EMBER

Global Electricity Review 2025

Record renewables growth led by solar helped push clean power past 40% of global electricity in 2024, but heatwave-related demand spikes led to a small increase in fossil generation.

8 April 2025

Lead authors : Euan Graham and Nicolas Fulghum
Other authors : Katye Altieri

About

Ember's sixth annual Global Electricity Review provides the first comprehensive overview of changes in global electricity generation in 2024, based on reported data. It presents the trends underlying them, and the likely implications for energy sources and power sector emissions in the near future. With the report, Ember is also releasing the first comprehensive, free dataset of global electricity generation in 2024.

The report analyses electricity data from 215 countries, including the latest 2024 data for 88 countries representing 93% of global electricity demand, as well as estimates for 2024 for all other countries. The analysis also includes data for 13 geographic and economic groupings, including Africa, Asia, the EU and the G7. It also dives deeper into the seven countries and regions with the highest electricity demand, which account for 72% of global electricity demand. In addition to electricity generation data, the report uses weather and capacity data to uncover the underlying trends shaping the global power sector.

We make all of the data freely accessible to empower others to do their own analysis and help speed up the switch to clean electricity.

Highlights

40.9%

Share of global electricity generation from low-carbon sources in 2024.

+29%

Growth rate of solar generation in 2024, a six-year high.

+4.0%

Electricity demand growth in 2024, which was amplified by heatwaves.

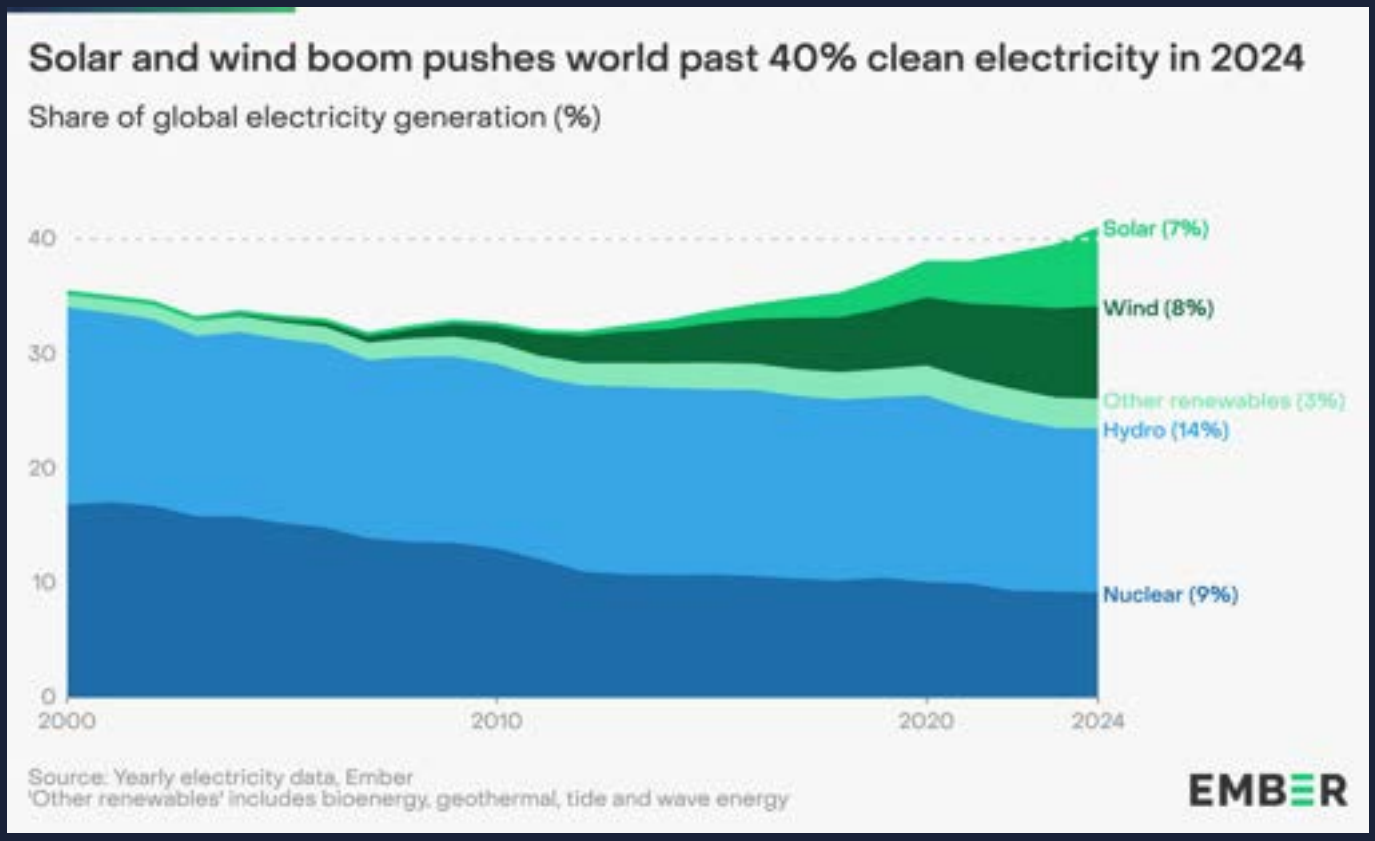
Contents

Contents

World surpasses 40% clean power as renewables see record rise

Clean power surpassed 40% of global electricity generation in 2024, driven by record growth in renewables, especially solar. Heatwaves contributed to high growth in electricity demand which resulted in a small increase in fossil generation, driving up power sector emissions to an all-time high.

Solar power has become the engine of the global energy transition, with both solar generation and capacity installations setting new records in 2024. Solar generation has maintained its high growth rate, doubling in the last three years, and adding more electricity than any other source over that period. At the same time, electricity demand saw a significant rise in 2024, outpacing the growth in clean electricity. Expanding technologies such as AI, data centres, electric vehicles and heat pumps are already contributing to the rise in global demand. However, the main reason why electricity demand growth was elevated in 2024 compared to 2023 was an increase in air conditioning use during heatwaves. This accounted for almost all of the small rise in fossil generation.



Key takeaways

01 Clean power surpasses 40% of global electricity generation

Generation from all low-carbon power sources – renewables plus nuclear – surpassed 40% of global electricity in 2024 for the first time since the 1940s. Renewable power sources added a record 858 TWh of generation in 2024, 49% more than the previous record of 577 TWh set in 2022. The record increase in renewables coupled with a small increase in nuclear output of 69 TWh brought low-carbon power to 40.9% (12,609 TWh) of the mix in 2024, compared with 39.4% in 2023. Hydro remained the largest source of low-carbon electricity (14.3%), followed by nuclear (9.0%), with wind (8.1%) and solar (6.9%) rapidly gaining ground and together overtaking hydro in 2024, while nuclear's share reached a 45-year low.

02 Solar generation doubles in three years

Solar generation has doubled over the last three years to reach over 2000 TWh. Solar was the largest source of new electricity generation globally for the third year in a row (+474 TWh) and the fastest growing source of electricity (+29%) for the 20th year in a row. More than half (53%) of the increase in solar generation in 2024 was in China, with China's clean generation growth meeting 81% of its demand increase in 2024. The fast pace of global solar growth is set to continue, with 2024 setting a new record for solar capacity installations in a single year – more than double the amount installed in 2022. Global solar power capacity reached 1 TW in 2022 after decades of growth, but reached 2 TW only two years later, in 2024.

03 Heatwaves the main driver of a small increase in fossil generation

Periods of hotter temperatures around population centres drove up demand for cooling in 2024 compared with 2023. This added 0.7% (+208 TWh) to global electricity demand, and meant that overall demand grew by much more (+4.0%) than in 2023 (+2.6%). Consequently fossil generation increased by 1.4%, and global power sector emissions rose by 1.6% to a new all-time high of 14.6 billion tonnes of CO2. Hotter temperatures were the main driver of the rise in fossil generation: without this, fossil generation would have risen by only 0.2%, as clean electricity generation met 96% of the demand growth not caused by hotter temperatures. The increase in global fossil generation in 2024 (+245 TWh) was virtually identical to that seen in 2023 (+246 TWh) despite the substantial difference in rates of demand growth.

The global power system will be dominated by two mega-trends over the rest of the decade: solar's share in the electricity mix rising rapidly as it continues its exponential growth, and robust electricity demand growth as electricity replaces other forms of energy powering the global economy.

Signs of this are already here: solar has been the largest source of new electricity for the last three years, and new drivers of demand such as EVs, heat pumps and data centres are contributing 0.7% to annual demand growth, more than twice as much as they did five years ago.

As we reach a tipping point where the increasingly rapid rise of clean generation outpaces structural growth in demand, changes to fossil fuel generation over the short-term will be dominated by fluctuations in weather, as seen in 2024 with the impacts of heatwaves. Despite this, it remains clear that clean generation growth and the uptake of flexible technologies such as battery storage will reduce reliance on fossil fuel power in the coming years, even in a world of faster demand growth.

We estimate that even if electricity demand grows at 4.1% per year until 2030, which exceeds current expectations, clean generation growth will be fast enough to keep pace. Dynamics in the world's largest emerging economies will play a crucial role. China and India are both moving towards a future of demand growth powered by clean electricity, helping to tip the balance towards a decline in fossil generation at a global level.

"Solar power has become the engine of the global energy transition. Paired with battery storage, solar is set to be an unstoppable force. As the fastest-growing and largest source of new electricity, it is critical in meeting the world's ever-increasing demand for electricity.

Amid the noise, it's essential to focus on the real signal. Hotter weather drove the fossil generation increase in 2024, but we're very unlikely to see a similar jump in 2025.

The world is watching how technologies like AI and EVs will drive electricity demand. It's clear that booming solar and wind are comfortably set to deliver, and those expecting fossil fuel generation to keep rising will be disappointed.

Cleantech, not fossil fuels, is now the driving force of economic development. The era of fossil growth is coming to an end, even in a world of fast-rising demand."

Phil MacDonald
Managing Director, Ember

Record rise in renewables pushes clean power generation above 40% of global electricity

Record renewables growth helped push clean power to a new milestone. However, heatwaves contributed to high growth in electricity demand, which resulted in a small increase in fossil generation.

Renewable generation showed a record increase in 2024, driven by a surge in solar power, a rebound in hydro and moderate wind growth. Hotter temperatures than in 2023 amplified the increase in electricity demand and led to a small rise in fossil generation (+1.4%). Consequently, power sector emissions increased by 1.6%, rising to a new record high of 14.6 billion tonnes of CO2. However, fossil generation would have remained almost unchanged in the absence of hotter temperatures, as clean generation rose quickly enough to meet the non-temperature related growth in electricity demand in 2024.

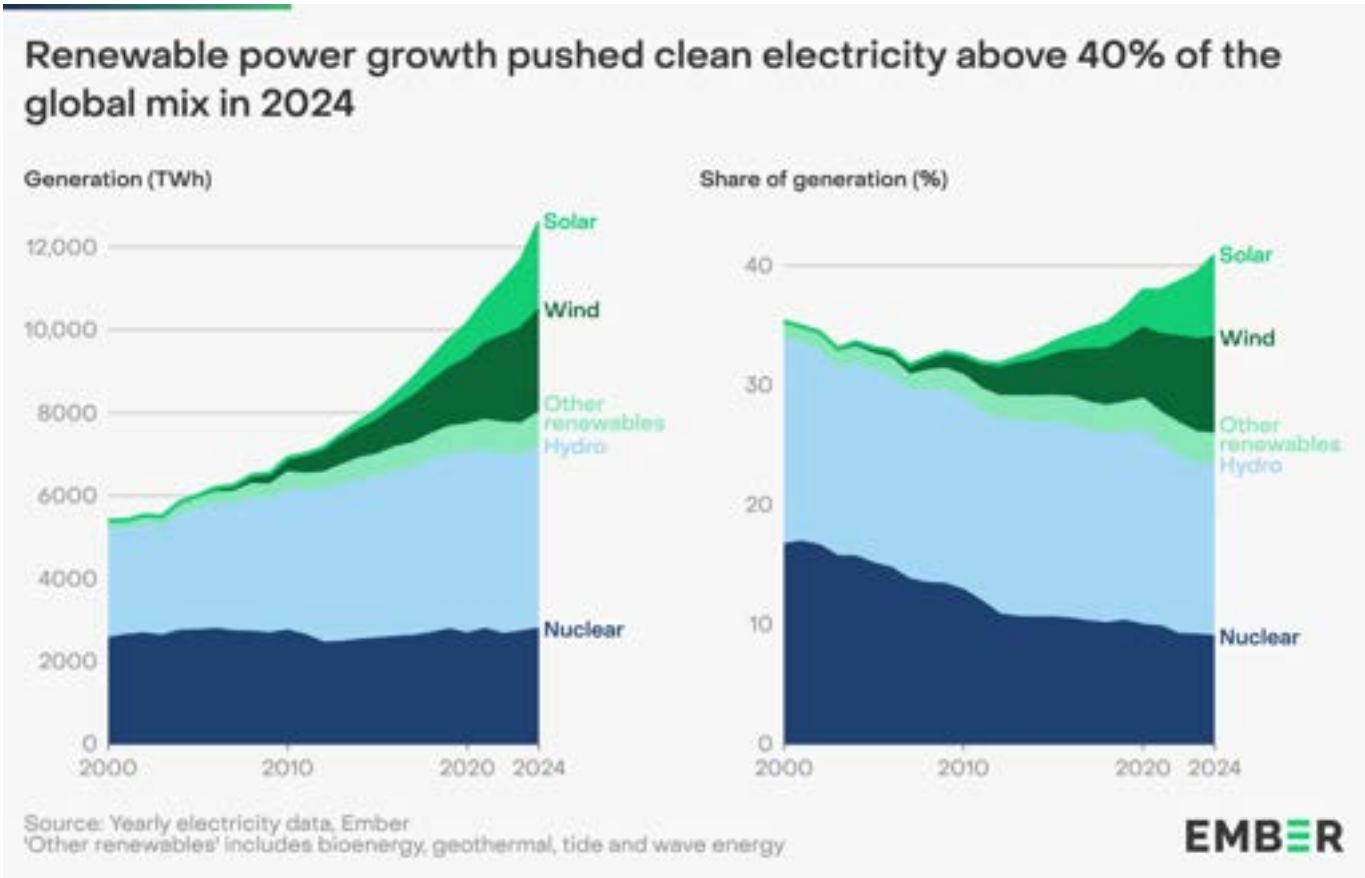
Record rise in renewables, led by solar, brings clean power to a new milestone

Clean power surpasses 40% of global electricity generation

A record surge in renewables spearheaded by solar power, combined with increased nuclear output, pushed clean electricity's share to 40.9% of global electricity in 2024, up from 39.4% in 2023. 2024 was the first year that low-carbon sources delivered more than 40% of global electricity since the 1940s, when the global electricity system was 50 times smaller than it is today.

The global share of wind (8.1%) and solar (6.9%) is rapidly increasing, together exceeding hydropower for the first time in 2024. Hydro remained the largest source of clean electricity, providing 14.3% of global electricity generation in 2024, followed by nuclear at 9.0%. Despite remaining the two largest sources of low-carbon electricity, hydro and nuclear are not increasing their share – with nuclear's share falling to a 45-year low in 2024 – as generation has been growing more slowly than electricity demand.

Other renewables, such as bioenergy and geothermal power, contributed 2.6% of global electricity in 2024.

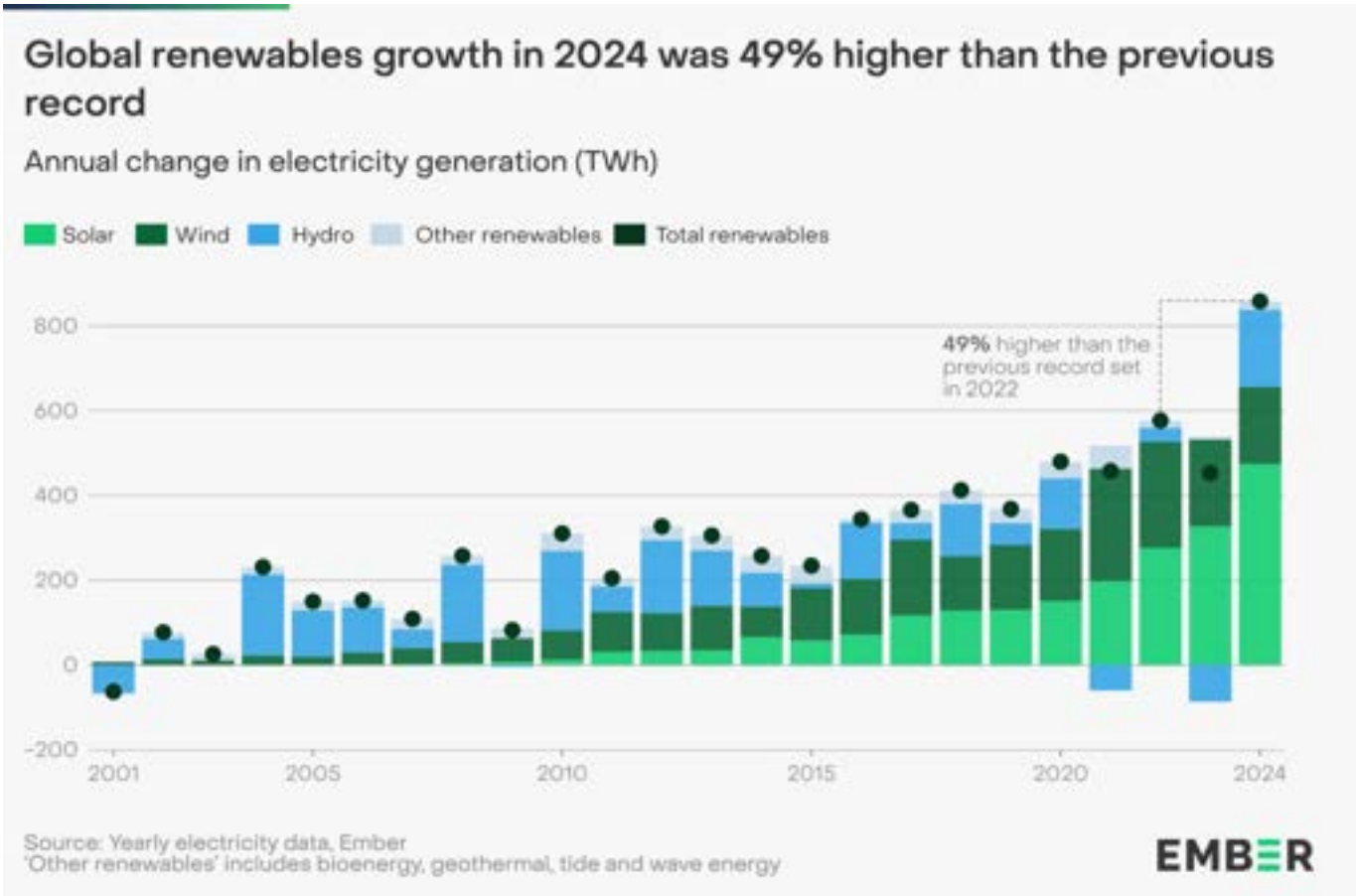


80 countries generated more than 50% of their electricity from clean sources in 2024, including 47 countries that reached more than 75%.

As the global share of clean sources rose, the share of fossil fuels in the electricity mix consequently fell from 60.6% in 2023 to 59.1% in 2024, dropping below 60% for the first time since the 1940s. Coal power provided 34.4% of global electricity in 2024 and gas 22%, with other fossil fuels contributing 2.8%.

Record renewables growth meets three-quarters of electricity demand growth

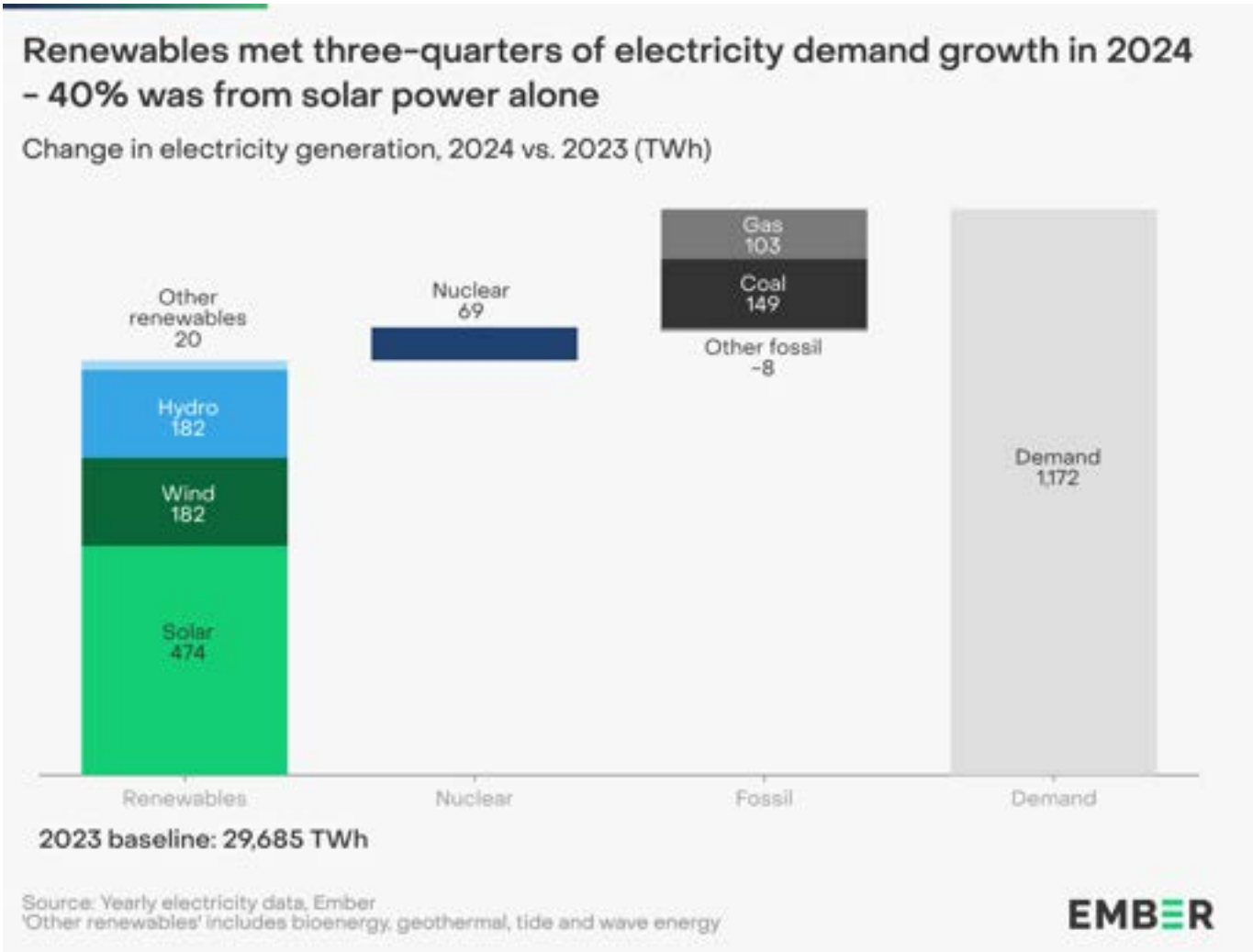
In 2024, renewable power sources collectively added a record 858 TWh of generation – a 49% increase over the previous record of 577 TWh set in 2022.



With the growth in solar, hydro and wind, renewables met three-quarters of the growth in electricity demand. Solar was the largest driver of new electricity growth, rising by 474 TWh (+29%) and meeting 40% of the global increase in electricity demand.

Hydropower output rose by 182 TWh in 2024, reaching a new all-time high. The growth in 2024 was a rebound from historic droughts in 2023, which constrained hydro production. Notably, China accounted for 72% of the rebound in global hydro generation in 2024, as the country was hit particularly hard by droughts in late 2022 and 2023.

However, despite the global increase in hydro generation in 2024, the capacity factor – the amount of generation per unit of capacity – of the global hydro fleet remained significantly below historical levels. The record generation in 2024 was only 2% above the previous record set in 2020, despite capacity increasing by 7% since then.



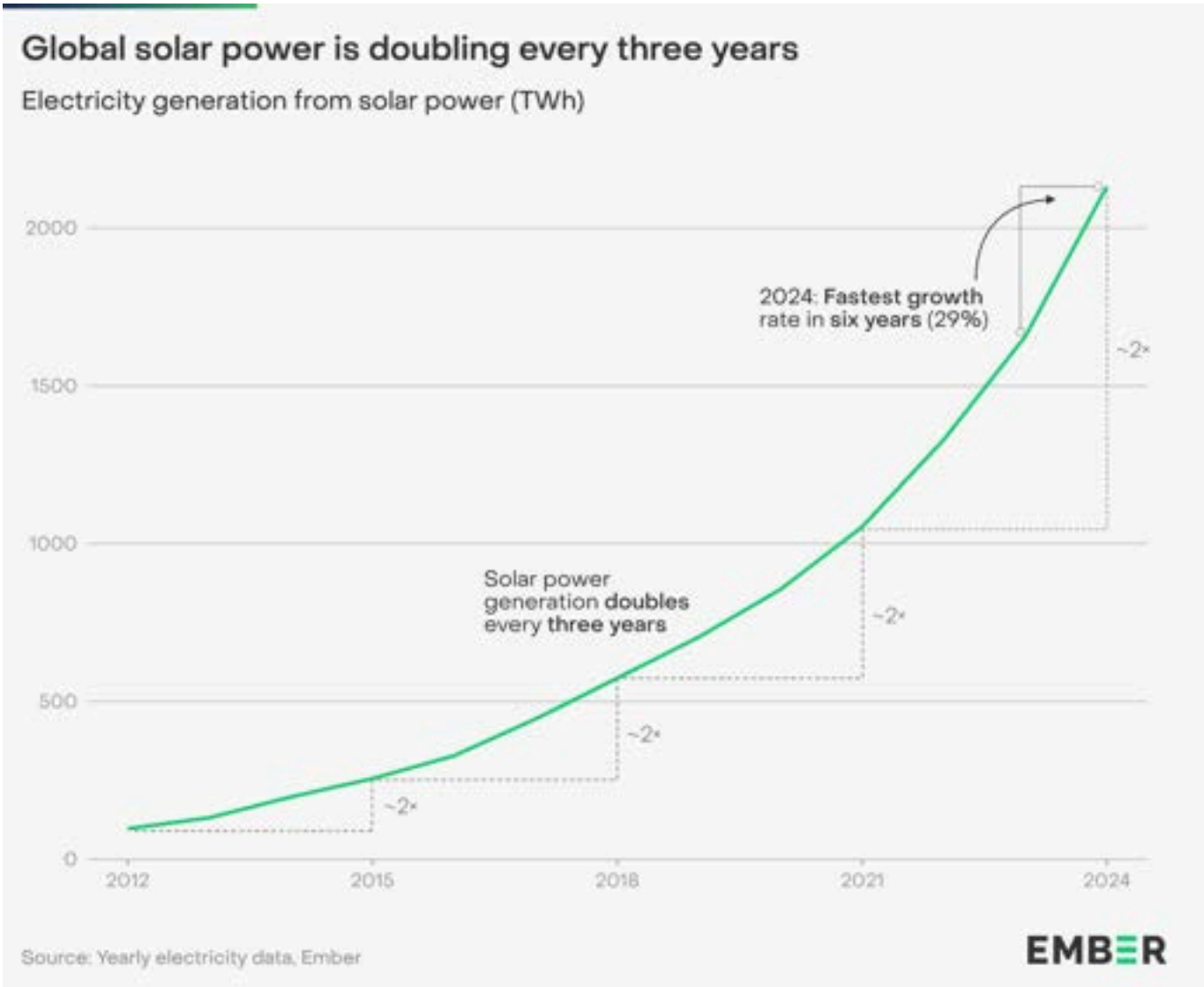
Wind generation also grew by 182 TWh (+7.9%) in 2024. While capacity additions remained high, slightly lower wind speeds in some geographies – especially in China and the EU – reduced potential generation gains. With capacity growth remaining strong across the world, generation is likely to return to higher growth in the coming years, though wind conditions will affect output from year to year.

Nuclear power increased by 69 TWh (+2.5%), rising for the second year in a row, driven largely by higher utilisation rates in France.

Together, renewables and nuclear met 79% of the demand increase. Fossil fuels met the remainder of the demand increase, which was largely caused by hotter temperatures (see more detail later in this chapter).

Record solar increase in 2024 as solar power maintains high growth rates

Solar power surged by a record 474 TWh in 2024, the largest annual growth ever recorded in absolute terms and the fastest increase in six years (+29%). Solar power has maintained its extraordinarily high growth rates even as the technology has become the primary driver of new electricity generation. As a result, solar generation has doubled every three years, reaching 2,131 TWh in 2024. For the third consecutive year, solar recorded the largest absolute increase of any electricity source. For the 20th year in a row, it remained the fastest-growing power source.



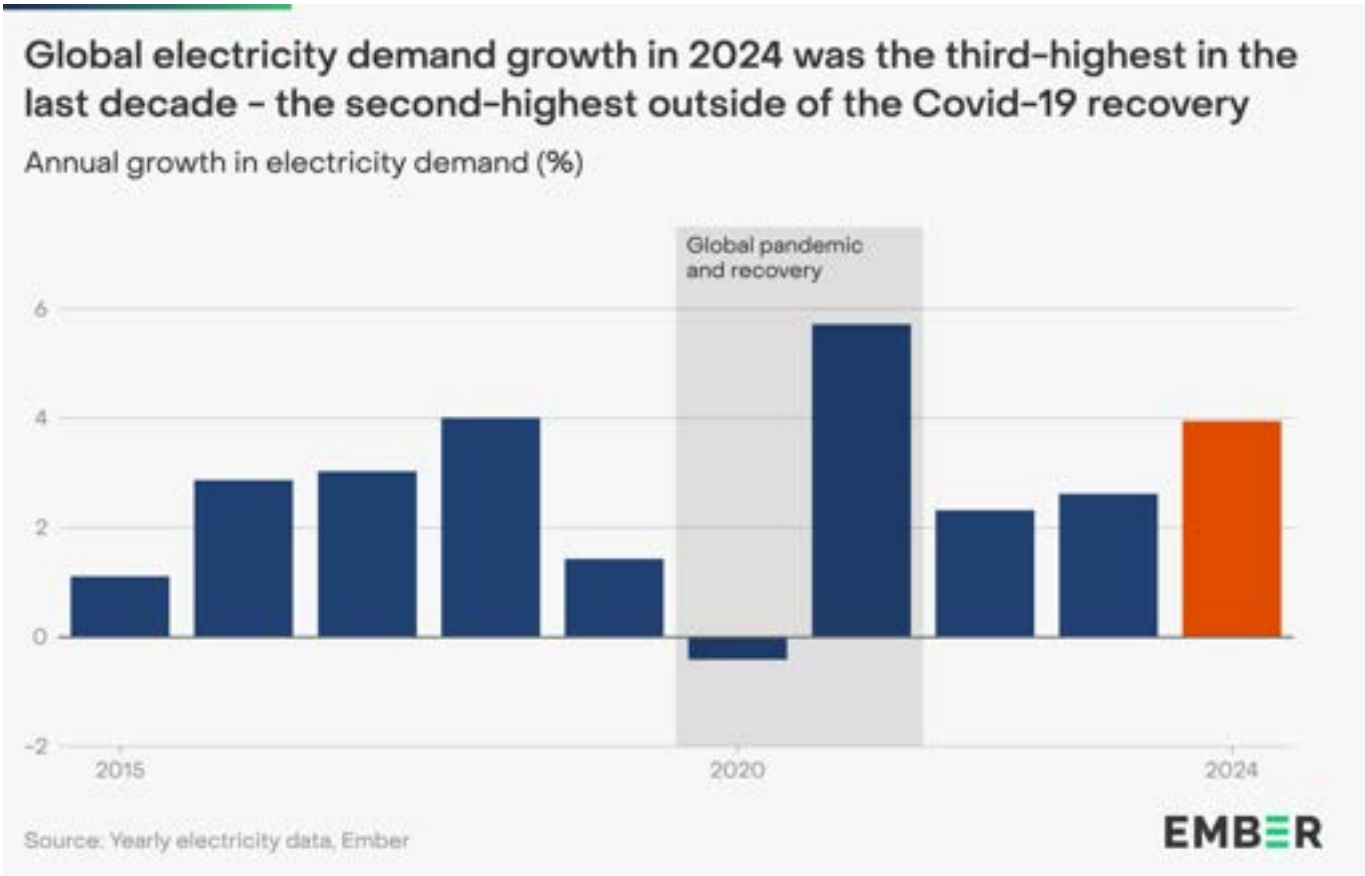
The surge in 2024 was driven by record solar capacity installations in 2023 and 2024. In 2023, new capacity installations jumped by 86% compared with 2022. In 2024, they increased by a further 30%, to a total of 585 GW. As capacity is installed throughout the year, a proportion of it only results in generation increases the following year.

Solar generation growth from the recent capacity boom was potentially even larger than observed, as reporting from distributed solar, such as rooftop installations, can be incomplete. Ember's data includes rooftop solar generation where possible and includes estimates in countries with large amounts of rooftop solar where reporting is inaccurate, but some underestimation is likely.

Hotter temperatures amplify high electricity demand growth

Electricity demand grows at the third-highest level in the last decade
Global electricity demand grew by 4.0% (+1,172 TWh) in 2024, crossing 30,000 TWh total demand for the first time. 2024 represents the third-highest percentage growth in electricity demand in the last ten years.

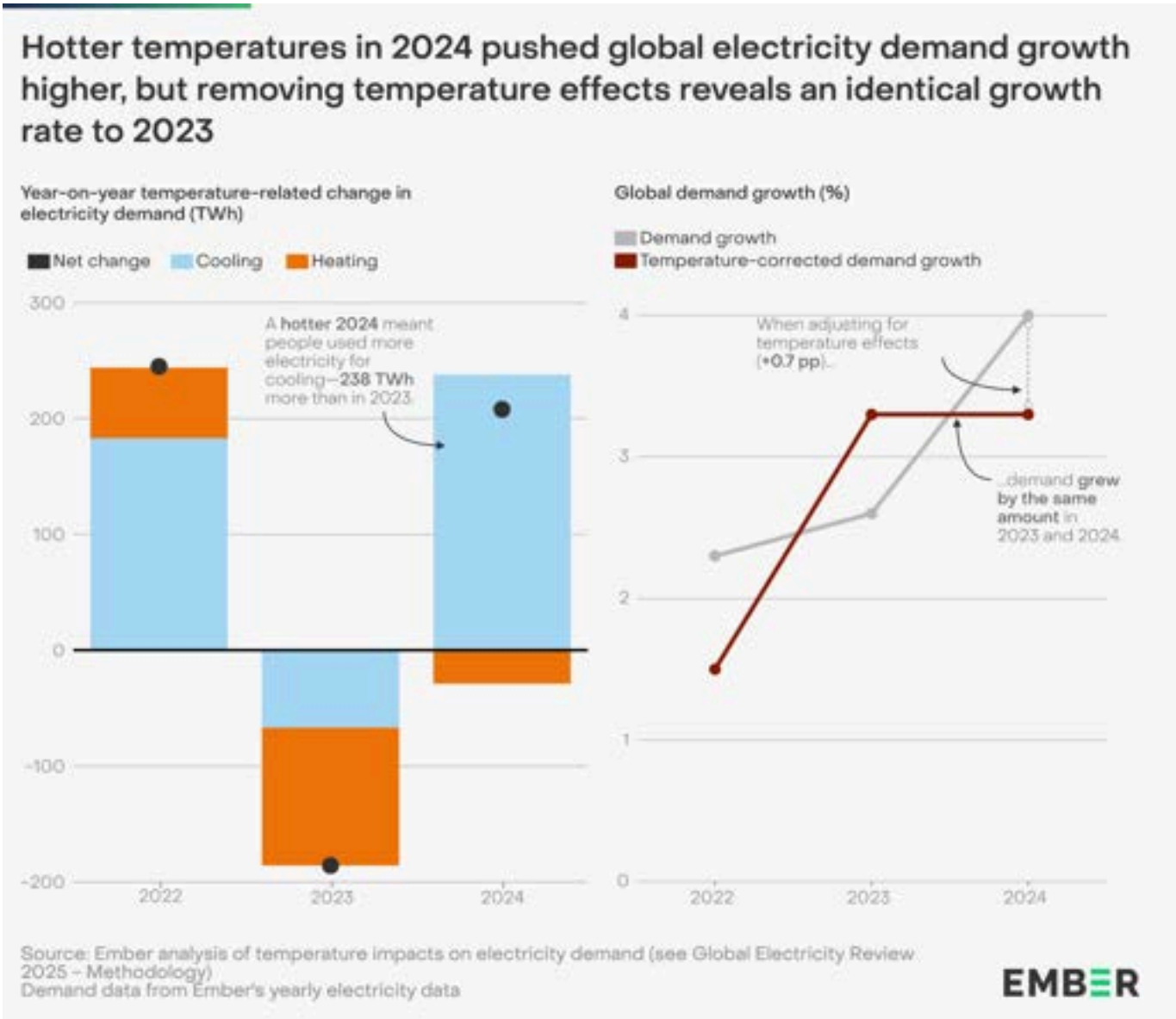
The increase in demand in 2024 was significantly higher than in 2023 and 2022, when global demand grew by 2.6% (+758 TWh) and 2.3% (+656 TWh) respectively. Unlike the post-pandemic rebound in 2021, the increase in 2024 was not driven by an acceleration in overall economic activity. GDP data shows similar rates of growth in 2024 (+3.2%) and 2023 (+3.3%), which implies that economic growth was not the driving factor behind the surge in demand in 2024.



Heatwaves amplify higher demand growth

Electricity demand growth accelerated from 2.6% in 2023 to 4.0% in 2024. However, accounting for differences in temperatures, demand growth was the same across both years at 3.3%.

Analysing temperature impacts on electricity demand, Ember estimates that nearly a fifth of the demand increase in 2024 was temperature-related (see Methodology for more detail). 2024 surpassed 2023 as the hottest year on record, and crucially showed especially high temperatures around population centres in major economies, particularly in China, the US and India (read more in Ember's analysis on heatwaves and electricity demand in these countries).



Higher temperatures had a twofold effect on demand in 2024. On the one hand, they increased cooling demand by 238 TWh compared to 2023. On the other hand, milder winters reduced the need for heating by 29 TWh. The net result was a temperature-related increase of 208 TWh. Had 2024 experienced the same temperature patterns as 2023, the overall electricity demand growth would have been only 3.3% (+963 TWh), rather than the 4.0% (+1,172 TWh) observed.

Recent years have shown how weather patterns affect electricity demand, leading to year-to-year variability on top of the underlying upwards trend from economic growth and electrification. In 2022, colder winters than normal in the United States created additional demand for heating, and summer heatwaves in the US and China amplified cooling demand. In 2023, there were less dramatic weather extremes, and so less demand for heating or cooling. In 2024, heatwaves led to higher demand for cooling.

Annual demand growth in both 2024 and 2023 would have been 3.3% without temperature impacts. The differences in weather patterns decreased demand growth from 2022 to 2023 by 186 TWh, reducing what would have been a rise of 3.3% down to the observed demand growth of 2.6%. In contrast, temperature impacts increased demand growth from 2023 to 2024 by 208 TWh, inflating what would have been a rise of 3.3% up to the 4.0% observed.

Even after these corrections for temperature, the underlying demand growth in 2023 and 2024 of 3.3% was higher than the ten-year average (2013-2022) of 2.5%. This is largely driven by applications such as EVs, heat pumps and data centres (see Chapter 2.2 for more analysis).

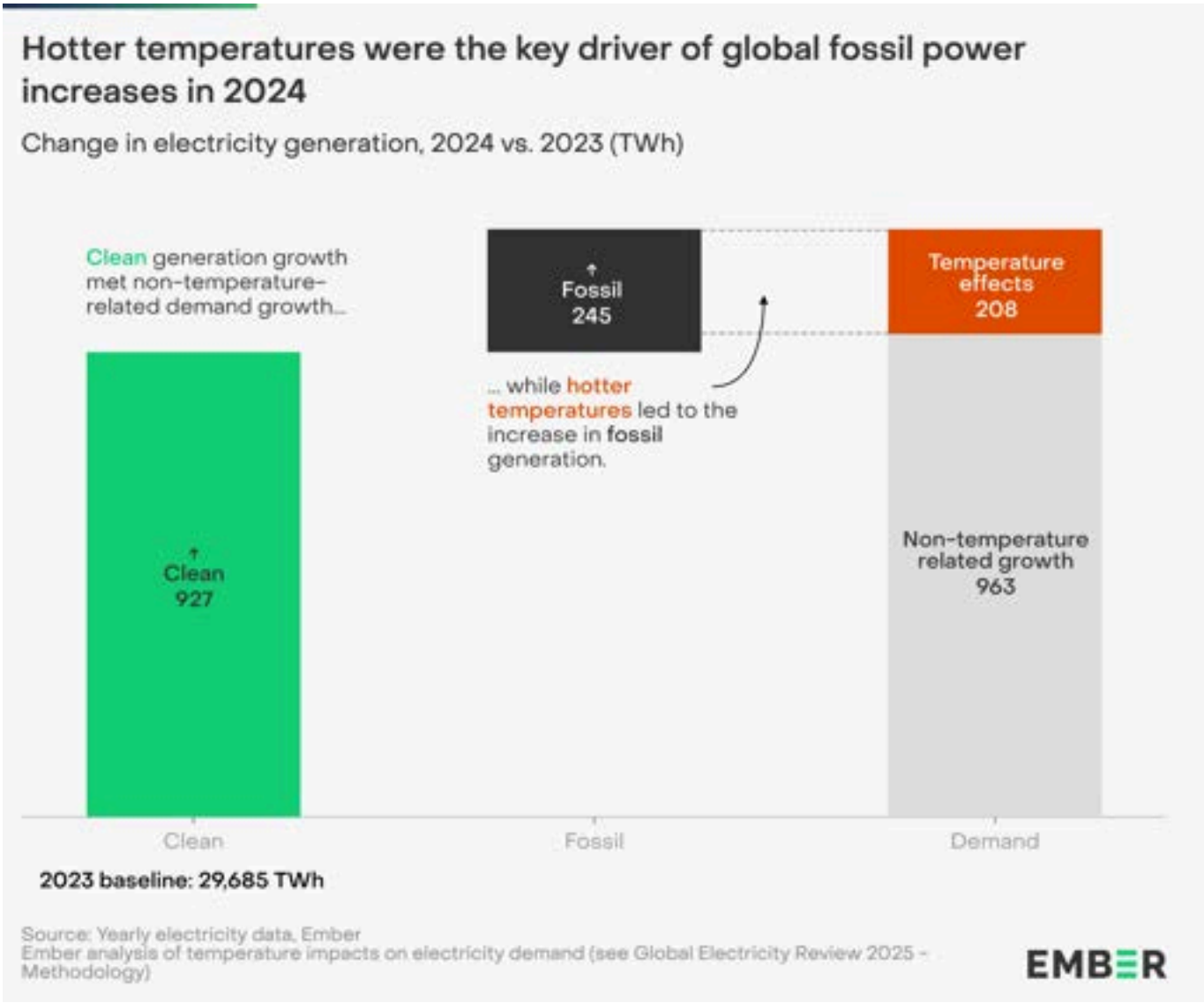
Heatwaves drive a small increase in fossil use

In 2024, global fossil generation increased by 245 TWh (+1.4%) – comparable to the increases of 246 TWh in 2023 and 201 TWh in 2022. This rise in fossil generation led to a 1.6% increase in global power sector emissions (+223 million tonnes of CO2), which reached a record high of 14.6 billion tonnes of CO2. However, Ember's analysis shows that fossil generation rose primarily as a result of hotter temperatures compared to 2023.

