



RENEWABLES IN THE GLOBAL ENERGY SYSTEM

Global energy demand continued to rise in 2023.33 The increase was reflected across all end-use sectors, as total final energy consumption (TFEC) grew 2.2%.34 The estimated share of renewable energy in TFEC in 2023 was 13.5%.³⁵ (→ See Figure 1.) Industry remained the largest end-use sector, accounting for 34% of total consumption, followed by buildings (31%), transport (31%) and agriculture (2.5%) and other energy uses (1.5%).36 In 2023, Iceland remained the country with the highest share of renewable energy in TFEC at 83%, owing to hydropower and geothermal; Lao People's Democratic Republic (PDR) (73%) and Gabon (66%) followed, both of which rely heavily on hydropower.³⁷ (→ See Figure 2.)

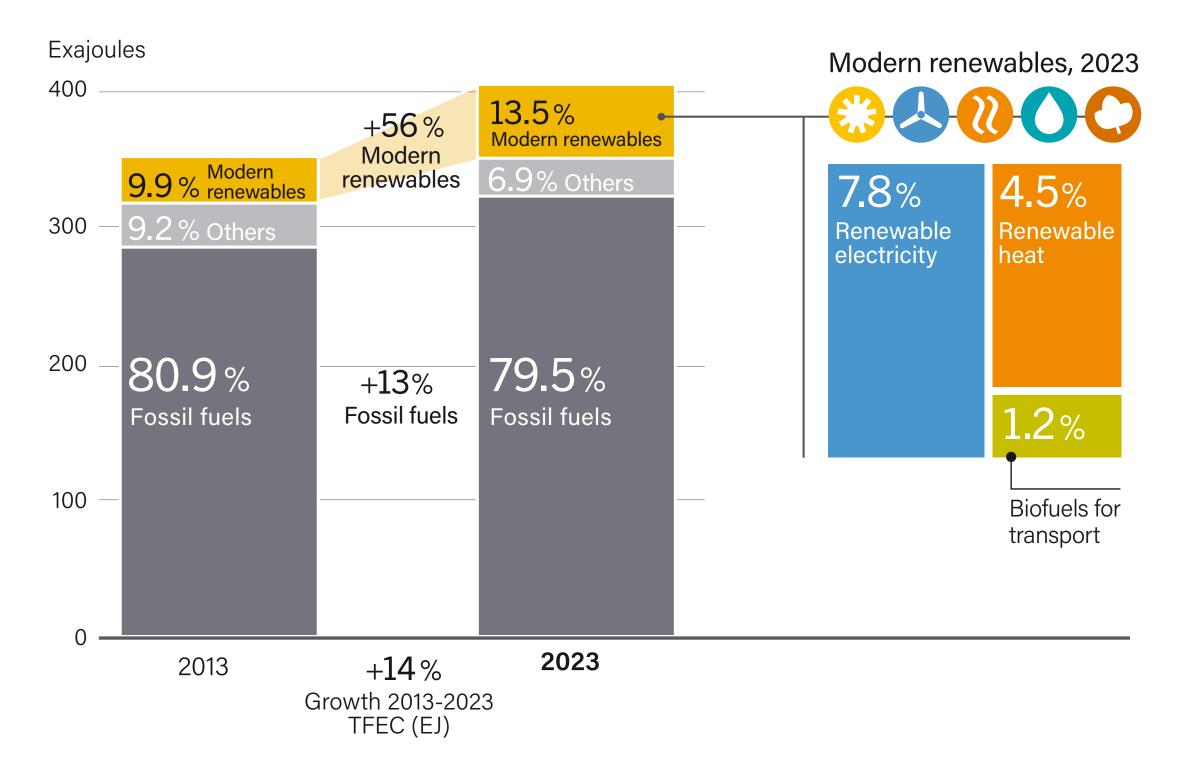


Sets of cooling towers in the data center



FIGURE 1.

Total Final Energy Consumption by Source, 2013 and 2023

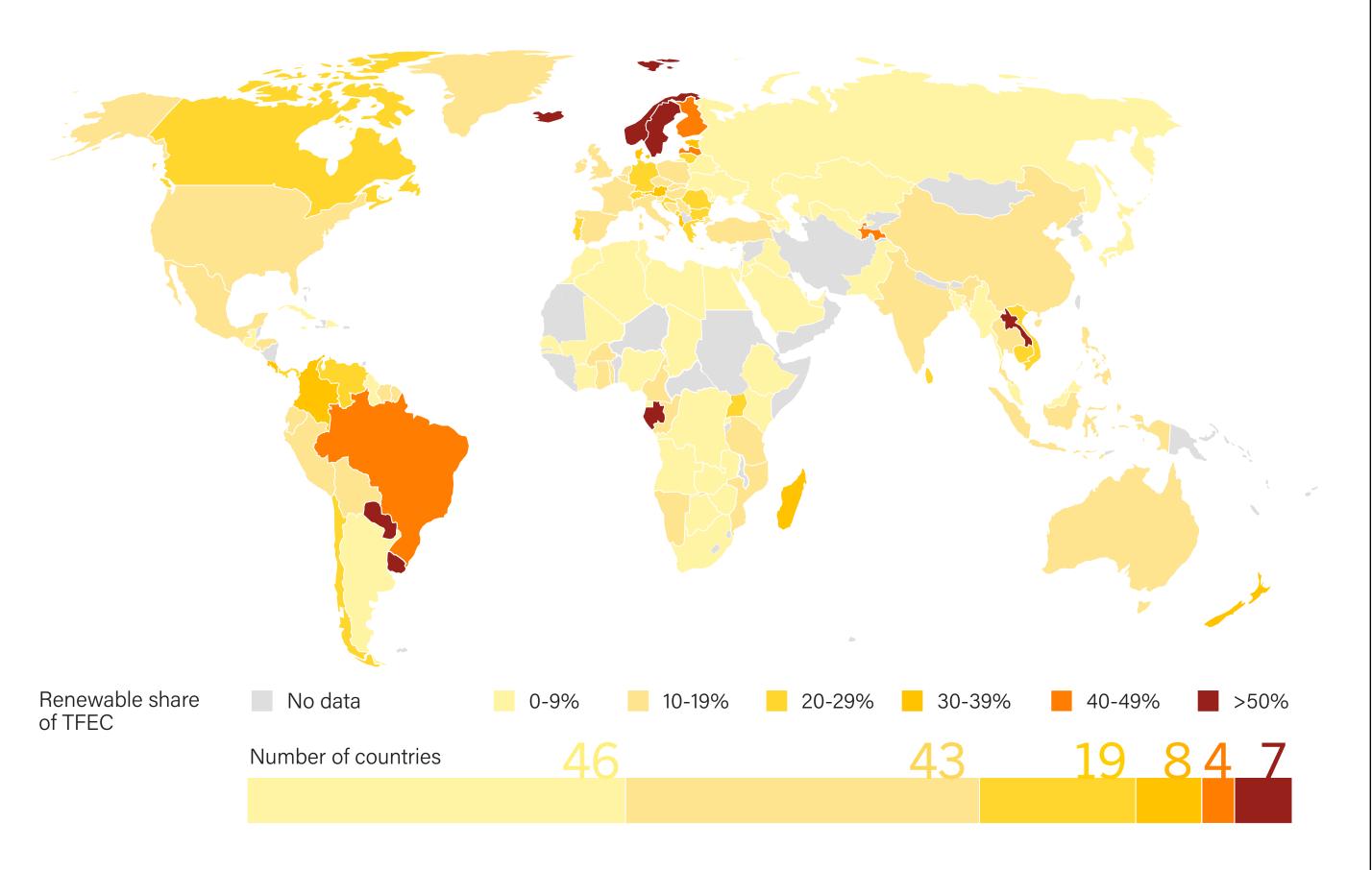


Source: Based on IEA World Energy Balance, 2025, processed by REN21. See endnote 35 for this section. Note: The 2023 data is a projection. The category "others" includes traditional biomass and nuclear.

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Source: See endnote 37 for this section.

Electricity demand increased 4.3% in 2024, up from growth of 2.5% in 2023 and well above the annual average growth of 2.7% between 2010 and 2023.³⁸ This increase was driven primarily by rising cooling needs and rapid industrial development in emerging economies.³⁹ Energy demand also rose in advanced economies, notably in the United States, where the proliferation of infrastructure for data centres created substantial new electricity loads.⁴⁰

Renewable capacity additions met two-thirds of the increase in global power demand, while the use of fossil fuels, particularly coal and natural gas, also increased.⁴¹ Electricity from coal reached a global all-time high in 2024, although the growth rate slowed to 0.88% (1.7% in 2023).⁴² In total, 44 GW of new coal-fired power capacity was commissioned in 2024, surpassing the 25.2 GW of coal capacity that was retired in the same period.⁴³

The number of people without access to electricity declined by more than 8 million from over 745 million in 2023 to around 737 million in 2024.⁴⁴ Sub-Saharan Africa accounted for the vast majority of the global electricity access gap, with 80% of those without access residing in the region.⁴⁵ Achieving Sustainable Development Goal 7.1 – universal electricity access by 2030 – would require the number of people without access to decline at a rate roughly ten times faster than the current pace.⁴⁶

Meanwhile, global progress on energy efficiency remained weak at around 1% in 2024.⁴⁷ This was unchanged from 2023 and well below the average annual gains of the previous decade.⁴⁸ This stagnation is particularly concerning in light of the commitment made at the 2023 United Nations Climate Change Conference in Dubai, United Arab Emirates (COP 28) to double the annual rate of energy efficiency improvement from 2% to 4% by 2030.⁴⁹ Gains were led primarily by the United States and the EU, where regulatory frameworks and market incentives helped reduce energy waste across sectors.⁵⁰

The insufficient deployment of renewables and slow progress on energy efficiency meant that emissions again increased in 2024, albeit at the slowest rate since the easing of the COVID-19 pandemic in 2021.⁵¹







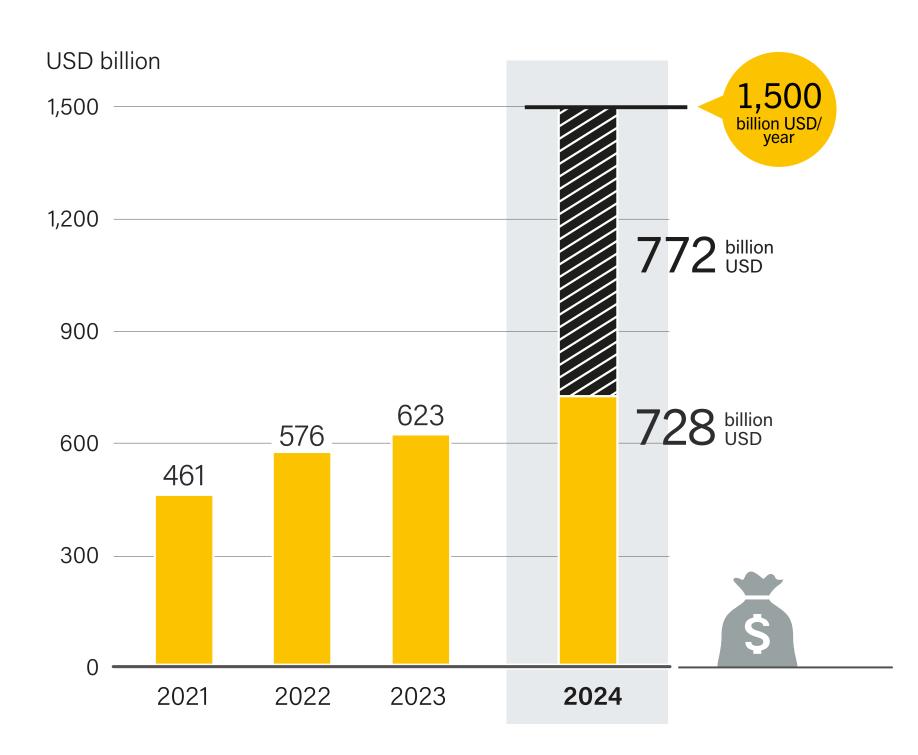
Several governments and private actors showed evidence of backsliding on climate and energy commitments amid rising trade barriers, grid-related constraints, political shifts and policy changes.⁵² In early 2025, the new United States administration announced plans to withdraw once again from the Paris Agreement, promote fossil fuels, and roll back domestic and international support for renewables and climate-related projects.⁵³ The EU postponed its implementation of stricter CO₂ emission standards that had been scheduled for 2025.⁵⁴ New Zealand reversed its ban on offshore oil and fossil gas exploration and withdrew incentives for EVs, although the government also took measures to speed up consenting processes for renewable energy installations.⁵⁵

The underlying economics of renewable energy have nonetheless continued to improve, and renewables increasingly outcompete fossil fuel technologies on cost grounds alone.⁵⁶ To achieve the internationally agreed target to triple renewable energy power capacity by 2030, an additional USD 772 billion investment will be needed between 2025 and 2030.⁵⁷ (→ *See Figure 3.*)



More than
investment needed to reach
COP28 tripling target.





Source: See endnote 57 for this section.







Global subsidies for fossil fuels remained high at

11 USD trillion

in 2023.

Only

22 countries

submitted updated NDCs by May 2025.

COP 29 delivered three notable energy pledges:

- A pledge on Green Energy Zones and Corridors – backed by 57 countries, including Belgium, Türkiye, and the United Kingdom, along with non-governmental actors – aims to connect renewable-rich areas with demand centres through large-scale inter-regional grids.8
- The Global Energy Storage and Grids
 Pledge, which included commitments from
 65 countries, sets collective goals to deploy
 1,500 gigawatts (GW) of energy storage,
 double global grid investment and build 25
 million kilometres of new grid infrastructure by
 2030.9
- The Hydrogen Declaration committed 62 countries to scale up green hydrogen production and reduce their reliance on fossil-based hydrogen.¹⁰ Green hydrogen output was less than 1 million tonnes in 2024, compared to 96 million tonnes for fossil-derived hydrogen.¹¹

The Group of Seven (G7) countries announced a pledge to phase out "unabated" coal

power plants between 2030 and 2035.¹² The language left room for interpretation, allowing countries to align with their own pathways towards net zero greenhouse gas emissions, seen as a concession to coal-dependent G7 members such as Germany and Japan.¹³ The G7 also remains unlikely to meet its earlier target of eliminating "inefficient" fossil fuel subsidies by 2025.¹⁴ Global subsidies for fossil fuels remained high at USD 1.1 trillion in 2023^{1,15} Although this was down from the record USD 1.7 trillion in 2022, it remains a major barrier to the energy transition.¹⁶

Whereas international-level pledges help set the tone for global ambition, **national commitments** determine whether this ambition translates into tangible progress. This is particularly evident in the case of energy access. An estimated 737 million people worldwide still lacked access to electricity as of 2024.¹⁷ Current improvement rates remain far below what is needed to meet the target for universal electricity access by 2030, set in Sustainable Development Goal (SDG) 7.1.¹⁸ While some governments have adopted

national energy access targets in line with SDG 7, underpinned by renewable energy strategies, many fall short on implementation and financing.¹⁹ (\rightarrow See Sidebar 2.).

