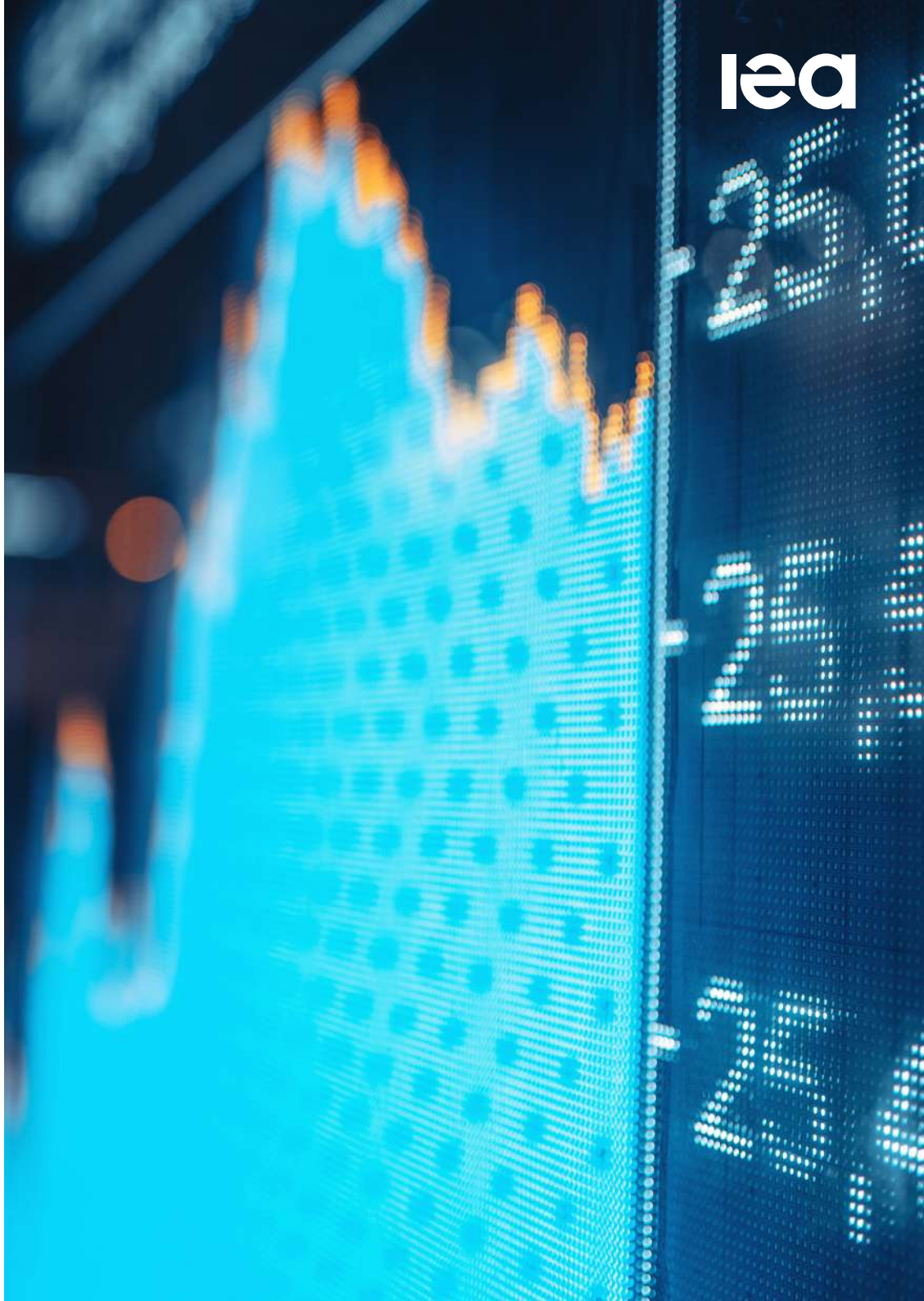
Clean Energy Market Monitor

March 2024



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Introduction to the first edition of the Clean Energy Market Monitor

Clean energy is growing rapidly, as annual deployment of a number of key technologies has accelerated in recent years driven by policy support and continued cost declines. From 2019 to 2023, clean energy investment increased nearly 50%, reaching USD 1.8 trillion in 2023 and growing at around 10% per year across this period. The clean energy economy is a major industrial sector and an important contributor to the global economy. However, its benefits remain too concentrated with most of clean energy deployment occurring in China and advanced economies.

The IEA regularly publishes comprehensive reports analysing recent progress in the development and deployment of clean energy technologies. These delve into the market dynamics, investment, innovation progress, manufacturing capacity, and deployment and cost evolutions of these technologies. The IEA also provides an annual assessment of technology progress using multiple indicators across a comprehensive suite of clean energy technologies and assesses this against the needs of the Net Zero Emissions by 2050 Scenario (NZE Scenario), as part of its Tracking Clean Energy Progress report.

In the case of fossil fuels, market evolutions play out in real time in the form of prices, demand and supply balances, and inventories, with market participants able to access timely data and analysis. For example, the IEA tracks fossil fuel markets in a series of monthly, quarterly and annual reports, which review recent market evolutions and provide near-term and medium-term outlooks for demand, supply, trade and security of supply metrics.

This new report, The Clean Energy Market Monitor, aims to fill a gap by providing a timely, concise and up-to-date overview of clean energy deployment for 2023 for a selected group of technologies. It is not intended to be a comprehensive tracking exercise or to provide detailed investment or technology trends. This is the first in a series, bringing together the most recent trends for selected key clean energy technologies and assessing the implications for energy markets more broadly. Given the acceleration of clean energy deployment since 2019, driven in part by Covid-19 recovery packages and the 2022 energy crisis, this first edition of the Clean Energy Market Monitor also analyses the energy market impacts of clean energy deployment trends since 2019.

Executive summary

Global clean energy deployment scaled new heights in 2023, with annual additions of solar PV and wind growing 85% and 60% respectively. Capacity additions for these two technologies reached almost 540 GW, with China accounting for the majority of both. Clean energy deployment in 2023, however, remained too concentrated in advanced economies and China, with the rest of the world continuing to lag well behind. In 2023, China and advanced economies accounted for 90% of capacity additions for wind and solar PV, and more than 95% of global sales of electric cars.

Electric car sales grew around 35% in 2023, reaching 14 million vehicles or one-in-five sales globally. China again led the way, with one-in-three cars sold being electric, while in the European Union it was one-in-four.

By contrast, heat pump sales globally saw a marginal decline from the record levels of 2022, as squeezed consumers avoided spending on big ticket items and concerns around high gas prices eased somewhat. The slowdown of heat pump sales highlights the importance of supportive policies to help cash-strapped consumers and reduce the gap between electricity and gas prices.

Nuclear capacity additions fell to 5.5 GW in 2023, although year-on-year variations in capacity additions are less meaningful for a technology with long project development and execution times. Construction of new nuclear reactors started on 5 projects in 2023. At the start of 2024, there were 58 reactors under construction worldwide - a total capacity of over 60 GW.

Hydrogen electrolyser capacity additions grew by 360% in 2023, but from a very low base. This increase was due largely to China, as the European Union ceded its leading position. The United States also increased the speed of deployment, but annual additions remained modest in absolute terms.

Energy efficiency is lagging behind, however. Our latest assessment shows an energy intensity improvement of around 1% in 2023, four times lower than the COP28 pledge to double the long-run rate of energy intensity improvement by 2030.

