies between SDG targets 7.2 and 7.3. In addition, the average efficiency of fossil fuel electricity generation increased from 36 percent in 2000 to 40 percent in 2019 thanks to growing use of relatively more efficient gas-fired plants and the construction of more efficient coal-fired plants in China and India. Major electricity-producing countries are seeing declines in transmission and distribution losses, indicating higher rates of electrification and a modernized supply infrastructure.

4 Primary renewable electricity, such as hydropower, solar PV, wind, and ocean energy is captured directly from natural resources. Electricity from geothermal, solar thermal, and biomass sources is renewable but it is not treated as 100 percent efficient in energy statistics owing to conversion losses.

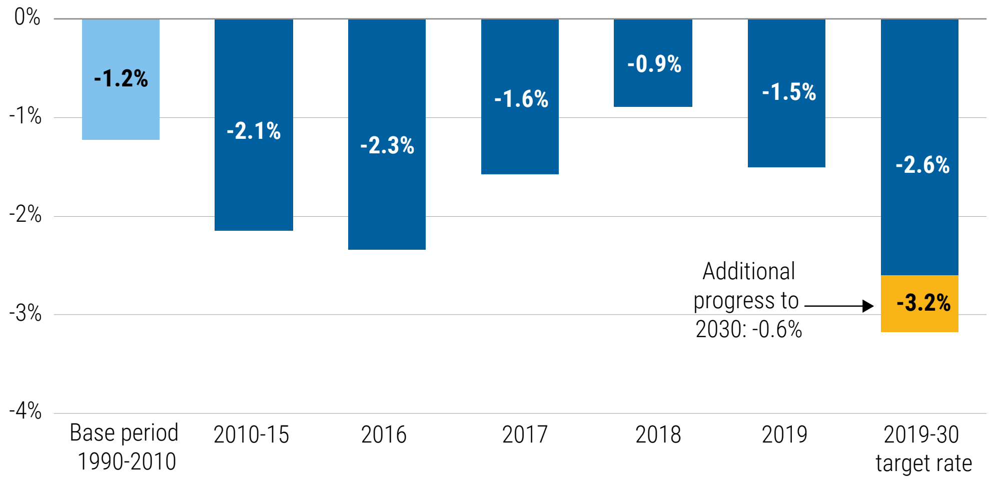
ARE WE ON TRACK?

SDG 7 commits the world to ensure universal access to affordable, reliable, sustainable, and modern energy. Achieving SDG target 7.3—doubling the global rate of improvement in energy intensity relative to the average rate over the period from 1990 to 2010—also contributes to reaching the other targets of SDG 7.[5] Energy intensity is the ratio of total energy supply to the annual GDP created—in essence, the amount of energy used per unit of wealth created. By using this measure of energy intensity to understand efficiency, we can observe how energy use rises or falls while also looking for the (social and economic) development factors that may affect those rates, along with other factors such as weather and behavior change. In general, energy intensity declines as energy efficiency improves.

Progress toward SDG target 7.3 is measured by tracking the year-on-year percentage change in energy intensity. Initially, an annual improvement rate of 2.6 percent between 2010 and 2030 was recommended by the United Nations to achieve the target, but since global progress has been slower than that in all years except 2015, the rate now required is at least 3.2 percent (figure 4.1).

Nevertheless, global energy intensity has shown gradual improvement since 1990[6] (figure 4.2). Recent numbers show that global energy intensity improved by 1.5 percent in 2019 to 4.69 MJ/U.S. dollar (2017 PPP [purchasing power parity]). This was the second lowest rate of improvement since the global financial crisis, but still better than the previous year's rate.

Figure 4.1 • Growth rate of primary energy intensity by period and target rate, 1990–2030

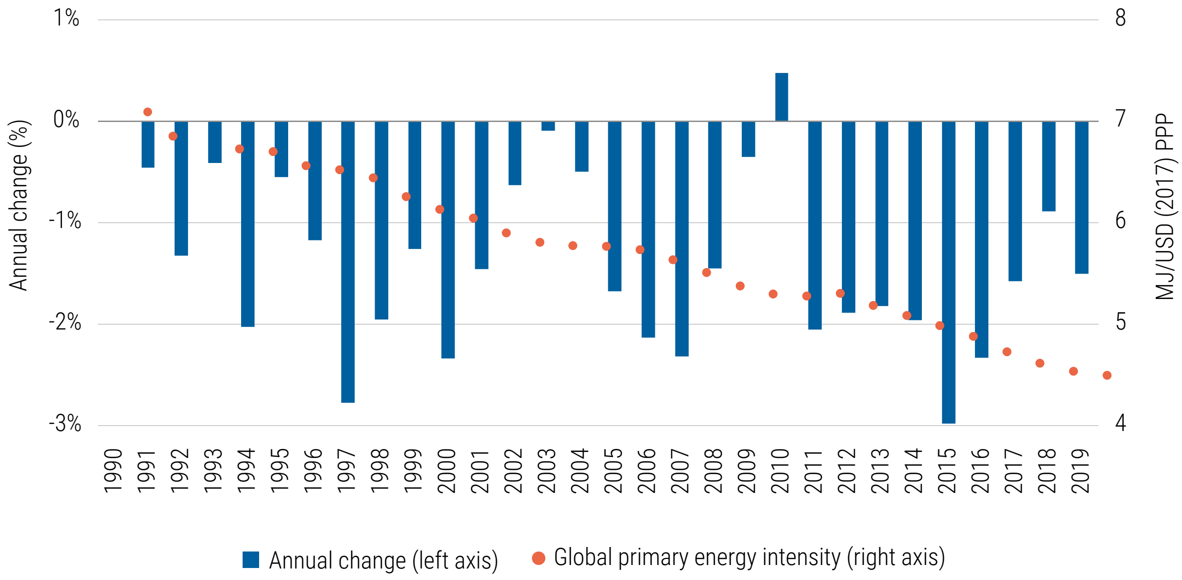


Source: IEA, UN, and World Bank (see footnote 6).

5 Revisions of underlying statistical data and methodological improvements explain the slight changes in growth rates in the base period (1990–2010) from previous editions. The SDG 7.3 target of improving energy intensity by 2.6 percent per year in 2010–30 remains the same, however.

6 Most of the energy data in this chapter comes from a joint dataset built by the International Energy Agency (https://www.iea.org/data-and-statistics/) and the United Nations Statistics Division (https://unstats.un.org/unsd/energystats/). GDP data is sourced from the World Bank's World Development Indicators database (http://datatopics.worldbank.org/world-development-indicators/).

Figure 4.2 • Global primary energy intensity and its annual change, 1990–2019



Source: IEA, UN, and World Bank (see footnote 6).
Note: MJ = megajoule; PPP = purchasing power parity.

LOOKING BEYOND THE MAIN INDICATORS

COMPONENT TRENDS

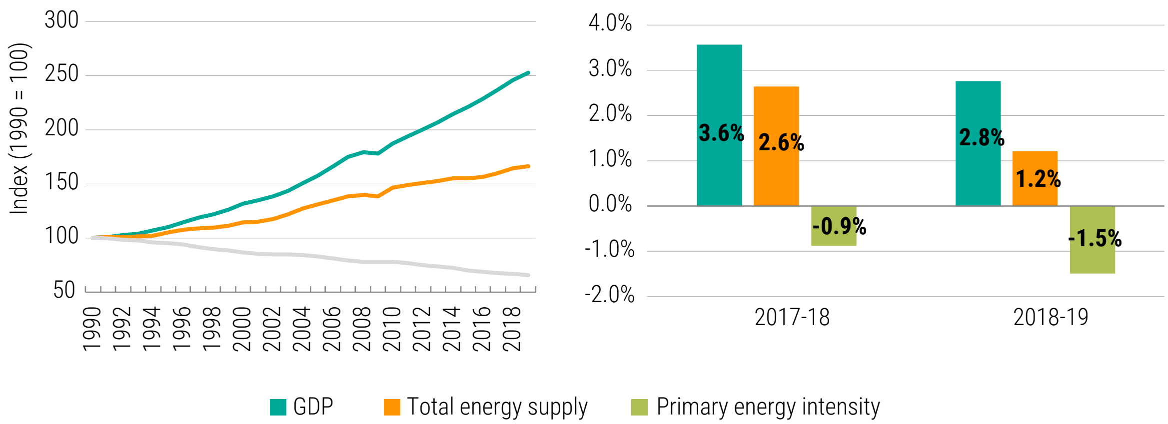
The impact of improvements in energy intensity is revealed by trends in its underlying components (figure 4.3, left). Between 1990 and 2019, global GDP increased by a factor of 2.5, while global total energy supply[7] grew by two-thirds.