As of May 2025, of the 195 Parties that had signed the Paris Agreement, 180 had submitted at least one set of **Nationally Determined Contributions (NDCs)** in the decade since 2015.²⁰ However, only 22 countries (together contributing just 21% of global greenhouse gas emissions) had submitted their updated NDCsⁱⁱ, which include climate targets for 2025-2035.²¹

Changes in government, leadership or political priorities led several countries to reverse or delay overall climate measures in 2024.²² Just 13 countries met the NDC submission deadline of 10 February 2025, and several major emitters missed the deadline.²³ However, all 22 of the updated NDCs submitted by May 2025 referred to renewable energy as a means to support climate mitigation and/or adaptation.²⁴

- Global subsidies for fossil fuels include the fiscal cost of support for fossil fuels through three support mechanisms: direct transfers, tax expenditures, and price support, based on combined data from the Organisation for Economic Co-operation and Development (OECD) and the International Energy Agency.
- ii To qualify as a new submission in the 2025 round, an NDC must define its contribution with a 2035 time frame. Countries that submitted their 2025 NDC updates by May 2025 were: Andorra, Brazil, Canada, Cuba, Ecuador, Japan, Kenya, Maldives, Marshall Islands, Montenegro, Nepal, New Zealand, the Republic of Moldova, Saint Lucia, Singapore, Switzerland, the United Kingdom, the United Arab Emirates, Uruguay, the United States, Zambia and Zimbabwe.

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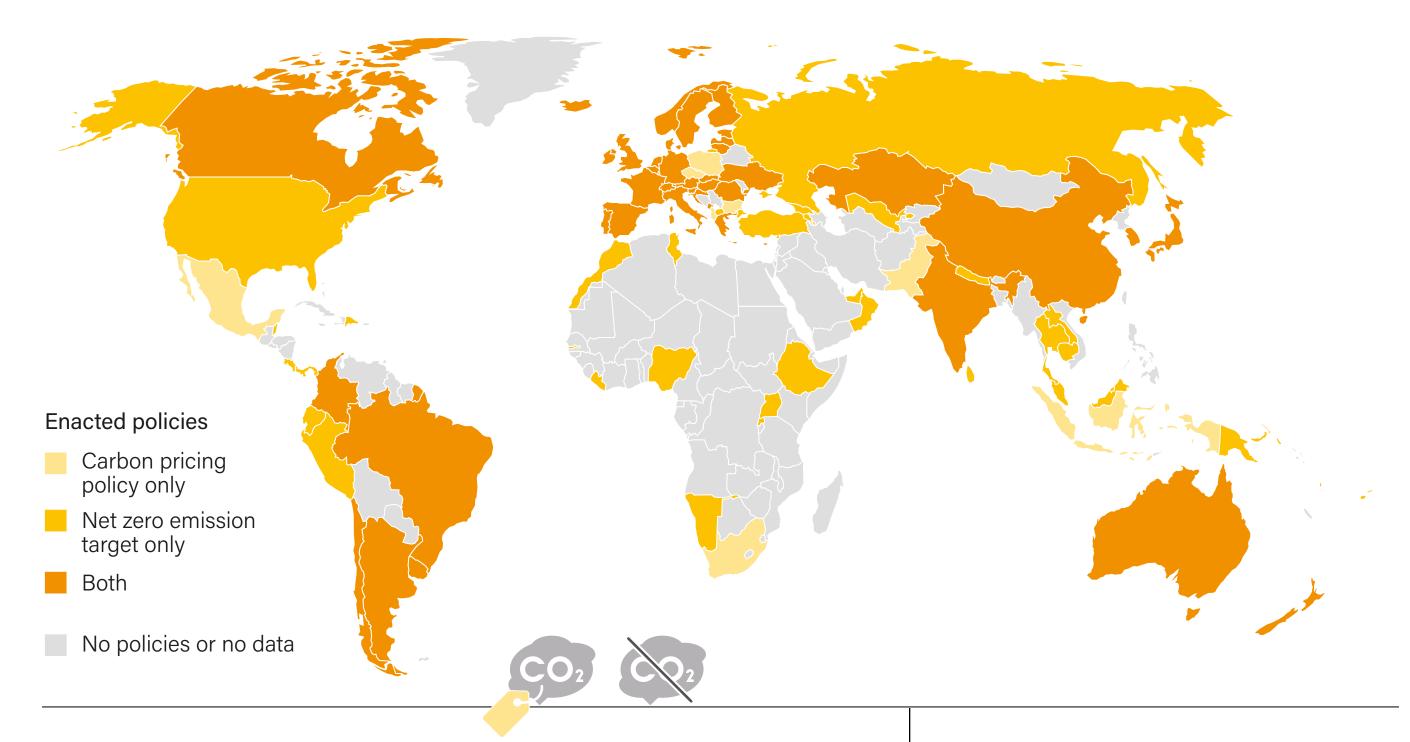


As of 2024, 53 countries had carbon pricing policies in place and 45 countries had both **net zero emission targets** and **carbon pricing policies** – including carbon taxes and emission trading systems (ETS).²⁵ (→ *See Figure 5.*) However, many of the existing carbon pricing policies cover only a small share of national emissions, or just one end-use sector: 51 countries covered emissions from industry, and 45 countries covered emissions from transport (including aviation), yet only 23 countries covered emissions from buildings and only 17 countries covered emissions from the agricultural sector.²⁶

As of 2024, 44 countries, including all EU Member States, had established emission trading systems.²⁷ Only two new countries initiated national carbon pricing frameworks during the year: Pakistan, through the adoption of its National Carbon Market Policy, and Brazil, where the Congress approved a framework law to establish a national ETS.²⁸ A total of 31 countries had carbon taxes in place in 2024, with no new policies enacted during the year; carbon tax rates ranged from less than USD 1 to USD 167 per tonne of CO₂ or CO₂ equivalent.²⁹ Uruguay had the highest carbon tax rate at USD 167 per tonne of CO₂ equivalent, followed by Switzerland and Liechtenstein (both with USD 132 per tonne of CO₂).³⁰



FIGURE 5.
Countries with Enacted Climate Change Policies, by Type of Measure, as of 2024



Note: Enacted climate change policies include policies that have been officially passed into legislation or an official policy strategy (including NDCs). They also include net zero emission targets that have already been achieved. Carbon pricing policies include emission trading systems and carbon taxes. Carbon pricing policies of sub-national jurisdictions are not included in this figure. The EU ETS applies in all EU Member States, the European Free Trade Association countries (Iceland, Liechtenstein and Norway) as well as Northern Ireland for electricity generation (under the Protocol of Ireland and Northern Ireland); some countries (Austria, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, Liechtenstein, Luxembourg, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Slovenia and Hungary) have an additional national scheme in place to complement the EU ETS.

Source: REN21 Policy Database. See endnote 25 for this section.





i Other countries with relatively high carbon tax rates in 2024 included Sweden (USD 127 per tonne of CO₂), Norway (USD 108 per tonne of CO₂ equivalent) and Finland (USD 100 per tonne of CO₂). The lowest carbon tax rates in 2024 were in Japan (USD 1.91 per tonne of CO₂), Argentina (USD 0.81 per tonne of CO₂ equivalent) and Ukraine (0.77 per tonne of CO₂). See endnote 30 for this section.



POLICY MECHANISMS

Beyond setting national targets, governments use various policy tools to stimulate renewable energy demand and guide progress towards achieving ambitions. These include feed-in tariffs (FITs), net metering and net billing, auctions and tenders, mandates such as renewable portfolio standards (RPS), and hybrid system incentives.⁷⁰

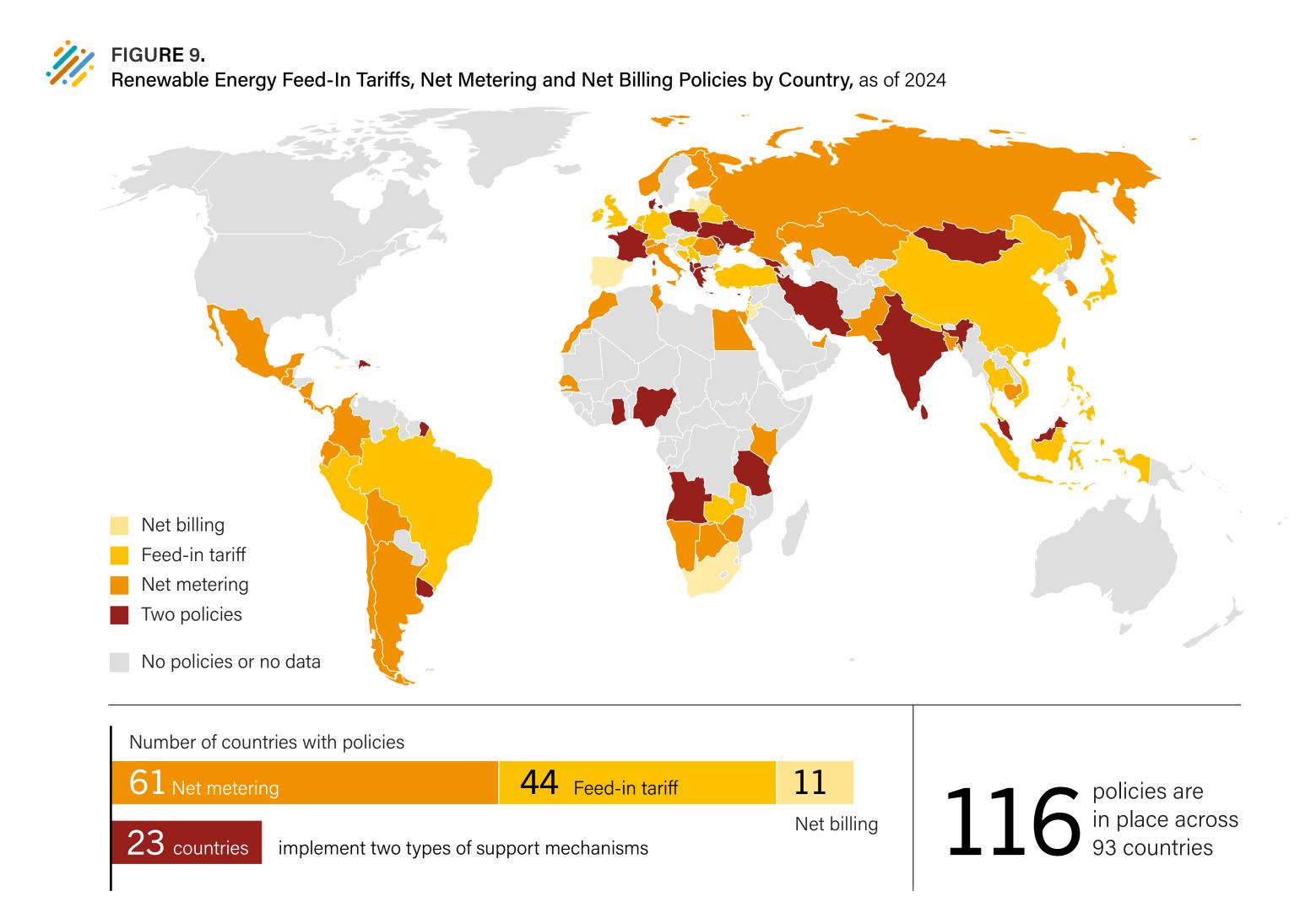
Policies such as **feed-in tariffs, net metering and net billing**ⁱ, which create incentives for renewable energy producers and help facilitate their participation in the energy system, received continued policy attention in 2024. During the year, 116 of these policies were in place across 93 countries.⁷¹ (→ *See Figure 9.*) This included 44 countries with feed-in tariffs, 61 countries with net metering policies, and 11 countries with net billing policies.⁷² 23 countries implemented feed-in tariffs alongside other support mechanisms; among them, 19 combined feed-in tariffs with net metering, while four (France, Greece, Moldova, and Poland) combined feed-in tariffs with net billing policies.⁷³

i Net metering typically credits surplus electricity at the full retail rate, offsetting consumption on a one-to-one basis, whereas net billing compensates exports at a lower rate – such as the wholesale or avoided cost – and separates billing for consumption and generation.



Net metering

was the leading policy tool in 2024, in place in 61 countries, including 19 that combined it with feed-in tariffs.

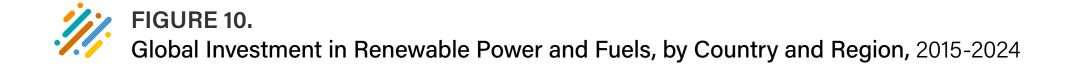


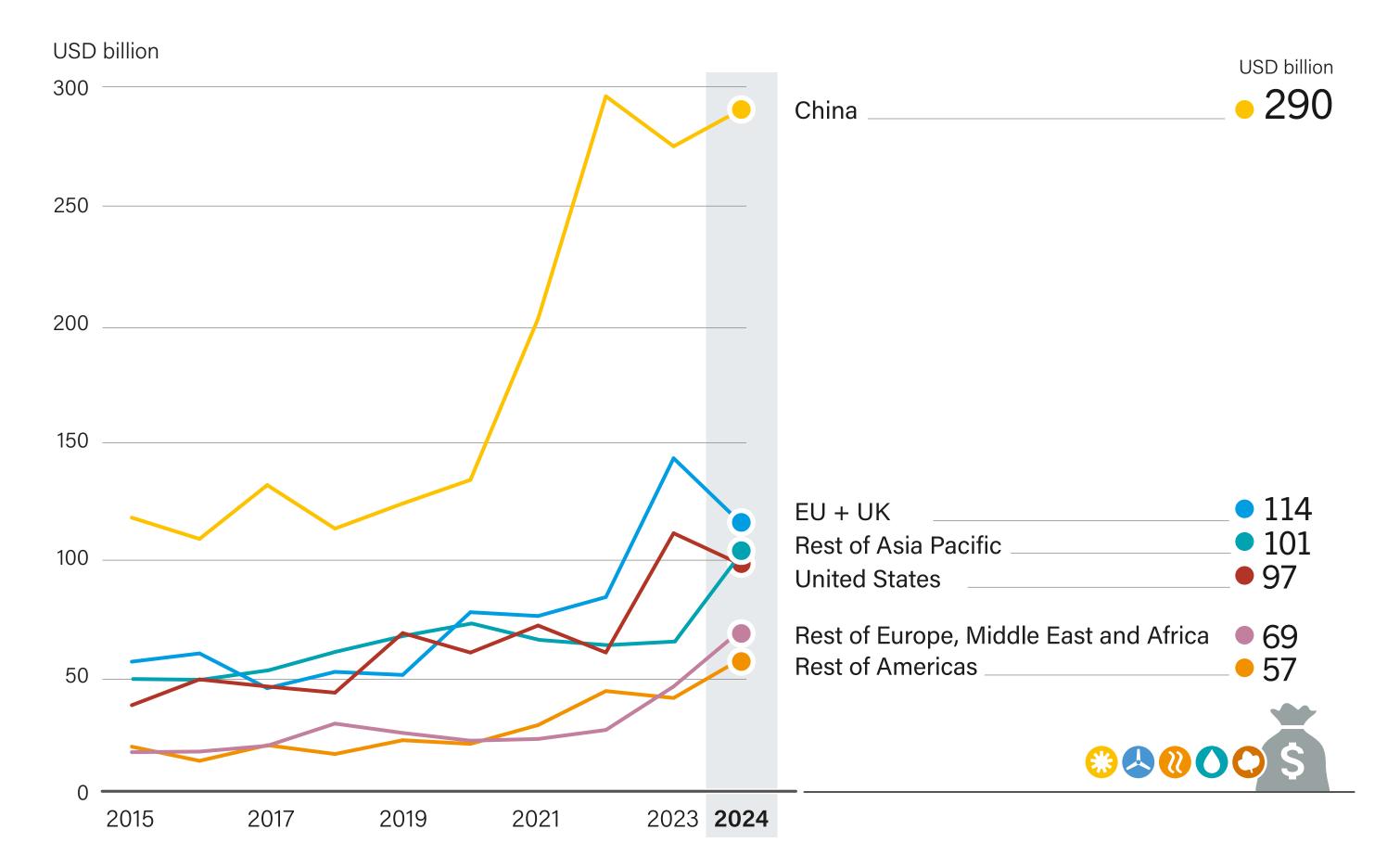
Source: REN21 Policy Database. See endnote 71 for this section.



