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CHAPTER 4
ENERGY EFFICIENCY

Main messages

- **Global trend.** Primary energy intensity, defined as the ratio of total energy supply to gross domestic product (GDP), is the main global indicator for energy efficiency. It declined 2.1 percent in 2022—more than four times the weak 0.5 percent improvement rate of 2021. Global energy intensity was 3.87 megajoules per US dollar (MJ/USD[23]) in 2022, when a global energy crisis induced major shocks to energy demand across many regions, and led to a strong decline in energy intensity.
- **2030 target.** Sustainable Development Goal (SDG) target 7.3 calls for the world's rate of energy intensity improvement to double by 2030 relative to the 1990–2010 average. Sluggish global progress in recent years means that energy intensity needs to improve by 4 percent a year on average in 2022–2030 to reach the SDG 7.3 target. This is roughly consistent with the Net Zero Emissions by 2050 Scenario of the International Energy Agency (IEA) and with the goal to double the global average annual rate of energy efficiency improvement by 2030 agreed on during the 2023 United Nations Climate Change Conference (COP28).
- **Regional highlights.** As a result of economic growth outpacing energy demand, energy intensity improved in all major regions in 2022, albeit at different speeds. Energy intensity declined by over 4 percent in Northern America and Europe, and improved by almost 6 percent in Oceania. The slowest progress, under 1 percent, was in Eastern and South-eastern Asia. Energy intensity in other major regions improved at rates similar to the global average of around 2 percent.
- **Trends in the 20 countries with the largest total energy supply.** From 2010 to 2022, energy intensity improved rapidly (relative to 1990–2010) in 15 of the 20 countries with the largest total energy supply. The annual rate more than doubled in this period in Australia, France, Italy, Japan, the Republic of Korea, Mexico, Saudi Arabia, Thailand, and Türkiye. But the 2.6 percent progress rate[24] required to meet SDG target 7.3 was met only by China, France, Germany, and the United Kingdom.
- **End-use trends.** Progress in energy intensity across end-use sectors accelerated in 2010–2022 compared to 2000–2010. The average annual improvement rate for buildings rose from 1.2 to 1.3 percent, and for industry from 0 to 1.4 percent. Passenger vehicles' annual progress rate increased from 0.7 to 1.6 percent, while heavy-duty trucks saw a smaller change, from 0.4 to 0.5 percent.
- **Electricity generation trends.** In 1990–2010, electricity generation efficiency increased from 40 to 42 percent. This rose to about 46 percent in 2010–2022, meaning that generation efficiency improved twice as fast in nearly half the time—largely due to the integration of renewable energy.

23 Based on purchasing power parity (PPP) rates of 2021.

24 When target 7.3 and indicator 7.3.1 were defined, the annual average rate of global energy intensity reduction stood at 1.3 percent for the baseline period of 1990–2010. Based on this figure, the target of doubling this average was set at 2.6 percent per year. Due to data revisions, the baseline annual improvement stands at 1.2 percent, but to avoid variations in the numerical target, the custodians of this indicator—IEA and the United Nations Statistics Division—decided to keep the target fixed at 2.6 percent.

Are we on track?

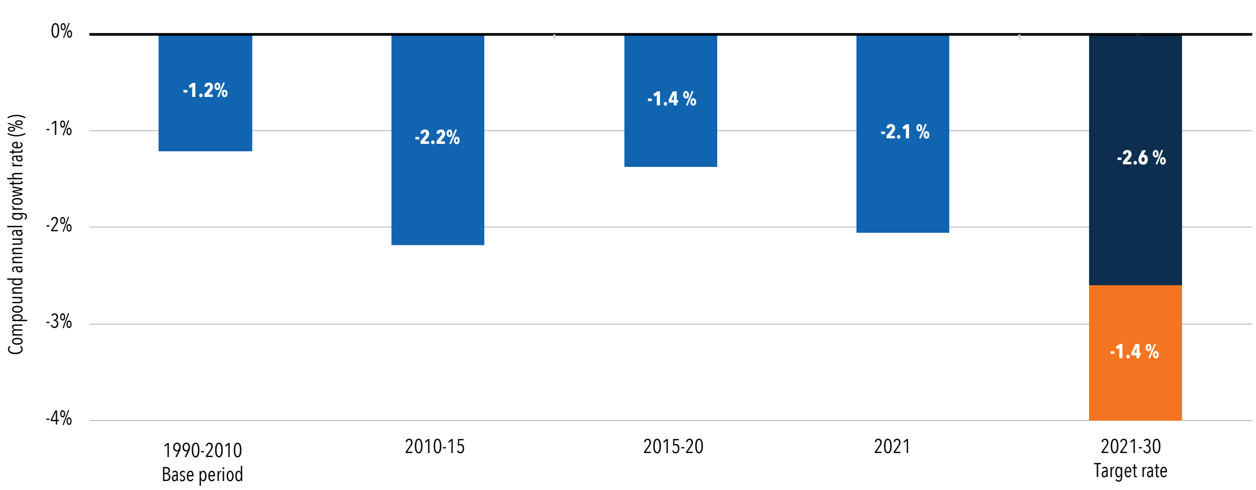
SDG 7 commits the world to ensuring universal access to affordable, reliable, sustainable, and modern energy. Target 7.3 calls for a doubling of the global rate of energy intensity improvement relative to the 1990–2010 average.

Energy intensity is the ratio of total energy supply to GDP, thus revealing the energy consumed per unit of wealth created. Energy intensity helps track changes in energy consumption and the factors influencing them, for example, changes in economic structure, weather, and behavior. All such factors being equal, as energy efficiency improves, energy intensity decreases.

Progress toward SDG target 7.3 is measured by the year-on-year percentage change in energy intensity. Initially, the United Nations recommended an annual improvement of 2.6 percent between 2010 and 2030 to achieve target 7.3. But given the slow pace of global progress in all years except 2015, energy intensity now needs to improve at an annual rate of 4.0 percent from 2022 onward. This figure is roughly consistent with the IEA's Net Zero Emissions by 2050 Scenario, under which the average rate of improvement is slightly over 4 percent in 2022–30. It is also in line with the goal of doubling the global average annual rate of energy efficiency improvement by 2030, as agreed on during COP28.

Global energy intensity improved by 2.1 percent in 2022, to reach 3.87 MJ/USD (2021 PPP), from 0.5 percent in 2021. This is in large part due to the global energy crisis, which triggered major disruptions in energy demand in many parts of the world. However, given the slower-than-required progress in previous years, the world is not yet on track to reach SDG target 7.3 by 2030 (figure 4.1).

FIGURE 4.1 • AVERAGE ANNUAL CHANGE IN GLOBAL PRIMARY ENERGY INTENSITY, BY PERIOD, 1990–2030



Source: International Energy Agency (World Energy Balances) and United Nations Statistics Division (Energy Balances).

SDG = Sustainable Development Goal.