The difference in growth rates for GDP and total energy supply is reflected by consistent improvements in global energy intensity, which fell by more than a third between 1990 and 2019, signaling trends in the decoupling of energy use from economic growth. In the period 2010–19, global intensity fell by nearly 16 percent, compared with a 10 percent decrease between 2000 and 2010.

More recently, growth in energy supply shrank by half from 2.6 percent in 2018 to just 1.2 percent in 2019, while GDP growth declined by less than a quarter, from 3.6 percent in 2018 to 2.8 percent in 2019. This resulted in an increase in the improvement rate for energy intensity—from 0.9 percent in 2018 to 1.5 percent in 2019 (figure 4.3, right).

Recent trends in energy efficiency are discussed in box 4.1.

Figure 4.3 • Trends in underlying components of global primary energy intensity, 1990–2019 (left); and growth rates of GDP, total energy supply, and primary energy intensity, 2017–19 (right)



Source: IEA, UN, and World Bank (see footnote 6).
Note: GDP = gross domestic product.

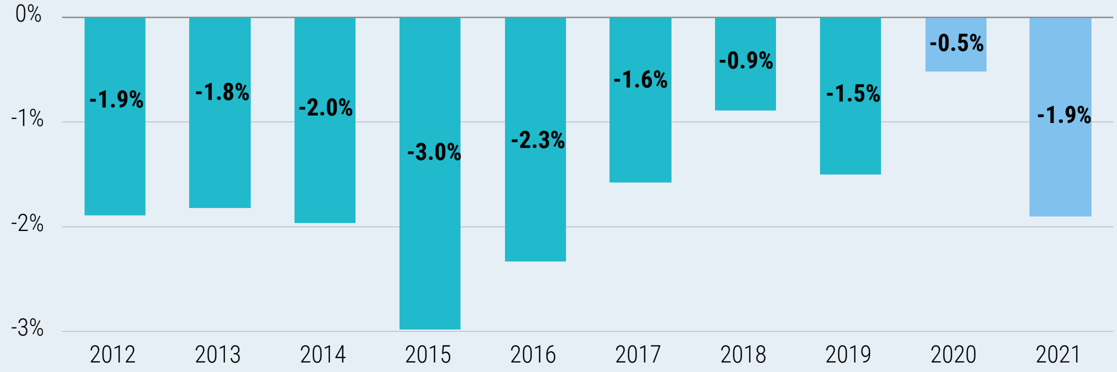
7 "Total primary energy supply" has been renamed "Total energy supply" in accordance with the International Recommendations for Energy Statistics (UN 2018).

BOX 4.1 • Recent energy efficiency trends

The COVID-19 pandemic has disrupted energy and economic trends in recent years. 2020 was one of the worst years ever for progress toward greater energy efficiency, as energy intensity improved by a mere 0.5 percent owing to low energy demand and prices, a slowdown in technical efficiency enhancements, and a shift in economic activity away from less energy-intensive services, such as hospitality and tourism (figure B4.1.1).

In 2021, global energy demand is estimated to have increased by about 4 percent as countries gradually emerged from lockdowns. Combined with a rebound in less-energy-intensive economic activity and rising energy prices and efficiency investments, this is estimated to have resulted in an energy intensity improvement of 1.9 percent, a return to the average rate during the previous ten years.

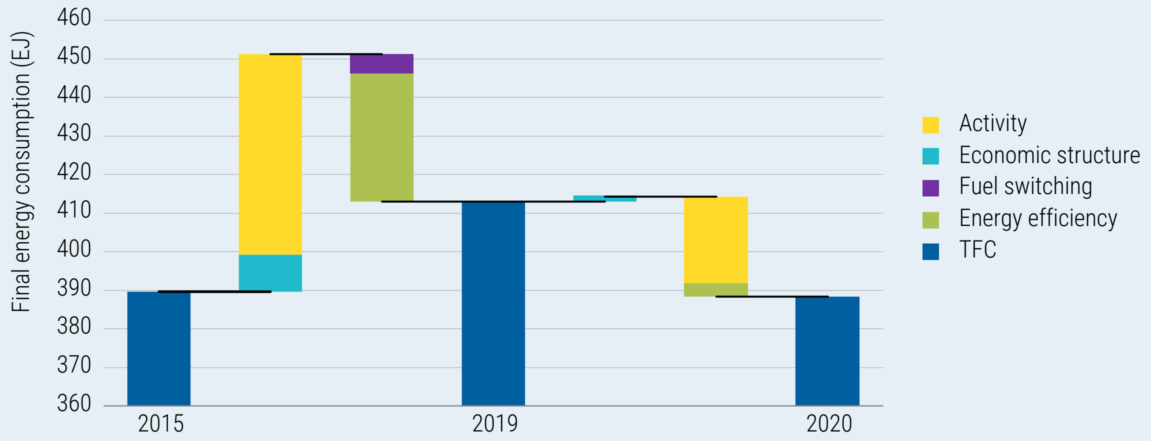
Figure B4.1.1 • Growth rate of global primary energy intensity, 2012–21



Source: IEA (2021d).

However, energy intensity improvements had already slowed before the pandemic, driven by strong demand for energy services and a shift in economic structure towards more energy-intensive industrial production, combined with only modest avoided demand from fuel switching toward electricity and slower rates of improvement in technical efficiency. Nonetheless, energy demand would have been 5 percent higher in 2019 if technical efficiency improvements between 2015 and 2019 had been as low as in 2020 (figure B4.1.2).

Figure B4.1.2 • Decomposition of change in global total final energy consumption, 2015–20



Note: TFEC = total final energy consumption in the industry, buildings and transport sectors.
Source: IEA 2021j.

Energy efficiency helped avoid nearly two-thirds of the potential increase in energy demand that could have occurred between 2015 and 2019 due to economic growth. An important contributor to changes in economic structure that added to global energy demand was strong demand for energy-intensive products in China, while a switch to less-energy-intensive fuels decreased energy demand.

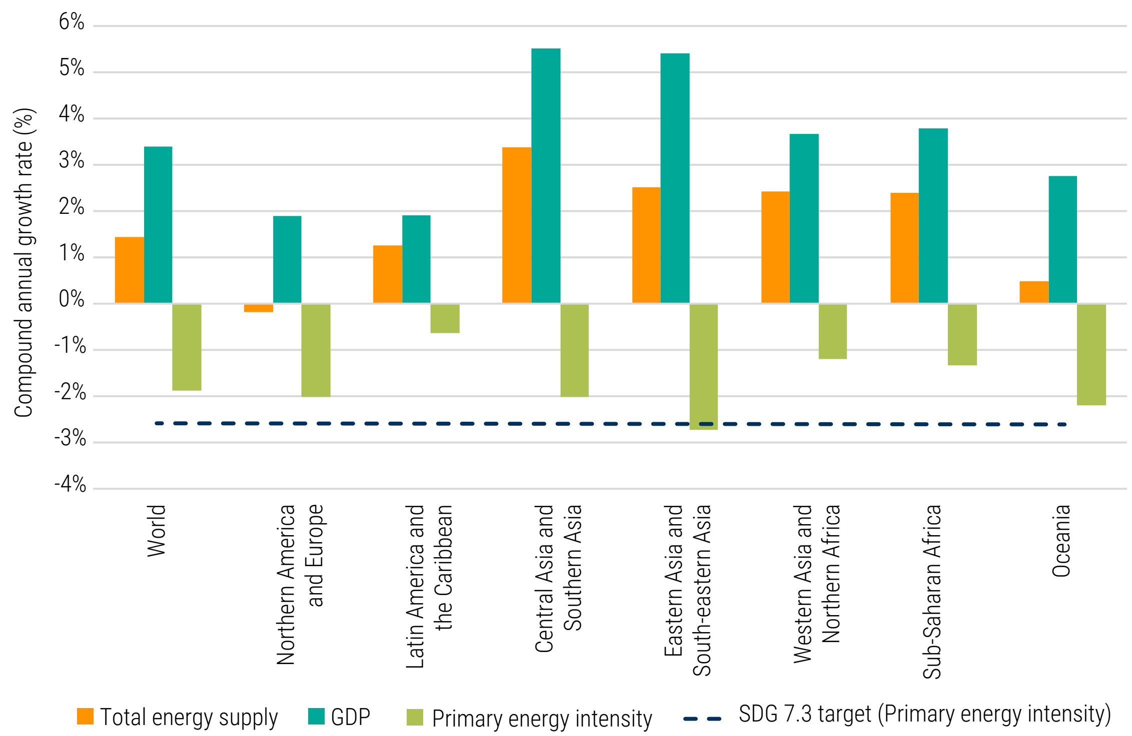
With disruptions caused by COVID-19 shaping recent trends, it is still unclear whether the rebound of energy intensity improvements in 2021 signals the start of a sustained recovery. However, increased investment trends, rising government spending on efficiency (in large part related to recovery plans enacted in response to COVID-19 crisis), and new announcements of higher climate ambition and other policy measures offer some encouraging signals.