Hotter temperatures the key driver of fossil power and emissions increases in 2024

Hotter temperatures compared to 2023 were a key reason behind the increase in fossil generation in 2024. Clean electricity generation surged by a record 927 TWh in 2024, which was sufficient to cover 96% of the electricity demand growth not caused by higher temperatures (+963 TWh).

However, fossil fuel generation rose to meet the additional demand increase of 208 TWh driven by high temperatures. This dynamic was especially pronounced in countries that experienced strong heatwaves, with coal rising to meet higher demand in China and India, and gas rising to meet demand in the US. On a global basis, if 2024 had experienced the same temperatures as 2023, fossil generation would have remained almost unchanged, with just a 0.2% increase.



Smaller-than-average increase in fossil generation in China and India, while the US rebounds from a fall in 2023

The world's three largest power consumers – China, India and the US – saw an increase in fossil generation in 2024, while the world's fourth largest, the EU, saw a decline.

China was still the country with the largest increase in fossil generation, but – despite the impacts of heatwaves – 2024's growth of 116 TWh was less than a third of its 2023 increase (+367 TWh) and only half its average annual increase over the last five years (+218 TWh).

India's fossil generation grew by 67 TWh in 2024, significantly lower than the 124 TWh increase recorded in 2023 and the country's lowest increase since the rebound after the Covid-19 pandemic.

Driven by a rise in electricity demand, the US also saw an increase in fossil generation (+34 TWh) in 2024. Gas generation rose significantly, as coal saw a moderate fall. This represents a rebound from 2023 which saw a year-on-year decline in fossil generation amid falling demand. US gas generation growth was equivalent to 57% of the global increase in gas generation in 2024. Despite record clean electricity growth, the US has now recorded an increase in fossil generation in three out of the last four years.

The EU continued to see a fall in fossil generation (-75 TWh) in 2024. This happened despite a small increase in power demand and an increase in electricity exports, as clean electricity growth significantly outpaced demand growth.

The mega-trends shaping the electricity transition

This section explores three trends that are having an outsized impact in shaping the global electricity transition, now and in the coming years: the staggering rise of solar, the new drivers of accelerated demand growth and the trajectories of China and India.

First we look at solar power, which has become the engine of the global energy transition, doubling every three years to become the largest and fastest-growing source of new electricity generation. As battery costs decline, the combination of batteries and solar is proving a winning combination, along with other forms of clean flexibility that will unlock the full value of solar.

We then discuss how emerging drivers like EVs, heat pumps and data centres have structurally raised demand growth. While expectations for future growth in power consumption have increased, the outlook remains uncertain. Clean generation is still expected to grow quickly enough to meet higher demand growth, but fossil power declines will remain unpredictable in the short-term.

Finally, we turn our focus to the two countries with the largest growth in electricity demand in the last two decades: China and India. The two economies are breaking the long-standing link between electricity demand growth and fossil fuel expansion in the power sector by deploying clean generation at a world-leading scale. Together, their progress in clean power can tip the balance towards a global decline in fossil generation.

Chapter contents

2.1 Solar is surging – flexibility can take it to the next level

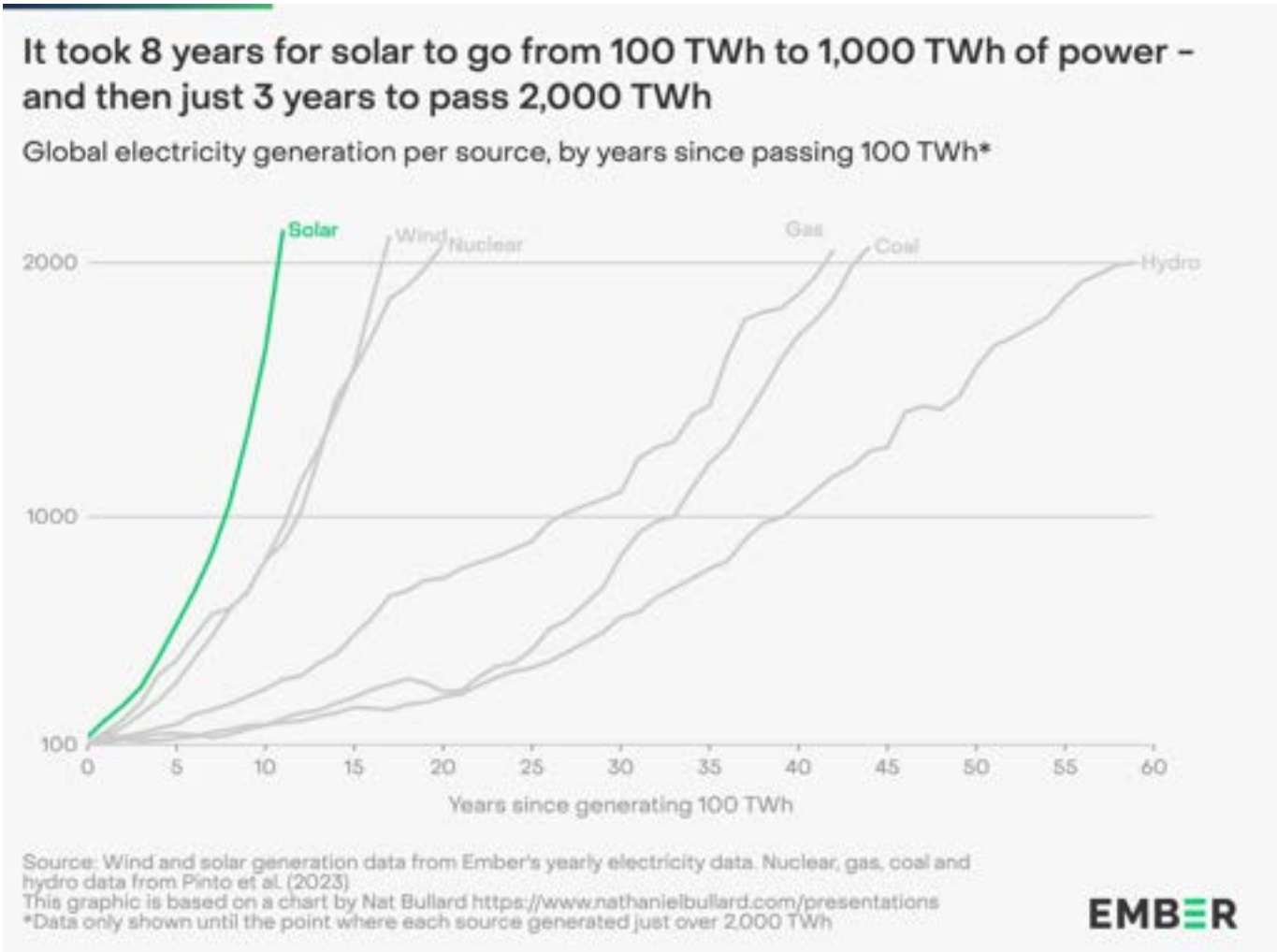
Solar surpassed 2,000 TWh of global generation in 2024, reaching this level faster than any other generation technology in history. This is reducing the need for additional fossil generation, enhancing energy security in countries reliant on fossil imports. As its exponential rise continues, doubling every three years, solar power is taking off in power systems all around the world and entering new markets. Combined with battery storage, which almost doubled in capacity last year, countries can unlock further benefits from low-cost solar power and enable fast growth to continue.

Solar power has become the engine of the global energy transition

Cheap solar power is already reshaping the electricity system

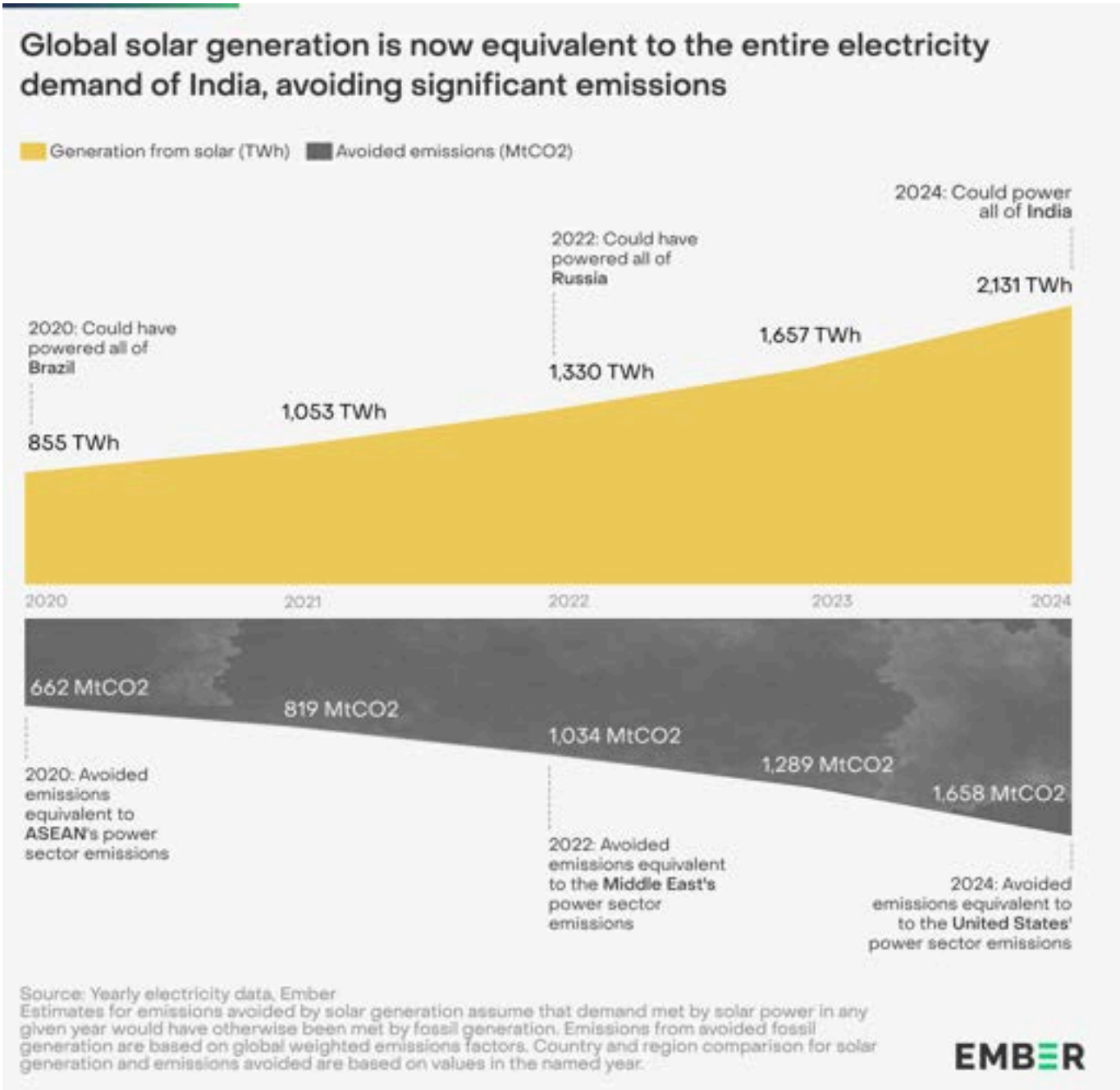
In 2024, for the first time, solar power supplied more than 2,000 TWh of electricity, increasing by 474 TWh (+29%) from the previous year. This was the largest increase in generation from any power source in 2024. Solar has now been the largest source of new electricity globally for three years in a row.

Having grown from 100 TWh to 1,000 TWh in eight years, solar generation made the jump from 1,000 TWh to 2,000 TWh in just three years. This means that it has continued its exponential rate of growth, doubling every three years.



Rapid solar growth is helping the world meet growing electricity demand and avoiding the use of more expensive fossil fuels. Global solar generation is now large enough to power all of India. Without the 2,131 TWh that solar power provides, global fossil generation would be 12% higher than it is today. In 2024, generation from solar avoided an estimated 1,658 million tonnes of CO2 (MtCO2) of emissions - equivalent to the United States' power sector emissions.

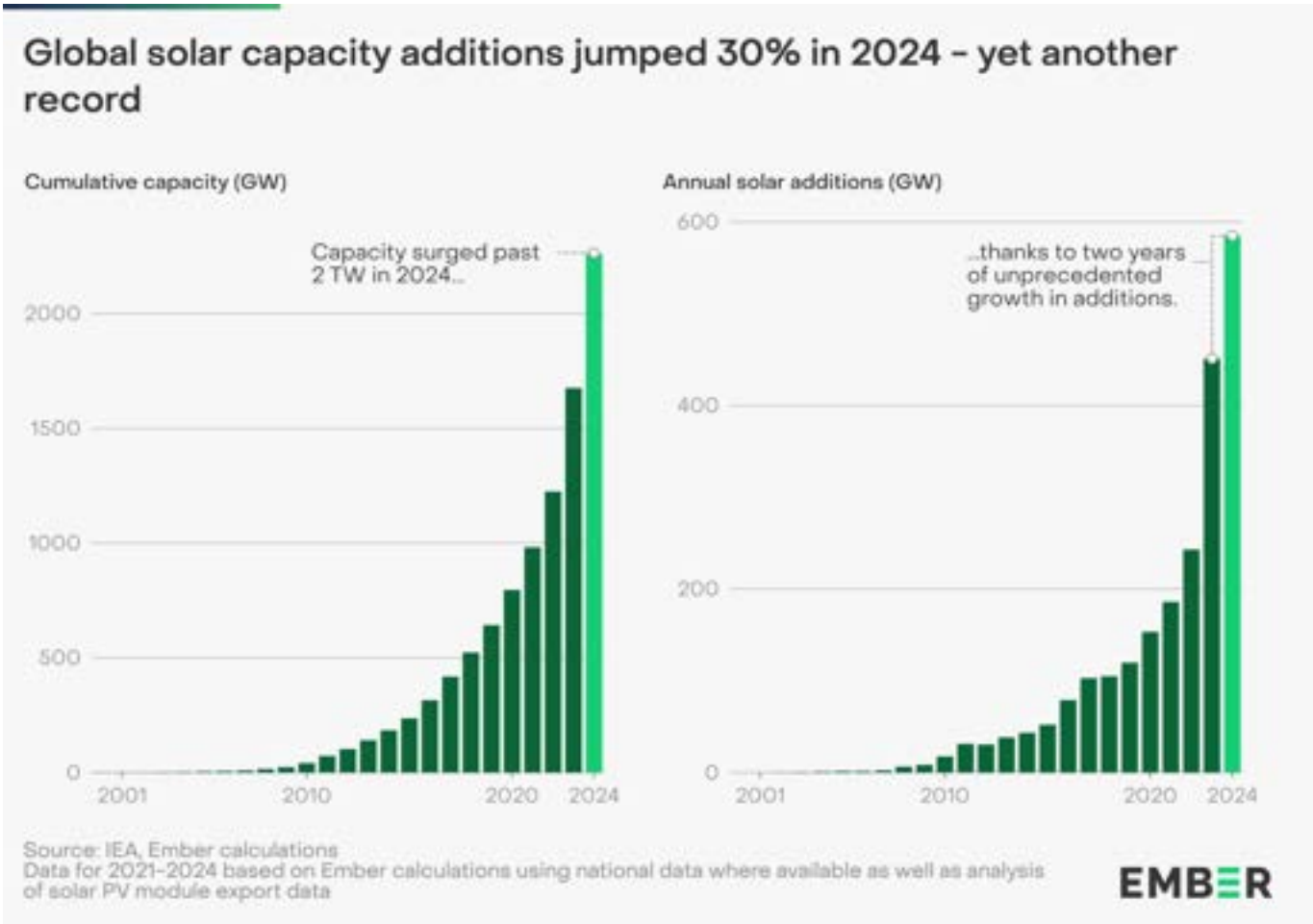
While the expansion of solar has contributed to falls in fossil generation in advanced economies such as the EU and the United States, the largest avoided fossil generation is in China, where annual coal generation would have been an estimated 783 TWh higher in 2024 if not for the build-out of solar power. In particular, the rise in coal generation in China seen in the last five years would have been an estimated 50% larger without the growth in solar generation.



Record capacity installations keep driving solar to new heights

Increases in generation have been achieved thanks to the pace of capacity additions. The world installed a record 585 gigawatts (GW) of solar capacity last year - 30% more than in 2023, and more than double the amount installed in 2022. Having surpassed 1 TW of solar power in 2022, it took only two years to install the next 1 TW.

This is not just unprecedented for solar power - it is a rate of growth that no power source has seen before. In fact, the solar capacity installed in 2024 is more than the annual capacity installations of all fuels combined in any year before 2023.



The rapid growth of solar is on display everywhere

The expansion of solar power is a worldwide phenomenon, with 99 countries doubling the amount of electricity they produce from solar power in the last five years. The majority of solar generation now comes from non-OECD countries (58%), with China alone making up 39% of the global total. But even as some countries are already integrating high shares of solar into their power systems, there is still room for rapid growth in other markets.

Solar is growing all around the world

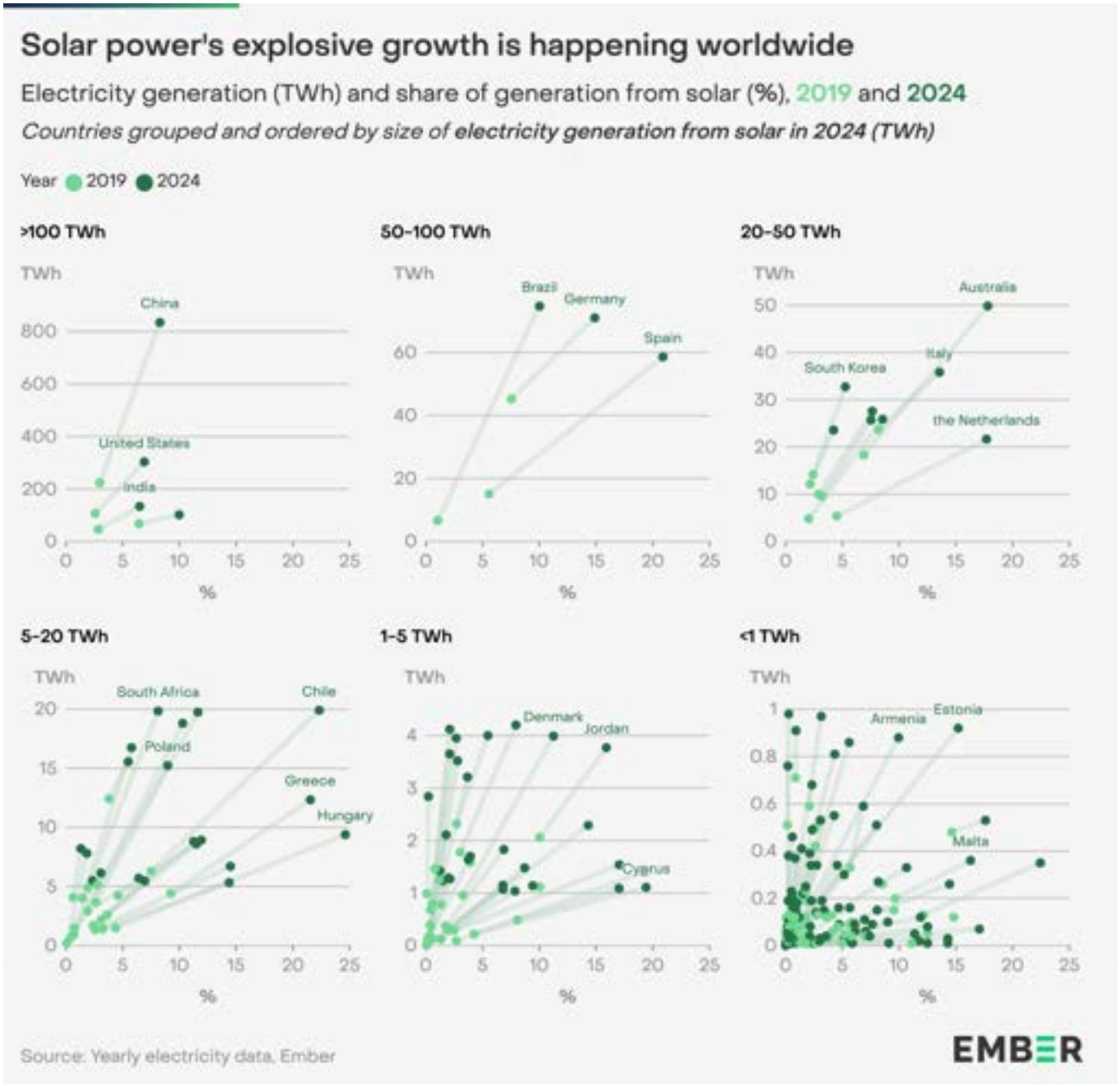
As solar's share of the global electricity mix has risen to 6.9% of global generation in 2024, some countries are showing it is possible to incorporate much larger amounts. There are now 21 countries that generate more than 15% of their electricity from solar power, up from just three countries five years ago.

In 2022, in response to Russia's invasion of Ukraine and rising energy prices, EU Member States strengthened their policies and targets for the clean electricity transition and

accelerated the rollout of cheap, fast-to-build sources of home-grown electricity, solar in particular. Of the 15 countries with the highest solar shares in 2024, seven were in the European Union.

Outside Europe, Chile generated 22% of its electricity from solar power in 2024, up from just 8% in 2019. Australia reached an 18% solar share in 2024, up from 7% in 2019.

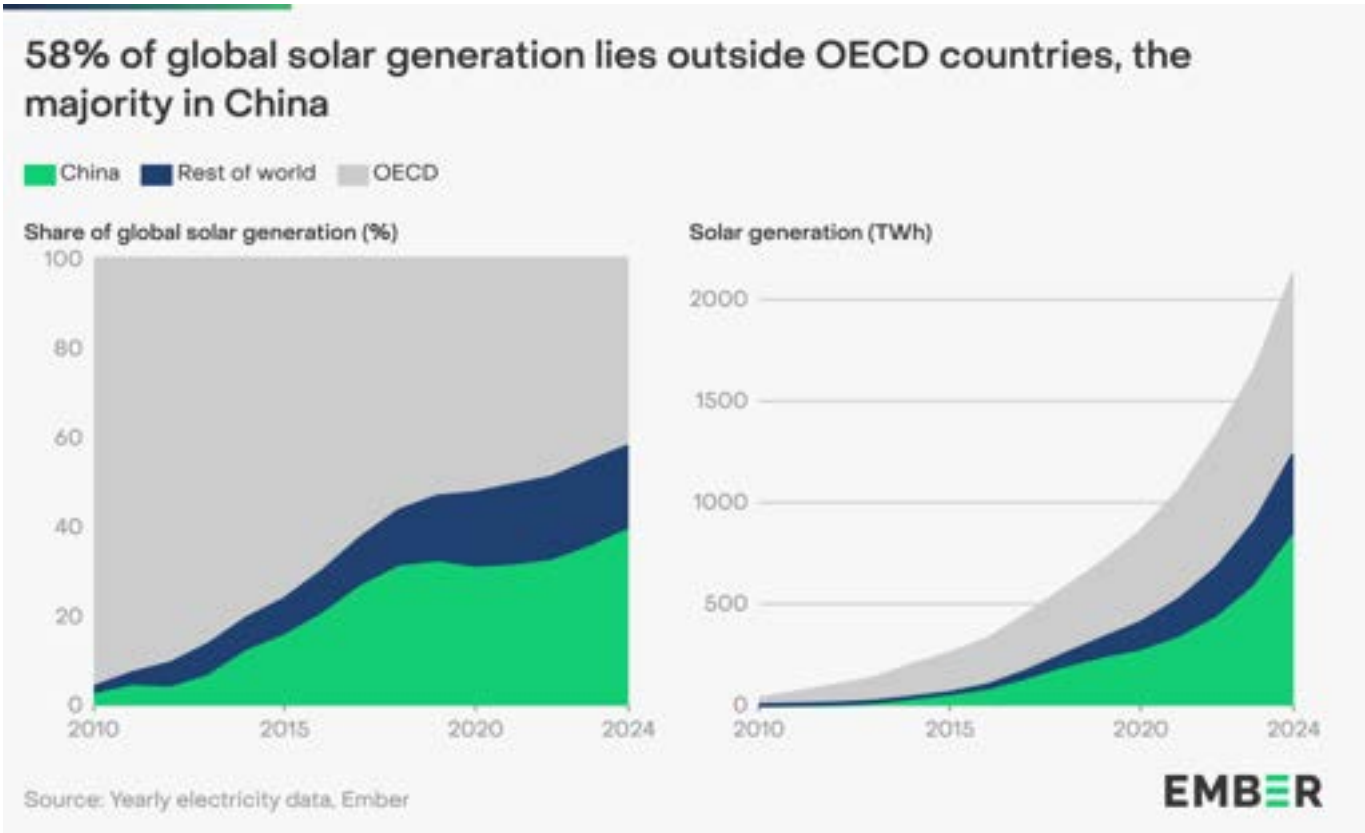
Rapid growth is happening elsewhere too. In 2024, 81% of the rise in solar generation took place in countries where it still made up less than a tenth of total output. For the first time ever, solar power was the largest single source of new electricity in China, rising by 250 TWh (+43%) to supply 8.3% of the country's electricity. In Brazil, solar generation increased by 23 TWh (+45%) last year, following a 71% increase in 2023. Solar now provides 10% of Brazil's electricity in 2024, up from just 1% five years ago.



Over the last five years, 99 countries have doubled the amount of electricity they produce from solar power. This includes emerging economies such as South Africa, countries with the largest power systems in the world such as China and the United States and countries with the highest shares of solar power in their electricity mix such as Hungary and Spain.

Growth in China means that more than half of solar generation is now outside of the OECD
In 2024, non-OECD economies accounted for 58% of global solar generation, with 39% in China alone. This marks a significant change from a decade ago, in 2014, when OECD countries made up 81% of global solar generation.

As this growth continues to spread, new solar superpowers are emerging. In 2022, India overtook Japan to become the third-largest solar generator in the world. In 2024, Brazil overtook Germany to become the fifth-largest. Alongside China, this means that BRICS members now represent three of the world's top five solar generating countries.

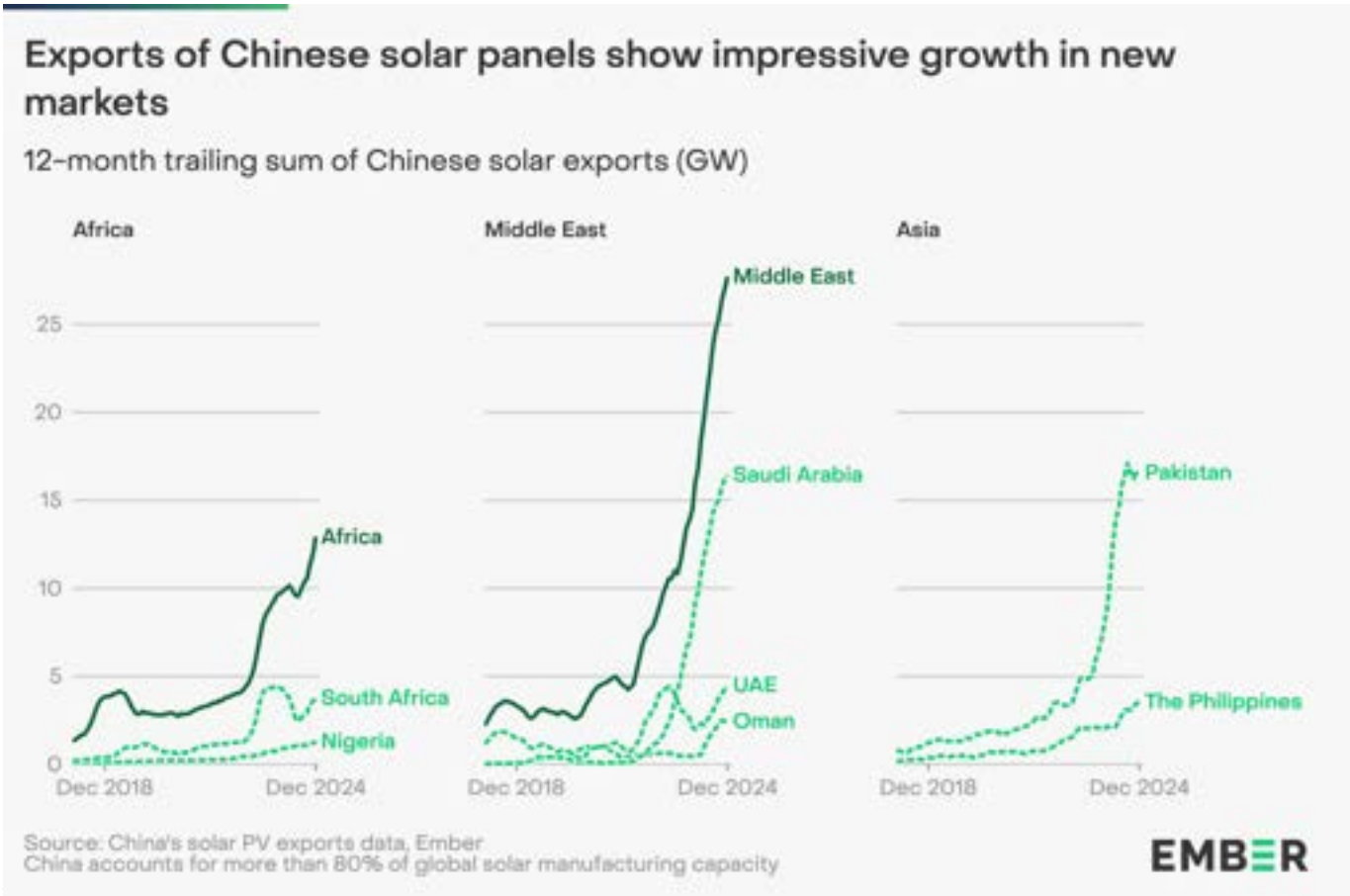


This trend shows no signs of slowing, with solar generation in China growing by 250 TWh in 2024, compared to the 142 TWh increase seen in OECD countries. Solar capacity installations in China were 30% higher than in 2023, while in India, 2024 installations doubled from the previous year (see Chapter 2.3).

Exports data reveals solar growth is taking off in new markets

Solar is now so cheap that large markets can emerge in the space of a single year - as evidenced in Pakistan in 2024. Amid high electricity prices linked to expensive contracts with privately-owned thermal power stations, rooftop solar installations in Pakistan's homes and businesses soared as a means of accessing lower cost power. The country imported 17 GW of solar panels in 2024 to meet this growing consumer demand, double the amount imported the year before. Within just a year, Pakistan became one of the world's largest markets for new solar installations in 2024. Pakistan's case shows that the low-cost, fast-to-build nature of solar power can transform electricity systems at an unprecedented rate. Updated system planning and regulatory frameworks are needed alongside this deployment to ensure a sustainable and managed transition.

There are signs in other regions that more rapid change could be around the corner. Because Chinese factories account for more than 80% of global solar manufacturing capacity, data on exports from China can act as a proxy for demand in countries without a domestic solar manufacturing industry. Data for 2024 reveals a considerable rise in solar exports to the Middle East and Africa - two of the world's sunniest regions that have historically had very low levels of installed capacity. In both regions, imports of solar panels have tripled in the last two years.



South Africa imported 3.8 GW of solar panels in 2024, following a record-breaking 2023 when 4.3 GW were imported as consumers turned to the technology amid rising blackouts. Nigeria and Morocco imported 1.3 GW and 1.1 GW respectively, marking the first time that either country has imported more than 1 GW in a single year.

In the Middle East, Saudi Arabia imported 16 GW in 2024, more than double the amount imported the year before. Oman saw the largest percentage growth in imports in the region, with 2.5 GW of imports in 2024 representing a fivefold increase from the year before.

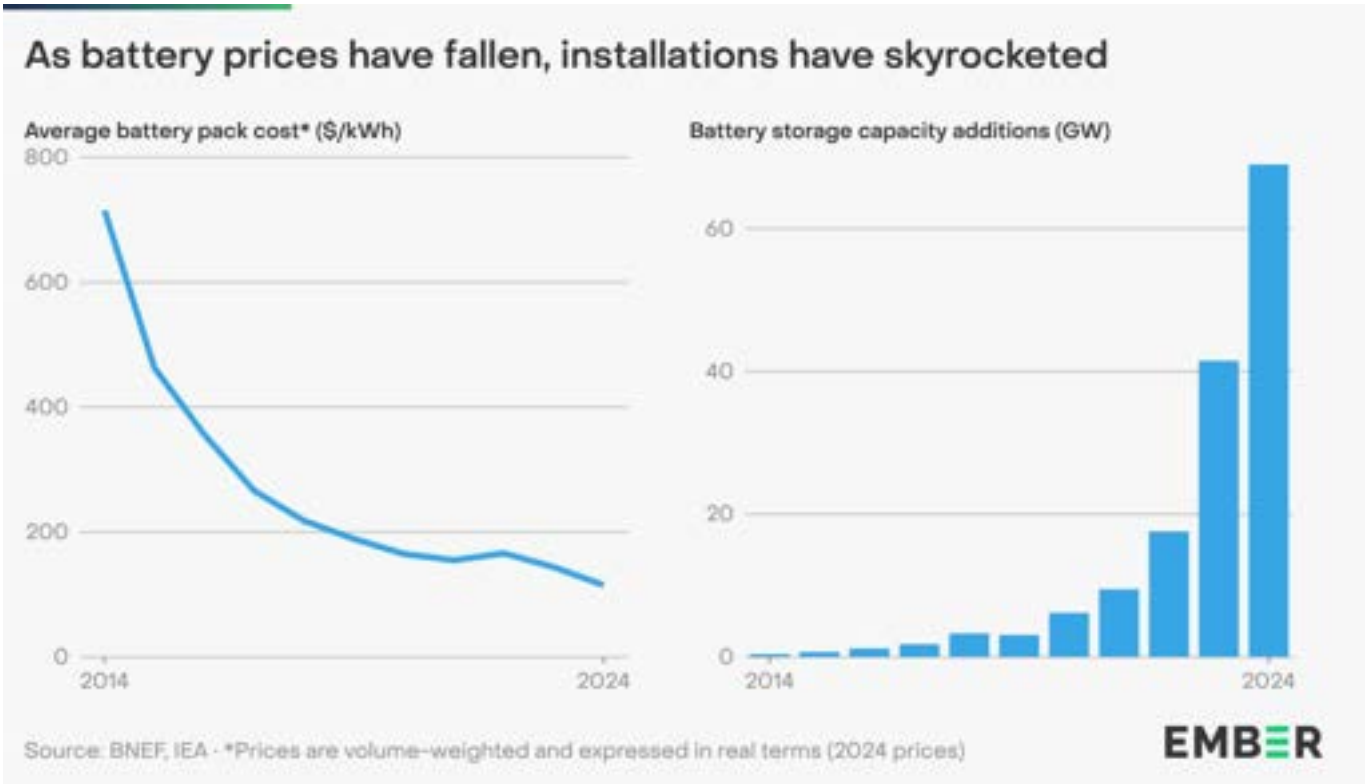
Flexibility can enable further growth in solar power generation

Solar power's role in the mix varies greatly throughout the day in markets with high solar shares. During the sunniest parts of the day, solar quickly becomes the main source of electricity in countries such as Chile and the Netherlands before dropping away again as the sun goes down. This variability can mean that low cost electricity goes unused during peak solar hours, and the impact of this on wholesale prices can affect the economics of projects for developers. Falling battery prices now mean there is an opportunity to better integrate far higher levels of solar and other variable sources of power.

Falling prices make battery storage a winning solution

Battery storage technology, much like solar panels, has undergone rapid cost reductions in the last decade. The average price of lithium ion battery packs dropped to $115 USD/kWh in 2024, a 20% cost reduction from the year before and 84% lower than the average cost a decade ago. As the price has fallen, annual installations of battery storage capacity have increased dramatically at an average rate of 67% per year over the last decade. 69 GW of battery storage capacity was installed in 2024 - almost enough to double total battery storage capacity, which stood at 86 GW in 2023.

The 20% fall in battery pack costs in 2024 marks the largest percentage reduction in cost in a single year since 2017, and the largest absolute reduction since 2019. These cost reductions have been driven by economies of scale as manufacturing capacity has stepped up, and by increased adoption of lower-cost battery chemistries such as lithium iron phosphate (LFP), which eliminates the need for nickel and cobalt. Material costs have also come down after a brief surge in lithium prices in 2022.

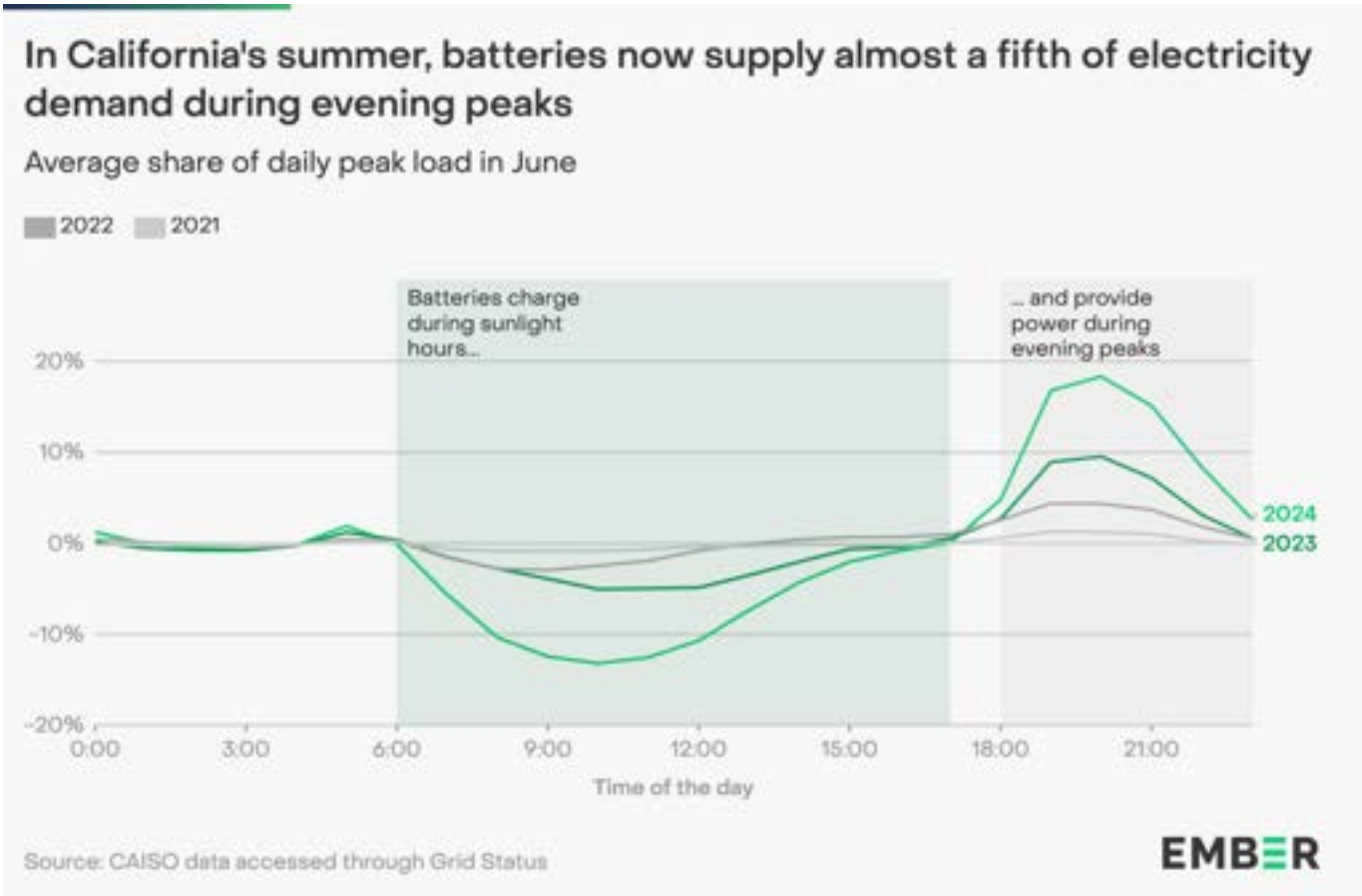


Solar and batteries combined are a powerful combination

The low cost of lithium ion batteries makes them an ideal choice for storing the excess electricity produced by solar power during the sunniest hours until it is most needed. Alongside other storage technologies, demand-shifting and enhanced interconnection between countries, they can enable larger amounts of solar power to be successfully integrated into power systems.