Looking beyond the main indicators

Component trends

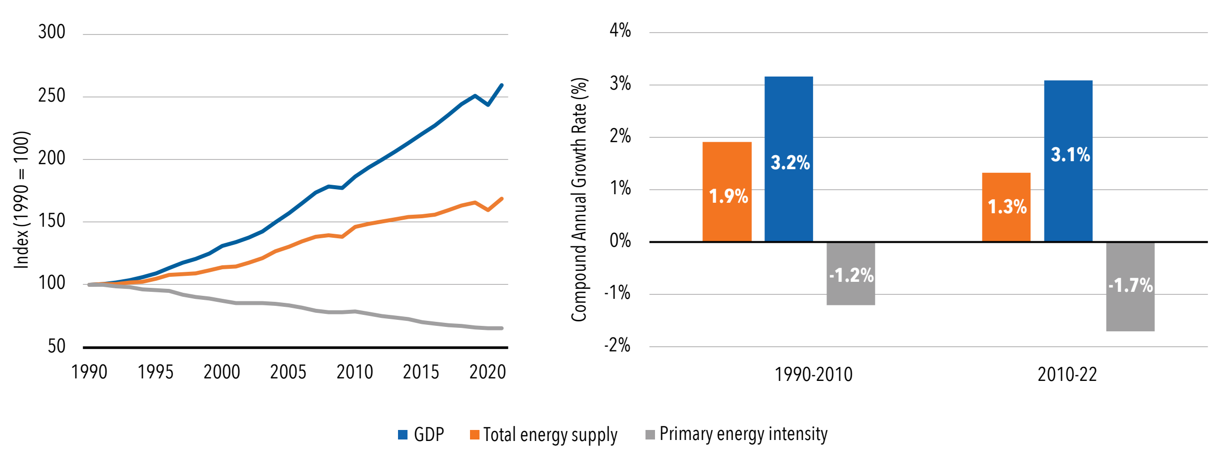
The year 2022 was marked by a global energy crisis, triggered by the onset of war in Ukraine. High energy prices and supply risks in many parts of the world slowed global energy demand, which grew by a mere 1.3 percent. This came after a more than 5 percent increase in 2021 following post-COVID rebounds—one of the largest single-year rises in the past 50 years. Globally, GDP growth was sluggish, at 3.4 percent, almost half the rate of 2021 (6.5 percent). Yet, since GDP grew faster than energy supply, energy intensity improved (decreased).

Over the longer term, the impact of improvements in energy intensity is revealed by trends in its underlying components (figure 4.2). Between 1990 and 2022, global GDP increased by a factor of 2.7, while total energy supply grew by 71 percent (or a factor of 1.71). This decoupling of energy use from economic growth yielded a consistent improvement in global energy intensity, which fell by over a third from 1990 to 2022.

Economic growth averaged 3.1 percent a year in 2010–22, very similar to the 3.2 percent average across 1990–2010. By contrast, energy demand grew notably slower in 2010–22 (1.3 percent a year on average) than in 1990–2010 (1.9 percent). This means that a similar level of GDP growth was achieved with less energy in 2010–22.

Much of the change in 2022 was due to severe shocks to the energy system, with high energy prices or supply risks compelling households and businesses to reduce their energy consumption. Given that consumers were under duress, the energy intensity improvement in 2022 cannot be viewed entirely as progress. Businesses were forced to close or curtail operations, and many people across the world struggled to afford basic energy needs. Sustained energy intensity improvement will require structural energy efficiency measures. The rate of improvement is estimated to have slowed down in 2023 and 2024 as some of the pressures of the energy crisis eased off.

FIGURE 4.2 • CHANGES IN THE COMPONENTS OF GLOBAL PRIMARY ENERGY INTENSITY, 1990–2022



Source: International Energy Agency (World Energy Balances) and United Nations Statistics Division (Energy Balances).

GDP = gross domestic product.

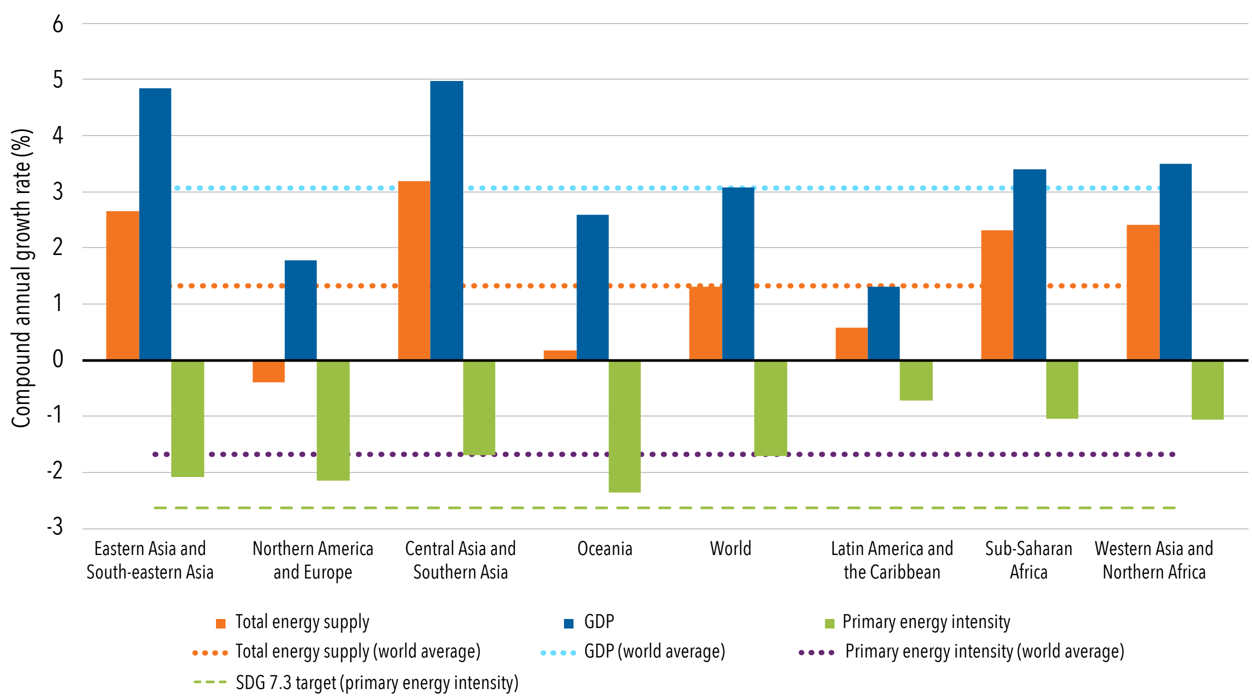
Regional trends

The global energy crisis in 2022 was a severe shock to energy markets around the world. In all major regions, total energy supply grew at a slower rate than GDP in 2022, and the energy supply even shrunk—by around 5 percent in Europe and 2 percent in Oceania. Northern America and Europe experienced the slowest GDP growth of any major region, at around 2 percent. Meanwhile, growth in both energy (4 percent) and GDP (6 percent) was the fastest in Central and Southern Asia.

