

# Global Electricity Review 2023

The background of the cover features a large, semi-transparent image of a wind turbine. Overlaid on the bottom right is a green network graphic consisting of interconnected nodes and lines, resembling a power grid or data network.

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Wind and solar reach record high in 2022, and expected to drive falling emissions as soon as 2023.

April 2023



## About

Ember's fourth annual Global Electricity Review aims to provide the most transparent and up-to-date overview of changes in global electricity generation in 2022 and a realistic summary of how "on track" the electricity transition is for limiting global heating to 1.5 degrees.

The report analyses electricity data from 78 countries representing 93% of global electricity demand and includes estimated changes in the remaining generation. It also dives deeper into the top ten CO<sub>2</sub> emitting countries and regions, accounting for over 80% of global CO<sub>2</sub> emissions.

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

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## Cover image

A fishing boat passes by wind turbines whirling to generate electricity at an offshore wind farm in Nantong, east Chinas Jiangsu province.

Credit: [Imagechina Limited](#) / Alamy Stock Photo

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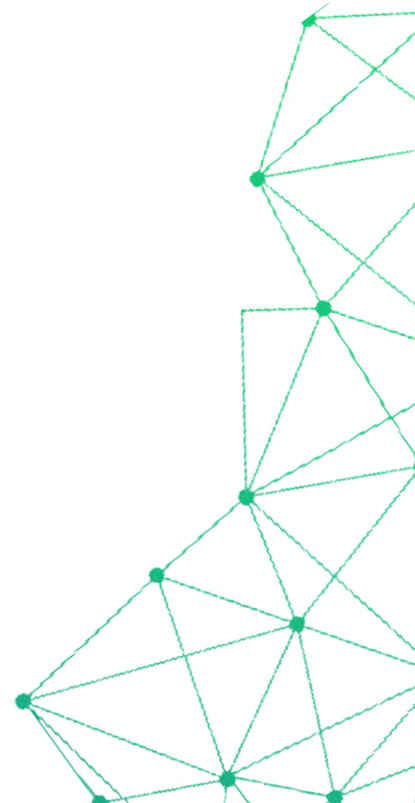
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# Highlights

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**+19%**

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Change in global wind and solar generation

**+1.1%**

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Change in global coal generation

**-0.2%**

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Change in global gas generation



## Foreword

# A new era of clean power – no more excuses

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**Chile's Minister of Energy, Diego Pardow, and Ember's Non-Executive Chairs, Baroness Bryony Worthington and Harry Benham, reflect on the findings of the Global Electricity Review and the journey ahead as the world transitions to clean electricity.**

“Tracking progress on how our electricity is generated is critical, as it is not only a huge source of greenhouse gases, it is also needed as an enabler of a cleaner and more efficient energy system overall.”

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**Baroness Bryony Worthington**

Ember's Non-Executive Chair



“We still have a long journey to travel, with many challenges ahead and with a clear objective: we must act quickly, always putting people at the centre. There are no more excuses.”

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**Diego Pardow**

Chile's Minister of Energy



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## Significant strides

### Foreword from Ember's Non-Executive Chairs

We are pleased to introduce the Global Electricity Review 2023 from Ember, now in its fourth year, in which we highlight again the continued surge in clean power generation worldwide.

This report showcases the significant strides made in the transition towards a sustainable and decarbonized energy system, and the promising outlook for achieving the critical milestone of peak emissions from the power sector – perhaps in this coming year. Wind and solar are growing at between 15–20% pa based on a 10 year average, so look set to exceed increases in annual electricity demand by the end of 2023.

The world has abundant supplies of wind and solar, and this report documents how, through technical innovation and policy execution, this abundance has been converted into on-the-ground energy supply. Often at a lower cost than fossil fuels and faster than other sources of clean electricity.

Other clean non-fossil fuel technologies are also playing their part – nuclear could be entering a renaissance in some countries but there have also been set backs, as unusual weather affected both hydro and nuclear plant.

Tracking progress on how our electricity is generated is critical, as it is not only a huge source of greenhouse gases, it is also needed as an enabler of a cleaner and more efficient energy system overall. As transport and heat sectors increasingly electrify, demand will increase, providing a stronger investment case for new clean capacity. But fossil fuels are still providing the backbone of the electricity system in many large economies and we need to understand and replicate the underlying success factors for rapid decarbonisation.

Ember is committed to using data analysis to tell the story of the clean transition and to providing insights that can increase the pace of change. We hope you find this report and the underlying public data sets useful and please provide us with feedback so we can continue to improve this publication.

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## No more excuses

### Foreword from Chile's Minister of Energy, Diego Pardow

Last September, when I had been Chile's Minister of Energy for two weeks, I had to travel to the Los Lagos region in the south of the country. In one of the activities on my schedule, I had the opportunity to meet Rodrigo Castillo, owner of a medical supply company who—thanks to a government program—was able to buy an electric car for his deliveries.

In 2019, Rodrigo faced—like the vast majority of Chileans—a significant rise in the price of fossil fuels. Added to this was an increase in inflation, which caused an overall rise in the cost of living for people.

Today, thanks to electrifying his transport, Rodrigo has managed to reduce his expenses by a third, which has made his company more competitive in his region. He is a concrete example of how the transition—in this case through electromobility—can offer not only cleaner cities and better jobs but also concrete improvements for citizens. That is what a green economy is all about.

In recent years, Chile has made important progress with respect to its transition. The latest achievements have positioned Chile as the best emerging country to invest in renewable energies, added to the high penetration of clean energies in our system, with last year's milestone standing out that, for the first time, solar and wind overtook coal in electricity generation.

In that respect, 2023 seems promising at a global level, especially thanks to the prediction of this report, which indicates that emissions from the electricity sector could begin to decrease as of this year. But we still have a long journey to travel, with many challenges ahead and with a clear objective: we must act quickly, always putting people at the centre. There are no more excuses.



## Executive Summary

# Wind and solar reach a record 12% of global electricity in 2022

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**As soon as 2023, wind and solar could push the world into a new era of falling fossil generation, and therefore of falling power sector emissions.**

The global electricity sector is the first sector that needs to be decarbonised, in parallel with electricity demand rising, as electrification unlocks emissions cuts throughout the entire economy. The [IEA Net Zero Emissions](#) scenario points to a 2040 net zero power sector; ten years ahead of a net zero economy in 2050. Tracking the electricity transition, therefore, is critical to assess our climate progress.

The decarbonisation of the power sector is underway, as record growth in wind and solar drove the emissions intensity of the world's electricity to its lowest ever level in 2022. It will be an impressive moment when power sector emissions begin to fall year-on-year, but the world is not there yet, and emissions need to be falling fast.

## 01

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### **Electricity at its cleanest, as wind and solar generate 12% of global power**

The carbon intensity of global electricity generation fell to a record low of 436 gCO<sub>2</sub>/kWh in 2022, the cleanest-ever electricity. This was due to record growth in wind and solar, which reached a 12%

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share in the global electricity mix, up from 10% in 2021. Together, all clean electricity sources (renewables and nuclear) reached 39% of global electricity, a new record high. Solar generation rose by 24%, making it the fastest-growing electricity source for 18 years in a row; wind generation grew by 17%. The increase in global solar generation in 2022 could have met the annual electricity demand of South Africa, and the rise in wind generation could have powered almost all of the UK. Over sixty countries now generate more than 10% of their electricity from wind and solar. However, other sources of clean electricity dropped for the first time since 2011 due to a fall in nuclear output and fewer new nuclear and hydro plants coming online.

## 02

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### **Limited coal increase, gas plateaus**

Power sector emissions rose in 2022 (+1.3%), reaching an all-time high. Electricity is cleaner than ever, but we are using more of it. Coal generation increased by 1.1%, in line with average growth in the last decade. The ‘coal power phasedown’ agreed at COP26 in 2021 may not have begun in 2022, but also the energy crisis didn’t lead to a major increase in coal burn as many feared. Gas power generation fell marginally (-0.2%) in 2022—for the second time in three years—in the wake of high gas prices globally. Gas-to-coal switching was limited in 2022 because gas was already mostly more expensive than coal in 2021. Only 31 GW of new gas power plants were built in 2022, the lowest in 18 years. But 2022 saw the lowest number of coal plant closures in seven years, as countries look to maintain back-up capacity, even as the transition picks up speed.

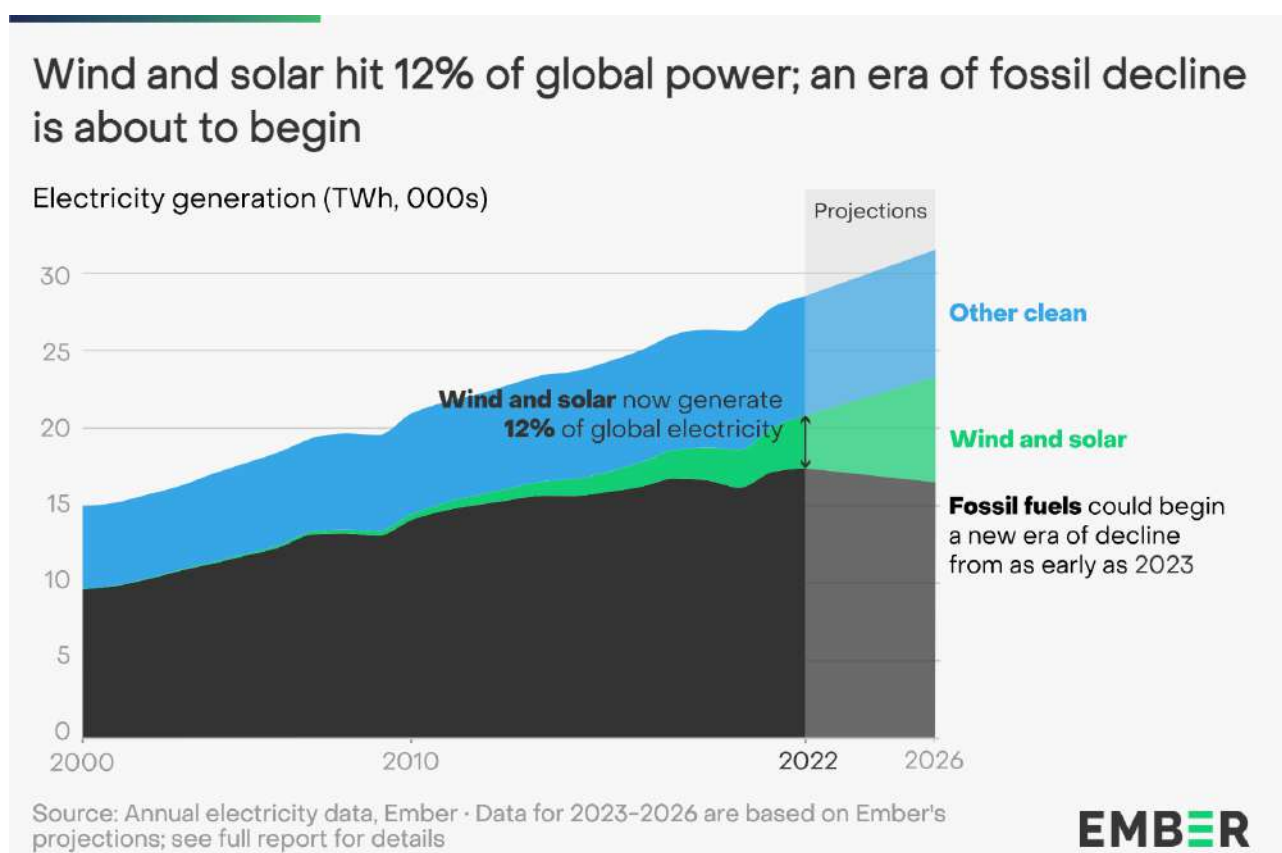
## 03

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### **2022 may be “peak” power emissions**

Wind and solar are slowing the rise in power sector emissions. If all the electricity from wind and solar instead came from fossil generation, power sector emissions would have been 20% higher in 2022. The growth alone in wind and solar generation (+557 TWh) met

80% of global electricity demand growth in 2022 (+694 TWh). Clean power growth is likely to exceed electricity demand growth in 2023; this would be the first year for this to happen outside of a recession. With average growth in electricity demand and clean power, we forecast that 2023 will see a small fall in fossil generation (-47 TWh, -0.3%), with bigger falls in subsequent years as wind and solar grow further. That would mean 2022 hit “peak” emissions. A new era of falling power sector emissions is close.



2022 will be remembered as a turning point in the world's transition to clean power. Russia's invasion of Ukraine made many governments rethink their plans amid spiking fossil fuel prices and security concerns about relying on fossil fuel imports. It also accelerated electrification: more heat pumps, more electric vehicles, more electrolyzers. These will drive reductions in emissions for other sectors, and will put more pressure to build clean power more quickly.

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A new era of falling power sector emissions is very close, thanks to the electricity superpowers of wind and solar. Wind and solar will need to maintain high growth rates this decade, even as they mature. More growth is needed from all other clean electricity sources, while more attention to efficiency is needed to avoid runaway growth in electricity demand. Urgent work is needed on ensuring wind and solar can be integrated into the grid: planning permissions, grid connections, grid flexibility and market design.

Falling fossil generation means not only that the coal power phasedown will happen, but also that—for the first time—a gas power phasedown is now within reach. However, just how quickly power sector emissions will fall is not yet set.

“In this decisive decade for the climate, it is the beginning of the end of the fossil age. We are entering the clean power era. The stage is set for wind and solar to achieve a meteoric rise to the top. Clean electricity will reshape the global economy, from transport to industry and beyond. A new era of falling fossil emissions means the coal power phasedown will happen, and the end of gas power growth is now within sight. Change is coming fast. However, it all depends on the actions taken now by governments, businesses and citizens to put the world on a pathway to clean power by 2040.”

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**Malgorzata Wiatros-Motyka**

Senior Electricity Analyst, Ember



# Achieving clean electricity worldwide by 2040

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The global electricity sector is the biggest CO<sub>2</sub> emitter and the first sector that needs to be decarbonised for the world to achieve net zero, as it helps unlock clean electrification of other sectors. To understand progress on climate goals, we must also closely track the electricity transition.

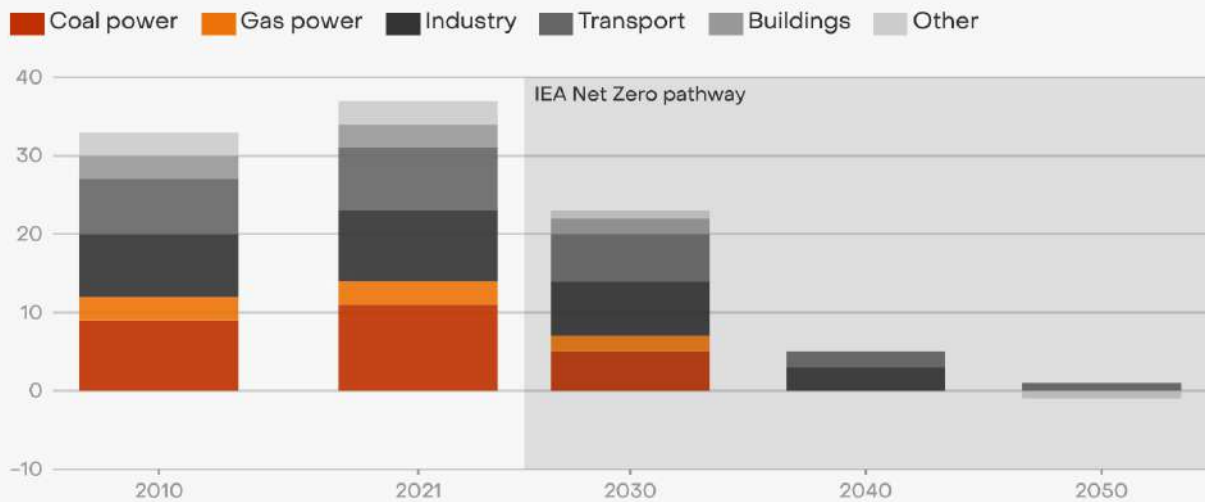
## First sector to hit net zero

The electricity sector needs to move from being the highest emitting sector to being the [first sector to reach net zero](#) emissions globally by 2040 so the world has a chance to achieve economy-wide net zero by 2050.