On the back of Covid-19 stimulus packages, there has been a significant acceleration in clean energy deployment since 2019. From 2019 to 2023, clean energy growth outpaced growth in fossil fuels by a ratio of two-to-one. The production of low-emissions electricity grew by around 1 800 TWh, despite the stagnation of hydro power and decline of nuclear power due to drought and forced outages of the nuclear fleet in the European Union. Fossil fuel-based electricity generation grew by slightly less than 850 TWh. In end uses, the consumption of clean energy grew around two times more than fossil fuels.

The deployment of five key clean energy technologies – solar PV, wind power, nuclear power, electric cars and heat pumps – from 2019 to 2023 avoids annual fossil fuel energy demand of around 25 EJ. This is equivalent to 5% of total global fossil fuel demand in all sectors in 2023, or almost the combined total energy demand of Japan and Korea from all sources last year.

The coal demand avoided is around 580 million tonnes of coal equivalent (Mtce) annually. This is 30% higher than the actual increase in global annual coal demand of around 440 Mtce from 2019 to 2023. The largest driver of avoided coal demand was deployment of solar PV and wind power in electricity sectors around the world, with the two technologies avoiding around 320 and 235 Mtce of annual coal demand respectively. This is equal to the annual coal demand for electricity generation of India and Indonesia combined.

Avoided demand for natural gas is around 180 bcm annually on an energy equivalent basis. This is nearly two times more than the actual increase in global annual natural gas demand of around 100 bcm from 2019 to 2023. The deployment of wind and solar PV provides the largest share of this avoided natural gas demand (155 bcm), although heat pump deployment also avoids around 15 bcm of annual demand and nuclear power also contributes. The avoided gas demand is more than the pre-invasion pipeline exports of natural gas from Russia to the European Union, which were around 150 bcm in 2021.

Avoided demand for oil amounts to almost 1 mb/d in energy equivalent terms. Without this, oil demand would have risen above the pre-pandemic level instead of hovering still slightly below it in 2023 on an energy equivalent basis. Electric cars provided the majority of avoided oil demand.

The deployment of solar PV, wind power, nuclear power, electric cars, and heat pumps from 2019 to 2023 avoids around 2.2 billion tonnes (Gt) of emissions annually. Without them, the increase in CO_2 emissions globally over the same period would have been more than three times larger.

At the global level, the deployment of solar PV over the last five years avoids around 1.1 Gt of emissions annually, equivalent to the annual emissions of Japan's entire energy sector. In some markets the impact is even more significant. In Australia and New Zealand, deployment of solar PV over the last five years avoids annually an amount of CO_2 equivalent to almost 10% of the region's total annual emissions from energy in 2023.

Avoided annual emissions from wind power amount to around 830 Mt of CO_2; from nuclear 160 Mt CO_2; from electric cars and heat pumps 60 Mt and 50 Mt CO_2 respectively. Although the reductions from electric cars and heat pumps are lower than the other technologies studied, they will increase in coming years as stock turnover raises the share of these technologies not just in annual new sales, but also in the much larger total stock of equipment in use.

Overview

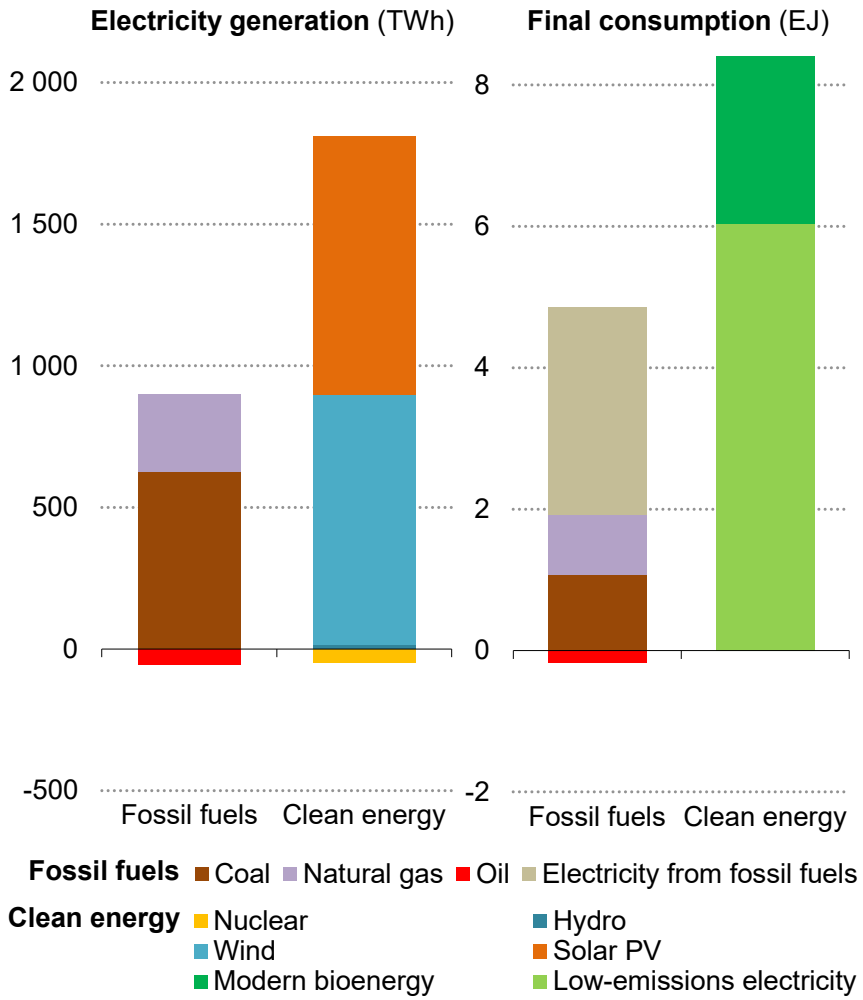
Clean energy has grown twice as fast as fossil fuels since 2019

Clean energy deployment has accelerated since 2019, partly on the back of government stimulus packages deployed to respond to the Covid-19 pandemic and 2022 energy crisis. A number of governments around the world have also enacted major policies to support the uptake of clean energy technologies.