Economic growth outpacing growth in energy demand resulted in energy intensity improving across all major regions, albeit at different speeds. Energy intensity improved by more than 4 percent over 2021–22 in Northern America and Europe, while it improved by nearly 6 percent in Oceania. Progress in 2022 was slowest in Eastern and South-eastern Asia, at a rate of less than 1 percent. Energy intensity in other major regions improved at a rate similar to the global average, approximately 2 percent. This is four times the global improvement rate of 2021.

Looking across a longer time period, on the other hand, average annual improvement in energy intensity between 2010 and 2022 was the lowest in Latin America, Sub-Saharan Africa, Western Asia, and Northern Africa, at around 1 percent each. In all other regions, an improvement rate of around 2 percent was recorded, pushing the global average annual rate to 1.7 percent for the period 2010–22 (figure 4.3). But this rate is insufficient to reach SDG target 7.3, which requires energy intensity to reduce (improve) by 2.6 percent between 2010 and 2030.

FIGURE 4.3 • AVERAGE ANNUAL CHANGES IN TOTAL ENERGY SUPPLY, GDP, AND PRIMARY ENERGY INTENSITY, BY WORLD REGION, 2010–22



Source: International Energy Agency (World Energy Balances) and United Nations Statistics Division (Energy Balances).

GDP = gross domestic product; SDG = Sustainable Development Goal.

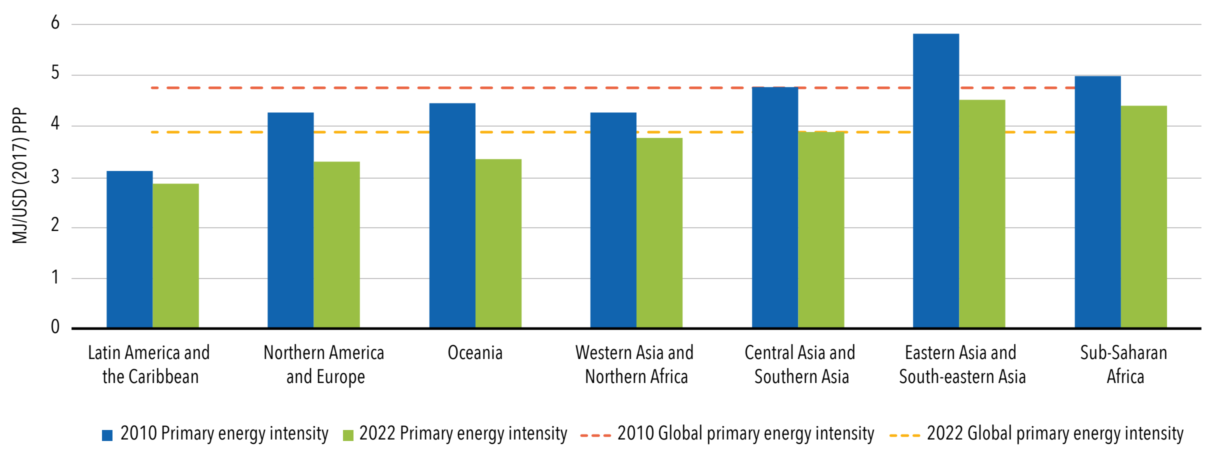
Change in primary energy intensity is an indicator for measuring an economy's energy efficiency improvement rate. It measures whether a country or region is becoming more efficient. Besides the change in intensity, measuring absolute levels of primary energy intensity helps evaluate how energy efficient (or inefficient) an economy is, keeping in mind that factors other than efficiency also affect intensity. World regions show notable differences in absolute levels of primary energy intensity.

Energy intensity was the lowest in Latin America and the Caribbean, which consumed around 3 MJ/USD of GDP (2021 PPP) in 2022. Intensity was highest in Eastern and South-eastern Asia, which consumed around 4.5 MJ/USD of GDP. However, between 2010 and 2022, energy intensity in Eastern and South-eastern Asia fell about 22 percent from almost 6 MJ/USD. This is the largest decline in any major region in this period. Given Asia's large population, this decline in energy intensity contributed toward global energy intensity falling from around 4.75 MJ/USD in 2010 to less than 3.9 MJ/USD in 2022, a nearly 20 percent decline.

Primary energy intensity in Northern America and Europe fell from around 4.3 MJ/USD to around 3.3 MJ/USD between 2010 and 2022, an improvement of 23 percent. This trend, however, is heavily influenced by the global energy crisis in 2022. Consumers in these regions reduced their energy consumption significantly to manage high energy prices and supply security risks. A similar decline was recorded in Oceania, of around 25 percent, from 4.4 MJ/USD to 3.3 MJ/USD, driven by similar forces. Energy intensity fell approximately 12 percent in Western Asia, Northern Africa, and Sub-Saharan Africa, where energy demand and GDP per remained significantly lower than in Northern America and Europe.

Meeting SDG target 7.3 requires doubling the global average annual rate of energy intensity improvement over 2010–30 relative to that in 1990–2010. When the target was set, doubling the rate meant annual energy intensity had to improve by around 2.6 percent per year between 2010 and 2030. Based on this target, the global primary energy intensity would be less than 2.8 MJ/USD in 2030. However, given the limited progress in recent years, meeting the original target requires an annual improvement rate of around 4.0 percent on average in the years remaining until 2030. Global primary energy intensity was slightly below 3.9 MJ/USD in 2022, indicating that a reduction of more than 27 percent is required until 2030 (figure 4.4).

FIGURE 4.4 • PRIMARY ENERGY INTENSITY, BY WORLD REGION, 2010 AND 2022



Source: International Energy Agency (World Energy Balances) and United Nations Statistics Division (Energy Balances).