Electricity generation is the single biggest contributor to global CO<sub>2</sub> emissions, [responsible](#) for over a third of world's total energy related emissions in 2021. As of 2021, about three-quarters of power sector emissions were from coal, and almost a quarter from gas. With proven solutions already available to tackle this challenge, decarbonising the power sector offers one of the most cost-effective routes to achieving rapid emissions reductions.

## Power sector transforms from largest CO2 emitter today to the first sector to reach net zero, by 2040

Emissions by sector (GtCO<sub>2</sub>)



Source: IEA World Energy Outlook 2022

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A Paris Agreement-compatible pathway for the global power sector was set out in detail by the International Energy Agency (IEA) in its 'Net Zero Emissions' (NZE) scenario published in May 2021 in the pioneering report [Net Zero by 2050](#). It was then updated in the [World Energy Outlook](#) report in 2022, where NZE is now a central scenario. We reference this scenario throughout this report as a realistic pathway to put the global power sector on track for 1.5 degrees.

Although there are many possible ways the power sector could reduce emissions in line with a 1.5 degree trajectory, the IEA NZE scenario is well respected by industry stakeholders, provides detailed benchmarks and is also largely in line with the [IPCC scenario for power sector decarbonisation](#).

Across all models, wind and solar are set to lead this shift, offering low cost and quick-to-deliver clean capacity. The [IPCC showed that](#) wind and solar can deliver over a third of the emissions cuts required this decade, and half of those emissions reductions would actually save money compared to the reference scenario. In many countries wind and solar are also economically attractive: lower cost than fossil fuels, and without the potential energy security risks of dependence on the global fossil fuel market.

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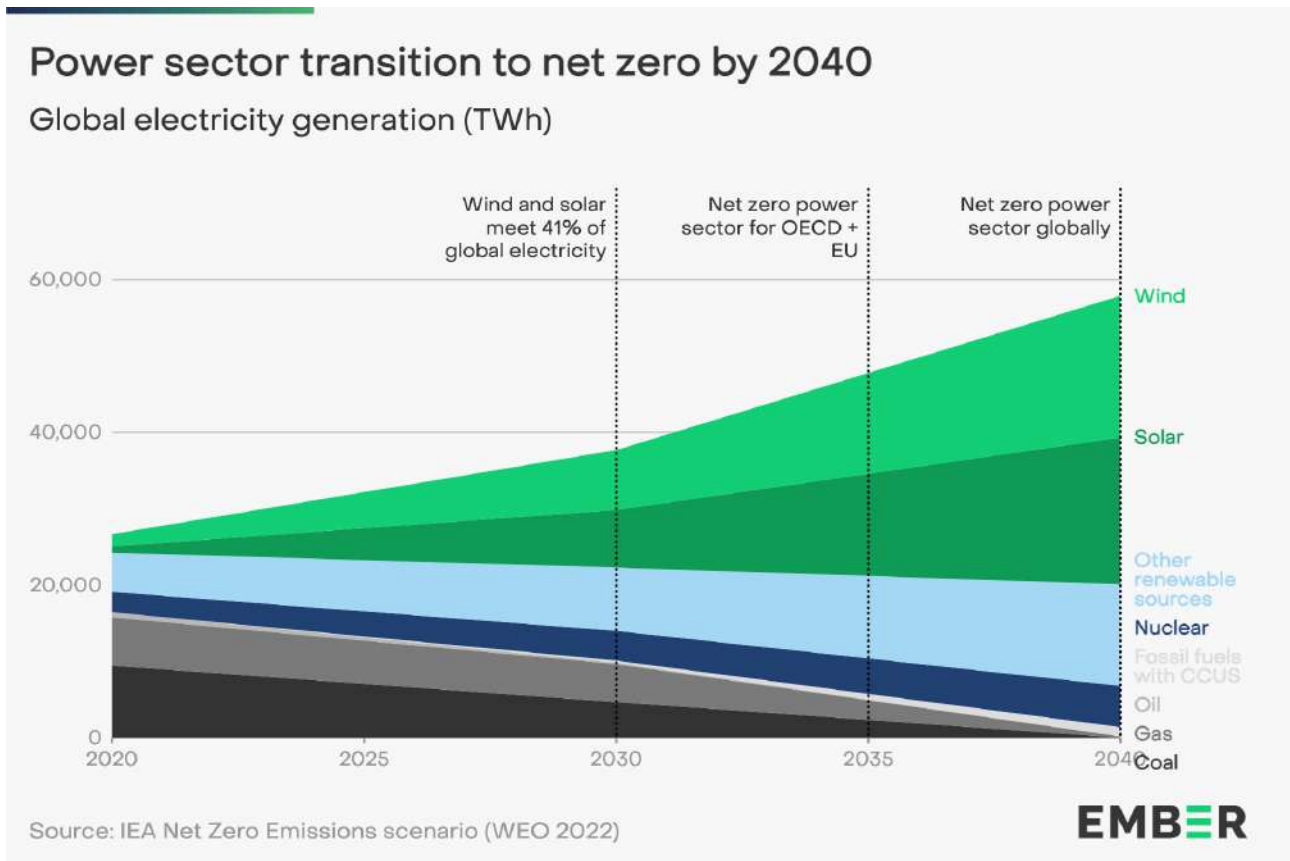
## Milestones for a 2040 global net zero power sector

The IEA NZE scenario shows a clear route to a net zero global power sector by 2040, and by 2035 for OECD countries. The pathway requires a massive expansion of clean power generation, requiring multiple technologies. In the IEA modelling, wind and solar are vital linchpins, providing 75% of the increase in clean power from now to 2050. Interconnections, networks, demand-side management and storage will all play a vital role alongside this deployment of clean power, and they will all need to expand to support the energy transition.

By 2030, wind and solar need to have increased to 41% of global electricity generation, up from 10% in 2021. Coal generation needs to fall by 54% and gas generation by 24%. At the same time, electricity demand will rise dramatically, by an average of 3.7% per year from 2021 to 2030, as electrification picks up pace.

While the shape of the path ahead is broadly clear, it is interesting to note the adjustments made by the IEA [when updating the NZE scenario from 2021 to 2022](#). The scenario remains largely the same except for a much larger forecasted fall in gas power from 2021 to 2030 (previously 5%, now 24%), and a smaller fall in coal power (previously 71% fall, now a 54% fall). This change likely reflects the slower progress in 2022 on coal phaseout, but also a newfound possibility that gas power could begin its phasedown this decade. Regardless, either version reflects the need for rapid declines in all fossil fuel power.

By 2040, the power sector needs to be net zero: to achieve this unabated coal power must be phased out globally, and unabated gas will only provide only 0.3% of global electricity.



## Expanding role of electricity on the path to net zero

Investment in clean electricity will ensure the most cost effective path to achieve net zero, not only in the power sector, but the entire energy system.

For developing countries, investment in clean sources will play a crucial role in meeting rising electricity demand, which is expanding as the world's population grows and countries increase standards of living. Globally, [one in ten people](#) still do not have access to electricity, mostly across Sub-Saharan Africa and Asia. Leapfrogging fossil fuels and moving directly to clean power will provide multiple benefits to health, the economy and climate, while increasing access to affordable energy as recommended by the United Nations in Sustainable Development Goal 7 ([SDG7](#)).



But it's not only developing countries where electricity demand will expand and clean investment needs to keep pace. Electricity underpins the decarbonisation of other sectors, as clean electricity replaces fossil fuel combustion in transport, heating, cooling and industry. In 2022, electricity accounted for 20% of world's final energy consumption. By 2030, it [is predicted](#) to account for 27%.

2022 was the year in which [electric cars](#), [heat pumps](#) and [electrolysers](#) (to produce green hydrogen) were pushed into the next level of growth. This trend is expected to continue, but to deliver on necessary emissions reductions it must be matched by investment in clean electricity to feed into the expanding electrified economy.

# Electricity is at its cleanest as wind and solar hit 12%

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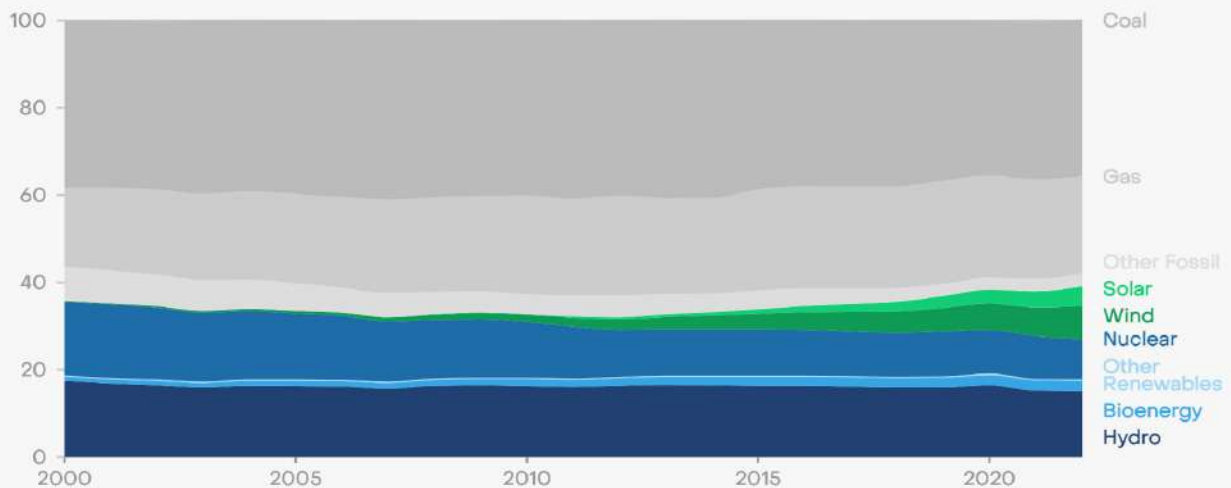
2022 beat 2020 as the cleanest ever year, as emissions intensity reached a record low of 436 gCO<sub>2</sub>/kWh. Wind and solar reached a record 12% of global electricity generation, but they still weren't built fast enough to meet all of the world's increasing need for electricity. Consequently, coal and other fossils met the remaining gap, driving up emissions to a new record high.

### Wind and solar help reduce emissions intensity of electricity

Record growth in wind and solar pushed electricity to its cleanest level ever: 436 gCO<sub>2</sub>/kWh. Solar added a record 245 TWh of generation in 2022, while wind added a record 312 TWh. As a result, 12% of the world's electricity came from solar and wind. That's up from a tenth of global electricity generation in 2021, which in itself was up from just 5% when the Paris Agreement was signed in 2015. Combined, solar and wind overtook nuclear generation in 2021 and are catching up with hydro generation. Over sixty countries now generate more than 10% of their electricity from wind and solar.

## Wind and solar grow to 12% of global power – pushing up the share of clean electricity to almost 40%

Share of electricity generation (%)



Source: Annual electricity data, Ember

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## The first fall in other clean electricity since Fukushima

In 2022, clean electricity sources—excluding solar and wind—saw their first year-on-year fall in generation since the Fukushima nuclear disaster in 2011. This was primarily because nuclear generation fell by 129 TWh (–5%) as France’s nuclear fleet suffered major outages and Germany and Belgium closed some reactors. In addition, growth in global hydropower was held back in regions that experienced extreme droughts, notably in the EU where generation fell by 66 TWh to its lowest level since at least 1990.

## Demand increased

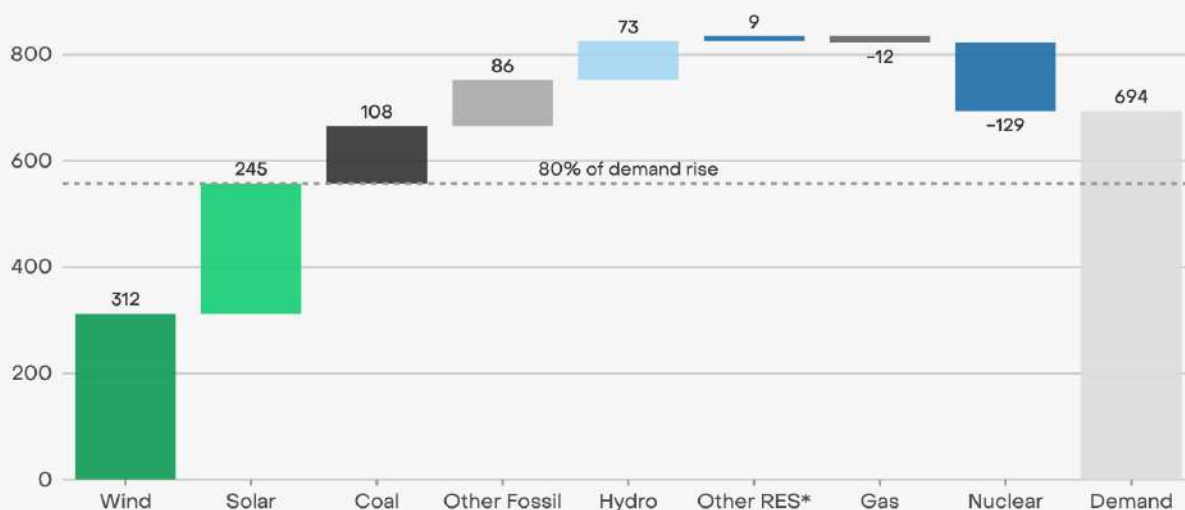
Global electricity demand grew by 2.5% (+694 TWh) in 2022, similar to the average growth of 2.6% in the previous decade (2010–2021). Much of last year’s increase was driven by demand increases in major economies, and three of them alone accounted for 93% of the global demand growth: China (54%), the US (21%), and India (18%). In contrast, electricity demand fell by 3% in the EU due to a combination of mild weather and efforts to reduce consumption in the face of affordability pressures and security of supply concerns (see chapter 6 for details).

## Wind and solar met the majority of demand growth

In 2022 growth in wind and solar met 80% of the increase in electricity demand, while all renewables together met 92% of the rise. In China, wind and solar met 69% of the growth in electricity demand in 2022, while all clean sources met 77%. In India, wind and solar met 23% of the demand growth, while all clean sources provided 38%. In the US, wind and solar met 68% of the demand growth.