REGIONAL TRENDS

Overall, since 2010, energy intensity has improved across the world, but significant differences in trends are observed across regions (figure 4.4). Emerging economies in Central, Southern, and Eastern and South-eastern Asia have seen a rapid increase in economic activity. However, the rise in total energy supply associated with such growth has been mitigated in part by significant improvements in energy efficiency, which have put downward pressure on the global average. Over the same period, mature economies in Northern America and Europe experienced a slight decrease in their total energy consumption, which reflects slower economic growth and a decoupling of the economy from energy usage. This last trend was enabled by a continued shift toward less-energy-intensive industrial activities (such as services) and the greater energy efficiency one typically observes when mature policies are in place, particularly in buildings (Northern America) and industry (Europe). In these economies, energy intensity improved at a rate slightly below global trends, leading to an absolute level of energy intensity slightly below the global average (figure 4.5). Similar trends and absolute levels of energy intensity have been observed for Oceania, where total energy supply increased modestly, while GDP grew faster than in Northern America and Europe.

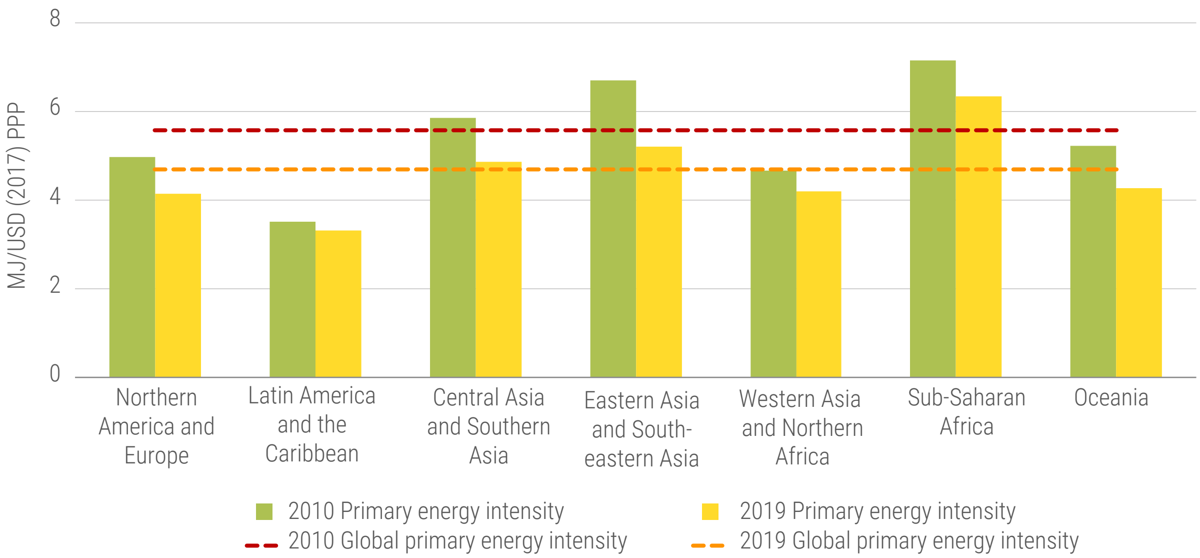
Latin America and the Caribbean, Western Asia and Northern Africa, and Sub-Saharan Africa recorded the smallest average gains in energy intensity improvement over the 2010–19 period (1.3 percent per year or less). However, trends differed across these regions. In Latin America and the Caribbean, both growth in total energy supply and GDP were among the lowest worldwide, but the region is also the least energy intensive region in the world, at 3.3 MJ/U.S. dollar (2017 PPP) (figure 4.5). In Western Asia and Northern Africa, and in Sub-Saharan Africa, on the other hand, growth in total energy supply and GDP were among the highest worldwide. In absolute terms, economic output in Sub-Saharan Africa is highly energy intensive, at 6.3 MJ/U.S. dollar (2017 PPP), reflecting the low value of economic output and the widespread use of inefficient solid biomass for cooking. The figure for Western Asia and Northern Africa was 4.2 MJ/U.S. dollar (2017 PPP) (figure 4.5).

Figure 4.4 • Growth rate of total energy supply, GDP and primary energy intensity at a regional level, 2010–19



Source: IEA, UN, and World Bank (see footnote 6).
Note: GDP = gross domestic product.

Figure 4.5 • Primary energy intensity at a regional level, 2010 and 2019



Source: IEA, UN, and World Bank (see footnote 6).
Note: MJ = megajoule; PPP = purchasing power parity.

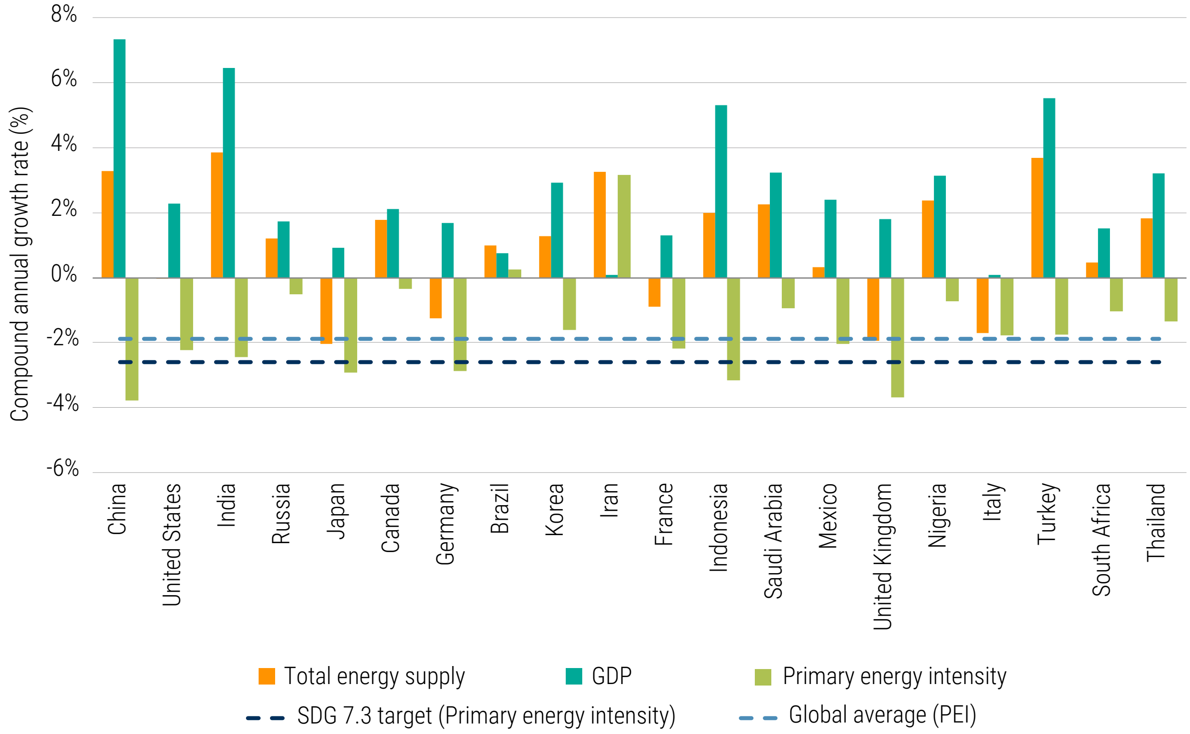
MAJOR COUNTRY TRENDS

Rates of improvement for energy intensity in the 20 countries with the largest total energy supply are central to realizing SDG 7.3, as these countries account for around three-quarters of global GDP and energy consumption. Over the period from 2010 to 2019, 13 of them raised their rate of intensity improvement compared with the previous decade, but less than half performed better than the global average, with only five (China, United Kingdom, Indonesia, Japan, and Germany) exceeding the level required by SDG 7.3 (figure 4.6).

Of these five countries, two—China and Indonesia—are major emerging economies. They have seen rapid structural changes in their economies, changes that have moved them toward higher-value activities that create more GDP for every unit of energy consumed. Particularly in China, concerted efforts to introduce energy efficiency policies over the period have quickened the pace of energy intensity improvements in various sectors.