In Europe, co-locating battery storage systems with solar plants improves the business case for solar. A recent study found that in Germany, the cost of building and operating utility-scale solar with integrated battery storage has now become cheaper than the equivalent cost for gas-fired power plants.

In the United States, California is at the forefront of using battery storage to complement large amounts of solar power. In 2024, batteries routinely met close to a fifth of daily peak load in the evening hours, displacing gas generation. This has been a rapid change: the average share of evening peak load met by batteries nearly doubled from 2023 to 2024, while just three years ago, California's battery fleet met less than 2% of evening peak load.



Batteries have now become so cost-competitive that they have opened up the possibility of round-the-clock solar power becoming a reality. In early 2025, the world's first 24-hour solar PV project was announced - 1 GW of baseload electricity capacity in Abu Dhabi. The state-owned renewable energy company Masdar provided a $6 billion investment to build 5 GW of solar and 19 GWh of battery capacity, planned to come online in 2027.

The potential for round-the-clock solar will be transformative, outcompeting fossil fuels both on costs and security of supply. The rapid growth of solar and batteries is already transforming electricity systems around the world, but there will be an even more profound shift in the coming years as energy storage technologies reach scale.

2.2 Clean generation is expected to meet higher levels of demand growth

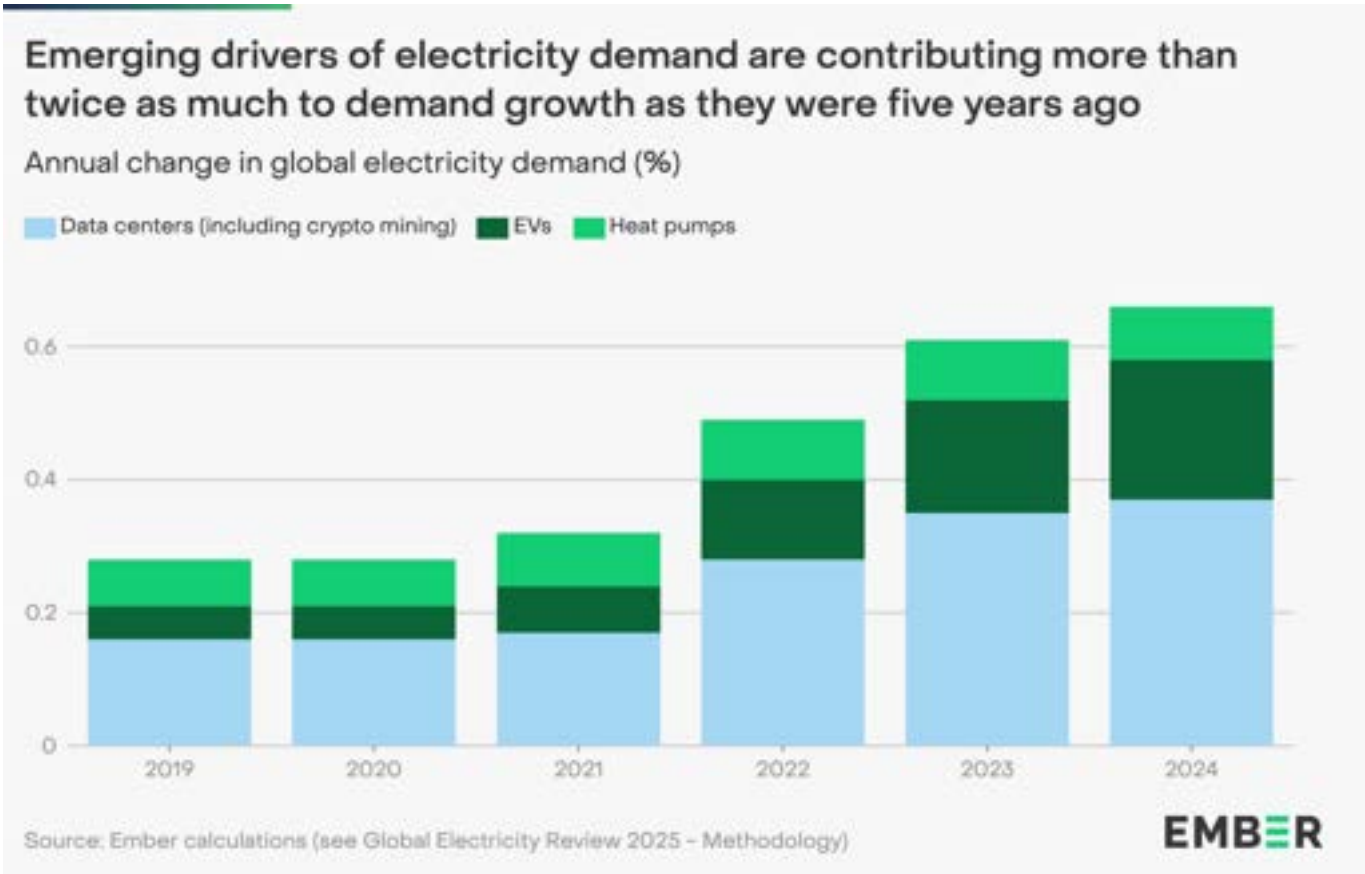
Emerging drivers of demand like EVs, heat pumps and data centres have structurally raised demand growth. Though long-term demand forecasts have been revised upwards, there remain uncertainties about the scale of growth that will materialise in the coming years. Clean generation is still expected to expand quickly enough to exceed higher levels of demand growth, but achieving significant reductions in fossil fuel generation will now require higher levels of clean deployment.

Demand growth is higher than it used to be

2023 and 2024 saw the same rate of electricity demand growth of 3.3%, once adjusted for differences in temperatures (see chapter 1). This is higher than the 2.5% average growth seen over the previous decade, and in part reflects the emergence of new drivers of electricity demand such as EVs, heat pumps and data centres. Combined, these three technologies increased electricity demand by 0.7% in 2024. This is more than double the rate of demand increase they contributed five years ago, when they were responsible for increasing global electricity demand by 0.3% per year.

Emerging drivers cause higher rates of electricity demand growth

Emerging drivers of electricity demand such as EVs, data centres and heat pumps have shown similar rates of growth over the last two years. These three technologies are estimated to have added 0.7% to global demand in 2024 (+195 TWh), a slight step up from the 0.6% they added in 2023 (+174 TWh).



Electrification is a major driver, as systems that once ran on fossil fuels switch to electricity, increasing electricity demand but reducing overall energy demand through efficiency gains. EV electricity demand grew by an impressive 38% in 2024 (+62 TWh), increasing from 163 TWh in 2023 to 225 TWh in 2024 and adding 0.2% to global electricity demand. This increase was five times larger than the growth in EV electricity demand seen in 2019. Heat pumps are estimated to have added an additional 22 TWh electricity demand in 2024, which was lower than the 25 TWh seen in 2023, as sales in key markets slowed slightly.

Demand from data centres and cryptocurrency mining is estimated to have increased by 20% (+111 TWh) in 2024, slightly higher than the increase seen in 2023. This added 0.4% to global electricity demand in both years. Crypto mining is estimated to have driven 40% of the overall 111 TWh increase in 2024.

These emerging drivers mean that electricity demand growth is structurally higher than it was over the previous decade, when it averaged 2.5% per year.

Expectations rise for future demand growth, but remain uncertain

Looking to the future, forecasts for electricity demand growth have been revised upwards. If high short-term forecasts become reality, it would represent a big step up in structural demand growth compared with 2024. The size of temporary factors driving demand growth in 2024 raise questions about whether this high growth will be maintained in 2025. In the longer term, the scale of future growth of emerging drivers of demand remains uncertain.

Expectations for future electricity demand growth are now much higher than they used to be

The International Energy Agency's (IEA) current outlooks for future electricity demand envisage higher levels of demand growth than was previously expected. The IEA's STEPS scenario released in October 2024 forecasts annual demand growth of 3.3% between 2023 and 2030, higher than the 2.7% growth they forecast in 2023 between 2022 and 2030. The upgrade to 3.3% annual growth equates to an additional 1,687 TWh of annual electricity demand by 2030, with the IEA citing increased expectations for demand from data centres as well as increased power usage for cooling, alongside electric mobility and light industrial consumption.

More recent analyses point to even faster growth. In February 2025, the IEA published a short-term forecast for the years 2025-2027, in which total generation is expected to increase by an average of 3.7% annually.

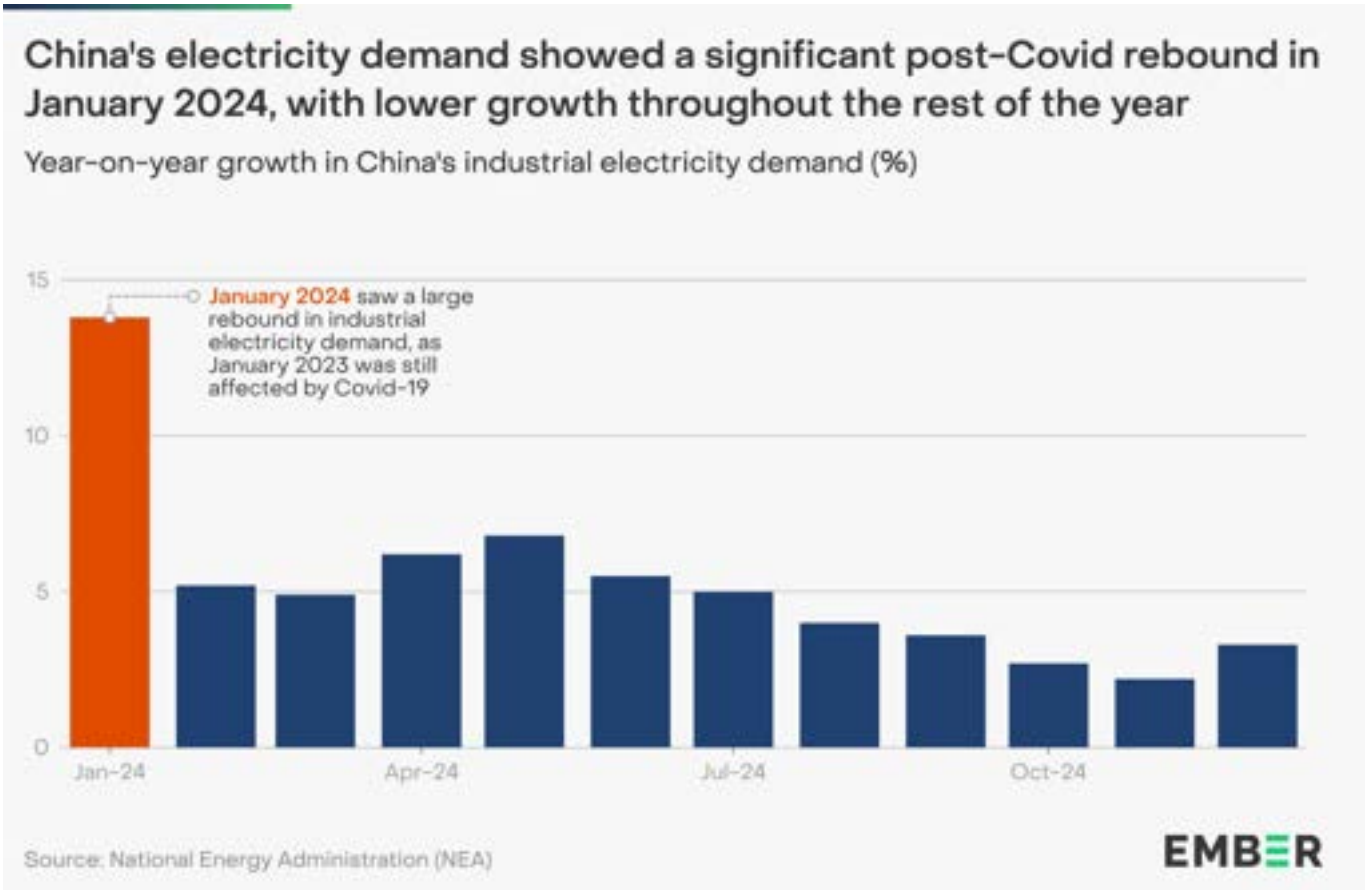
Factors driving demand growth in 2024 raise questions about whether this high growth will be maintained in 2025

There are reasons to question whether the levels of demand growth forecast by the IEA for the next three years will materialise. If they do, this would represent a significant increase in structural demand growth. Two key factors – the impact of heatwaves globally and a rebound in industrial demand in China in January 2024 – added considerably to demand growth last year but will not contribute this same amount year after year. Combined, these factors were responsible for almost a quarter of the demand growth seen in 2024; without them, demand growth would have been 0.9% lower.

Temperature effects were the most significant temporary factor, adding 0.7% to demand growth in 2024 because of much higher temperatures around population centres compared with the year before (see Chapter 1). If 2025 sees the same intensity of heatwaves as in 2024,

this would result in no year-on-year impact on demand growth caused by temperatures. If other demand growth were to remain stable year-on-year, then 2025 would see electricity demand growth of 3.3% instead of the 4.0% seen in 2024. If summer temperatures in 2025 are cooler than in 2024, then demand growth would be even more modest.

Secondly, China's industrial demand growth is unlikely to be as high in 2025 as it was in 2024, when it was still being influenced by the economic recovery from Covid-19. January 2024 saw a significant rebound (+58 TWh) in industrial electricity demand in China compared to the reduced level seen in January 2023, which was affected by Covid-19. The increase in Chinese industrial demand in January 2024 alone contributed 0.2% to global demand growth in 2024. The high rate of growth seen in the first month of the year was not sustained throughout the rest of 2024.

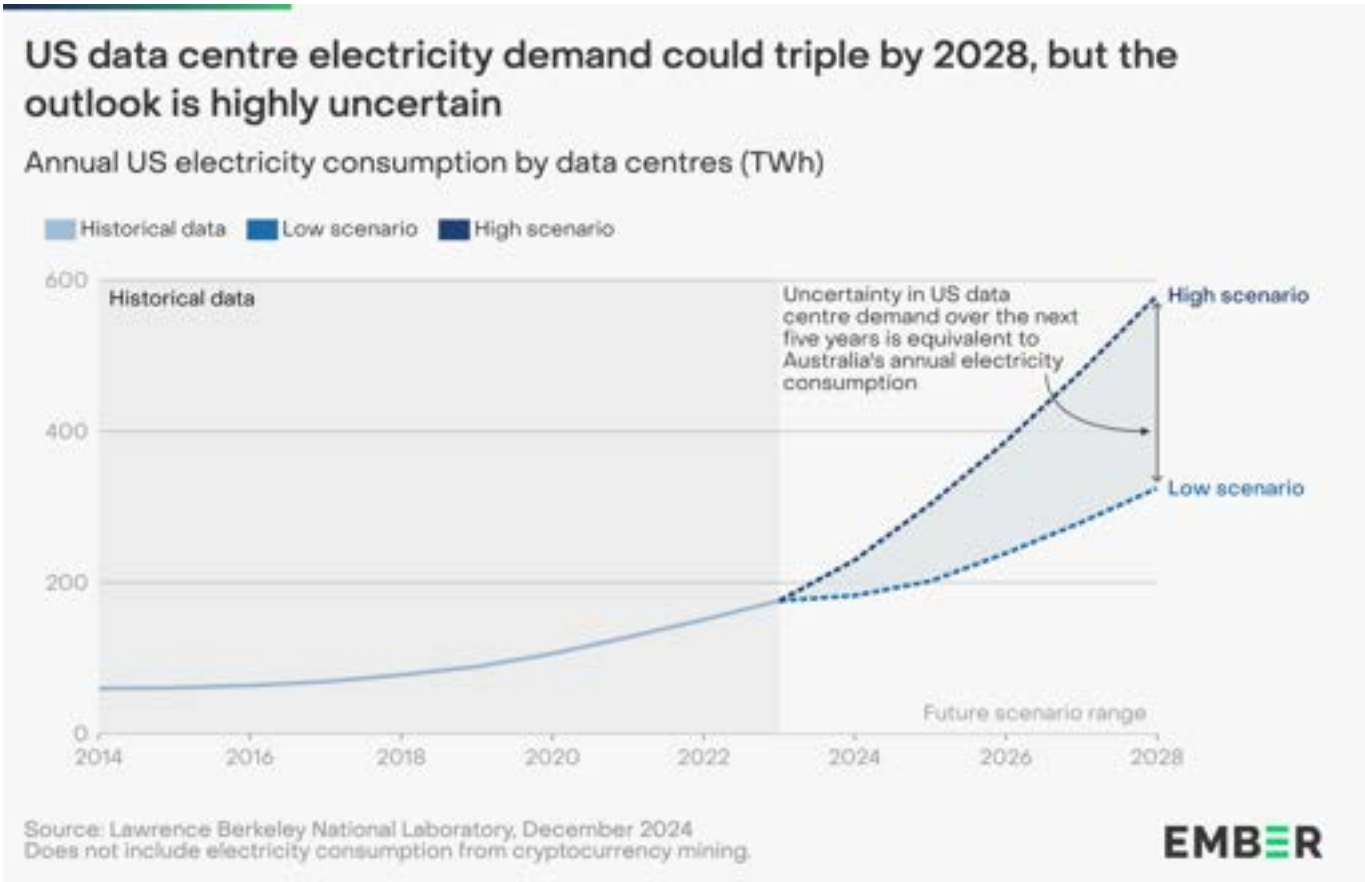


Without these additional factors driving demand growth beyond 2024, the IEA's forecast of 3.7% annual growth in total power generation over the next three years would represent a significant step up in structural growth. It remains to be seen if such high levels materialise.

Large uncertainties remain across many sectors

Electricity demand growth forecasts are being revised upwards amid intense speculation about the impact of new major consumers such as data centres.

Rising demand for electricity to train models for artificial intelligence has increased data centre power consumption in recent years, following a period of stable demand in the sector. Looking forward, recent projections from the Lawrence Berkeley National Laboratory (LBNL) suggest that electricity consumption by US data centres could triple from 176 TWh in 2023 to reach 580 TWh in 2028 – which would then account for 12% of US electricity demand. However, the LBNL's lower-end estimate places demand from data centres at 325 TWh, just over half the high-case estimate. The uncertainty in these forecasts by 2028 is equivalent to Australia's annual electricity consumption.



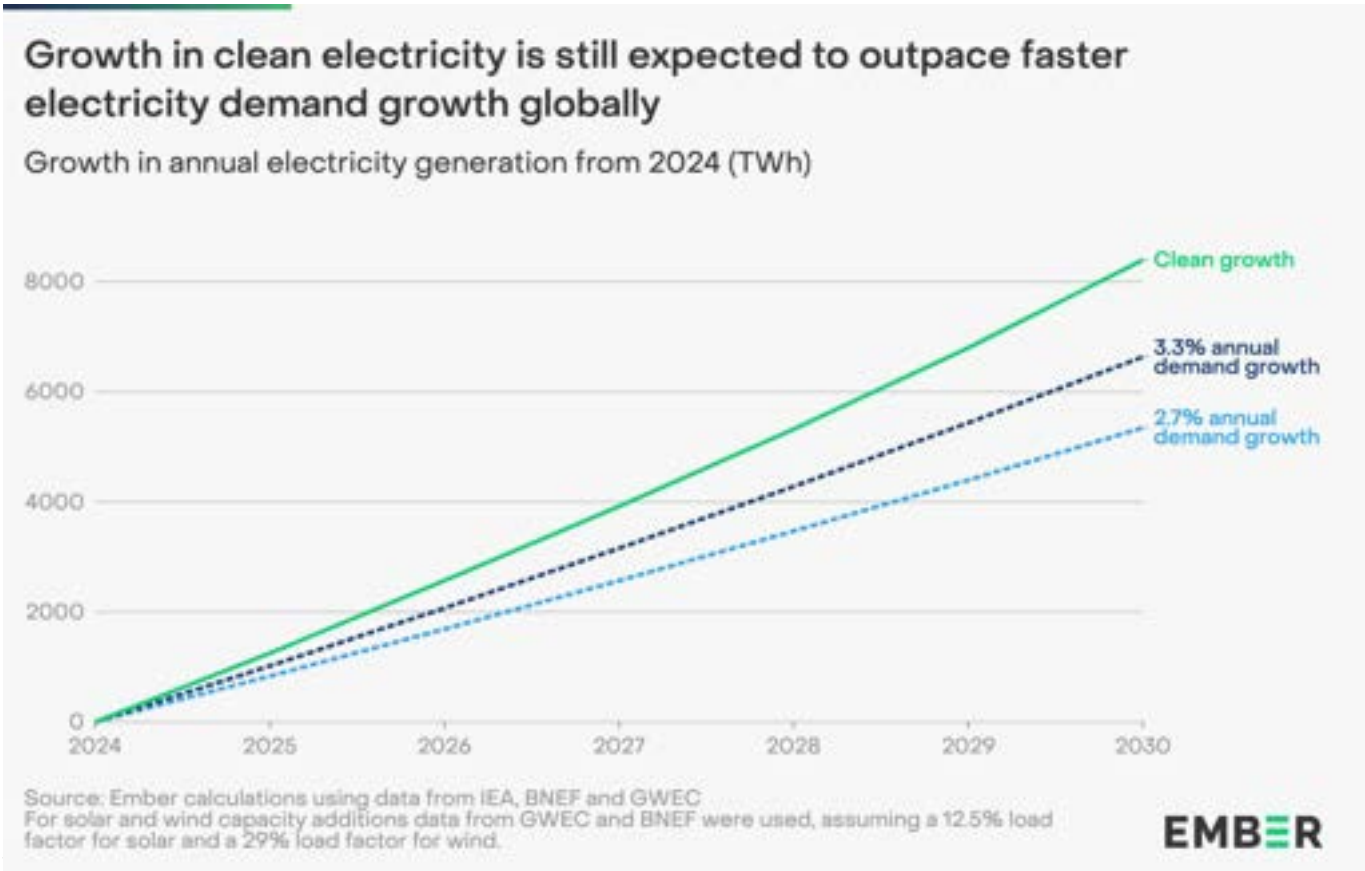
Clean electricity is growing quickly enough to meet higher levels of demand growth

Clean generation is still expected to exceed growth in electricity demand

Forecasts for wind and solar capacity additions from the Global Wind Energy Council (GWEC) and Bloomberg New Energy Finance (BNEF) predict strong growth in both technologies. BNEF predicts solar capacity additions to reach close to 1 TW per year by 2030, up from the 585 GW seen in 2024. Meanwhile, GWEC expects annual wind capacity additions to reach 182 GW by 2028.

Assuming typical capacity factors, we estimate that these new additions would result in solar generation growth of 21% on average per year between 2024 and 2030, and wind generation growth of 13% per year. Combined with modest growth in hydro and nuclear power, clean generation is expected to grow at an average rate of 9% per year between now and 2030, adding a combined 8,399 TWh of annual generation by 2030.

The expected growth in clean sources would be sufficient to keep pace with a demand increase of 4.1% per year to 2030, which exceeds the 3.3% demand growth expected in the IEA's STEPS scenario as well as their short-term forecast of 3.7% growth over the next three years.



The expectations for demand and clean growth mean that fossil generation is set for structural decline over the rest of the decade, by a small margin in the near-term and a confident margin by the end of the decade.

Separating the signal from the noise for future fossil generation

Clean generation growth is expected to exceed demand growth over the rest of the decade, but in the short-term the higher expectations for demand growth means the gap with clean generation growth has narrowed. Over the next few years, the size of changes in fossil generation will be small but noisy, and partially determined by fluctuations in weather conditions from one year to the next.

As an example, temperature effects increased demand growth by 208 TWh in 2024, but reduced demand growth by 186 TWh in 2023. Weather conditions can also impact the supply of clean generation: wind and hydro conditions in 2024 were both below the long-term average. If global weather conditions in 2024 had been in line with the five-year average, wind generation would have been 3.7% higher (+92 TWh) and hydro generation would have been 2% higher (+86 TWh). How these factors interact in the coming years will significantly determine the scale of fossil generation declines.

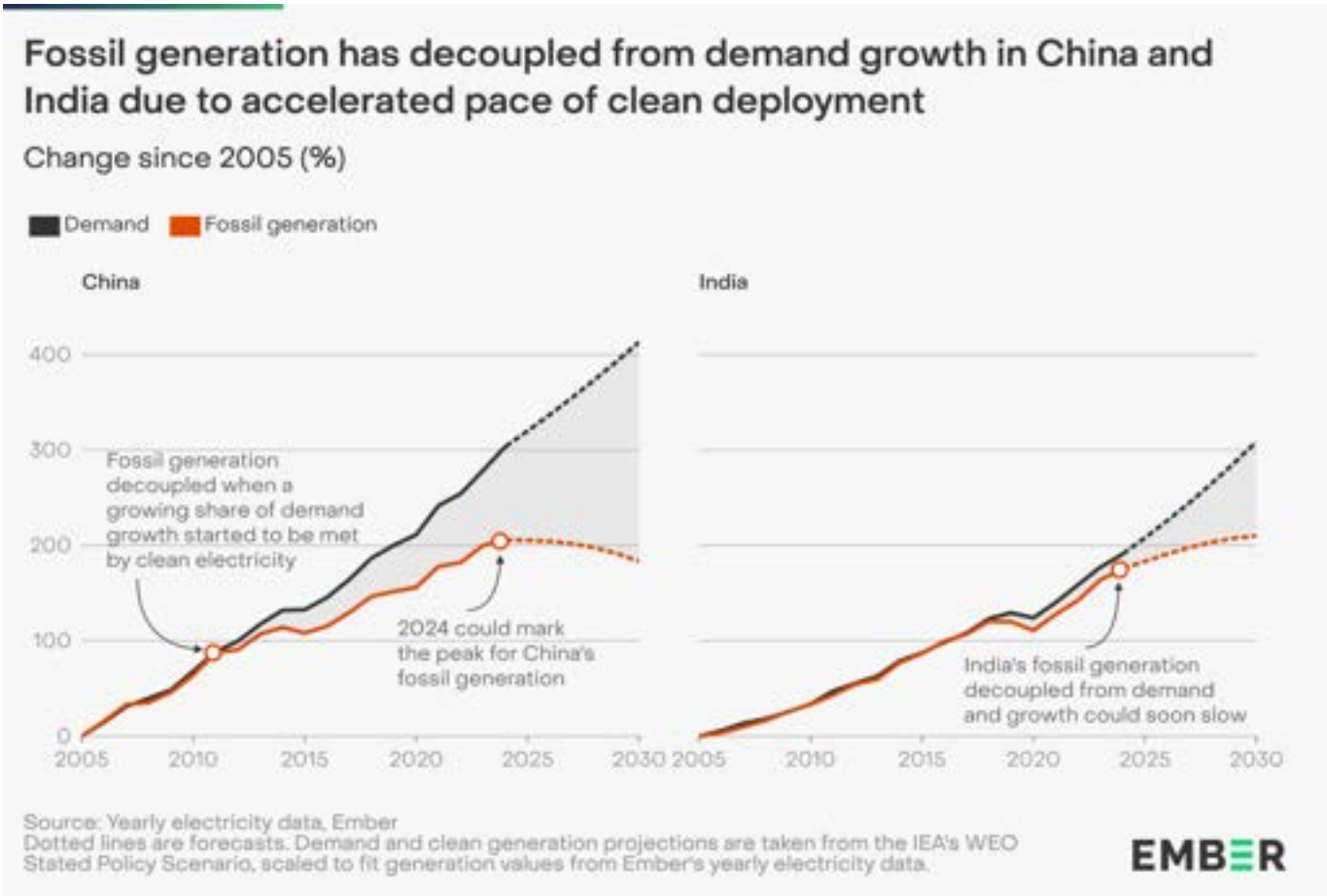
Although the world is close to a new era of structurally falling fossil power, in the short-term there are likely to be year-on-year fluctuations with small increases or decreases in fossil generation depending on weather conditions and other temporary factors. In the long-term, despite higher demand growth projections, clean growth will be sufficient to maintain consistent declines in fossil generation. However, based on current industry forecasts these declines will initially be small. Unlocking rapid declines in fossil generation will require faster deployment of clean generation, alongside the expansion of grids and flexibility mechanisms such as storage.

2.3 Future electricity demand growth in India and China will be powered by clean sources

China and India are breaking the long-standing link between electricity demand growth and fossil fuel expansion in the power sector. In 2024, China's clean electricity additions met 81% of demand growth, driven by record installations of wind and solar capacity. India's solar capacity additions in 2024 doubled compared to 2023. The two largest emerging economies are on a path of clean electricity expansion that is set to reverse their power sector fossil growth trends, tipping the global balance on fossil generation.

China and India are decoupling electricity demand growth from fossil growth

China's and India's economic development has been accompanied by large increases in electricity demand. India's electricity demand has tripled in the last two decades, while China's has quadrupled. Fast paced clean electricity deployment is now breaking a long-term trend, as fossil generation is no longer growing at the same rate as electricity demand. This decoupling is happening because a growing share of demand growth is being met by an expansion of clean sources rather than fossil generation.



In China, this process started in the early 2010s, with rising wind, hydro and nuclear power meeting increasing shares of demand growth. In recent years, solar has surged to the point where clean sources are now growing at a rate fast enough to meet all demand growth – bar yearly fluctuations in weather affecting demand and hydro output – and are on track to start replacing fossil generation.

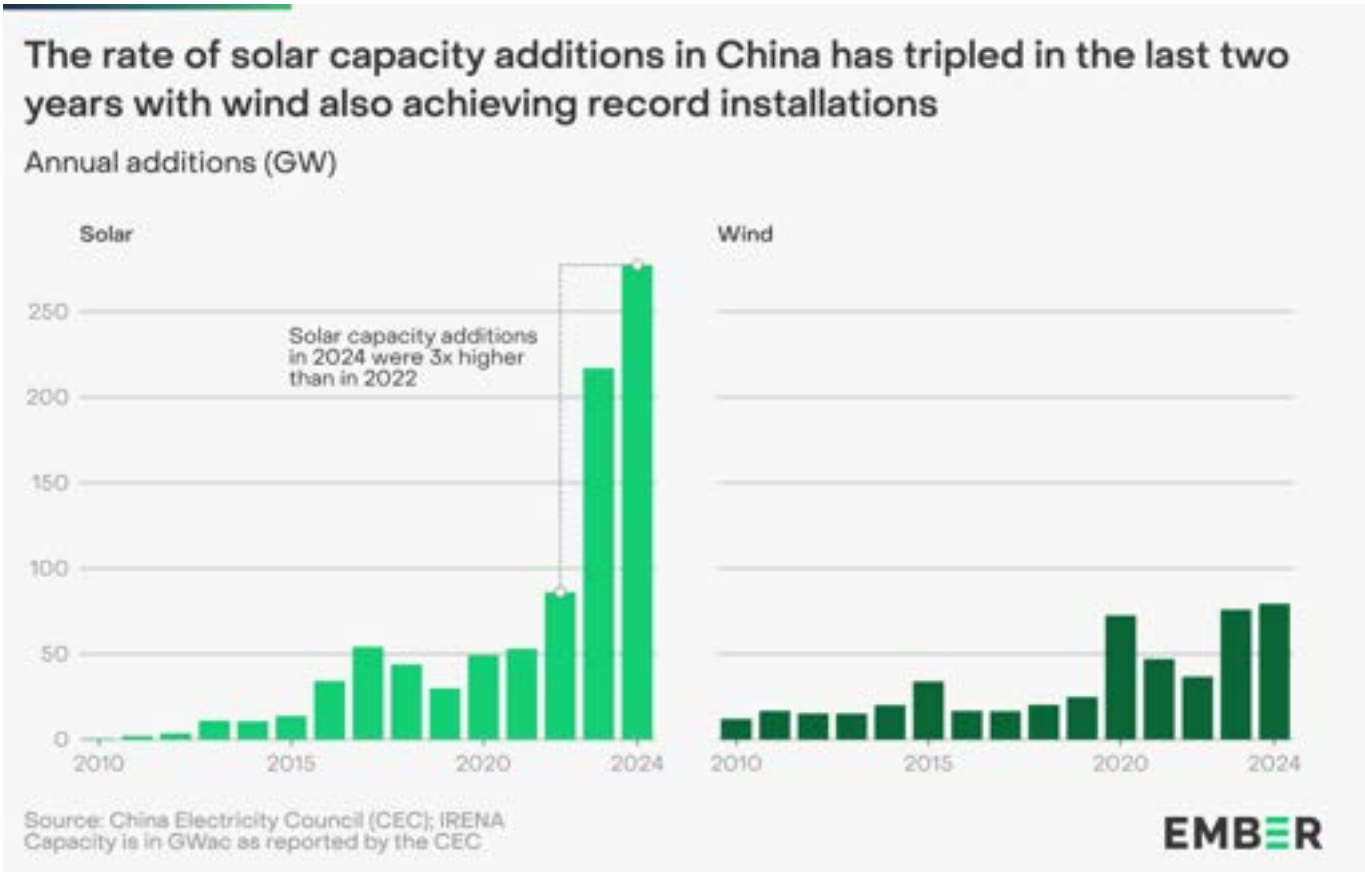
India's decoupling of demand growth and fossil growth began more recently. In 2024, India still met about two-thirds of its demand growth with fossil fuels, specifically coal power. With increasing deployment of clean capacity, India could meet all new demand growth with clean electricity as soon as 2030, according to the IEA's STEPS scenario. This would lead to a plateauing of fossil generation in the country. Ember's modelling of India's power sector to 2032 shows that limiting the growth of fossil fuels through a build-out of renewables, particularly solar power, brings cost benefits.

The end is in sight for China's fossil-based demand growth

China's staggering growth in electricity demand over the last two decades was accompanied by a rapid rise in fossil generation. Wind, solar, hydro and nuclear deployments have now reached levels sufficient to meet China's structural (non-temperature related) annual rise in power demand. As a result, a substantial expansion of fossil generation is increasingly unlikely.

Clean electricity deployment in China takes the next step

In the last two years, China has seen a surge in clean electricity, primarily driven by large-scale wind and solar rollouts. Solar capacity jumped by 217 gigawatt of AC capacity (GWac) in 2023—more than double the 86 GWac added the previous year (many countries report solar capacity data in AC instead of DC. DC capacity is used in this report if not otherwise specified). In 2024, capacity installations increased further to reach 277 GWac. This constitutes more than a tripling of the installation rate in just two years. Wind capacity saw the highest-ever additions in 2024, with 79 GW installed after a record-setting 2023 (76 GW).



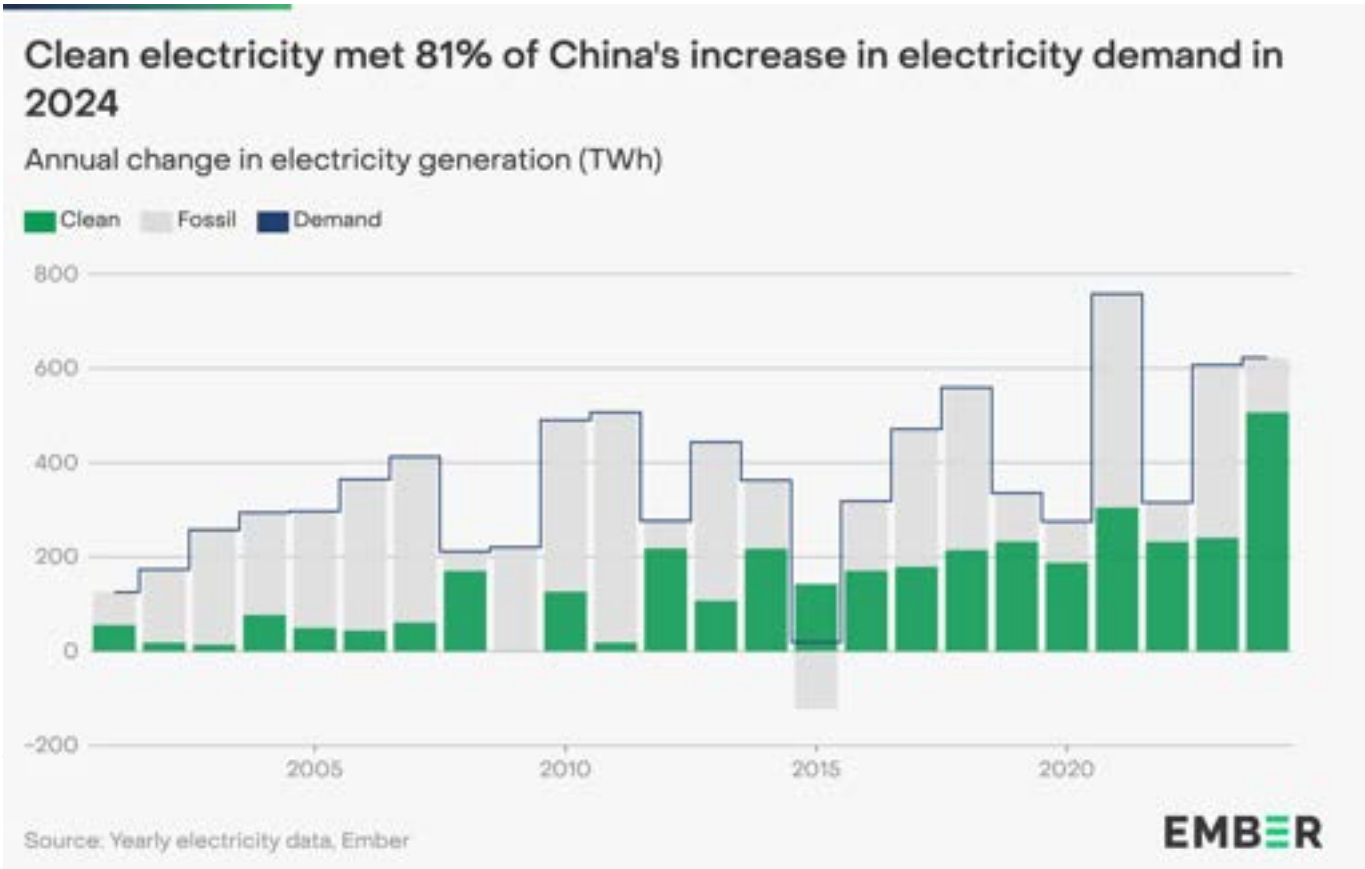
With this rapid increase in 2023 and 2024, China more than doubled its total installed solar capacity in just two years, rising from 393 GWac in 2022 to 887 GWac in 2024. China led the world in 2024 as it made up an estimated 57% of global solar capacity additions and 60% of global wind capacity additions. The step-up in capacity deployment in the last two years will not be an outlier. BloombergNEF expects China's solar capacity deployment in 2025 to increase by a further 12% compared to 2024. As of 2024, China had nearly twice the amount of wind and solar capacity under construction as the rest of the world combined, pointing to continued fast growth in the coming years.

Additionally, China boasts the largest pipeline for large-scale hydroelectric power stations and nuclear plants, and has seen the largest increases from these sources of any country in recent years.

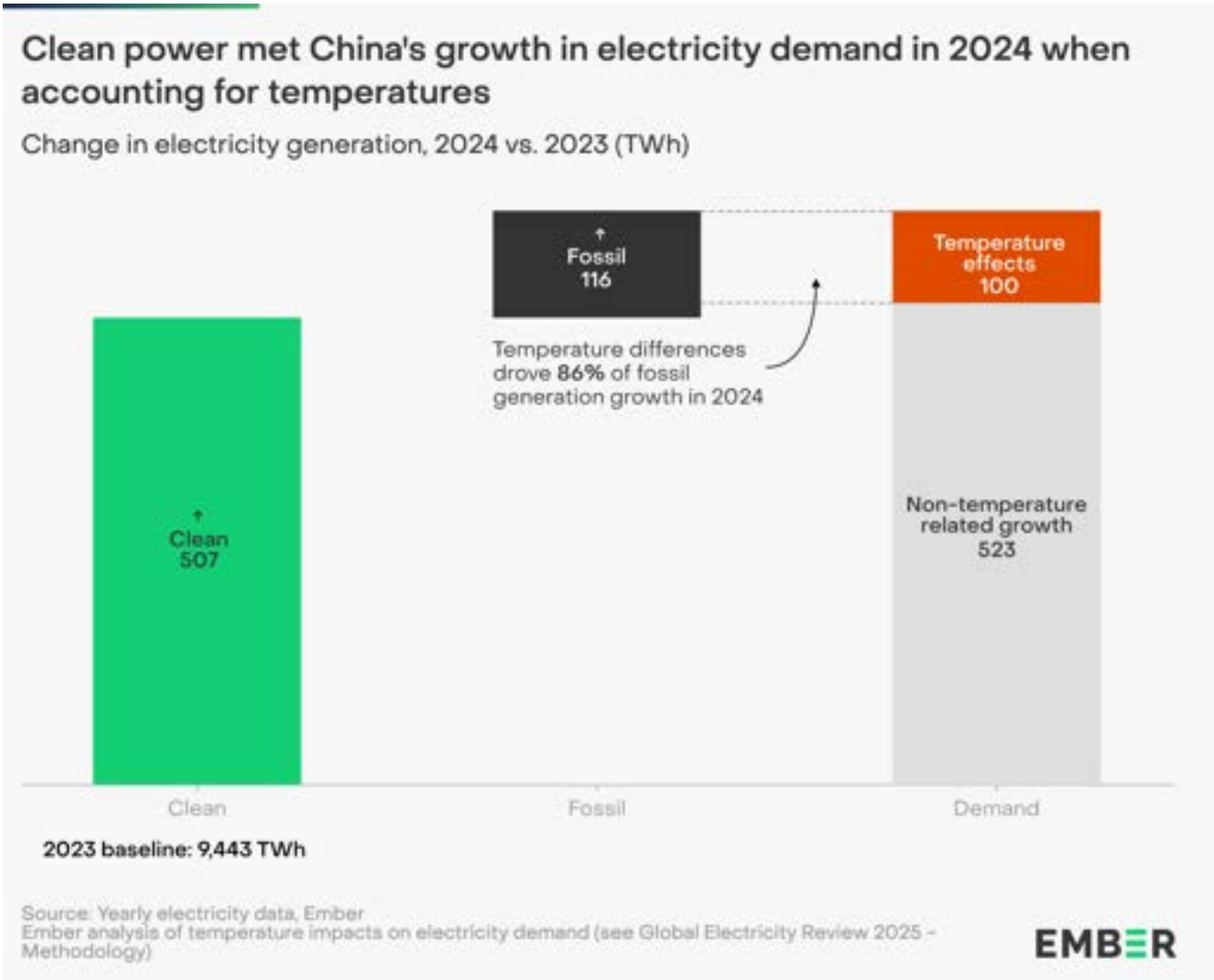
Combined, the scale of clean power deployment in China has reached a level where it can meet the structural growth in China's electricity demand.