### Growth in wind and solar met 80% of the rise in electricity demand in 2022

Global change in electricity generation by source (TWh)



Source: Annual electricity data, Ember · \*Other renewables includes bioenergy

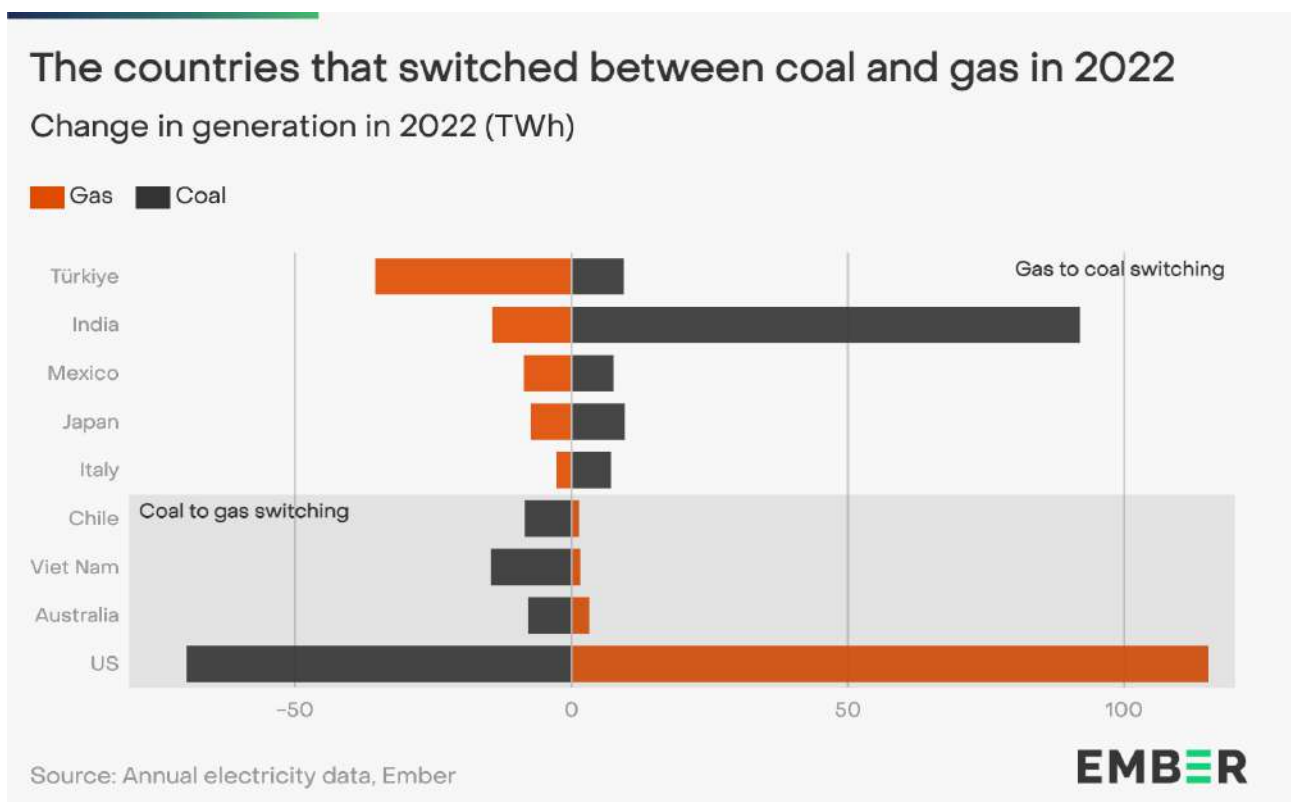
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## Coal increased to meet the shortfall

Coal and other fossil fuels (mainly oil) increased to meet the remainder of the rise in electricity demand, as well shortfalls from nuclear and gas generation. Coal rose by 108 TWh (+11%) year on year, reaching a record high generation of 10,186 TWh. Other fossil generation rose by 86 TWh (+11%).

Trends among countries and regions varied significantly: coal fell in the US (-70 TWh, -7.8%) in 2022 compared to the year before, but rose in China (+81 TWh, +1.5%), India (+92 TWh, +7.2%), Japan (+9.7 TWh, +3.1%), and in the EU (+27 TWh, +6.4%).

Coal power's increase of 1.1% is in line with average growth in the last decade. One might have expected a larger rise in coal generation in 2022, given the price spikes in gas and security of supply concerns. But at a global level, there was actually as much switching from coal to gas, as there was switching from gas into coal. That is in part because gas prices were already higher than coal before 2022, so much of the switching into coal had already happened the year before. It is also in part because of the US, where three major factors—coal plant retirements, coal transport disruption and new gas power plant capacity—led to a substantial switch from coal to gas generation, as gas prices stayed much lower than in the rest of the world.



## Gas plateaued

Global gas generation declined slightly by 0.2% (-12 TWh) in 2022 compared to the previous year. It might have been expected that high, volatile gas prices would cause a bigger fall in gas, however the energy crisis did not lead to large-scale gas-to-coal switching (as described above).

However, at a national level, some countries still saw increases in gas generation. For example, gas generation rose in the US (+7.3%), where it is replacing coal. But gas generation fell in most other countries, including Brazil (-46%) and Türkiye (-32%) due to good hydro generation, and in India (-22%) due to high gas prices.

Other fossil fuels—mainly oil— increased by 86 TWh, where there were some instances of gas-to-oil switching (although this datapoint is a little tentative, because of poor reporting by Middle Eastern countries which have the majority of oil generation).

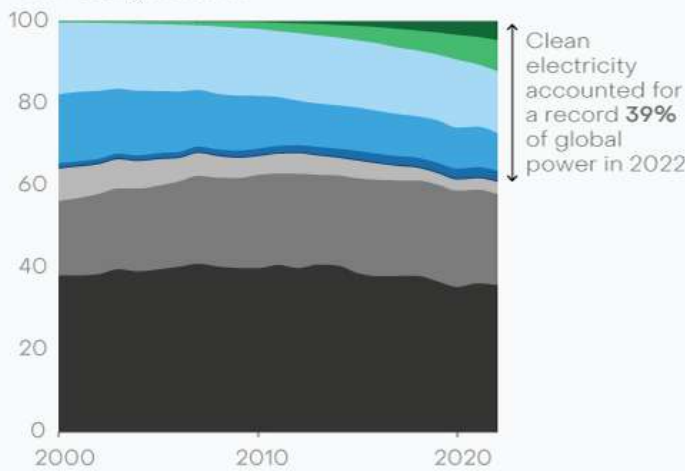
## Emissions reached a record high

Overall, fossil generation rose by 183 TWh (+11%) in 2022, setting a new record. As a result, power sector CO<sub>2</sub> emissions rose by 160 million tonnes (+1.3%) reaching a record high of 12,431 mtCO<sub>2</sub>. Emissions intensity is heading in the right direction, but absolute emissions are not yet falling. This means that the power sector is not yet seeing the emissions cuts needed for net zero, as emissions should be falling by an average 7.6% annually this decade, as per the [IEA Net Zero Emissions](#) scenario.

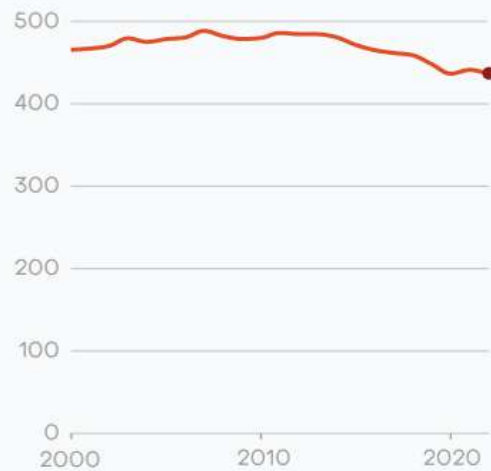
# How the world can simultaneously have record clean electricity and record high power sector emissions in 2022

■ Wind ■ Solar ■ Hydro ■ Nuclear ■ Bioenergy ■ Other renewables  
■ Other fossil ■ Gas ■ Coal

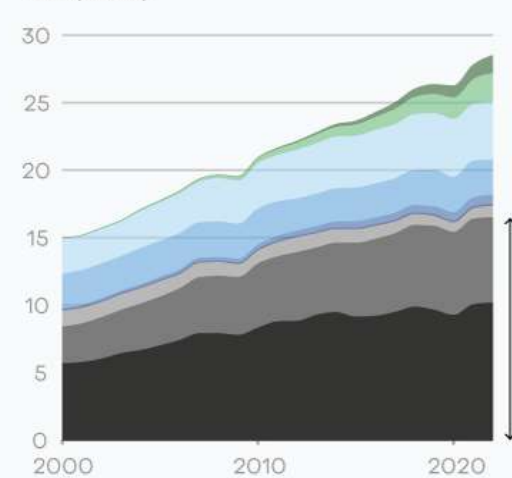
**As the proportion of clean power rises...**  
% of total generation



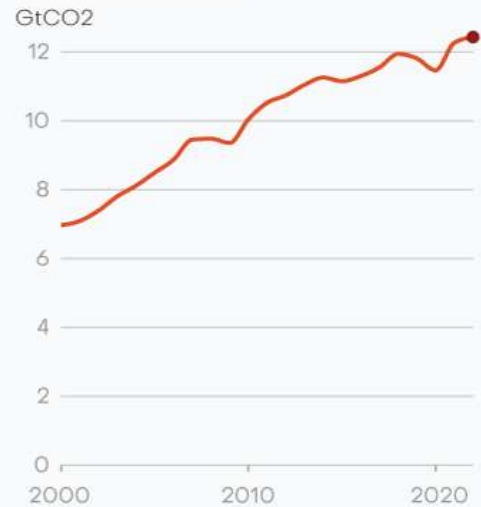
**... each unit of electricity emits less CO2**  
gCO2 per kWh



**But electricity demand has been rising faster than clean power, so fossil generation has picked up...**  
TWh (000s)



**... causing emissions from the power sector to increase**  
GtCO2



Source: Annual electricity data, Ember  
CO2 intensity and emissions calculated from generation multiplied by fixed fuel emissions factors

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## 2022 was an accelerator year for the transition to renewables

Russia's invasion of Ukraine and the global energy crisis in 2022 may well be remembered as a turning point that made many governments rethink their reliance on fossil fuels. Energy security concerns and new policies led to [the largest ever upward revision](#) of IEA's renewable power forecast in 2022.

The EU's [REPowerEU plan](#) was developed to rapidly reduce reliance on fossil fuel imports from Russia, largely by growing the use of renewable electricity and improving energy efficiency. In the US, the Inflation Reduction Act that was introduced in August 2022, directs nearly \$370 billion of government funding to clean energy, with the goal of substantially lowering the nation's carbon emissions by the end of this decade. Other major economies continued to roll-out existing policies, like China's [14th Five-Year Plan](#) and new [market reforms](#).

Additionally, [investment](#) in clean energy technologies matched that of fossil fuels for the first time in 2022. Developing economies like [Indonesia](#) and [Viet Nam](#) secured commitments for international funding in 2022 from historic high emitters like the UK, US, and EU to support them in displacing coal with renewables and hence decoupling their economic growth from emissions.

The energy crisis provides a clear motive for low-carbon energy transitions: the need for greater energy diversification, reduced reliance on fossil fuels, and an acceleration of renewable energy. However, the crisis also risks locking in some fossil [infrastructure](#), with some countries securing long term contracts for gas.

While 2022 may be seen as the turning point, the impacts of the policy developments on clean electricity agreed throughout the year won't be felt for a while. The change that we have witnessed so far in clean power and in electrification is therefore only the tip of the iceberg.



# The global electricity system is transforming – but not yet fast enough

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Wind and solar are the new energy superpowers. They are pushing us towards a new era of falling fossil generation, which will mean not only a phasedown of coal power but also of gas power. But we're not there yet. Keeping global heating to 1.5 degrees means delivering on the huge expectations set for wind and solar, and picking up speed on other clean electricity sources (including nuclear and hydro) that are currently being built too slowly. There remains much work to be done to achieve the rapid falls in power sector emissions needed this decade.

## Wind and solar emerge as the world's future superpowers

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The speed that solar and wind are already changing the global electricity supply is astounding. The rise alone in global solar generation in 2022 could have met the annual electricity demand of Australia, and the rise in wind generation could have powered all of Türkiye. Together, global wind and solar generation in 2022 exceeded the total electricity demand of the EU.

## Wind and solar generation, in perspective

TWh

Global wind and solar generation, 2022



Source: Annual electricity data, Ember

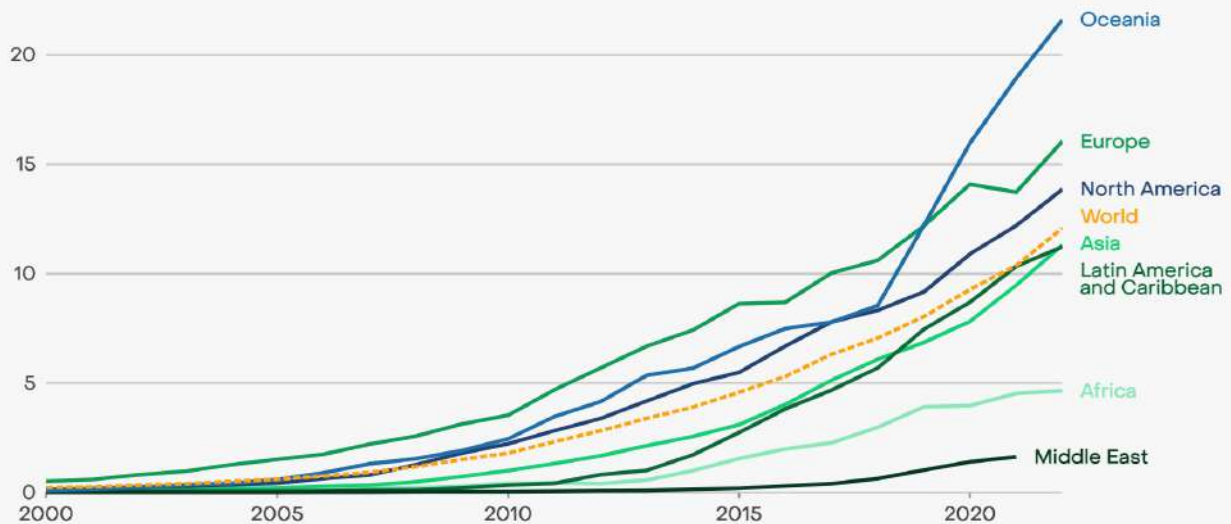
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## Same journey, different speeds

Solar and wind are changing the electricity mix in every region of the world. Europe started that shift earliest, and has been leading throughout this century. However, recently Europe has been overtaken by Oceania, mostly due to rapid growth in Australia. North America also started wind and solar deployment early and has been ahead of the global average. Asia started later, but is catching up fast, and is now almost at the world average. Latin America's wind and solar surged from 2014 to 2021, but then slowed in 2022. Africa has slowed in the last few years. The Middle East stands out as the only region that is still at the start of its journey, with poor data transparency that also makes it difficult to estimate changes in 2022.

## Same journey, different speeds

Share of electricity generation from solar and wind (%)



Source: Annual electricity data, Ember

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## Leaders and laggards

The EU generated 22% of its electricity from wind and solar in 2022. Seven EU countries generated around a third or more of their electricity from wind and solar in 2022, including Germany (32%), Spain (33%) and the Netherlands (32%). Poland and Hungary are now above the global average of 12%. At the edge of Europe the picture is varied: Türkiye is above the global average, at 15%, Russia is at 1%.

In North America, the US (15%) is above the global average; Canada is behind at 7%.

Three of the world's top five absolute generators of wind and solar are in Asia. China is above the global average, at 14% (1241 TWh); Japan is just under the global average at 11% (107 TWh), India, is just under, at 9% (165 TWh). Most other countries in Asia are at the start of their solar and wind journey: South Korea (5%), Pakistan (4%), Thailand (4%), the Philippines (2%), Singapore (2%), Bangladesh (1%) and Malaysia (1%). All Eurasian countries, except for Kazakhstan, have almost zero.

In Latin America, many countries are at or above the global average: Uruguay (36%), Chile (28%), Brazil (15%), Argentina (12%). However, some countries—for example, Cuba (1.4%), Colombia (0.7%), Ecuador (0.3%), Venezuela (0.1%) and Paraguay (0.0%)—have built little so far. Apart from Cuba, however, they do all have a high clean share because of large hydro resources.