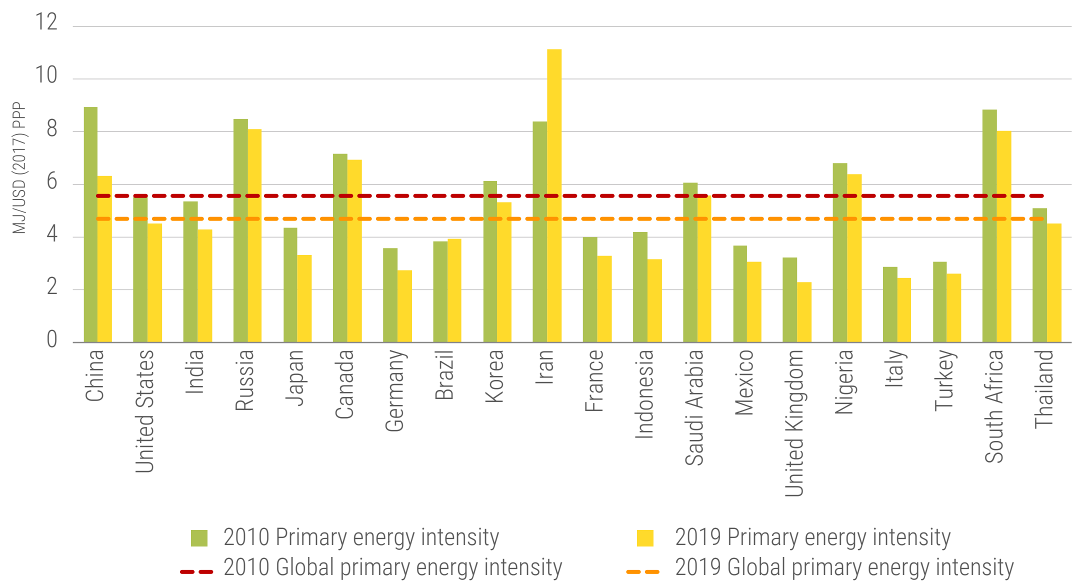
The economies of the United Kingdom, Japan, Germany, and France have expanded as their energy use declined. In Italy, energy intensity improved as total energy supply dropped and GDP remained nearly constant. These trends suggest that economic growth is being decoupled from energy use, as economic activity has largely shifted to high-value, service-related activities that are less energy intensive. In addition, the economies of these countries all have strong, decades-long records of policy action on energy efficiency.

Figure 4.6 • Growth rate of total energy supply, GDP, and primary energy intensity in the 20 countries with the largest total energy supply, 2010–19



Source: IEA, UN, and World Bank (see footnote 6).
Note: Countries along the x-axis are ordered by total energy supply. GDP = gross domestic product; SDG = Sustainable Development Goal; PEI = primary energy intensity.

Figure 4.7 • Primary energy intensity in the 20 countries with the largest total energy supply, 2010 and 2019



Source: IEA, UN, and World Bank (see footnote 6).
Note: Countries along the x-axis are ordered by total energy supply.
MJ = megajoule; PPP = purchasing power parity.

In absolute terms, the energy intensity of eight of the top 20 energy-consuming countries has remained above the global average over the past decade (figure 4.7). Three of the eight (Iran, Russia, and South Africa) are also among the top 25 countries worldwide with the highest energy intensities.

Globally, average energy intensity has fallen by nearly 1 MJ/U.S. dollar (2017 PPP) since 2010. Certain countries have made progress by moving further below the global average, including India, Indonesia, Japan, the United States, and the United Kingdom. Others, such as China and South Africa, despite remaining more energy intensive than the global average, are improving and shifting toward the global average. Countries where progress has been slowest include those where energy-intensive fossil fuel extraction represents a major share of GDP—namely Iran, Brazil, Nigeria, Canada and Russia.

Digitalization has played a prominent role in enabling countries to make progress toward SDG 7.3, as discussed in box 4.2.

BOX 4.2 • Digitalization: The key to accelerating progress toward SDG 7.3 and net-zero emissions by 2050

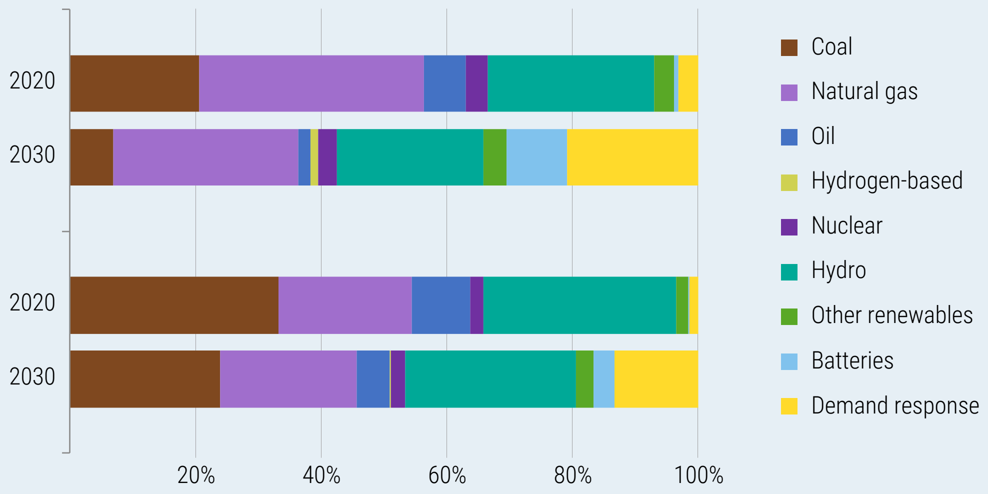
Digitalization is transforming the energy sector and promises to accelerate progress on SDG 7.3. With the proliferation of digital devices and low-cost sensors, a wealth of granular and continuously updated data is now available to optimize energy supply and use. Over the last five years the deployment of connected devices with automated controls—appliances, devices, and sensors—grew by around 33 percent per year to reach 9 billion in 2021, up from 7 billion the year before (4E 2021). This brings challenges in terms of ensuring the energy efficiency of IT infrastructure. Overall energy use by connected devices decreased moderately over the past decade, while increased energy efficiency and operational improvements have enabled a decoupling of data use, internet traffic, and associated electricity use (Malmodin and Lundén 2018; IEA 2021g). Continued efforts in research and development and incentives for energy efficiency are needed to maintain this trend. In particular, the steep growth in devices calls for close attention to enhancing the efficiency of connected devices and IT infrastructure—for example, by reducing the energy consumed during network standby (IEA 2021d).

Digitalization provides insight into how to direct energy efficiency measures so they have the greatest effect and yield the greatest benefit. For example, in the building sector, energy management systems and related technologies can help reduce energy consumption significantly. In the U.S. General Services Administration, building operating costs could be cut by 20 percent by enabling the buildings to interact with the power grid (ACEEE 2019). The IEA 4E Technology Collaboration Programme estimates that smart home technologies can help decrease household energy use by 20–30 percent (4E 2018), and evidence from the United Kingdom has shown that households can use digital technologies to reduce their energy consumption by up to a third (WEC 2018).

Digitalization also offers systemwide benefits, including increased reliability and resilience, operational efficiency, cost reductions, and investment optimization, providing opportunities for a more active participation of customers, including in voluntary peak-reduction schemes. In addition, digitalization can foster economic and social development. For instance, digitally enabled mobile communications technology can play a crucial role in bringing decentralized clean energy solutions to vulnerable urban or marginalized communities via innovative business models. Across Africa, five million people gained access to electricity through pay-as-you-go solar home electricity systems in 2018 alone (IEA 2019a). These models, enabled by smart meters and two-way digital communication, have helped customers in urban, peri-urban, and rural areas to leapfrog traditional providers and install efficient technologies in their dwellings by allowing customers to pay back costs in installments. At the same time, digitalization offers the opportunity to monitor and raise awareness on energy use, which can result in actions to increase energy savings and lower bills.

Digitalization is critical for accommodating growing shares of variable and distributed renewables. According to IEA's Net Zero Emissions by 2050 Scenario, flexibility in electricity networks will quadruple by 2050 to accommodate rising shares of variable renewable resources (wind, solar), with a growing share of the flexibility provided by distributed resources and demand response (IEA 2021c).

Figure B4.2.1 • Electricity system flexibility by source in IEA's Net Zero Scenario, 2020 and 2030



Source: IEA 2021f.