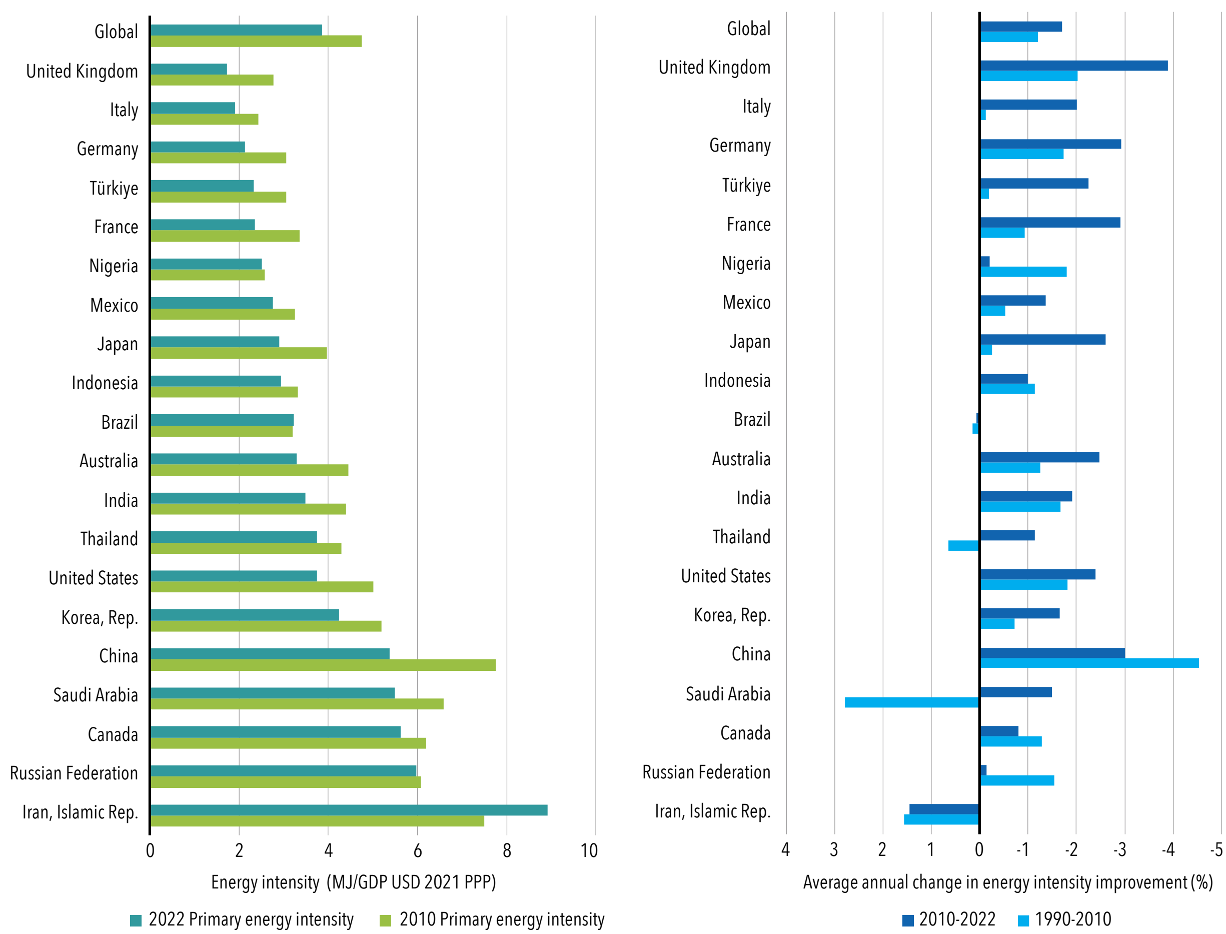
MJ = megajoule; PPP = purchasing power parity.

Trends in the 20 countries with the largest total energy supply

The 20 countries with the largest total energy supply are central to achieving SDG target 7.3, since they represent 75 percent of the world's energy use—and of its GDP. Between 2010 and 2022, energy intensity rates improved relative to the baseline period of 1990–2010 in 15 of these countries. The average improvement rate more than doubled in 2010–22 relative to that in 1990–2010 in nine countries (Australia, France, Italy, Japan, the Republic of Korea, Mexico, Saudi Arabia, Thailand, and Türkiye), but the 2.6 percent required for SDG target 7.3 was met by only China, France, Germany, and the United Kingdom.

Absolute levels of energy intensity differ widely across the selected countries. European countries such as the United Kingdom, Italy, and Germany saw the lowest levels in 2022, at around 2 MJ/USD (2021 PPP) or less. On the other side of the spectrum, Canada, Saudi Arabia, and China reported levels at least 2.5 times more intense, at over 5 MJ/USD. China's energy intensity improvements over 2010–22 were significant: it started in 2010 as the most-energy-intensive major economy, at almost 8 MJ/USD; this had dropped to around 5.5 MJ/USD by 2022 (figure 4.5).

FIGURE 4.5 • LEVELS OF AND CHANGES IN PRIMARY ENERGY INTENSITY IN THE 20 COUNTRIES WITH THE LARGEST TOTAL ENERGY SUPPLY



Source: International Energy Agency (World Energy Balances) and United Nations Statistics Division (Energy Balances)

GDP = gross domestic product; MJ = megajoule; PPP = purchasing power parity.

When analyzing the drivers behind the change in primary energy intensity over 2010–22, several interesting trends emerge. Among emerging markets and developing economies (EMDEs), energy intensity improved in India, China, Indonesia, and Türkiye over 2010–22, and all but Indonesia saw improvement of more than 2 percent on average per year. This was mainly because a high GDP growth rate of at least 4 percent per year, on average, outpaced growth in total energy supply, which was more sluggish, at around 3 percent per year on average. These countries developed rapidly and expanded their economies, thanks in part to a growing (energy-intensive) industrial sector.

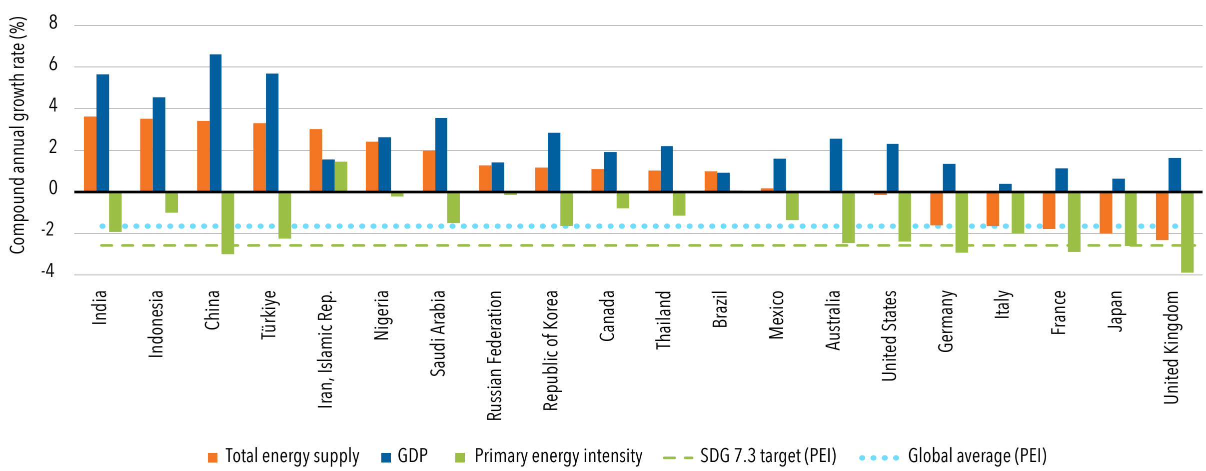
Several advanced economies, on the other hand, also saw their energy intensity improve at 2 percent or more over 2010–22, but due to different reasons. In Germany, Italy, France, Japan, and the United Kingdom, for example, primary energy intensity improved because total energy supply fell while GDP grew moderately, indicating decoupling and a move toward a more energy efficient economy.