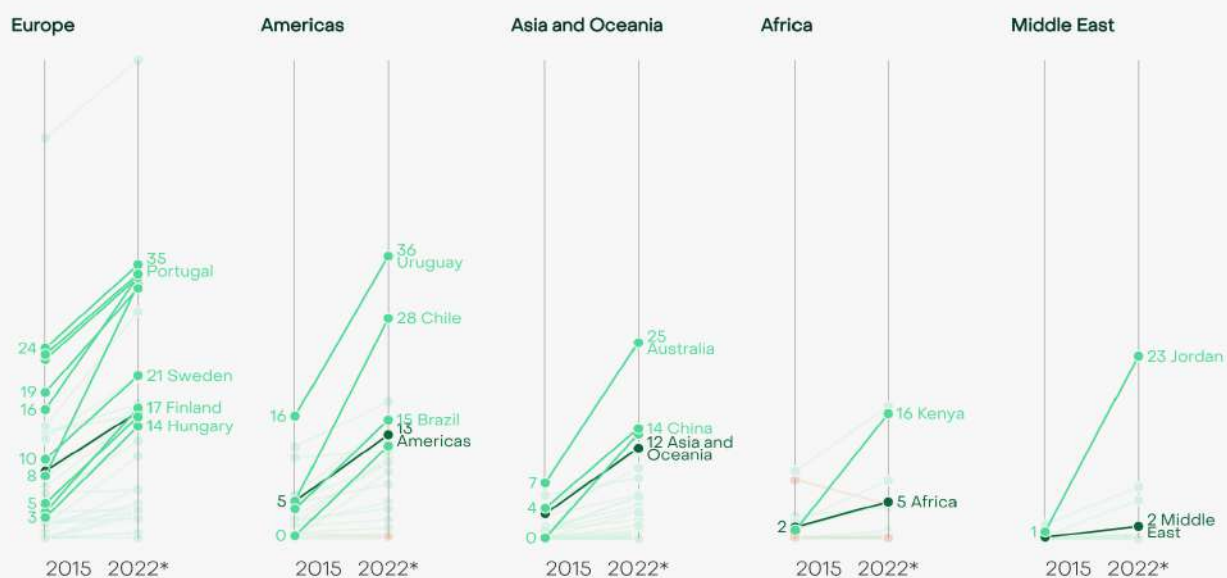
In Africa, Namibia (25%), Morocco (17%) and Kenya (16%) lead for wind and solar share. But elsewhere reliance on solar and wind is mostly far below the global average.

In the Middle East, solar and wind have yet to establish themselves. Many countries have under 1% in the mix. This includes Bahrain, Iran, Iraq, Kuwait, Lebanon, Oman, Qatar, and Saudi Arabia. Saudi Arabia has published big [plans](#) for renewables, however with little demonstrable progress towards those so far.

## Wind and solar takes off around the world

Share of total electricity generation (%)

Countries with more than 10 percentage point increase highlighted



Source: Annual electricity data, Ember

\*Or latest year; only countries generating more than 10TWh - from all sources - are included in this graphic

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## Lessons learned from two decades of solar and wind deployment

The wide variation in wind and solar uptake is a reflection of diverging approaches to energy transition and power system reform across countries. Case studies of wind and solar rollout show the enormous patchwork of policy decisions, market forces and national momentum that feed into what makes a national energy transition successful or not. Here we look at three case studies in more detail. First, China's innovative rooftop policy that pushed solar to new levels in 2022. Second, Chile's rise in solar and wind, and how it has rapidly cut its coal use and power sector emissions. And third, lessons from Europe's stop-start policies on onshore wind that have prevented more rapid and cheaper growth of wind.

### Innovative rooftop solar policy: China case study

About a fifth ([55 GW](#) of 268 GW) of all the solar panels installed globally in 2022 were on China's rooftops. This was largely driven by an innovative policy called Whole-County Rooftop Solar. The project is a three-year scheme. 2022 was the second year, with [installations doubling](#) from the 29 GW added in 2021.

The scheme was implemented with a top-down structure, but carried out at the city or county level. By late 2021, there were 676 counties from 31 provinces that had [enrolled](#) into the scheme. A single developer (often a state owned enterprise) administers the entire county-wide application. The developer works in conjunction with a network of smaller 'village-level' or 'town-level' developers, who take on the work of identifying the rooftops and securing project development rights. In some instances, the panels are owned by the individual, and the individual sells surplus power back to the developer. In other instances, the panels are owned by the developer, and instead of earning rent, the rooftop owner receives discounted electricity.

This total county-scale approach enables a fast roll-out and cheap prices. The speed and coverage of roll-out is unprecedented: by the end of 2023 each county developer needs to have commissioned installations to cover 50% of the available area at government buildings, 40% at schools and hospitals, 30% for industrial buildings and 20% for rural households. It also means cheap prices: cheap financing can be secured to keep costs down, and all components can be bought at wholesale prices.

## How wind and solar have cut power sector emissions: Chile case study

Chile has seen a significant increase in its wind and solar generation. Combined, wind and solar have gone from generating just 0.6% of total power in 2012 to 28% in 2022, becoming the largest source of electricity in Chile and overtaking coal. The rise of wind and solar generation over the last ten years has driven a 27% decline in coal power generation, reducing emissions from the power sector by 15%, despite overall demand growing by more than a quarter in the same period.

The ten years prior to 2012 told a very different story. Chile relied on coal to meet its growing electricity demand. As demand rose by nearly 50%, coal generation increased fourfold, prompting emissions to rise by 159%, or 20 MtCO<sub>2</sub>, more than the annual power sector emissions of Chile's neighbour Peru.

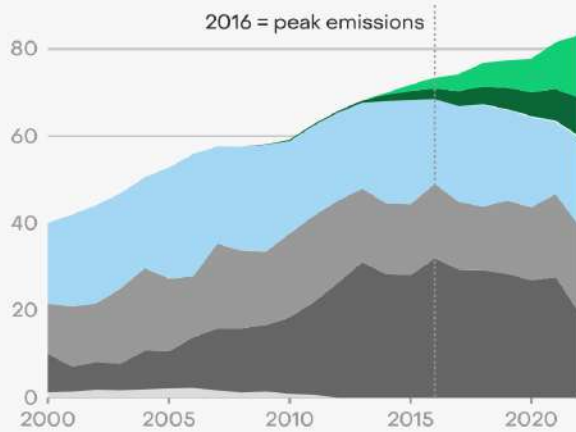
The year 2022 was particularly remarkable for Chile's power sector. Solar generation expanded by a third, while wind and hydro power each increased by more than 22%. The overall increase in renewable electricity of 9.2 TWh far exceeded the overall demand increase of 1.7 TWh (+2.1%), allowing a 30% drop in coal generation. Ultimately, this caused power sector emissions to fall by an impressive 18% compared to 2021.

Chile is now planning for the phase-out of coal. In September, it joined the Powering Past Coal Alliance, where the country [pledged to phase out coal by 2030](#). That brought the date forward by ten years, where it had previously planned for a 2040 phase out date. It is clear that wind and solar will be the driving forces to help phase out coal and continue to cut Chile's power sector emissions.

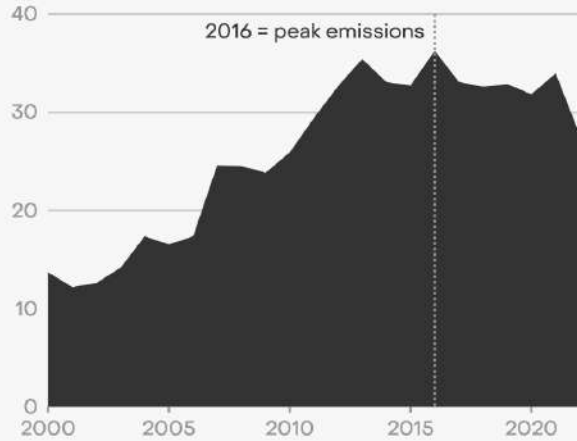
## Chile reduces power sector emissions through solar and wind expansion, even as electricity demand continues to grow

Coal Gas & other fossil Net imports Hydro Other renewables Solar Wind

Generation (TWh)



Emissions (MtCO<sub>2</sub>)



Source: Annual electricity data, Ember

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## Bumpy road for onshore wind: Europe case study

Some of the biggest wind countries in Europe have seen stop-start policies. This resulted in years of lost opportunity, not only slowing down growth, but creating a huge impact on companies and employees. It is one of the reasons that there is still [underinvestment](#) in the supply chain today.

Germany had been a world leader in onshore wind, but during 2017–2021, it only installed around a third of the capacity that it achieved in the four years before that (1.4 GW average per year, compared to 4.3 GW per year). The [main causes](#) for this slowdown were a lack of land for construction, investor uncertainty and slow licensing procedures. Germany has now swung back to a faster pace of rollout: in 2023 auction volumes were raised to 23 GW. The change in government and Russia's war in Ukraine prompted this, with new legislation including setting aside 2% of total land area for onshore wind.

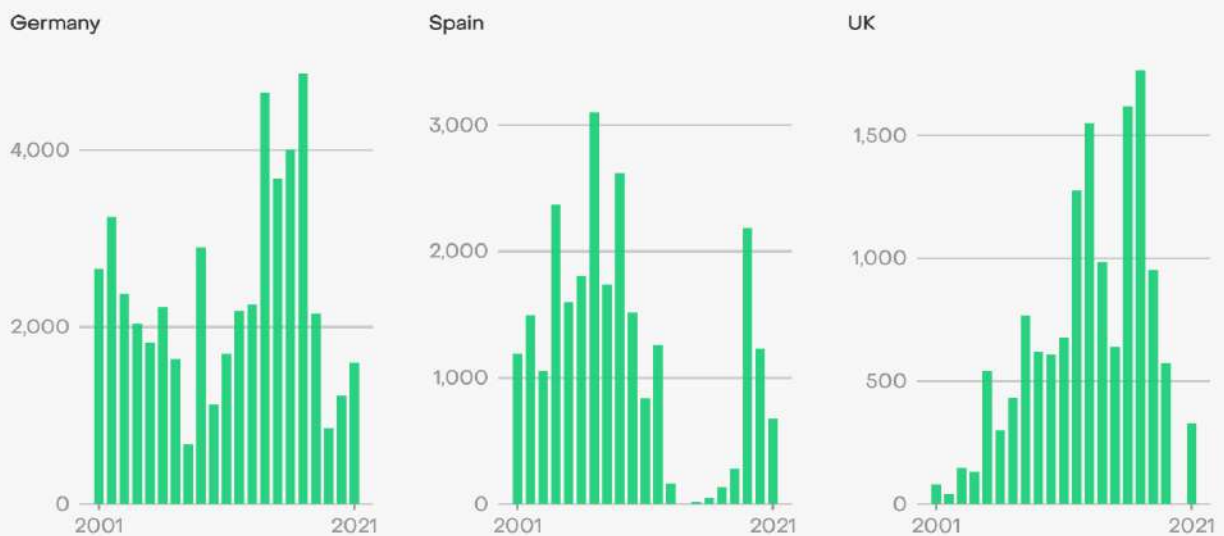
Spain's onshore wind was a victim of its own success. There was no [pass-through](#) of the costs to customers, leading to an overall "tariff deficit" of €25bn, which was impossible to increase as the financial crisis hit Spain in 2012. This created a pause, with only 600 MW installed in the following six years. Spain's build rate has now increased again.



The UK government put an effective moratorium on new onshore wind farms in 2015 in England because of concerns over the visual impact of wind farms. It is still in place seven years later. However, in December 2022, the government began consultations to lift the block, while maintaining the ability for local communities to oppose projects. It is not clear how or if this will be implemented, and thus how quickly build-rates will pick up as a result.

## On-off: how not to do it

### Onshore wind capacity added annually (MW)



Source: IRENA

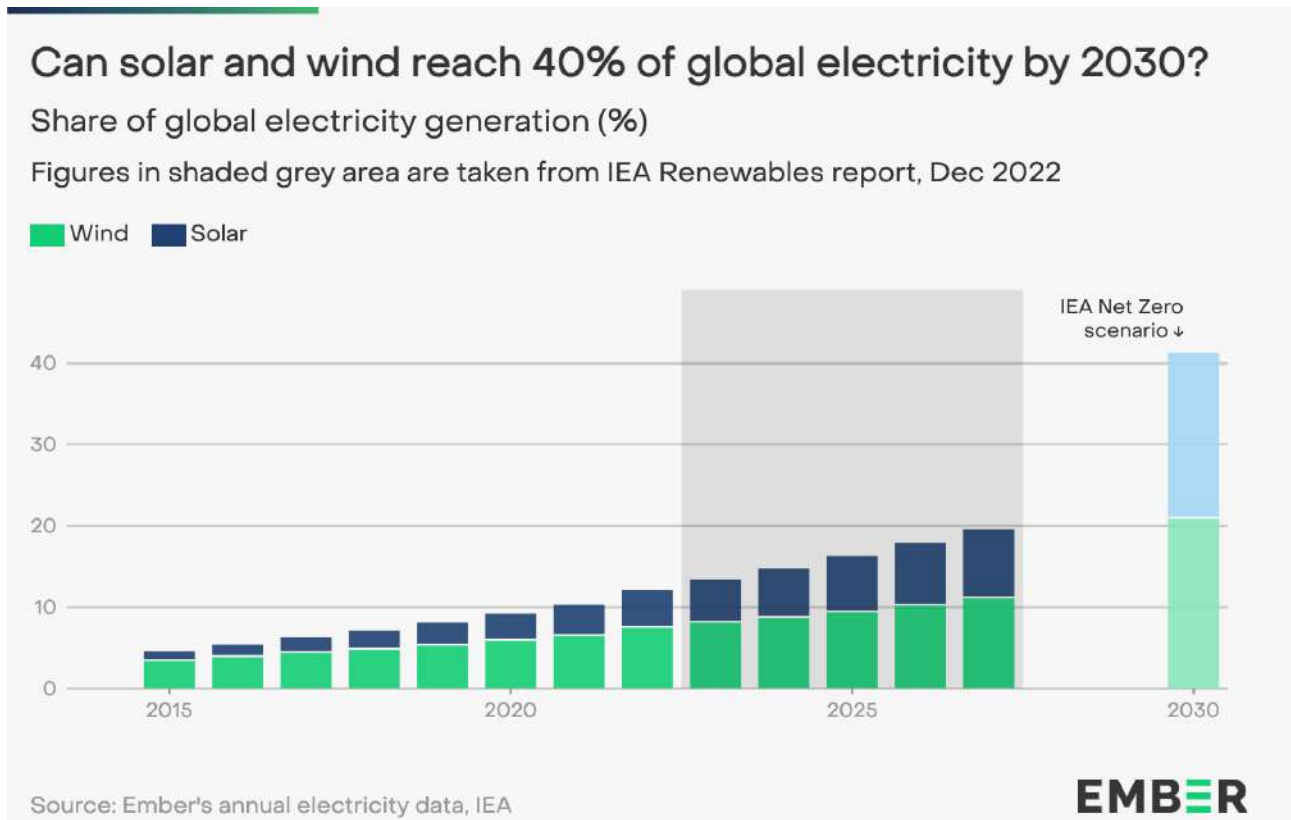
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## Solar and wind are the new superpowers, but how much will they grow?

A lot is expected from solar and wind in order to achieve climate targets. The [IEA Net Zero Emissions scenario](#) shows that solar and wind need to rise from 12% of global electricity supply in 2022 to 41% by 2030. A similar starring role for wind and solar is set out in the IPCC [synthesis report](#), released in April 2022. The median of all the scenarios assessed by the IPCC shows the same as the IEA: wind and solar are [expected to rise to 41% of global electricity](#) by 2030.