Digital platforms and connected appliances will be essential to full, efficient utilization of a range of flexibility options, including behind-the meter connected devices. Virtual power plants, which aggregate distributed energy resources like batteries and rooftop solar PV panels, as well as demand-side flexibility, could play a crucial role in bringing new sources of flexibility to the system. One recent study suggests that global virtual power plant aggregations are growing faster than traditional demand response, which typically involves utilities contacting large power consumers to reduce demand. While virtual power plant capacity is expected to rise from 4.5 GW in 2020 to 43.7 GW in 2029, the capacity of demand-response programs could double in the same timeframe (Guidehouse 2020).

END-USE TRENDS

Using a variety of metrics (as discussed in the note to figure 4.8), energy intensity can be examined across key sectors such as industry, transport, buildings, and agriculture. Over the 2010-19 period, the rate of improvement accelerated across all sectors, with the exception of the residential buildings sector (figure 4.8).

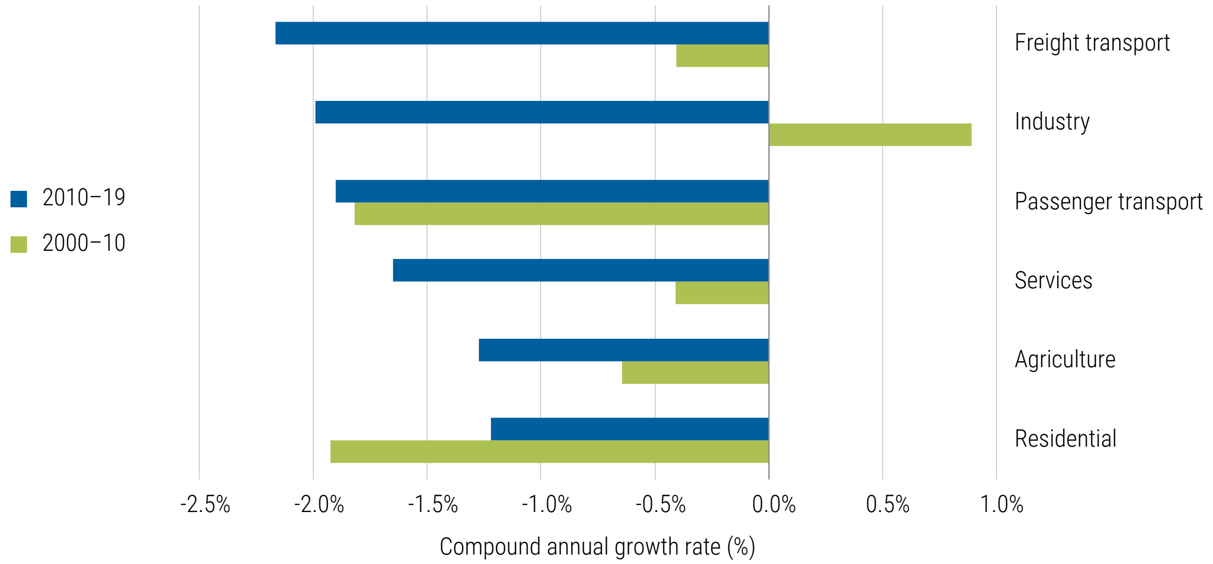
In the industry sector, which comprises highly energy intensive economic activities such as the manufacture of cement, iron, and steel, energy intensity improved by 2 percent per year, on average, during the 2010s. This was a major enhancement, since sectoral energy intensity had deteriorated in the preceding period. The progress was largely driven by emerging Asian economies such as China and India through, for example, more efficient manufacturing processes (IEA 2017). Furthermore, the framework for mandatory energy efficiency policies in the industry sector tends to be more developed than for other sectors around the world (IEA, 2018).

Between 2010 and 2019, the freight transport sector experienced the highest rate of improvement in energy intensity, at 2.2 percent a year. This drop in intensity is steeper than the 0.4 percent annual reduction seen in the 2000–10 period. Energy intensity for passenger transport also improved at a slightly faster rate (1.9 percent a year) in the past decade than in the previous one (1.8 percent). The transport sector is one of the primary sources of global greenhouse gas emissions. As people travel more frequently and over longer distances, and as they consume more imported goods, the sector is growing rapidly. Although stronger fuel economy standards in major markets are improving energy efficiency, these are offset by behavioral changes. For example, consumer demand for larger private road vehicles—comparatively energy intensive forms of transport—remains strong, particularly as living standards rise in emerging economies (IEA, 2019b, 2019c). In 2020, SUV sales constituted around 40 percent of all passenger car sales, up from just 20 percent ten years earlier (IEA, 2021b). As a consequence, fuel consumption of new light-duty vehicles improved at only half the rate observed at the beginning of the last decade (GFEI, 2022).

The residential sector, which is responsible for nearly a third of energy consumption worldwide, has seen a slowdown in the rate of energy intensity improvement, from 1.9 percent in the first decade of the new century to 1.2 percent annually between 2010 and 2019. Mitigating the effects of the growing demand for space cooling, heating, and appliances would require stricter enforcement of building energy codes and more-stringent minimum energy performance standards, especially in emerging economies, where a large share of new dwellings is going up. In the service sector, energy intensity improved by 1.6 percent annually between 2010 and 2019, a major improvement from the 0.4 percent rate in the previous decade.

The improvement rate for agriculture's energy intensity also saw significant progress—from 0.6 percent a year in 2000–10 to 1.3 percent between 2010 and 2019, as economic output of the sector outpaced growth in energy demand.

Figure 4.8 • Compound annual growth rate of energy intensity, by sector, 2000–2010 and 2010–2019



Source: IEA, UN, and World Bank (see footnote 6).
Note: The measures for energy intensity used here differ from those applied to global primary energy intensity. Here, energy intensity for freight transport is defined as final energy use per metric ton-kilometer; for passenger transport, it is final energy use per passenger-kilometer; for residential use, it is final energy use per square meter of floor area; in the services, industry, and agriculture sectors, energy intensity is defined as final energy use per unit of gross value-added (in 2017 U.S. dollars purchasing power parity). It would be desirable, over time, to develop more refined sectoral and end-use-level indicators that make it possible to examine energy intensity by industry (e.g., cement, steel) or end use (e.g., heating, cooling). Doing so will not be possible without more disaggregated data and statistical collaboration with the relevant energy-consuming sectors.

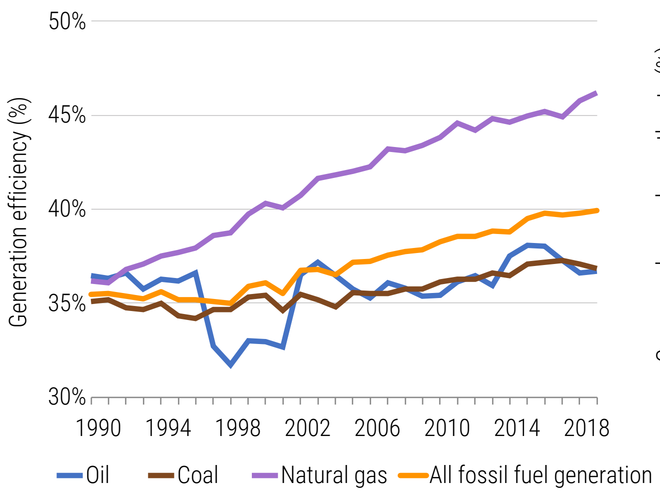
TRENDS IN EFFICIENCY OF ELECTRICITY SUPPLY

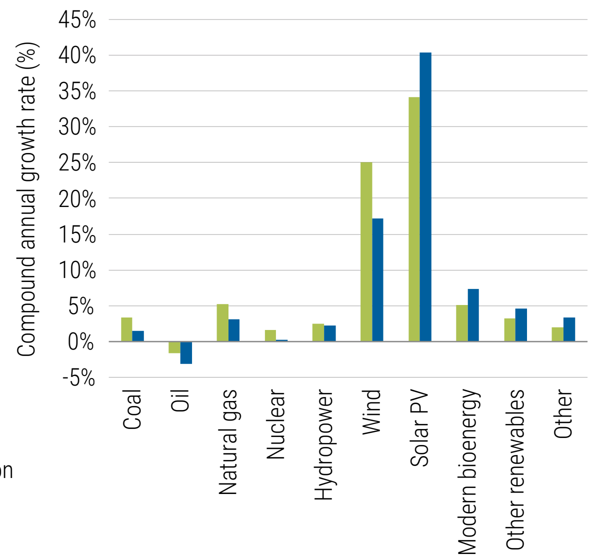
In addition to improvements in end-use efficiency, the rate of improvement in global energy intensity is also influenced by changes in the efficiency of electricity supply. These changes include reductions in transmission and distribution losses driven by a modernized supply infrastructure and improvements in the efficiency of fossil fuel generation. After showing flat rates of improvement during the 1990s, the efficiency of fossil fuel generation improved steadily between 2000 and 2015 (figure 4.9). However, efficiency rates for total fossil fuel generation have stalled around 40 percent in recent years, with efficiency improvements of electricity generation from natural gas balancing out a decrease in efficiency of generation from coal and oil.