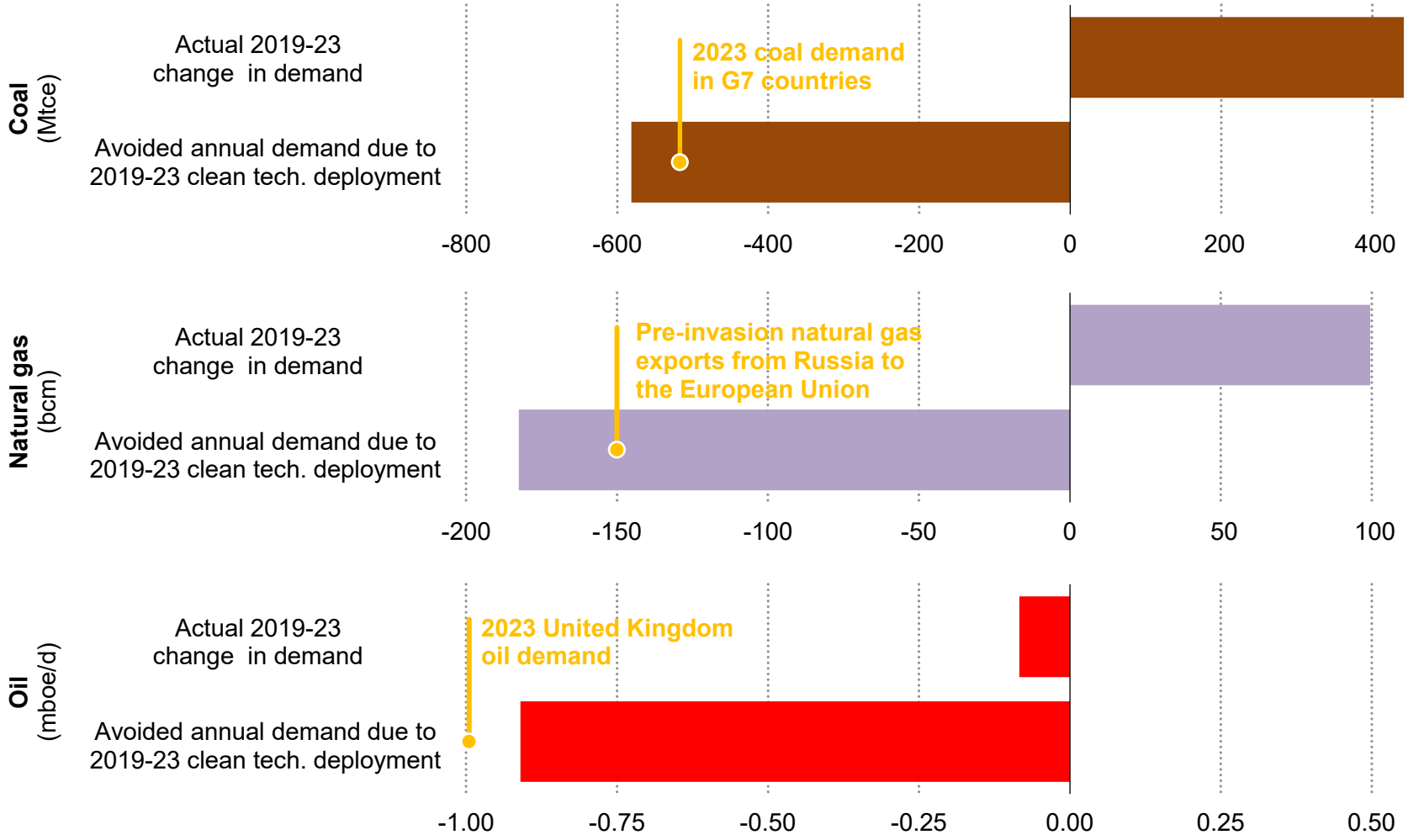
Since 2019, clean energy growth has outpaced growth in fossil fuels by a ratio of two-to-one. The production of low-emissions electricity grew by around 1 800 TWh, despite disruption to hydro power due to drought and forced outages in nuclear power, notably in Western Europe. Fossil fuel-based electricity generation grew by slightly less than 850 TWh, which is less than the growth of solar PV alone (910 TWh since 2019), but also less than the output increase of wind power (885 TWh).

In end uses, the story is the same. Increased electrification and the growth of clean electricity supply has meant that the consumption of clean electricity has grown by around 6 EJ, while modern biofuels grew around 2.3 EJ. This is around twice the growth in consumption of fossil fuel-based energy carriers, consisting of fossil fuel-based electricity and the direct consumption of fossil fuels in end uses.

Global growth in clean energy and fossil fuels, 2019-2023



Without this clean energy deployment, the development of energy markets would have looked very different



Cumulative deployment of solar PV, wind power, nuclear power, electric cars, and heat pumps over the last five years from 2019 to 2023 avoids annual fossil fuel demand of around 25 EJ. This is equivalent to around 5% of global fossil fuel demand in 2023, or slightly less than Japan and Korea's combined annual energy demand from all sources in 2023. This calculation of avoided fossil fuel demand takes into account indirect fossil fuel use in the electricity sector caused by increased electricity demand from heat pumps and electric cars.

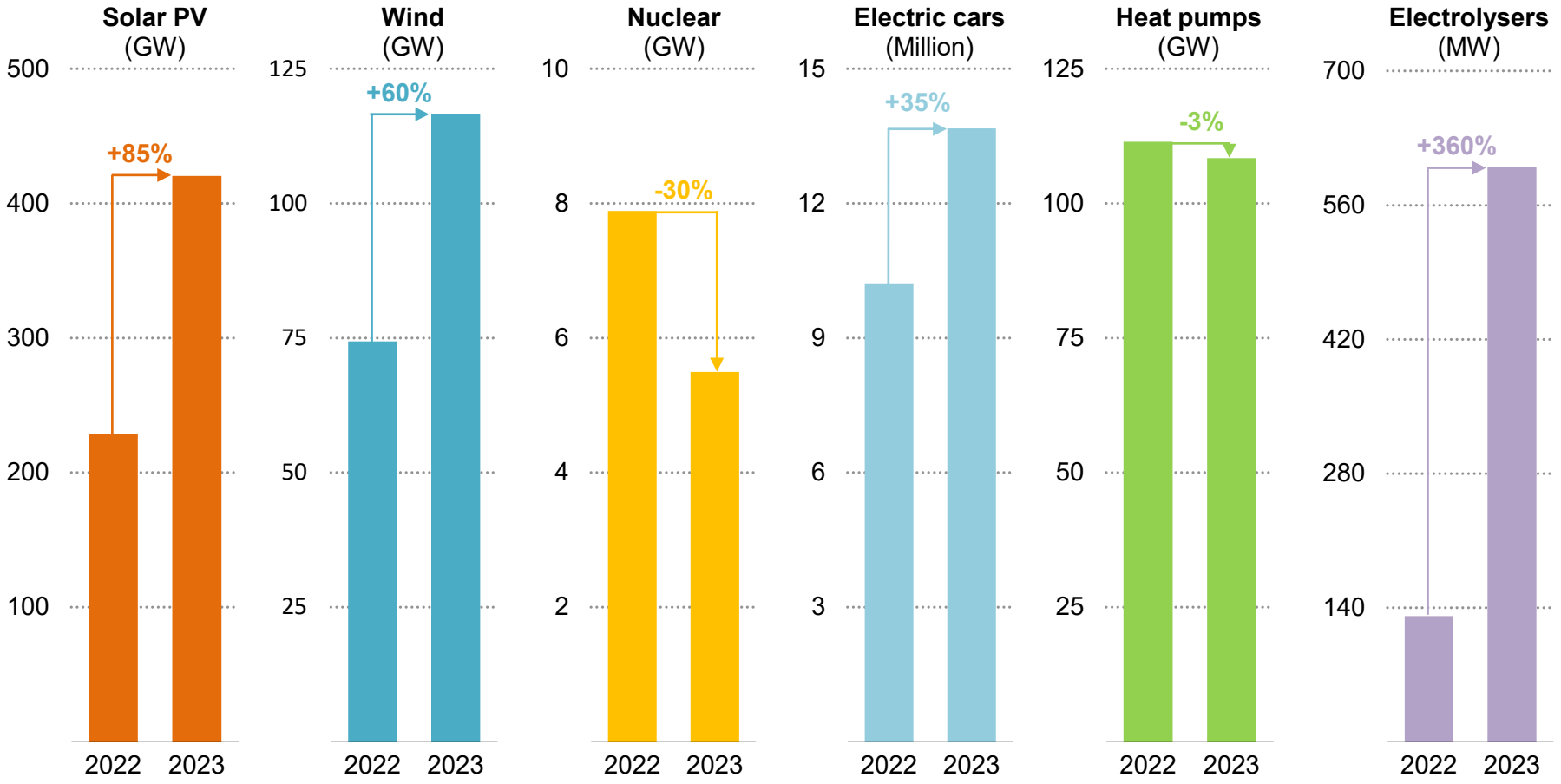
Avoided annual coal demand amounts to around 580 million tonnes of coal equivalent globally (Mtce). This compares to the increase of global annual coal demand of 440 Mtce from 2019 to 2023. The largest contribution to avoided coal demand comes from the deployment of wind and solar in electricity sectors around the world. The deployment of solar PV from 2019 to 2023 avoids around 320 Mtce of coal demand annually, and the deployment of wind power around 235 Mtce. To put this in perspective, the total avoided coal demand from solar PV and wind power is equivalent to the entire coal consumption for electricity generation of India and Indonesia combined in 2023.

