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CHAPTER 4
ENERGY EFFICIENCY

Main messages

- **Global trend.** Primary energy intensity[23] (defined as the ratio of total energy supply to gross domestic product) improved—that is, decreased—by only 0.8 percent in 2021. This is well below the decade's average rate of improvement and marks the second year in a row of rates under 1 percent. Also in 2021, global energy intensity stood at 4.59 megajoules (MJ) per 2017 US dollar. The year's slow progress in energy efficiency coincided with a robust economic recovery from the onset of the COVID-19 pandemic, a recovery that saw the largest annual increase in energy consumption in 50 years. This increase—of over 5 percent—reflected a shift toward energy-intensive industries and the recovery of other demand sectors amid the easing of lockdowns.
- **2030 target.** Energy intensity improvements continue to fall short of the United Nations' Sustainable Development Goals (SDGs), which aims to double the global rate of improvement in energy efficiency between 2010 and 2030 compared with the 1990–2010 baseline. From 2010 to 2021, global energy intensity improved by an annual average rate of 1.6 percent—better than the 1.2 percent rate from 1990 to 2010, but below the 2.6 percent set out in SDG target 7.3. The particularly low rates of 2020 (0.6 percent) and 2021 (0.8 percent) played a significant part in the decade's low average. To meet SDG target 7.3 by 2030, annual improvements through 2030 must now accelerate to over 3.8 percent. Prioritizing energy efficiency in policy and investment can help the world achieve this target, promote economic development, improve health and well-being, and ensure access to clean energy.
- **Regional highlights.** No region achieved the 2.6 percent improvement rate set by SDG target 7.3 between 2010 and 2021. Eastern and South-eastern Asia came closest, at 2.2 percent. Oceania reached 2.0 percent, in part thanks to its exceptional progress in 2021, when energy intensity decreased 7 percent. Average annual improvement rates of 1.8 percent in both Northern America and Europe, and Central and Southern Asia were also above the global average and historical trends. In contrast, Western Asia and Northern Africa (0.8 percent), Latin America and the Caribbean (0.7 percent), and Sub-Saharan Africa (1.1 percent) performed below historical averages.
- **Trends in the top 20 countries with the largest total energy supply.** Between 2010 and 2021, 13 of the 20 countries with the largest total energy supply[24] saw their average annual rate of improvement in energy intensity accelerate compared with the 1990–2010 baseline. However, only the United Kingdom (3.4 percent), China (3.2 percent), and Indonesia (3.0 percent) exceeded SDG target 7.3. The improvement rates in Japan and Germany fell slightly short of 2.6 percent, after an increase in their energy intensity in 2021.

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23 Hereafter referred to as *energy intensity.* See note to figure 4.9 for a definition of energy intensity by sector.

24 At the country level, total energy supply is made up of production + imports - exports - international marine bunkers - international aviation bunkers ± stock changes. It represents the total energy used within a country, taking into account losses in transformation and other processes.

- **End-use trends.** Improvement in energy intensity quickened in all but one sector in 2010–21 compared with the previous decade. The exception was the residential buildings sector, where the improvement rate fell by half, to less than 1 percent a year on average. Passenger transport sustained nearly the same annual rate as that of the previous decade, while freight transport's rate declined slightly. Progress was also evident in industry, at over 1.6 percent.
- **Electricity supply trends.** Since 2010, the efficiency of generating electricity from fossil fuels has steadily improved, despite a slowdown in 2021 following a record increase in energy demand. The growing share of renewables in electricity generation is also contributing to efficiency gains on the supply side, as they do not incur the thermal losses of converting fossil fuels into electricity. This link between renewable energy[25] and a lower energy intensity highlights the synergies between SDG targets 7.2 (increasing renewable energy) and 7.3 (improving energy efficiency).

Are we on track?

SDG 7 commits the world to ensure universal access to affordable, reliable, sustainable, and modern energy. Target 7.3 calls for doubling the global rate of energy intensity improvement relative to the 1990–2010 average. This means improving energy intensity on average by 2.6 percent per year from 2010 to 2030.[26]

Energy intensity is the ratio of total energy supply to gross domestic product, revealing the energy used per unit of wealth created. It helps track changes in energy use and the factors influencing these rates, such as economic structure, weather, and behavior changes. All these 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 the target. But because global progress has been slower in all years except 2015, the rate required from 2021 forward is on average 3.8 percent. This figure is in line with the Net Zero Emissions by 2050 Scenario of the International Energy Agency (IEA), which requires average rates of improvement of slightly over 4 percent until 2030, and with the goal of doubling the global average annual rate of energy efficiency improvement by 2030 agreed during the 2023 United Nations Climate Change Conference (COP28).[27]

25 Primary renewable electricity 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 because of conversion losses.

26 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 target 7.3 of improving energy intensity by 2.6 percent per year in 2010–30 remains the same, however. Detailed datasets with country data for the SDG 7 indicator discussed in this chapter can be accessed at no charge at https://trackingsdg7.esmap.org/downloads.

27 The Net Zero Emissions by 2050 Scenario maps a way to achieve a 1.5°C stabilization in the rise in global average temperatures alongside universal access to modern energy by 2030.

Recent numbers[28] show that global energy intensity improved by only 0.8 percent in 2021, to 4.59 MJ/USD (2017 PPP [purchasing power parity]), in a context of a strong economic rebound after the COVID-19 crisis and the largest annual increase in total energy supply in the past 50 years (figure 4.1). For the second year in a row, the improvement rate was well below long-term averages (figure 4.2).