China's record clean power additions put falling fossil power generation in sight

Growth in clean electricity generation met 81% of China's increase in electricity demand in 2024, the highest share since 2015 when demand fell. The 6.6% (+623 TWh) rise in electricity demand was largely met by a rise in wind and solar generation (+356 TWh), and a rebound in hydro generation (+130 TWh). Consequently, fossil generation only increased by 116 TWh, a third of the increase seen in 2023.



However, hotter temperatures in 2024 compared to 2023 resulted in an elevated demand rise. The impact was particularly large during the heatwaves the country experienced in the summer of 2024. Without the effects of hotter temperatures, clean generation would have been enough to meet 97% of China's rise in electricity demand.



Additionally, January and February saw the last effects of the rebound in industrial electricity demand after Covid-19 restrictions were lifted in early 2023. This temporary boost contributed to a 10.9% increase in overall electricity demand over January and February 2023, amounting to nearly a quarter (24%) of China's total demand growth in 2024. For the rest of the year, demand grew at a much more moderate rate of 6.1%.

Short-term uncertainties, but long-term outlook points to falling fossil generation in China

China is close to meeting all demand growth with clean sources, which will mark a turning point where fossil fuels reach their peak and begin to decline. In the short term, uncertainties remain on both the demand and supply sides.

On the demand side, temperature fluctuations drive temporary changes from year to year. On the supply side, China's hydro output rebounded by 130 TWh in 2024 after drought-induced lows in 2023. Yet capacity factors were still below historical levels, and further recovery in 2025 remains uncertain. While wind and solar outputs are generally more stable, the large installed capacity means that even small changes in wind conditions across years can significantly affect generation. In 2024, poorer wind conditions in China masked underlying growth from new capacity. Solar output varies less from year to year, but can still affect output notably.

These short-term factors can obscure underlying trends, making year-on-year predictions challenging. However, with rapid expansion in solar and wind capacity, further increases in fossil generation are becoming less likely. In fact, 2025 may mark the first decline in fossil generation since 2015 – even as electricity demand continues to rise – signaling an end to the era of sustained large-scale fossil generation growth in China.

India's fossil surge could already be slowing

With China close to entering a new era of falling fossil generation, India is likely to become the country with the largest fossil generation growth in coming years, surpassing China. Just like in 2023, India recorded the second-largest increase in fossil generation of any country, at 67 TWh in 2024. However, India and similar emerging economies now have cleaner alternatives to fossil-led growth, limiting a potential surge in fossil generation.

India's clean power deployment is ramping up

The economics for new power have shifted heavily in favour of renewables. The cost of solar power fell by more than 90% between 2010 and 2023. Consequently, deployment is rising sharply worldwide, and India is no exception. India's solar power capacity increased by 24 GWac in 2024 – more than twice as much as in 2023. Only China and the US installed more

solar capacity in 2024. Installations are only expected to increase further. Utility-scale projects already under construction as of January 2025 will nearly double India's wind and solar capacity.

There are currently 143 GW of wind and solar capacity under construction in India, consisting of 82 GW of solar, 25 GW of wind and 36 GW of hybrid capacity (wind and solar), according to government reporting. These projects all have an expected completion date before the end of 2028.

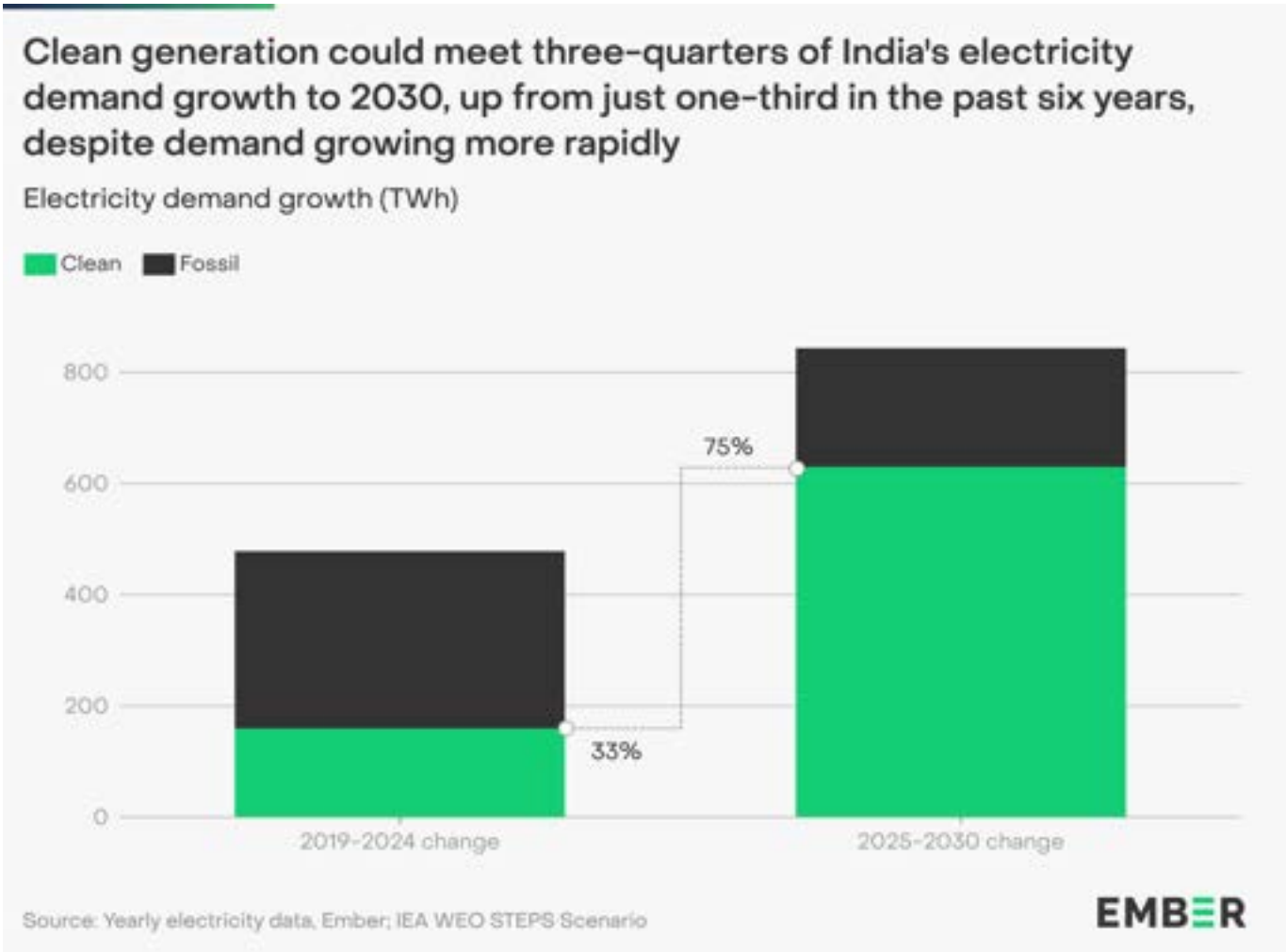
India's government has set a broader target of 500 GW for clean power capacity by 2030, up from 211 GW in 2024. Additionally, there are 5 GW of nuclear capacity and 15 GW of hydro capacity currently under construction, with commissioning expected before the end of 2028.

As explored in chapter 2.2, storage is a critical element of the continued build-out of flexible, cost-effective clean power, and India is no exception. To further accelerate the deployment

and integration of solar power in India, the Indian government has advised implementing agencies and state utilities to include energy storage systems with a minimum of two hours of storage alongside solar facilities.

Clean electricity is reducing the need for additional fossil power

India's rapid clean capacity growth will significantly reduce the increase in fossil generation over the next few years. In the six years between 2019 and 2024, electricity demand increased by 478 TWh, with clean generation meeting 33% of this increase. The IEA's STEPS Scenario projects a further 844 TWh rise in electricity demand by 2030. Despite this larger increase, the rapid deployment of clean power, predominantly from solar and wind, could meet an estimated 75% of this demand growth.

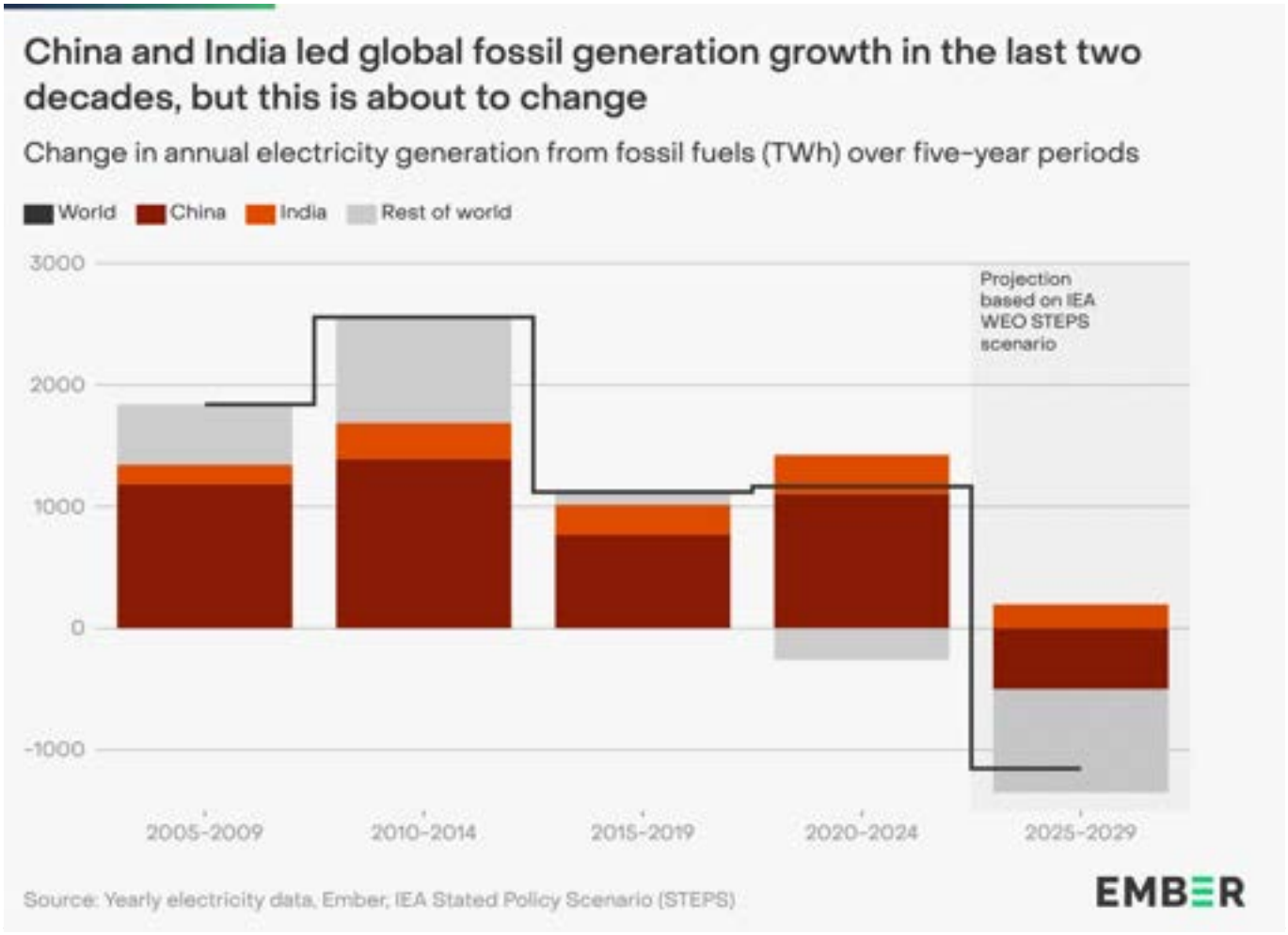


Clean growth in China and India can tip the balance towards a decline in fossil generation at a global level

Bending the curve of fossil generation at a global level depends on country level trends. The first major emitters to industrialise – the EU, the US and other OECD economies – have seen fossil generation peak in the early 20th century and have contributed to a reduction of fossil use in the power sector for more than 15 years.

Simultaneously, fast growing Asian economies, especially China and India, have seen a rapid increase in electricity demand and fossil consumption for electricity. As a result, they have dominated the global increase in fossil generation over the past two decades.

In the last five years, global annual fossil generation has increased by 1,165 TWh. China alone accounted for 1,104 TWh of this increase, which was equivalent to 95% of the net global increase between 2020 and 2024. India contributed a further 322 TWh, or 28% of the net global increase. Other countries combined saw a net reduction of 260 TWh in fossil generation.



In the next five years, it is the trend reversal in China and India that will tip the balance towards a global decline in fossil generation. Using the IEA's STEPS Scenario, India's fossil generation is expected to grow by an estimated 197 TWh by 2029. This is consistent with estimates from India's existing renewable capacity pipeline. This increase would be just under half of the increase over the previous five years.

The largest reversal according to the STEPS scenario would come from China, turning an increase of 1,104 TWh in the previous five years into a fall of 501 TWh for 2025-2029. As discussed earlier, this shift is driven by the rapid expansion of clean electricity, which has decoupled demand growth from fossil generation. Combined with larger falls in the rest of the world of 849 TWh, global fossil generation in 2029 would be 1,153 TWh (6.3%) lower than in 2024.

With China and India turning towards clean growth, established clean energy players need to double down

Overall, 115 countries making up 39% of global electricity demand have seen their fossil generation remain the same or decline over the last five years. If China and India join this group, it would raise the share of global electricity demand in economies with falling fossil generation to 79%, thereby tipping the balance on global fossil generation and power sector emissions.

Consolidating the fall in global fossil generation not only requires the rapid scale-up of clean power in China and India, but also the continued reduction of fossil generation in the United States, the EU and other advanced economies. Recent US policy announcements, signalling a trend reversal away from clean power back towards a growth model relying on more fossil fuels, risk slowing the decline of US fossil generation, which peaked in 2007.

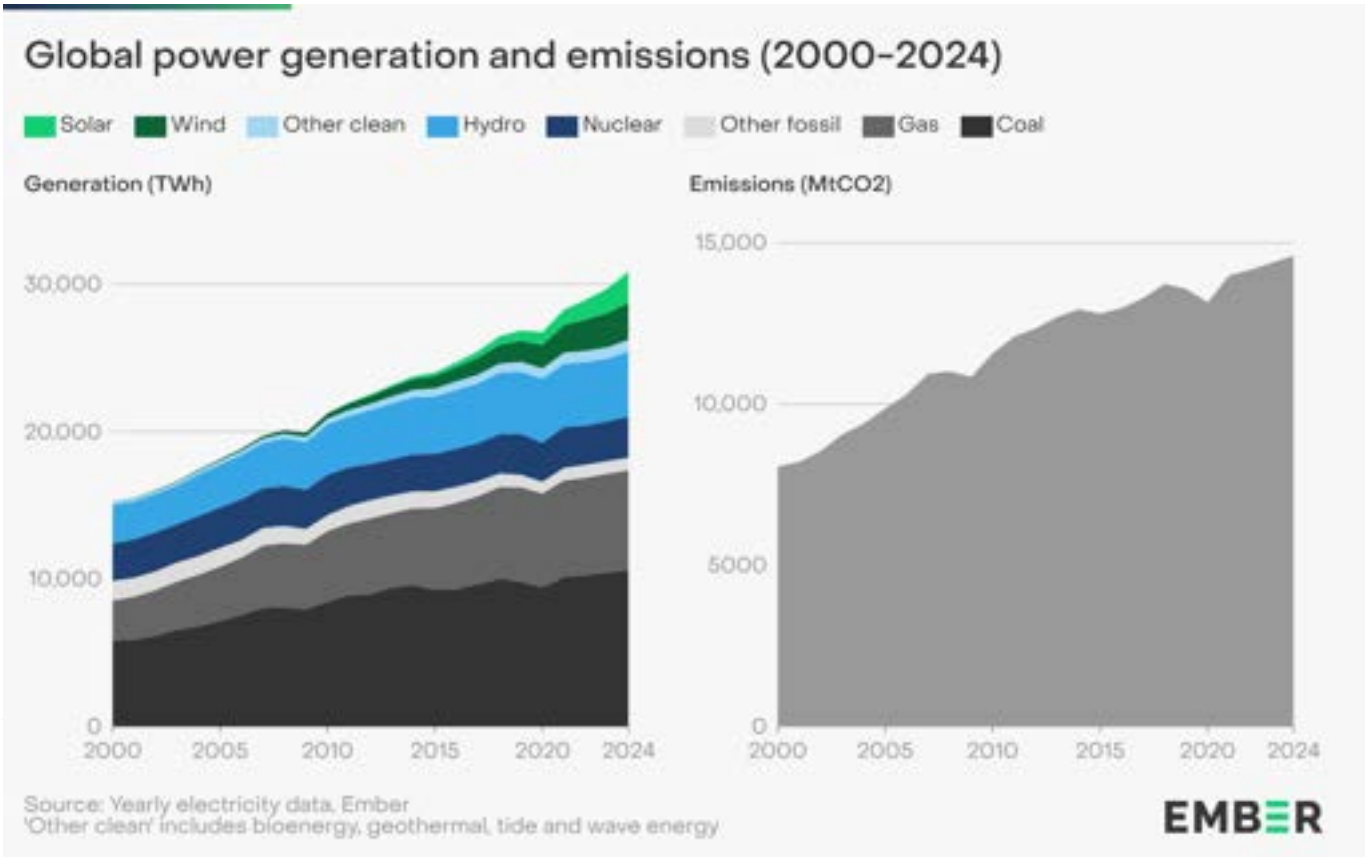
The overall trend in the global power sector shows that the next few years will be marked by a rapid and increasing build-out of renewables, with solar power at the forefront. Countries that focus on adapting appropriate policies to take advantage of integrating these low-cost and fast-to-deploy technologies will reap the benefits of the clean energy transition. Those who choose to turn their backs risk being left behind.

Chapter 3: Global Electricity Trends

Data on the global electricity sector in 2024

Data on the global electricity sector in 2024, including generation, demand and emissions, with an overview of changes in the last year and trends in the last two decades.

Chapter contents



3.1 Global electricity demand

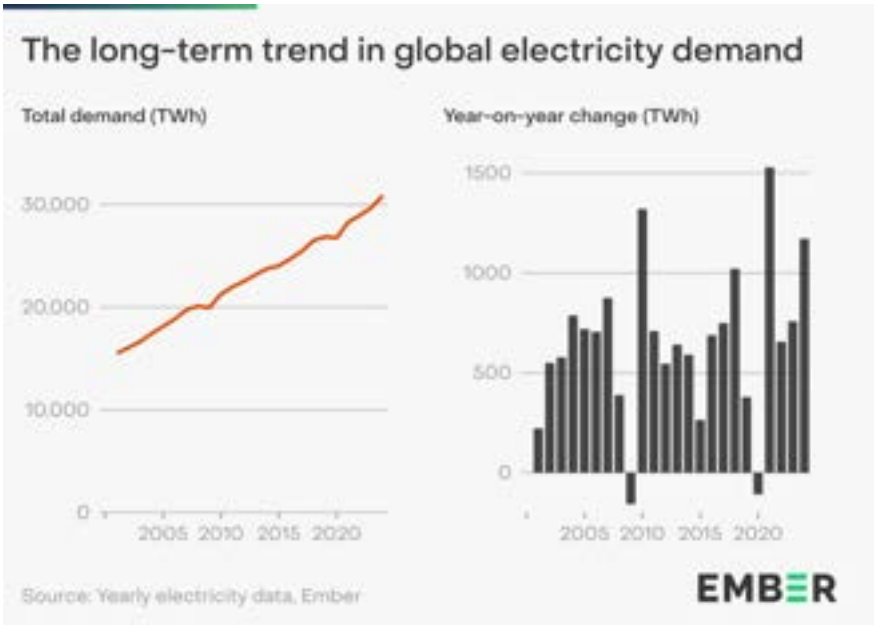
Key highlights

01 **Electricity demand saw the third-largest absolute increase ever in 2024**

02 **China's per capita electricity use overtook France's for the first time in 2024, and was five times that of India's**

03 **A fifth of the demand increase in 2024 was due to the impacts of hotter temperatures compared to 2023**

Global electricity demand increased by 4% (+1,172 TWh) in 2024. This was the third-largest absolute increase in electricity demand ever, only surpassed by rebounds in demand in 2010 from the global recession and in 2021 from the Covid-19 pandemic. This increase is significantly above the average annual demand growth of 2.5% in the previous ten years (2014-2023).



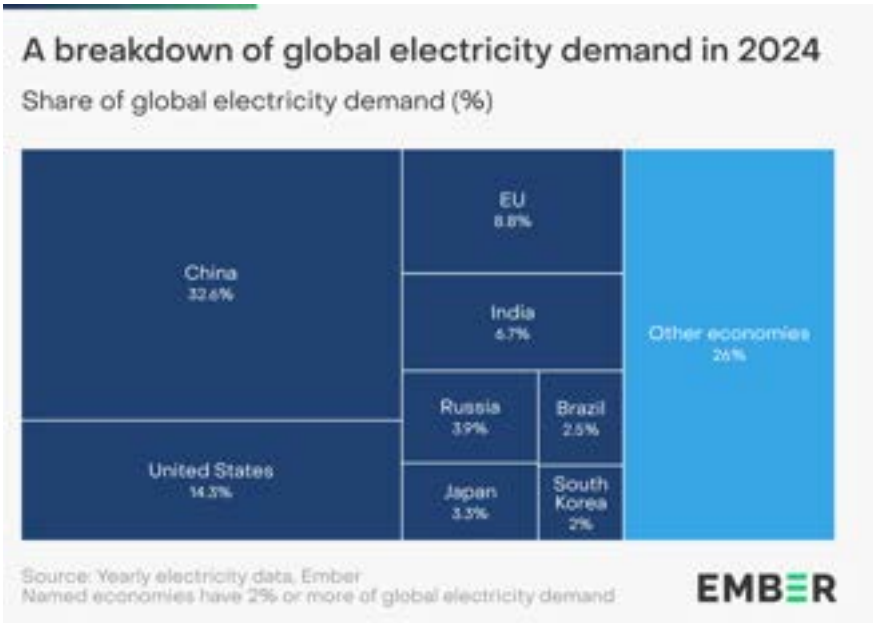
Global electricity demand rose to 30,856 TWh, crossing 30,000 TWh for the first time. Since the turn of the century, electricity demand has doubled.

Some of the exceptional growth in 2024 was due to weather conditions. As explored in chapter 1, we calculate that hotter temperatures added 0.7% to global demand in 2024. Nonetheless, emerging drivers of electricity demand such as electric vehicles (EVs), data centres and heat pumps also added 0.7% to global demand growth in 2024 (+195 TWh), a slight step up from the 0.6% they added in 2023 (+174 TWh). See more in chapter 2.2.

China recorded the largest increase in electricity demand, adding 623 TWh (+6.6%), which accounted for more than half of the global increase. The US saw a rise of 128 TWh (+3%). India's demand increased by 98 TWh (+5%). As recent Ember analysis shows, all three countries experienced heatwaves that drove up electricity demand beyond increases due to economic activity.

Other countries with substantial increases were Brazil (+35 TWh, +4.9%), Russia (+32 TWh, +2.8%), Viet Nam (+26 TWh, +9.5%) and Türkiye (+18 TWh, +5.6%).

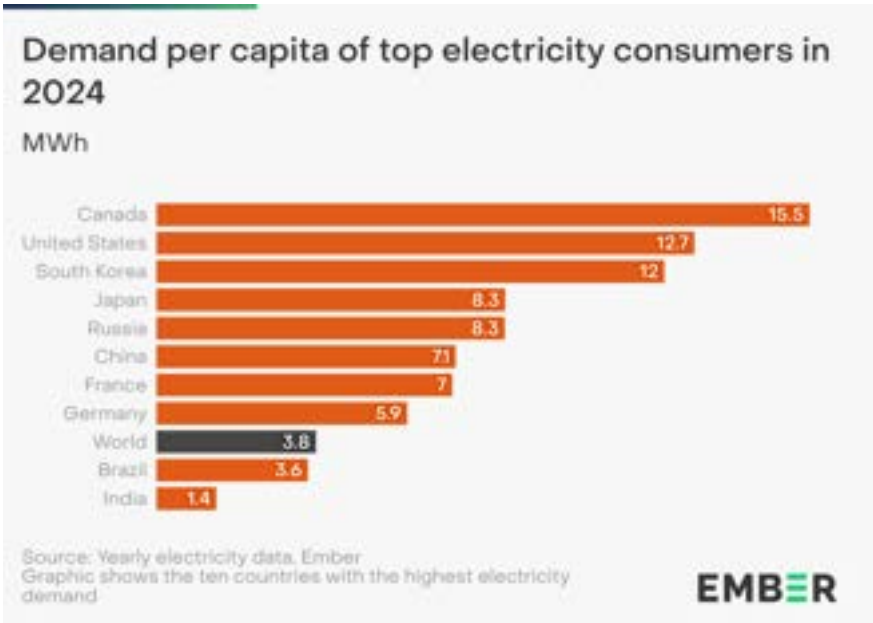
China's share of global electricity demand has increased due to its continued demand growth above the world average. With 10,066 TWh, China's electricity demand contributed roughly a third (32.6%) of the global total, up from 28% five years ago.



China's global share of demand was more than double that of the US at 4,401 TWh (14.3% of the global total). The EU made up 8.8% (2,727 TWh) of global electricity demand. India's electricity demand reached 2,054 TWh (6.7% of global demand).

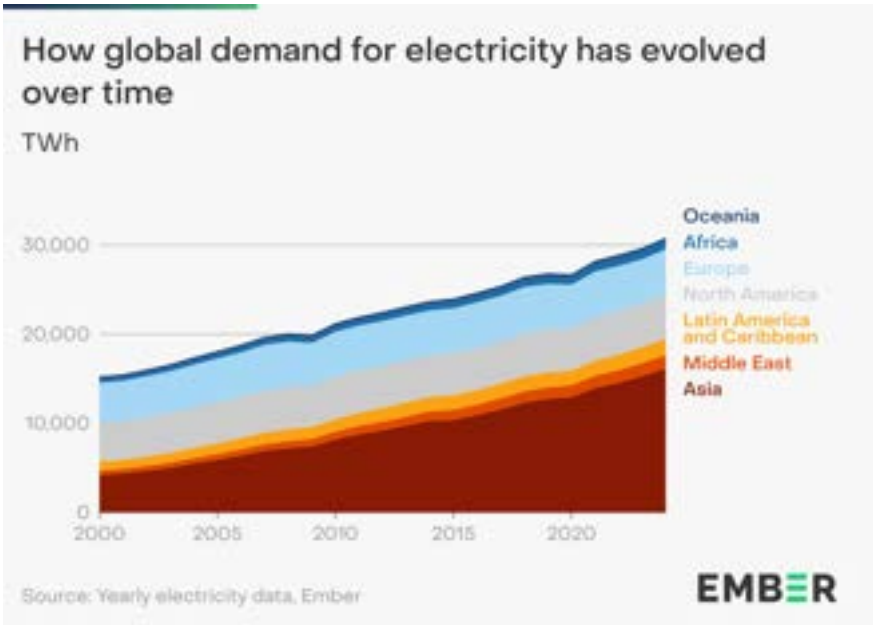
26% of global electricity demand comes from economies that each contribute less than 2%.

Among the top ten electricity consumers, the difference in per capita consumption remained vast. Canada had the highest per capita demand for electricity at 15.5 megawatt hours (MWh). This was more than 10 times higher than India, which places last among this group at 1.4 MWh.



China's per capita demand (7.1 MWh) was almost double the world average of 3.8 MWh, overtaking France in 2024 and Germany in 2023.

Asia's electricity demand has grown fourfold since the turn of the century from 4,199 TWh in 2000 to 16,153 TWh in 2024 (+285%), driven by demand increases in China, and increasingly India, Indonesia, Viet Nam and other fast-growing economies.



This trend was not replicated elsewhere. Demand outside Asia grew by just 3,624 TWh (+33%) over the same period, from 11,079 TWh to 14,703 TWh.

Despite moderate increases in the past decade, the entire continent of Africa accounted for just 3.1% of total global electricity demand in 2024, less than Japan.

3.2 Global electricity generation

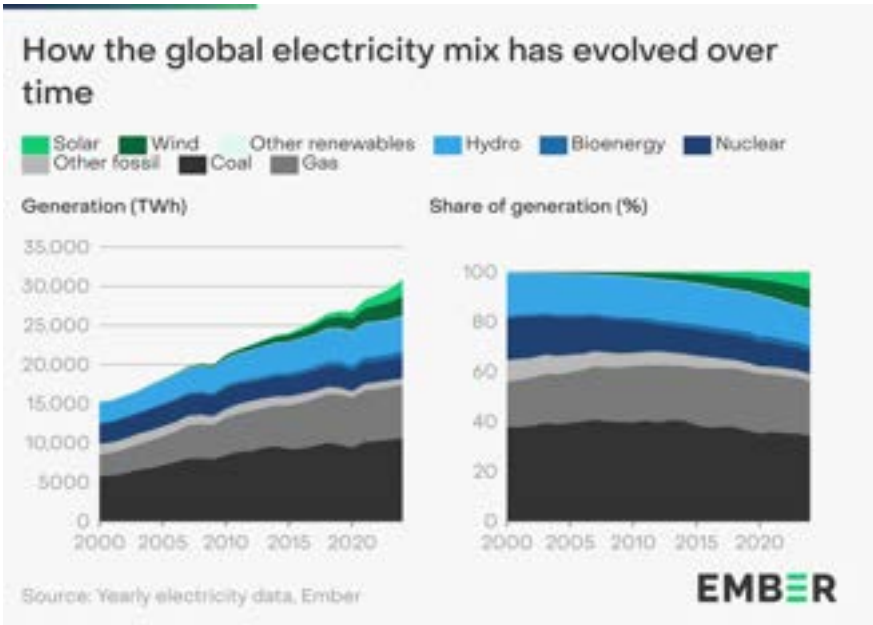
Key highlights

01 **Low-carbon sources surpassed 40% of global electricity generation, driven by record renewables growth**

02 **Global solar generation has doubled in three years, continuing its pattern of exponential growth**

03 **Wind and solar have met more than half of global growth in electricity demand since 2015**

In 2024, low-carbon power sources rose to 40.9% of global electricity generation, the highest level since the 1940s when hydro generation alone met over 40%.



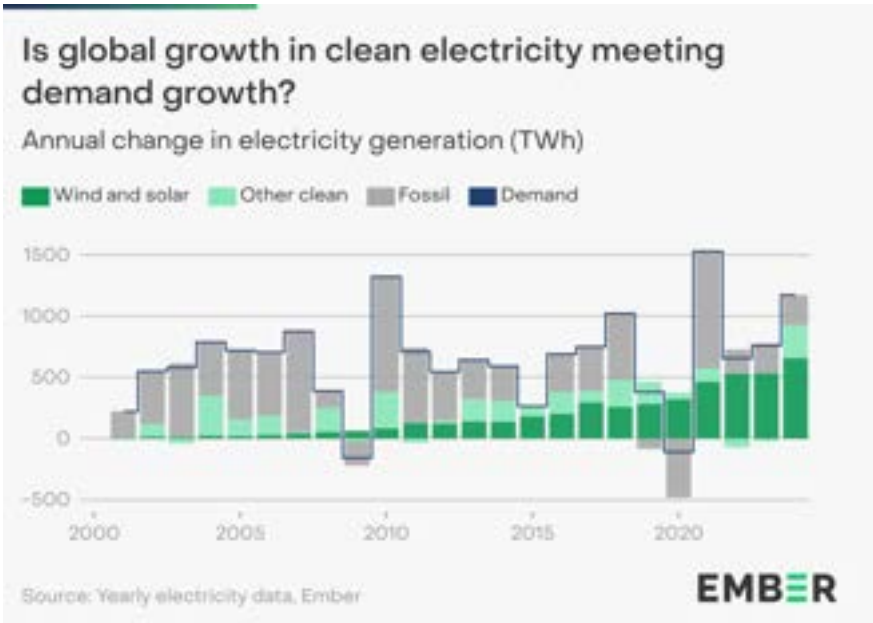
Solar and wind power are the fastest-growing sources of electricity. Combined, they accounted for 15% of global electricity in 2024, with solar contributing 6.9% and wind 8.1%. The two sources combined now produce more electricity than hydropower at 14.3%. They already surpassed nuclear generation in 2021, which continues to reduce in share (9% in 2024). The rise in wind and solar power over recent years has been remarkable, with solar in particular maintaining rapid growth rates despite reaching high levels of absolute generation. Solar power has doubled in the three years since 2021, continuing its pattern of exponential growth.

The share of fossil sources declined to 59.1% in 2024, despite increases in absolute generation. It has declined substantially since the peak of 68.3% in 2007 and is set to fall further in the coming years as renewable generation growth continues to accelerate. The share of coal generation has fallen significantly, from 40.8% in 2007 to 34.4% in 2024, with more consistent falls in the last 10 years. The share of gas generation has fallen for four consecutive years since it peaked in 2020 at 23.9%, reaching 22% in 2024.

Clean generation met 79% of the increase in global electricity demand in 2024. Electricity generation from clean sources grew by 927 TWh (+7.9%), the largest increase ever recorded. The clean generation increase in 2024 would have been large enough to meet the rise in electricity demand in all but three years in the last two decades.

However, heatwaves in 2024 elevated cooling demand, which was the main driver of a small 1.4% increase in fossil generation (+245 TWh), similar to the rise in the previous two years. Without the impact of hotter temperatures, fossil generation would have remained flat.

Renewables growth alone met 73% of the increase in electricity demand. In total, renewable power sources added a record 858 TWh of generation in 2024, 49% more than the previous record set in 2022 of 577 TWh.



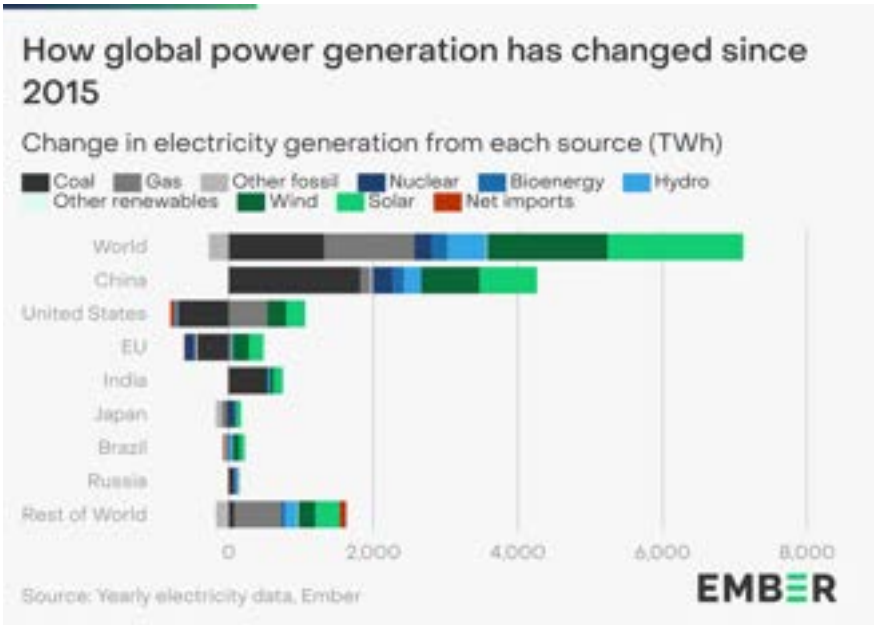
Solar dominated the growth in electricity generation as it was the largest source of new electricity for the third year in a row. Solar added 474 TWh (+29%) in 2024. Solar's increase alone met 40% of global electricity demand growth in 2024. Wind growth remained more moderate (+182 TWh, +7.9%), with lower wind speeds in some geographies leading to the lowest increase in wind generation in four years despite continued capacity additions. Hydro generation rebounded in 2024 (+182 TWh) as drought conditions in 2023 eased, particularly in China.

Nuclear generation increased by 69 TWh (+2.5%), mostly as a result of less downtime for reactors in France as well as small increases from new reactors in China.

The global increase in fossil generation came mostly from coal which rose by 149 TWh (+1.4%). Gas generation increased by 103 TWh (+1.6%). Other fossil fuels saw a minor fall of 7.7 TWh (-0.9%).

China and India saw the largest increases in coal generation in 2024, together totalling more than the global net increase. The gas generation growth in the US alone (+59 TWh, +3.3%) was equivalent to 57% of the global increase. Gas generation in the US is rising mainly as a result of coal-to-gas switching. Ember's analysis shows that heatwaves also played a role in raising fossil generation in China, India and the US in 2024.

Since 2015, solar and wind have been the two largest-growing sources of electricity, meeting more than half (52%) of global demand growth. Solar generation has grown eightfold since 2015, from 256 TWh in 2015 to 2,131 TWh in 2024. Wind generation tripled from 830 TWh in 2015 to 2,494 TWh in 2024.



China has dominated changes in the global electricity system since 2015, recording the largest increases of any country for solar, wind, hydro, nuclear and coal. China accounts for 45% of global growth in wind and solar generation since 2015. At the same time, global coal generation would have fallen since 2015 without the increase in China.

India saw the second-largest increase in coal generation behind China. India's rise in coal generation was equivalent to 40% of the global increase in coal since 2015.

The US was responsible for 43% of the global increase in gas generation since 2015. Its gas generation increased by 40% (+531 TWh) over the same period.

3.3 Global power sector emissions

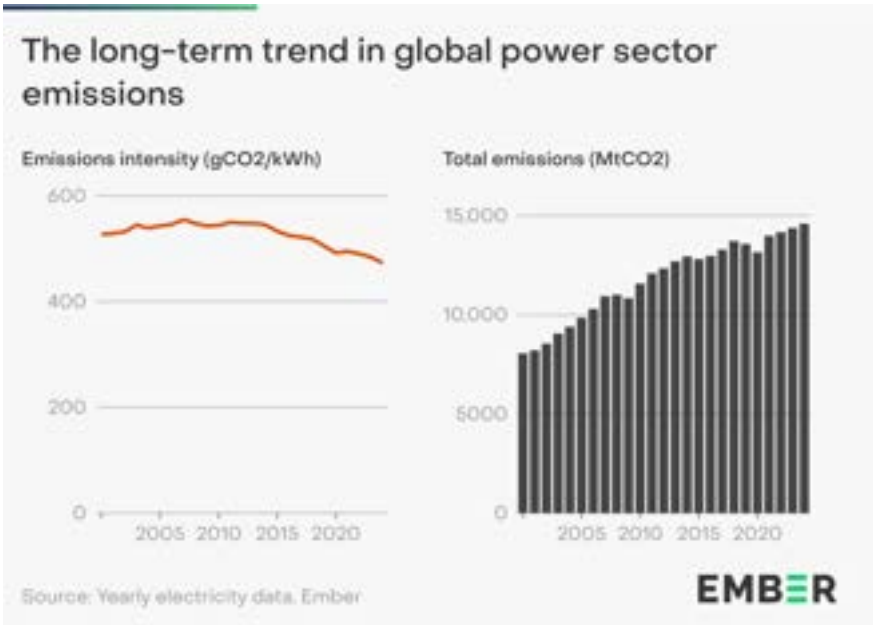
Key highlights

01 **Power sector emissions hit a new record high as heatwaves drove a small rise in fossil generation**

02 **Carbon intensity fell by 15% since its peak in 2007, driven by clean generation growing faster than fossil generation**

03 **Africa and Latin America each make up less than 4% of global power sector emissions, despite representing 19% and 8% of the global population respectively**

Global power sector emissions reached a new record high in 2024, rising by 1.6% or 223 million tonnes of CO2 (MtCO2), compared to 2023. This increase was similar to 2023 (+1.5%) and 2022 (+1.3%) and was driven by an increase in fossil generation, predominantly from coal. However, without the impact of 2024's heatwaves, fossil generation would only have risen by 0.2% from 2023, and power sector emissions would have remained almost unchanged (see Chapter 1).



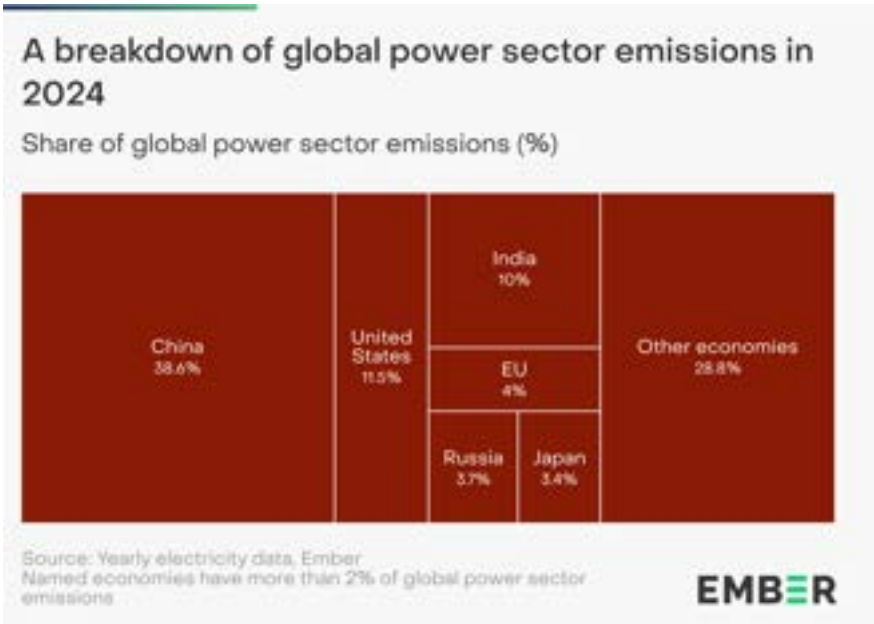
Despite the overall increase in power sector emissions, the emissions intensity (emissions per unit of electricity produced) of global power generation continued to decrease. Emissions intensity dropped by 2.3% to 473 grams of CO2 per kilowatt hour (gCO2/kWh), down from 484 gCO2/kWh in 2023. Emissions intensity has now fallen in nine of the last ten years, with the only increase occurring in 2021 as fossil generation rebounded following large falls in demand during the Covid-19 pandemic.