Avoided annual natural gas demand is equivalent to around 180 billion cubic metres (bcm). The majority of this comes from growing capacity additions of wind power and solar PV in electricity sectors over the period from 2019 to 2023, which avoids around 155 bcm of natural gas consumption annually at the global level. This is equivalent to pipeline natural gas exports from the Russian Federation (hereafter "Russia") to the European Union before the invasion of Ukraine, which were around 150 bcm in 2021. The deployment of heat pumps over the same period avoids around 15 bcm of annual natural gas consumption; this will rise over time as stock turnover raises the share of heat pumps in the total operating equipment for space heating. The avoided natural gas demand of around 180 bcm is nearly two times more than the actual increase in global natural gas demand of around 100 bcm from 2019 to 2023.

Avoided annual demand for oil is equivalent to almost 1 million barrels of oil equivalent per day (mboe/d). Most of this comes from the growing sales of electric cars, which avoid around 0.55 mboe/d annually. Our forthcoming report, Global EV Outlook 2024, will provide more comprehensive analysis of the recent dynamics of electric vehicle (EV) deployment and avoided fossil fuel demand across all vehicle segments including two-wheelers, buses and trucks. Without the impact of electric cars, global oil demand would have risen above the pre-pandemic level, instead of hovering still slightly below in energy equivalent terms. Growing biofuel deployment has also contributed to restricting oil demand growth.

As clean energy deployment climbed new heights for some key technologies

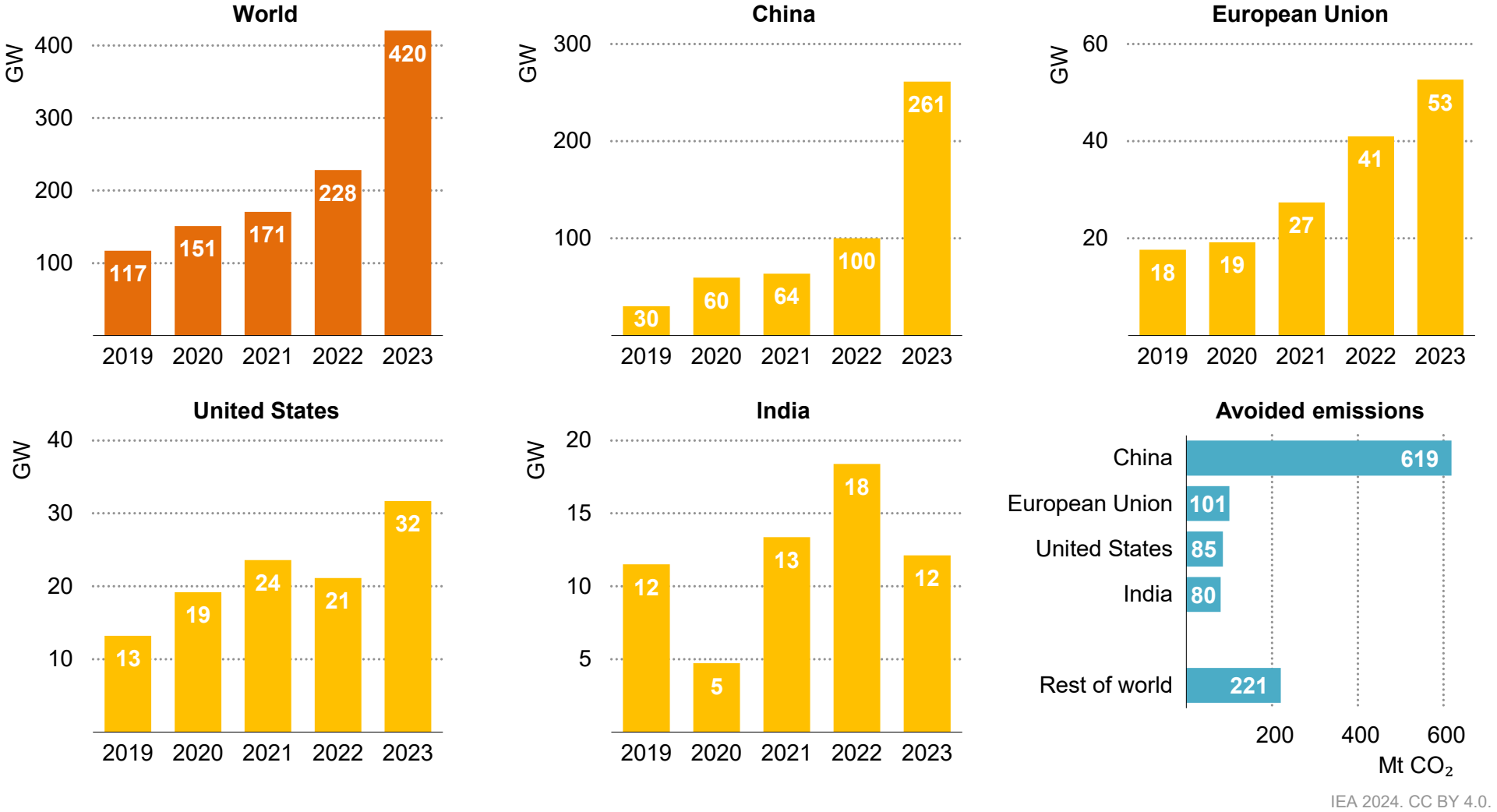
Annual deployment of selected clean energy technologies, 2022 and 2023



Note: “Annual deployment” refers to sales or capacity additions. GW = gigawatt; MW = megawatt; Mn = million.

Clean energy deployment

Solar PV capacity additions and avoided emissions



Notes: “Avoided emissions” refers to avoided emissions in one year from cumulative deployment since 2019 to 2023.

Solar PV capacity additions exploded thanks to China

Global solar PV capacity additions increased by over 80% from 2022 to 2023 and broke a new record, reaching over 420 GW. The People's Republic of China (hereafter "China") alone accounted for over 80% of global increase in solar PV capacity additions. Despite the phase out of central government subsidies for utility, commercial and industrial-scale applications, solar PV deployment grew 2.5-fold in China with the country accounting for an unprecedented 62% of global additions. China's rapid expansion of manufacturing resulted in a 50% reduction in PV module costs since December 2022, improving the competitiveness of solar PV compared to provincial benchmark electricity prices mostly based on coal power generation.