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

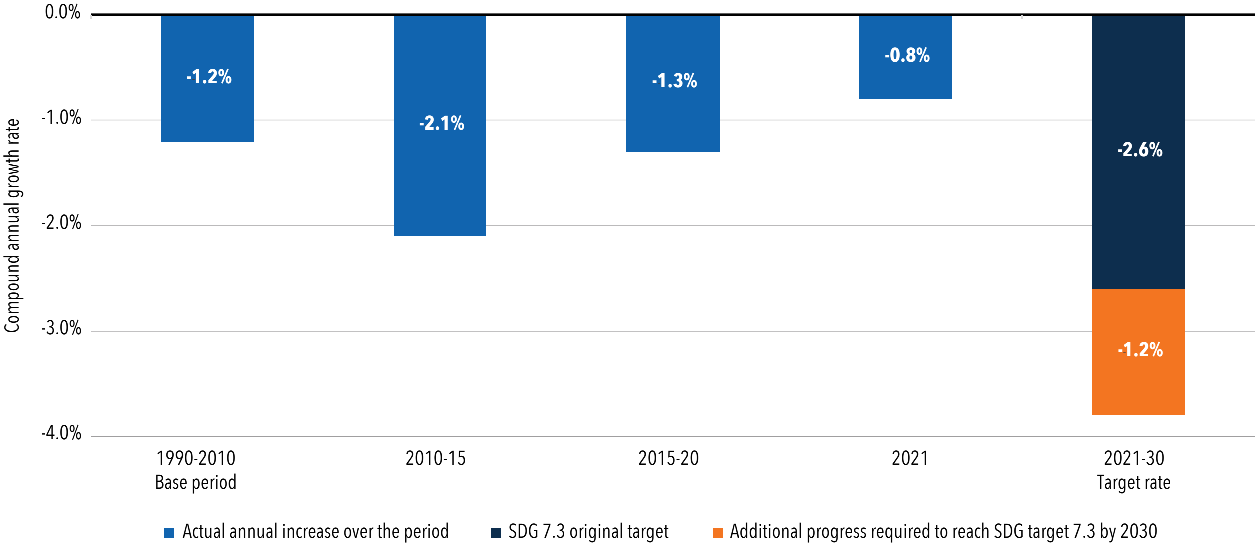
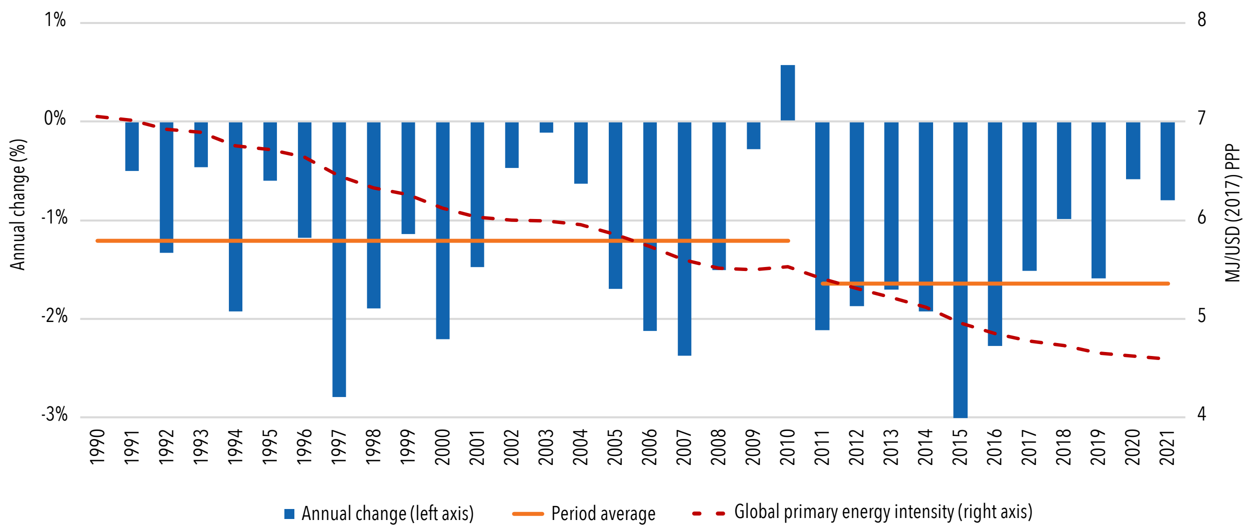


FIGURE 4.2 • GLOBAL PRIMARY ENERGY INTENSITY AND ANNUAL CHANGE, 1990–2021



MJ = megajoule; PPP = purchasing power parity.

28 The majority of the energy data in this chapter (including the data used in nearly all of the figures) comes from a joint data set 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 are primarily sourced from the International Monetary Fund's World Economic Outlook database (https://www.imf.org/en/Publications/SPROLLs/world-economic-outlook-databases), complemented by data from the World Bank's World Development Indicators (https://databank.worldbank.org/source/world-development-indicators) and the CEPII's CHELEM database (http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=17).

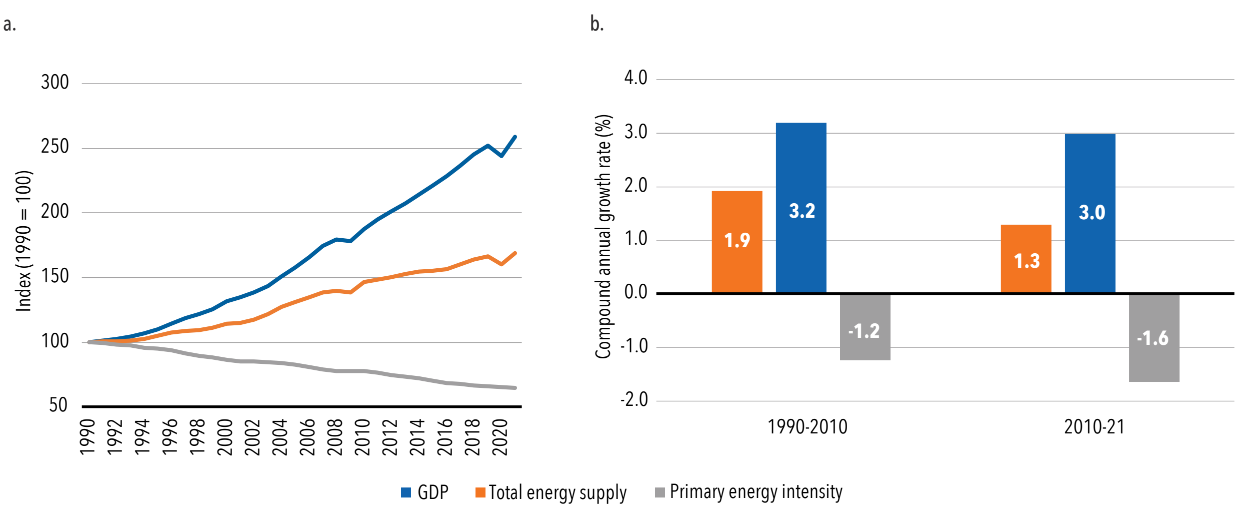
Looking beyond the main indicators

COMPONENT TRENDS

The year 2021 was marked by a strong economic rebound following the COVID-19 crisis. Globally, economic growth reached almost 6.2 percent, and total energy supply increased 5.4 percent. As GDP increased slightly more than energy supply, energy intensity improved (decreased), but this improvement was similar to that of the previous year, because of a larger share of energy-intensive industry in energy demand and the recovery of other demand sectors that had been affected by lockdowns the previous year.

Over the longer term, the impact of improvements in energy intensity is revealed by trends in its underlying components (figure 4.3). Between 1990 and 2021, global GDP increased by a factor of 2.6, and global total energy supply grew by 69 percent (or a factor of 1.69).[29] This decoupling of energy use from economic growth yielded a consistent improvement in global energy intensity, which fell by more than a third between 1990 and 2021.

FIGURE 4.3 • CHANGES IN COMPONENTS OF GLOBAL PRIMARY ENERGY INTENSITY, 1990–2021



GDP = gross domestic product.

At 3.0 percent a year, average economic growth in 2010–21 was slightly lower than growth in 1990–2010 (3.2 percent). Energy demand increased only 1.3 percent a year, revealing how the decoupling of the two is accelerating and that similar levels of GDP growth can be achieved with a smaller increase energy consumption.

The fastest improvement rate was 2.1 percent between 2010 and 2015. Progress slowed to 1.2 percent in 2015–21, in large part because of the pandemic's impact in 2020 and 2021. For 2022, values are expected to have returned to earlier levels, but more effort is needed to reach the required 3.8 percent.

29 *Total primary energy supply was renamed total energy supply*, in accordance with the International Recommendations for Energy Statistics (UN 2018).