The decline in emissions intensity is driven by the growing share of clean power in the mix, which reached 40.9% in 2024. As of 2024, the emissions intensity of the global power sector has fallen by 15% since the peak of 555 gCO2/kWh in 2007.

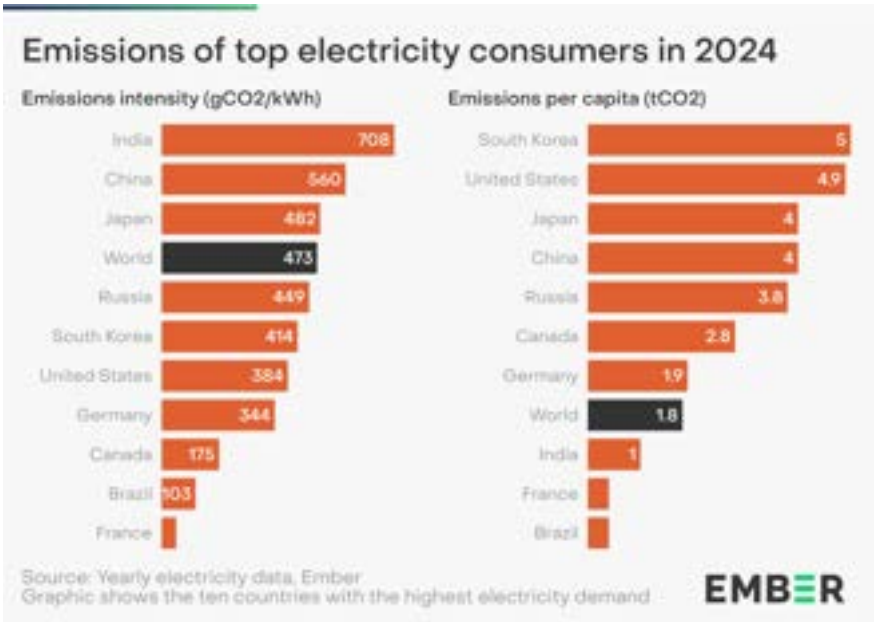
China's size and reliance on coal generation kept it as the world's highest power sector emitter in 2024, with emissions reaching 5,640 MtCO2, four times those of the US and India.

Emissions from power generation in the US amounted to 1,683 MtCO2, accounting for 11.5% of the global total. India's power sector emissions reached 1,457 MtCO2, now close to matching the US and reaching 10% of global power sector emissions for the first time.

China accounted for 38.6% of global power sector emissions - more than the US, India, the EU, Russia and Japan combined. Countries individually producing less than 2% of global power sector emissions made up the remaining 28.8% of the global total.



India and China had the highest emissions intensity of electricity production among the top ten electricity consumers. India's emissions intensity remained particularly high at 708 gCO2/kWh, compared to the global average of 473 gCO2/kWh. However, India's emissions intensity has been falling as clean generation has been growing faster than coal.

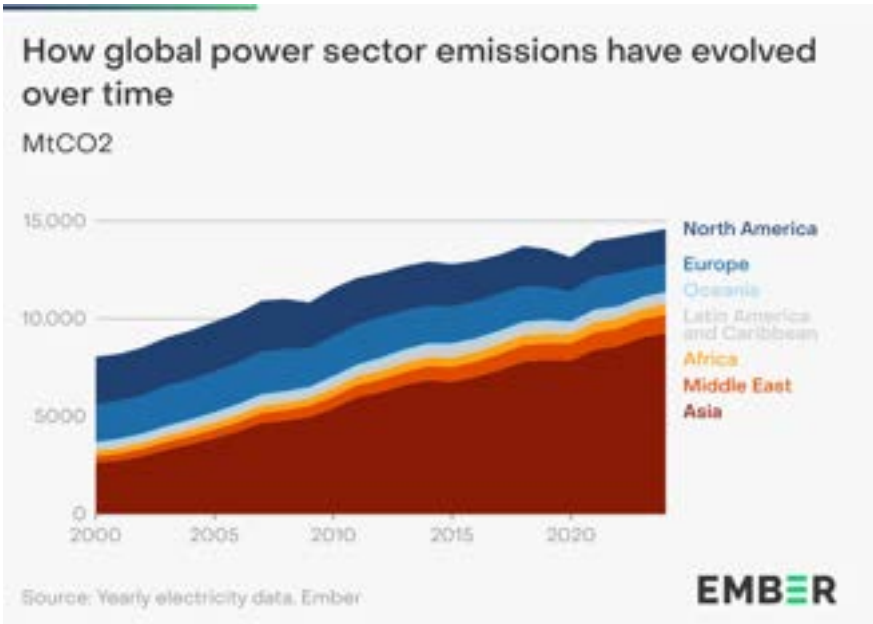


Canada, Brazil and France had the lowest emissions intensity due to their high shares of low-carbon generation from hydro and nuclear, along with a growing share of wind and solar.

Despite this, Canada's emissions per capita (2.8 tCO2) were nearly three times larger than India's (1 tCO2), driven by substantially higher per capita demand for electricity.

South Korea (5 tCO2) and the US (4.9 tCO2) had the highest power sector emissions per capita among the ten biggest electricity consumers due to a combination of high per capita electricity demand and a high share of fossil generation in the mix. China's emissions per capita have risen to match Japan's at 4 tCO2.

Driven by rapidly growing electricity demand in Asian economies, Asia's share of global power sector emissions has surged over the last two decades. In 2000, Asia made up a third (33%) of global power sector emissions. In 2024, this had risen to nearly two-thirds (63%).



Power sector emissions in North America and Europe have both fallen by a third since peaking in 2007. Within Europe, EU power sector emissions have halved (-52%) since 2007, whilst emissions in Russia and Türkiye have risen. In the Middle East, emissions have risen more sharply, driven by growing electricity demand in large markets such as Saudi Arabia and Iran, where fossil fuels dominate the electricity mix.

In 2024, African countries still only made up 3.6% of global power sector emissions, despite accounting for 19% of the world's population. Similarly, Latin America and the Caribbean contributed just 3.2% of global power sector emissions while representing 8% of the global population.

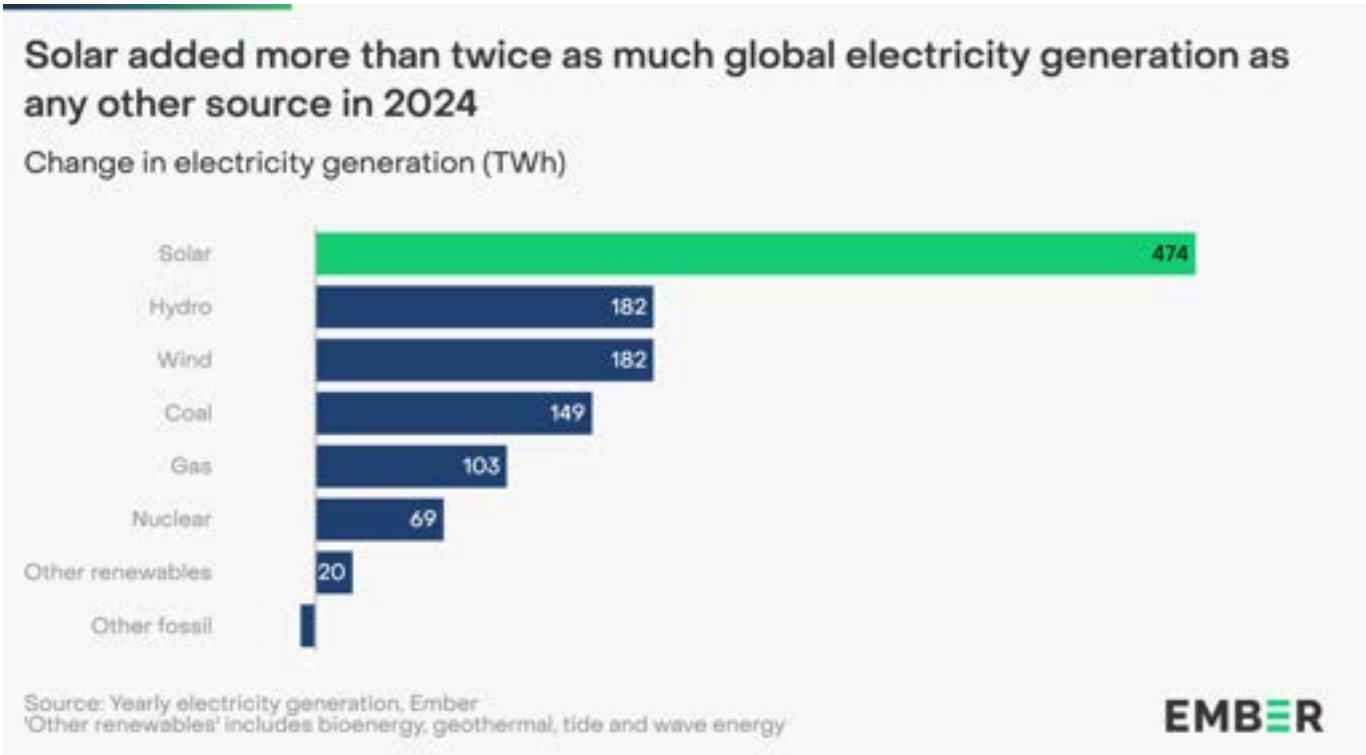
Chapter 4: Global Electricity Source Trends

Analysis of the different electricity sources in 2024

Data on global electricity generation from solar, wind, hydro, nuclear coal and gas in 2024, with an overview of changes in the last year and trends in the last two decades.

We have ordered the sections according to the fastest growing sources (% growth) of electricity in 2024.

Chapter contents



The global power sector became cleaner in 2024

	2023 Electricity generation (TWh) Share of generation (%)	2024 Electricity generation (TWh) Share of generation (%)	Change Generation (TWh) Percentage change (%)	CAGR 2019-2023 (%)
Electricity demand	29,685 TWh	30,856 TWh	1,172 TWh 4.0% ▲	2.3%
Total clean	11,683 TWh 39.4%	12,609 TWh 40.9%	927 TWh 9.6% ▲	4.7%
Total renewables	8,983 TWh 30.3%	9,842 TWh 31.9%	858 TWh 9.6% ▲	6.2%
Solar	1,657 TWh 5.6%	2,131 TWh 6.9%	474 TWh 28.6% ▲	23.6%
Wind	2,312 TWh 7.8%	2,494 TWh 8.1%	182 TWh 7.9% ▲	12.8%
Hydro	4,235 TWh 14.3%	4,416 TWh 14.3%	182 TWh 4.3% ▲	0.3%
Other renewables*	780 TWh 2.6%	800 TWh 2.6%	20 TWh 2.5% ▲	4.4%
Nuclear	2,699 TWh 9.1%	2,768 TWh 9.0%	69 TWh 2.5% ▲	0.3%
Total fossil	18,002 TWh 60.6%	18,247 TWh 59.1%	245 TWh 1.4% ▲	1.0%
Coal	10,453 TWh 35.2%	10,604 TWh 34.4%	149 TWh 1.4% ▲	0.8%
Gas	6,684 TWh 22.5%	6,788 TWh 22.0%	103 TWh 1.6% ▲	1.4%
Other fossil**	865 TWh 2.9%	857 TWh 2.8%	-8.0 TWh -0.9% ▼	-1.0%

Source: Yearly electricity data, Ember
*'Other renewables' generation includes bioenergy, geothermal, tidal and wave generation. **'Other fossil' generation includes generation from oil and petroleum products, as well as manufactured gases and waste.

EMBER

4.1 Solar

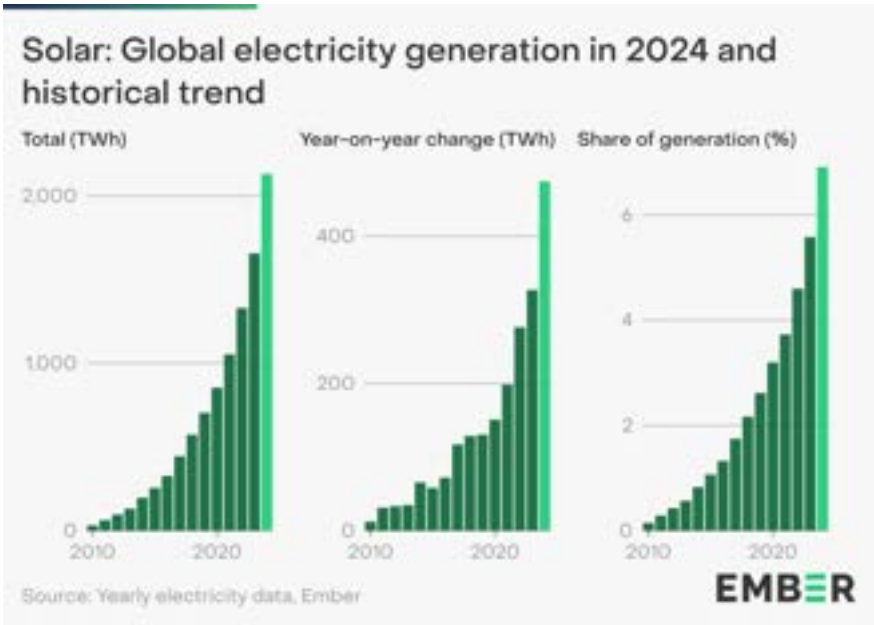
Key highlights

01 Solar added twice as much generation as any other electricity source in 2024 - 45% more than in 2023

02 China added more solar generation than the rest of the world combined in 2024

03 Global solar power continues to double every three years, maintaining high growth rates even as it scales

2024 represented another record year for solar power as it rose by 474 TWh to a new high of 2,131 TWh (+29%). The share of solar in the global electricity mix reached 6.9%, up from 5.6% in 2023.

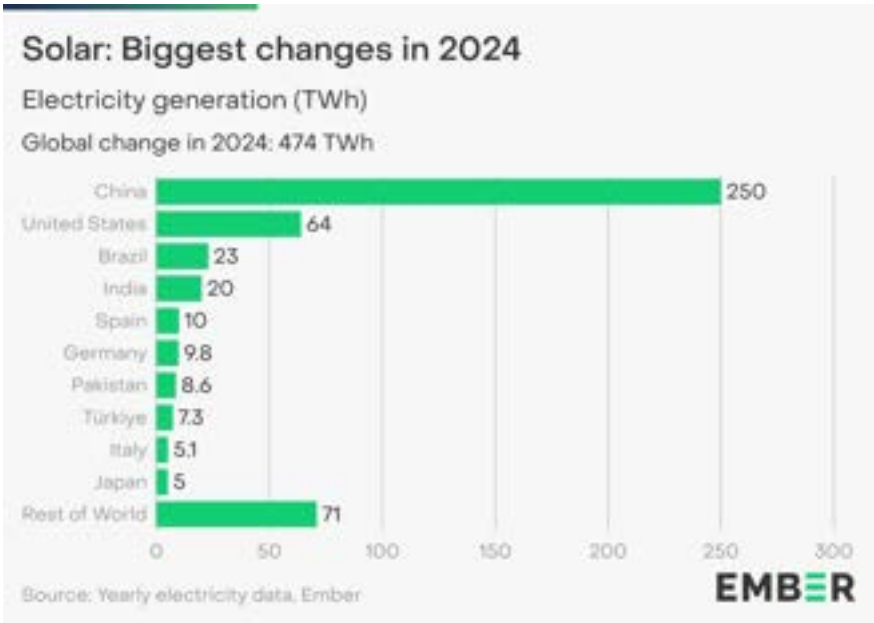


The increase of 474 TWh was 45% higher than in 2023 (+327 TWh). Solar added more than twice as much electricity generation in 2024 as any other electricity source.

Solar generation is now more than 20 times larger than it was in 2012, and its share of global generation over the same period has increased sixteenfold.

Global solar power continues to double every three years, maintaining high growth rates even as it scales: 2024's growth rate of 29% was the fastest in six years. Solar generation took eight years to go from 100 TWh to 1,000 TWh, but it has only taken three years to double to over 2,000 TWh in 2024.

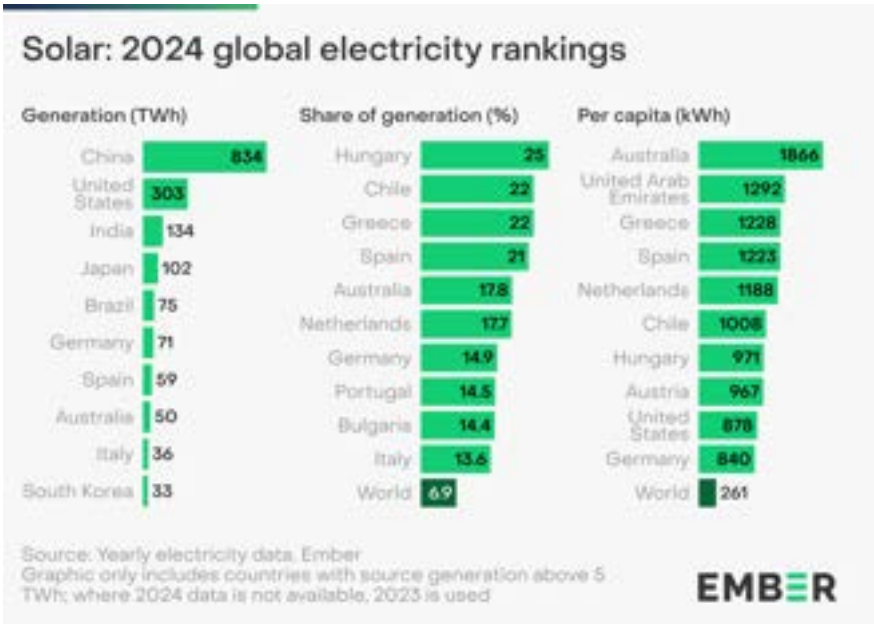
China continues to be the country with the largest rise in solar generation, adding 250 TWh – more than half of the global change in generation (53%) in 2024 and four times more than the second largest increase in the United States (+64 TWh). This pushed up China's solar generation by an astonishing 43% compared to 2023.



The US, Brazil, India and Germany also saw record increases in generation, driven by record capacity installations in 2023 and 2024.

Brazil has quickly become one of the world's largest solar markets. Its 23 TWh (+45%) increase in solar generation in 2024 made it the country with the third-highest growth for the second year in a row.

In absolute terms, China is the global leader on solar. Its total solar generation reached 834 TWh in 2024, greater than the global total just five years ago in 2019. 39% of the world's solar generation came from China in 2024.



Just eight years ago, Brazil ranked 58th in the world for solar generation. In 2024, it overtook Germany to become the fifth-largest solar generator, despite Germany also seeing a record increase.

42 countries now generate at least a tenth of their electricity from solar. Of countries with more than 5 TWh of solar generation, Hungary became the country with the highest share of solar in the electricity mix at a quarter (25%), ahead of Chile (22%). Both countries' solar shares were less than 2% in 2015.

Australia remained the country with the highest solar generation per capita at 1,866 kWh, over seven times the world average.

4.2 Wind

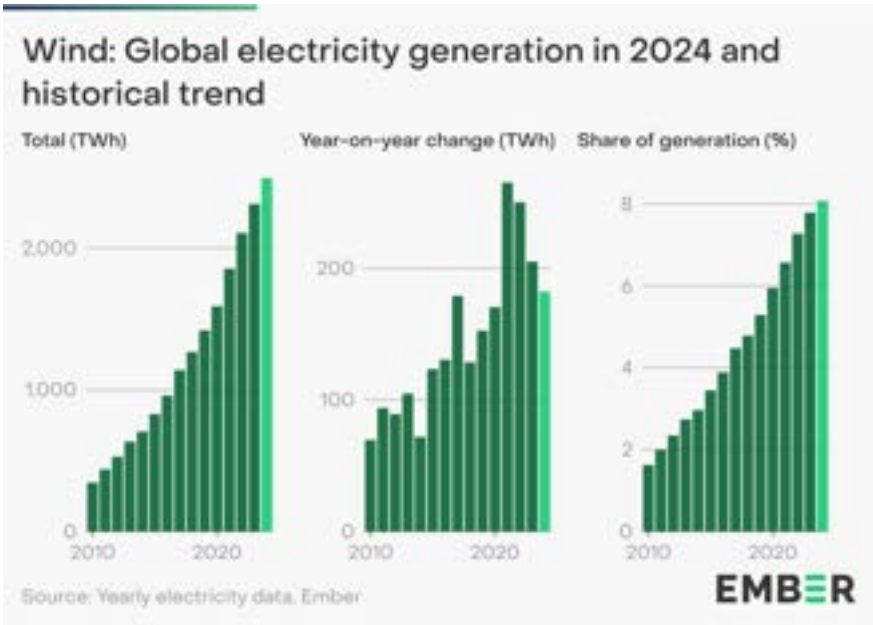
Key highlights

01 **Wind generation has tripled since 2015, reaching a new record high in 2024**

02 **Weather conditions meant wind generation growth was modest in 2024, but it was still the second-fastest growing source of new electricity**

03 **35 countries generated more than a tenth of their electricity from wind power in 2024**

Global wind generation reached a new record high of 2,494 TWh in 2024, up 182 TWh (+7.9%) from 2023. Wind's share in the global electricity mix reached 8.1%, up from 7.8% in 2023.

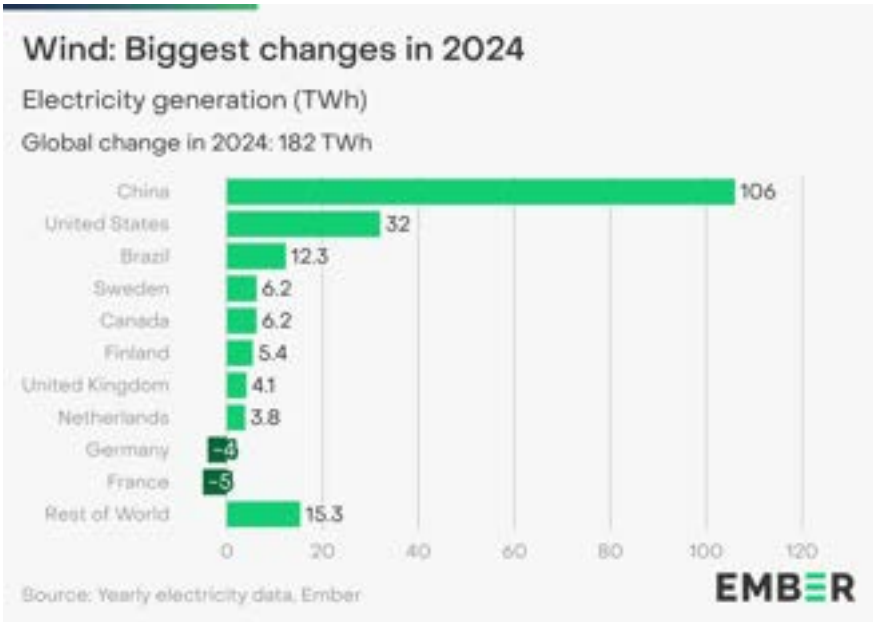


Wind generation has tripled since 2015, and its share in the global electricity mix has more than doubled since then.

Despite this positive overall trend, growth in wind generation has slowed for the third year in a row. However, it was still the source with the second-largest increase in 2024, behind solar. While capacity additions remained high, wind generation growth was limited by less windy conditions compared to 2023, particularly in China.

With wind capacity growth remaining strong across the world, generation is likely to return to higher growth in the coming years.

China accounted for well over 50% of the global wind increase in 2024, with its wind generation rising by 106 TWh (+12%). China's wind generation increase in 2024 was more than three times larger than that of the US, which saw the second-biggest increase in wind.

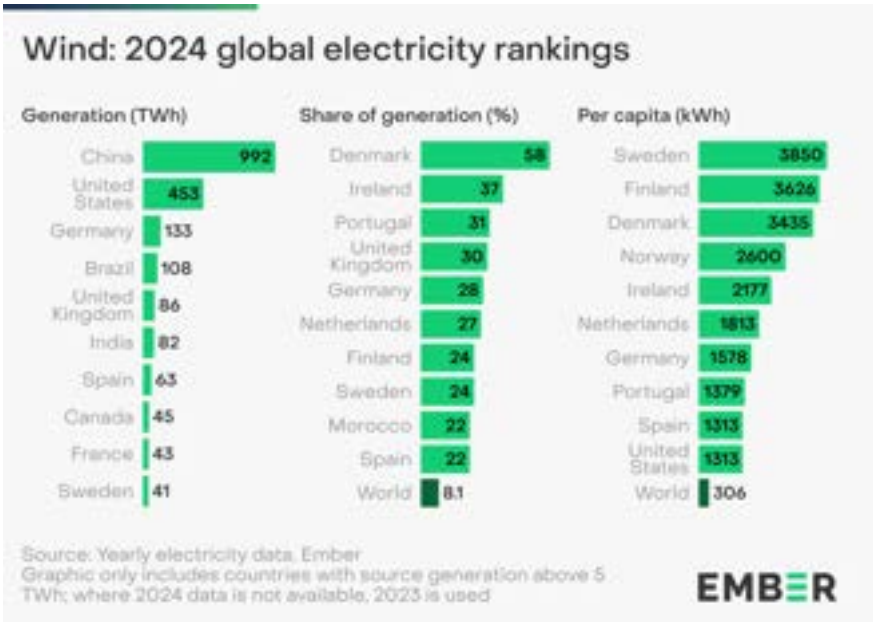


China has seen a large boom in wind power since 2020. In the most recent data on capacity additions from 2023, 66% of global onshore capacity additions and 64% of global offshore capacity additions were in China.

Wind generation in the US rebounded last year, increasing by 32 TWh, after a fall of 13 TWh in 2023. The 2024 growth was a result of improved wind conditions, as well as new wind capacity.

Wind generation growth was more modest in Europe in 2024 than in 2023, with Germany and France seeing falls of 4 and 5 TWh respectively. Although capacity additions continued in 2024 in these countries, less favourable wind conditions than in 2023 led to lower-than-expected generation.

China's wind generation in 2024 was 992 TWh, which was more than the entire world's wind generation eight years ago. China currently accounts for 40% of global wind generation.



Overall, EU countries lead in shares of wind generation. Of countries with more than 5 TWh of wind generation, Denmark was the global leader in 2024 at 58%. The top ten also includes Ireland, Portugal, Germany, the Netherlands, Finland, Sweden, and Spain. Outside Europe, Morocco (22%) was a notable leader.

Among countries with the highest share, Finland doubled its share of wind generation since 2020, from 12% to 24%. Morocco also saw a significant rise in wind generation in 2024 (+3.3 TWh, +50%) and now has the ninth-largest share of wind power globally.

On a per capita basis, Nordic countries generated the most power from wind in 2024 with Sweden, Finland, Denmark and Norway remaining as the top four. Their per capita generation from wind was ten times the world average.

4.3 Hydro

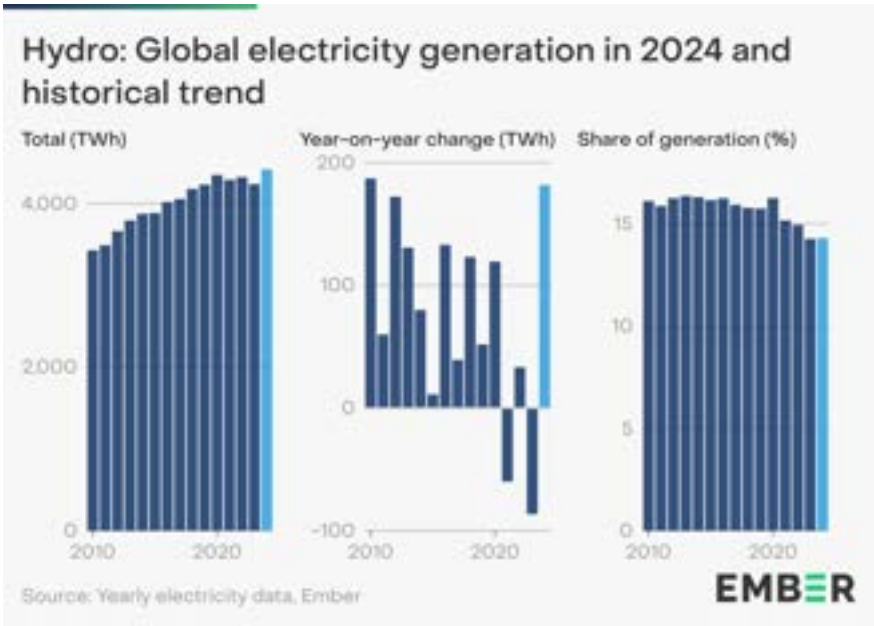
Key highlights

01 **Hydro generation rebounded in 2024, mostly because of better weather conditions after widespread droughts in 2023**

02 **Global hydro generation reached a new record high in 2024, however its utilisation rates were still below the ten-year average**

03 **China accounted for 71% of the global rise in hydro generation in 2024**

Hydro power rebounded in 2024 after droughts in key countries in 2023, with global generation increasing by 182 TWh (+4.3%).



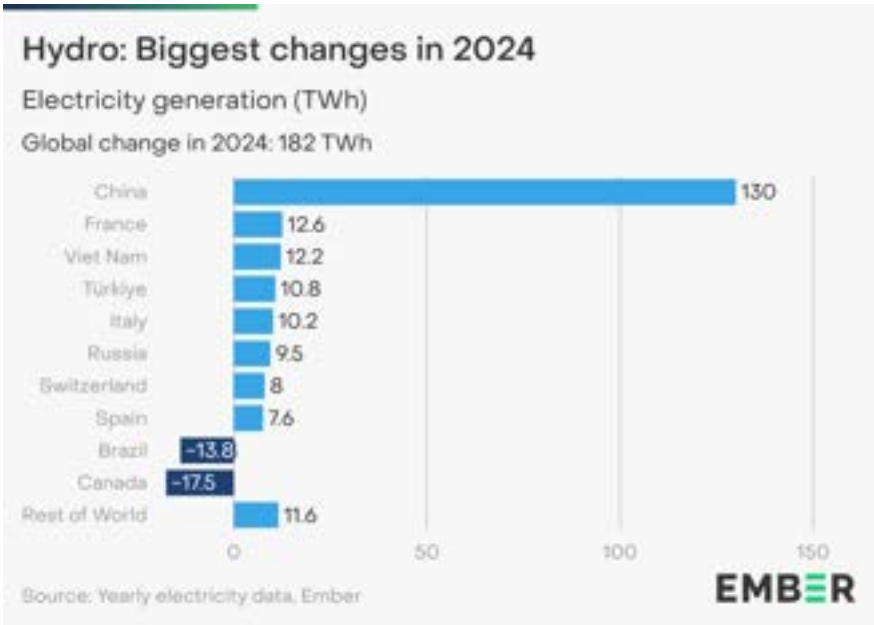
This rise in 2024 was largely the result of improving conditions rather than new capacity. In 2023, the most recent year with available capacity data, hydro capacity increased by only 1.4%, and China was the only country to install more than 1 gigawatt (GW).

Total hydro generation reached an all time high of 4,416 TWh in 2024. The previous high was in 2020, which was followed by declining total generation in 2021, a small rise in 2022, and again a decline in 2023. However, it is important to note that hydro capacity factors remain significantly below the ten-year average. While hydro generation in 2024 was 2% higher than the previous record in 2020, capacity has increased by an estimated 7% since then.

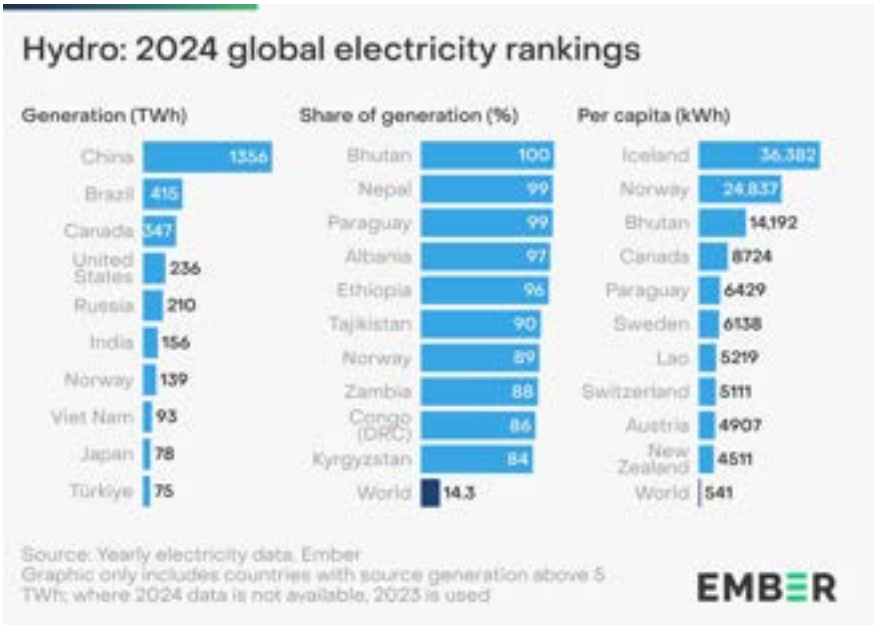
The share of hydro in global electricity generation was 14.31% in 2024, a fractional increase over 14.27% in 2023. However, the share of hydro has been on a slow decline as electricity demand has been growing faster than hydro generation.

China accounted for 71% of the global hydro generation increase in 2024, with its hydro output rising by 130 TWh (+11%). Heavy rains saw Chinese hydro generation increase in 2024 after it fell in 2023 due to droughts (-72 TWh). In addition to improved conditions, China has continued to add new hydro capacity.

Whilst rainfall improved in China and Europe, droughts cut Brazil's hydro generation (-14 TWh). Canada saw a second year in a row of poor conditions leading to declining hydro generation (-17 TWh). US hydro generation stayed near 20-year lows as droughts continued in the north west.



China extended its lead in hydro power generation, rising to 1,356 TWh in 2024. In 2003, it had the same hydropower generation as Brazil. In 2024, it had more than three times that of Brazil and four times that of Canada. However, both Brazil and Canada rely on hydro for about 55% of their electricity generation. In contrast, hydro only contributes 13% to China's electricity mix.



Hydropower is unique, with many power systems having a near-total reliance on just one source of electricity - the top ten countries get 84% or more of their electricity from hydro. This high level of reliance on hydro brings risks related to drought and climate change, with power outages in Ecuador providing a recent example.

Iceland and Norway lead the world in per capita hydro generation with 36,382 kWh and 24,837 kWh respectively.

4.4 Nuclear

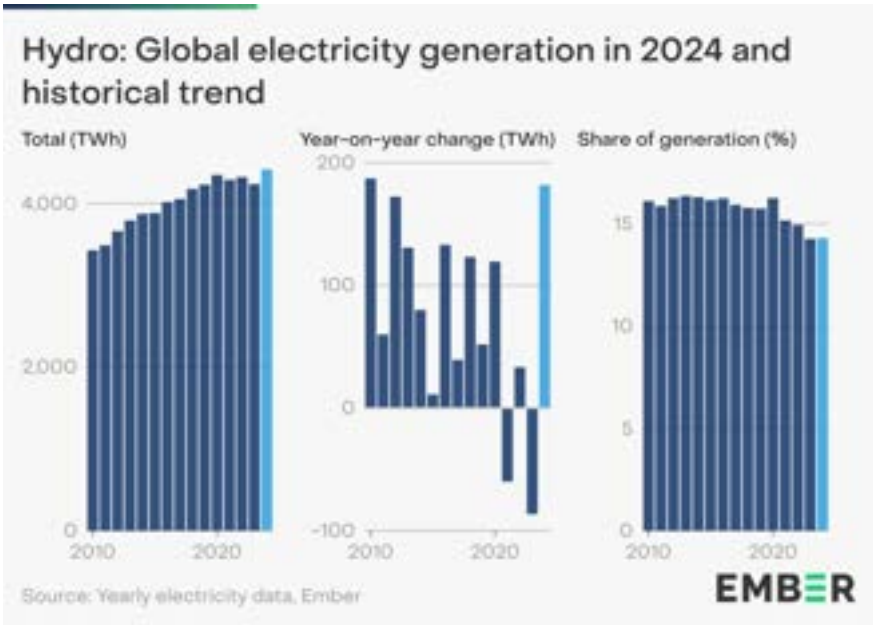
Key highlights

01 **Nuclear generation rose by 2.5% in 2024**

02 **However, nuclear growth continues to lag behind electricity demand growth and its share in the global electricity mix fell to a 45-year low**

03 **The rise in 2024 was driven by French units returning from outage, some units in Japan returning to service, and a few new units being commissioned globally**

Nuclear generation grew in 2024 (+69 TWh, +2.5%) following a similar increase in 2023 (+59 TWh, +2.2%). Total global nuclear generation in 2024 (2,768 TWh) narrowly hit a record high.



Nuclear made up 9% of the global electricity mix in 2024, the lowest value in more than 45 years. Its share has seen consistent declines in the last decade as the rise in nuclear generation has lagged behind the rise in global electricity demand.

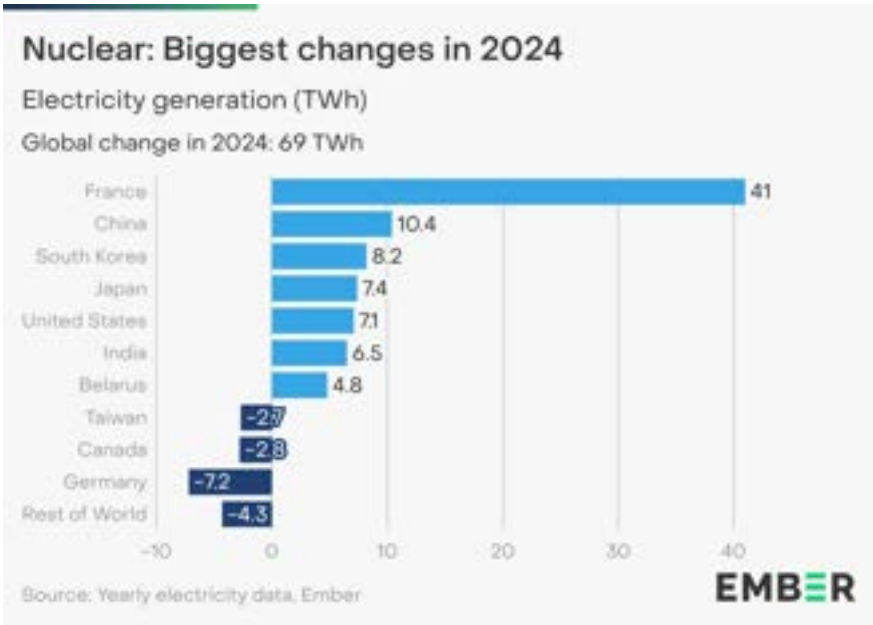
Four units were closed in 2024, the lowest number in ten years. However, only seven were commissioned in 2024, although construction was started at 11 units, as the global interest in new nuclear rises.

Even as some countries are phasing out nuclear power, global generation from nuclear plants is still expected to rise. Japan is restarting some of its reactors, maintenance works are progressing in France, and new reactors are due to begin commercial operation in various markets, including China, India, South Korea and Europe.

The country with the largest increase in nuclear generation in 2024 was France (+41 TWh, +12%), where generation slowly returned to higher levels throughout 2023 and 2024 after outages in 2022.

China's nuclear generation rose by 10 TWh as four new units were commissioned in 2024. The rise of nuclear power in China has slowed dramatically from 17% per year from 2000 to 2019, to 5% per year from 2019 to 2024.

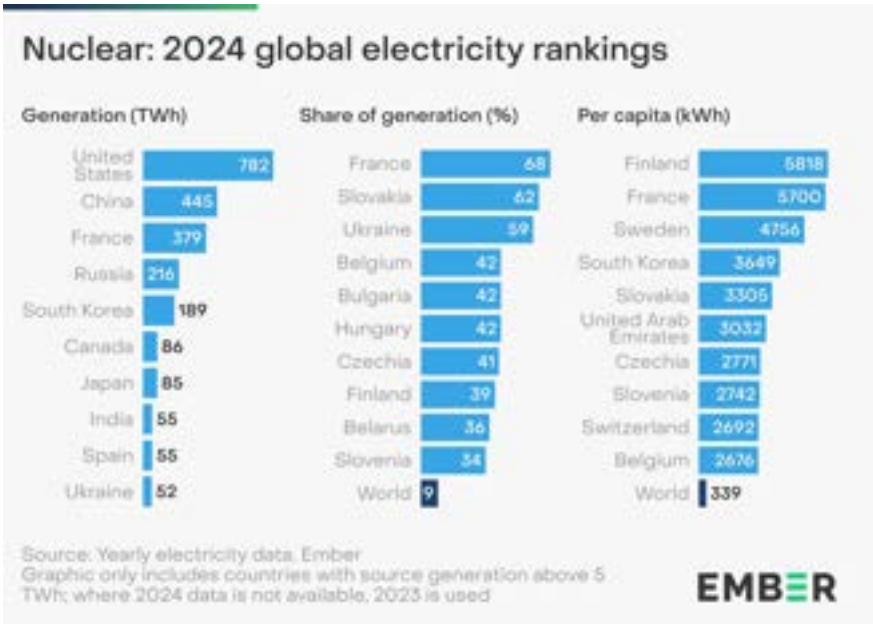
Japan's nuclear generation rose by 7.5 TWh last year, as 2 reactors restarted in 2023 and two restarted in 2024. Nuclear generation in the US rose by 7.1 TWh. One new unit came online, but there are no further reactors under construction as of 2024.



Nuclear power generation fell by 7.2 TWh in Germany in 2024, reflecting the final closures of its nuclear fleet in April 2023. Taiwan had a decline in nuclear generation for the fifth year in a row (-2.7 TWh) due to its planned nuclear phaseout policy.