In the United States and Australia, meanwhile, energy demand remained relatively stable while the economy grew over 2 percent per year on average, leading to energy intensity improvement of slightly over 2 percent per year. In the Republic of Korea, Thailand, and Mexico, both GDP and total energy supply grew, but the economy grew slightly faster than energy consumption, leading to moderate energy intensity improvement rates.

Economy and energy demand grew in parallel over 2010–22 in EMDEs such as Nigeria and Brazil—meaning energy intensity remained relatively flat. In these countries, just as in Canada, Saudi Arabia, the Islamic Republic of Iran, and the Russian Federation, fossil fuel extraction is an important driver of GDP. As a result, their energy intensity improvement rates have been slightly lower. Policy ambition to move away from fossil fuels to renewables while adopting more efficient electricity-powered technologies can help these countries accelerate progress on energy intensity (figure 4.6).

Energy intensity improved approximately 1.7 percent over 2010–22 globally. Meanwhile, achieving SDG target 7.3 by 2030 requires progress in energy efficiency in the 20 countries with the largest total energy supply. These countries can shift the needle, and will largely determine the global trend in the years to come.

FIGURE 4.6 • AVERAGE ANNUAL CHANGES IN TOTAL ENERGY SUPPLY, GDP, AND PRIMARY ENERGY INTENSITY IN THE 20 COUNTRIES WITH THE LARGEST TOTAL ENERGY SUPPLY, 2010–22



Source: International Energy Agency (World Energy Balances) and United Nations Statistics Division (Energy Balances)

GDP = gross domestic product; PEI = primary energy intensity; SDG = Sustainable Development Goal.

Efficiency trends in end-use sectors

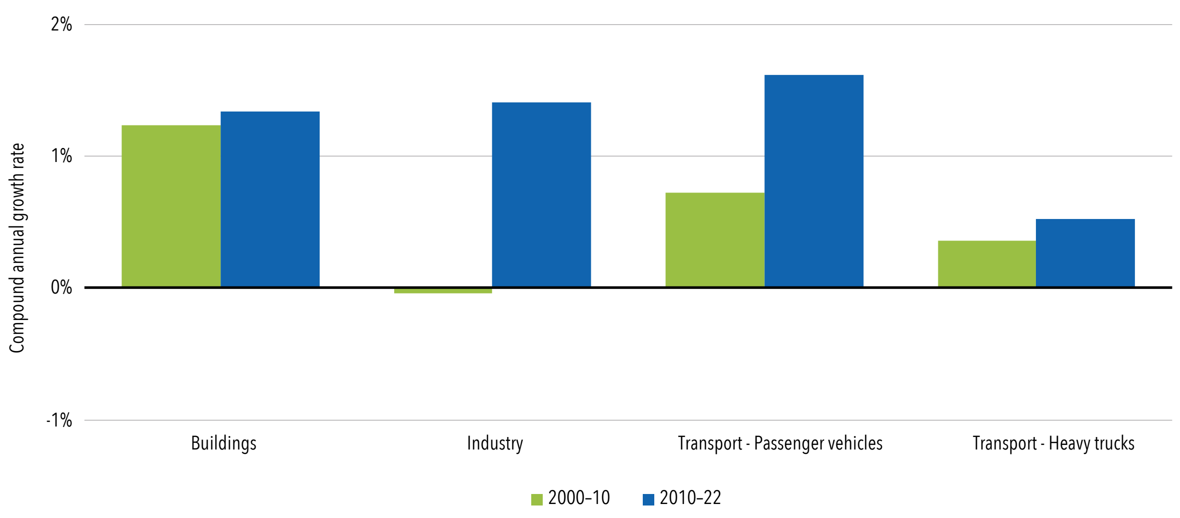
Next to overall energy intensity improvement, it is useful to analyze progress in different end-use sectors. Understanding which sectors are seeing rapid or slow improvement can help policy makers select national policy priorities. Between 2000 and 2010, progress in energy intensity was the fastest for buildings, followed by passenger transport and heavy trucks, whereas industry became slightly more energy intensive.

Between 2010 and 2022, progress in energy intensity across all end-use sectors improved compared with the previous decade. The average annual improvement rate for buildings increased slightly, from 1.2 percent to around 1.3 percent, as existing buildings became more energy efficient through retrofits, electrification of heating, and more efficient appliances, and new construction improved energy efficiency.

Progress compared with the previous decade was the largest for industry, from around 0 percent to 1.4 percent. Industrial processes have become more efficient and less fossil fuel is consumed for industrial heating, adding to efficiency gains.

Passenger vehicles registered a similar step up in energy efficiency, from around 0.7 percent per year on average over 2000–10 to 1.6 percent in 2010–22. This positive trend was driven by improved fuel economy standards and rapid adoption of electric vehicles (EVs), including two- and three-wheelers, and buses. EV sales, however, remain heavily concentrated in China, Europe, and the United States. Improvements compared with the previous decade were the slowest for heavy-duty trucks, from around 0.4 percent per year on average to 0.5 percent (figure 4.7).

FIGURE 4.7 • AVERAGE ANNUAL CHANGE IN ENERGY INTENSITY, BY SECTOR, 2000–10 AND 2010–22



Source: International Energy Agency (World Energy Balances) and United Nations Statistics Division (Energy Balances).

Note: Energy intensity is estimated as the ratio of total final energy consumption for each end-use sector to a sectoral activity indicator: floor space (buildings), value-added (industry), passenger-kilometers (passenger vehicles), or metric ton-kilometers (heavy trucks). These indicators are obtained from IEA's Global Energy and Climate Model. Their positive values denote an improvement (decrease) of energy intensity.