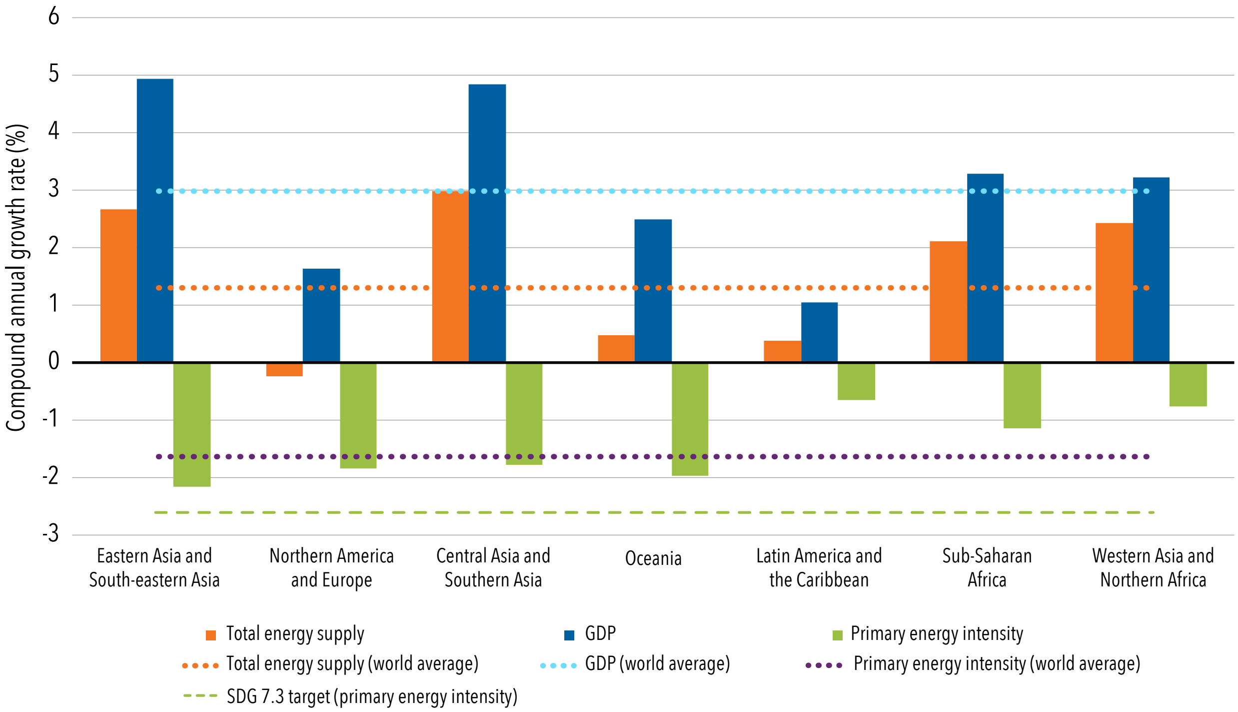
REGIONAL TRENDS

The COVID-19 crisis affected energy consumption and GDP across the world. All regions saw weaker or declining GDP in 2020, followed by a rebound in 2021, with variations depending on the timing and length of pandemic-related restrictions. In 2021, the economic recovery led to GDP growth of at least 4.5 percent in every region, with Central and Southern Asia growing at 7.6 percent. At the same time, energy consumption increased significantly in all regions, except Oceania, limiting reductions in energy intensity.

Despite the large increase in energy consumption, all regions reduced their energy intensity. Oceania achieved the greatest improvement, at almost 7 percent. Northern America and Europe lowered their energy intensity by a mere 0.2 percent, putting downward pressure on global progress.

Energy intensity has improved across the world since 2010, with significant differences across regions (figure 4.4). Economies in Asia, excluding the Middle East, saw a rapid increase in economic activity and a slower rise in total energy supply, thanks to substantial improvements in energy efficiency. Given Asia's large population, the effect on the global average was significant.

FIGURE 4.4 • AVERAGE ANNUAL CHANGES IN TOTAL ENERGY SUPPLY, GDP, AND PRIMARY ENERGY INTENSITY, BY REGION, 2010–21

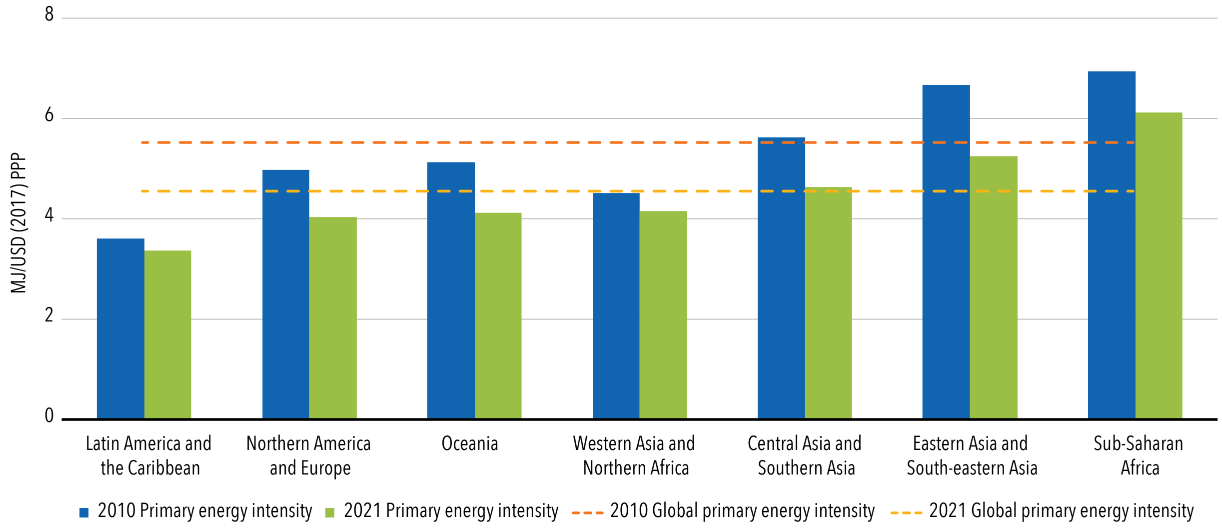


GDP = gross domestic product; SDG = Sustainable Development Goal.

Over the same period, countries in Northern America and Europe experienced much slower economic growth but also a decrease in their total energy supply, thanks to a decoupling of the economy from energy usage. This trend was enabled by a continued shift toward less-energy-intensive activities (such as services) and the impacts of long-standing energy efficiency policies, first implemented during the 1970s. Also in these regions, energy intensity improved at a rate slightly above global trends, and their energy intensity level stayed below the global average (figure 4.5). Similar trends are evident in Oceania, where total energy supply increased modestly while GDP grew more rapidly than in Northern America and Europe.

Latin America and the Caribbean, Western Asia and Northern Africa, and Sub-Saharan Africa recorded the smallest average improvements in energy intensity from 2010 to 2021 (1 percent per year or less). In Latin America and the Caribbean, total energy supply slightly increased and GDP growth was among the lowest worldwide, but the region was also the least energy intensive in the world, at 3.36 MJ/USD (2017 PPP) (figure 4.5). In contrast, in Western Asia and Northern Africa, and in Sub-Saharan Africa, growth in total energy supply and GDP exceeded the global average. Economic output in Sub-Saharan Africa was highly energy intensive, at 6.12 MJ/USD (2017 PPP); the intensity for Western Asia and Northern Africa was much lower, at 4.15 MJ/USD (2017 PPP).