The US continues to be the largest producer of nuclear power globally with 782 TWh in 2024, ahead of China (445 TWh), and France (379 TWh).

Only three countries rely on nuclear power for more than half of their electricity generation: France, Slovakia and Ukraine.



A new nuclear power plant commissioned in 2022 meant Finland rose to become the country with the highest per capita nuclear generation in 2023 and stayed at this spot in 2024, ahead of France.

4.5 Gas

Key highlights

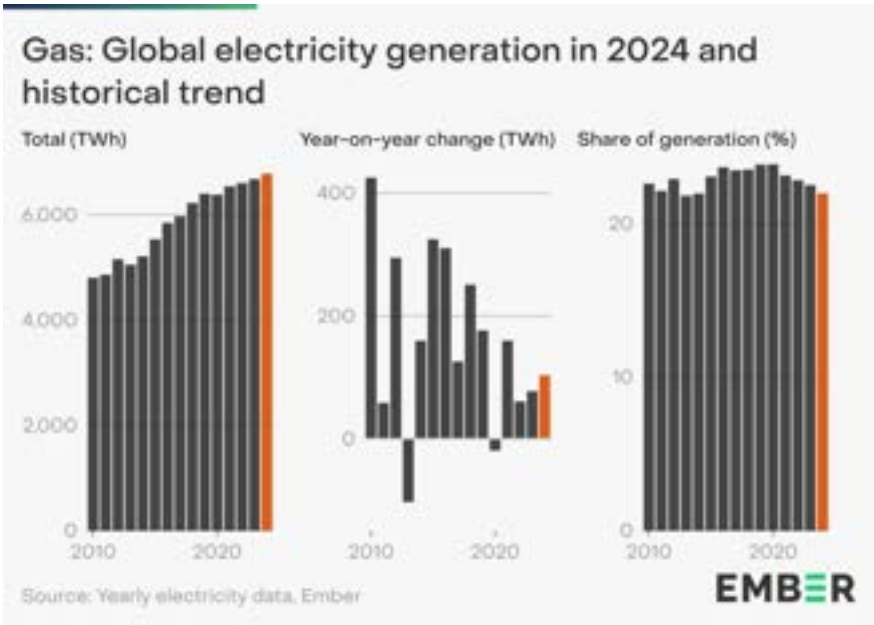
01 **Gas generation rose by 1.6% to a record high, in part due to heatwaves driving increased demand**

02 **Gas's market share has been falling for four years - it peaked at 24% in 2020 and fell to 22% in 2024, the lowest since 2013**

03 **The US was responsible for 43% of the global increase in gas generation since 2015**

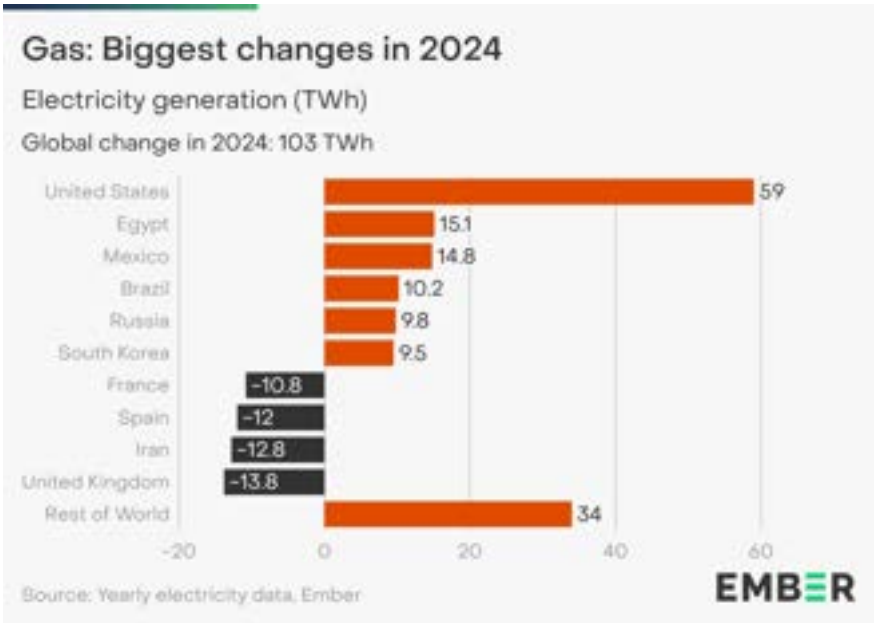
Global gas generation rose by 1.6% (+103 TWh) to a record high of 6,788 TWh in 2024.

Despite this, its market share fell for the fourth year in a row, as generation rose more slowly than electricity demand. Its share peaked at 24% in 2020 and fell to 22% in 2024, the lowest since 2014.



In absolute terms, gas generation has grown by 22% since 2015 (+1,246 TWh), with the US responsible for 43% of this increase.

The increase in gas generation in the US (+59 TWh) was 57% of global growth in 2024. Egypt had the second-largest growth (+15.1 TWh) ahead of Mexico (+14.8 TWh). In Mexico, gas replaced coal and oil generation. Brazil, Russia and South Korea also recorded large increases in gas generation in 2024 of around 10 TWh.

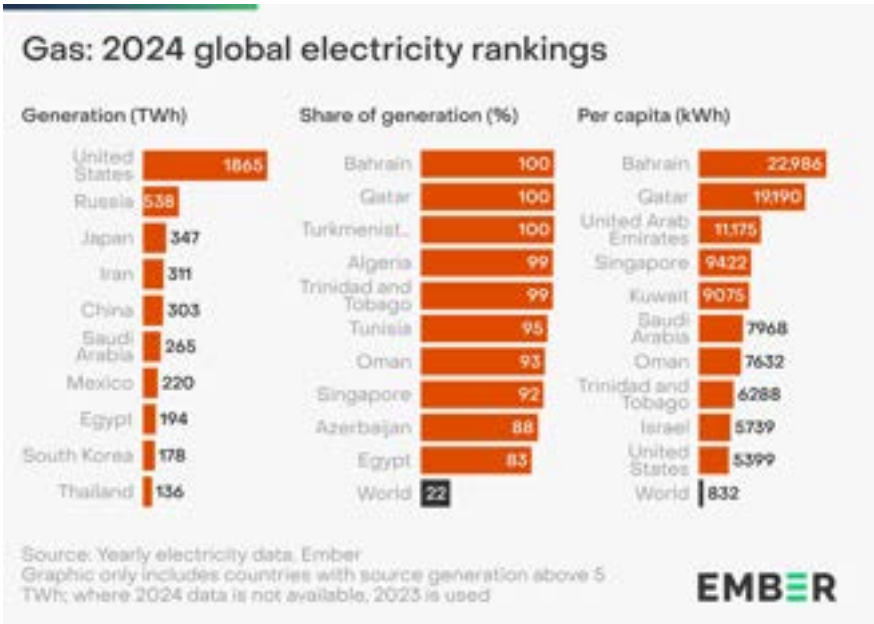


Gas generation fell in the UK (-14 TWh), Spain (-12 TWh) and France (-11 TWh) as wind and solar generation continued to expand. Across the EU, gas generation was down by 26 TWh, falling for the fifth year in a row.

Iran also recorded a substantial decline of 13 TWh in 2024, reversing an increase of 10 TWh in 2023.

The US was the world's largest producer of electricity from gas in 2024, with 1,865 TWh. This was more than three times larger than Russia, which remained in second place at 538 TWh.

15 countries generated more than 80% of their electricity from gas in 2024. These countries are predominately in the Middle East, North Africa and Central Asia.



Countries in the Middle East had the highest per capita gas generation, led by Bahrain (22,986 kWh, 2023 value as 2024 unavailable) and Qatar (19,190 kWh). This was driven by two factors: a high share of gas in their electricity mix and high per capita demand.

4.6 Coal

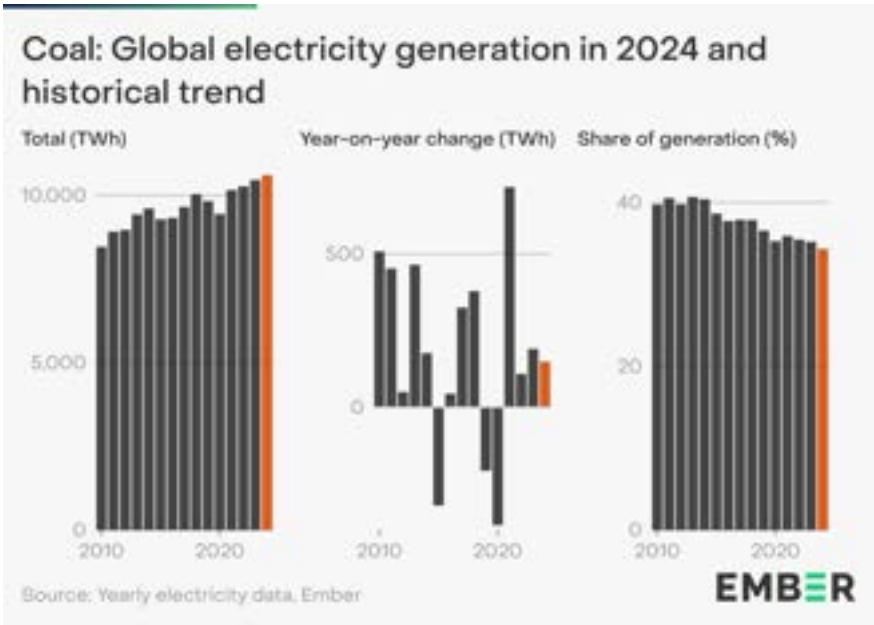
Key highlights

01 **Coal generation rose by 1.4% to a new record in 2024, driven by high electricity demand growth in part caused by heatwaves**

02 **Coal's share of global electricity generation fell to 34% in 2024 as electricity demand grew faster than coal generation**

03 **China accounted for 74% of the global increase in coal generation in 2024**

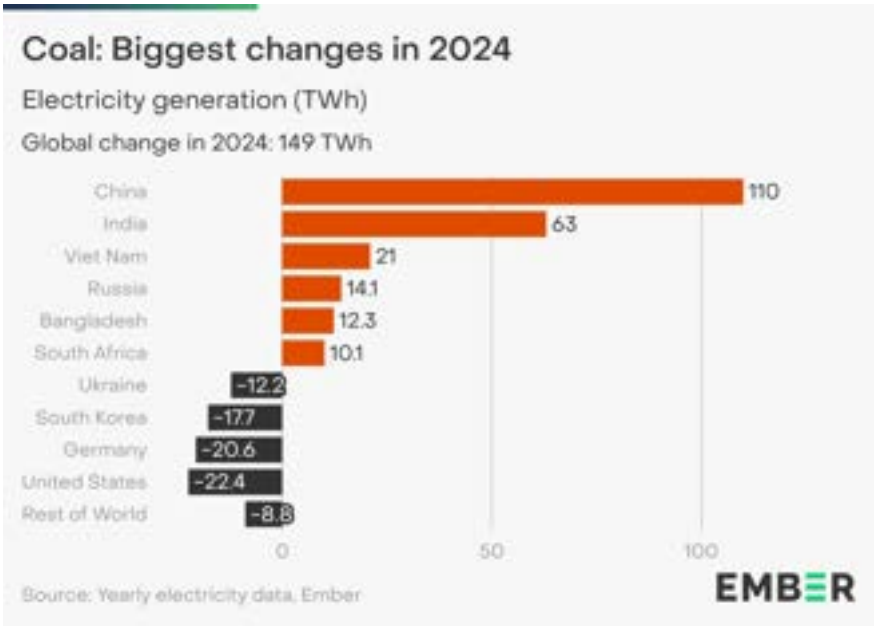
Global coal generation grew by 1.4% (+149 TWh) in 2024, rising to a new record high. This increase was slightly below the rise in 2023 (+190 TWh, +1.9%).



Coal remains the largest single source of electricity generation. However, coal has been growing more slowly than electricity demand, leading to its share of global generation falling to 34% in 2024.

In 2015, 59 countries generated at least a fifth of their electricity from coal, which fell to 40 countries in 2024.

The largest increase in coal generation in 2024 was in China (+110 TWh, +1.9%), which accounted for 74% of global growth in coal generation. Notably, this was significantly less than China's 2023 coal increase of 341 TWh, despite heatwave-related demand spikes driving up China's coal generation in 2024. Ember's analysis found that 59% of China's 2024 annual coal generation growth happened in just August and September amid soaring temperatures. The growth in China's coal generation in 2024 was suppressed by remarkable solar growth and a strong rebound in hydro generation.

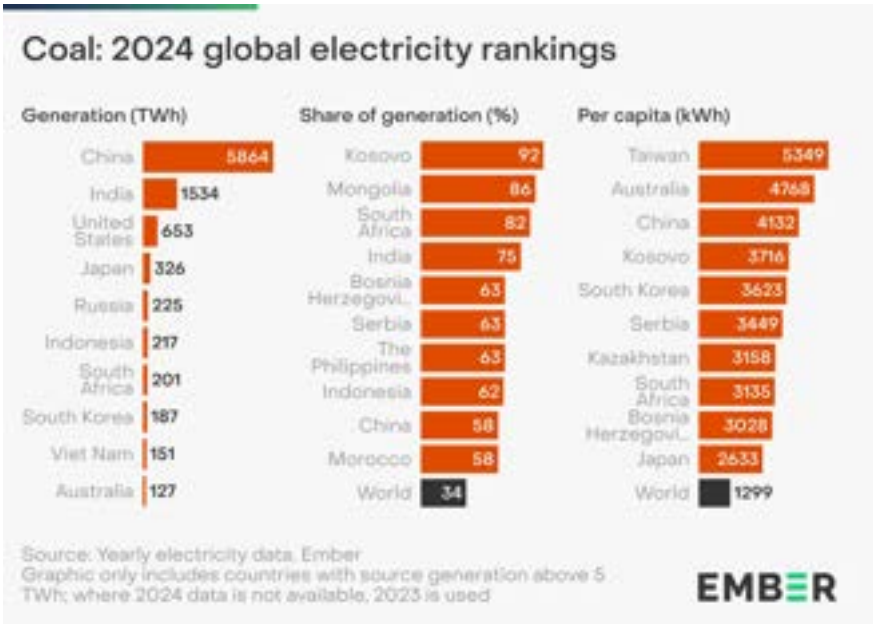


Coal generation increased in India by 63 TWh (+4.3%) and in Viet Nam by 21 TWh (+16%). Bangladesh recorded a 115% increase in coal generation (+12 TWh) in 2024.

Coal generation continued to shrink in the US (-22 TWh, -3.3%), although the coal decline in 2023 was much larger (-156 TWh, -19%). In Germany, coal fell by 21 TWh (-17%) in 2024, even as the country closed its last nuclear plant in 2023.

Of countries with available data for 2024, 37 showed falls in coal generation.

China accounted for 55% of global coal generation (5,864 TWh) in 2024. India produced the second-largest amount of electricity from coal with 1,534 TWh, followed by the US with 653 TWh.



Kosovo had the world's highest share of coal power in 2024 (92%), although its total output remains small. Mongolia and South Africa complete the top three with 86% and 82%, respectively. India produced 75% of its electricity from coal in 2024, more than double the global average of 34%.

Kazakhstan – which was fifth in 2023 — dropped out of the top ten, with its coal share declining from 67% in 2023 to 55% in 2024. Two countries moved into the top ten in 2024: Serbia and Bosnia Herzegovina, both with 63%.

The highest coal generation per capita was recorded in Taiwan (5,349 kWh), Australia (4,768 kWh) and China (4,132 kWh), which were all more than three times the world average of 1,299 kWh.

Analysis of key power consumers in 2024

Data on the world's seven largest power consumers in 2024, with an overview of changes in the last year and trends in the last two decades. Collectively, they account for 72% of global electricity demand.

We have ordered these countries and regions according to their total electricity demand in 2024.

Chapter contents

Key electricity stats in 2024

Figures for global totals and major electricity markets

Country or region	Demand (TWh)	Clean generation (TWh)	Year-on-year change in clean generation (TWh)	Clean share (%)	Wind and solar share (%)	Fossil share (%)	Emissions (MtCO2)
World	30,856	12,609	927	41	15	59	14,602
China	10,066	3,836	507	38	18	62	5,640
United States	4,401	1,839	100	42	17	58	1,683
EU	2,727	1,950	120	71	29	29	585
India	2,054	462	32	23	11	78	1,457
Russia	1,195	435	9	36	1	64	544
Japan	1,022	322	21	32	11	69	493
Brazil	760	669	24	90	25	10	77

Source: Yearly electricity data, Ember

EMBER

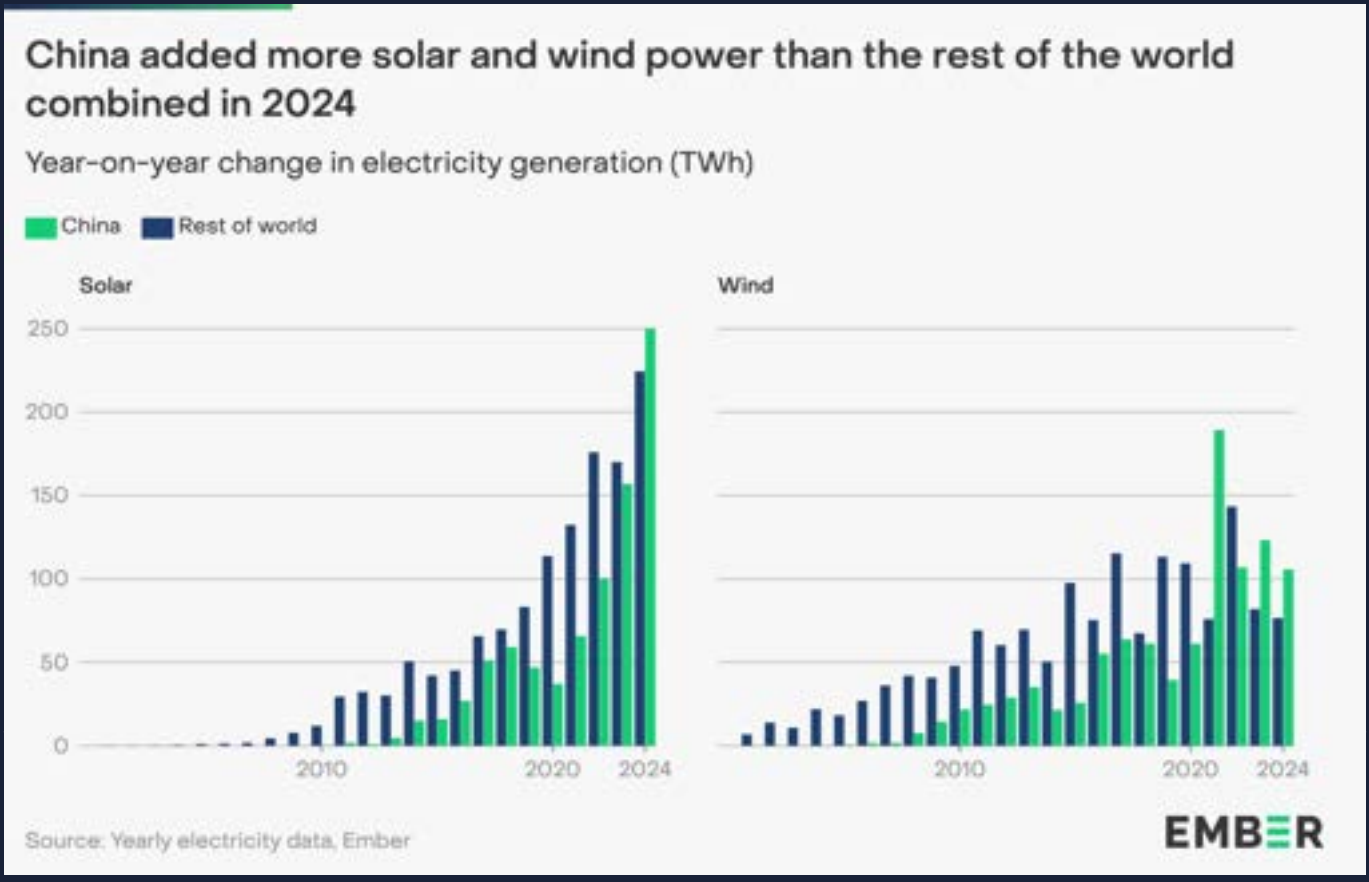
5.1 China

Key highlights

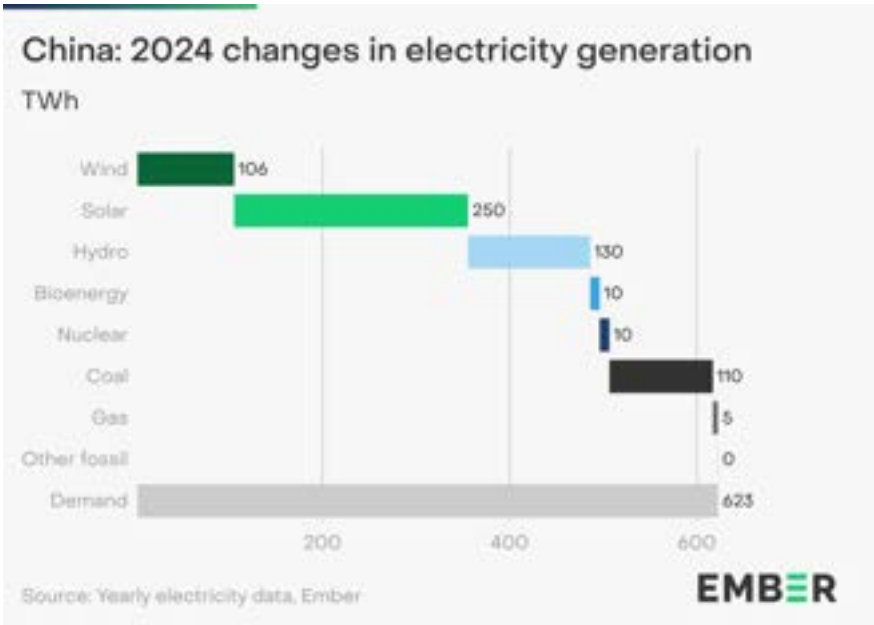
01 **China accounted for more than half of the global increase in wind and solar power in 2024**

02 **Clean generation met 81% of the 2024 demand increase in China**

03 **Coal generation rose to a record high in 2024, but supplied only 18% of the demand rise and solar grew more than twice as much**



China's electricity demand continued to grow - by 6.6% in 2024 (+623 TWh), down only slightly from 6.9% in 2023.



Demand growth was given a temporary boost in 2024: hotter temperatures contributed significantly to higher cooling demand in the summer months, and January and February showed a rebound in industrial demand from lower levels in 2023, as the last Covid-19 restrictions were lifted in early 2023.

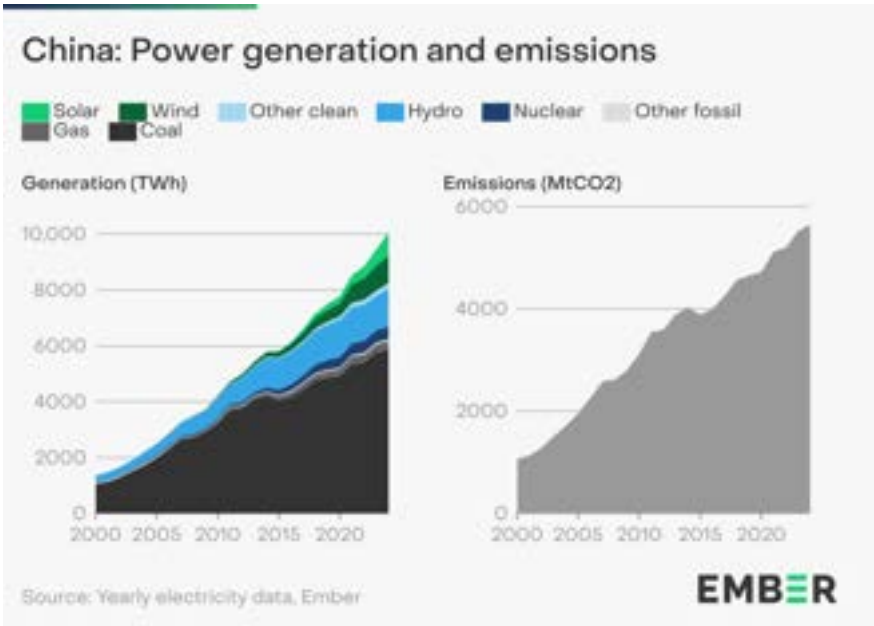
81% of the demand growth was met with the rise in clean generation - wind, solar, hydro, nuclear and bioenergy generation all rose. Wind and solar generation combined met more than half of the increase in electricity demand. Just 18% of the increase in demand was met with the rise in coal generation.

The biggest change in China's electricity generation compared to 2023 was the continued explosive growth of solar. Solar generation was up 250 TWh (+43%) in 2024 compared to 2023, which had itself recorded an increase of 37% compared to 2022. Also of note was the rebound in hydro generation, which was up 130 TWh (+11%) in 2024 as the drought conditions of 2023 eased.

China had the world's largest increase in coal generation in 2024 (+110 TWh, +1.9%), but this was less than a third of the increase in 2023 (+341 TWh, +6.3%). This lower level of growth is significant given the impact of heatwaves on increasing demand in 2024. Solar's increase of 250 TWh was more than twice as large as the rise in coal.

In 2024, China's solar growth accounted for 53% of total global solar growth, while China's 106 TWh of wind growth was 58% of the global total.

Electricity demand in China has increased sevenfold from 2000 (1,347 TWh) to 2024 (10,066 TWh).



Only 30% of the demand rise from 2000 to 2015 was met with rising clean electricity (and 70% from fossil sources). But since 2015, over half (53%) was met with clean electricity (and 47% from fossil sources). Wind and solar generation has tripled over the past five years, from 629 TWh in 2019 to 1,826 TWh in 2024.

Coal's share has been falling - from 70% in 2015 to 58% in 2024 - even as absolute coal generation set a new record in 2024, 45% higher than in 2015.

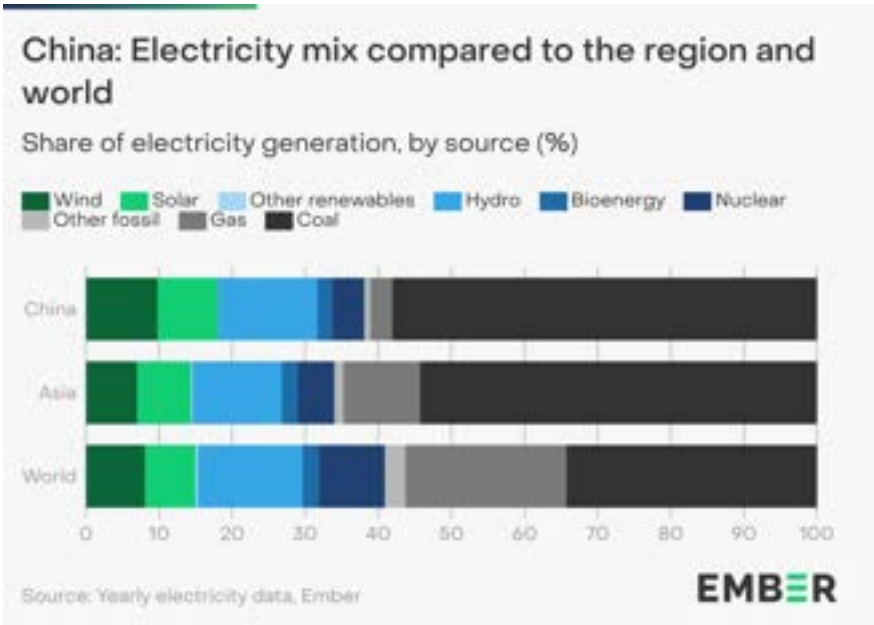
Despite the growth in solar and wind, China relied on fossil fuels for 62% of its electricity in 2024, making it the world's largest power sector emitter.

Total power sector emissions rose 2.2% to 5,640 MtCO2 in 2024, lower than the average annual growth between 2019 and 2023 of 3.9%. Forecasts suggest that China is approaching the tipping point on coal generation and that peak emissions are on the horizon (read more about this in Chapter 2.3). China accounted for 39% of global power sector emissions in 2024.

China plays an outsized role in the global electricity transition. It has over half of the world's coal-fired installed capacity, and is simultaneously home to over 80% of the global solar manufacturing industry. China dominates the global growth in wind and solar generation, accounting for 54% in 2024, but also the global growth in coal generation, accounting for 74%.

Clean power made up 38% (3,836 TWh) of China's electricity mix in 2024, just below the global average of 41%. Hydro was the largest single source of clean power at 13.5% (1,356 TWh).

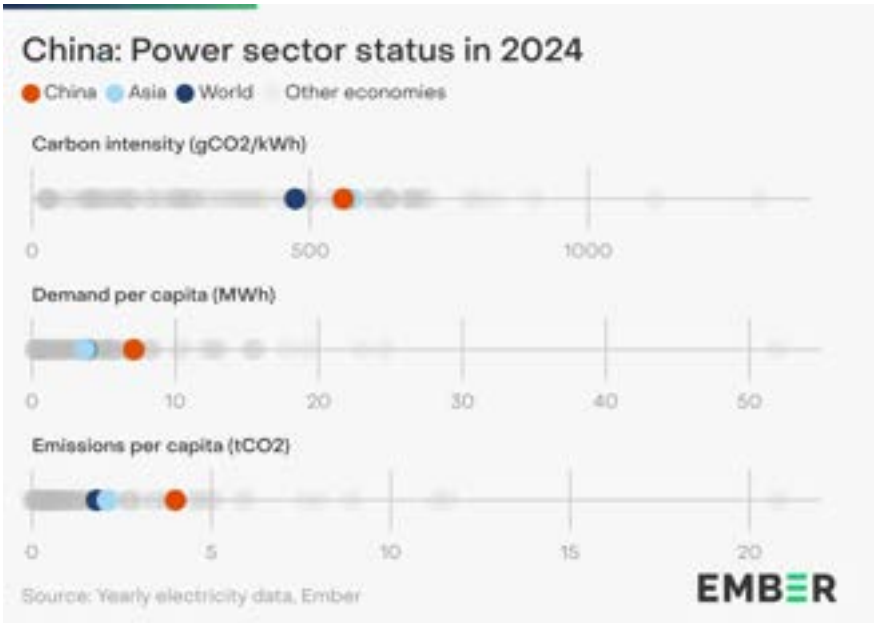
China's wind and solar generation hit a new record share of 18% (1,826 TWh) in 2024, remaining above the global average of 15% and overtaking the US for the first time. China's clean share and wind and solar share both remain above the average clean share and wind and solar share in Asia.



China's coal share of 58% (5,864 TWh) remains just above the regional average of 54% and significantly above the global average of 34%. In 2024, China was responsible for 55% of global coal generation.

China's carbon intensity of electricity generation was 560 gCO2/kWh, down 4.1% from 2023, but still significantly above the global average of 473 gCO2/kWh due to its dependence on coal.

China's per-capita electricity demand of 7.1 MWh was almost double the global average (3.8 MWh) and the regional average (3.7 MWh). China's demand per capita was five times India's in 2024.



Due to its growing per capita demand and high reliance on coal generation, China's per capita power sector emissions (4 tCO2) remained at more than double the global average of 1.8 tCO2 and the average in Asia of 2.1 tCO2.

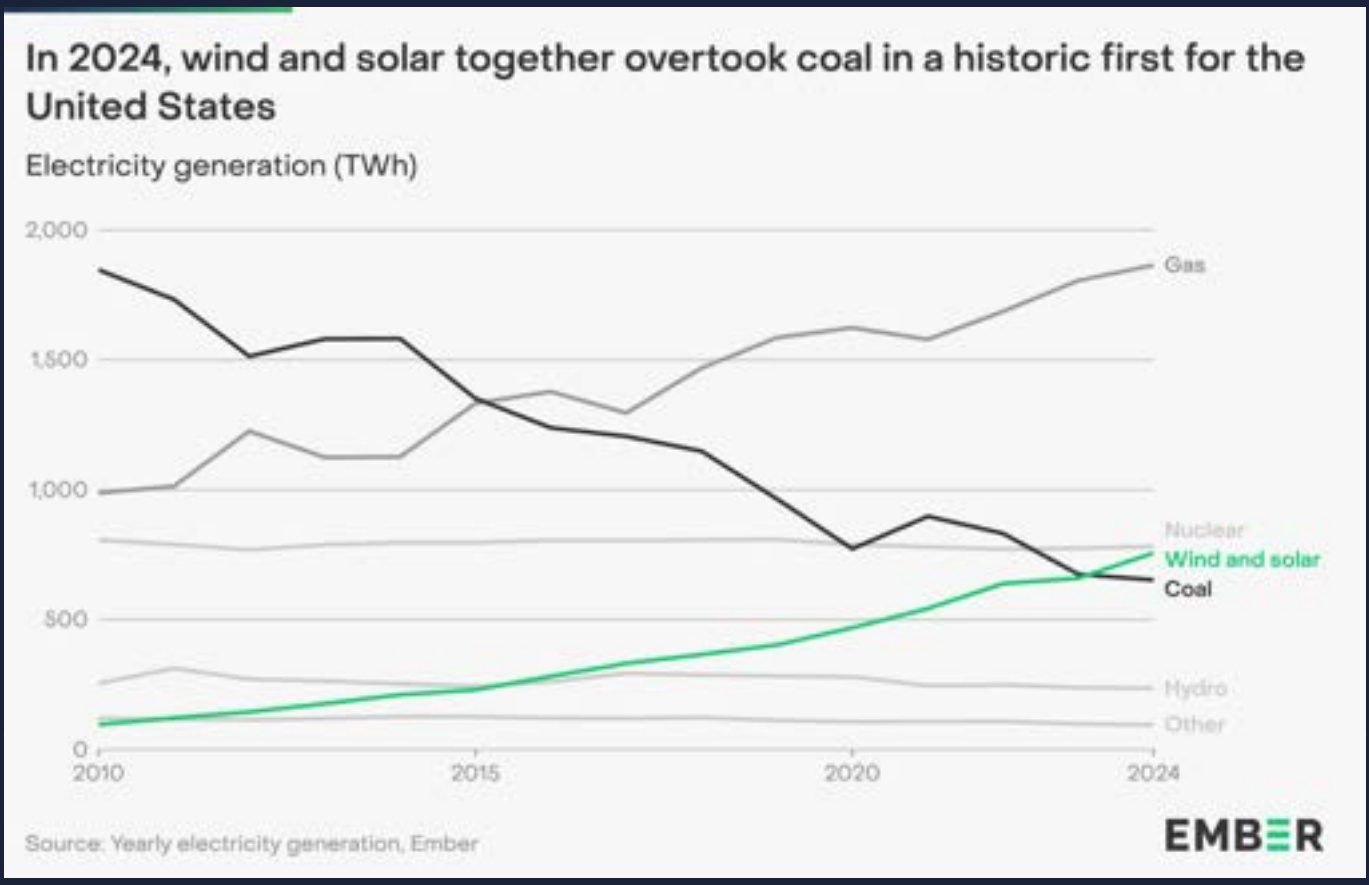
5.2 United States

Key highlights

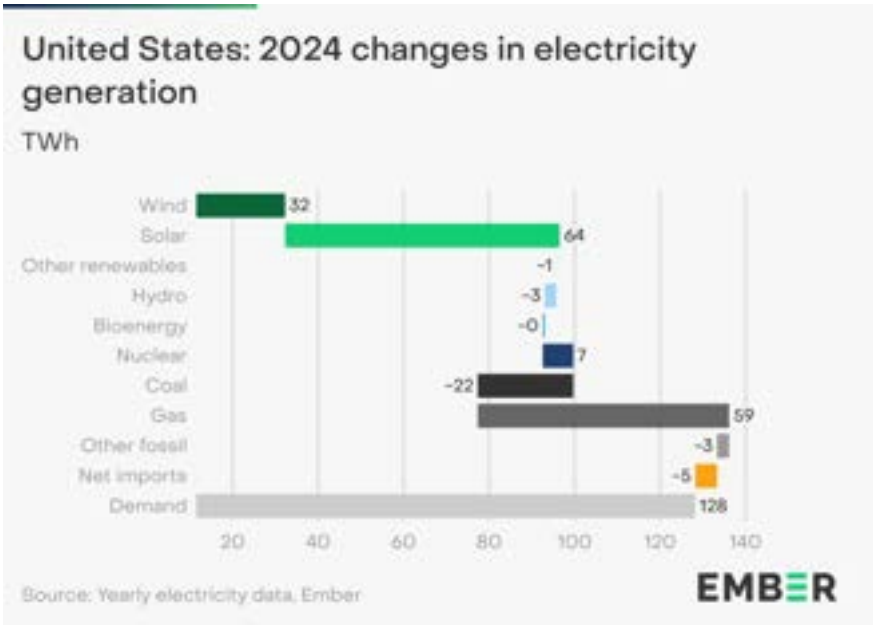
01 **In 2024, wind and solar together generated more electricity in the US than coal for the first time, with coal's share in the mix falling to an all-time low of under 15%**

02 **Gas generation rose as electricity demand accelerated, with the US accounting for more than half (57%) of global growth in gas generation in 2024**

03 **Solar generation rose more than gas, recording its highest ever annual increase of 64 TWh**



Electricity demand in the United States grew by 3% (+128 TWh) in 2024, caused partly by heatwaves over the summer months and partly as a rebound from a milder summer in 2023 when demand decreased by 1.3% (-55 TWh).



The demand rise was predominantly met with higher solar, wind and gas generation, which also made up for a fall in coal generation (-22 TWh).

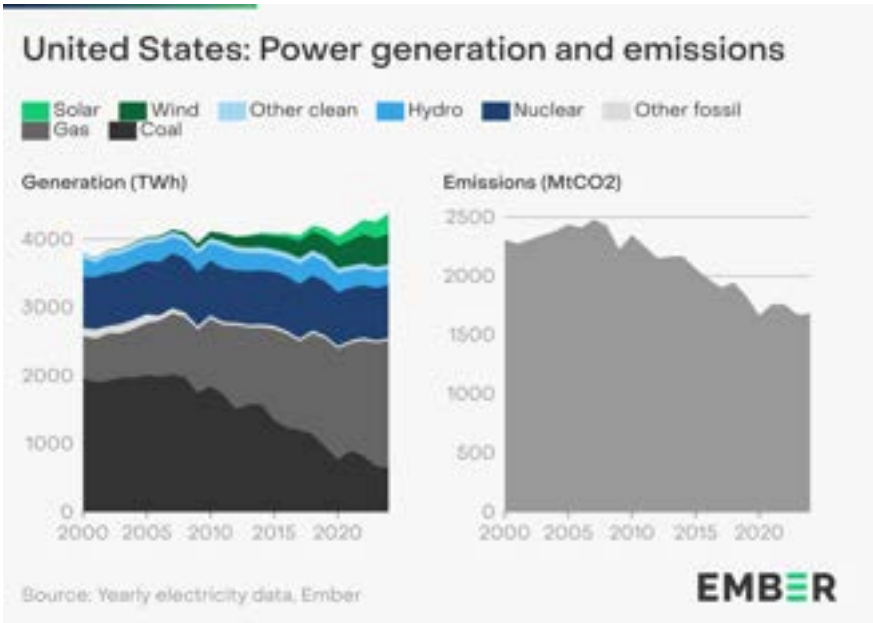
2024 saw the largest-ever increase in solar generation in the US (+64 TWh). This was the second-largest increase of any country, after China. Significant capacity additions spurred by the Inflation Reduction Act have begun to feed through to generation increases. Wind generation rose as a result of improved wind conditions from 2023 as well as a moderate increase in wind capacity.

Gas generation in the US increased by 3.3% (+59 TWh). This was the largest rise in gas generation seen in any country in 2024 and more than half (57%) of the global increase in gas generation.

Coal power has been in terminal decline in the US since its peak in 2007. Since then, coal power has fallen by two-thirds (-1,364 TWh). Coal fell below 15% of the US electricity mix for the first time in 2024. Coal power was predominantly replaced by an increase in wind and solar generation (+722 TWh since 2007) and gas generation (+968 TWh since 2007). Gas generation rose to record levels in 2024, doubling compared to 2007. The US has been responsible for 43% of the global increase in gas generation since 2015.

The partial coal-to-gas switch meant that power sector emissions have not declined as fast as coal power. Since 2015, emissions have fallen by 18%, from 2,062 MtCO2 to 1,683 MtCO2 in 2024.

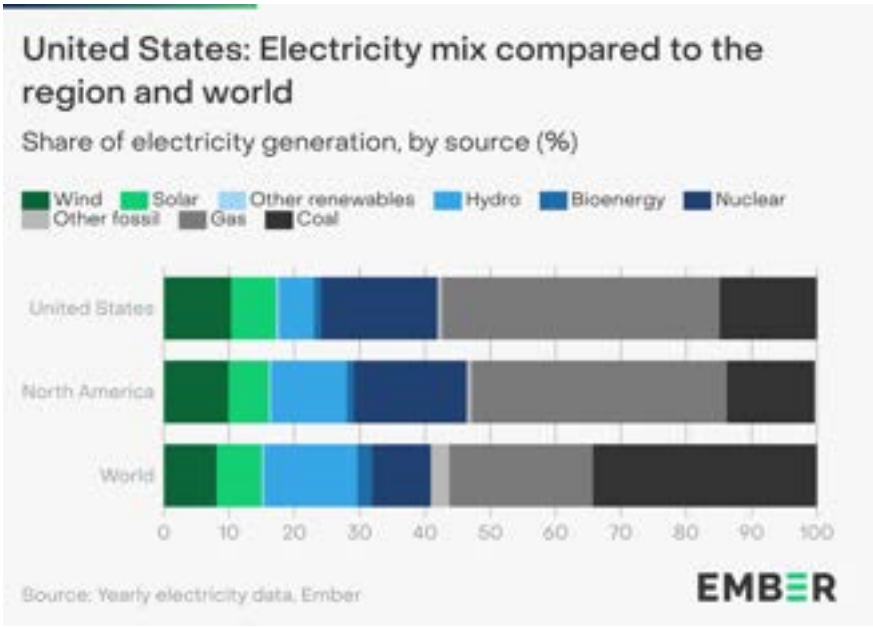
Wind and solar together have more than tripled (+527 TWh) in the US since 2015, generating 757 TWh of electricity in 2024. This continued growth meant that wind and solar overtook coal power in the US for the first time in 2024, generating 17% of the country's electricity.