Trends in the efficiency of electricity generation

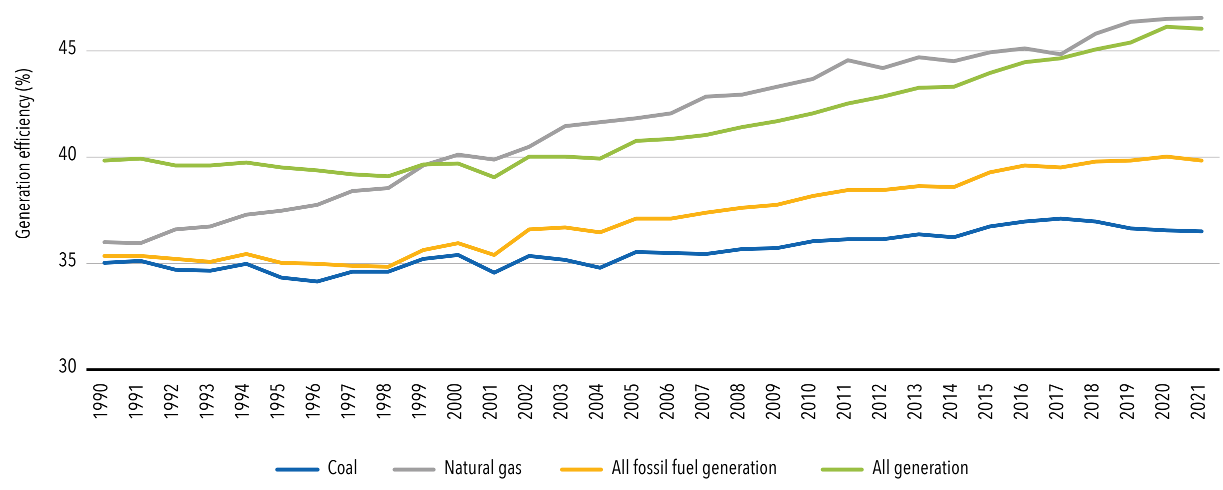
Primary energy intensity can also be lowered by boosting the efficiency of electricity generation, thus reducing primary energy use. Measures include modernizing infrastructure to reduce transmission and distribution losses, improving the efficiency of fossil fuel generation, phasing out inefficient power plants, and increasing renewables' share of the electricity generation mix.

Analysis of the two major fossil fuels used for electricity generation—coal and natural gas—shows that average efficiency increased between 2000 and 2022, after flat improvement rates in the 1990s. Efficiency improvements from natural gas offset slower improvements from coal generation (figure 4.8). An important factor influencing supply efficiency is renewables' share of the electricity generation mix. By convention, most renewable energy technologies are treated as 100 percent efficient, even though the conversion of resources such as sunlight and wind into electricity generates minor losses. Increasing renewables' share of the mix thus has a direct impact on the efficiency of electricity generation. The rapid deployment of renewable energies, especially in the past 15 years, has contributed to overall generation efficiency.

Between 1990 and 2010, overall generation efficiency increased from around 40 to 42 percent. Between 2010 and 2022, it increased further, to around 46 percent. Thus, in almost half the number of years, generation efficiency improved by twice as many percentage points. This growth was largely driven by the greater use of renewable energy to generate electricity. Between 2010 and 2022, the efficiency of coal-based generation remained flat, at around 36 percent, whereas that of gas-based generation improved moderately, from around 44 percent to nearly 47 percent.

Renewable energy is set to experience steady growth between 2022 and 2030, boosting overall generation efficiency further. Global natural-gas-fired generation is expected to see moderate but steady average annual growth, at about 1 percent, over 2025–27, and global coal-fired generation is expected to stagnate in the same period.

FIGURE 4.8 • GLOBAL ELECTRICITY GENERATION EFFICIENCY, BY FUEL TYPE AND OVERALL EFFICIENCY, 1990–2022



Source: International Energy Agency (World Energy Balances) and United Nations Statistics Division (Energy Balances).

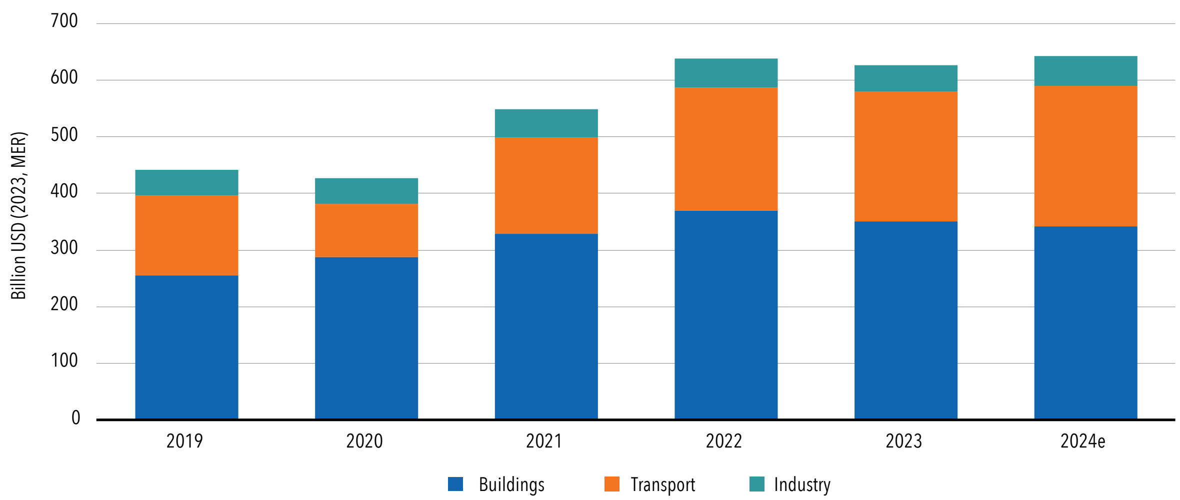
Investment in efficiency, electrification, and end-use renewables

Investment in energy efficiency, electrification, and end-use renewables has risen around 45 percent since 2019, reaching a total of about USD 640 billion. End-use investment in transport has grown the fastest, at around 77 percent, followed by 34 percent in buildings and 13 percent in industry. Total end-use-related investment grew around 16 percent relative to 2021, reaching new heights. The buildings sector represents the largest share of global end-use investment, at around USD 370 billion, followed by transport, at nearly USD 220 billion.

In 2023, efficiency investments in buildings are estimated to have fallen by around 5 percent and in industry by 8 percent. Strong EV sales supported the growth of end-use-related investments in transport by around 6 percent, although the total for 2023 is estimated to have remained relatively stable. The headwinds in the buildings and industrial sectors were partly caused by macroeconomic factors such as high inflation and high interest rates. This made efficient technologies more expensive to purchase and also meant that access to affordable finance to fund the investments was more limited.

Global end-use investment was still heavily centralized in the United States, Europe, and China, which together accounted for around three-quarters of the global total. EMDEs represented a smaller portion of efficiency-related investment, even though these countries represent over one-third of the global GDP. End-use investment is estimated to have grown strongly in EMDEs in 2023, however, including 10 percent growth in buildings. Europe, Asia Pacific, and Northern America registered combined end-use investment growth of 55 percent from 2019 to 2023. Europe represented the largest regional market, at USD 200 billion—a third of global investment—followed closely by China, also accounting for almost a third. Other Asia Pacific countries, such as India, Japan, and the Republic of Korea, together with Northern America, accounted for the other third of total investments (figure 4.9).

FIGURE 4.9 • GLOBAL INVESTMENT IN ENERGY EFFICIENCY, ELECTRIFICATION, AND RENEWABLES FOR END USES BY SECTOR, 2017–24E



Source: IEA 2024d.

Note: An energy efficiency investment is defined as the incremental spending on new energy-efficient equipment or the full cost of refurbishments that reduce energy consumption. The intention is to capture spending that leads to reduced energy consumption. 2024e = estimated values. MER = Market exchange rate.