Introduction







Source: See endnote 4 for this section.

728 USD billion

total investment in renewable power and fuels in 2024.

Despite the strong emphasis on industrial policy support, spending on renewable energy and enabling technologies supply chains fell slightly from USD 145 billion in 2023 to USD 140 billion in 2024.8 This decline reflects growing caution in the market, particularly within the solar photovoltaic (PV) sector, where oversupply has become a critical issue.9 **Global solar PV manufacturing** capacity was expected to surpass 1,100 gigawatts (GW) by the end of 2024 – more than double the current demand.10 As a result, module prices have more than halved since early 2023, pushing many solar PV manufacturers into negative net margins.11 These challenging conditions have led to the cancellation of around 300 GW of planned polysilicon manufacturing capacity and 200 GW of wafer manufacturing projects, representing an estimated USD 25 billion in lost investment.12

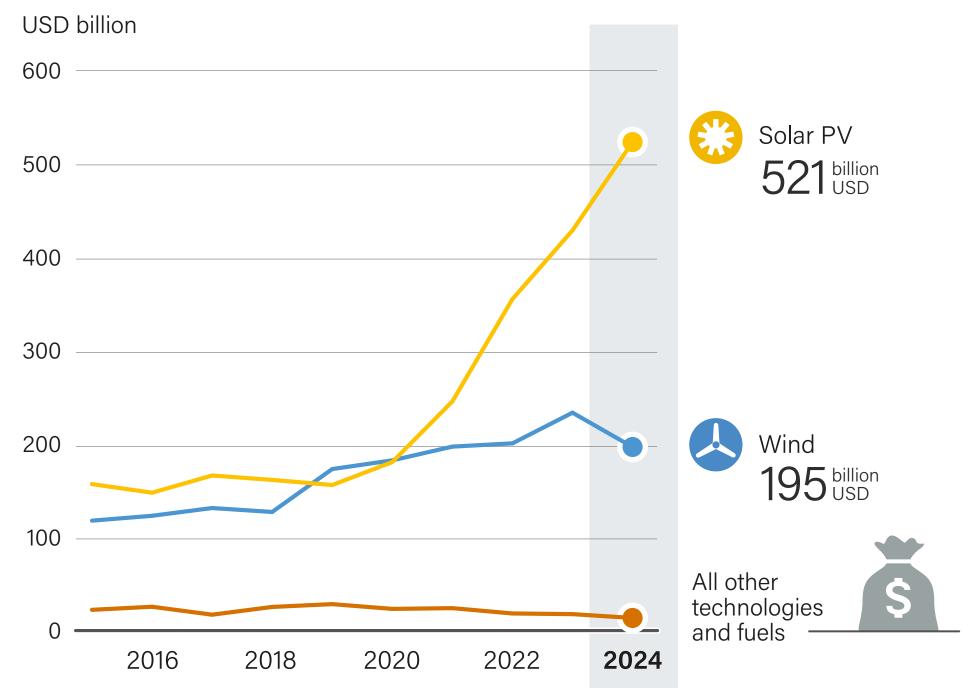
A significant barrier to accelerating renewable energy deployment in emerging and developing economies is the persistently high **cost of capital**.¹³ For utility-scale solar PV and wind energy projects, the weighted average cost of capital in these regions is often more than twice that in advanced economies.¹⁴ (→ *See Figure 11*.) This disparity arises from factors including political and economic instability, currency risks, and underdeveloped financial markets, which collectively elevate the perceived investment risk.¹⁵ Consequently, financing costs constitute a substantial portion of the levelised cost of electricity in these countries, making renewable energy projects less financially viable and hindering their implementation.¹⁶



Introduction



Global Investment in Renewable Power and Fuels, by Technology, 2015-2024



Source: See endnote 22 for this section.

72%

was the share of solar PV of global renewable investment in 2024.

22%

was the growth in solar PV related investment in 2024.

After a period of relative stagnation, global investment in **liquid biofuels** increased in both 2023 and 2024.³⁷ Most of this investment was in hydrotreated vegetable oil (HVO) production capacity, as well as conventional ethanol in Brazil and India.³⁸ In addition to ethanol for road fuel, investments gained momentum in the use of ethanol as aviation fuel (alcohol-to-jet), mainly in the United States.³⁹ Among the leading companies, BP had the largest announced production capacity in its pipeline – a combined 130,000 barrels per day of ethanol and HVO and sustainable aviation fuel (SAF) capacity – positioning BP as a global frontrunner in bioenergy.⁴⁰ Other oil majors, including Chevron, Eni, ExxonMobil, Shell, and TotalEnergies, also made large strides, particularly with advanced biofuels, although many projects are still in development.⁴¹

Despite a 7% overall decline in the global **solar thermal** market in 2023, due mainly to a 7.7% drop in China, notable growth occurred in some areas.⁴² In India, also a solar thermal leader, the market grew 27%.⁴³ Interest has risen as well in southern Africa and Latin America, with solar thermal growth reported in Mozambique (40%), South Africa (12%), Mexico (5%) and Brazil (3%).⁴⁴

The rising prominence of **nuclear energy** presents another shift in the energy investment landscape. This risks diverting capital from renewable energy efforts, potentially crowding out the broader renewables agenda.

Despite broader market gains, renewable energy companies experienced plummeting stock values in late 2024 amid fears that the incoming US administration could enact policies eroding the competitiveness of renewables.⁴⁵ Market dynamics have added to the uncertainty.⁴⁶ The demand outlook for renewable energy technologies is clouded by

volatile pricing, supply chain overcapacity and investor scepticism.⁴⁷ Large energy companies, including BP, have contributed to this trend by scaling back their renewable energy strategies and redirecting investment towards fossil fuels.⁴⁸ (\rightarrow See Sidebar 4). Meanwhile, private investors, including major hedge funds, have expressed waning interest in clean energy due to concerns about profitability and political risk, with some declaring that "clean is dead for now".⁴⁹

In addition, there has been growing uncertainty about the future availability of international climate finance. Policy shifts – such as the loss or redirection of financing for the US Agency for International Development and various climate-related funds – pose a serious threat to renewable energy initiatives in developing countries.⁵⁰ A lack of clarity on the future of tariffs and tax credits triggered steep declines in funding and investment for renewables in early 2025.⁵¹

ENERGY EFFICIENCY AND ENABLING TECHNOLOGIES

Investment in **energy efficiency and enabling technologies** was an estimated USD 871 billion in 2024, a 12% increase from 2023.⁵² This was driven mainly by a 20% increase in investment in electrified transportⁱ, which reached USD 747 billion and surpassed investment in renewables.⁵³ Markets for other technologies slowed, with heat pump investments declining 5%, hydrogen falling 42% and clean industryⁱⁱ plummeting 50%.⁵⁴ However, between 2020 and 2024, electrification of end-uses experienced the fastest growth.⁵⁵ During the same period, investments in fossil fuels and nuclear energy also grew but at a slower rate; their relative share in total energy investment declined, reflecting a broader trend towards renewable energy and enabling technologies.⁵⁶ (→ *See Figure 14.*)

i Electrified transport investment is based on preliminary sales data and estimated prices of electric vehicles, fuel cell vehicles, and electric charging infrastructure and hydrogen refuelling stations. Private charging investment for commercial vehicles is not included.

ii Clean industry investments include investments in bioplastics, circular economy, clean ammonia and clean steel.

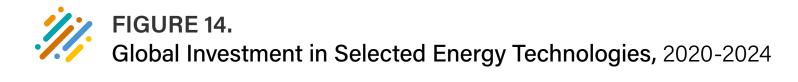


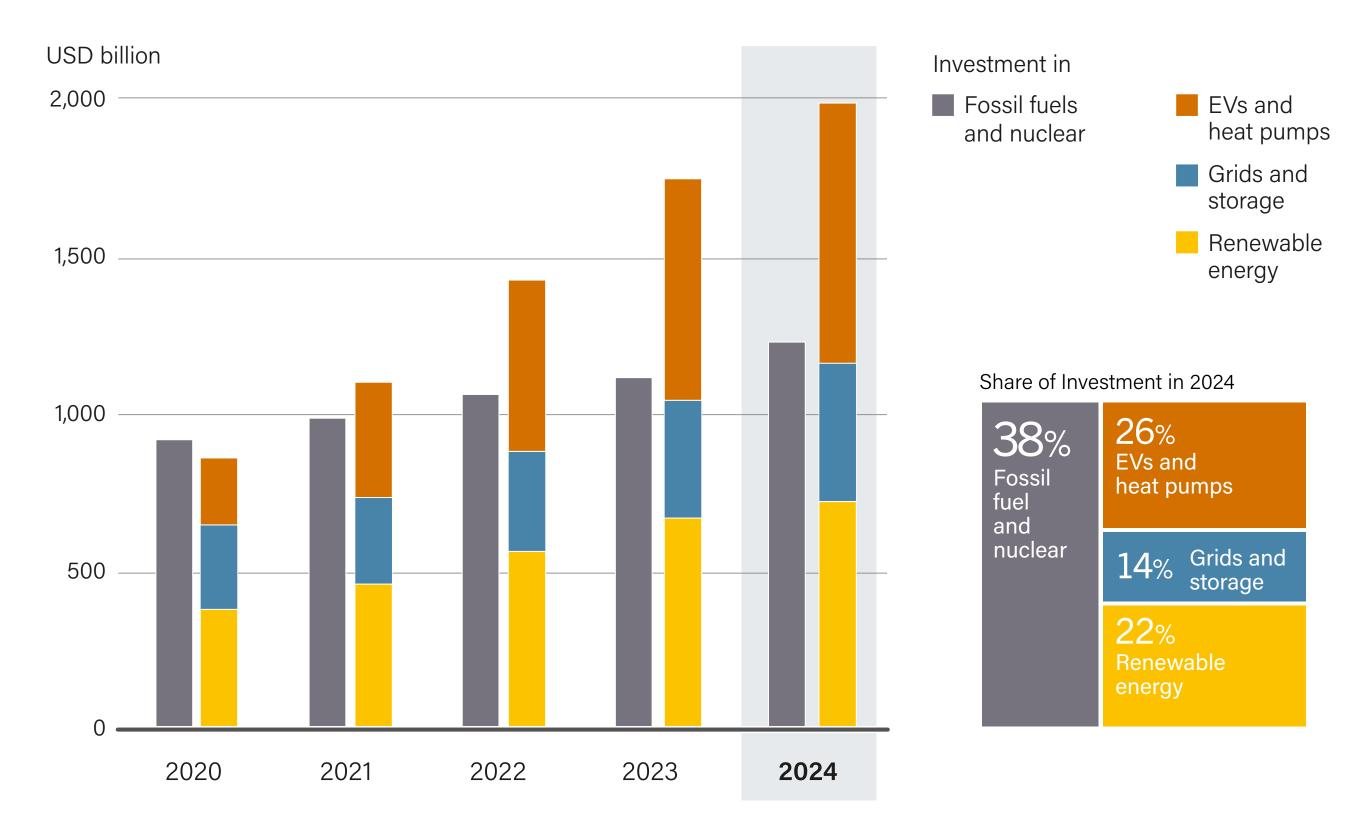
Global demand for **heat pumps** weakened in early 2024, although some regions may have reached a turning point.⁵⁷ Sales in China grew 13% in the first few months of 2024 – the second consecutive year of double-digit growth – consolidating its position as the largest domestic heat pump market (30% of the global total).⁵⁸ In the United States, the second largest market, sales fell 1% in the first half of the year, and in the EU they fell nearly 50%.⁵⁹ Factors contributing to the decline in European heat pump sales included falling natural gas prices, a slowdown in the construction sector (with a large share of heat pumps installed in new buildings) and an uncertain political and regulatory landscape.⁶⁰

Investment in **clean industry projects**ⁱ fell nearly 50% in 2024.⁶¹ Clean steel projects took the biggest hit in financial commitments, with investment falling to around USD 17.3 billion, down from USD 40.2 billion in 2023.⁶² Green hydrogen made from renewables remained costly and in scarce supply, and some producers (such as Europe's ArcelorMittal) delayed planned investments in hydrogen-based projects.⁶³ Unlike in 2023, few developers of new clean steel and ammonia facilities allocated capital for "co-located" hydrogen plants and renewable energy installations.⁶⁴

Despite these setbacks, clean **hydrogen** projects – encompassing both renewable and low-carbon sources – reached a major milestone, with final investment decisions (FIDs) rising sharply from 102 projects in 2020 (worth around USD 10 billion) to 434 projects in 2024 (worth around USD 75 billion).⁶⁵ The share of total hydrogen investment dedicated to clean hydrogen supply projects also increased, from more than 60% in 2020 to 75% in 2024.⁶⁶

Global investment in **power grids** and **energy storage** reached a record high in 2024. Grid spending rose 15% to USD 390 billion, with growth across all regions, notably in Europe.⁶⁷ Investment in energy storage increased 36% to USD 54 billion, driven largely by developments in Asia and the United States.⁶⁸ Despite this progress, investment in grid infrastructure still needs to increase significantly to support the expansion of renewable generation required to achieve net zero greenhouse gas emissions targets by 2050.⁶⁹



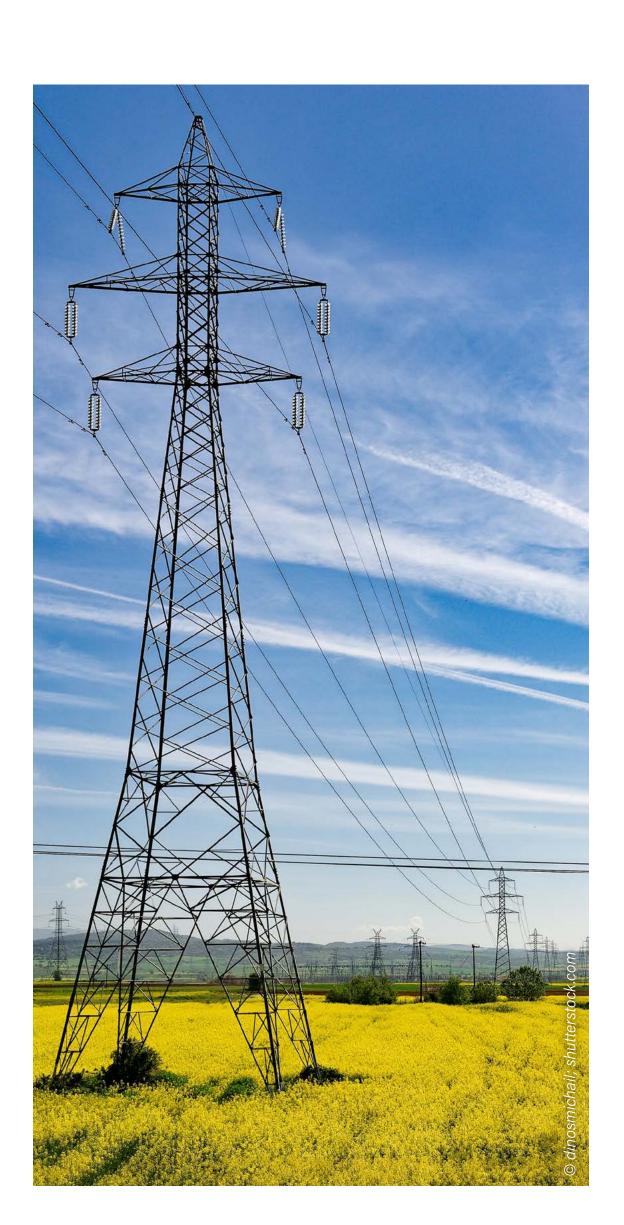


Source: See endnote 56 for this section

← 34

i Clean industry projects include, bioplastics, circular economy, clean ammonia and clean steel.