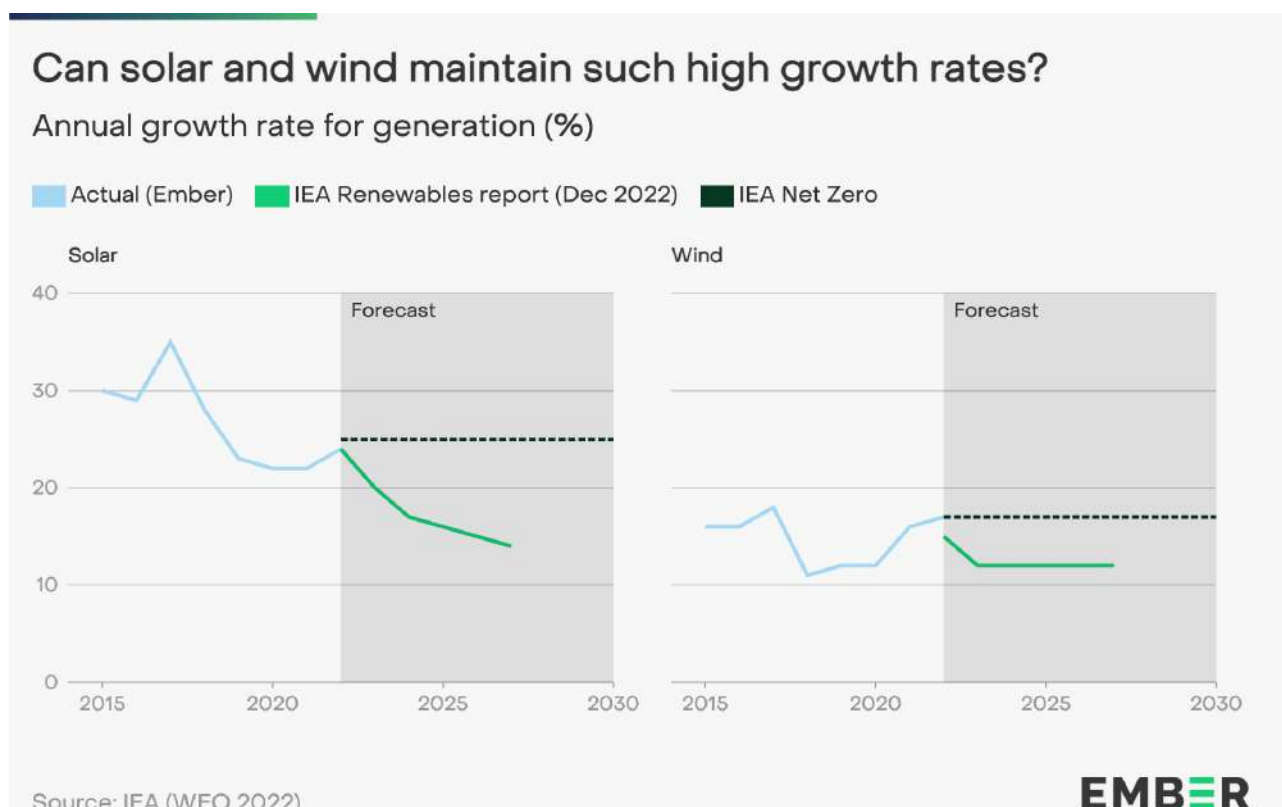


According to the latest [IEA's short-term forecasts](#) from December 2022, solar and wind are lagging behind on this trajectory, rising to “only” 20% of global electricity share by 2027. Without doubt, this is a conservative estimate, the under-forecasting of wind and solar by the IEA is [well documented](#). Regardless, it is still far from clear whether we can achieve the 41% market share needed by 2030.



Considering growth rates offers an alternative and perhaps more encouraging perspective. According to the [IEA Net Zero Emissions scenario](#), annual growth rates of 25% for solar and 17% for wind need to be maintained from 2021 to 2030. These were almost exactly achieved in 2022: 24% for solar and 17% for wind. From 2015 to 2021, growth rates were near those levels: 26% and 14%.

Consistently achieving such high growth rates gets harder as market share rises. Still, there are reasons to believe that wind and solar may grow much faster than the [conservative IEA forecast](#) from December 2022 sets out.



Solar is relatively new as a key player in the global power mix: it lagged seven years behind wind in reaching the critical milestone of generating 1% of the world's electricity. Wind achieved this in 2008, but solar only passed that mark in 2015. However, solar is catching up: it has been the fastest growing electricity source for each of the last 18 years. Global solar capacity already exceeds wind capacity, although with lower load factor, it produces less electricity than wind. 2023 is likely to be the first year where solar adds more generation than wind.

One major advantage of solar is the speed of deployment. Wind requires complex supply chains, permissions and offtake contracts. The time it takes to buy a solar panel and install it on a roof can be measured in days, rather than months or years. This means that new-build wind in the next few years can be forecasted with a fair degree of accuracy. Predicting solar growth is much harder.

In the short term, there is a huge opportunity for solar to grow even faster than forecast. Major new solar manufacturing plants came online in China in 2022, [reportedly](#) increasing annual manufacturing capacity by 66%, from 361 GW at the end of 2021 to 600 GW at the end of 2022. This rise in China's solar manufacturing capacity far exceeds the expectations for solar panel demand in 2023. Compared to 2022, the number of solar panels installed during 2023 is expected to increase

between 27% (BNEF) and 5% (IEA). The 66% rise in supply might, however, drive more demand. Against this backdrop, it is understandably difficult to predict just how quickly solar might grow in 2023—let alone in 2030. Researchers are likely to err on the cautious side, meaning it is very possible that solar growth will exceed those expectations.

What is clear is that solar and wind are on track to have a massive presence in the global power mix. They will without question fundamentally change the global electricity system. As with any rapid change, problems and opportunities abound.

For wind, many countries have ambitious targets that are held back by implementation. For solar, the opposite is true. Far more solar panels are being installed—or could easily be installed—than are currently planned for. Policymakers must harness the influx of solar power. That means understanding what it means for skills needed, changes to market design and tariffs (given the solar generation profile is quite specific), unlocking rooftop access, auction design for utility scale, power system flexibility, solar manufacturing supply chains and trade policy.

## **The world's largest clean electricity sources are underperforming**

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Despite their rapid growth and place in the future global power mix, the world's largest sources of clean electricity are neither solar nor wind, at least not yet. Instead, hydro and nuclear are currently the largest clean sources, generating 15% and 9% of the world's electricity respectively in 2022. Although the growth expectations for these technologies are smaller compared to solar and wind, they are not currently being expanded at the rate needed to limit global warming to 1.5C. Hence their slowdown could have big implications for the electricity transition.

## The falling market share of nuclear and hydro

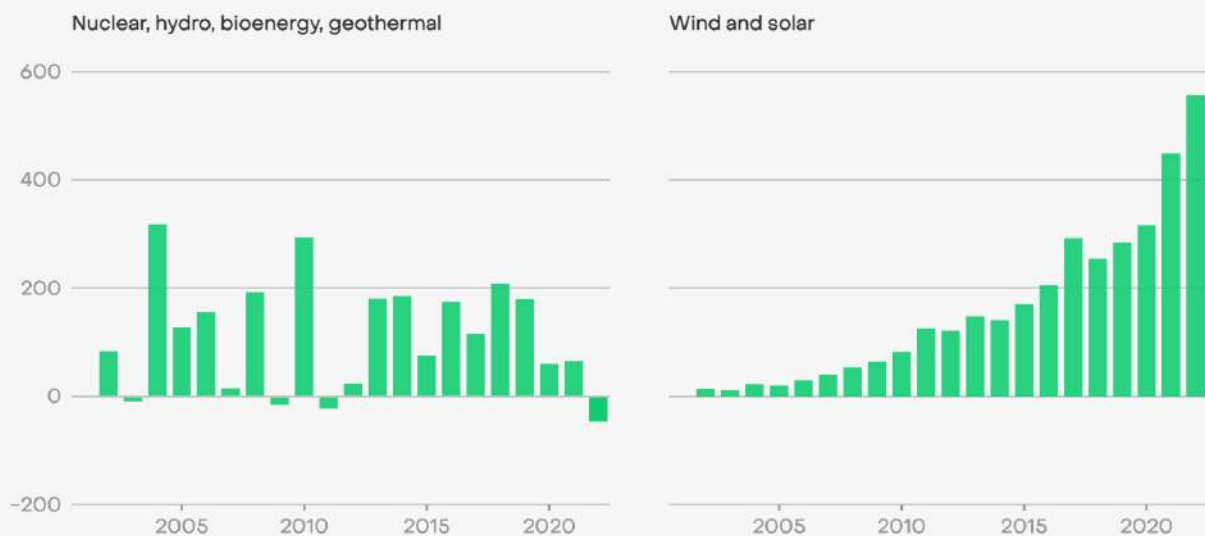
In 2022, clean electricity sources (excluding solar and wind) saw their first year-on-year fall in generation since the Fukushima nuclear disaster in 2011. This grouping includes the two largest sources, hydro and nuclear, and also other technologies that currently contribute a smaller proportion of low-carbon electricity: bioenergy, CCUS, hydrogen, geothermal and marine. The fall in 2022 was predominantly due to the nuclear plant outages in France, while the small rises in hydro and bioenergy only partly offset this. Whilst it is unlikely this fall will continue in future years, it is clear that growth is slowing: in both 2020 and 2021, clean electricity (excluding wind and solar) grew at half the average annual growth since 2000.

Already, nuclear and hydro's market share had been falling throughout this century, because growth rates were below that for global electricity demand. Nuclear's share of global electricity production fell from 17% in 2000 to 9% in 2022, while hydro fell from 18% to 15%.

Their pace of growth has been eclipsed by the rise in solar and wind. In 2022, solar and wind added 557 TWh; this was five times the average amount added by nuclear, hydro and bioenergy (105 TWh yearly average 2000–2022).

### Clean electricity, excluding solar and wind, fell in 2022

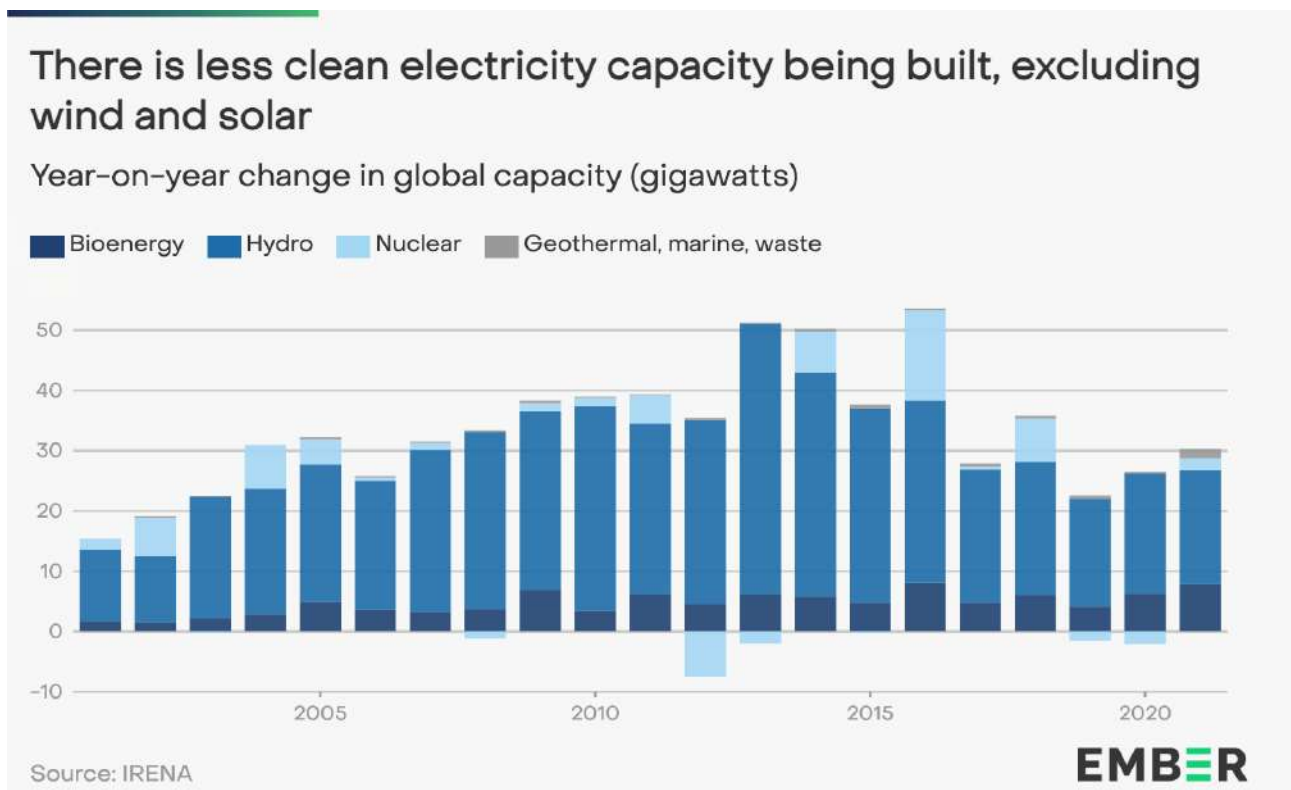
Yearly change in electricity generation (TWh)



Source: Annual electricity data, Ember

Capacity data offers some insight into this stalling in nuclear and hydro generation. Net nuclear capacity actually fell from 2019 to 2021, as more plants closed than opened.

Hydropower capacity growth has slowed in recent years. From 2017 to 2021, an average of 20 GW per year was added, compared to 33 GW in the five years before that. That was largely due to the slowdown in China, which had been building around half of the world's hydro capacity.



## Did 2022 kickstart a nuclear renaissance?

There are 440 nuclear power reactors online today, providing 9% of the world's electricity. An additional 48 are planned to come online from 2023 to 2027, according to the [World Nuclear Association](#). Nineteen are in China, eight in India, six in South Korea, four in Türkiye and three in Russia. That's reasonable progress: they will provide 60 GW of capacity and generate around 420 TWh every year, which would add a third of the net nuclear generation increase required in the IEA Net Zero Emissions scenario from 2021 to 2030, not taking into account the decommissioned plants coming offline.

However, 2022 brought new momentum in nuclear power that may see even more nuclear plants come online. With long timelines for construction, they will have limited impact in the next few years, but could provide substantial amounts of clean power after that.

In the United States, the Inflation Reduction Act has [provisions](#) to substantially help boost nuclear power by keeping older plants online, building supply chains for new build plants using current technology, and expanding R&D budget for new small modular reactors (SMRs). The closure of the Diablo Canyon nuclear plant in California was also postponed.

Japan has seen a major shift, not just by [restarting](#) existing nuclear plants (with record [support](#) from the Japanese public), but also [proposing](#) new plants. In south east Asia, the Philippines, Indonesia and Vietnam [progressed](#) discussions on nuclear power. South Korea [announced plans to build](#) four more nuclear reactors by 2030 and extend the life of ten older units, increasing nuclear market share from 27% in 2021 to 30% in 2030, and then to [35% by 2036](#).

China is [planning](#) to increase nuclear power capacity from 50 GW in 2021 to 70 GW in 2025, following the announcement of its 14th Five-Year Plan in 2021. Russia set a 2045 [target](#) to increase nuclear power from 20% of electricity today to 25%, with plans to build 16 reactors by 2035.

In Europe, there was momentum too. Poland [progressed](#) the first of six new planned nuclear plants, the UK [proposed](#) to build eight new reactors and allocated R&D [funding](#) for modular reactors, France's EDF has brought forward the [construction](#) start date of its six planned reactors, Romania [announced](#) plans to build two new plants, one of two new plants in Hungary [began](#) construction, and Slovakia brought one unit online and is considering [future](#) growth. Construction woes also hit in Europe: commercial operation of Finland's new nuclear power plant has been [postponed](#), France's new [Flamanville](#) plant has been postponed again, and the UK's [Hinkley C](#) plant has seen costs spiral.

## Wake up call for 1.5C

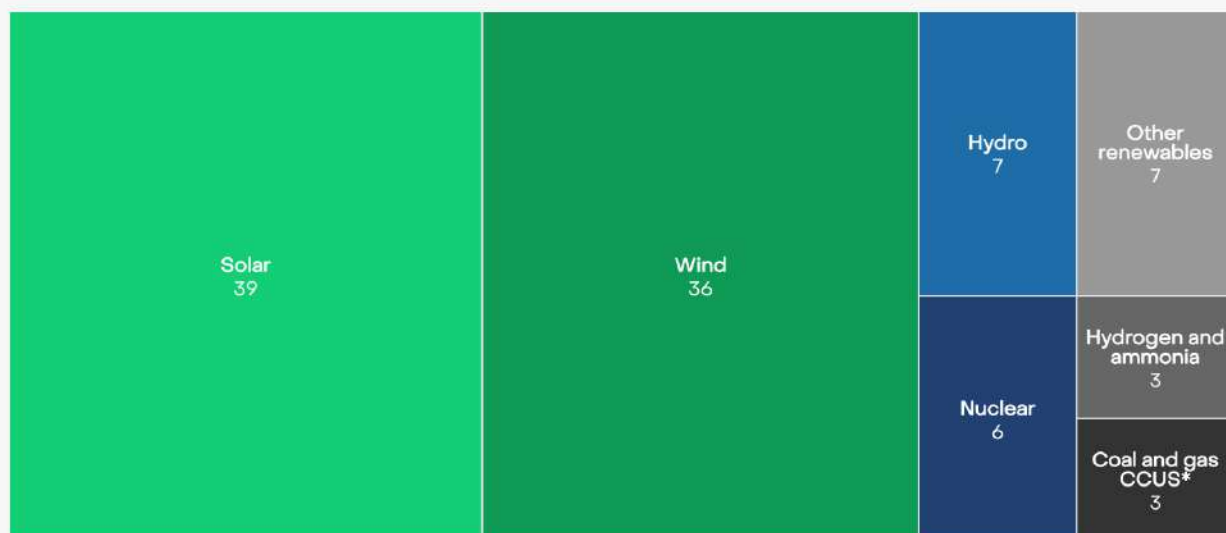
The recent slowdown in nuclear and hydro generation growth shows the importance of maintaining sufficient focus on deploying all clean electricity sources.