Policy recommendations

Primary energy intensity improved by around 2.1 percent globally in 2022—more than four times the rate of 2021. This was driven by the 2022 global energy crisis, which triggered major shocks to energy demand in many regions. However, the energy intensity improvement of 2022 remains insufficient to achieve SDG target 7.3, which requires intensity to improve 2.6 percent per year between 2010 and 2030. The world is thus not yet on track to achieve the target for 2030. Given the slower than required progress in recent years, energy intensity must now decline by at least 4.0 percent on average per year through 2030 if target 7.3 is to be met.

Estimates for 2023 and 2024 indicate a slowdown in progress as energy intensity improvement drops to approximately 1 percent per year as some of the pressures of the 2022 global energy crisis ease off. While there are still significant regional differences in 2023, estimates for 2024 indicate smaller regional variations. Progress is set to slow slightly in advanced economies while remaining steady or increasing slightly in many EMDEs.

Energy efficiency policies and investments in cost-effective measures need to be scaled up significantly if the global target is to be met. Global investment in energy efficiency and electrification increased rapidly over 2019–22, but this growth is estimated to have stabilized in 2023 and 2024. Government support is crucial to enable consumers to invest in energy-efficient technologies, which can significantly lower energy bills. Universal access to electricity and clean cooking, increased electrification, and the incorporation of renewable energies improve energy intensity by making energy end uses significantly more energy efficient and reducing supply-side inefficiencies. More joint efforts are needed to leverage the synergies between the various SDG 7 targets.

Energy efficiency can deliver many shared benefits to people, such as lowering energy bills, improving health outcomes, and creating new jobs. A strong, early focus on energy efficiency is essential to achieve net zero emissions by 2050. But despite the many benefits of energy efficiency, there are still obstacles preventing people and businesses from investing in energy efficiency improvements. Faster progress in efficiency requires a people-centered approach to ensure fair outcomes, improve skills, create decent jobs, and bring about social and economic development, while engaging people as active participants.

In all sectors, the greatest efficiency gains are achieved by a package of policies that combine three main types of mechanisms: regulation, information, and incentives. Careful policy design and implementation will help leverage energy efficiency's full potential to bolster energy security, create jobs, increase living standards, cut energy bills, and reduce emissions. Successful examples of implementation have the potential to be replicated to boost energy efficiency globally. IEA has published an Energy Efficiency Policy Toolkit summarizing the main tools to be used across sectors (IEA 2024b). Both the technologies and the resources to double energy efficiency improvement by 2030 are available (UN 2021). While countries should work to develop a framework that includes different instruments and covers multiple sectors, in the short term, prioritization can be useful. Some policies can be implemented faster or can have larger effects. This depends on national circumstances, such as the existing policy mix, the structure and size of the economy, available fiscal space, and the country's institutions.

Buildings

Buildings account for about 30 percent of the world's final energy consumption and more than half its electricity consumption (IEA 2024a). To stay on the pathway toward net zero emissions by 2050 and accelerate the rate of energy intensity progress between now and 2030, buildings need to rapidly become more efficient.

Building energy codes set the minimum requirements for energy use in buildings. They may establish the requirements for the overall energy efficiency of an entire building (performance-based codes) or of individual building components, such as insulation, lighting systems, or heating and cooling systems (prescriptive codes). They may also include both types of requirements to provide flexibility to the market. Only energy-code-compliant buildings may be constructed. Building energy codes can also include requirements for on-site renewable energy production, embodied carbon, energy management, and the integration of smart appliances and equipment to enable a demand response. New buildings as well as existing buildings undergoing major renovations could be subject to building energy codes, which can make buildings more efficient and help the industry prepare for, and adapt to, market changes. As of 2024, approximately 85 building energy codes were implemented globally, with around half of the newly constructed buildings subject to energy efficiency requirements (IEA 2024a).

To complement building energy codes, countries can mandate **energy performance certificates** (EPCs), which offer information on a building's energy performance and energy demand, indicating how efficient—and often how environmentally friendly—the building is. EPCs can differ, but some of the key elements may include an energy efficiency rating, property details, energy efficiency recommendations, and the estimated energy use and carbon emissions.

For existing buildings, **retrofit grants** are an effective incentive tool to promote efficiency. Grants can reduce the up-front costs of energy-efficient technologies and make them more financially viable for consumers. This can help create a market pull, encouraging stakeholders to comply with energy efficiency regulations by implementing efficiency measures to improve the energy performance of buildings. Grants typically provide payment before the retrofit is done and cover part of the costs, for example, of adding insulation, upgrading heating or cooling systems, or installing solar photovoltaics.

Other supportive measures include mandatory energy and/or carbon disclosure programs at the point of a building's sale and/or lease; other financial and nonfinancial incentives linked to the building's energy performance; utility-based rewards and procurement regulations; periodic energy audits for large consumers; and training for architects, builders, building assessors, and inspectors.

Appliances

Appliances represent 45 percent of a typical building's electricity use and are responsible for almost 3 gigatons of carbon dioxide ($GtCO_2$) emissions a year (IEA 2024b). To stay on the pathway toward net zero emissions by 2050 and accelerate the global rate of energy intensity improvement between now and 2030 would require appliances to be 30–40 percent more efficient by 2030.

Minimum energy performance standards (MEPS) for appliances establish a minimum efficiency threshold to address efficiency improvement barriers, such as potentially higher purchase prices or product availability, and ensure fair competition in competitive markets. Equipment that does not comply with these minimum requirements may not be sold on the market. The MEPS-induced turnover of a product's stock occurs over a longer or shorter time period depending on the product's lifetime and possible policies to incentivize early replacement, such as financial rewards. Through MEPS, only more efficient products may be sold as new equipment. Less efficient equipment will leave the stock gradually as it is replaced. MEPS are among the longest standing energy efficiency policy instruments and are often quite cost-effective in improving the energy efficiency of products on the market. Comprehensive, harmonized, and regularly updated MEPS are crucial to accelerating efficiency improvement. As of 2023, more than 115 countries, representing 98 percent of global electricity consumption, have MEPS for at least some appliances (IEA 2024b).

Labeling programs can complement MEPS. They provide information to support decisions toward purchasing more energy-efficient products. Comparative labels, which are often mandatory, have a classification scale, which enables consumers to compare the energy performance of different products and is generally found on all products of the same type. Endorsement labels, which are voluntary, are found only on best-in-class models or those exceeding a certain efficiency level. These two types can also complement each other. Today, 107 countries have a labeling scheme for appliances.

Attractive **loans and rebates** can incentivize the adoption of more efficient appliances by helping to lower the up-front investment costs of appliances and offering financial support. They encourage consumers to buy more efficient products and motivate suppliers to produce them. Incentives also drive innovation and the adoption of new technology and practices. Rebates and loans are regularly combined in one policy instrument. Rebates can be expensive for governments, nevertheless, and require careful design. Low-cost loans provide funding up front and are available for highly efficient models. In many cases, the eligibility criteria include scrapping an old but functioning appliance.