RENEWABLE POWER

In 2024, **global electricity generation** reached a record high of around 30.9 thousand terawatt-hours (TWh), with renewables accounting for nearly one-third (31.9%) of the total.⁶ (→ *See Figure 16.*) Fossil fuels remained the dominant electricity source, generating 18.2 thousand TWh and representing 59.1% of the total, although this share has been declining; nuclear power accounted for the remainder (9%).⁷

Hydropower remained the largest source of renewable electricity (14.3% of the total), while wind and solar power saw the most dynamic growth.⁸ Between 2015 and 2024, solar power generation increased 16-fold, reaching 2,132 TWh (6.9%), while wind generation rose nearly 4-fold to 2,494 TWh (8.1%).⁹ Bioenergy and geothermal power together contributed 800 TWh (2.6%).¹⁰ Thanks to the steady rise in wind and solar generation renewables are helping to meet rising electricity demand while increasingly displacing fossil fuels in the power sector.¹¹

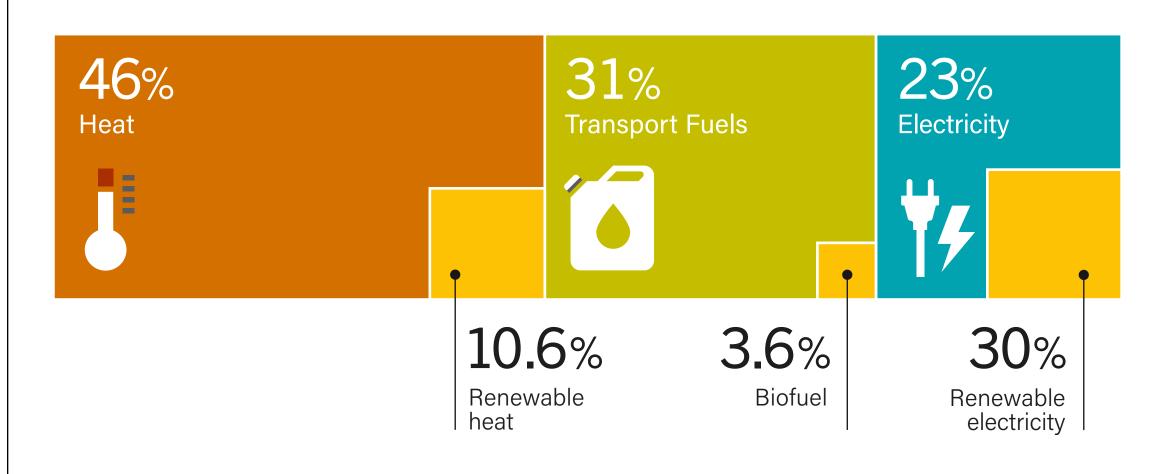
23%

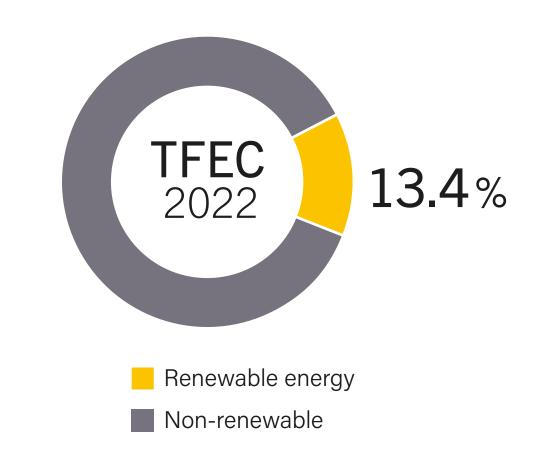
of total final energy consumption is met by electricity.



FIGURE 15.

Total Final Energy Consumption (TFEC) and Share of Modern Renewable Energy, by Energy Carrier, 2022





Source: See endnote 2 for this section.

← 36 →

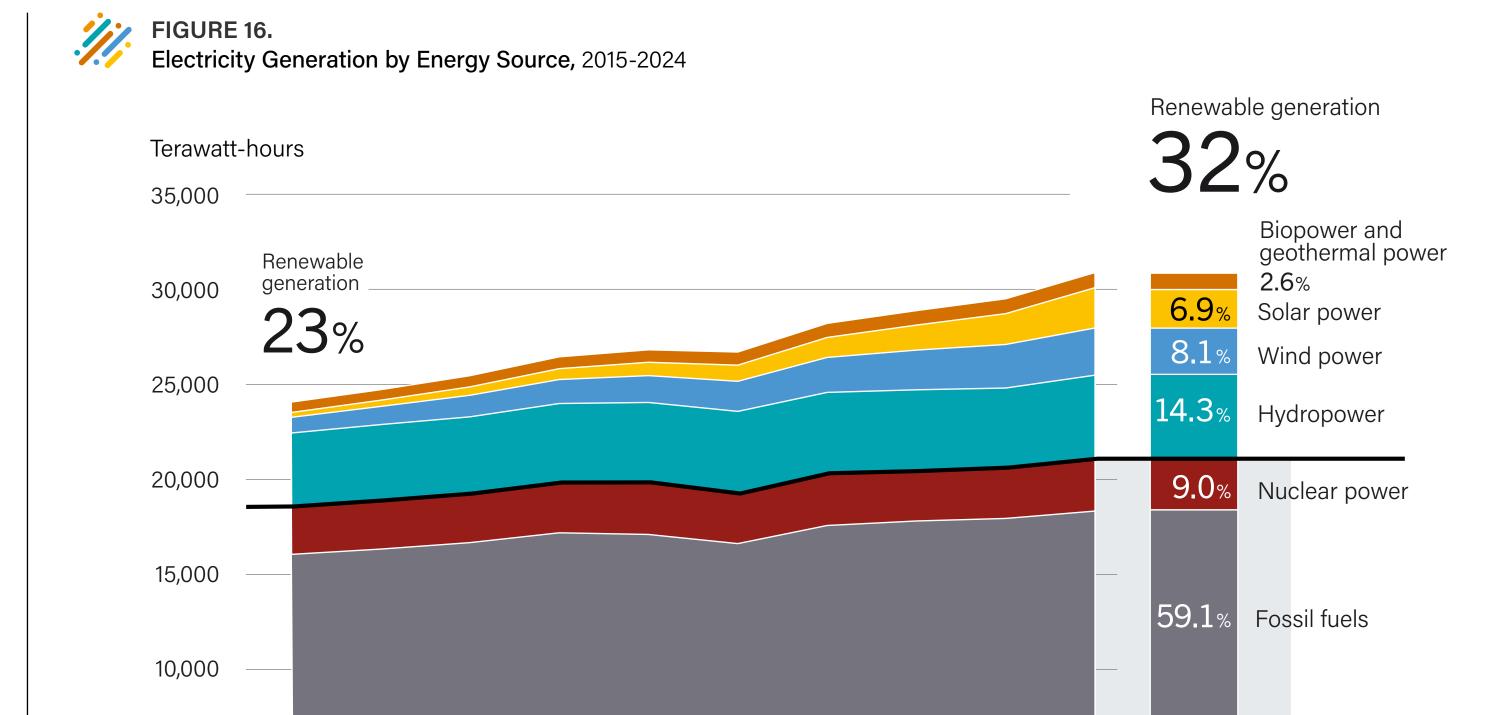




Global renewable power capacity additions totalled 741 gigawatts (GW) in 2024, with China alone accounting for 60.2% (445 GW).¹² (→ See Figure 17.) Europe contributed 12.4% (92 GW), followed by Asia and Oceania (excluding India and China) with 9.8% (73 GW) and North America with 7.6% (56 GW).13 India added 36 GW (4.8%) in 2024, while Brazil added 2.4% (18 GW), and the rest of Latin America and the Caribbean added just 1.0% (8 GW).¹⁴ Africa and the Middle East collectively accounted for only 1.7% (13 GW) of renewable power capacity additions.¹⁵ Most growth continued to be concentrated in a few key markets (particularly China), while many regions remain greatly under-represented in the global energy transition.

Solar PV was the clear driver of this growth, accounting for 81% of new capacity additions in 2024, followed by wind power at 16%.¹6 (→ See Figure 18.) Hydropower contributed just 2%, and other renewables - bioenergy, geothermal, concentrated solar thermal power (CSP) and ocean power accounted for only 1% of newly installed capacity.¹⁷ Solar PV holds a dominant position not only as the most rapidly expanding renewable energy technology, but also as the largest overall source of renewable power capacity.





Source: See endnote 6 for this section.

2015

2017

2019

2021

2023

2024

5,000







Total cumulative installed **solar PV** capacity passed the 2 terawatt (TW) mark in 2024, reaching 2.25 TW nearly double the global total in 2022. In 2024 an estimated 602 GW of new capacity was added – up 32% over 2023 – comparable to the cumulative capacity installed globally by 2019. This continued growth was driven by historically important markets such as China (around 60% of the growth), the United States (8%), and India

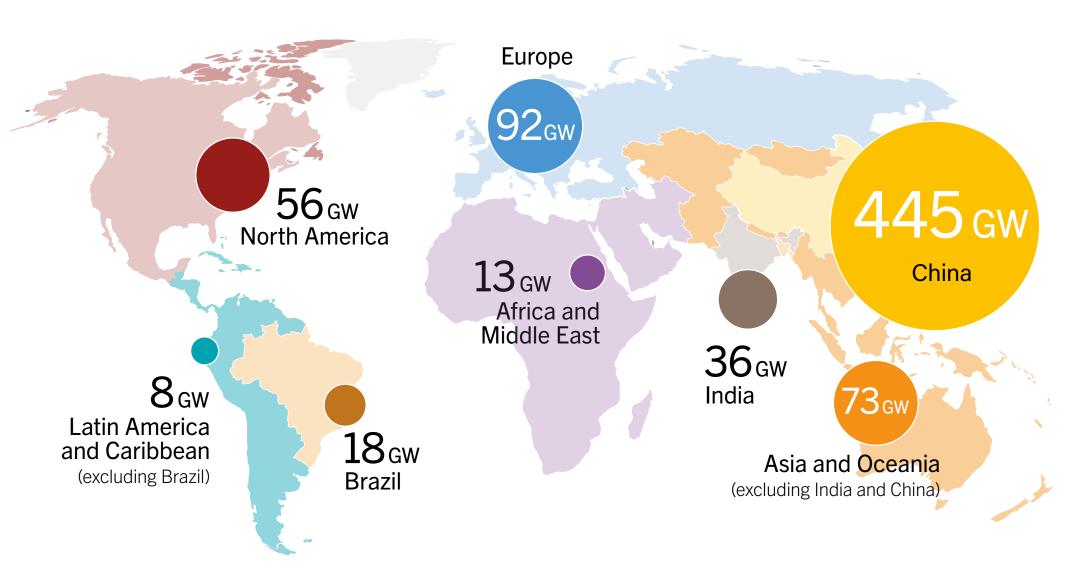
(5%); however, some new entrants were also significant. For example, in Pakistan (3%) solar PV combined with battery systems has become an attractive option for achieving energy autonomy.²⁰ Pakistan alone installed more solar PV capacity in 2024 than Italy, France and Australia combined.²¹

An estimated 116.8 GW¹ of new **wind power** capacity was connected to the world's grids in 2024, a record high despite marginal growth (0.2%).²² **Onshore** wind installations rose 3.1%, to 109 GW, whereas **offshore** additions fell 27.5%.²³ China again dominated global wind power additions, accounting for 68.3%; not including China, global additions fell 9.6%.²⁴ The cumulative wind power capacity in operation grew

11.2% to 1,135.4 GW during 2024.²⁵ The wind industry had another challenging year, and deployment was slowed by several factors, including political and policy instability, increasing costs and risks, permitting and grid-related challenges, and rising opposition in some key countries.²⁶ However, installations picked up in some emerging markets, and several countries saw positive policy developments.²⁷

i The data in this section reflect wind power capacity that was newly grid-connected during 2024 and in operation by the end of 2024. Accounting for decommissioning, net additions were an estimated 114.9 GW in 2024. Including more than 9 GW of capacity that was mechanically installed in China, India and the United States, but not necessarily grid-connected, global wind power additions in 2024 were closer to 127 GW. "Mechanically installed" refers to capacity that is in place and ready to produce electricity but not officially connected to the grid. See endnote 22 for this section.

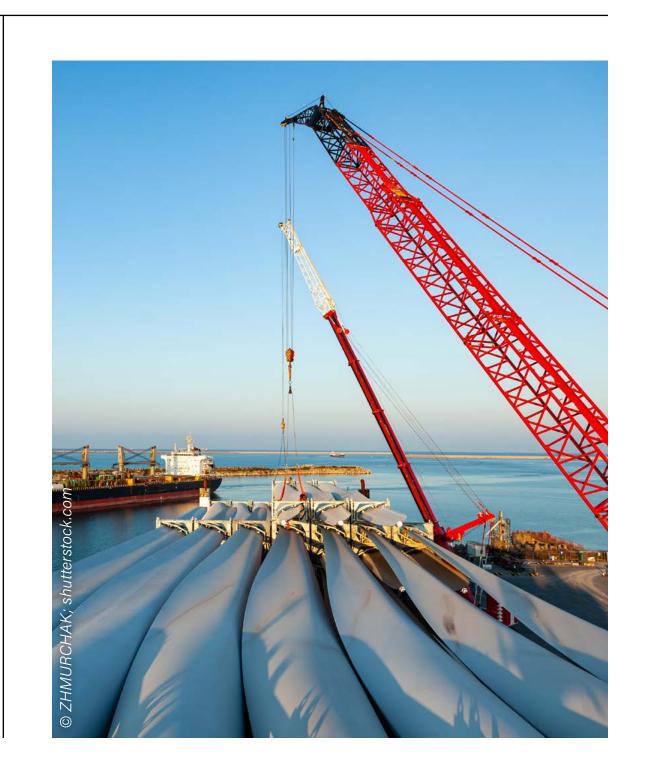




Additions in 2024
+741 GW

Share of Renewable Power Capacity Additions

12%
Europe
10%
Asia and Oceania
8%
North America
India
5%
Rest of world



Source: See endnote 12 for this section.