FIGURE 4.5 • PRIMARY ENERGY INTENSITY, BY REGION, 2010 AND 2021



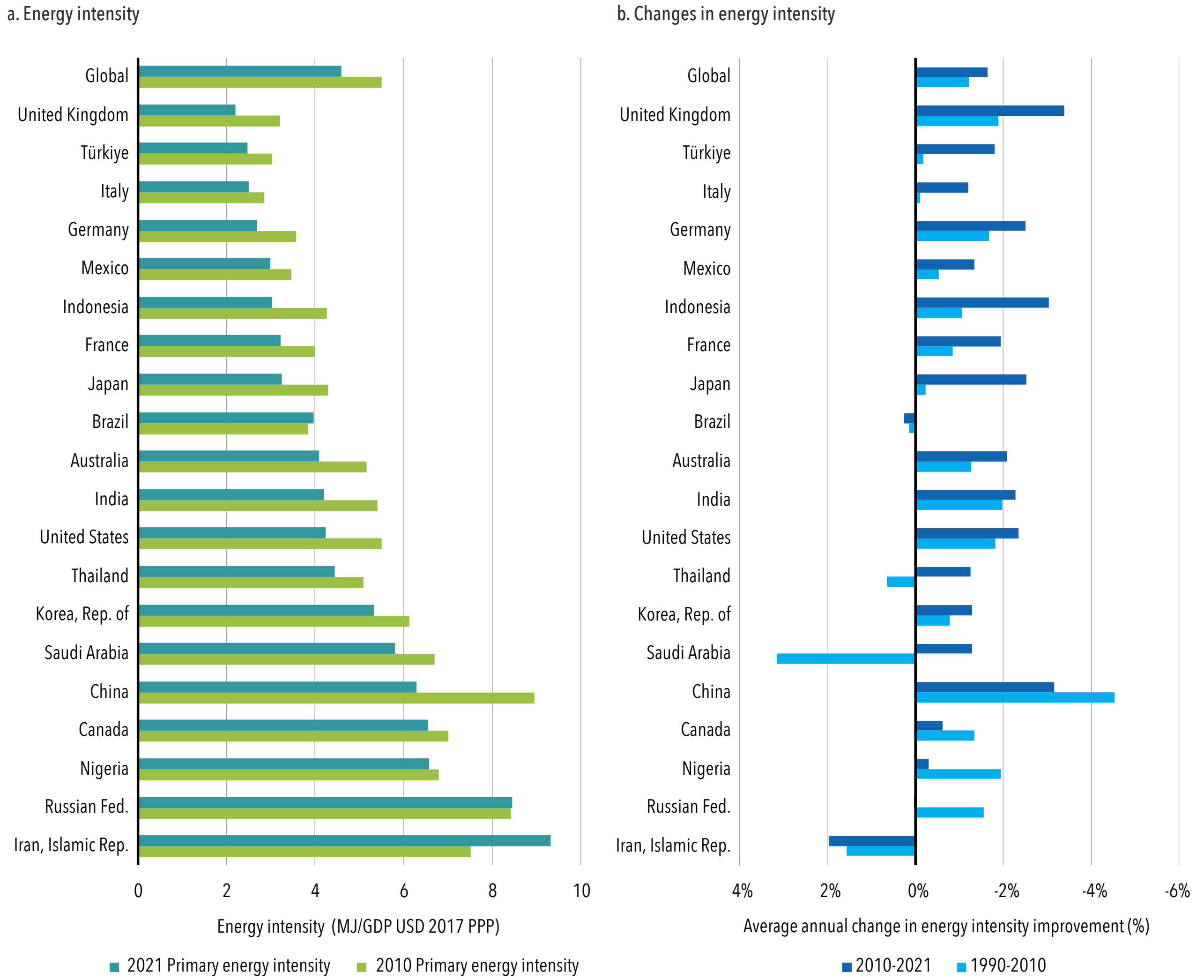
MJ = megajoule; PPP = purchasing power parity.

Three regions—Eastern Asia and South-eastern Asia, Latin America and the Caribbean, and Western Asia and Northern Africa—doubled the rate of improvement of energy efficiency in 2010–21 compared with 1990–2010. However, for the latter two, these rates remained low, at 0.7 and 0.8 percent, respectively.

TRENDS IN TOP 20 COUNTRIES WITH LARGEST TOTAL ENERGY SUPPLY

The 20 countries with the largest total energy supply are central to achieving SDG target 7.3, as they represent three-quarters of global GDP and energy consumption. Between 2010 and 2021, 13 of these countries improved their energy intensity rates relative to the previous decade. However, only China, the United Kingdom, and Indonesia exceeded the 2.6 percent improvement required (figure 4.6). This group included two others, Japan and Germany, until a slowdown in 2021 pulled their average below the threshold. Six countries (Mexico, France, Indonesia, Japan, Türkiye, and Italy) more than doubled their improvement rates in 2010–21 compared with 1990–2010.

FIGURE 4.6 • LEVEL OF AND CHANGES IN PRIMARY ENERGY INTENSITY IN THE 20 COUNTRIES WITH LARGEST TOTAL ENERGY SUPPLY



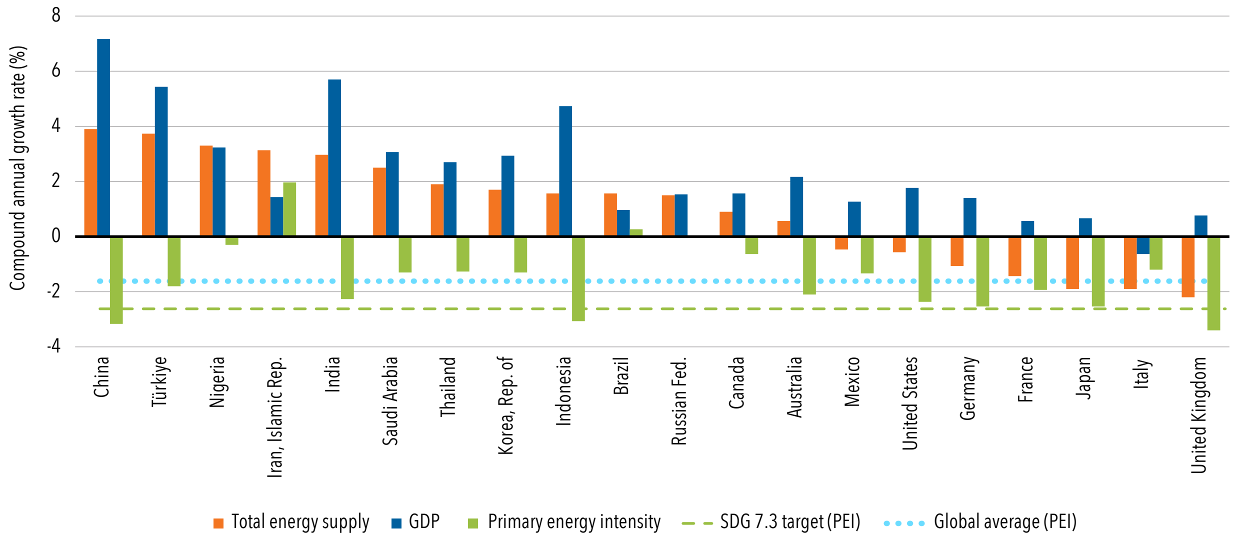
GDP = gross domestic product; MJ = megajoule; PPP = purchasing power parity.

However, in more than half of the top 20 countries, the COVID crisis reversed the trend. In 2020, four of them—China and the United Kingdom (which had significantly reduced their energy intensity over the decade), Mexico, and Australia—saw energy intensity improvement fall to its lowest level in a decade. Most of the 20 major countries improved their energy intensity levels in 2021, but 6 became more energy intensive, lowering the global average.

In absolute terms, the energy intensity of the 20 countries with the largest total energy supply ranges from slightly over 2 MJ/USD to more than 9 MJ/USD. Economies that rely heavily on extractive industries, such as fossil fuel producers, or energy-intensive industries tend to have much higher energy intensity due to their economic structure, not necessarily because of lower efficiency.