Solar and wind will undoubtedly dominate growth in clean electricity. Since 2015, 76% of the growth in clean electricity generation has been from solar and wind, and the [IEA Net Zero Emissions scenario](#) anticipates that they will account for 75% of all clean electricity growth to 2040.

However, these technologies alone are not enough. Growth in other clean electricity sources will be very helpful, if not essential, for the world to reach fully clean electricity by 2040. A larger toolkit of options lowers the risk that the world fails to decarbonise electricity at the required pace. They also provide some of the flexibility essential to integrating variable renewable sources.

### Solar and wind will provide three quarters of new clean electricity

Share of the increase in clean power from 2021 to 2040 (%)



Source: IEA Net Zero Emissions scenario (from WEO 2022) · \*Carbon capture, utilisation and storage



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Hydro needs a fivefold rise in investment, according to IRENA's 2023 report [The changing role of hydropower](#). The report highlights the need to double hydro capacity by 2050, the lack of policy mechanisms to make that happen, and the importance of a sustainable approach that avoids severe ecological damage. This investment in hydro needs to maximise flexibility to help integrate more solar and wind, with an emphasis on electrical capacity and storage. IRENA's report also identifies the huge potential of floating solar on hydro reservoirs to increase generation and reduce evaporation.

Nuclear also needs increased attention to meet climate targets, with the IEA's 2022 report [Nuclear Power and Secure Energy Transition](#) calling for a renaissance. The report highlights the importance of life extensions for ageing plants, diversification away from Chinese and Russian designs, bringing down costs and delivering on time, as well as the future potential of small modular reactors.

Elsewhere, bioenergy's growth is slowing, as significant [climate risks](#) in the technology are exposed, and many governments are losing faith in subsidising expensive internationally traded wood pellets. Unlike solar and wind, bioenergy also relies on an often expensive fuel, and so has not been able to mature away from subsidies.

## New clean power technologies

The clean power toolkit includes not only wind, solar, hydropower, nuclear and bioenergy, but also green hydrogen, carbon capture and storage (CCS) and more niche technologies including geothermal, marine and concentrated solar power. Clean power is in the midst of an innovation revolution, and there will be surprises as different technologies progress at unpredictable speeds. CCS and hydrogen are two of the most contentious in terms of what they might be able to deliver.

Carbon capture and storage of fossil fuels is expected to play a small role in a future clean electricity system. The [IEA Net Zero Emissions scenario](#) shows 2% by 2050, and the median of the 1.5 degree IPCC scenarios [shows around 1–2% by 2040](#). The biggest reason for that slow uptake is lack of policy support: there are very few large-scale demonstrations of CCS in the power sector. Although there



is currently a lot of [interest](#) in CCS, most is outside the utility sector: only the UK, Canada and the US have proposed large CCS projects with gas power. China is [developing CCS with coal power](#) and there are also some efforts in the [US](#).

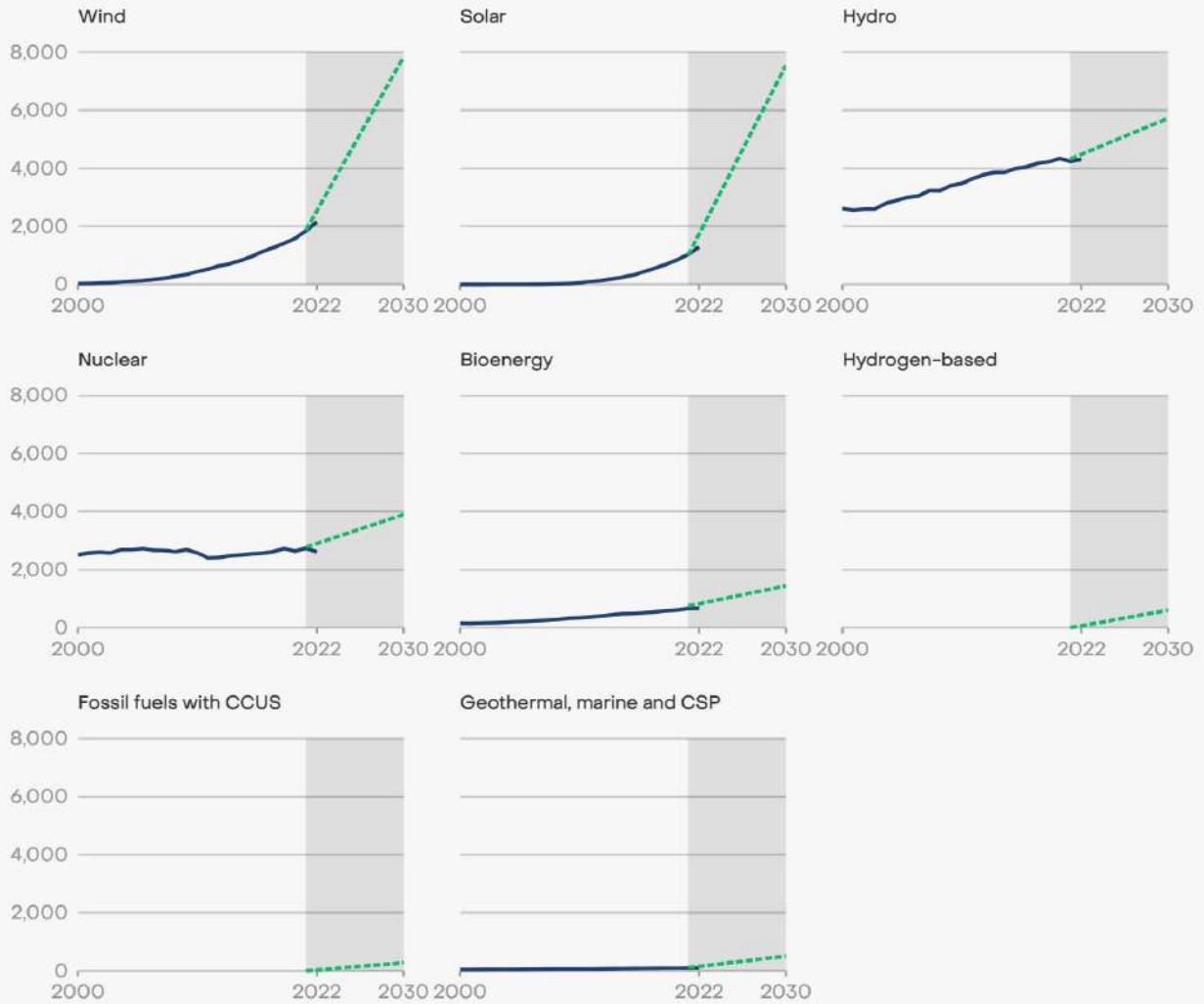
Green hydrogen is essentially a form of electricity storage, the result is no net electricity generated, but rather the flexibility to match demand to variable supply. Surplus clean electricity on windy or sunny days can be converted into hydrogen, stored, then burned when there is limited wind and sun. However, the costs and inefficiencies mean it is far from a panacea. Likewise, importing hydrogen by ship to burn it comes with technical and economic [challenges](#). Hydrogen's reputation is muddied by the different colours (that is, the sources used to generate it, fossil vs clean), and the end-to-end carbon savings actually produced by these approaches. Regardless, hydrogen will undoubtedly start to be used in gas power plants this decade. Germany alone is [proposing to build up to 20 GW of new hydrogen-ready gas power plants](#). Many gas power plants can be [converted](#) to burn hydrogen.

Both CCS and hydrogen are starting from a baseline of almost no generation today. Only time will tell how much they contribute to clean power in the future. What is important is that they do not detract from maximising the growth of solar and wind, which is unquestionably needed. And since the origins of both technologies are rooted in fossil fuels, it is also important that they do not detract from the overall momentum to phase out unabated fossil fuels.

# All clean power sources need to grow, not just wind and solar

Electricity generation, terawatt hours

■ Generation (TWh) ■ IEA Net Zero pathway



Source: Annual electricity data, Ember, IEA (WEO 2022)



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## Close to a tipping point where clean sources meet all demand growth

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Meeting all growth in electricity demand with clean power is a critical tipping point.

First, this marks the point where power sector emissions stop rising. Clean power can actually go to replacing fossil fuels, instead of just meeting rising demand. When one kilowatt hour of clean power replaces coal or gas, power sector CO<sub>2</sub> emissions fall by around 900 grams and 400 grams respectively.

It is also the point at which clean power is meeting the electricity growth needed to decarbonise other sectors. When one kilowatt hour of clean power is used in an electric car to replace oil or in a heat pump to reduce gas, emissions would fall by 700 grams and 600 grams of CO<sub>2</sub> [respectively](#). These emission falls happen outside of the power sector.

In the long term, as electrification of the economy picks up, the emissions savings of clean power will be larger outside the power sector than inside the power sector, as long as clean power grows in line with the electric economy.

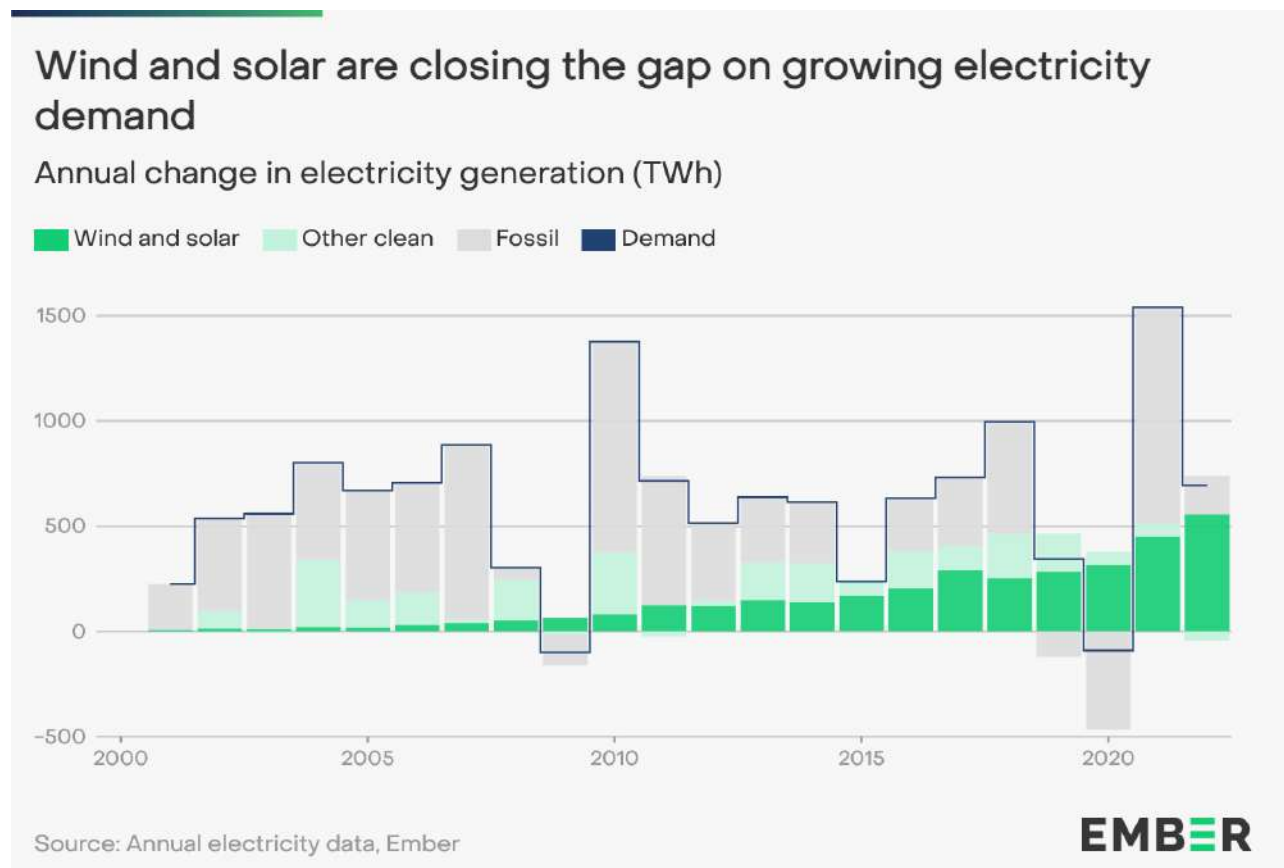
### Getting close to the global tipping point

The gap between the growth in clean electricity generation and the growth in electricity demand has been narrowing in recent years.

In 2022, clean power came close to meeting all the growth in electricity demand. Electricity demand rose by 694 TWh (+2.5%) in 2022, in line with the average growth for 2010–2021. In 2022 growth in wind and solar met 80% of the increase in electricity demand, while all renewables together met 92% of the rise. However, as a result, coal and other fossil fuels still had to rise to meet the remaining gap in demand as well as the shortfalls from nuclear and gas generation.

Every year, this gap has been closing. For example, the growth in wind and solar in 2018 met 26% of the demand growth, compared to 80% in 2022.

Clean power growth has met all of the electricity demand rise before: in 2015 and 2019, but only because electricity demand was below average. There is a strong possibility that clean power growth is able to meet all growth in electricity demand as early as 2023 (see [A new era of fossil decline: as soon as 2023?](#)).



## Continental shift

Since 2015, the growth in clean power has been accelerating, and this is changing the global electricity sector. In North America and Europe, electricity demand has been broadly unchanged in recent years, and so the growth in clean power reduced fossil generation. Fossil generation in the EU and US both peaked in 2007, and then in Australia in 2009, Japan in 2012, and South Korea in 2018. However, none of these countries are also contending with rapid growth in electricity demand.

The rest of the world is generally still seeing fast-rising electricity demand. Encouragingly, more and more of that rise is being met with clean power.

Over half of the electricity demand rise in Asia (52%) was met with clean electricity in the seven years from 2015 to 2022, double the 26% achieved in the seven years before that. That's important, since 84% of the global electricity demand rise from 2015 to 2022 happened in Asia.