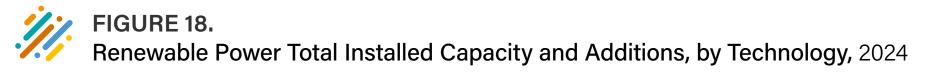
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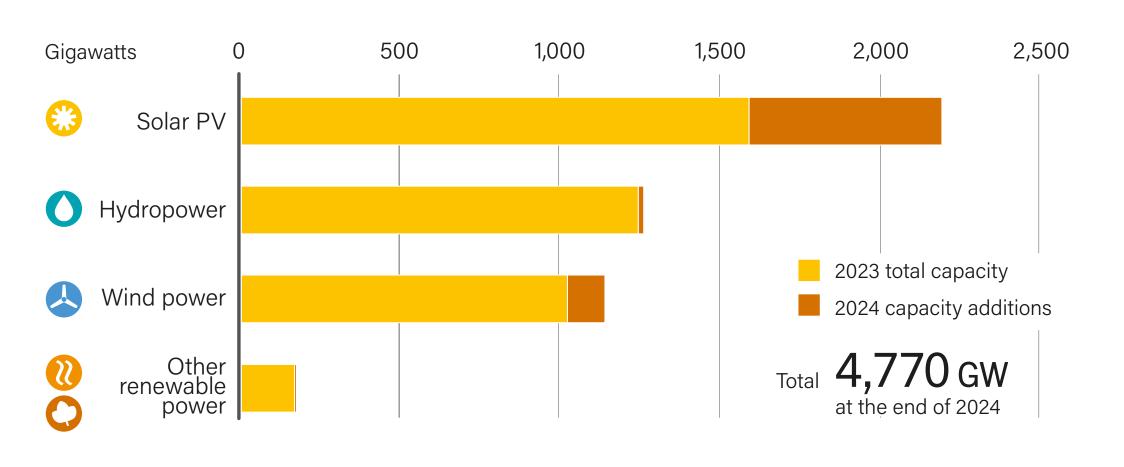


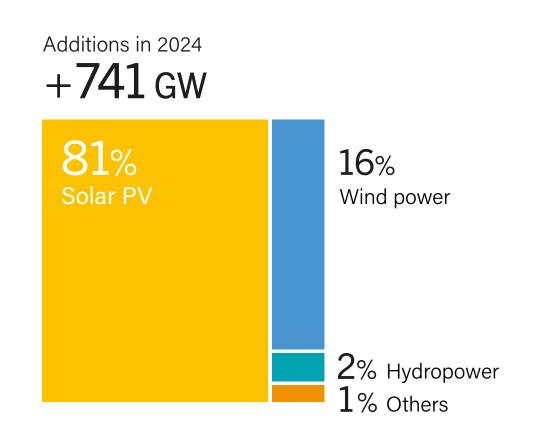
In 2024, **hydropower** continued to play a central role in renewable electricity generation, with total output reaching an estimated 4,578 TWh.²⁸ Globally 16.2 GW capacity was added in 2024.29 China remained the dominant player, adding 6.7 GW of new conventional capacity and maintaining its position as the top hydropower producer, generating more than 1,400 TWh.30 Other countries that contributed to new capacity additions included Tanzania (added 1.9 GW), Ethiopia (1.2 GW), Bhutan (1.1 GW) and Pakistan (0.9 GW).³¹

Capacity in bioenergy, geothermal, ocean power and CSP remained relatively flat, collectively totalling 177 GW.³² **Biopower** capacity increased 4.6 GW in 2024, due mainly to new installations in China and France, reaching a global total of 155 GW.33 Electricity generation from solid biomass power facilities increased globally to 711 TWh, although it fell in Europe with major producers such as Sweden, Finland, Denmark, and the Netherlands seeing reductions, driven by shifts in energy policy, market competitiveness and lower pellet imports.34

Global **geothermal** electricity generation reached an estimated 99 TWh in 2024.³⁵ At least 400 megawatts (MW) of new capacity was added during the year, bringing the total installed capacity to around 15.1 GW.³⁶ More than half of these additions were in New Zealand, followed by notable developments in the Philippines, Türkiye, Indonesia, the United States and Japan.³⁷







Source: See endnote 16 for this section.



annual growth in global renewable capacity in 2024.



Total installed **concentrated solar thermal power** (CSP) capacity grew by 350 MW to reach 7.2 GW in 2025.³⁸ The positive dynamics of 2023 continued, with several new projects initiated in China, where the CSP pipeline continued to expand and the first projects of the country's current five-year period were connected to the grid.³⁹ China's favourable policies for CSP are helping the country to drive the global CSP market.⁴⁰

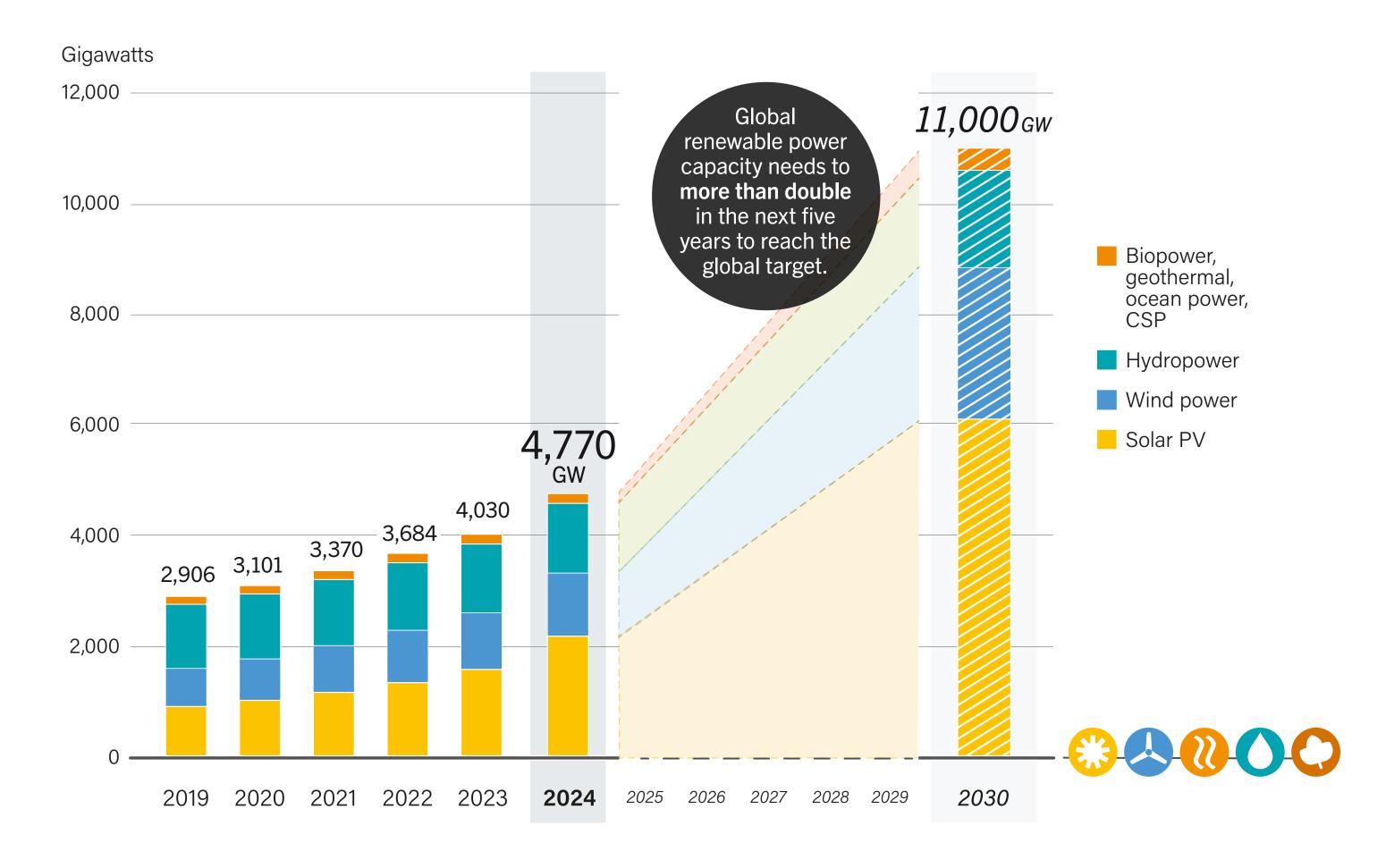
For **ocean power**, the global installed capacity remained relatively unchanged in 2024, with 1.6 MW (net) added.⁴¹ The installed capacity increased by 2.6 MW in the Russian Federation and fell by 1 MW in the Republic of Korea (with downsizing or decommissioning of an existing plant).⁴² Policy and investment activity increased compared to previous years.⁴³

Despite the progress of recent years, at the end of 2024 the world remained far from its collective renewable power capacity target of 11,000 GW by 2030.⁴⁴ Meeting this goal will require more than doubling the current installed capacity within just six years, with unprecedented acceleration in deployment.⁴⁵ (→ See Figure 19.)

+1,040 GW/year

needed annually from 2025 to 2030 to meet the global tripling target, nearly 40% higher than the record set in 2024.





Source: See endnote 45 for this section.

← 40 →







of energy education still focuses on fossil fuels. Only 32% is dedicated to renewables as of 2024.

global solar PV manufacturing capacity by end-2024.

Nearly double current PV demand.

MANUFACTURING, LABOUR AND SUPPLY CHAINS

The rapid scale-up in renewable energy deployment has been mirrored by a surge in manufacturing capacity, particularly for solar PV. Global solar manufacturing capacity was expected to exceed 1,100 GW by the end of 2024, nearly double the solar PV demand in 2024.46 This oversupply has driven module prices down by more than half since early 2023, squeezing profit margins and triggering market instability.⁴⁷ In 2024 alone, around 300 GW of polysilicon and 200 GW of wafer manufacturing projects - worth an estimated USD 25 billion – were cancelled.48 Vulnerabilities in the solar PV supply manufacturing sector have prompted new efforts to strengthen supply chain resilience and diversify sourcing amid growing deployment needs.49

In the wind sector, uncertainties due to stop-start government policies and unpredictable procurement cycles have created high demand volatility.⁵⁰ These factors combined with permitting bottlenecks have led to razor-thin or even negative margins and have rendered investment in the supply chain unviable.⁵¹ In some key regions (Europe, Americas) investment in the supply chain has been insufficient to meet ambitious targets and expected demand beyond the next couple of years.⁵² China continued to dominate turbine manufacturing as well as the world's supply chain for critical components and raw materials.⁵³ Chinese turbine manufacturers represented 6 of the world's top 10 and, for the first time, held the top four spots.⁵⁴ While heavily reliant on their home market, China's biggest manufacturers looked to expand sales overseas and opened new factories around the world.55 Despite record installations and orders, however, intense competition and oversupply of components further reduced profitability for Chinese manufacturers.56

The workforce needed to sustain the energy transition is falling short.⁵⁷ Addressing workforce and skills challenges is essential to maintain the momentum of renewable energy growth and to achieve global net zero greenhouse gas emissions by 2050. In 2023, the renewable energy sector employed around 16.2 million people.⁵⁸ (→ See Sidebar 5.)

By 2030, a global shortfall of 7 million skilled workers is projected, particularly in engineering, project management and technical installation roles.⁵⁹ The demand for green skills is rising much faster than the supply. In 2023, job postings requiring at least one green skill increased 22.4%, while the green talent pool grew by 12.3% across the 48 countries covered in a recent study.60 This mismatch is compounded by a misalignment in education and training systems. As of 2024, 68% of energy-related degree programmes focused on fossil fuels, with only 32% dedicated to renewables.61

The fast development of the renewable energy manufacturing industry is increasingly attracting attention to the working conditions along supply chains. Governments, industry players and civil society organisations are looking into safeguards to ensure that the industry develops with respect for worker's rights. Focus is also given to solutions for avoiding or mitigating potential environmental impacts of renewables deployment.⁶² (→ See Sidebar 6.)

i Green skills refer to the abilities that support environmentally sustainable practices, including those related to energy efficiency, renewable energy, waste reduction, and environmental conservation.

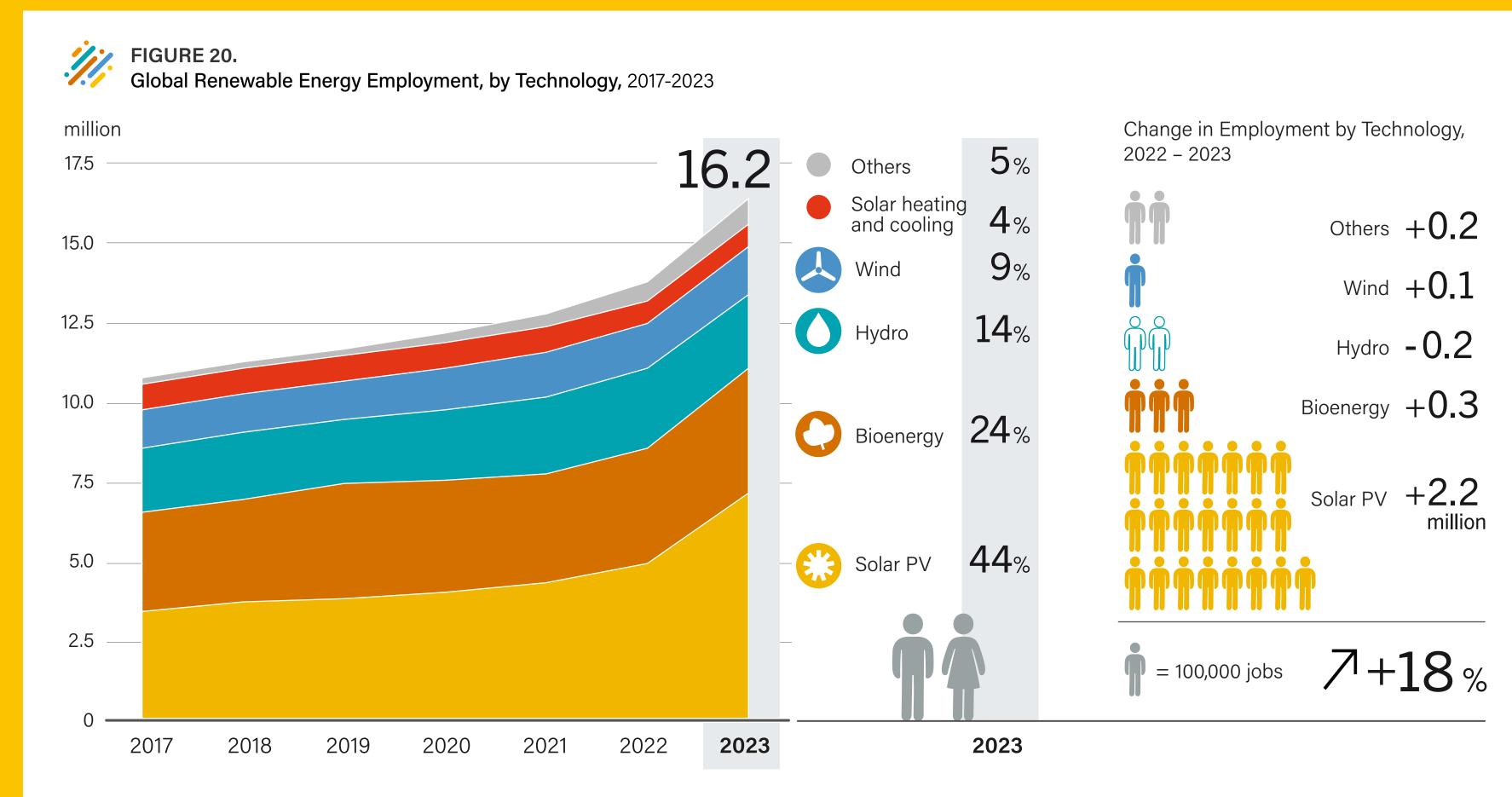


continued

Globally, despite substantial growth in renewable energy employment in some countries and regions, direct and indirect renewable energy jobs accounted for only 0.4% of the total labour force of 3.65 billion in 2023, while direct and indirect jobs in all energy sectors made up around 1.8%.