After remaining largely flat for most of the 2010s, demand has risen in three of the last four years, at an average of 1.8% per year.

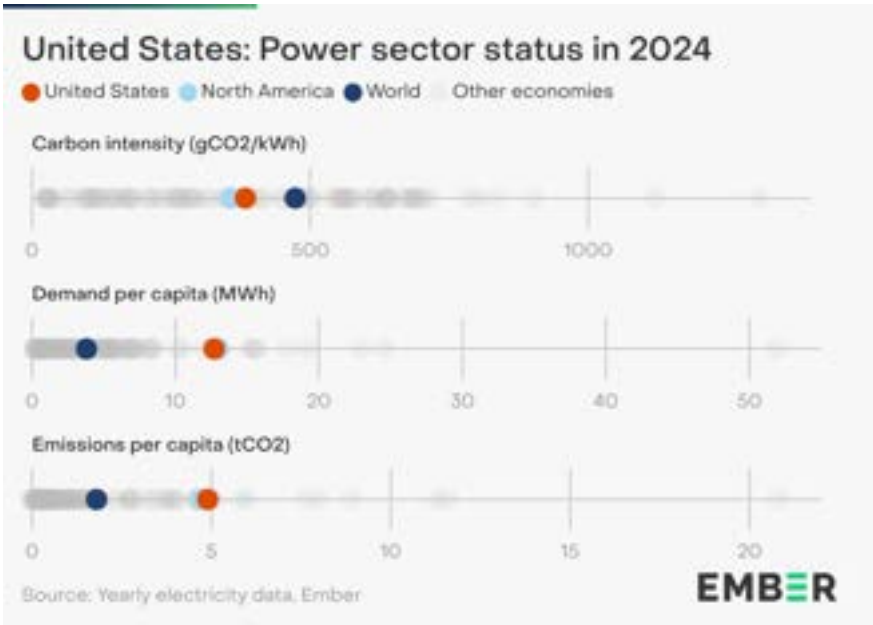
The growth in clean electricity came only from solar and wind – bioenergy, nuclear and hydro generation were all lower in 2024 than in 2015.

The United States generated 42% of its electricity from clean sources in 2024, in line with the global average. 17% of the country's electricity was generated by wind and solar power, which was just above the global average (15%), but lower than China (18%).



58% of US electricity came from fossil fuels in 2024, which was in line with the global average of 59% despite coal's significant decline. This was due to the country's reliance on gas power, which supplied 43% of its electricity in 2024 (1,865 TWh). This was more than double the gas generation of all other G7 members combined.

The carbon intensity of US electricity generation was 384 gCO2/kWh - below the global average of 473 gCO2/kWh. Although the fossil share was similar to the global average, the US has a larger reliance on gas than coal, leading to carbon intensity.



The United States was the country with the 11th highest electricity demand per capita (12.7 MWh) in 2024. Its demand per capita has remained consistently high and in 2024, reached its highest level since 2014. Its demand per capita is twice as high as that of the EU.

As a result of high electricity demand, power sector emissions per capita were 4.9 tCO2, more than double the global average of 1.8 tCO2.

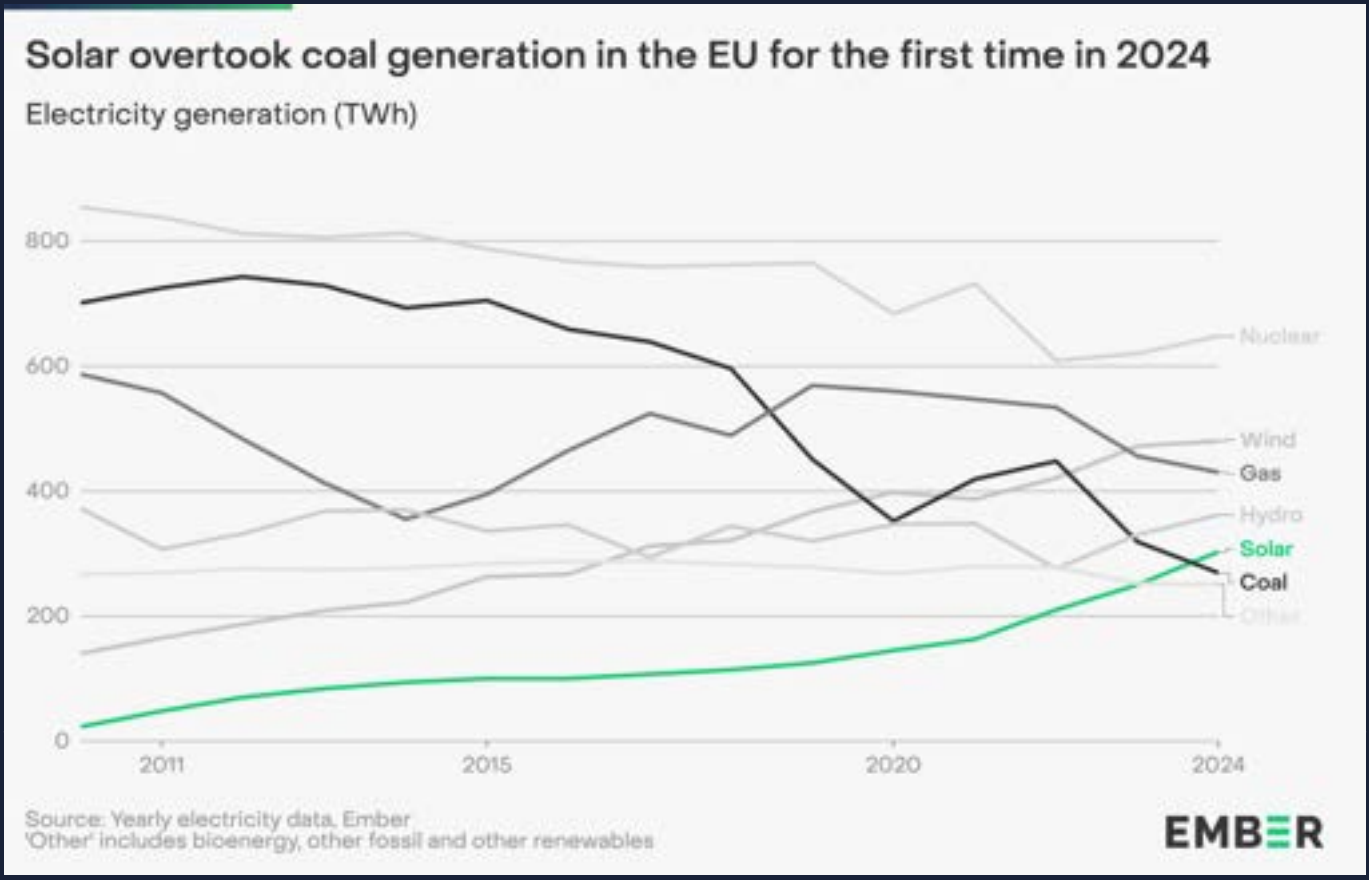
5.3 European Union

Key highlights

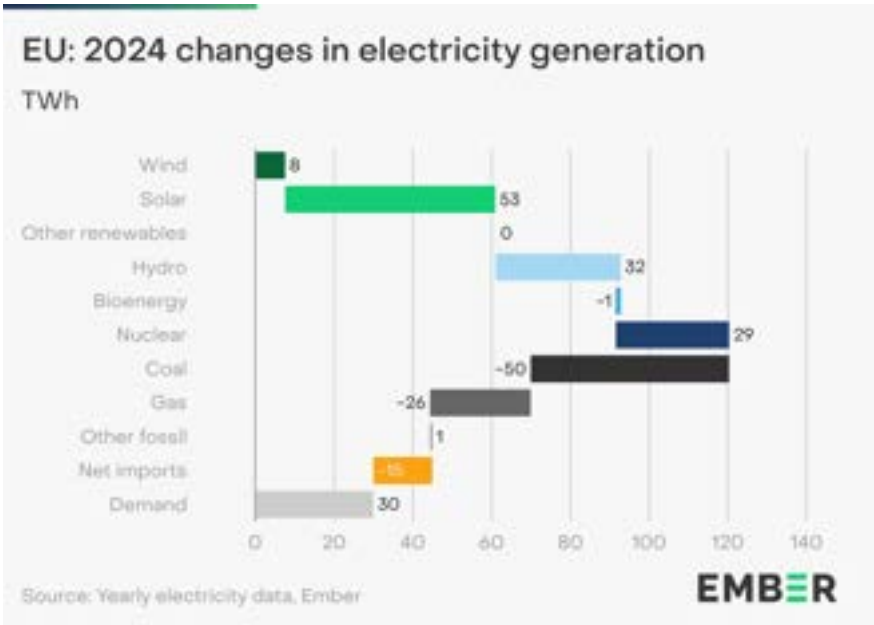
01 **Solar power overtook coal generation in the EU for the first time in 2024**

02 **In 2024, the EU saw the largest fall in coal generation globally**

03 **The EU's biggest two generation sources – nuclear and wind – are both low-carbon, with gas and coal in third and sixth place respectively**



In 2024, solar was the European Union's fastest-growing power source, with a 21% increase (+53 TWh) compared to 2023. This rise accounted for 11% of the global increase in solar generation. The EU saw a record amount of new capacity additions in 2024, driving this solar increase despite lower solar radiation in 2024 than in 2023.



Wind generation grew by 8 TWh year-on-year in 2024. This growth is lower than the average 30 TWh year-on-year increase seen between 2019 and 2023. While capacity additions continued in 2024, wind conditions were less favourable than in 2023, leading to lower than expected generation.

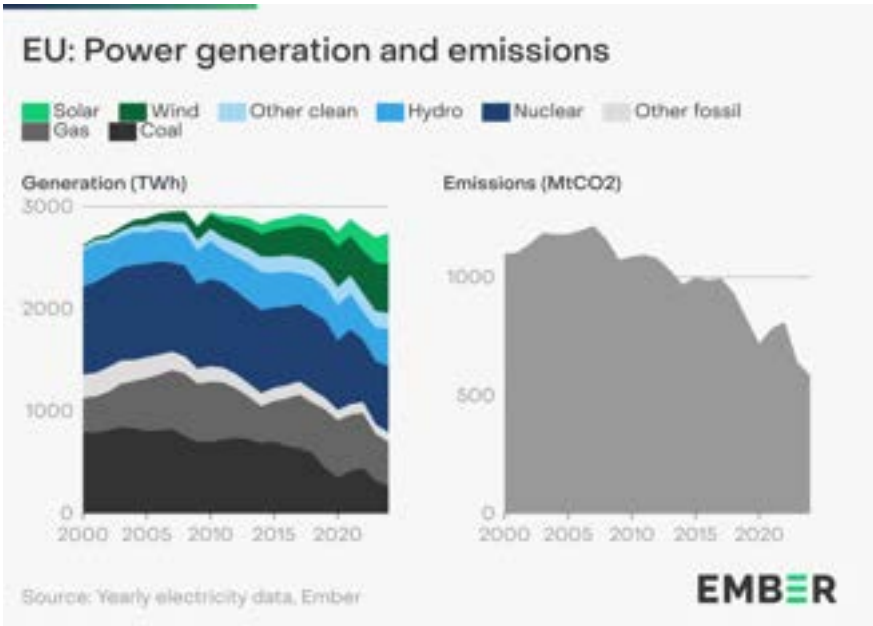
Hydro and nuclear generation increased by 32 TWh (+9.6%) and 29 TWh (+4.6%) respectively. Hydro increased due to favorable rainfall across most of Europe, while nuclear power was boosted because of reduced downtime in France.

Fossil gas generation fell for the fifth year in a row (-26 TWh, -5.6%). Coal generation in the EU fell by 50 TWh (-16%), continuing a second consecutive year of decline. This was the largest decline in any power sector globally.

EU demand rose by 30 TWh (+1.1%), steadying after large falls in 2022 and 2023.

The EU has proven that a deep transformation of the power sector is achievable and beneficial. In 2024, EU power sector emissions were down to 585 million tonnes of CO2 (MtCO2), below half of their 2007 peak.

Over the last five years, coal generation has fallen by 182 TWh (-40%), with Austria, Sweden and Portugal phasing it out completely, while countries with large coal fleets like Germany saw significant plant closures. At the same time, gas generation has decreased in each of the last five years, and was 139 TWh (-24%) lower in 2024 than it was in 2019. The reduction in gas generation has enhanced the bloc's energy security amidst Russia's invasion of Ukraine and the gas price volatility seen over the last three years. EU fossil generation is now at its lowest level for more than forty years (793 TWh).



The key driver of this has been a significant rise in wind and solar generation. Wind and solar's share in the EU power mix has increased from 17% in 2019 to 29% in 2024, with wind generation increasing by 113 TWh (+31%) and solar generation by 179 TWh (+143%).

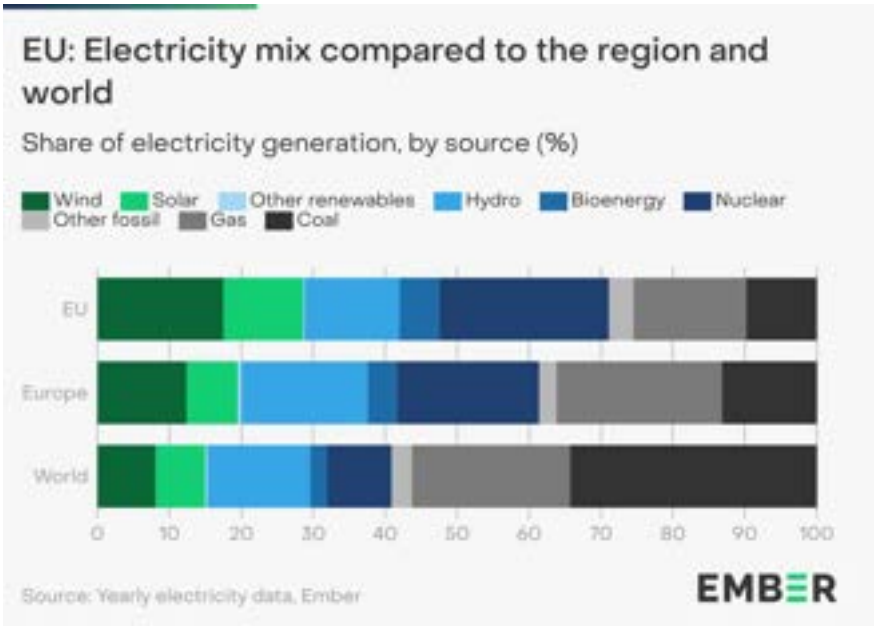
Hydropower capacity has remained unchanged over the last five years, with changes in generation dominated by weather conditions. Meanwhile, nuclear capacity has decreased from 110 GW to 96 GW, although the largest changes in generation have come from outages and maintenance.

As a result of its power sector transformation, the EU has cemented its position as a global leader in clean power, showing it is possible to integrate high shares of variable renewables. 71% of the region's electricity came from clean sources in 2024, far above the global average of 41%. The EU's biggest two generation sources – nuclear and wind – are both low-carbon, with gas and coal in third and sixth place respectively.

The EU obtained 18% of its electricity from wind power, more than double the global average. Solar provided 11% of the EU's electricity generation in 2024, surpassing coal for the first time ever. Out of the 15 countries with the highest solar shares in 2024, seven were EU Member States. France's sizeable

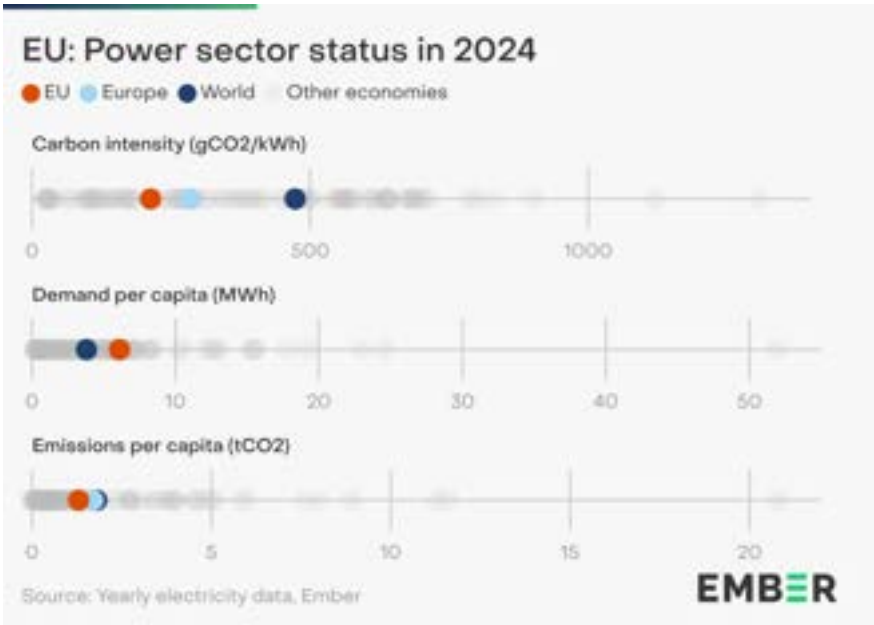
nuclear fleet meant that the bloc generated 24% of its electricity from nuclear power, above the global average.

Fossil generation provided 29% of the EU's electricity, half of the global average of 59%. The main difference was a much lower share of coal generation. Coal generation fell to below 10% (9.8%) of total EU electricity generation, compared to the global average of 34%.



The carbon intensity of electricity generation in the EU was 213 gCO2 per kWh in 2024, less than half the global average (473 gCO2/kWh).

The EU's per capita power demand was 6.1 MWh, 60% higher than the world average and half the demand per capita of the United States.



The low CO2 intensity and demand per capita meant that the EU's per capita power sector emissions were 1.3 tonnes of CO2 (tCO2), 28% less than the world average of 1.8 tCO2 and about one third of those in China and the United States.

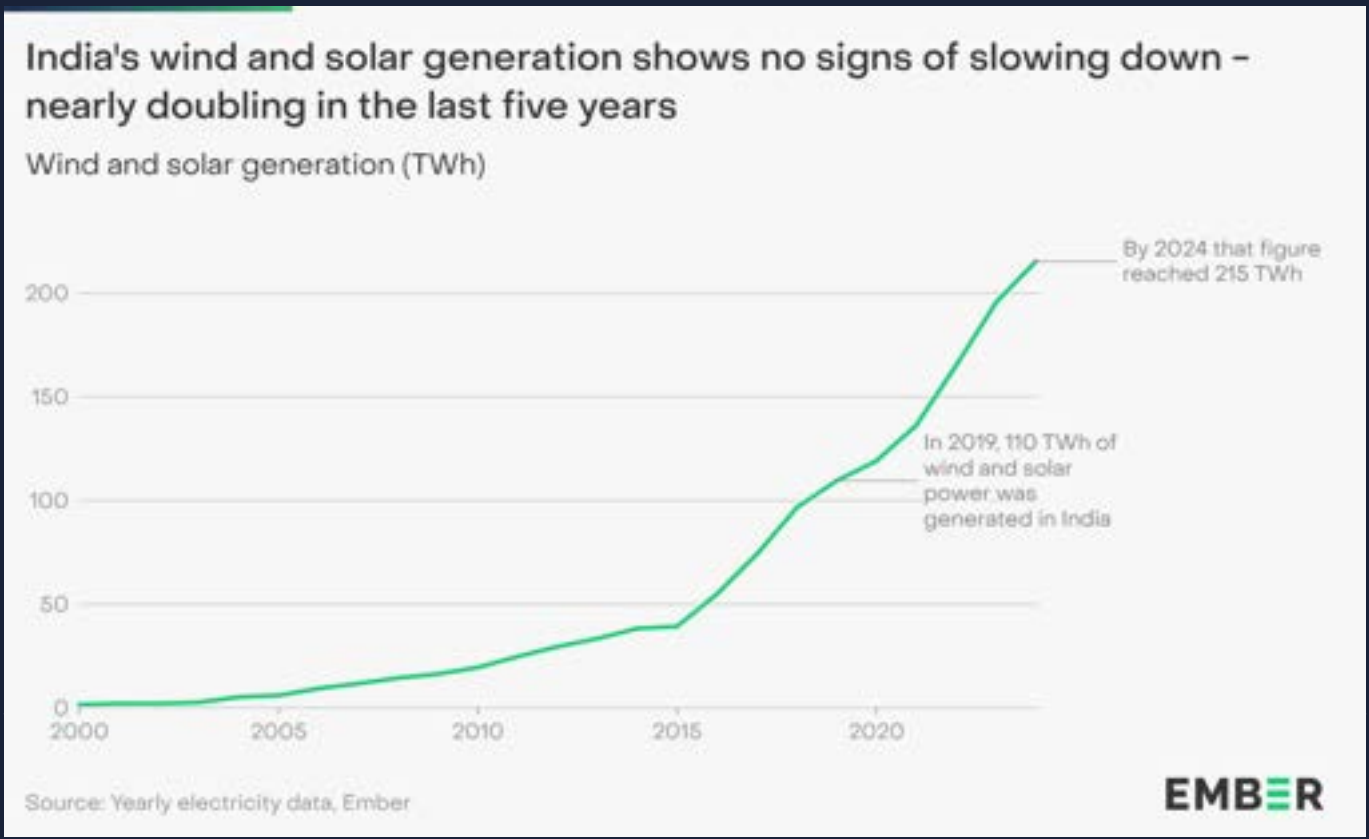
5.4 India

Key highlights

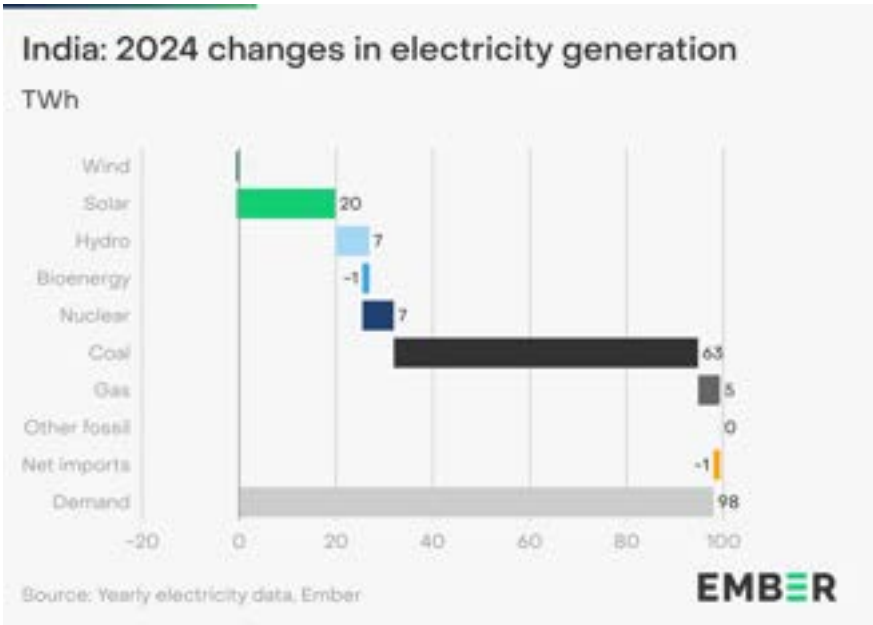
01 **India’s wind and solar generation doubled in the five years leading to 2024**

02 **India overtook Germany to become the world's third largest generator of electricity from wind and solar in 2024**

03 **Coal generation growth met 64% of India’s electricity demand growth in 2024, a substantial decline from the 91% in 2023**



India's power demand increased by 5% (98 TWh) in 2024, slightly less than the 7% growth in 2023, and in line with the country's average annual demand growth rate for the last decade (+5.5%). India had the third-largest demand increase in the world.



Clean generation increased by 32 TWh (+7.4%) in 2024, meeting 33% of India's demand increase. The clean generation increase was in part due to a rebound of hydro (+7 TWh, +4.7%) after a decline of 26 TWh in 2023.

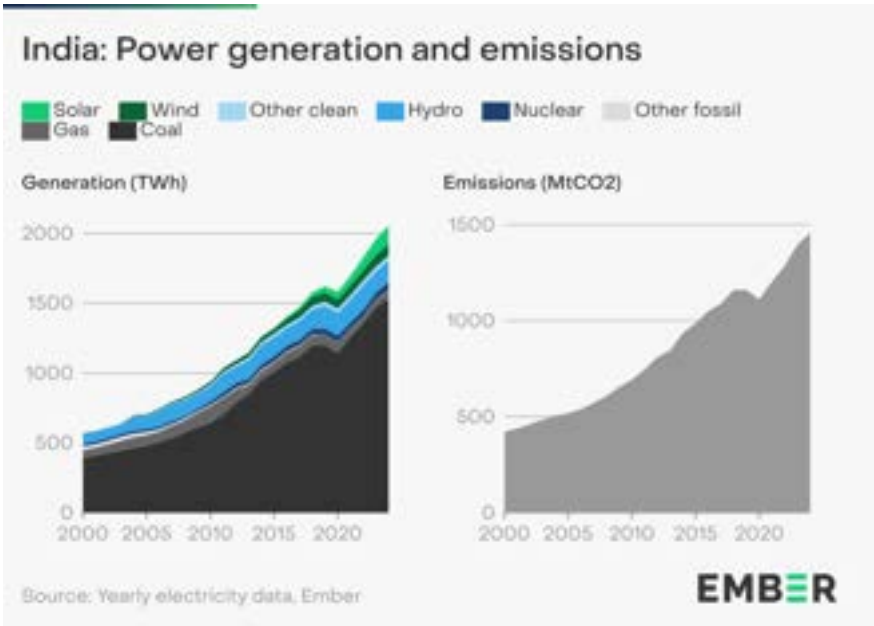
India recorded the fourth-largest increase in solar generation of any country in 2024 at 20 TWh (+18%), more than the total solar generation of the United Kingdom. This was driven by record capacity additions in 2024, more than double the additions in 2023. However, lower solar radiation meant that the generation increase seen in 2024 did not fully reflect the impact of this capacity boom.

Fossil generation increased by 67 TWh (+4.4%) in 2024, significantly lower than 2023's figure of 124 TWh (+8.8%). Coal generation grew by 4.3% in 2024, almost half the average of the prior three years (8.8%). Coal generation growth met 64% of India's electricity demand growth in 2024, a substantial decline from the 91% in 2023.

India's demand had been rising by more than 7% every year since the Covid-19 decline of 2020, but in 2024, demand growth fell back to the historic ten-year trend of around 5%.

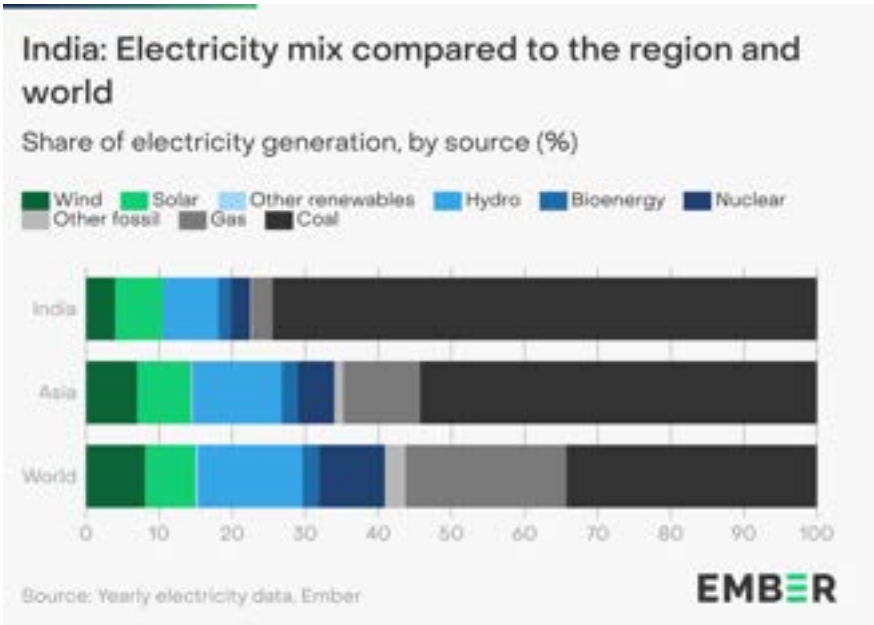
India's wind and solar generation almost doubled over the five years leading to 2024, from 110 TWh to 215 TWh. As a result, India overtook Germany in 2024 to become the world's third largest generator of electricity from wind and solar. Hydro generation in 2024 was roughly the same as five years ago, and nuclear power increased by 10 TWh (+21%) over the same period.

India's coal-fired power generation also continued to rise, almost doubling from 2012 (787 TWh) to 2024 (1,534 TWh). In 2018, India overtook the US to become the second-largest coal generator, and now has more than twice the coal generation of the US.



As a result, power sector emissions continue to rise, reaching 1,457 MtCO2 in 2024. This makes India the world's third-largest power sector emitter, although emissions per capita remain well below the global average.

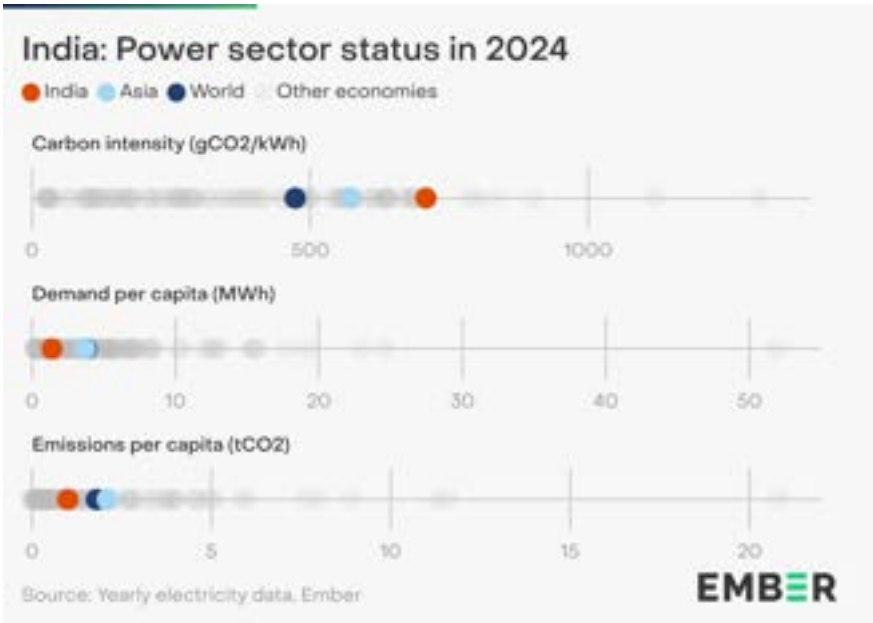
India is one of only ten countries that is currently planning for a tripling of renewables capacity by 2030 (from 2022), with the goal of reaching 500 GW of clean power capacity. By October 2024, the country had achieved 200 GW of RE capacity. India is focused on domestic policies that support solar modules, batteries, and electrolysers to support the energy transition, while meeting development milestones such as the recent delivery of 100% electricity access.



India generated 78% of its electricity from fossil sources in 2024, primarily driven by coal at 75%. This is above the 66% regional average for Asia and well above the 59% global average.

Clean generation made up 22% of India's electricity mix in 2024. Hydro was India's largest clean electricity source at 8%. Solar and wind combined reached 10% in 2024. However, this is still below the global average (15%) and China (18%).

The carbon intensity of India's power sector was 708 gCO2/kWh in 2024. This is higher than both the average in Asia of 573 gCO2/kWh and the global average of 473 gCO2/kWh.



Despite having the third-highest demand of any country, the electricity demand per capita was 1.4 MWh, less than half of the Asian regional average of 3.7 MWh and the global average of 3.8 MWh.

India's electricity is heavily coal-reliant. However, the low per capita electricity use meant that India's per capita emissions were 1 tCO2, much lower than the global average (1.8 tCO2).

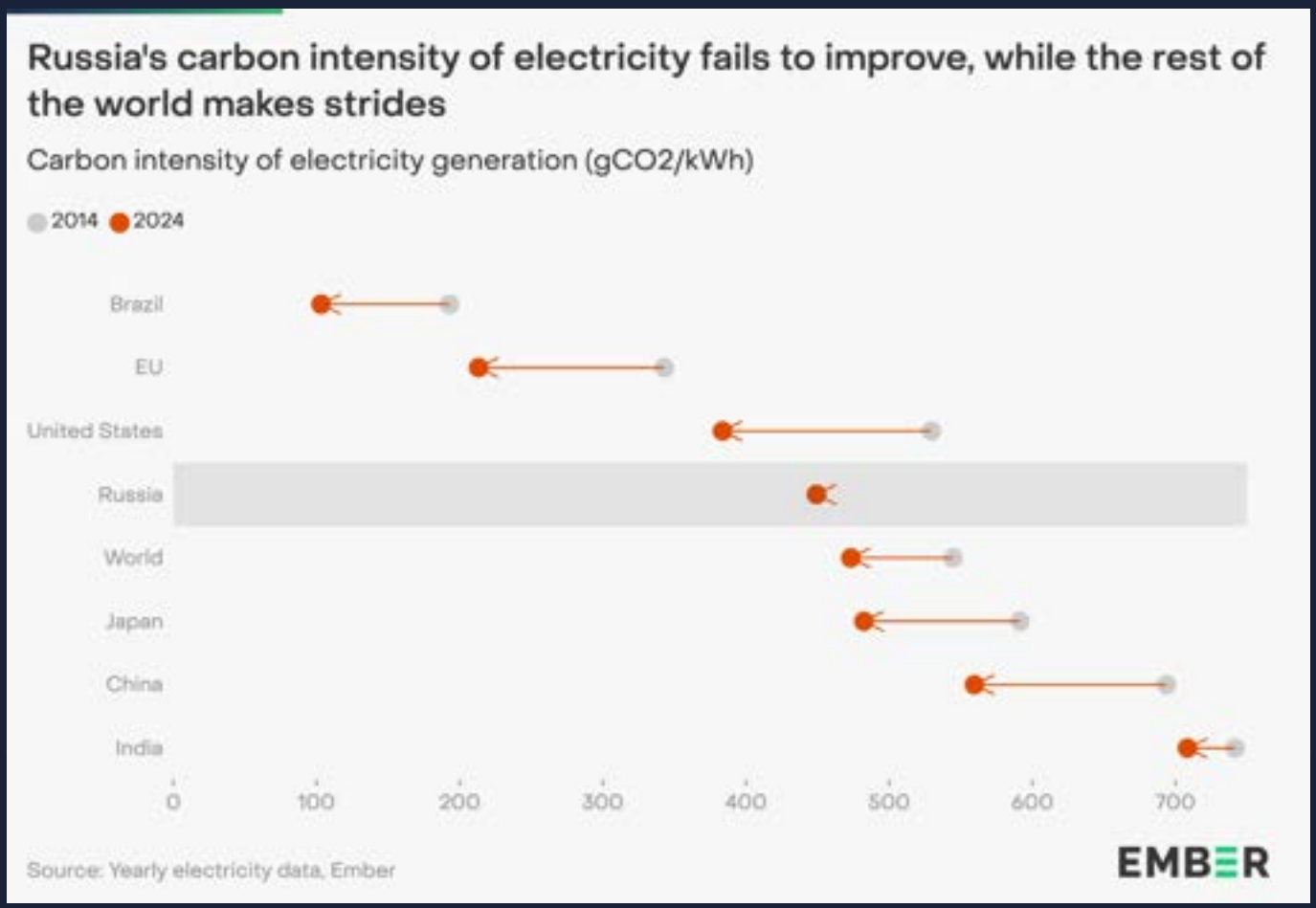
5.5 Russia

Key highlights

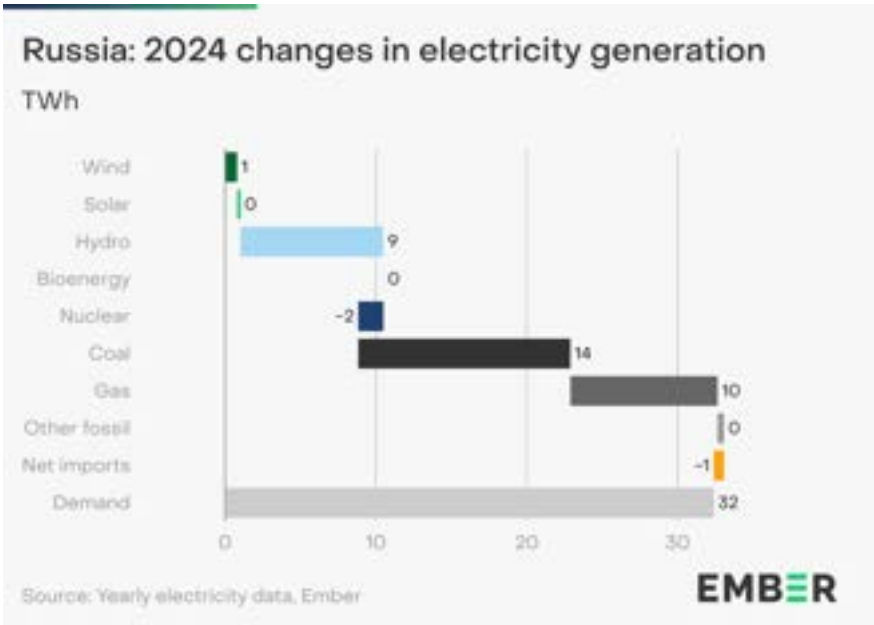
01 **Russia set a new record high for both coal and gas generation in 2024**

02 **Wind and solar accounted for less than 1% of Russia's electricity mix, the second-lowest share in the G20**

03 **The carbon intensity of Russia's electricity generation in 2024 remained unchanged from a decade ago**



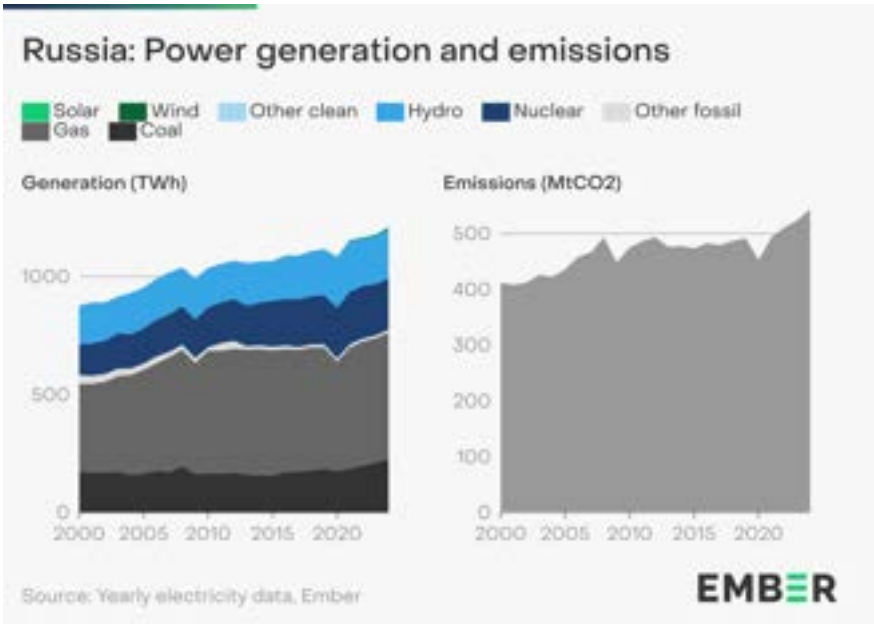
Demand in Russia grew by 32 TWh (+2.8%) in 2024, lower than the global demand increase of 4%. Excluding the 5.7% rise in 2021, following the Covid-19 pandemic, this was Russia's highest demand increase since 2010. Fossil generation met most of this increase, with a 14 TWh (+6.7%) coal rise and a gas increase of 9.8 TWh (+1.9%).



Hydro increased by 9.5 TWh (+4.7%) in 2024, following a 3.2 TWh (+1.6%) increase in 2023. Nuclear saw a small decline of 1.7 TWh (-0.8%) in 2024.

Wind and solar only play a small role in Russian generation. Wind saw a 0.8 TWh increase and solar generation grew by 0.2 TWh.

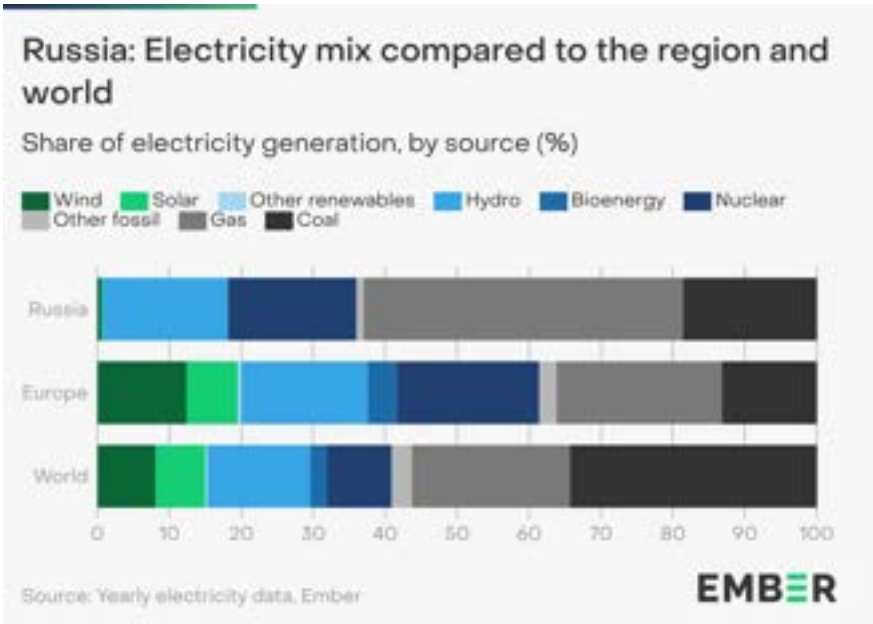
Russia set a new record for both coal and gas generation in 2024, with fossil generation continuing to meet growing electricity demand. As a result, Russia was the world's fourth-largest power sector emitter with a total of 544 million tonnes of CO2 (MtCO2) in 2024.