Countries where fossil fuel extraction is a major part of GDP—namely, the Islamic Republic of Iran, Brazil, Nigeria, Saudi Arabia, the Russian Federation, and Canada—are among those with the slowest progress. High energy intensity indicates the potential for a transition toward the use of cleaner and more efficient energy sources to achieve significant progress. The annual rate of change in energy intensity is an important indicator and policy target for tracking both diversification and energy efficiency goals.

FIGURE 4.7 • AVERAGE ANNUAL CHANGES IN TOTAL ENERGY SUPPLY, GDP, AND PRIMARY ENERGY INTENSITY IN THE 20 COUNTRIES WITH THE LARGEST TOTAL ENERGY SUPPLY



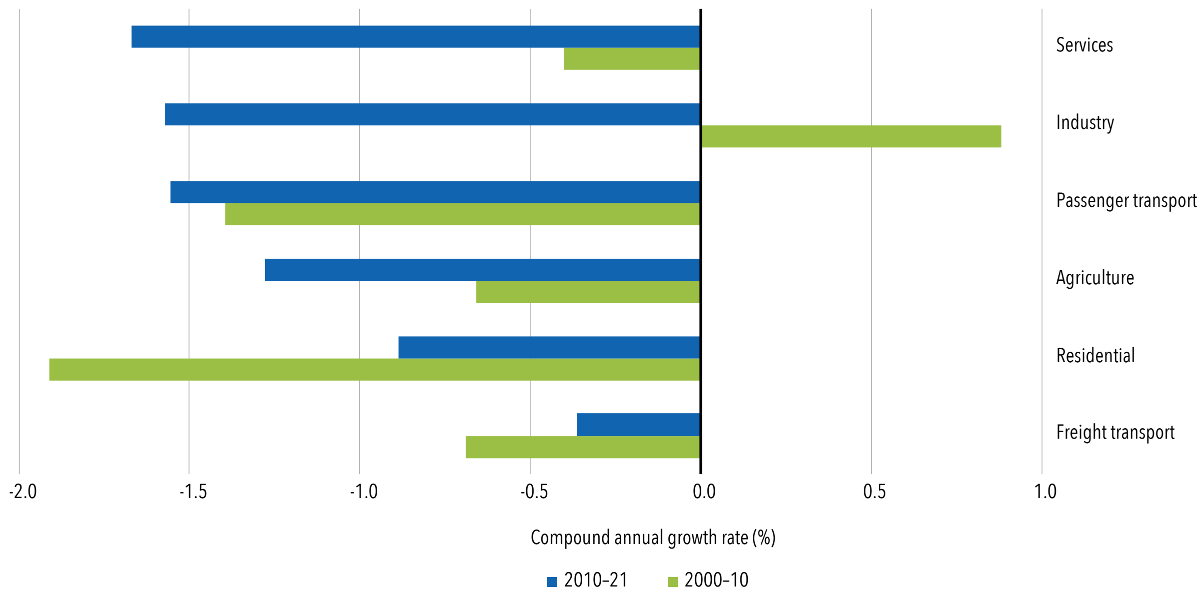
Note: Figures show changes between 2010 and 2021. Countries are set in decreasing order of total energy supply growth.
GDP = gross domestic product; SDG = Sustainable Development Goal, PEI = primary energy intensity.

Between 2010 and 2021, the United Kingdom, Japan, France, Germany, the United States, and Mexico grew their economies while reducing their energy use, indicating a decoupling of economic growth from energy consumption. These countries have decades-long records of policy action on energy efficiency and, except Mexico, increasingly service-based economies, which are less energy intensive than manufacturing. In contrast, countries with higher energy demand (see the left side of figure 4.7) are building new infrastructure with energy-intensive industrial products, such as steel and cement. Economic growth in emerging markets and developing economies also results in increased access to energy services, driving up energy demand.

END-USE TRENDS

Sectoral energy intensity is calculated as the ratio of final energy consumption to a sectoral activity indicator, such as industrial gross value added or surface area. Between 2010 and 2021, sectoral energy intensity improvement accelerated across all but the residential buildings sector, where it nearly halved from its value in the 2000–10 period (figure 4.8).

FIGURE 4.8 • AVERAGE ANNUAL CHANGE IN ENERGY INTENSITY, BY SECTOR, 2000–10 AND 2010–21



Note: The measures for energy intensity in this figure differ from those applied to global primary energy intensity. Here, energy intensity for freight transport is defined as final energy use per tonne-kilometer (including road and rail transport only, obtained from IEA's Global Energy and Climate Model); for passenger transport, it is final energy use per passenger-kilometer (including only road and rail transport, obtained from the Global Energy and Climate Model); 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 USD purchasing power parity).

In industry—which comprises highly energy-intensive economic activities such as the manufacturing of cement, iron, and steel—energy intensity improved by an average of 1.6 percent per year between 2010 and 2021. This rate represents a major achievement, reversing the trend of the previous decade (2000–10), when the sector's energy use per unit of value added increased. Amid the economic recovery following the onset of the COVID-19 pandemic, industrial demand for energy surged to record levels, mainly due to an increase in energy-intensive industrial processes.

Between 2010 and 2021, the energy intensity of passenger transport improved at a slightly faster rate (1.6 percent a year) than in the previous decade (1.4 percent). Freight transport's improvement slowed after 2010, dropping from 0.7 percent to 0.4 percent. After being one of the hardest-hit sectors, passenger transport experienced rapid recovery in 2021 as lockdowns were lifted and people resumed travelling. However, demand had not returned to pre-pandemic levels by 2021.

Electrification is playing a key role in increasing efficiency and limiting growth in demand for passenger transport. In 2021, 6.5 million electric vehicles (EVs) were sold, more than doubling 2020 sales and representing about 10 percent of car sales worldwide. At the same time, however, the average size of cars increased, with SUVs accounting for almost half of global sales (IEA 2023c). SUVs are typically heavier and less fuel-efficient, consuming on average 20 percent more energy than medium-size vehicles to travel the same distance (IEA 2024a).

The residential sector, which includes final residential uses such as heating, cooling, and cooking, saw a slowdown in the annual rate of energy intensity improvement, from 1.9 percent in the first decade of this century to 0.9 percent in the second. Final energy demand in the residential sector was the least affected by COVID-19 restrictions in 2020 and saw only a small increase in 2021.

In the services sector, energy intensity improved by 1.7 percent a year between 2010 and 2021, returning to pre-pandemic levels in 2021. This is a notable shift from the previous decade's average of just 0.4 percent.

Annual improvement rates also accelerated in agriculture, rising from 0.7 percent in 2000–10 to 1.3 percent in 2010–21, as the sector's economic output outpaced growth in its energy demand.