Expanding the renewable energy workforce globally, especially in developing countries, requires education and skills development that is inclusive of gender, social equity and the reskilling of workers from the fossil fuel sector. As of May 2025, 22 countries had submitted their latest round of Nationally Determined Contributions (NDCs) towards reducing greenhouse gas emissions under the Paris Agreement, but fewer than 10 of these countries referred to skilling or vocational training in the renewable energy sector to support their climate goals. They included Andorra, Brazil, Canada, Kenya, the United Arab Emirates, the United Kingdom and Uruguay.

Although renewable energy employment is expanding, much of the growth remains regionally concentrated. Realising the full potential of jobs in renewables will require coherent policies and enabling institutional frameworks, investment, education, skilling and reskilling across regions and communities.



Note: Employment data shown in this figure refers to direct and indirect jobs in renewable energy. Indirect employment includes employment in the upstream industries that supply and support the core activities of renewable energy deployment. Workers in such positions may be engaged in the production of steel, plastics or other materials, or provide financial and other services.

Source: See endnote 58 for this section.

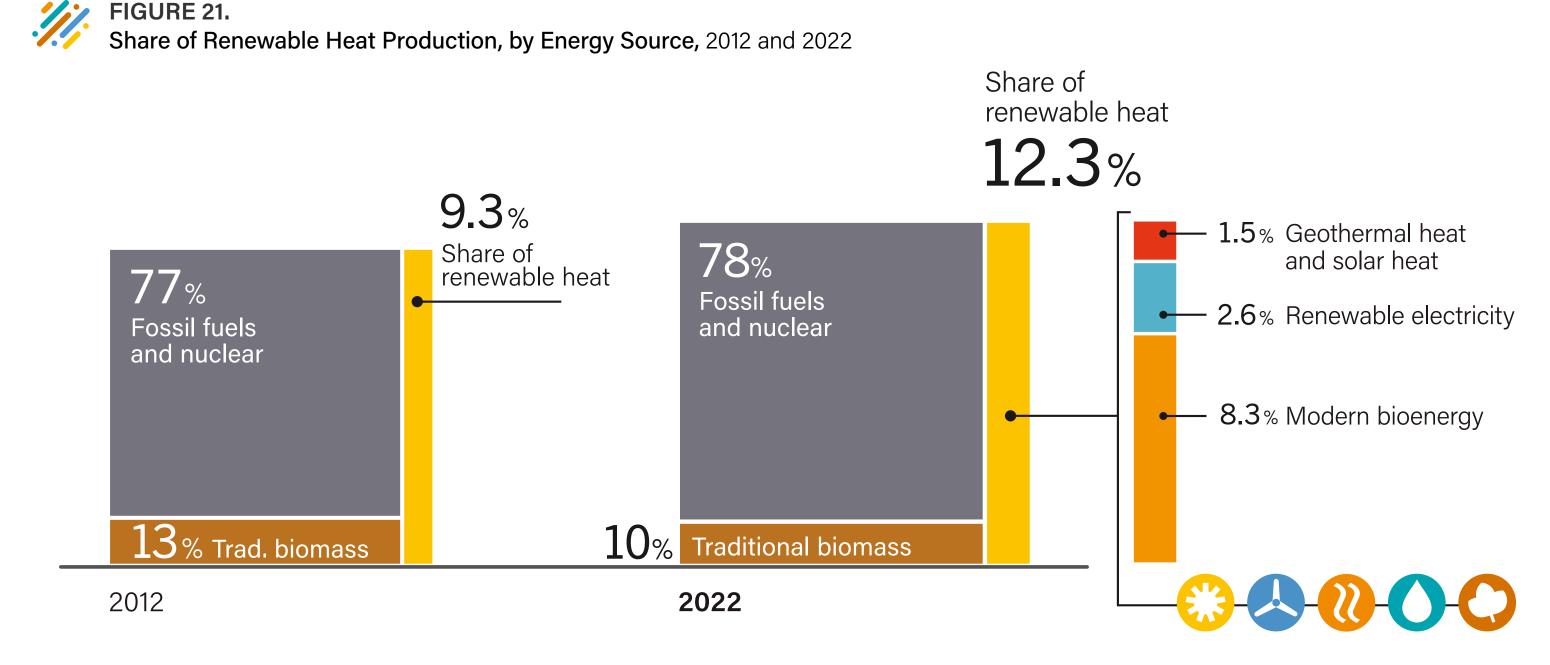
← 43 →



RENEWABLE HEAT AND FUELS

In 2022 (latest data available), the share of moderni renewable energy in total **heat** production reached 12.3%.⁶³ (→ See Figure 21.) The share of traditional biomass in total heat supply fell to 10%.64 Meanwhile, fossil fuels remained dominant, maintaining a stable and high share of around 77%.65

Total renewable heat supply increased 3.2% in 2022.66 Modern bioenergy provided 8.3% of global heat in 2024, with solid bioenergy playing a major role in supplying district heat networks.⁶⁷ The EU led the pellet market, accounting for 44% of production and 50% of consumption in 2023 - mainly for residential use; after years of growth, production stagnated in 2023 because of higher input prices, falling industrial demand and a record warm winter.68 Renewable electricity for heat grew steadily, highlighting the growing role of electrification in the heat sector.⁶⁹ However, direct renewable heating technologies continue to provide only a modest contribution to global heat supply, due in part to limited policy support.70



Source: See endnote 63 for this section.

growth in total renewable heat supply in 2022.



Toftlund District Heating Solar Park, Denmark

i Modern renewable energy in total heat production includes modern bioenergy, renewable electricity, geothermal heat and solar heat. It excludes traditional biomass used for heating.



Geothermal heat, which does not include ground-source heat pumps, supplied around 245 TWh (882 petajoules), with China alone accounting for an estimated two-thirds of global geothermal heat output.⁷¹ Due to China's rapid expansion in this sector, the country now produces 43% more geothermal heat than the entire world did in 2019.⁷² Among other leading countries, geothermal continued to grow in Türkiye; Iceland saw only modest increases, and Japan experienced a decline.⁷³

By the end of 2024, **solar thermal heating systems** were supplying direct heat to millions of residential, commercial and industrial clients in at least 134 countries.⁷⁴ The global market for solar thermal water collectors contracted 14.2% in 2024, due mainly to an ongoing decline in China, the largest market.75 However, during the year, China also commissioned the world's largest solar thermal plant, demonstrating continued investment in large-scale applications despite the overall market declin.⁷⁶ (→ See Snapshot China.) Small-scale systems continued to lose market share in several regions, whereas demand grew for largescale solar collectors (water, air and concentrating systems) - including for district heating systems and industrial process heat - as cities and companies sought to decarbonise their operations.⁷⁷ Solar thermal heating technologies continued to face multiple challenges, including market competition due to a lack of awareness and an imbalance in incentives.⁷⁸

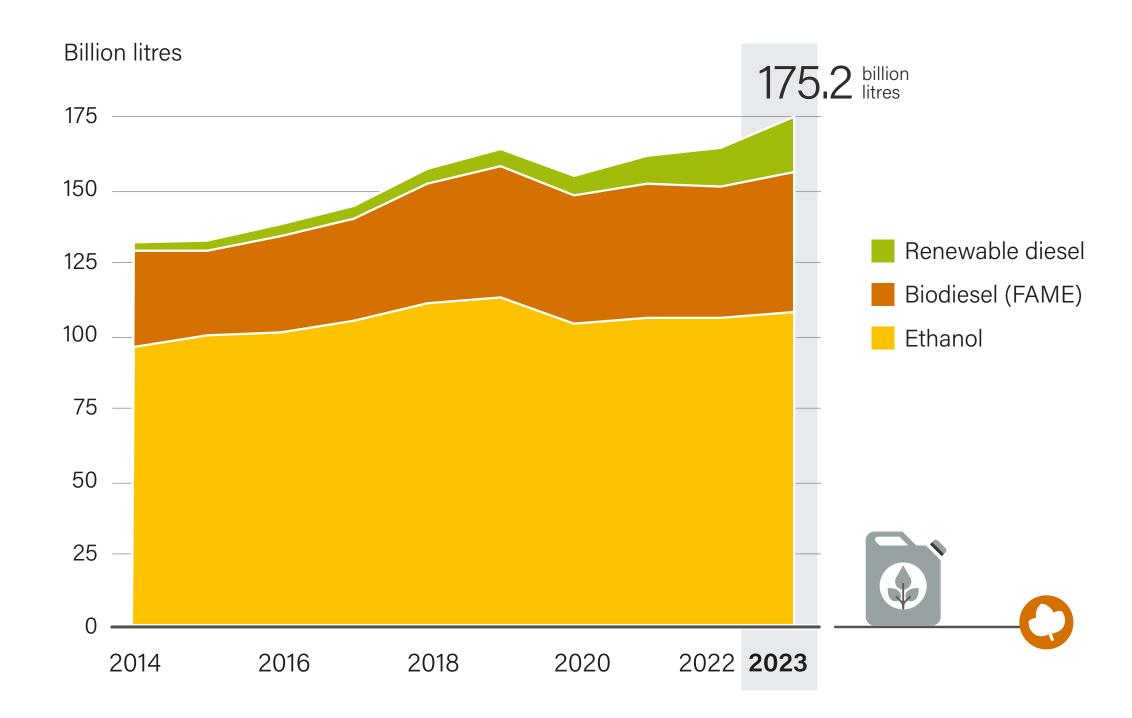
Liquid biofuel production rose 7% in 2023, reaching a total of 175.2 billion litres, led by Brazil, India, Indonesia, and the United States.⁷⁹ (→ *See Figure 22*.) In 2024,

following a full year of B35 implementation - the world's highest national mandate for blending biodiesel in petrol – Indonesia reported palm oil-based biodiesel production of 13 billion litres and consumption of 12.6 billion litres.80 Ethanol and renewable diesel production hit record highs in the United States, while the EU remained the largest bio-based diesel market despite a decline in Swedish blend mandates.81 In 2024, Brazil enacted the Fuel of the Future law, setting blending levels for biomethane, higher blending mandates for ethanol (from 22% to 27%, with a potential to reach 35%) and biodiesel (increasing one percentage point annually, starting 2025, to reach 20% by march 2030), and also setting greenhouse gas reduction targets for the aviation sector and a national programme for green diesel.82 Sustainable aviation fuel (SAF) production grew but still covered less than 1% of aviation fuel demand; in 2024, new SAF mandates in India, Indonesia and the Republic of Korea are expected to drive future growth.⁸³





FIGURE 22.
Global Supply of Ethanol, Biodiesel and Renewable Diesel, 2014-2023



Note: FAME stands for Fatty Acid Methyl Ester, a type of biodiesel produced through the transesterification of vegetable oils or animal fats with methanol. It is commonly used in transport and is typically blended with fossil diesel in varying proportions (e.g., B7, B20)

Source: See endnote 79 for this section.

 \leftarrow 46 \rightarrow







Table 1. Top Five Countries for Total Renewable Energy Supply by Technology/Source, 2024

	1	2	3	4	5
Total renewable power capacity	China	United States	Brazil	India	Germany
🗱 Solar PV	China	United States	India	Germany	Japan
Wind power	China	United States	Germany	India	Brazil
O Hydropower	China	Brazil	Canada	United States	Russian Federation
Biopower	Germany	United Kingdom	United States	China	Italy
@ Geothermal power	United States	Indonesia	Philippines	Türkiye	New Zealand
Total biofuels production	United States	Brazil	Indonesia	China	India
Total pellets production	United States	Viet Nam	Germany	Canada	Latvia
Solar water heating collector capacity	China	Türkiye	Brazil	United States	India

Source: See endnote 84 for this section.



Solar PV in China



Table 2.
Top Five Countries for Per Capita Renewable Energy Supply by Technology/Source, 2024

	1	2	3	4	5
Total renewable power capacity per capita	Iceland	Norway	Sweden	Austria	Finland
🔅 Solar PV	Netherlands	Australia	Germany	Estonia	Spain
Wind power	Sweden	Finland	Denmark	Ireland	Norway
O Hydropower	Norway	Iceland	Canada	Sweden	Paraguay
Biopower	Germany	Czech Republic	United Kingdom	Latvia	Italy
	Iceland	New Zealand	Costa Rica	El Salvador	Nicaragua
Total biofuels production per capita	Sweden	United States	Finland	Brazil	Denmark
Total pellets production per capita	Estonia	Latvia	Austria	Germany	United States
Solar water heating collector capacity per capita	Barbados	Cyprus	Greece	Israel	Austria

Source: See endnote 85 for this section.