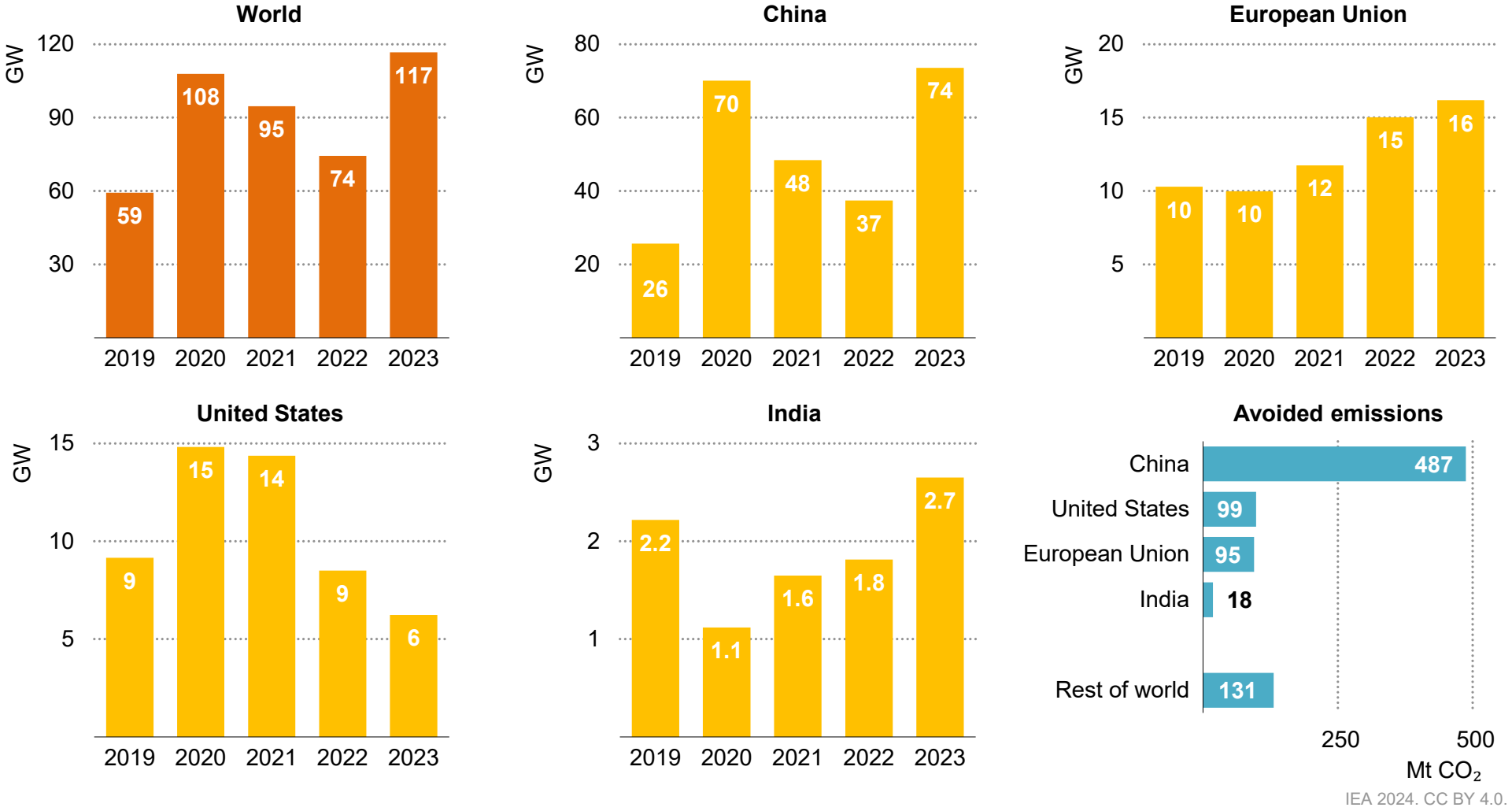
In the European Union (EU), annual solar PV additions rose by a quarter and reached a record level 52 GW last year. Following Russia's invasion of Ukraine, the EU member states have improved the policy environment to accelerate renewables deployment, with the goal of reducing natural gas consumption. This has led annual solar PV additions to nearly double since 2021. High retail electricity prices due to the energy crisis also triggered consumers to rapidly install solar PV panels on their roofs to reduce their energy bills.

In the United States, solar PV capacity additions increased 50% year-on-year following the easing of supply chain issues that caused a decline in annual capacity additions in 2022. Federal tax incentives and state-level support have continued to drive both utility-scale and rooftop solar PV applications.

In 2023, India added 12 GW of solar PV, one-third lower than in 2022. This was caused by lower competitive auction volumes for utility-scale solar projects in previous years combined with supply chain issues. Brazil's solar PV additions increased by over 20% year-on-year, driven by the net metering scheme that stimulates rooftop solar PV additions. In 2023, capacity additions of solar PV in Brazil surpassed those of India.

Globally, the deployment of solar PV from 2019 to 2023 reduces annual CO_2 emissions by around 1.1 billion tonnes (Gt). This is equivalent to the total annual emissions of Japan. By far the largest contribution to emissions reductions occurs in China, where solar PV capacity additions avoid more than 600 Mt. In Australia and New Zealand, solar PV capacity deployment from 2019 to 2023 avoids emissions equivalent to 10% of the region's total annual emissions from energy in 2023.

Wind capacity additions and avoided emissions



Notes: “Avoided emissions” refers to avoided emissions in one year from cumulative deployment since 2019 to 2023.

Wind additions return to growth globally, but some challenges remain

Global wind capacity additions jumped almost 60% in 2023 to break the 2020 record. Onshore wind projects accounted for over 85% of global wind growth last year. China accounted for more than 60% of global wind expansion as the country almost doubled its additions compared with 2022.

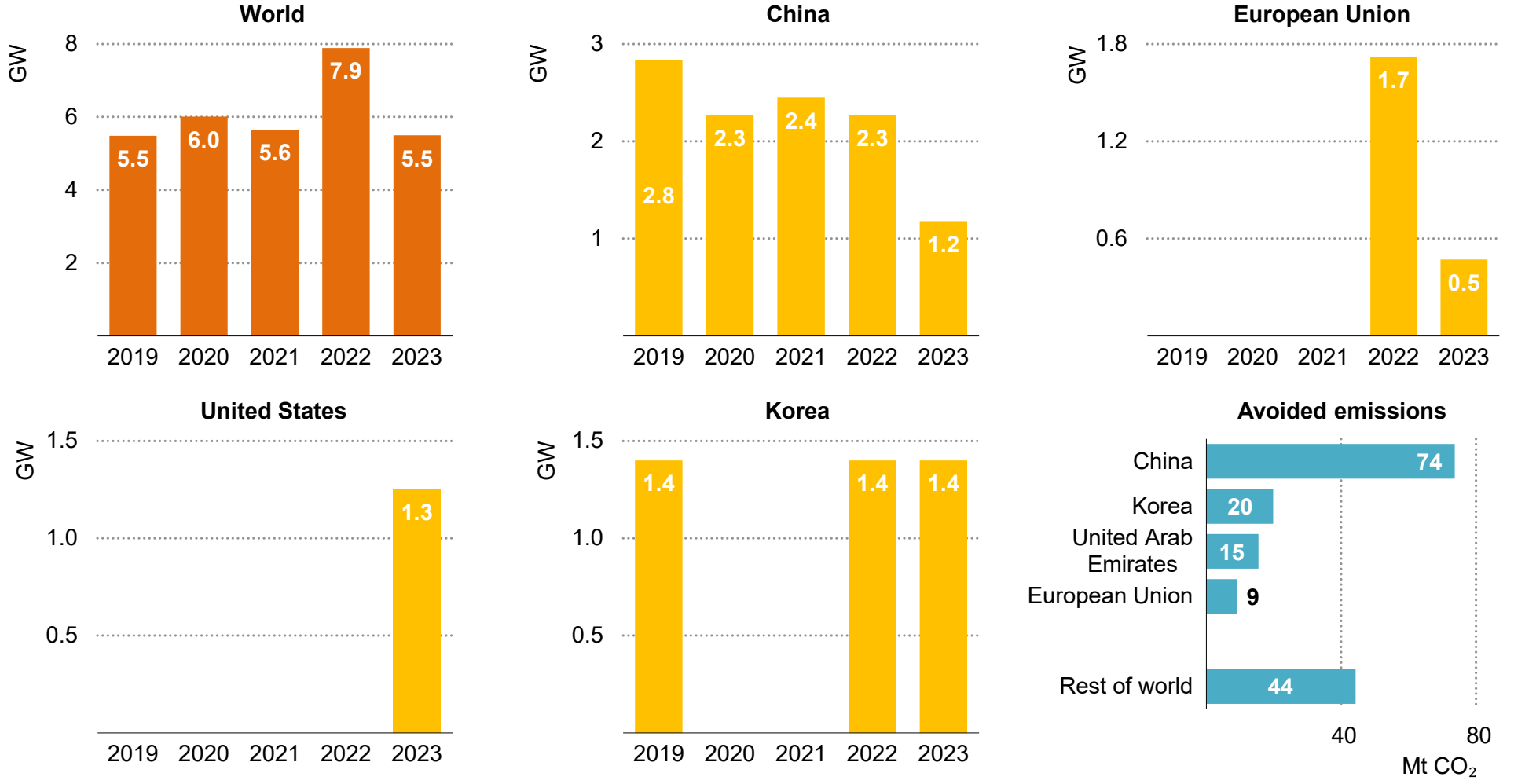
In the European Union, wind additions only increased by slightly less than 10% in 2023 with onshore wind deployment slowing down. Developers have been facing multiple challenges, including rising equipment costs, inflation, and supply chain constraints, which have made them less eager to participate in competitive auctions. Most countries in Europe have introduced policies to address the challenges posed by slow and complex permitting procedures for wind projects. In fact, more policies and regulatory changes have been instituted in the last two years to ease permitting than over the previous decade. However, the impact of these policies will only be visible in the coming years considering project development timelines.