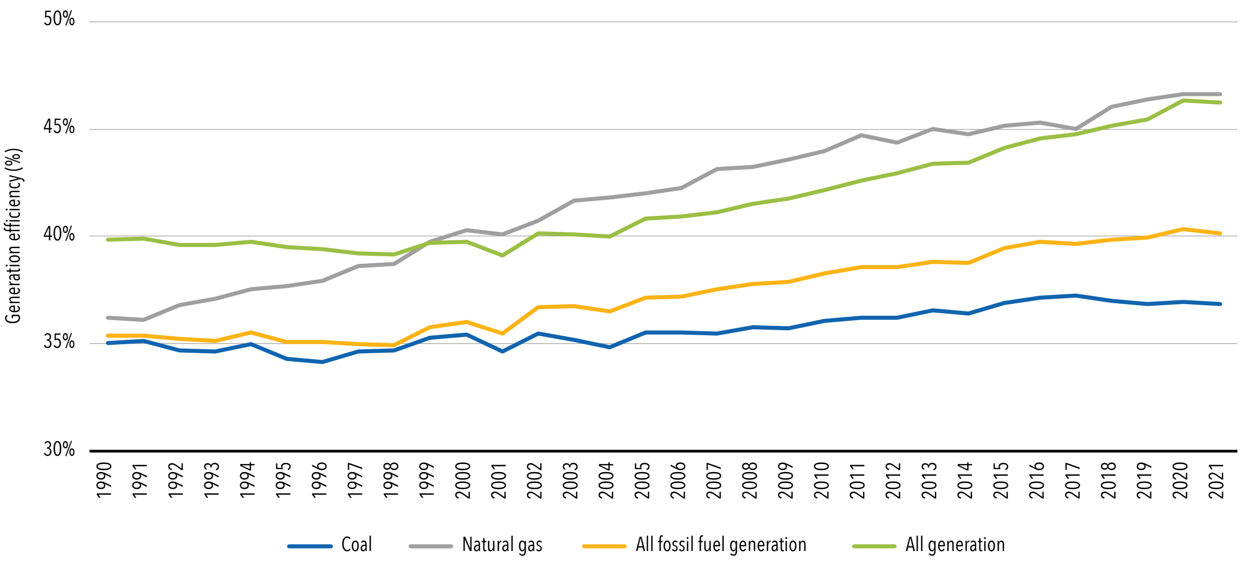
TRENDS IN THE EFFICIENCY OF ELECTRICITY GENERATION

Improving the efficiency of electricity generation[30] can also lower energy intensity by 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 adding renewable energy sources to the electricity mix.

Analyzing the two major fossil fuels used for electricity generation, coal and natural gas, average efficiency increased between 2000 and 2021, after showing flat rates of improvement during the 1990s. Efficiency improvements from natural gas balanced out slower improvements from coal generation (figure 4.9).

An important factor affecting supply efficiency is the share of renewable energy sources in the mix. By convention, most renewable energy technologies are treated as 100 percent efficient, even though minor losses occur in the conversion of resources such as sunlight and wind into electricity. Thus, adding more renewable energy in the electricity mix has a direct impact on the efficiency of electricity generation. The rapid deployment of renewable energies, particularly in the past 15 years, has contributed to an upward trend in overall efficiency.

FIGURE 4.9 • GLOBAL EFFICIENCY OF ELECTRICITY GENERATION, BY TYPE OF FUEL AND TOTAL, 1990–2021



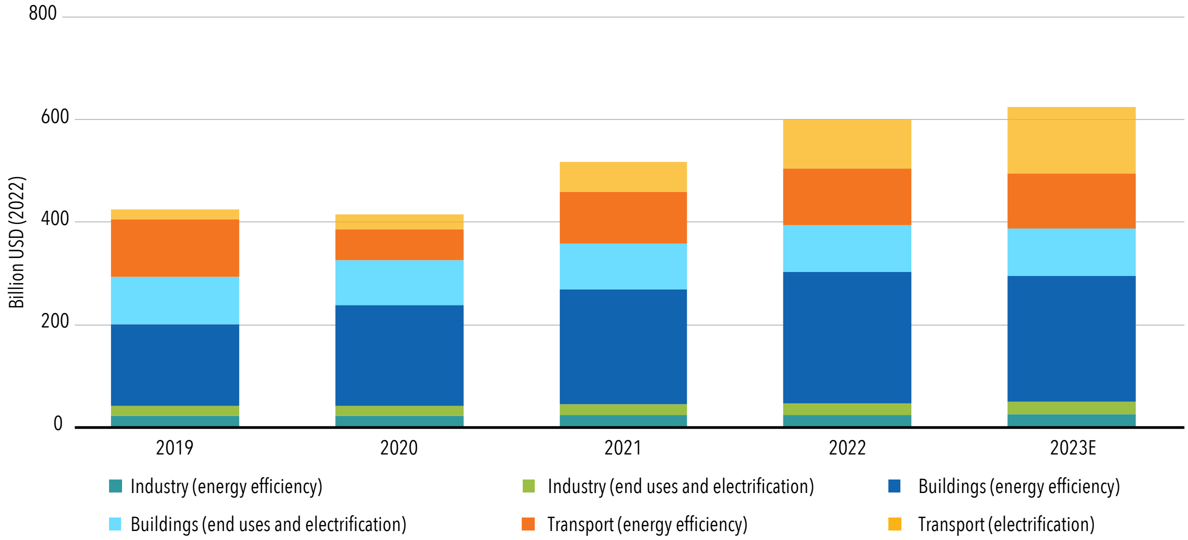
Adding renewables to the electricity mix and electrifying final uses can significantly improve progress in energy intensity, as efficiency improves on both the supply and demand sides. The implementation of targeted energy efficiency measures can also help phase out or limit the use of inefficient generation equipment, highlighting the synergies between SDG targets 7.2 and 7.3.

30 The efficiency of electricity generation is calculated as the energy output (electricity) over the energy input (such as fossil fuels or other energy sources) on a global scale.

INVESTMENT IN ENERGY EFFICIENCY

In 2020, annual investment in energy-efficient equipment and electrification of end uses decreased only slightly, to about USD 415 billion (figure 4.10). Europe, China, and Northern America accounted for nearly 80 percent of this spending. Unprecedented growth in Europe's buildings sector offset the decline of investment in transport efficiency, while industry spending remained largely unchanged. Investment in building efficiency measures made up two-thirds of total efficiency spending in 2020.

FIGURE 4.10 • INVESTMENT IN ENERGY EFFICIENCY, BY SECTOR, 2015–23



Source: IEA 2023a.
E = estimate.

In 2021, after weak or no growth in the second half of the previous decade, energy efficiency–related investment began to increase, reaching almost USD 520 billion, driven by government stimulus programs in the buildings sector and a recovery in transport investment. Investment in buildings' energy efficiency rose to over USD 220 billion. Investment in transport efficiency reached USD 100 billion (or almost pre-pandemic levels), while investment in transport electrification doubled, following the accelerated adoption of EVs. Investment in industry remained steady, at slightly above USD 40 billion.

The 2022 energy crisis led to a rapid increase in energy efficiency investments, with governments, industry, and households investing nearly USD 600 billion, a new record. At least 16 high-profile national plans are driving increases in efficiency, including the US Inflation Reduction Act, the REPowerEU Plan, the European Union's recast Energy Efficiency Directive, and Japan's Green Transformation (GX) Initiative. Most of this spending is by high-income countries. Low- and middle-income countries could use recovery packages to boost spending, which would create jobs and promote economic growth (IEA 2022).

Inflation and high interest rates are expected to have slowed investment growth in 2023 to 4 percent a year. With investment in other sectors stalling, the increase was driven mainly by investments in transport electrification, which continues to grow at a rapid rate of 35 percent year-on-year. Total energy efficiency–related investment is estimated to have reached a record level of just over USD 620 billion, about USD 200 billion above pre-pandemic levels.

Policy recommendations

Energy intensity is expected to improve at a more rapid pace in 2022 and 2023 but still fall short of meeting SDG target 7.3. Stronger government policies and regulations are needed to accelerate improvements and reach an annual average of 3.8 percent through 2030, in line with the target.

The 2022 energy crisis brought home the fact that well-designed and well-implemented energy efficiency policies can deliver multiple benefits beyond savings in energy and emissions. These benefits include stronger energy security; reduced exposure to global shifts in energy prices; lower energy prices; lower energy bills for households and businesses; new jobs in energy efficiency retrofits; and improved health and well-being.