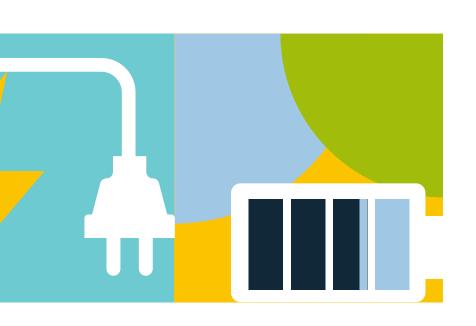
Geothermal Power Plant in Iceland



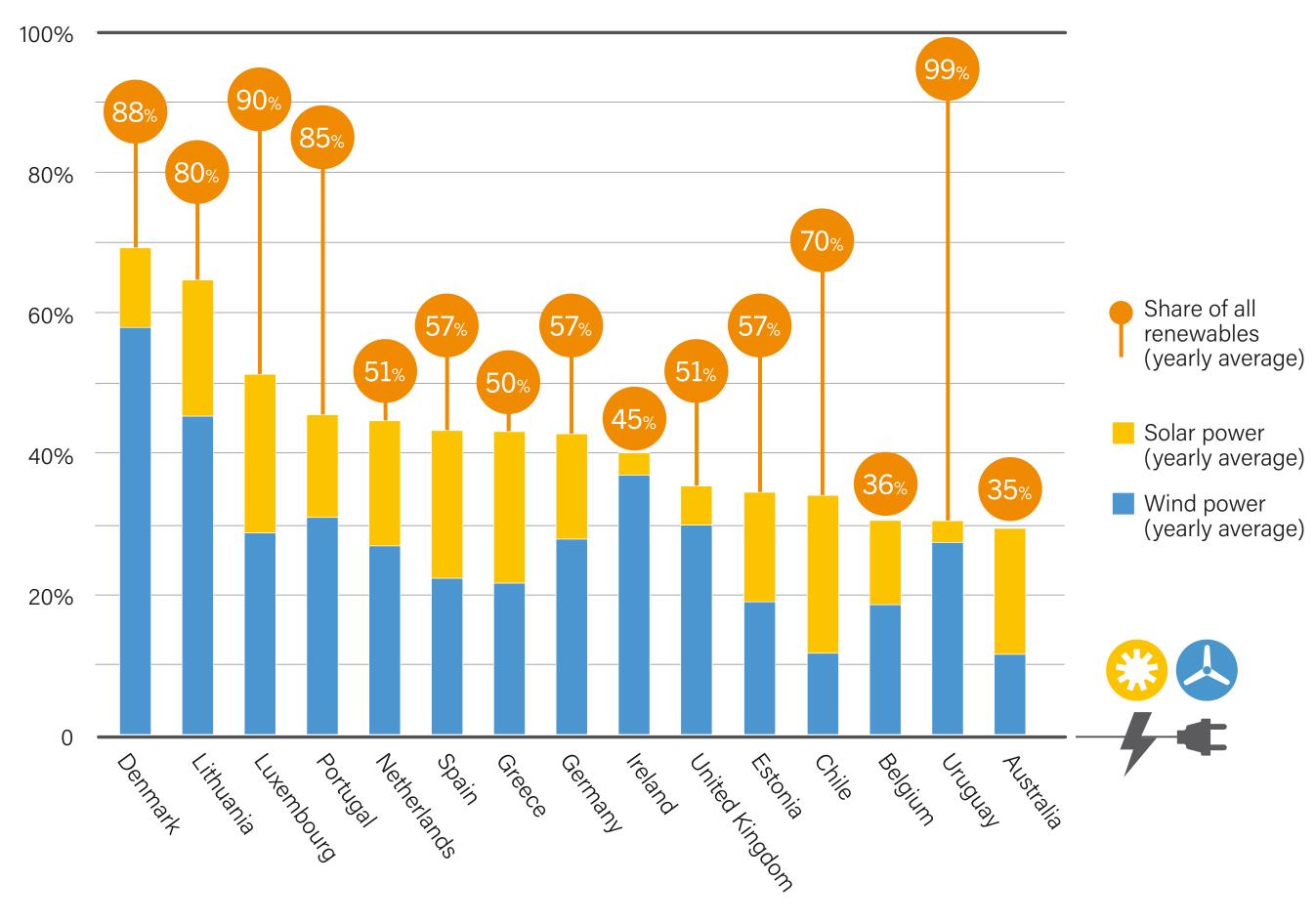
ENERGY SYSTEMS AND INFRASTRUCTURE

In 2024, the power sector continued to spearhead the adoption of renewable energy. During the year, 33 countries generated more than half of their electricity from renewable sources, and 15 countries successfully integrated more than 30% variable renewable electricity – solar and wind power specifically – into their electricity mix.¹ (→ See Figure 23.)

The power system infrastructure is evolving to support the upward trend of electrification and the integration of more distributed and variable renewable electricity into the world's grids.² In 2024, in addition to reinforcing and expanding transmission networks and interconnections, regulators and system operators increasingly focused on flexibility measures - including energy storage, demand response and the use of digital technologies - to ensure grid stability and reliable supply.3

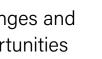






Note: Renewable energy sources for electricity generation include all modern renewables (geothermal, hydropower, modern bioenergy, ocean energy, solar energy and wind power).

Source: See endnote 1 for this section.





REN21

Energy storage systems - such as batteries, pumped storage, thermal storage and hydrogen - can help stabilise power grids, especially in the context of increased penetration of variable renewables. Battery energy storage systems were the fastest growing energy storage technology in 2024. An estimated 69 GW of new battery storage capacity was deployed globally during the year, bringing the total installed capacity to an estimated 150 GW.²² The grid-connected segment accounted for 78% of this growth.²³ (→ See Figure 24.)

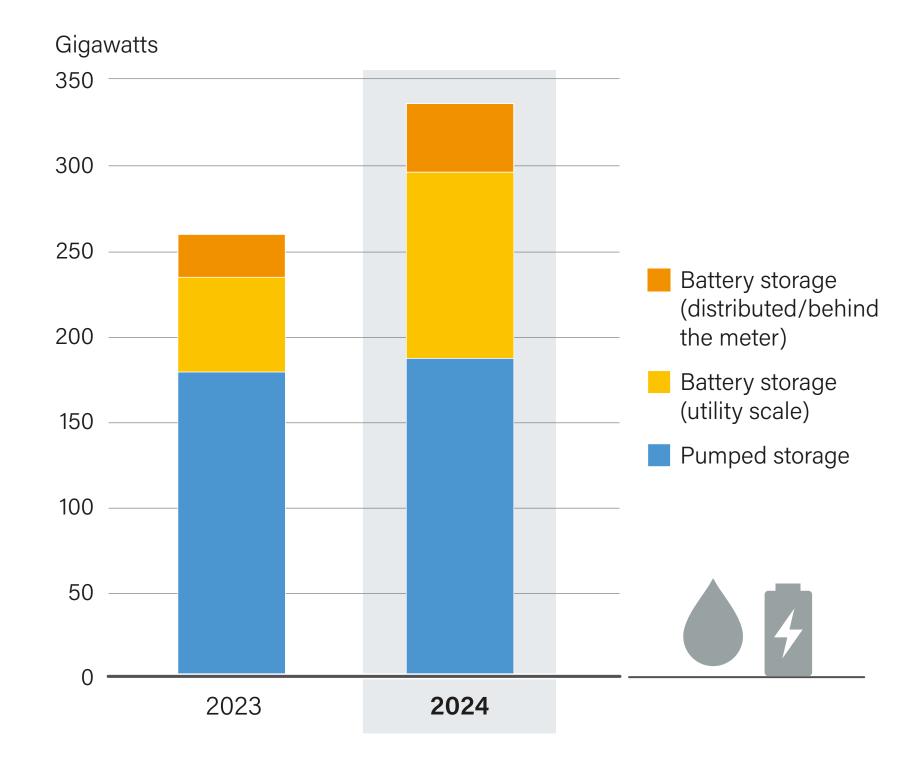
China led in battery storage deployment with 67% of global new installations, driven by provincial policies requiring battery capacity to be co-located with new solar and wind power installations.²⁴ The United States and Canada were the second largest contributors of battery capacity, with the United States adding 10.4 GW for a total of 26 GW nationwide.²⁵ Strong growth also occurred in Europe, Latin America and the rest of the Asia Pacific region.²⁶

Both the capacity of battery installations and the duration increased during the year. Altogether, around 17 installations of more than 1 GW were deployed in 2024, up from only 4 a year earlier, and an estimated 140 projects of more than 1 GW each were planned for 2025 and 2026.²⁷ In Europe, the average duration of battery storage increased from 1.4 hours in 2023 to 2.0 hours in 2024, whereas in the United States and Canada the average duration of new installations in 2024 was 3.0 hours.²⁸

Global investment in stationary energy storage projects (excluding pumped storage and hydrogen) increased 36% in 2024 to reach USD 54 billion.²⁹ Meanwhile, the global average cost for battery storage projects dropped by one-third to USD 104 per megawatt-hour, driven by the lower price of battery packs due to oversupply caused by slowing sales of electric vehicles.³⁰

Pumped storage remained the leading energy storage technology in 2024, with 189 GW of global installed capacity.³¹ Capacity additions during the year totalled 8.4 GW, an increase of 4.5% compared to 2023.³²





Source: See endnote 23 for this section



Global investment in stationary energy storage projects in 2024.

i The duration of a battery storage system refers to how long it can supply power to the grid.



Heat consumption represented 73.8% of the industry sector's total final energy consumption in 2022, of which 87.6% was from fossil fuels and 12.4% from renewables^{i,9} The renewable energy mix of the heat consumed by industries was dominated by modern bioenergy at 89%, followed by electric heat (10.4%) and very small shares of solar and geothermal heat (0.1% and 0.2%, respectively).¹⁰

The **buildings** sector accounted for 31% of TFEC in 2022, with a renewable energy share of 17.7%, up from 12.1% a decade earlier.¹¹ This reflects an increase in the direct use of renewables in buildings, as well as the higher penetration of renewables in the power sector.¹² The main energy consumers in buildings are thermal uses, such as heating, domestic hot water, cooking and cooling spaces. Although heat accounts for most of the

energy consumption in buildings, cooling is the fastest growing end use and was the main driver of rising electricity demand in the sector in 2024.¹³

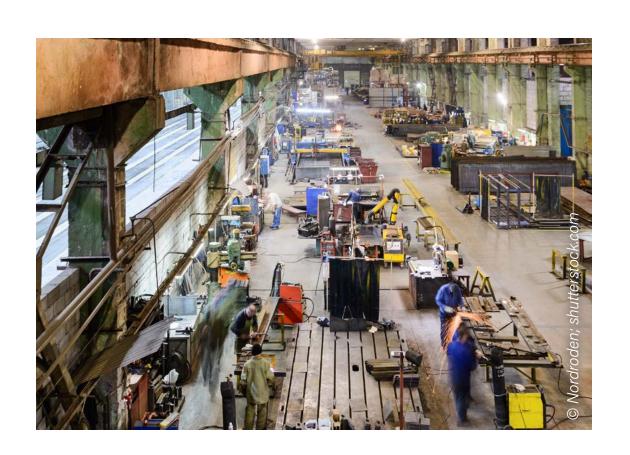
Global energy consumption in the buildings sector fell slightly in 2023, due mainly to warmer winters and lower heating demand, which was offset in part by increases in other end uses.¹⁴ Meanwhile, electricity use in buildings is rising: in 2024, the buildings sector

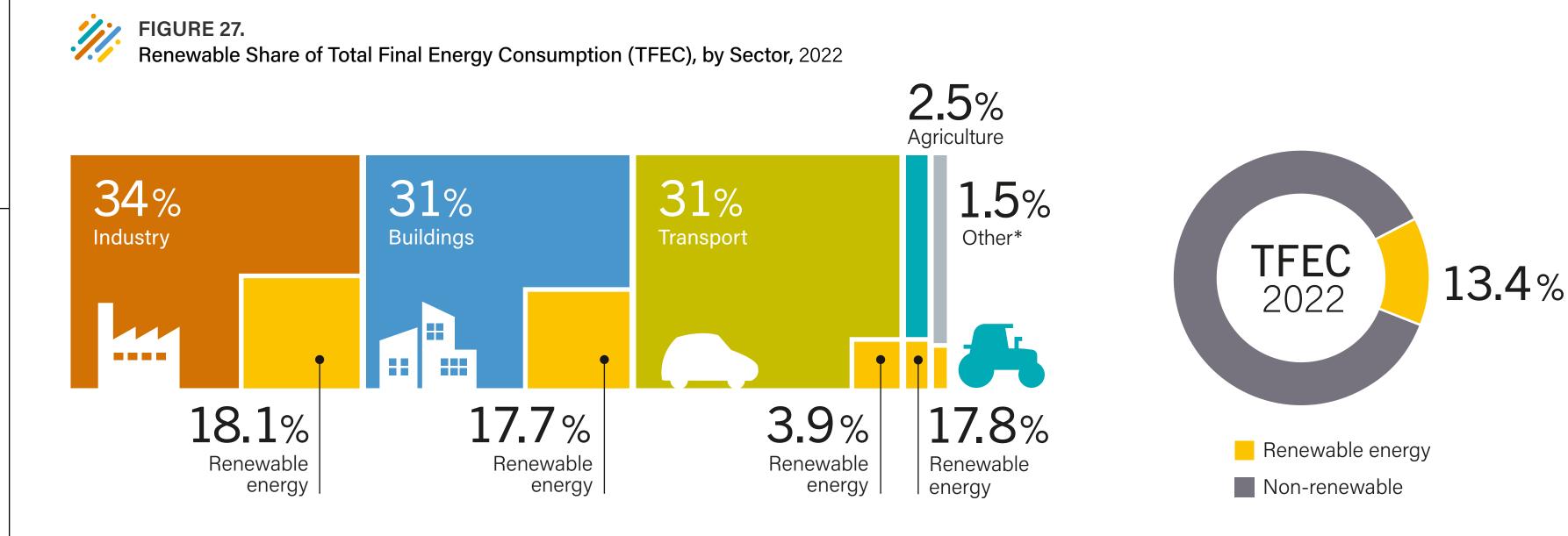
accounted for nearly 60% of the overall growth in electricity consumption.¹⁵ Factors included heatwaves leading to growing demand for space cooling in countries such as India and China, and rising electricity demand from data centres.¹⁶ (→ See Box 1.) The United States, European Union (EU) and China together accounted for almost half of all energy consumption in buildings in 2023.¹७

i Renewables-based district heating supplies 3.4% of the renewable heat in the industry sector. See endnote 9 for this section.

73.8%

was the share of heat in the industry sector total final energy consumption in 2022.





Source: See endnote 3 for this section.