Power sector emissions in Russia had been relatively flat from 2013 until they dropped due to Covid-19 restrictions in 2020, but have been on a steady increase since then. Emissions were up by 20 MtCO2 in 2024, an increase of 3.8% over 2023, more than double the global average.

Nuclear and hydro generation have been rising in Russia. In 2024, nuclear generation was 10% higher than in 2015, though falling slightly in market share. Partly due to higher rainfall, hydro generation was 25% higher in 2024 compared to 2015. Solar and wind remained a tiny part of the electricity mix.

Russia has not started its clean energy transition. Its share of wind and solar generation combined was less than 1% of its total power mix, the second-lowest in the G20. Russia lags well behind the European average (20%), China (18%), and the global average of 15%.

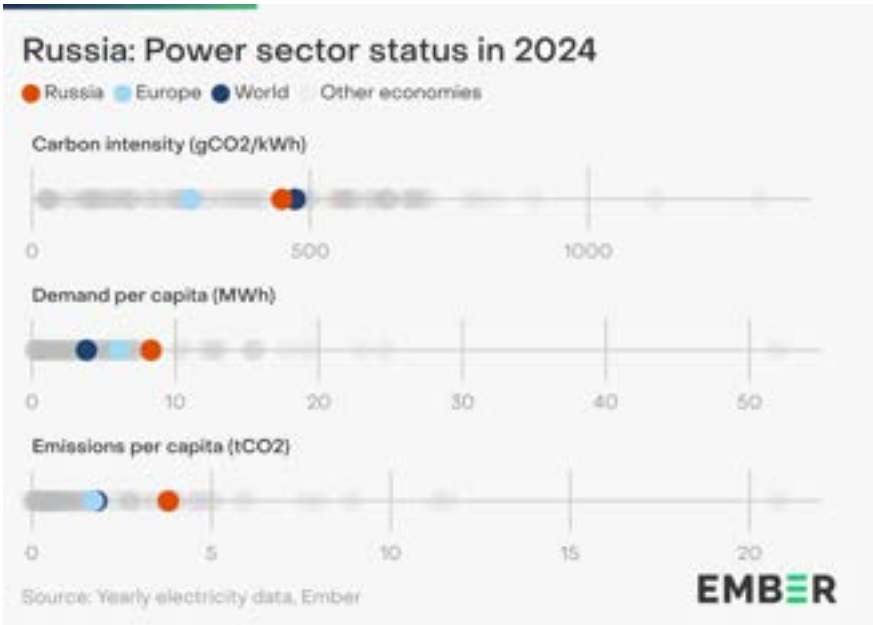


Fossil fuels made up 64% of Russia's electricity mix in 2024. Gas made up the largest share at 44%, followed by coal which accounted for 19% of the country's electricity generation. Clean power made up 36% of the electricity mix with nearly all of it coming from hydro and nuclear, contributing 17% and 18% respectively.

Russia's carbon intensity of electricity was 449 gCO2/kWh in 2024, just below the global average of 473 gCO2/kWh.

Russia's demand per capita was 8.3 MWh, more than twice the global average of 3.8 MWh.

As a result of the relatively high demand, Russia's power sector emissions per capita in 2024 were 3.8 tCO2, more than double the global average of 1.8 tCO2.



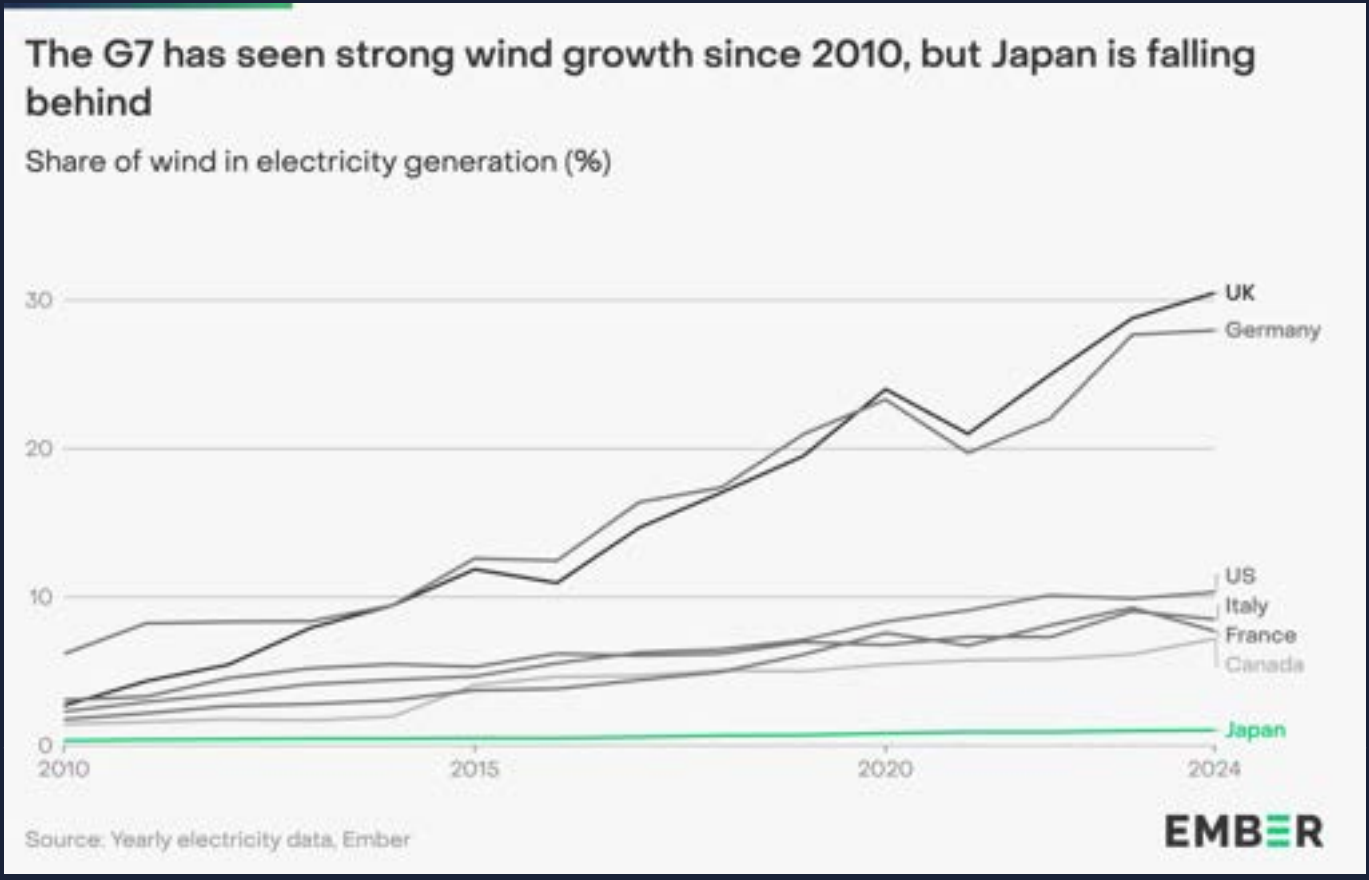
5.6 Japan

Key highlights

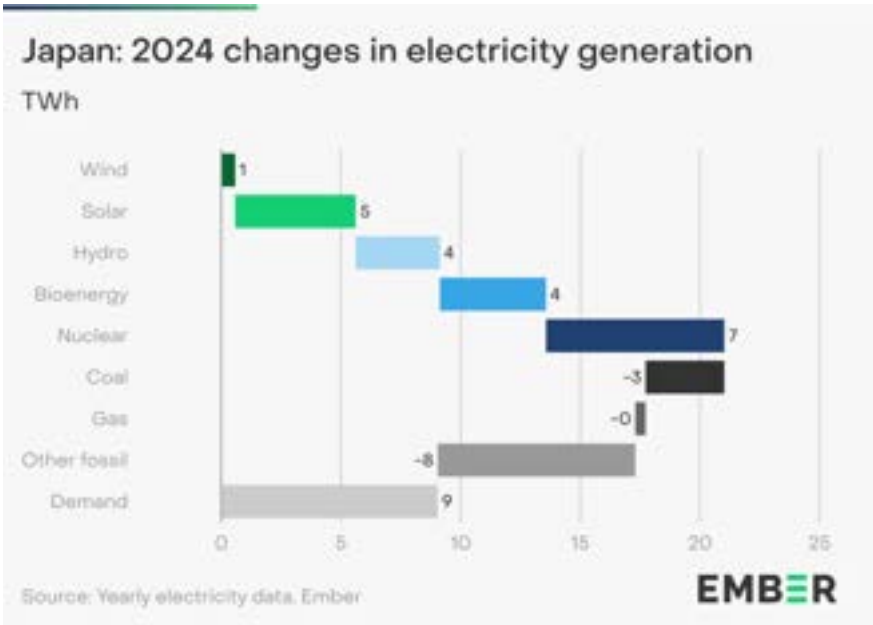
01 **Wind power has grown significantly in all G7 countries except Japan**

02 **Japan remained the fourth-largest solar generating country globally**

03 **Japan's power sector emissions fell by 1.4% in 2024**

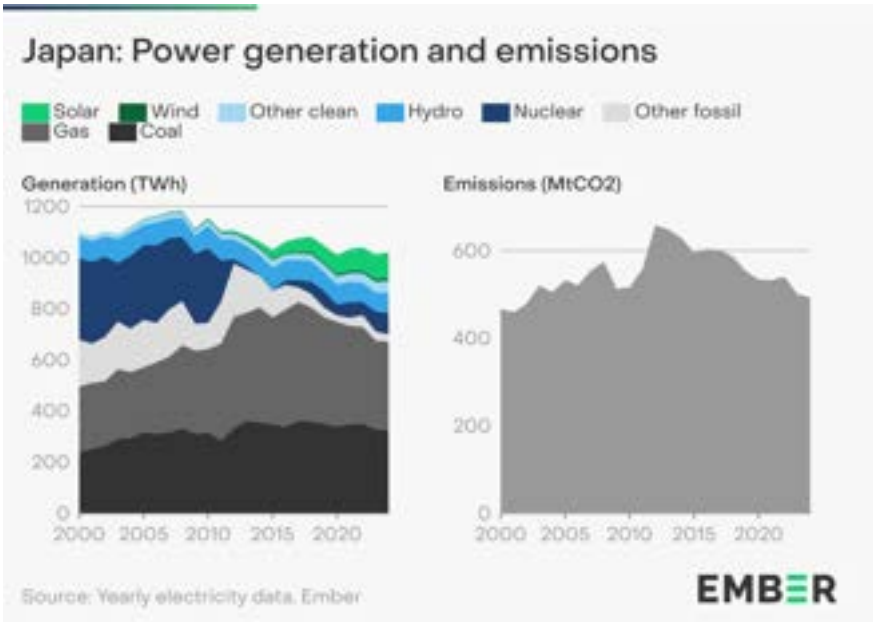


In 2024, Japan's power demand increased by 9 TWh (+0.9%), in part as a result of hotter temperatures in summer months. Fossil generation fell by 12 TWh (-1.7%). This was much lower than the fall in fossil generation in 2023 (-63 TWh, -8%).



Japan's clean generation growth was led by an increase in nuclear generation (+7.5 TWh, +9.6%) and solar (+5 TWh, +5.2%). Overall clean generation was up by 21 TWh (+7%), just over half of the increase in 2023 (+36 TWh; +13.6%).

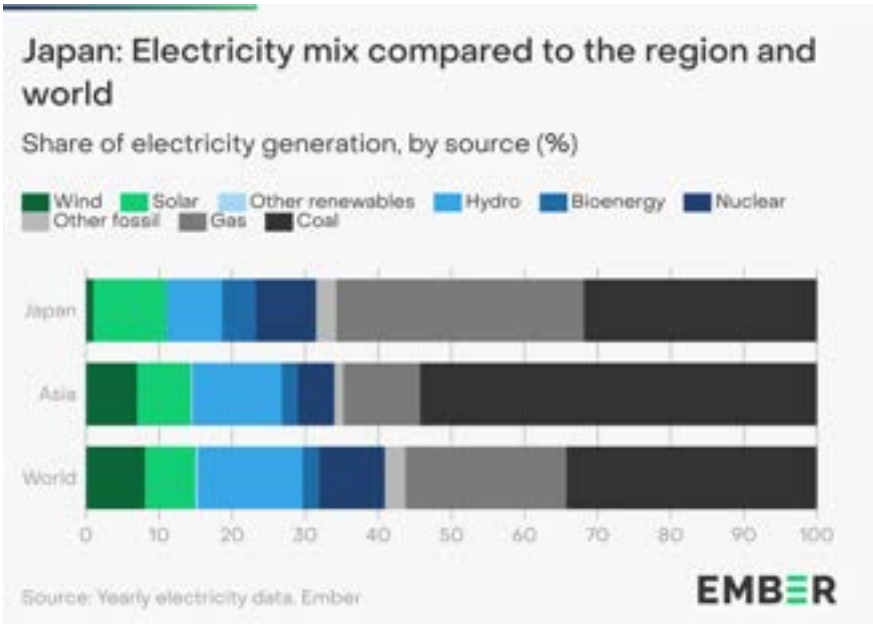
Japan's power sector emissions peaked in 2012 and have declined 25% since then, reaching 493 million tonnes of CO2 (MtCO2) in 2024. This was the lowest value in the past 22 years, but still slightly higher than in 2000. This is because coal and gas still generate around two-thirds of Japan's electricity, though in recent years they have been increasingly replaced by nuclear and solar.



Solar's share in the mix has grown significantly in Japan, rising fivefold from 2% of generation in 2014 to 10% in 2024. On the other hand, wind was just 1% of generation in 2024. This is in stark contrast to the rest of the G7, where wind has risen to an average of 12% of total electricity generation.

Nuclear generation has grown in recent years owing to the reopening of reactors closed following the Fukushima nuclear disaster. Two units reopened in 2024. However, due to the slow recovery of nuclear power and the lack of wind power, Japan produced less clean electricity in 2024 (322 TWh) than it did in 2000 (420 TWh).

Japan's largest source of clean electricity was solar (10%) in 2024. However, despite significant wind potential, its share of wind is only 1%. As a result, the wind and solar share was only 11% in 2024, below the global average (15%), regional average (14%), and its neighbour China (18%).

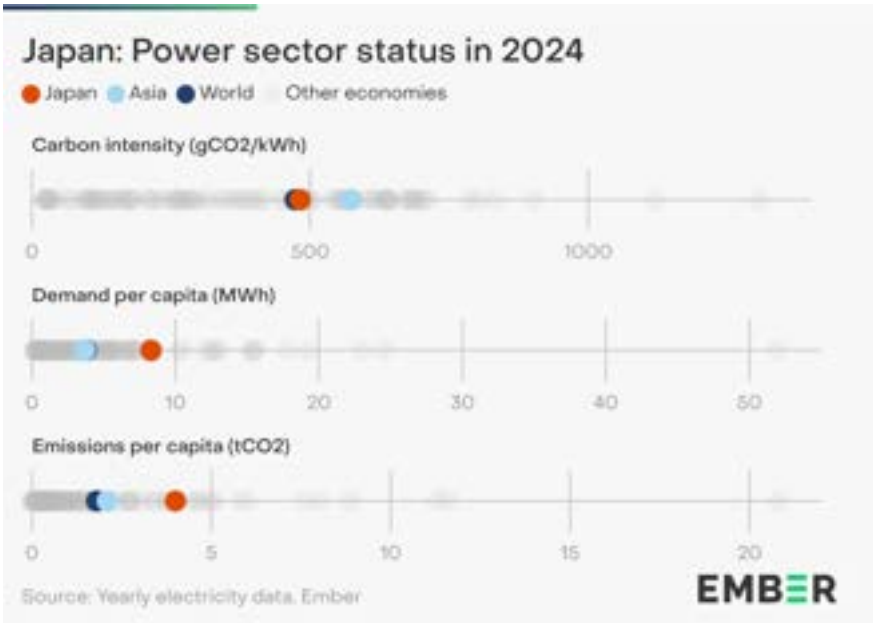


In 2024, Japan relied on fossil fuels for 69% of electricity generation. This is more than the regional average of 66% and global average of 59%.

The share of nuclear in electricity generation was 8.3%, up from 7.6% in 2023 due to the restart of additional nuclear reactors in 2024. There are currently 10 reactors under review for potential restart, and the recent 7th long-term strategic energy plan aims for 20% nuclear share in generation by 2040.

The carbon intensity of Japan's power sector was 482 gCO2/kWh in 2024, virtually unchanged from 2023, and just above the global average of 473 gCO2/kWh. Due to the lower contribution of coal in Japan as compared to most of Asia, its carbon intensity was lower than the Asian regional average of 573 gCO2/kWh.

However, Japan's emissions per capita of 4 tCO2 were more than twice the global average of 1.8 tCO2 and almost twice the regional average of 2.1 tCO2. This is primarily due to Japan's large demand per capita at 8.3 MWh.



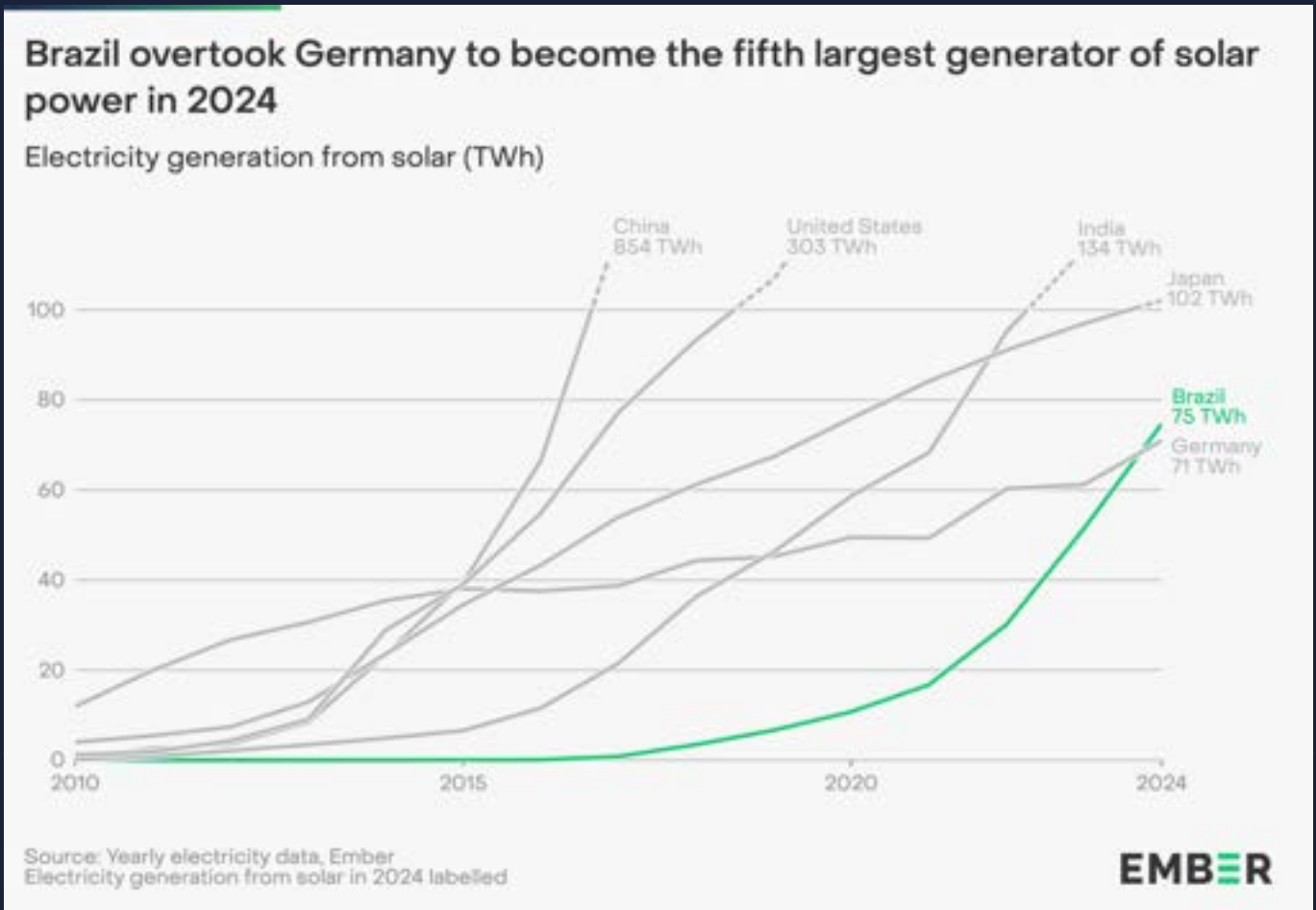
5.7 Brazil

Key highlights

01 **In 2024, Brazil had the world's third-largest increase in both wind and solar generation**

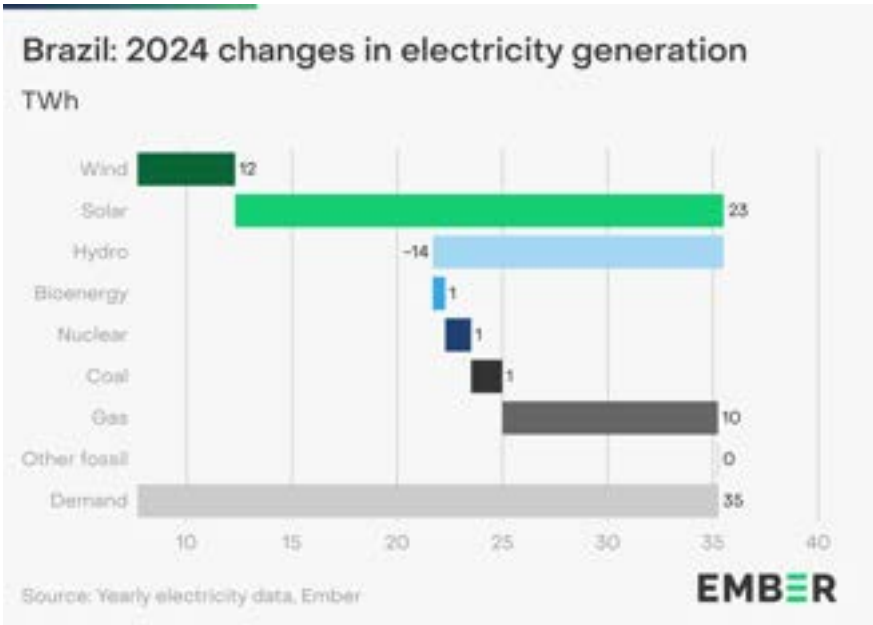
02 **Brazil has overtaken Germany to become the fifth-largest solar generator**

03 **Brazil's power sector emissions peaked a decade ago, and in 2024 were down 32% from 2014**



Electricity demand in Brazil was up by 35 TWh (+4.9%) in 2024, similar to the demand increase in 2023 (+35 TWh, +5%). Both years' increases were triple that of 2022 (+11 TWh, +1.6%).

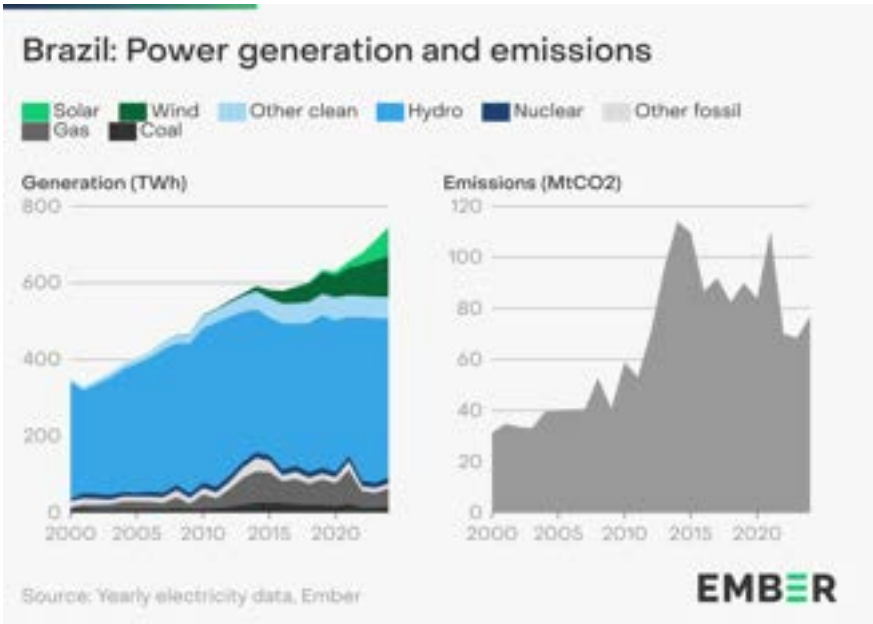
Brazil's demand increase was primarily met by solar (+23 TWh, +45%) and wind (+12 TWh, +13%). Its increase in solar generation was the third-largest of any country in 2024.



Brazil became the fifth-largest solar generator in 2024, surpassing Germany in the global rankings. Brazil also had the third-largest increase in wind generation in 2024, maintaining its fourth place globally in terms of total annual wind generation.

Hydro generation was down 14 TWh (-3.2%) in 2024 due to an intense and widespread drought. Brazil's fossil generation increased by 12 TWh (+18%), primarily due to gas increasing by 10 TWh (+27%), countering the fall in hydro generation.

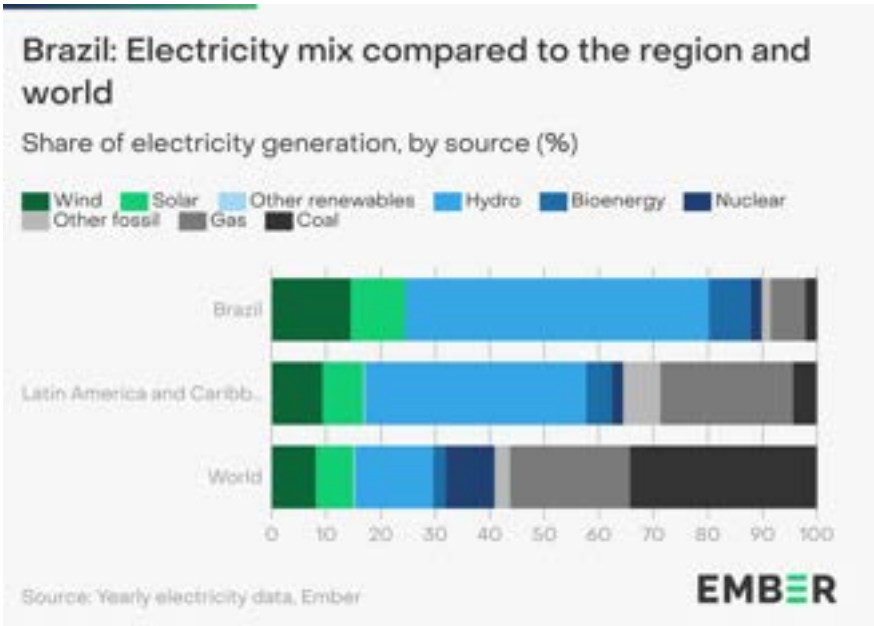
Brazil has a high share of renewables due to its large hydroelectric base and the rapid expansion of solar and wind power in recent years. Its share of wind and solar has been growing rapidly in recent years, reaching 24% in 2024, a substantial increase from 17% in 2022 and up from just 5.8% in 2016.



Brazil's power sector emissions peaked in 2014 at 114 million tonnes of CO2 (MtCO2). Growing wind and solar have since reduced the need for fossil power. In 2024, a decade past the peak, its power sector emissions were 32% below 2014 levels, at 77 MtCO2.

Brazil's power sector emissions have fluctuated since the peak due to variability in weather conditions, with rainfall and drought affecting hydro output. In 2024, drier conditions prevailed and overall, there was a slight decline in hydro generation (-14 TWh) that was almost all offset by rising fossil generation (+12 TWh) such that power sector emissions increased slightly from 2023 to 2024 (+8 MtCO2).

Brazil generated 90% of its electricity from clean sources in 2024, with hydro dominating the mix at 56%. Its share of wind and solar (24%) was above the global average (15%) and the average in Latin America (17%).



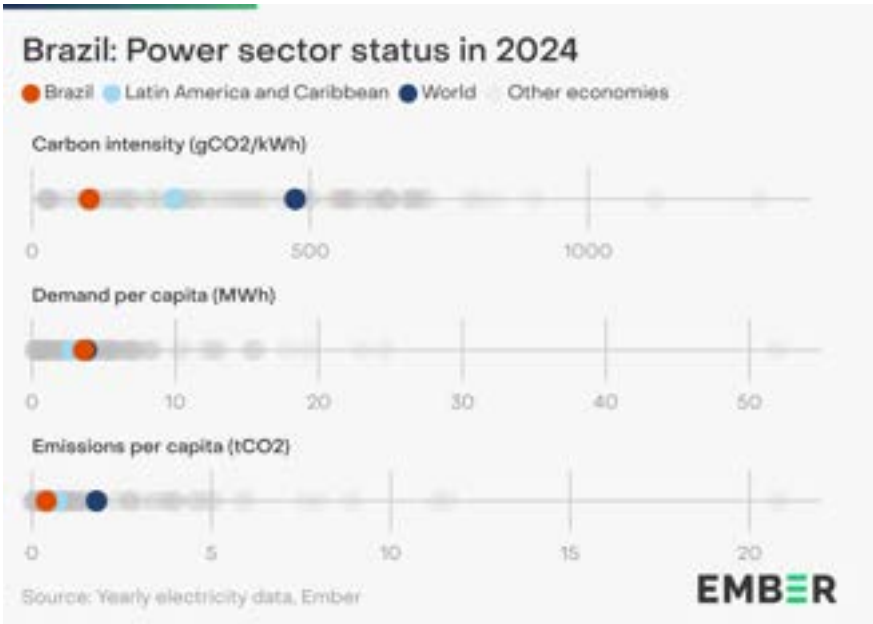
Over 87% of Brazil's electricity came from renewables in 2024, which was by far the highest of any G20 country and almost triple the global average of 32%.

Brazil relied on fossil fuels for just 10% of its electricity in 2024, a sixth of the global average of 59%.

In 2024, Brazil's carbon intensity of electricity generation was 103 gCO2/kWh, the second-lowest in the G20 and less than a quarter of the global average (473 gCO2/kWh).

Brazil's electricity demand per capita was 3.6 MWh in 2024, just below the world average of 3.8 MWh but above the regional average of 2.8 MWh.

Brazil's per capita emissions from electricity generation (0.4 tCO2) are the lowest in the G20 and less than a quarter of the global average of 1.8 tCO2.



Clean power poised to begin the era of fossil fuel decline

In a world of higher electricity demand growth, clean electricity is stepping up to the challenge. Spearheaded by exponential solar expansion, clean power is set to grow faster than demand, marking the start of a permanent decline in fossil generation.

2024 both clarified and consolidated the shape of the global clean power transition. At first glance it might appear an unremarkable year, as global fossil generation increased for another year. However, the main driver of this increase was the change in temperature between 2024 and 2023. Stripping out these temperature effects, clean generation met 96% of the demand increase in 2024. Isolating the trend from the short-term fluctuations, it becomes clear that the world is very close to an era of falling fossil fuel generation.

2024 also cemented solar power as the engine of the global energy transition. Global solar generation increased by nearly a third, continuing its lead as the largest and fastest-growing source of new electricity. Its rise was on display everywhere in 2024, from world leaders like China, India, Brazil and the EU to new markets in Saudi Arabia and Pakistan. The startling expansion and cost reduction of battery storage offer another positive, enhancing the economics of solar power still further.

New drivers of demand – data centres for AI and cryptomining, and electrified transport and heating – raise pressing questions about how to meet rising power consumption. 2024 has shown that solar and batteries, the new engines of growth, are best placed to deliver cheaply and at scale, and are already doing so. While demand growth is undoubtedly going

to be higher than in previous years, Ember's analysis shows that clean growth is set to outpace it, making long-term investments to grow fossil generation a risky bet.

Any near-term increases in fossil fuel generation should not be mistaken for failure of the energy transition. As we pass the tipping point where clean generation structurally outpaces demand growth, any changes to fossil fuel generation over the short-term will mostly reflect fluctuations in weather, as seen in 2024 with the impacts of heatwaves. But while changes in fossil generation in the short-term may be noisy, the direction and ultimate destination are unmistakable. The global energy transition is no longer a question of if, but how fast.

The significant advances of 2024 were achieved despite unfavourable geopolitical headwinds. In 2025 those winds are strengthening again, with an increased prospect of tariffs on international trade and a US administration pinning its energy hopes on fossil fuels. However, while playing an important role, the US is not the central driver of the global clean energy transition – this role has fallen more and more to China. China registered more than half of the global increase in both solar and wind power in 2024 and is the world leader in both clean energy manufacturing and deployment. There is no indication that China is slowing its own transition to an electrified economy, nor that its trade relationships with other Global South countries will do anything but intensify.

Beyond China, the rapid clean energy build registered by India, Brazil and the EU is a sign that other major economies are forging ahead. Notably, India is rapidly expanding its own solar and battery manufacturing sector. Meanwhile, uncertainties over trade relations with the US are likely to increase many governments' appetite for the clean energy transition, in regions including Europe and Latin America, because it offers a route to reduced dependence on volatile global markets for coal and gas.

The imperative for the energy transition is clear: the world is upgrading from an inefficient energy system reliant on securing a constant supply of expensive and polluting fossil fuels. In the new energy system, electricity will be at the heart, with clean electrons powering everything from transport to steel production. Solar and wind, backed by a suite of clean flexibility solutions like improved grids and storage, will be the engine powering the world. 2024 shows unmistakably that the transition to this new energy system is very much underway. Governments and businesses that act decisively to embrace clean energy and quickly move away from fossil fuels will be rewarded with a more resilient, competitive, and secure energy future.

Methodology

Generation, imports and demand

Yearly data from 2000 to 2023 is gross generation, taken primarily from the Energy Institute's Statistical Review of World Energy, the Energy Information Administration (EIA), Eurostat and IRENA. 2024 data is an estimate of gross generation, based on generation gathered from monthly data. This estimate is calculated by applying absolute changes in monthly generation to the most recent annual baseline.

Net imports from 1990 to 2023 are taken from the EIA and Eurostat, with recent data estimated in the same manner as generation. Demand is calculated as the sum of generation and net imports, and where possible validated against published direct demand figures. Because it uses gross generation and does not include transmission and distribution losses, it will tend to be higher than end-user demand.

Monthly data is gathered for 88 countries from over 70 sources, including national transmission system operators and statistical agencies, as well as data aggregators such as ENTSO-E. In some cases, data is published on a monthly lag; here we have estimated recent months based on our generation model.

Monthly data is often reported provisionally, and is far from perfect. Every effort has been made to ensure accuracy, and where possible we compare multiple sources to confirm their agreement.

Bioenergy has typically been assumed (by the IPCC, the IEA, and many others) to be a renewable energy source, in that forest and energy crops can be regrown and replenished, unlike fossil fuels. It is included in many governmental climate targets, including EU renewable energy legislation, and so Ember includes it in "renewable" to allow easy comparison with legislated targets. However, we recognise the IPCC reported lifecycle carbon intensity of bioenergy is significantly higher than other renewables and nuclear, and this is incorporated into our power sector emissions estimate. More information about Ember's classification of electricity sources can be found in the full methodology for Ember's Yearly Electricity Data under "Fuel Types".

References to CO2 emissions in this report are using CO2 equivalent emissions which include emissions from other greenhouse gases such as methane (CH4). Power sector emissions are based on the methodology from Ember's Yearly Electricity Data which can be found here.

Calculation of temperature impacts on electricity demand

This methodology outlines the approach used to quantify the impact of temperature on global electricity demand. By using regression analysis with temperature data and monthly electricity demand, this analysis isolates temperature-driven variations from structural changes in electricity consumption.

Geographic coverage
The analysis aims to deliver a global level account of temperature effects on demand. For this purpose, it includes country/region-level analysis for 14 countries and regions. The analysis was carried out for Australia, Brazil, Canada, China, the EU, India, Iran, Japan, Mexico, Russia, South Africa, South Korea, Türkiye, the United Kingdom and the United States. Together, these power sectors accounted for 82% of global electricity demand. The assessed impact in included countries is scaled to match 100% of global demand.

Data Sources
Meteorological Data: Temperature data was sourced from the ERA5 reanalysis via Open-Meteo, providing hourly 2-metre temperature.

Electricity Demand Data: Monthly electricity demand data was obtained from Ember's Monthly Electricity data.

Population Data: Population figures were derived from NASA's Gridded Population of the World dataset, with a resolution of 0.25 degrees (~30 km).

Time Period: The analysis of temperature effects covers the period from 2015 to 2024, depending on the availability of data for each country.

Normalising Monthly Electricity Demand
Monthly electricity demand was normalised by dividing observed demand by its 12-month trailing average. This process helps to minimise the influence of long-term structural factors such as economic growth or increased electrification, isolating seasonal and temperature-related changes.

Temperature Data
A 1-degree resolution grid was created for each country. Population data was assigned to each grid cell, and hourly temperature data was extracted for the centre of each cell.

Population Weighting for temperature and CDD/HDD values
Population weighted temperatures were calculated by weighting temperature for each grid cell by the corresponding population.

Similarly, cooling degree days (CDD) and heating degree days (HDD) values were calculated and weighted using the same approach. This ensures that temperature metrics reflect conditions in populated areas, where electricity demand is concentrated. It also accounts for the non-linear relationship between temperature and energy use. Cooling degree days and Heating degree days were defined as follows:

- Cooling degree days (CDD): The sum of degrees by which daily temperatures exceed 22°C, reflecting cooling demand.

- Heating degree days (HDD): The sum of degrees by which daily temperatures fall below 18°C, reflecting heating demand.

Regression Analysis
To understand the relationship between temperature and electricity demand, we used regression analysis to identify how changes in temperature, measured through cooling degree days and heating degree days, influence electricity demand per country. The

analysis helps quantify the extent to which higher or lower temperatures drive changes in monthly electricity use.

Calculating Anomalies
Monthly temperature, HDD and CDD anomalies were calculated with respect to a ten-year baseline (2015-2024). Using a relatively short and recent baseline makes the anomalies more relevant to recent changes in electricity demand.

Calculating Absolute Impact
The impact of temperature on demand was derived by applying the identified relationship of CDD and HDD data and monthly electricity demand to the CDD and HDD anomalies. These were then scaled by normalised demand into absolute impacts in TWh. For some countries, monthly demand reporting can be lower than annual reported values. Where applicable, temperature impact values derived from monthly data were scaled to match annual demand figures. Combined country level assessments for the 15 included regions were aggregated and scaled to match total global electricity demand of all countries in 2024.

Demand disaggregation

Electricity demand growth from EVs is estimated from changes in EV stock by vehicle type, multiplied by reference values for electricity consumption by vehicle type. Vehicle types include passenger cars, buses, trucks and vans, for both battery electric vehicles and plug-in hybrid electric vehicles. Historic stock data is taken from the IEA's Global EV Data Explorer. Demand growth in 2024 is estimated using sales data for passenger cars taken from BNEF, and assumes recent growth rates are maintained across other vehicle types.

Electricity demand growth from data centres (including cryptocurrency mining) is estimated using IEA data. As IEA data only goes back to 2019, the same value for demand growth was used in 2019 as in 2020, based on the assumption that growth at this point in time was linear (see assessment of historic estimates from Lawrence Berkeley National Laboratory). For 2023-2024, IEA projections for cryptocurrency mining have been substituted for real data from Cambridge University's Cambridge Bitcoin Electricity Consumption Index (CBECI) to more accurately estimate cryptocurrency mining electricity consumption growth for recent years. The estimates for cryptocurrency mining electricity demand growth are estimated using growth in Bitcoin electricity demand, scaled to fit estimates for total crypto demand in

2022. Bitcoin makes up the large majority of proof-of-work cryptocurrency mining activity and other cryptocurrencies based on proof-of-stake mechanisms use considerably less energy.

Electricity demand growth from heat pumps is estimated using changes in stock data, multiplied by annual average consumption. Data for 2024 assumes that the reduction in sales in key markets seen in the first half of 2024 continued throughout the rest of the year.

Other data sources

This report makes use of a variety of datasets curated by Ember, including data on exports of Chinese solar PV modules and global solar capacity installations.

A full methodology for Ember's data on exports of Chinese solar PV modules can be found here.

Solar capacity additions are estimated using available monthly capacity data from national sources for countries that made up 80% of solar capacity additions in 2023. National monthly data is generally available for all of 2024, with exceptions for a few countries where the final months of 2024 are estimates based on market growth rates in available months. Estimates for remaining countries are made through analysis of Chinese solar PV module export data. A full methodology can be found here.

Acknowledgements

Lead Authors
Nicolas Fulghum, Euan Graham

Other authors
Katye Altieri

Data visualisation
Chelsea Bruce-Lockhart, Lauren Orso

Project Manager
Josie Murdoch

Editors
Richard Black, Hannah Broadbent

Other contributors
Aditya Lolla, Ardhi Arsala Rahmani, Beatrice Petrovich, Claire Kaelin, Dave Jones, Eva Mbengue, Kavya Sharma, Libby Copsey, Matt Ewen, Neha Rajput, Phil MacDonald, Rashmi Mishra, Reynaldo Dizon, Rini Sucahyo, Sachin Sreejith, Sam Hawkins.

Peer reviewers
A.K. Saxena (TERI), Bryony Worthington (Ember), Hannah Ritchie (Our World in Data), Harry Benham (Ember), Kingsmill Bond (Ember), Nathaniel Bullard (Business Climate Pte. Ltd), Xunpeng 'Roc' Shi (UTS/ISETS).

Cover image
The cover of this report was designed by Reynaldo Dizon and is based on real data used for the analysis within this report, showing growth in solar power across the world – as a share of generation, and in absolute terms – over the past five years.

© Ember, 2025

Published under a Creative Commons ShareAlike Attribution Licence (CC BY-SA 4.0). You are actively encouraged to share and adapt the report, but you must credit the authors and title, and you must share any material you create under the same licence.