In the United States, wind additions declined by more than a quarter in 2023 compared with 2022. This is mainly due to uncertainty over the tax credit extension before the adoption of the Inflation Reduction Act (IRA), resulting in an empty project pipeline and supply chain issues. Wind capacity additions are expected to increase significantly in the coming years driven by long-term policy visibility provided by the IRA. In India, a larger number of projects awarded in previous years led year-on-year deployment to increase by almost 50%.

Offshore wind growth has recovered from a major drop in annual additions in 2022 resulting from a rush to complete projects in China in 2021 before the phase out of central government incentives. However, the recovery was not strong enough to beat the record level of offshore wind capacity additions worldwide in 2021. Overall, the offshore industry outside of China is facing challenges with investment costs today more than 20% higher than only a few years ago. In 2023, developers have cancelled or postponed 15 GW of offshore wind projects in the United States and the United Kingdom because pricing for previously awarded capacity does not reflect the increased costs facing project development today.

Total deployment of wind power from 2019 to 2023 avoids around 830 Mt of CO_2 emissions annually, larger than the annual emissions of Germany. China again tops the rankings with the largest avoided emissions. In the European Union, wind power deployment over the five-year period from 2019 to 2023 avoids the equivalent of almost 5% of the region's annual emissions in 2023.

Nuclear capacity additions and avoided emissions



Notes: “Avoided emissions” refers to avoided emissions in one year from cumulative deployment since 2019 to 2023.

Nuclear additions fell in 2023 but policy momentum remains strong

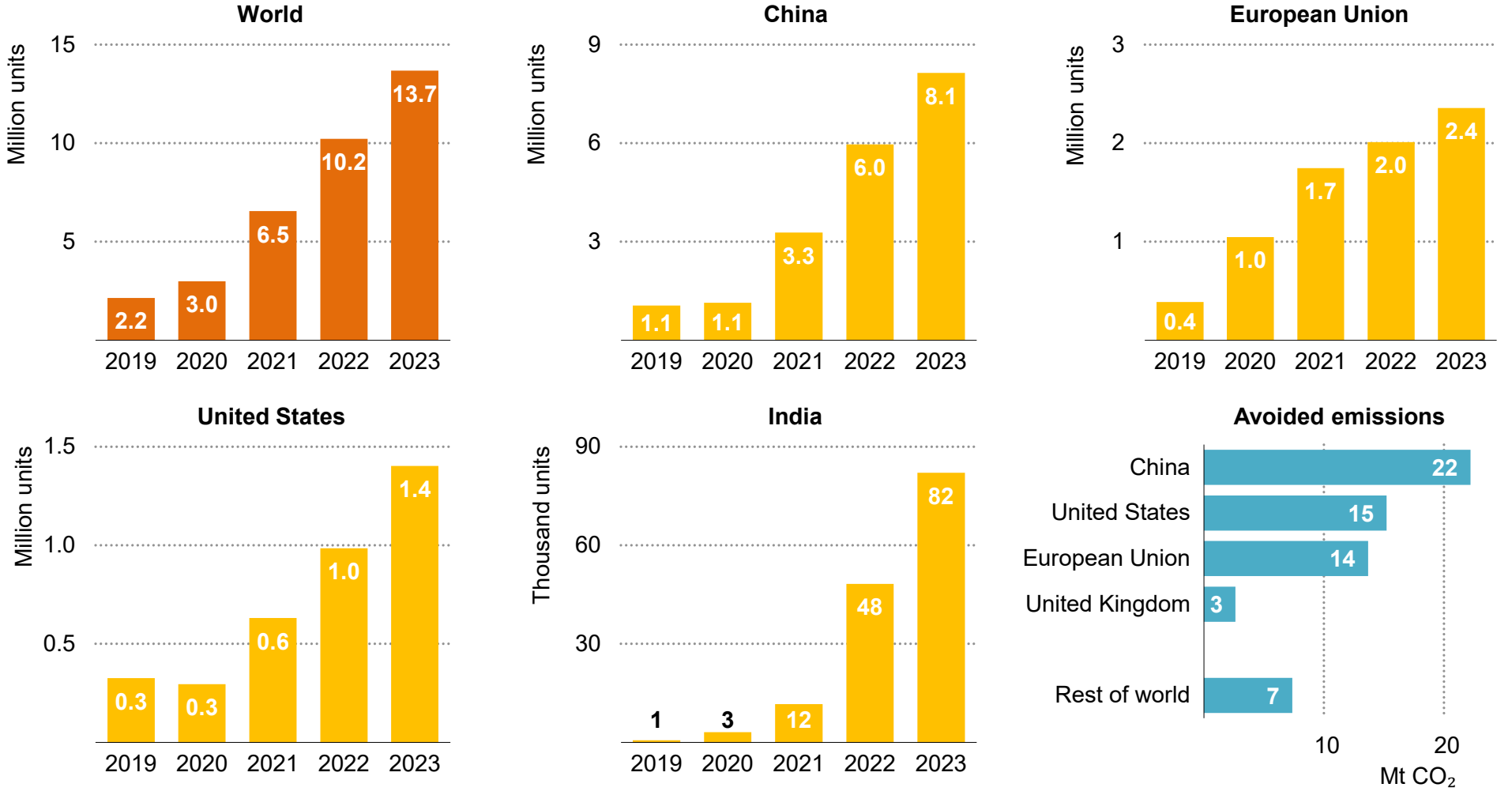
Nuclear power is an important low-emissions source of electricity today – providing 9% of total electricity globally – and critical in the path to net zero emissions by 2050, providing baseload power, grid stability and flexibility, and optimising the use of grid capacity. In 2023, 5 new nuclear reactors came online, one each in Belarus, China, Korea, Slovak Republic, and the United States. The total nuclear capacity added was 5.5 GW in 2023, 30% less than in 2022. Over the last 5 years, 28 reactors in 10 countries with a total capacity of 30.5 GW started operations. Collectively, output from all these nuclear reactors avoids over 160 Mt of CO_2 emissions per year by displacing mainly coal-fired power and natural gas-fired power.

Emerging markets and developing economies accounted for three-quarters of all the new nuclear capacity brought online from 2019 to 2023. These economies account for an even higher share of the avoided emissions, with around 80% of the global total, as new nuclear primarily displaces unabated coal-fired power in these regions. Over the past five years, China added 11 GW of nuclear power, by far the largest of any country in the world, and one-third of the total. The United Arab Emirates successfully started operations at its first three reactors and new reactors also came online in Belarus, India, Pakistan, and Russia.