Another factor affecting supply efficiency for global electricity is the share of renewable energy sources in the mix. Statistically, most renewable energy technologies are treated as being 100 percent efficient, even though minor losses do occur in the conversion of resources such as sunlight and wind into electricity. Even so, both statistically and actually, more renewable energy in the electricity mix boosts the efficiency of electricity supply.

In 2019, renewable energy comprised 26.2 percent of global electricity consumption, up from 19.7 percent in 2010, making a notable contribution to energy efficiency. Growth in electricity generation was particularly strong for solar PV and wind, which grew at an annual average rate of 40.4 percent and 17.2 percent, respectively, between 2010 and 2019 (figure 4.9). As for fossil fuel generation, growth rates were all lower in 2010–19 than in the 1990–2010 period, with electricity generation from oil decreasing even faster than in previous decades. The combined effect of these growth rates has been to improve the overall efficiency of electricity supply by reducing losses experienced when converting energy supply into electricity. These trends therefore highlight the synergistic relationship between the targets of SDG 7.2 and SDG 7.3, as energy intensity improves with rising shares of renewable electricity in the power generation mix, while energy efficiency improvements enable an increase in the share of renewables in the global energy mix (see box 4.3).

Figure 4.9 • Trends in global fossil fuel electricity generation efficiency (left) and growth in electricity generation by fuel type (right), 1990–2019





Source: IEA (2021h); International Energy Agency (IEA), and United Nations Statistics Division (UNSD).

POLICY RECOMMENDATIONS AND CONCLUSIONS

Continued shortfalls in energy intensity improvement imply that strengthened government policies on energy efficiency are needed to meet the SDG 7.3 target by 2030. In addition to helping reach the target, well-designed and well-implemented policies can deliver a range of benefits beyond savings in energy and emissions. These include better health owing to better air quality, reduced energy bills for households and businesses, and new jobs in energy efficiency retrofits.

Strong policy action is also vital as a signal to investors that energy efficiency is a long-term priority, helping to create more certainty for investors and to catalyze the transformative investments needed to return the world to a path to meet the target of SDG 7.3.

ENERGY EFFICIENCY POLICY

Governments have several policy tools for increasing energy efficiency, including regulatory instruments that mandate higher efficiency levels in buildings, appliances, vehicles, and industry; fiscal or financial incentives to encourage installations of energy-efficient equipment and retrofits; and information programs to help energy users make informed decisions. The following section describes some options and policies.[8]

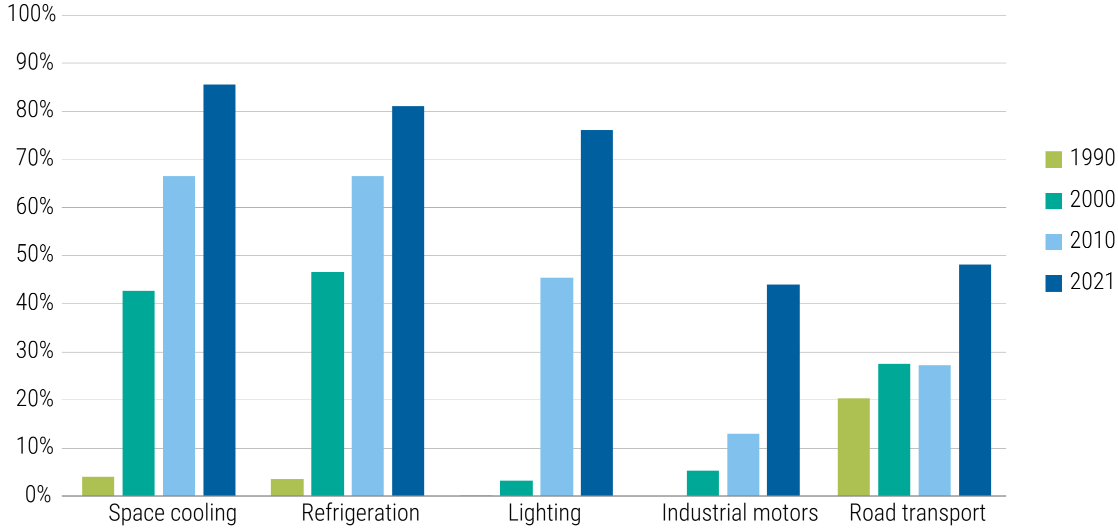
More than a hundred countries now have mandatory performance standards and/or labels related to the energy efficiency of key end uses such as air conditioners, refrigeration, lighting, industrial motors, and passenger cars (IEA 2021d). Additional or expanded standards and labeling schemes are under development in more than 20 countries, mainly in Asia and East and Southern Africa. However, policies are still lacking in many markets undergoing rapid growth in the ownership of appliances, industrial equipment, and vehicles.

More broadly, performance standards and labels apply to more than a hundred types of appliances and equipment in the commercial, industrial, and residential sectors. However, policy coverage is often low. For example, only 40–50 countries have implemented minimum performance standards for washing machines, dishwashers or TVs. As a result, expanding programs in countries where policies presently cover only a limited number of products offers significant scope for further efficiency gains.

Performance standards and labels, adopted early in Europe and North America, now cover a high proportion of key energy-consuming end uses in these regions. Globally, such policies are most commonly used for appliances. For example, more than 80 percent of global energy use for air conditioners and refrigerators is currently covered by minimum energy performance standards, compared with less than half of energy use for industrial motors and road transport (figure 4.10).

8 More information and examples can be found in the IEA's Global Policies Database (IEA 2022b), the World Bank's Regulatory Indicators for Sustainable Energy (RISE) (World Bank 2021), the Global Status Report of Renewable Energy Policy Network for the 21st Century (REN21 2019), or the recommendations of IEA's Global Commission for Urgent Action on Energy Efficiency (IEA 2020).

Figure 4.10 • Global energy use coverage of mandatory energy efficiency standards for key end uses, 1990-2021



Source: IEA analysis for IEA (2021d) based on CLASP (2021) and other sources.
Note: Coverage for space cooling, refrigeration, and lighting is shown for residential sectors.

There is also great variation in the strength of programs across countries. Significant scope exists for enhanced international cooperation in this area to help governments introduce new standards, learn from others' experience, and adopt best practices.

If ambition levels are regularly adjusted to reflect technological progress, performance standards and labels can achieve substantial reductions in energy consumption. For example, long-running appliance efficiency policies have helped to halve the average energy consumption of many common appliances such as refrigerators, air conditioners, lighting devices, televisions, washing machines, and cooking appliances (IEA, 2021a). These huge gains have been achieved even as the price of these appliances has fallen by an average of 2–3 percent per year, suggesting that more-stringent policies could curb emissions further while still benefiting consumers. In the United States, for instance, the energy efficiency standards and labeling program led to net annual fuel savings of around USD 40 billion in 2020, a reduction of USD 320 in the average annual household fuel bill.

Government actions to reduce the cost of energy-efficient equipment or retrofits include economic incentives such as grants, loans, and tax breaks. In New Zealand, a series of energy efficiency programs have combined government and third-party funding with homeowner contributions to replace insulation and heating systems in older houses. Launched in 2018, the program provides subsidies for low-income homeowners. A 2011 cost-benefit analysis of a previous iteration of the insulation grants program found that it delivered health benefits well over NZD 1 billion (USD 610 million) (Grimes et al. 2012). Carbon pricing, the phasing out of fossil fuel subsidies, and cost-reflective energy pricing, coupled with safety net schemes for vulnerable consumers, are also important tools to make energy efficiency investments more attractive.

Bulk procurement is another effective way of easing the cost of such investments, as governments can leverage their considerable purchasing power to procure efficiency services or products. In India, for example, more than 350 million LED lamps have been distributed though the Unnat Jyoti by Affordable LEDs for All (UJALA) program. The economies of scale of the program have helped reduce the price of LED lamps by a factor of ten (EESL 2017).