IEA has identified milestones to achieve 4 percent annual progress in energy intensity for the remainder of the decade, aligned with the doubling target agreed at COP28. These include electrifying final uses, increasing productivity in the industrial sector, reaching higher annual retrofit rates, adopting more efficient appliances and lighting equipment, continued adoption of EVs, and behavioral changes that help reduce energy demand (IEA 2023b).

Governments have a range of policy instruments at hand to increase energy efficiency, such as those introduced in IEA's Energy Efficiency Policy Toolkit. These include information programs to help energy users make informed decisions, regulations mandating higher efficiency levels in buildings, appliances, vehicles, and industry, and fiscal or financial incentives for installing energy-efficient equipment and carrying out retrofits (IEA 2024b). The following sections describe policies that can lead to significant energy efficiency improvements, classified by sector.

POLICIES FOR THE APPLIANCES SECTOR

Energy efficiency labeling. Labeling programs help consumers select more energy-efficient products and appliances. Comparative labels, typically mandatory, include a classification scale for comparing energy performance across all products of the same type. Endorsement labels, usually voluntary, recognize best-in-class models and are affixed only to the most efficient options. Both types of labels help move consumers toward more efficient models.

Label designs vary worldwide, with no universal standard design. It is essential that a label be easily understood by the target consumer, and thus reflect cultural and other local norms. Implementation may require a variety of regulations, institutions, and types of infrastructure. Access to testing facilities can be challenging, for example. International cooperation and regional harmonization play an important role in aligning regulations, reducing compliance costs, and facilitating implementation in new markets.

Comparative energy efficiency labeling is also important for market analysis, by providing a source of standardized data on all models offered in the market. It is also a driver for the implementation of other policies, such as Minimum Energy Performance Standards and rebates and discounts for high-efficiency models. More than 110 countries have labeling schemes. Examples of regional cooperation and harmonization include the Equipment Energy Efficiency Programme in Australia and New Zealand, the EU Energy Label, and most recently, the CARICOM Energy Efficiency Labelling Programme.

Minimum energy performance standards. Minimum Energy Performance Standards (MEPS) help remove inefficient products from the market. The levels set should align with international best practices but be adapted to local circumstances and market conditions. MEPS require active market surveillance and regular updates to match market and technological improvements, while being implemented in a way that allows manufacturers and importers to adapt in a timely way.

Initially adopted in Europe and Northern America, MEPS now cover a large share of key energy-consuming end uses in these regions and are expanding their reach across the world. Over 80 percent of global energy used for air conditioners and refrigerators is covered by MEPS (IEA 2023a); coverage is lower for other appliances and final uses. More than 110 countries have implemented MEPS. Countries that have relatively new programs have the potential to leapfrog to the most efficient and competitive technologies (IEA 2021a).

The stringency of MEPS programs varies widely across countries. Enhanced international cooperation would help governments introduce new standards, learn from others' experiences, and adopt best practices. Regional harmonization is essential to ensure compliance, lower costs of implementation, and mitigate cross-border dumping of inefficient products, while expanding markets for more efficient models.

Economic incentives for high-efficiency appliances. Purchase rebates and financing tools targeting models in the highest energy efficiency classes can encourage manufacturers and importers to offer more efficient products, and consumers to choose them. Several countries have implemented such rebates. Singapore, for example, offers climate vouchers worth around USD 220 for purchasing high-efficiency models of selected appliances, including refrigerators, air conditioners, and washing machines.

To reduce the burden of high up-front costs, some countries offer low- or zero-interest credit. In areas with limited access to credit, governments work with banks and utilities to simplify requirements. For example, "on-bill finance" models involve utilities providing credit to their customers and adding monthly loan payments to utility bills, such as in the Ecofridges program in Senegal. In Ghana, an "on-wage financing" model was used. In that model, loans are paid back through salary deductions, with employers acting as guarantors.

POLICIES FOR THE BUILDINGS SECTOR

Building energy codes. Building energy codes are regulations that set minimum requirements for energy use in buildings. They may specify overall building efficiency (performance-based codes) or the efficiency of individual components such as insulation, lighting systems, or heating and cooling systems (prescriptive codes). Requirements should take into account local climate conditions and include provisions for on-site renewable energy production, energy management systems, electrification of end uses, and demand-response readiness.

Building energy codes should be applied to both new buildings and to those undergoing major renovations, and set deadlines for efficiency upgrades. Energy efficiency requirements should be updated every three to five years, with increasing stringency. Ideally, regulations include a plan for the evolution of these codes with timelines and milestones for updates, in order to help the industry prepare for, and adapt to, new requirements. Codes should specify a clear compliance path for architects, builders, and property developers to follow. As of 2023, around 80 countries had adopted mandatory national energy codes for residential buildings (IEA 2023a).

Energy performance certificates for buildings. Energy performance certificates (EPCs) provide information on a building's energy performance and demand, indicating its efficiency. EPCs typically include an energy efficiency rating (usually from A to G), recommended measures for improving the rating, and estimates of annual energy use based on standard usage patterns.

EPCs can be used to assess the overall energy performance of the real estate market, guiding specific policies for different building types. Residents of low-performing buildings can be eligible to receive targeted retrofit grants, while high-performing buildings can qualify for tax benefits and favorable financing terms for their purchase.

Incentives for building retrofits. In some countries, the buildings of today are expected to account for up to 80 percent of the total building stock in 2030. Retrofits are therefore critical to improving energy efficiency. The most effective retrofits enhance the building envelope (e.g., by adding insulation and improving glazing), involve a switch to more efficient equipment (such as heat pumps or renewables-based heat solutions), and incorporate digital energy management.

Incentives include subsidies, rebates, and low interest rates, among others. They can target simple retrofit measures or aim for deep renovations that substantially improve building performance. The MaPrimeRénov' program in France includes various measures with a focus on low- and middle-income households.

POLICIES FOR TRANSPORT

Energy labels for vehicles. Labels inform consumers about a vehicle's fuel (or electricity) consumption, helping them identify the most efficient models. Labels cover both new and used vehicles, and can be displayed in car showrooms and online. Increasingly, EV labels include metrics for driving range.

In addition to information on energy consumption (e.g., liters/100 kilometers, miles per gallon, watt-hours/kilometer), labels can include information on carbon dioxide and other air pollutants, as well as on fuel cost savings—helping people choose vehicles that cost less to run. More than 35 countries across the world have vehicle efficiency labels in place.

Fuel economy standards. Fuel economy standards regulate the fuel efficiency of new vehicles and promote advanced technologies. When well monitored and enforced, they can greatly reduce fuel use. These standards are most effective in countries with large markets and vehicle manufacturing facilities. Typically, standards for passenger cars require manufacturers to maintain the average efficiency of their sold cars below a certain threshold that is regularly updated based on market trends.

Fuel economy or emissions standards for new cars and trucks can be found in more than 40 countries, covering over 80 percent of new vehicle sales worldwide. These standards increasingly include provisions for zero-emissions vehicles. Most recently, Chile set standards for light-duty vehicles.

Incentives to buy electric vehicles. Several countries offer EV rebates and tax benefits to reduce the price gap between EVs and internal combustion engine vehicles. These incentives usually combine vehicle tax reductions and subsidies, such as purchase rebates or tax credits. Purchase rebates are common in many European countries, Japan, the Republic of Korea, and some Canadian provinces and US states, among others. The United States provides a vehicle tax credit at the national level.