Advanced economies added close to 8 GW of new nuclear power from 2019 to 2023, 25% of the global total, marking a shift in nuclear market leadership. Displacing both coal and natural gas, the new nuclear capacity in advanced economies avoids around 35 Mt of CO_2 emissions per year. Over the past five years, Korea added over 4 GW of new nuclear, the most of any advanced economy. In the European Union, Finland completed the first EPR design outside of China, and Slovakia completed one reactor. In the United States, the first AP1000 design reactor was brought online.

The policy landscape has been shifting in favour of nuclear, with many countries taking steps to extend operations at existing nuclear power plants and to build new ones. Extending operations, where it is safe to do so, is critical as two-thirds of the global fleet has been in operation for more than 30 years, and nuclear lifetime extensions are a proven cost-effective option. Construction of new nuclear reactors started on 5 projects in 2023, and on 33 projects over the past five years. At the start of 2024, there were 58 reactors under construction worldwide, with a total capacity of over 60 GW. The pace of development for nuclear power needs to accelerate to an average of 33 GW of capacity additions per year in the 2030s, if the technology is to fulfil its role in the path to achieving net zero emissions by 2050. Innovation in nuclear technology, including small modular reactors, is poised to help open new markets and expand opportunities for nuclear power.

Electric car sales and avoided emissions



Notes: “Avoided emissions” refers to avoided emissions in one year from cumulative deployment since 2019 to 2023.

Sales of electric cars increased 35% in 2023

In 2023, global sales of electric cars reached around 14 million, meaning almost one-in-five cars sold was electric. Electric car sales last year were 35% higher than sales in 2022 and more than six times the level in 2019. Over the period from 2019 to 2023, the average annual growth rate was 60%.

China remains the largest market for electric cars. In 2023, electric car sales in China reached over 8 million, constituting almost 60% of global sales. As a result, in 2023, more than one-in-three cars sold in China was electric. Electric car sales increased by around 35% in China in 2023, despite the phase out of purchase subsidies in 2023.

The European Union represents the second largest electric car market. Around 2.4 million electric cars were sold in the European Union last year, representing one-in-four cars sold. Compared to the previous year, sales increased around 20%.

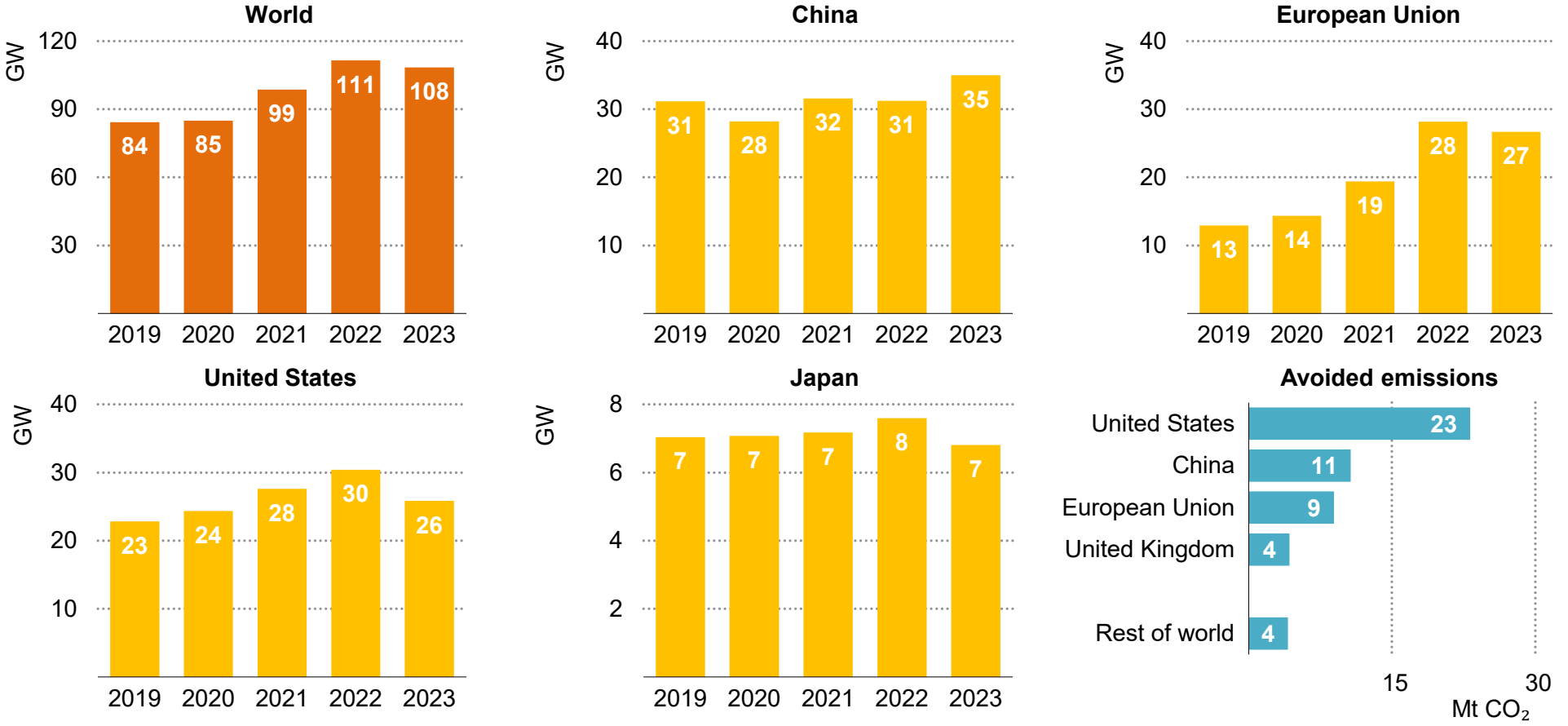
The United States remains the third largest electric car market. Around 1.4 million electric cars were sold in the United States in 2023, representing an increase of more than 40% compared to sales in 2022. Around one-in-ten cars sold in the United States last year was electric.

In the past few years, electric car sales in India have increased rapidly, although the country still represents a very small share of global electric car sales. Electric car sales in India increased four-fold from 2021 to 2022 and another 70% in 2023.

From 2019 to 2023, over 35 million electric cars were sold globally. These vehicles have contributed to avoiding demand for fossil fuels as well as the associated emissions. In total, around 60 Mt CO_2 is avoided annually because of electric car deployment since 2019. While sales shares of electric cars are almost 20%, electric cars represent just 3% of total cars on the road (similar to the sales share about five years ago). As stocks turn over, emissions reductions from electric cars will increase dramatically.

Progress in electric mobility goes beyond just cars. Particularly in emerging market and developing economies, the electrification of two- and three-wheelers as well as city buses is increasing. The upcoming Global EV Outlook 2024 report will explore in more comprehensive detail the market trends of electric vehicles across different road modes and the associated impacts on energy and emissions. The accompanying online data and policy explorers will also provide more details on the electric mobility landscape.

Heat pump sales and avoided emissions



Notes: heat pumps that deliver heat directly to households and residential or commercial buildings for space heating and/or domestic hot water provision. It includes natural source heat pumps, including reversible air conditioners used as primary heating equipment. It excludes reversible air conditioners used only for cooling, or used as a complement to other heating equipment, such as a boiler.

Source: IEA analysis based on data from ChinaIOL; European Heat Pump Association; Air-Conditioning, Heating, and Refrigeration Institute; Canada National Statistical Agency; Japan Refrigeration and Air Conditioning Industry Association.

Heat pump sales stalled as household budgets were squeezed

Global sales of heat pumps decreased by 3% in 2023 after two consecutive years of double-digit growth fuelled by the energy crisis. This slowdown reflects broader aversion to large-ticket purchases among consumers amid higher interest rates and inflation. Heat pumps are a large investment for households, and sales are particularly sensitive to borrowing costs and consumer sentiment. At the same time, natural gas prices have mostly declined from their peaks in 2022, highlighting the need to tilt energy tariffs and taxes in favour of cleaner consumer choices.