Industry

Industry accounts for 37 percent of global final energy consumption (IEA 2024a) and around 20 percent of global greenhouse gas emissions (UNEP 2024). To stay on the pathway toward net zero emissions by 2050 and accelerate the rate of global industrial annual energy intensity improvement between now and 2030, industry needs to decouple the production of outputs from energy demand and increase the share of electricity in its energy consumption to 30 percent by 2030, from 23 percent in 2022 (IEA 2024b).

MEPS for industrial electric motors are a regulatory instrument in the industry policy package. They establish the requirements for a minimum level of energy efficiency that electric motors must meet in order to be sold in a particular jurisdiction. MEPS typically specify these minimum efficiency levels based on the motors' size, type, and application. Motors meeting or exceeding the specified efficiency levels are considered compliant, and noncompliant models are not allowed to be sold on the market. Efficiency is generally measured as the ratio of a motor's output power (mechanical power delivered to the load) to its input power (electrical power consumed).

MEPS for electric motors are often based on international standards for efficiency classes, and they can help countries meet their energy efficiency and carbon dioxide emission targets. These standards not only support motors in becoming more efficient overall, but they also help ensure efficiency levels across manufacturers are comparable for motor users. MEPS for industrial electric motors have been implemented in 62 countries, covering over half of the global industrial motor fleet as of 2022 (IEA 2024a).

Industrial energy efficiency networks (EENs) promote the exchange of energy-efficiency-related knowledge and information. They differ in structure but generally consist of a group of energy managers from different industrial sites that meets regularly to share knowledge and experience on improving industrial energy efficiency. They can operate solely for information exchange among peers, or they can include elements such as energy reporting and the setting of energy saving targets. These networks act to guide industries in becoming more efficient, in line with government policies, and to provide governments with improved industry-specific insight to develop more effective policy. There are over 1,000 industrial EENs worldwide (IEA 2024b), and this number is growing as governments seek to expand their policies and industries seek to reduce costs, energy consumption, and emissions.

Energy management systems (EnMSs) enable energy consumers to manage their energy consumption for energy efficiency as well as saving costs. A key framework for EnMSs is the international standard ISO 50001, which is based on a continuous cycle of monitoring, targeting, and implementing efficiency measures. In 2023, the International Organization for Standardization issued certificates in 105 countries; 58 percent of the 9,500 certificates awarded to industry were to those that were less energy intensive.

Transport

Private cars and vans were responsible for more than 25 percent of global oil use (IEA 2024c) and around 10 percent of energy-related CO2 emissions in 2022 (IEA 2024a). To stay on course toward net zero emissions by 2050 and accelerate the rate of global annual energy intensity improvement between now and 2030, cars need to become 5 percent more efficient every year (IEA 2024b).

Fuel economy standards regulate the efficiency of new vehicles by, in the simplest terms, defining annual corporate average standards, or targets, for fuel economy (miles per gallon or kilometer/liter) or greenhouse gas (GHG/CO2) emissions (in grams per mile/kilometer). There are different designs, but, in general, they define a standard for all auto manufacturers, for every year that the regulation applies. Some countries offer flexibility mechanisms, for example, credits for overcompliant manufacturers, which they can use in future years or trade with underachieving manufacturers. Fuel economy standards have increasingly included provisions to facilitate the adoption of EVs (including battery electric and plug-in hybrids) and fuel cell vehicles. These standards support the development of advanced technologies; can significantly reduce fuel use, boost energy security, and reduce emissions; help increase regulatory certainty for manufacturers; and may be most appropriate in countries with large markets and vehicle manufacturing facilities. Currently, fuel economy or emission standards for new cars exist in more than 40 countries (IEA 2024a), covering over 80 percent of new passenger vehicle sales globally.

Vehicle efficiency labels can complement fuel economy standards and provide consumers with information that helps them identify the most efficient vehicles. They can cover new and used vehicles, benefiting all vehicle purchasers. Labels can be in different formats, including displayed on vehicles in car showrooms and online. Increasingly, EVs feature labels with metrics that also include a vehicle's driving range. National comparison websites can also help potential buyers identify the most-fuel-efficient vehicles by category. Consumers can compare makes and models and identify the best-performing vehicles. In addition to information on fuel economy, labels can also include information on CO2 and air pollutant emissions, as well as information on fuel cost savings. Information on fuel cost savings will help buyers choose vehicles that cost less to run. Today, over 35 countries across the world have vehicle efficiency labels (IEA 2024b).

Subsidies for passenger EVs play a key role in accelerating electric car sales, especially to early adopters, and are in place in many markets. They can accelerate EV adoption by reducing the price gap between EVs and vehicles with internal combustion engines. Subsidies are typically in the form of discounts or rebates. They can also be implemented as tax reductions through income tax credits. Discounts and rebates are the most commonly used incentives to lower the purchase price of EVs. They can be fixed direct discounts deducted from a vehicle's cost at the point of sale, or rebates/refunds assigned once a vehicle has been purchased. Subsidies, which boost EV adoption, have been implemented in most major EV markets. The incentive levels and eligibility requirements differ, and consumers can, accordingly, choose more efficient or more affordable EV models.

Agriculture

Energy is needed at every stage of agrifood systems. The adoption of energy efficiency measures across agrifood value chains can help agrifood systems be more sustainable and resilient. Key steps include optimizing the efficiency of the use of agricultural inputs (e.g., mechanization, fertilizers, and irrigation systems); reinforcing insulation in biogas plants and integrating heat recovery systems while maintaining productivity levels; reducing the distance between points of agricultural goods' production and consumption; and enhancing cold chains to reduce energy use and minimize food loss and waste.

Cross-cutting

As electricity systems accommodate more renewables, there is a growing need for new sources of flexibility, driving greater interest in **demand-side management**. Today, almost all flexibility comes from traditional thermal-powered generation and hydropower. However, as variable renewables increase, demand response enabled by smart, connected appliances and efficient user behavior, as well as battery storage, are emerging as effective sources of flexibility. Future energy systems are expected to include several integrated and interconnected flexibility services. Digitalization can also play an important role in energy management, helping energy users manage their electricity load.

Energy efficiency obligation (EEO) schemes require the "obligated parties" to meet the energy or emission savings targets within their customer portfolios. Obligated parties may be energy utilities, retail energy sales companies, energy distributors, transport fuel distributors, and/or transport fuel retailers. EEO schemes are market-based instruments that do not prescribe measures to be deployed by obligated parties to meet their set targets (within certain limits). Some EEO schemes include "white certificates" (also called energy savings certificates), documents certifying that a certain reduction of energy or emission consumption has been achieved. White certificates are typically tradable between over- and under-performers and combined with an obligation to achieve a certain energy or emission savings target. EEO schemes are in use in 31 countries, and their number has grown steadily over the past 20 years (IEA 2024b).