Countries also offer tax exemptions to reduce the costs of acquiring and owning EVs, often as complements to subsidies. Many countries exempt EVs from value-added tax, registration taxes, and excise duties, or reduce these amounts for EV buyers. Additional benefits can include reduced tolls and parking charges. Norway, for example, combines tax exemptions and fee reductions to significantly lower the costs of buying and owning an EV.

POLICIES FOR INDUSTRY

Industrial energy efficiency networks. Energy efficiency networks consist of energy managers from different industrial sites who meet regularly to share knowledge and experiences relevant to improving energy efficiency. These networks may operate solely to facilitate the sharing of information among peers, or may include elements such as energy reporting and the setting of energy-saving targets. They guide industries to become more efficient, align with government policies, and offer insights to inform more effective policy development.

There are more than a thousand industrial energy efficiency networks worldwide and this number is growing as governments seek to expand their policies and industries seek to reduce costs, energy use, and emissions. Efficiency networks were first introduced in Switzerland and have expanded across the world, with successful examples in Germany, Ireland, China, and Argentina, among others.

Minimum energy performance standards for motors. Electric motors and motor systems in industrial and infrastructure applications, such as pumps, fans, and compressors, consume about half of the world's electricity. Electric motors are categorized by energy efficiency under IEC Standard 60034-30 series, ranging from IE1 (lowest efficiency) to IE5 (highest efficiency). Many motors sold around the world do not even meet IE1 efficiency requirements.

By 2023, 62 countries had MEPS for industrial electric motors, covering 57 percent of motors' energy consumption worldwide (IEA 2023a). Some countries—including Switzerland, Türkiye, the United Kingdom, and countries in the European Economic Area—recently adopted IE4 levels for motors in the 75–200 kW range. Efficiency gains can also be achieved by implementing digital technologies and systemwide measures, such as using variable speed drives, which many regulations include when setting MEPS (4E IEA 2022).

Energy management systems. Energy management systems involve practices that improve energy efficiency on an ongoing basis. The process of implementing a system begins with an energy audit to identify opportunities for improvement, followed by the setting of measurable targets and objectives, and the implementation of associated measures. Elements of the process are verified and improved over time.

One of the key frameworks for energy management systems is the international standard known as ISO 50001. This framework centers on monitoring, targeting, and implementing energy-saving measures in a cycle of continuous improvement. In 2022, the number of ISO 50001 certificates issued worldwide grew by almost 30 percent, to 28,000 (IEA 2023a).

Policies and initiatives to promote energy management systems include mandating their implementation by large energy consumers, organizing national awards and acknowledgments, and offering preferred energy tariffs to users with certified energy management systems.

CROSS-CUTTING MEASURES AND POLICIES

Digitalization and system-level efficiency. Digital technologies and data hold great potential to accelerate the clean energy transition across the energy sector. Advances in digital technologies and services, declining costs, and increasing connectivity have accelerated the digital transformation of energy in recent years, particularly in electricity networks. Grid-related investment in digital technologies has grown by over 50 percent since 2015 and was expected to reach 19 percent of total grid investment in 2023 (IEA 2023d).

Digitalization can improve efficiency across all demand sectors, introducing technologies and creating new sources of detailed data to support new business models and revenue streams. It enables smart energy management systems in buildings, increases automation and the optimization of industrial processes, and facilitates the implementation and upgrading of intelligent transport systems. In electricity systems, technologies like machine learning, smart meters, and other digital technologies help integrate greater shares of variable renewables and better match supply and demand from decentralized sources such as EVs and connected appliances.

Several countries and regions have recently put forward strategies and action plans to facilitate the digital transformation of their energy systems, while others are beginning to mandate the use of digital technologies to support the clean energy transition. Many of them incentivize and support the rollout of smart meters and the adoption of digital devices across sectors (IEA 2021b).

Energy efficiency obligation schemes. Energy efficiency obligation (EEO) schemes are market-based programs that specify an outcome (energy savings or cost-effectiveness) to be delivered by a utility or other market participant (such as an energy services company). Auctions allow market actors to bid for funds to deliver specific energy savings. As of 2022, there were 48 EEO programs in 23 jurisdictions. Sixteen countries in the European Union and 24 US states operate EEOs (in the United States, they are called Energy Efficiency Resource Standards).

Some EEO schemes issue "white certificates" (also called energy savings certificates), which certify a certain reduction in energy or emissions. White certificates are generally tradable and come with an obligation to achieve an energy or emissions savings target. They can be obtained by implementing efficiency measures in various sectors. Uruguay, France, and Italy are among the countries to use them.

Conclusions

The rate of energy intensity improvement remains below the annual 2.6 percent necessary to reach SDG target 7.3. The COVID-19 crisis worsened an already slowing trend, with energy intensity improvement dropping to 0.6 percent in 2020 and 0.8 percent in 2021, down from an average rate of 1.3 percent over 2015–20, and 2.1 percent in 2010–15.

To meet the SDG target 7.3 of doubling the global rate of energy intensity improvement by 2030, the average rate must now be at least 3.8 percent per year through 2030, to make up for slow progress in the past. This rate would need to be slightly higher—consistently over 4 percent for the rest of this decade—to put the world on track for IEA's Net Zero Emissions by 2050 Scenario.

Preliminary analysis of 2022 data indicates an above-average improvement rate, reaching about 2 percent, as the energy crisis curbed energy consumption and prompted the rapid implementation of new policies and an increase in energy efficiency investments. This remains under the SDG 7.3 target values. A return to long-term trends is expected in 2023, with energy intensity improvement dropping to around 1.3 percent (IEA 2023a).

Energy efficiency policies and investment in cost-effective measures need to be scaled up significantly. Given the multiple benefits of energy efficiency, doing so is a smart choice for governments. Many countries recognize as much: energy efficiency–related spending accounted for about two-thirds of the USD 1 trillion mobilized by governments for post-pandemic economic recovery between 2020 and 2022 (IEA 2022).

Improving efficiency at scale is key to achieving affordable, sustainable energy access for all. Low levels of intensity improvement, significant investment opportunities, the potential for economic recovery, and the pressing need to expand energy access highlight the importance of enacting policies that foster rapid progress.

Universal access to electricity and clean cooking, increased electrification, and the incorporation of renewable energies improve energy intensity by significantly increasing the efficiency of energy end-uses and reducing inefficiencies on the supply side. More joint efforts are needed to leverage the synergies between the various SDG 7 targets.

National and subnational governments use an array of policies to help meet their energy efficiency goals. Policy packages combine regulations, information, and incentive mechanisms. Successful examples of implementation have the potential to be replicated to enhance energy efficiency at the global level. IEA has published an Energy Efficiency Policy Toolkit summarizing the main tools to be used across various sectors (IEA 2024b).

Both the technologies and resources to double energy efficiency improvement by 2030 are available (UN 2021). Weak improvement rates and inadequate investments indicate a major missed opportunity for the global community. Prioritizing energy efficiency in policies and investments over the coming years can help achieve SDG target 7.3, promote economic development, improve health and well-being, and ensure universal access to clean energy.

ANNEX 1.
METHODOLOGICAL NOTES

Chapter 4. Energy efficiency

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: International Monetary Fund's World Economic Outlook database (https://www.imf.org/en/Publications/SPROLLs/world-economic-outlook-databases/), complemented by data from the World Bank's World Development Indicators (https://databank.worldbank.org/source/world-development-indicators) and the CEPII's CHELEM database (http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=17).

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

$$Freight\ transport\ energy\ intensity = \frac{Freight\ transport\ TFEC\ (MJ)}{Tonne\text{-}kilometers}$$

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.

ANNEX 2.
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