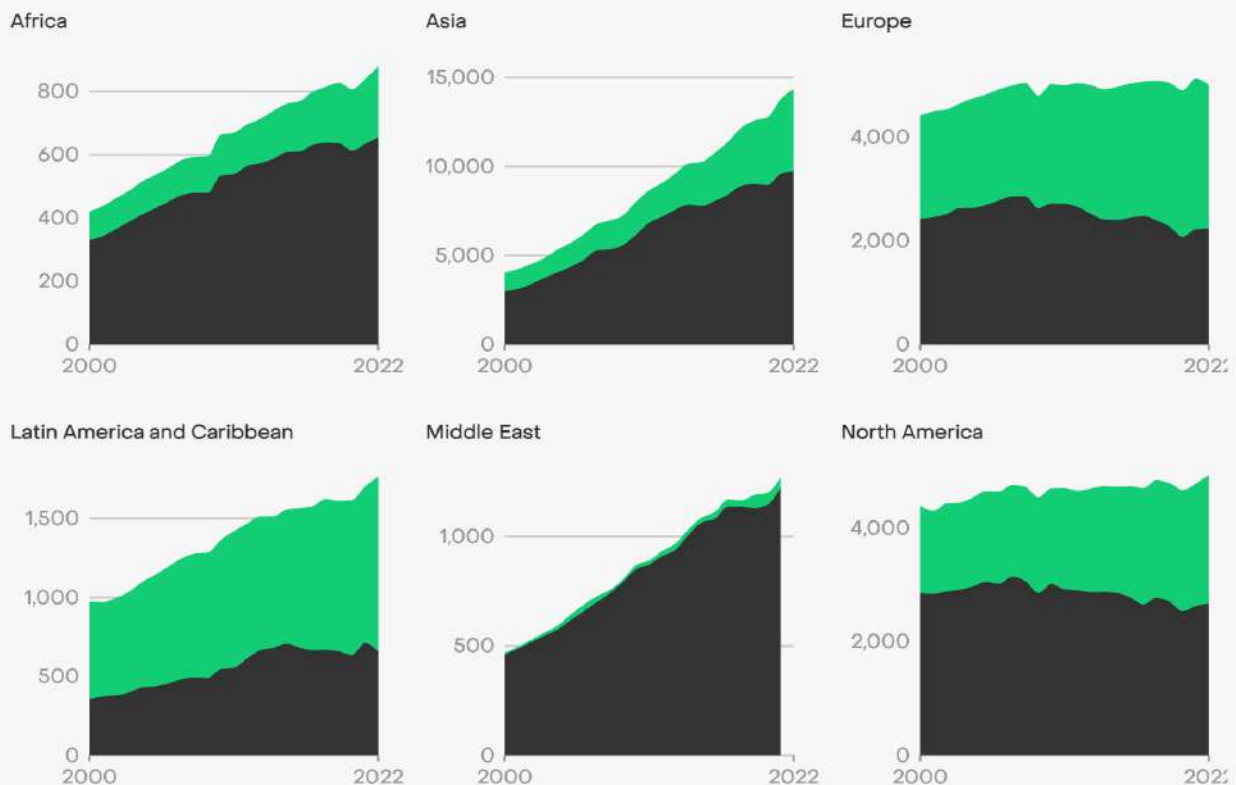
Africa's proportion of electricity demand growth met by clean sources also roughly doubled, from 23% during 2008–2015 to 61% during 2015–2022. The rise in clean power in the Middle East was only enough to meet 14% of the electricity demand rise during 2015–2021, although in the previous seven years there was no net growth in clean power generation.

Latin America was unique in being the only region over the last seven years that increased clean power fast enough to meet rising electricity demand and to reduce fossil generation.

## Fast-growing regions are getting closer to meeting all demand growth with clean power

Electricity generation (TWh)

■ Fossil ■ Clean



Source: Annual electricity data, Ember

## China and India: are they close?

In the last ten years, three-quarters of the global electricity demand growth was in China and India (61% and 12% respectively). The IEA [estimates](#) that for the next three years, these two countries will continue to account for most of the rise in global demand: China will account for 54% while India for 9%. Hence, the outlook for these two countries is critical to understanding the global transition.

In China, clean generation growth is coming closer to meeting all electricity demand growth. In 2022, wind and solar generation increased by 259 TWh meeting 69% of the growth in the electricity demand while all clean sources met 77%.

However, China's average electricity demand growth rate during the last ten years was 6%, substantially higher than the 4.4% increase in 2022. If electricity demand rises back to that trend, then clean power isn't so close. With China's electricity demand per capita already in line with the EU's, the impact of energy efficiency savings on electricity demand may be even more important than the growth in clean power in determining when fossil generation begins to fall.

With the growth in China's wind and solar generation, alongside the continued build of nuclear, hydro and bioenergy, China will likely reach peak power sector emissions and therefore peak coal in line with its 2025 target, or potentially earlier. However, it is less clear how quickly coal power will fall in the second half of this decade, which is critical to the climate since China generated 53% of the world's coal-fired electricity generation in 2022.

In India, clean electricity growth is still a way off meeting all electricity demand growth. In 2022, electricity demand rose significantly (+124 TWh, +7.2%) as the economy bounced back after a slowdown in 2021 amid a second wave of the Covid-19 pandemic. India's wind and solar rose only by 29 TWh, meeting 23% of the demand growth, while all clean sources rose by 47 TWh, providing 38%. Hence clean power played a relatively small role in slowing India's rising fossil generation.

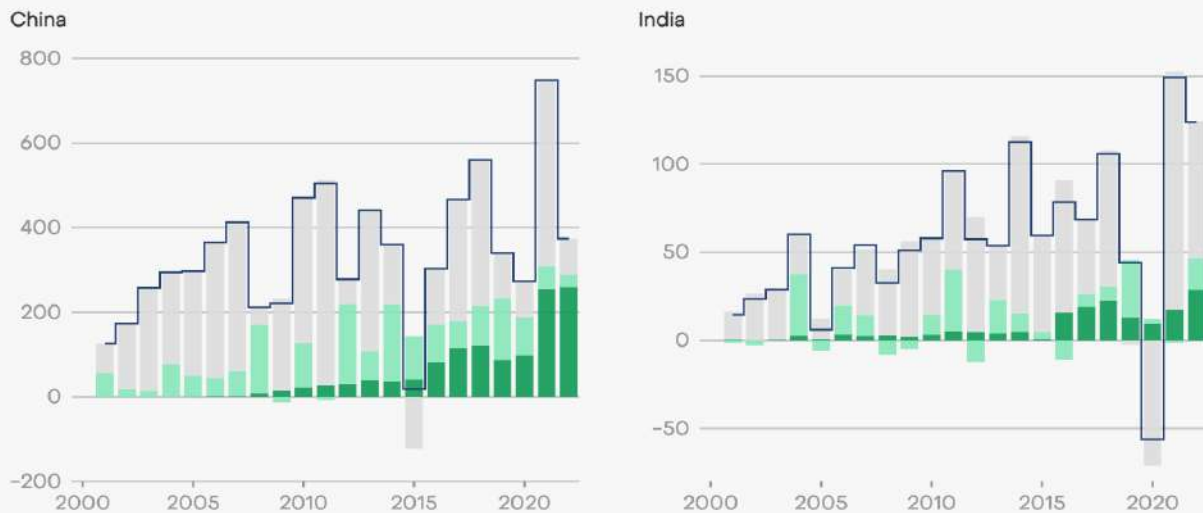
Predicting electricity demand growth is a contentious subject within India. The last ten years (2012–2022) have averaged 5.3% annual growth in electricity demand. India's recent draft [National Electricity Plan 14](#) (NEP14) assumes there will be 6.1%

growth on average each year until financial year 2032. As solar and wind build rates increase to meet the government's target of 450 GW by 2030, the additional solar and wind generation could [meet](#) annual demand growth of around 4–5% through to 2030. But if electricity demand grows faster, then coal generation will likely continue to grow.

## China and India are partially meeting demand growth with clean sources

Annual change in electricity generation (TWh)

Wind and solar Other clean Fossil Demand



Source: Annual electricity data, Ember

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## Electrification means more need for clean power

It is not only rapidly developing economies that will see an increase in demand for electricity. As clean electrification takes off, and the energy system is rebuilt around clean electricity, mature economies will also have to grapple with how to meet rising demand with clean sources.

The share of electrification in the total final energy consumption is increasing. This is predicted to rise from 20% in 2021 to 27% by 2030 as electrification helps to decarbonize different sectors, especially transport and heating, as noted by the [IEA](#). This will mean a notable increase in electricity demand. All economies will therefore need to ensure they are building enough clean power to both meet rising electricity demand and replace fossil fuels.

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## A new era of declining power sector emissions

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2022 may mark the end of growth in fossil fuels, finally reaching a peak for power sector emissions. This would be a step in the right direction, but there remains much work to do to achieve the rapid declines in emissions needed for a pathway aligned with 1.5C.

### A new era of fossil decline: as soon as 2023?

As soon as 2023, wind and solar could push the world into a new era of falling fossil generation, and therefore of falling power sector emissions. The fall will be small in 2023, but it will get bigger every year as wind and solar grow further, which could mean power sector emissions will never peak higher than they did in 2022.

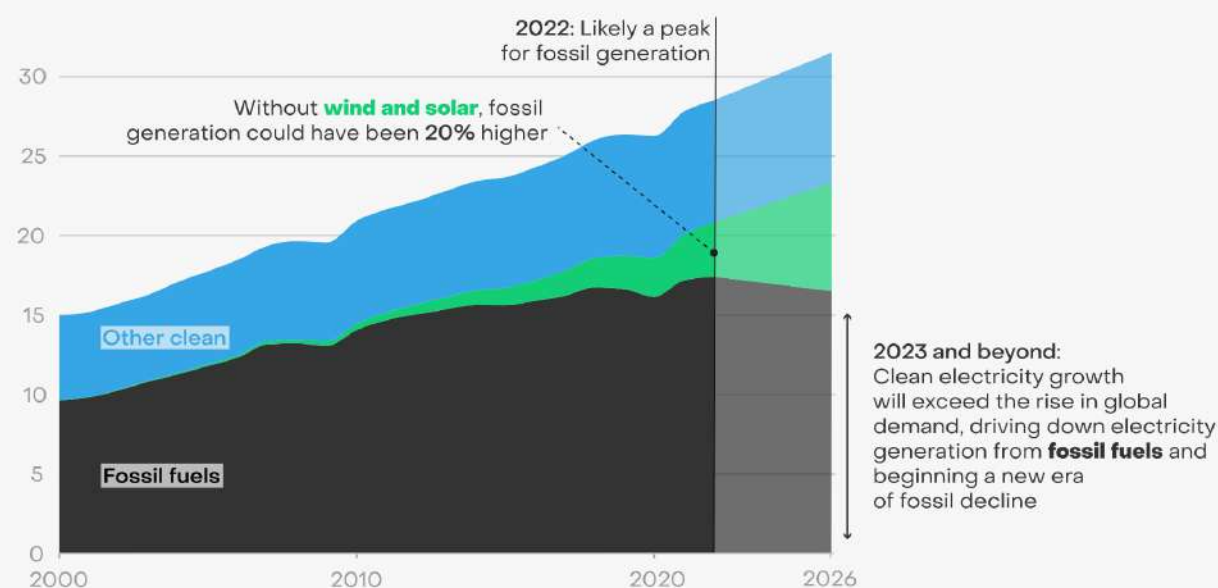
Fossil generation has fallen before, but only when electricity demand was below average due to economic woes: in 2009, 2015, 2019 and 2020. 2023 would be the first time for this to happen at a structural, enduring level.

Historically, much of the rising electricity demand has been met with fossil generation. But all that changed as solar and wind started to take over. Wind and solar generated 3,444 TWh in 2022 globally. If wind and solar had not been built, and instead that was generated with additional fossil fuels, with coal and gas in proportion to the current mix, then power sector emissions would have been 2.4 gigatonnes higher in 2022. Or, to rephrase, power sector emissions could have been 20% higher in 2022 without wind and solar.



## A new era of falling fossil generation is about to begin

Actual and projected electricity generation (TWh, '000s)



Source: Annual electricity data, Ember  
2023–2026 figures based on growth rate from 2012–2022: electricity demand (+2.5%), wind and solar (+19%) and other clean power (+1.7%)

**EMBER**

Ember predicts that the first fall in fossil generation will happen in 2023. This is based on the assumption that 2023 will see the average percentage growth rate of the last ten years for electricity demand (+2.5%, +726 TWh), wind and solar generation (+19%, +641 TWh), and other clean power (+1.7%, +132 TWh). This would lead fossil generation to a small fall of 47 TWh (–0.3%) in 2023. This small fall is in the range of uncertainty, but if fossil generation doesn't fall in 2023, it is fairly certain that it will fall from 2024, when wind and solar will have had a further year of growth.

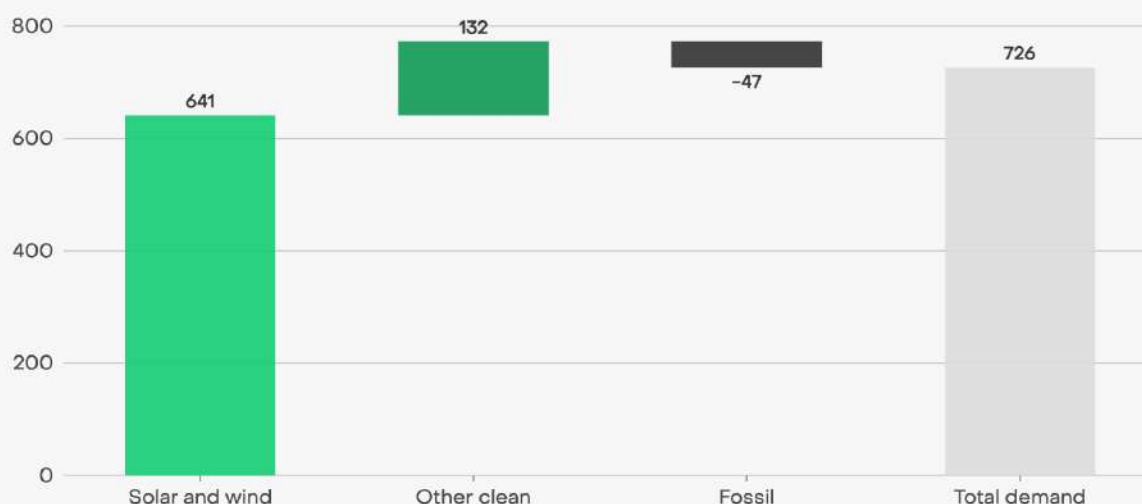
Ember's perspective is that it is a reasonable assumption to apply these growth rates to 2023. First, electricity demand growing at 2.5% looks reasonable given the macroeconomic forecasts at the moment. Electricity demand rose by 2.5% last year, and the latest [IMF forecast](#) is showing slightly lower global GDP growth in 2023 than 2022, although weighted more towards China. Secondly, solar and wind generation growing at 19% seems reasonable based on market outlooks of solar and wind capacity additions. The most conservative is the IEA, which [forecast](#) a rise in wind and solar generation of 16% for 2023. Others show much higher: [BNEF](#) forecast that solar capacity will rise by 28% in 2023. Third, other clean electricity growing at 1.7% seems conservative—the IEA forecast a 5% rise in [hydro](#) generation and a 4% rise in [nuclear](#) generation in 2023. Fossil generation is

forecast to fall 20% in the [EU](#) in 2023, and 8% in the [US](#), compared to a rise of 3% and 2% respectively in 2022.

Other research bodies are forecasting this moment happening soon. The view that power sector emissions may fall as soon as 2023 is also shared by Rystad Energy. In February, Rystad Energy [forecast](#) that total economy-wide emissions would peak in 2025, with the power sector seeing a fall in emissions in 2023. In January, the IEA [forecast](#) that the world is “close to the tipping point” of falling power sector emissions in their analysis to 2025, but they did not state which year this may happen.

### Fossil generation is expected to fall in 2023, as growth in clean power exceeds the rise in demand

Projected year-on-year change in global electricity generation (TWh)



Source: Ember calculations; Annual electricity data, Ember

**EMBER**

### Solar and wind take market share from fossil generation

Since 2015, there is a clear trend of solar and wind taking market share from fossil generation. Globally, wind and solar market share has risen by 7 percentage points, whilst fossil market share fell by 5 percentage points.