← 56 →



DRIVERS OF RENEWABLE ENERGY ADOPTION

Electrification

A key vector for renewable energy adoption in demand sectors is the electrification of end uses, including through the uptake of technologies such as heat pumps, electric vehicles and electric arc furnaces.²⁹ In 2022, the share of electricity in the world's TFEC was 23%, up slightly from 22% in 2020.³⁰ (→ *See Figure 28.*)

Electricity accounted for 26.2% of the **industry** sector TFEC in 2022 (renewable electricity was 9.3% of TFEC).³¹ High-temperature industrial processes remain heavily reliant on fossil fuels, despite technological advances in electrification, such as industrial heat pumps and electric steam crackers.³² Non-energy-intensive sectors have electrified more rapidly. The technologies needed to electrify heavy industries are still in early development stages, and the sector may suffer from a lock-in of assets due to significant upfront investments.³³

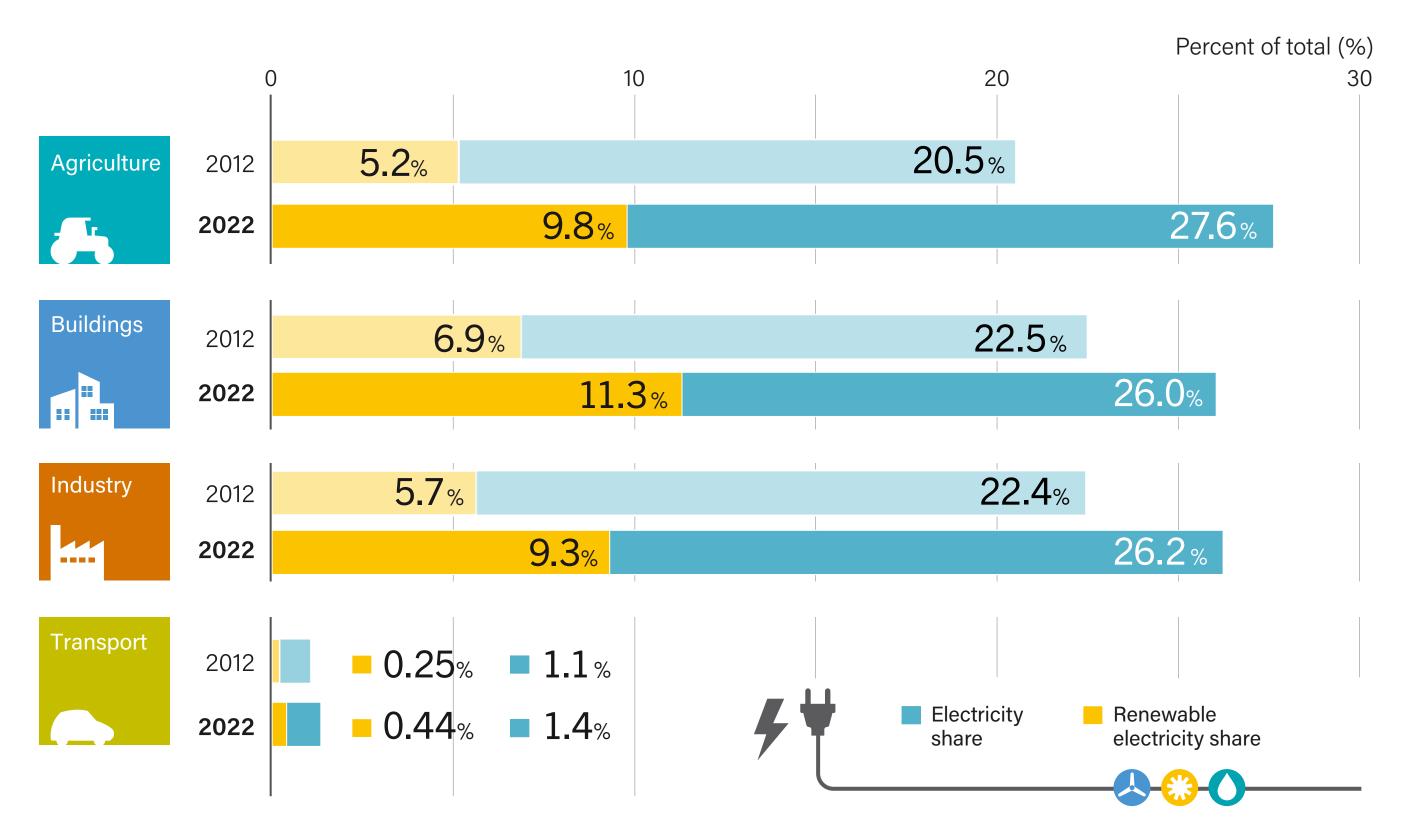
In the **buildings** sector, the adoption of electric appliances such as heat pumps for heating and cooling can drive up the overall electricity share, which reached 26% of TFEC in 2022 (11.3% of TFEC was renewable electricity).³⁴ Heat pump sales fell 1% globally in 2024, reflecting a sharp 10% decline in the first half of the year.³⁵ In the second half of the year, sales recovered strongly in some regions, such as the United States (up 15%) and Japan (up 5%), but this increase was not sufficient to compensate for the decline in Europe (down 21%) and the lack of growth in China.³⁶ Possible reasons for the European sales decline include the slowdown of the construction sector, high prices of electricity compared to fossil gas and uncertainty about supporting policies.³⁷

The highest share of electricity in TFEC was in the **agriculture** sector, accounting for 27.6% in 2022 (renewable electricity was 9.8% of TFEC).³⁸ Electrification can be advanced by switching to electric agricultural equipment (such as tractors and water pumps). The share of renewables in the electricity supply is supported by increases in on-farm renewable electricity generation.³⁹



FIGURE 28.

Electricity and Renewable Electricity Shares of Total Final Energy Consumption, by End-Use Sector, 2012 and 2022



Source: See endnote 30 for this section.

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In 2023, the global installed solar water pump capacity reached 1.1 gigawatts (GW), up 1.8% from 2022.⁴⁰ India was home to 94% of this capacity.⁴¹ Globally, however, diesel fuel accounts for nearly three-quarters (74%) of the energy used for water pumping.⁴² The biggest challenge to the widespread adoption of solar irrigation systems is affordability. Other factors that influence farmers' willingness to adopt electric machinery include upfront costs, machine sizes, battery autonomy and the availability of charging infrastructure.⁴³

The **transport** sector has the lowest electrification rate of all demand sectors in 2022, at 1.4% of TFEC, with renewable electricity representing 0.4% of TFEC. However renewable electricity use in the sector grew 15% in 2022.⁴⁴ Electrification of transport relies heavily on the adoption of electric vehicles and the availability of charging infrastructure.

Electric vehicle sales continued an upward trend in 2024, with more than 17 million units sold globally, representing more than one-fifth of global car sales.⁴⁵ Electric vehicle adoption is expanding beyond China (the leading market) and high-income countries, with record sales reported in emerging economies such as Brazil, India, Thailand and Türkiye.⁴⁶

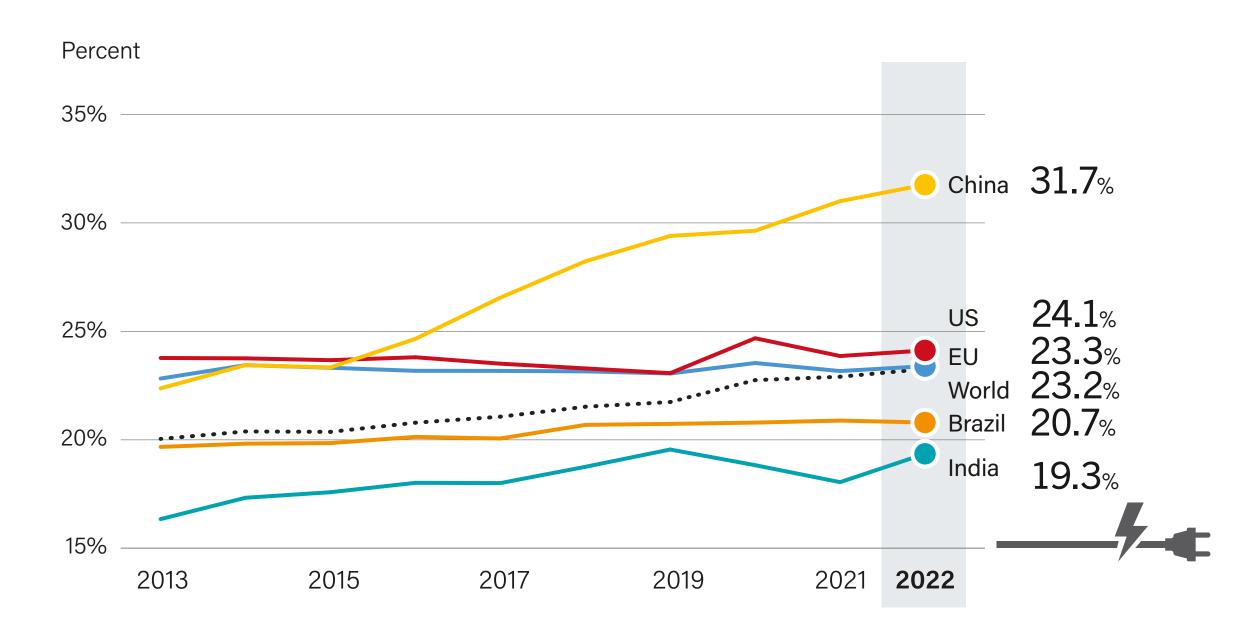
The number of charging points globally has doubled since 2022.⁴⁷ Electrification of rail transport also advanced, with many countries and regions exploring rail development and electrification.⁴⁸ India, the world's fourth biggest railway network, achieved 98.8% rail electrification by the end of 2024, and China, the second largest rail network, reached 75% as of 2023.⁴⁹

By country, China had the highest share of electricity in its TFEC, and the fastest rate of electrification, growing from 22.3% in 2012 to 31.7% in 2022.⁵⁰ The industry sector was responsible for almost 50% of the surge in China's electricity demand between 2022 and 2024 (with solar PV manufacturing accounting for one-third of this increase).⁵¹ The buildings sector, including growing demand for cooling, accounted for 40% of the growth in China's electricity demand.⁵² While the share of renewables in China is rising steadily, the country depended on fossil fuels for 62% of its electricity generation as of 2024.⁵³ India, another major energy-consuming country, also showed an upward electrification trend from 2012 to 2022, with economic expansion and a surging interest in cooling driving the increase in electricity demand.⁵⁴ (→ See Figure 29.)

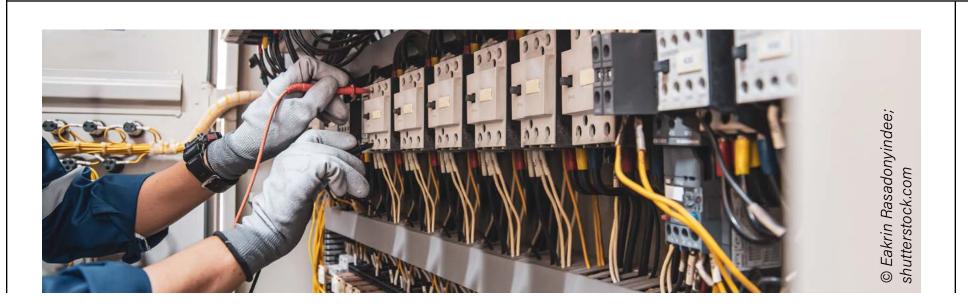


FIGURE 29.

Share of Electricity in Total Final Energy Consumption in Major Country/ Region, 2013-2022



Source: See endnote 54 for this section.



The industry sector accounted for almost

50%

of China's electricity demand growth between 2022 and 2024.



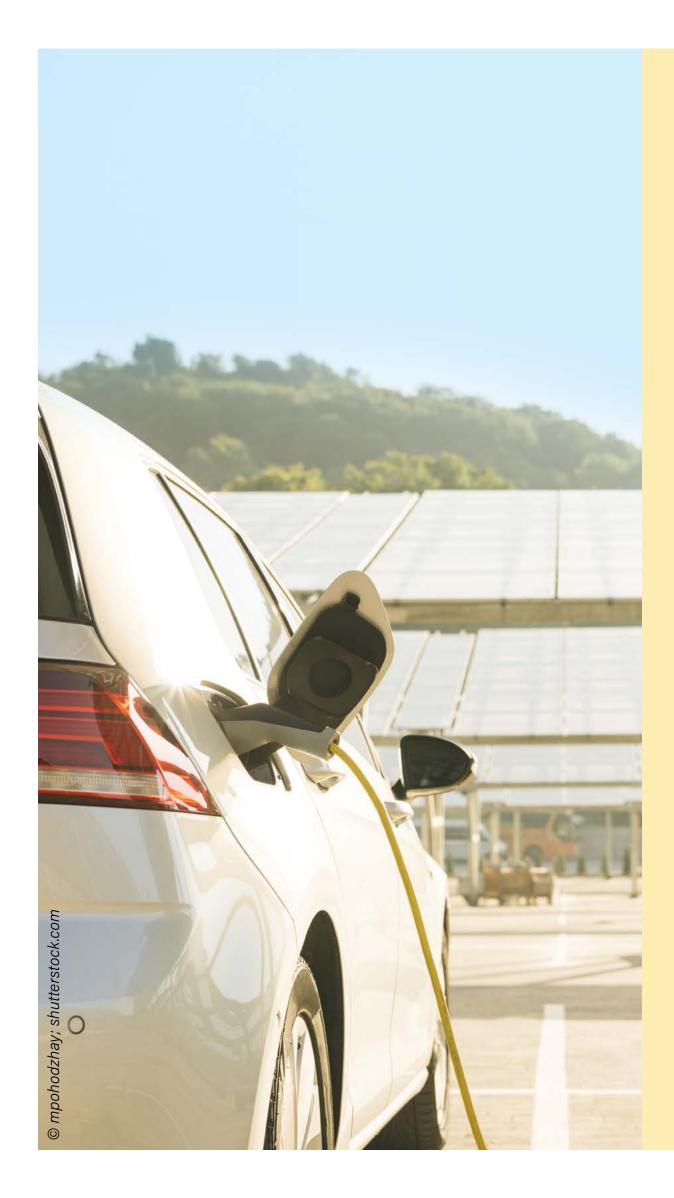
CHALLENGES AND OPPORTUNITIES

CHALLENGES TO RENEWABLES IN 2024

- → Climate ambition weakened as several governments rolled back previous commitments, while trade restrictions and unpredictable regulatory environments added uncertainty across renewable energy markets.
- → Fossil fuel subsidies continued to distort energy markets, diverting public resources and disadvantaging renewables.
- → Tight financial conditions, including high interest rates, inflation, currency volatility, and debt burdens, made capital harder to access, especially in developing economies. Increasing running costs and uncertain returns resulted in narrow market margins, further undermining investor confidence.
- → Project development was slowed by structural barriers, including permitting delays, misinformation, and, in some cases, public resistance. Skilled labour shortages and lack of grid capacity and flexibility further limited deployment capacity.
- **Energy demand rose**, driven by an increase in demand for cooling, growing digital infrastructure and expanding electric vehicle fleets. At the same time, **energy access** remains a major challenge, with millions of people still lacking basic electricity services, especially in sub-Saharan Africa.
- → The uptake of renewables is concentrated in a limited set of technologies particularly solar PV and wind power and in specific regions, leaving many parts of the world underserved.







OPPORTUNITIES FOR 2025 AND BEYOND

- → As governments seek to enhance energy security and resilience, renewables are becoming central to national energy strategies. New commitments at the national and international levels reflect growing recognition of renewable energy as essential for both climate mitigation and adaptation.
- Distributed and off-grid solar PV systems are expanding rapidly, particularly in emerging economies. This reflects growing demand from the public and demonstrates the viability of decentralised solutions.
- → The rise in power purchase agreements, particularly among tech giants and industrial actors, underscores increasing confidence in renewables as a reliable and cost-effective energy source.
- → Sectoral integration and electrification in housing, mobility, and industry are creating new opportunities for renewable energy adoption, as the transition becomes embedded in broader economic strategies.
- → **Digitalisation and artificial intelligence** are further enhancing grid operations, improving system planning, and enabling smarter, more adaptive energy systems.