POLICIES FOR LEVERAGING DIGITAL TECHNOLOGIES TO SCALE UP EFFICIENCY

In order to take advantage of the multiple benefits that energy efficiency and digitalization can offer, national and subnational governments need to:

- Chart the steps needed to make progress on standardization and embedded interoperability. In 2021, the United Kingdom adopted a comprehensive energy system digitalization strategy and action plan (UK BEIS 2021), while the European Union launched a roadmap on digitalization in the energy sector (action plan expected for 2022) (EC 2021).
- Systematically address barriers to data access, sharing, and use, and ensure robust mechanisms for data protection and cyber resilience for the entire energy value chain. This includes overcoming social barriers by building public awareness and acceptance. Costa Rica's smart grid strategy, launched in 2021, includes interoperability, data security, and cybersecurity as guiding principles, as well as capacity building and research support related to smart grids (SEPSE 2021).
- Build capacity to use digital tools for data management and analysis, with specific programs aimed at underprivileged communities. Capacity building is an integral part of India's Revamped Distribution Sector Scheme, approved in 2021, which also includes communication and consumer engagement plans (MOP 2021).
- Take measures to enable investments and encourage the development of innovative business models, including by implementing an innovation-friendly regulatory environment and a clearly defined legal framework. Regulatory sandboxes have been used in countries such as Australia, Italy, the Netherlands, the United Kingdom, and the United States to test innovative technologies and business models (IEA 2019d).
- Leverage digital tools and data to monitor and improve energy efficiency policies. For example, the Hot Maps pilot projects in Europe use an open-source GIS mapping tool that allows city planners to visualize geographical areas with potentially high heating or cooling loads that could be prioritized for efficiency upgrades under heating or cooling action plans (Hotmaps 2022).

Initiatives such as IEA's Digital Demand-Driven Electricity Networks (3DEN) are currently working on recommendations on how to accelerate the uptake of digital technologies for demand-side flexibility and energy efficiency (IEA 2022a).

ENERGY EFFICIENCY INVESTMENT

In 2020, despite the COVID-19 crisis, overall energy efficiency investment held steady at nearly USD 270 billion, but trends differed widely across sectors and regions, with Europe, China, and Northern America accounting for nearly 80 percent of the spending (figure 4.11). Unprecedented growth in the buildings sector, concentrated in Europe, outweighed a heavy decrease in transport efficiency investments, while spending in the industry sector remained largely unchanged. Investment in energy efficiency measures in buildings accounted for two-thirds of the total efficiency spending in 2020 as a result of the scaling up of efficiency policies put in place before the COVID-19 crisis and the early effects of economic recovery measures (IEA 2021d).

Deploying readily available efficiency technologies is one of the most cost-effective means of saving energy while reducing emissions and achieving wider SDG objectives. However, global annual investment in energy efficiency needs to triple by 2030 to reach the target of SDG 7.3 and achieve net-zero emissions by 2050 (UN 2021).

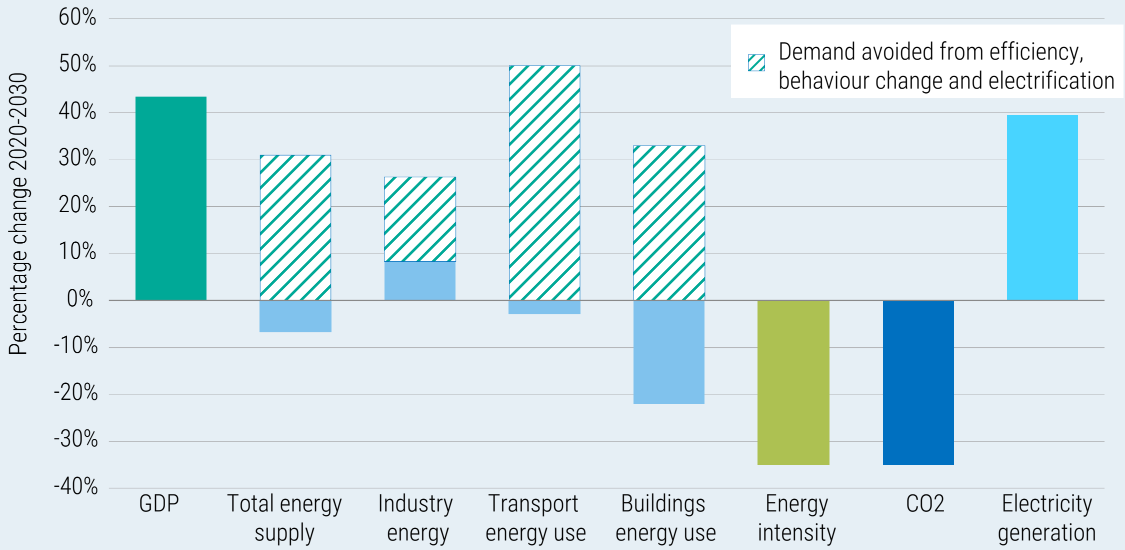
BOX 4.3 • Energy efficiency's role in delivering net-zero ambitions

Building on the momentum of COP26 in Glasgow in November 2021, the pace and ambition of climate goals has accelerated, with more than 50 countries, including the European Union, pledging to reach net-zero emissions by 2050 or soon thereafter. Achieving these goals is essential to give the world an even chance of limiting the rise in the average global temperature to 1.5°C.

In IEA's Net Zero by 2050 Scenario, energy efficiency is frontloaded into the pathway for reducing global emissions of greenhouse gases, with over 40 energy efficiency milestones identified (IEA 2021f). Fast deployment over the next 10 years is feasible, as efficiency depends on cost-effective technologies that are widely available on the market today. Moreover, around 80 percent of the energy efficiency gains in the scenario over the next decade result in overall cost savings to consumers.

Energy efficiency also enables other clean energy measures, such as renewable energy, to outpace growing demand for energy services triggered by rising prosperity and population, especially in emerging economies. In the scenario, the global economy grows more than 40 percent by 2030, yet it uses 7 percent less energy. Without the contribution of energy efficiency, electrification, and behavior change, total energy consumption would be around 30 percent higher in 2030, making it difficult to phase out fossil fuels.

Figure B4.3.1 • Macroeconomic and energy indicators in the IEA's Net Zero by 2050 Scenario

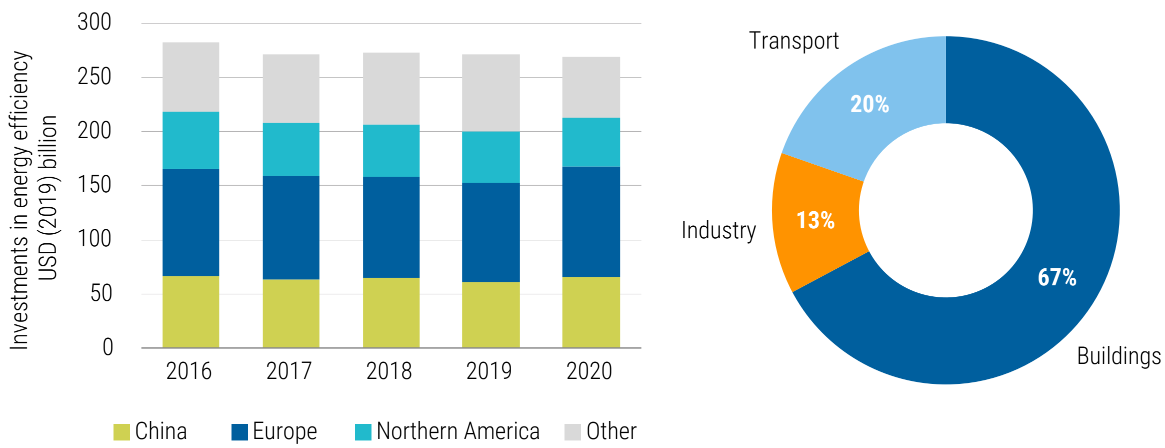


Source: IEA (2021f).

These results are achievable under the scenario through a strong and determined focus on energy efficiency in all sectors, even with the number of households growing by 15 percent by 2030, the floor area of buildings expanding by around a fifth, car traffic increasing by more than 10 percent, and 50 percent more goods moving around the world. Only industrial energy consumption rises over the next ten years in the scenario, though by less than it would without added efficiency, as the world produces 9 percent more steel, 21 percent more petrochemicals, and 5 percent more cement per year by 2030 to meet development needs.

Electrification of transport and heat in buildings and industry is key for decarbonization, with power generation increasing 40 percent in the scenario. Technologies such as electric vehicles and heat pumps are several times more efficient at the device level, but for system decarbonization benefits to be realized they must be powered by renewable sources.

Figure 4.11 • Energy efficiency investment by region, 2016–20 (left), and by sector, 2020 (right)



Source: IEA 2021i.