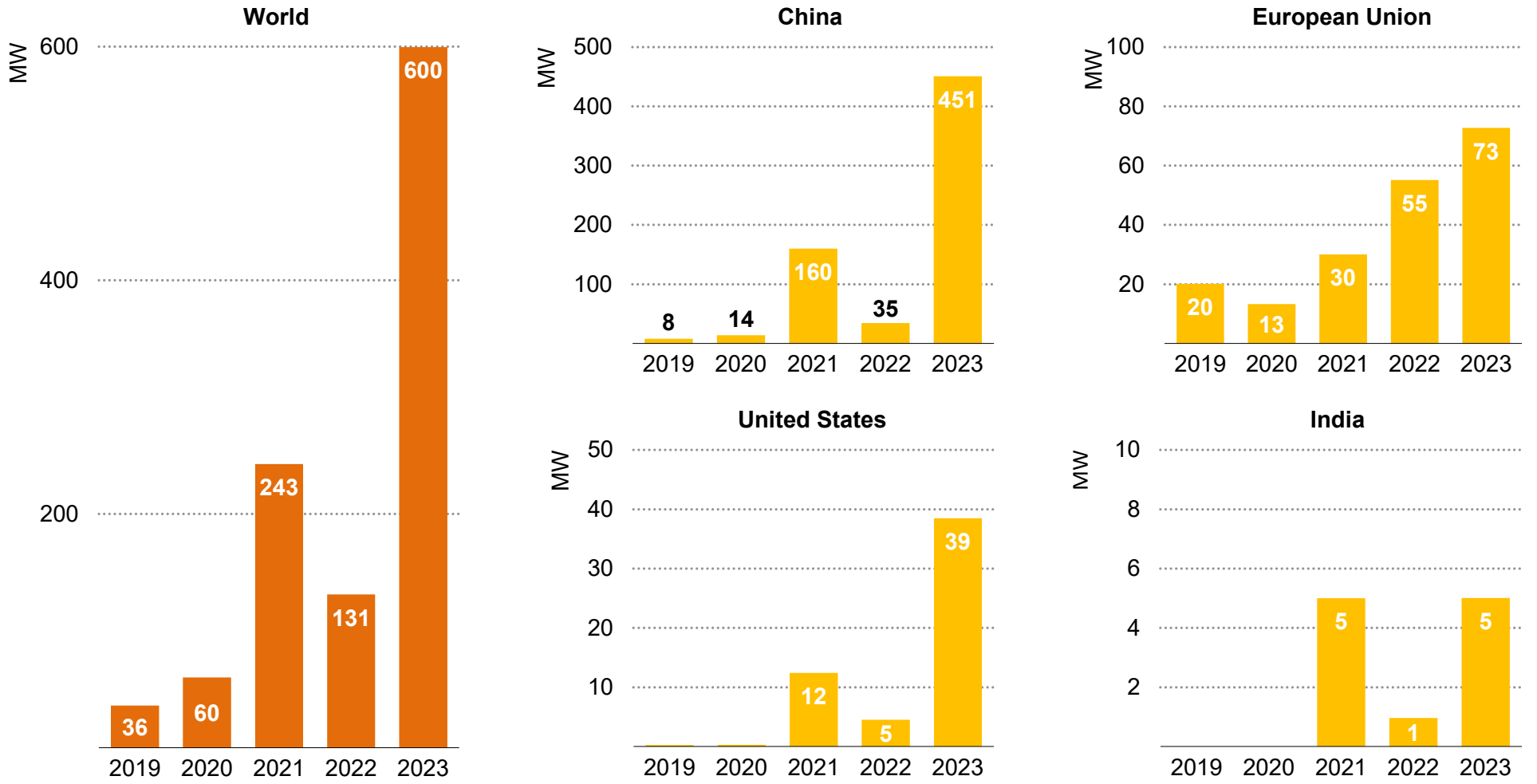
In the United States, heat pump sales decreased by 15%, partly due to postponed purchases in anticipation of new financial incentives for low-income households that are soon expected to be up and running. Nonetheless, heat pump market shares continued to rise as they exceeded gas equipment sales, which plummeted even further, by a record 20%. Looking ahead, nine states accounting for nearly a quarter of residential energy use have recently pledged to aim for heat pumps to account for around two-thirds of heating and cooling equipment sales by 2030.

China was the only major market where heat pump sales grew at a robust 12%, as consumer activity recovered after Covid-19 restrictions were lifted. In Japan, one of the most mature markets for heat pumps, sales declined by 10% amid low consumer spending.

In the European Union, sales fell by 5% as the rush driven by the energy crisis has moderated. In addition, construction of new buildings, where a large part of new heat pumps are installed, slowed. Though sales continued to grow in a range of countries, this was not sufficient to balance out a major downturn in Italy where the Superbonus was scrapped, and significant declines in Poland and Finland. In Germany, sales of heat pumps grew by 50%, but market shares increased only marginally, as sales of fossil fuel equipment also went up sharply as a result of a heated debate on boiler bans. While heat pump sales stagnated in France, their market share continued to expand with sales exceeding those of fossil fuel-fired systems by nearly 60%.

Worldwide, heat pumps for space and water heating installed since 2019 avoid around 50 Mt of CO_2 emissions annually.

Hydrogen electrolyser additions



Note: The unit is MW of electrical input. Source: IEA (2023), Hydrogen Production and Infrastructure Projects Database, (October 2023 release, interim update).

Electrolysers installed capacity is growing, but from a very low base

In 2023, global installed capacity of water electrolysers for dedicated hydrogen production exceeded 1 GW, marking an historic milestone in the energy landscape, reaching about 1.3 GW. This achievement was underpinned by a remarkable surge in annual additions, which soared to 600 MW, two-and-a-half times the previous peak of 240 MW set in 2021. Notably, the capacity added in 2023 nearly matched the cumulative global installed capacity up to 2022. However, it is still far from the annual multi-gigawatt additions required to keep climate goals within reach.

From accounting for less than 10% of the global installed capacity in 2020, China has emerged as a dominant force since 2021 and reached an installed capacity of more than 650 MW by the end of 2023, representing close to half of the global installed capacity. This transformation has been fuelled by the scaling up of project sizes by Chinese developers, with several projects now exceeding 100 MW in capacity. Consequently, China now hosts six of the world's largest operational electrolysis projects, including the 260 MW facility in Kuqa, developed by Sinopec for hydrogen production and use in refining operations. However, the project is not expected to operate at full capacity until 2025.

While other regions have witnessed steady growth in electrolyser deployment, none have experienced a surge akin to China's trajectory. Demand uncertainty and lack of regulatory clarity, coupled with recent challenges such as inflation, the fall in fossil fuel prices, and slow implementation of support mechanisms have hindered faster adoption.

The European Union accounted for around one-third of global installed capacity in 2020, but has now ceded its leading position, with additions barely surpassing 70 MW in 2023. The United States emerged as the third-largest market after the European Union, with additions exceeding 30 MW. The majority of this increase is attributed to a single project, the Cavendish NextGen Hydrogen Hub in Florida. In addition, the largest electrolysis plant in operation today out of China is a 40-MW project that started operations in the United States in January 2024.

Annual additions in other markets such as the Middle East and India remained limited to small demonstration projects. However, these are expected to become major markets soon, especially in the case of the Middle East. The world’s largest project under construction (Neom Project, more than 2 GW of expected installed capacity) is in Saudi Arabia and the first electrolysers have already been delivered.

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