CONCLUSIONS

The improvement rate for energy intensity continues to remain below the annual 2.6 percent rate initially projected as a prerequisite to reaching the target of SDG 7.3. The rate of energy intensity improvement in 2019 was 1.5 percent, the second lowest since the global financial crisis. However, it was still higher than the rate in 2018. On average, energy intensity improved by 1.9 percent annually since 2010, compared with just 1 percent during the previous decade. In order to meet SDG 7.3's target of doubling the global rate of energy intensity improvement by 2030, the average rate of improvement must now be 3.2 percent per year through 2030 to make up for slow progress in the past. This rate would need to be even higher, consistently over 4 percent for the rest of this decade, to put the world on track to reach net-zero emissions from the energy sector by 2050, as envisioned in the IEA's Net Zero by 2050 Scenario.

Early estimates for 2020 point to a substantial decrease in intensity as a result of the COVID-19 crisis, but the outlook for 2021 suggests a return to the average rate of improvement during the previous decade. To bring the SDG 7.3 target within reach, energy efficiency policies and investment in cost-effective energy efficiency measures need to be scaled up significantly. Given the multiple benefits of energy efficiency, it is an obvious choice for government support, and this has been reflected in a range of recent stimulus packages throughout the world. Energy efficiency–related spending makes up around two-thirds of the total USD 400 billion a year mobilized by governments with their recovery measures between 2021 and 2023[9] (IEA 2021d). This focus on cross-sector energy efficiency also opens an opportunity for continued investment beyond initial recovery efforts.

One of those benefits is that improved efficiency at scale would be a key factor in achieving affordable, sustainable energy access for all. Continued low levels of intensity improvement, the significant potential opportunities for investment and economic recovery, and the pressing need for expanded access all point to the need for urgent action by governments to enact policies that would foster rapid progress toward an annual intensity improvement of at least 3 percent. As underlined by the recommendations of the United Nations' High-Level Dialogue on Energy, efficiency measures and strategies need to address the main barriers to the adoption of such measures and promote structural and behavioral change to support the achievement of the target (UN 2021).

Decoupling the national economy from energy use has been central to the progress that some countries are

9 As monitored by the Fall 2021 update of the IEA Sustainable Recovery Tracker (IEA 2021e).

making toward energy efficiency. In Japan, for example, minimally energy intensive sectors (e.g., services) play a more prominent role in the economy than high-intensity sectors like heavy manufacturing. Still, some developing economies are seeing similar trends as their economies grow and their service and low-intensity manufacturing sectors gather steam.

From the sectoral perspective, the sole exception to the better rate of energy intensity improvement recorded in the past decade was the residential buildings sector. Freight transport experienced the highest rate of improvement, followed by industry and passenger transport. However, as demand for larger passenger cars continued to grow, global average fuel consumption improved more slowly than energy intensity during the decade, despite strengthened fuel efficiency standards in many countries.

Digitalization has also been an emerging trend reshaping the energy landscape and facilitating progress toward improved energy efficiency. Wide-scale data collection, analysis, and application can help direct energy efficiency measures to where they can be most impactful, offering significant opportunities for energy efficiency outcomes across sectors. Some applications for households, for example, could cut total energy use by up to 33 percent (WEC 2018). In addition to the opportunities to optimize efficiency, digitalization can also support deep decarbonization by making it possible to increase and exploit flexibility in the power system, including from behind-the-meter connected devices. Finally, digitalization can also support efforts to widen access to energy thanks to innovative business models such as pay-as-you-go, which benefited five million people in 2018 (IEA 2019a). To take full advantage of the opportunities digitalization offers, governments should consider developing policies to apply digital technologies comprehensively to improve efficiency and produce positive social and economic outcomes.

National and subnational governments already have an array of policies to help them meet their energy efficiency goals. Successful policies of various types are in force around the world, including energy efficiency standards, financial incentives, market-based mechanisms, capacity-building initiatives, and regulatory measures. All encourage investment in energy efficiency and catalyze energy markets in favor of cleaner, more efficient operations.

The world has all of the technology and resources necessary to improve energy efficiency by 50 percent by 2030. The current low rates of improvement and investment point to a major missed opportunity for the global community. Making energy efficiency a priority in policy and investment over the coming years can help the world achieve SDG 7.3, promote economic development, improve health and wellbeing, and ensure universal access to clean, efficient energy.

METHODOLOGY

Total energy supply (TES) in megajoules (MJ)	This represents the amount of energy available in the national territory during the reference period. It is calculated as follows: Total energy supply = Primary energy production + Import of primary and secondary energy – Export of primary and secondary energy – International (aviation and marine) bunkers – Stock changes. (Definition consistent with International Recommendations for Energy Statistics.) *Data sources:* Energy balances from the International Energy Agency (IEA), supplemented by the United Nations Statistics Division (UNSD) for countries not covered by IEA as of 2017.
Gross domestic product (GDP) in 2017 U.S. dollars (USD) at 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. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. GDP is measured in constant 2017 USD PPP. *Data source:* World Development Indicators database: http://datatopics.worldbank.org/world-development-indicators/).
Primary energy intensity in MJ/2017 USD PPP	$Primary\ energy\ intensity = \frac{TES\ (MJ)}{GDP\ (USD\ 2017\ PPP)}$ Ratio between TES and GDP is measured in MJ per 2017 USD PPP. Energy intensity (EI) 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. EI is an imperfect indicator, as changes are affected by other factors other than energy efficiency, particularly changes in the structure of economic activity.
Average annual rate of improvement in energy intensity (%)	Calculated using compound annual growth rate (CAGR): $CAGR = \left(\frac{EI_{t2}}{EI_{t1}}\right)^{\frac{1}{(t2-t1)}} - 1\ (\%)$ Where: EI_{t2} is energy intensity in year *t1* EI_{t1} is energy intensity in year *t2* 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 by the different end-use sectors, excluding nonenergy 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 it is included in the transport sector. *Data sources:* Energy balances from IEA, supplemented by UNSD for countries not covered by IEA as of 2017.
Value added in 2017 USD 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 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, revision 3. *Data source:* WDI database.

Industrial energy intensity in MJ/2017 USD PPP	$Industrial\ energy\ intensity = \frac{Industrial\ TFEC\ (MJ)}{Industrial\ value\ added\ (USD\ 2017\ PPP)}$ Ratio between industry TFEC and industry value-added, measured in MJ per 2017 USD PPP. *Data sources:* Energy balances from IEA and value-added from WDI.
Services energy intensity in MJ/2017 USD PPP	$Services\ energy\ intensity = \frac{Services\ TFEC\ (MJ)}{Services\ value\ added\ (USD\ 2017\ PPP)}$ Ratio between services TFEC and services value-added measured in MJ per 2017 USD PPP. *Data sources:* Energy balances from IEA and value-added from WDI.
Agriculture energy intensity in MJ/2017 USD PPP	$Agriculture\ energy\ intensity = \frac{Agriculture\ TFEC\ (MJ)}{Agriculture\ value\ added\ (USD\ 2017\ PPP)}$ Ratio between agriculture TFEC and agriculture value-added measured in MJ per 2017 USD PPP. *Data sources:* Energy balances from IEA and value-added from WDI.
Passenger transport energy intensity in MJ/passenger-kilometer	$Passenger\ transport\ energy\ intensity = \frac{Passenger\ transport\ TFEC\ (MJ)}{Passenger\text{-}kilometers}$ Ratio between passenger transport final energy consumption and passenger transport activity measured in MJ per passenger-kilometers. *Data source:* IEA Mobility Model.
Freight transport energy intensity in MJ/tonne-km	$Freight\ transport\ energy\ intensity = \frac{Freight\ transport\ TFEC\ (MJ)}{Ton\text{-}kilometers}$ Ratio between freight transport final energy consumption and activity measured in MJ per tonne-kilometer. *Data source:* IEA Mobility Model.
Residential energy intensity in MJ/unit of floor area	$Residential\ energy\ intensity = \frac{Residential\ TFEC\ (MJ)}{Residential\ floor\ area\ (m^2)}$ Ratio between residential TFEC and square meters of residential building floor area. *Data source:* IEA Mobility Model.
Fossil fuel electricity generation efficiency (%)	$Generation\ efficiency = \frac{Electricity\ output\ from\ coal, oil, and\ natural\ gas}{Coal, oil, and\ natural\ gas\ input}\ (\%)$ Ratio of the electricity output from fossil fuel–fired (coal, oil, and gas) power generation and the fossil fuel TES input to power generation. *Data source:* IEA Energy Balances.
Power transmission and distribution losses (%)	$Power\ transmission\ and\ distribution\ losses = \frac{Electricity\ losses}{(Electricity\ output\ main + Electricity\ output\ CHP + Electricity\ imports)}\ (\%)$ Where: Electricity losses are electricity transmission and distribution losses; 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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