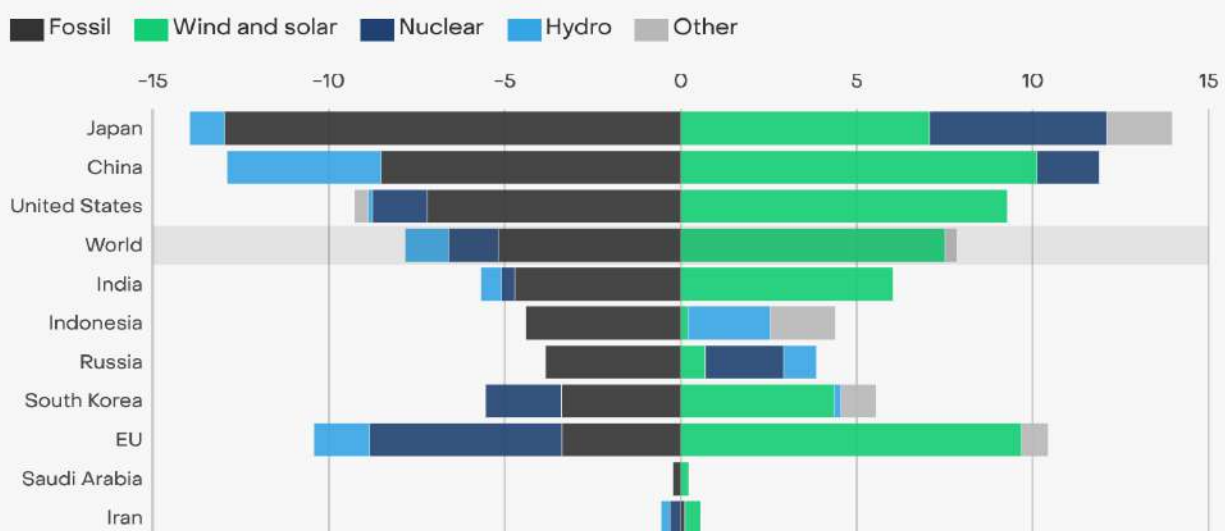
The graph below shows the change in electricity mix of the ten most CO<sub>2</sub> emitting countries, which confirms that it is mostly wind and solar driving the reduction in fossil market share.

Six of those regions saw a major market share increase in wind and solar in 2022 compared to 2015 and this led mostly to a mirror fall in fossil generation. There were only two exceptions: the EU (which had an exception in 2022 because of record low hydro and nuclear), and Japan (because it returned mothballed nuclear units back into operation since 2015).

Four of those regions saw almost no market share rise in wind and solar. Saudi Arabia and Iran met increased electricity demand with more gas and oil generation, which already dominated, leaving their electricity mix the same in 2022 as it was in 2015. Russia somewhat reduced the market share of fossil generation through an increase in nuclear generation, and Indonesia through a combination of hydro, geothermal and bioenergy generation.

## Wind and solar growth reduce fossil fuel market share across major emitting countries

Percentage point change in electricity mix, from 2015 to 2022 (or latest year)



Source: Annual electricity data, Ember.

The ten regions selected are those with the biggest CO<sub>2</sub> emissions; Note, the EU had an exceptional year in 2022, with record low nuclear and hydro generation

## Coal phasedown but without closing coal?

In late 2021, global leaders at COP26 agreed to ‘phase down’ unabated coal power. However, fewer coal power plants were closed in 2022 than in any year since 2014.

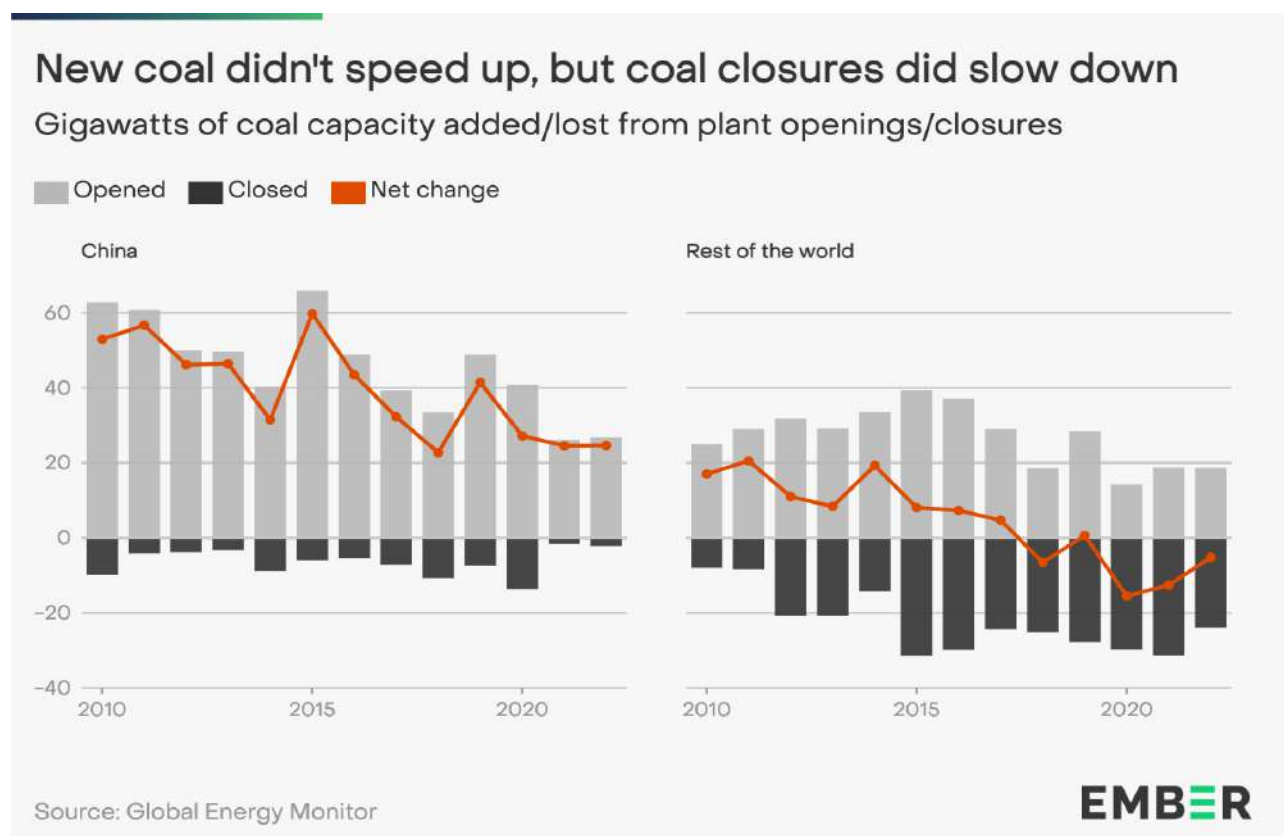
In China, only 0.1% of its coal fleet retired in 2022 (the same as in 2021). This followed power cuts in [2021](#), which led President Xi Jinping to [announce](#) in 2022 to “establish the new before demolishing the old”, pushing coal closures to the back of the political agenda. But China’s appetite for new coal also showed a [revival](#). New coal power plants—announced, permitted, and under construction—accelerated dramatically in China in 2022, with new permits reaching the highest level since 2015, and 50 GW of coal power capacity started construction in China in 2022, a more than 50% increase from 2021. The coal power capacity starting construction in China was six times as large as that in all of the rest of the world combined. This meant the net rise in coal capacity (+2%) was bigger than the rise in coal generation (+1.5%); consequently, utilisation of China’s thermal power plants fell to [4379 hours](#) in 2022, which was below 50% for the first time.

Like China, India also faced power cuts in 2021, which then [continued](#) into 2022. In India, the Central Electricity Authority [asked](#) that no coal power plants be closed until 2030, so India—like China—is also positioning itself to keep coal power plants open for now.

In the EU, old coal plants even reopened. There were 26 old coal units brought back on emergency standby in 2022 during this winter, as Russia cut off almost all pipeline gas into Europe. However, the average utilisation of the 26 units during the winter was just 18% and [they added only 1% to Europe’s generation in 2022](#), and most of the plant reactivations were planned for one or two winters only. Commitments by European countries to phaseout coal are largely unimpacted.

While this trend may unnerve those hoping for rapid coal power plant closures, the ‘coal power phasedown’ needs to be measured on CO<sub>2</sub> emission falls, not just on the number of coal power plants closed. Keeping the lights on is more important than closing coal power plants. Coal’s interim role—before it is closed—is to run in more of a back-up mode, but this will increasingly contribute to oversupply. This oversupply must not slow down the rest of investment into the transition and therefore slow down the overall fall in coal generation.

Plans to phase down coal must therefore consider how to reduce generation, as well as retire capacity. Both [Indonesia](#) and [Viet Nam](#) have secured commitments for international financing to support them in phasing down coal use and expanding clean energy. India is also considering whether to negotiate a clean energy transition [deal](#); if it does, it may not be as explicit in its commitments to phasedown coal.



## A gas power phasedown is coming soon

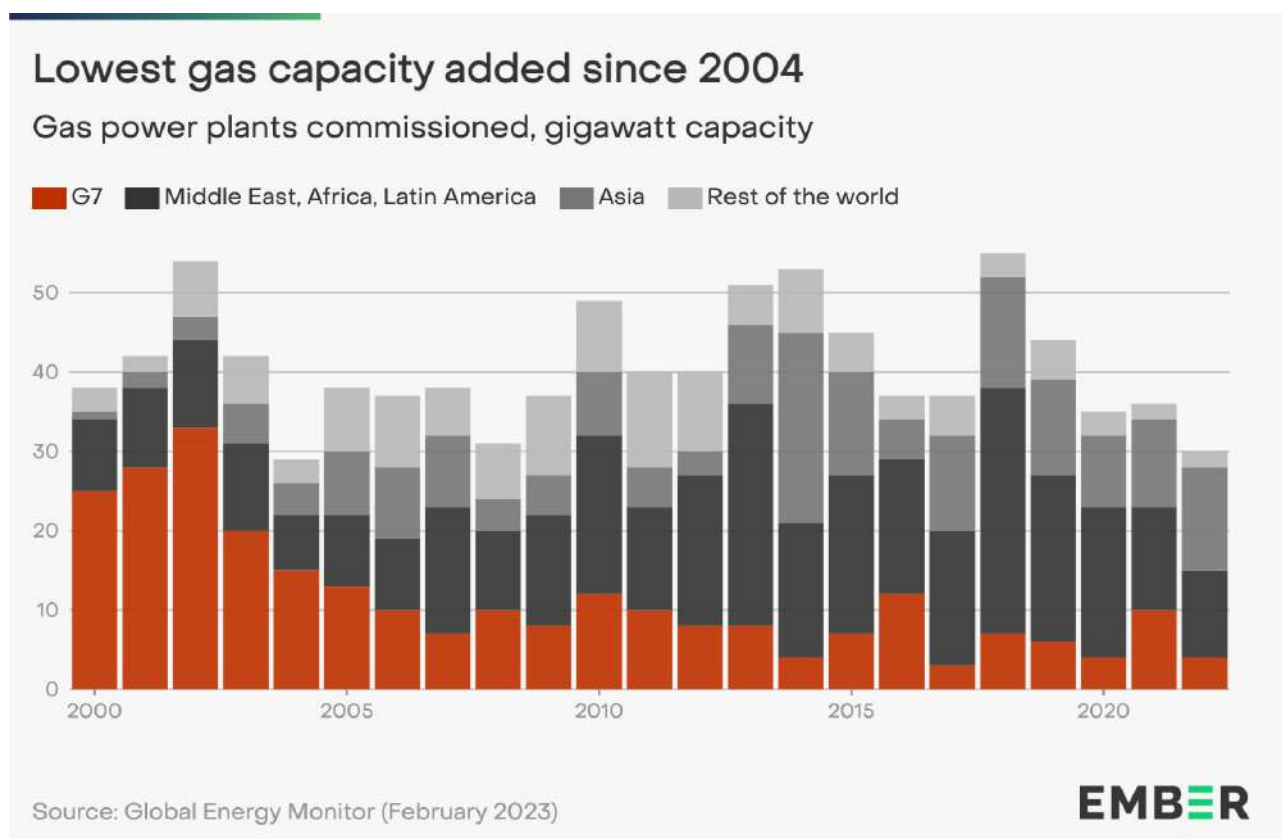
2022 changed everything for gas. Russia's invasion of Ukraine triggered record-high gas prices that have forever [changed the perception](#) of gas as secure, abundant and cheap.

In the G7, which generated 40% of the world's gas power in 2022, the rise of clean power will mean the simultaneous phasedown of coal and gas, where previously the focus had first been on a coal power phasedown. It is clear that G7 countries are interested in a gas phasedown: in June 2022, the G7 [strengthened](#) their commitment to decarbonise their electricity supplies by 2035. The IEA Net Zero pathway shows [only 2% of the G7's electricity](#) coming from unabated gas in 2035.

The Middle East, Africa and Latin America accounted for 39% of the growth in global gas generation in the last decade (2012–2022), as gas met most of the rise in electricity demand across those regions. But wind and solar generation is meeting more and more of the electricity demand growth: in 2022 it was enough to meet about 2% electricity demand growth across those regions in total, double the rate of 2018. Some countries may embrace clean electricity even more aggressively to aim for falls in gas power. This is particularly relevant for the Middle East region, which generated 15% of the world's gas generation in 2022. Because there is very little coal power across most of these countries, wind and solar will impact almost exclusively upon gas.

In Asia, there was five times as much coal power as gas power in 2022. The concern was always that [Asia would grow gas power to replace part of its coal generation](#). But the energy crisis has reduced the risk of gas bridge: most countries in Asia rely on imported gas. The heightened concerns over cost and security mean there is a genuine opportunity for a lasting transition directly from coal to clean electricity. The potential of gas power as a bridge in Asia is smaller than it has ever been. The question is whether the growth in clean power will be enough to cut coal power emissions without a switch to gas.

The amount of new gas power plants built in 2022 was the lowest in 18 years. 31 GW was built in 2022, according to Global Energy Monitor [data](#). With the time lag in building new power plants, it's unlikely that this is related to the energy crisis of 2022. That impact will be felt in the coming years, and it's likely that it will lead to even lower build rates.



The capacity changes in 2022—fewer coal plant closures, but fewer new gas plants—suggest that rather than a rapid fall in only coal power, there will likely be a more equal fall in both coal and gas power. Gas power plants will still have a role to play in the mid-term: some running a lower number of hours every hour, and some potentially repowered to run on hydrogen.

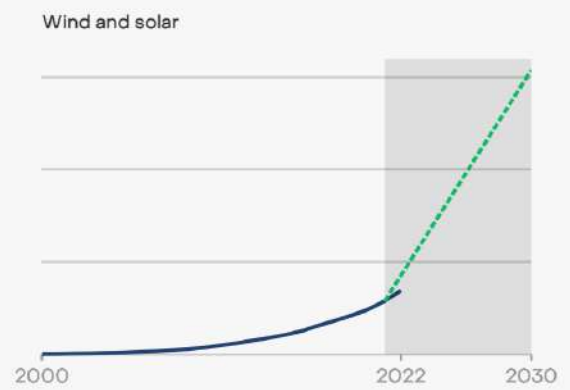
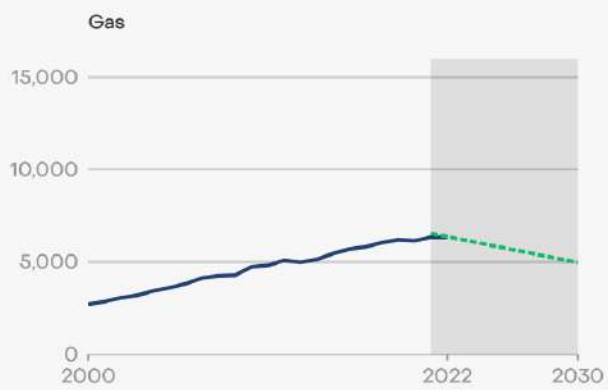
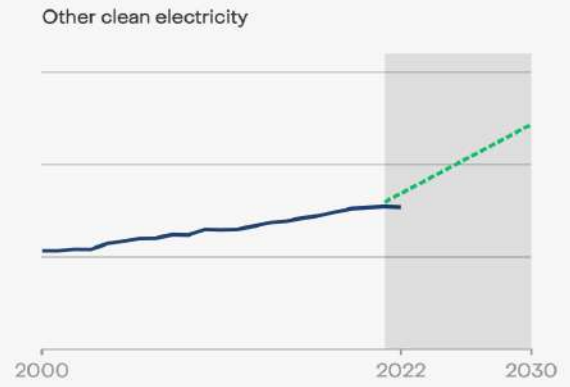
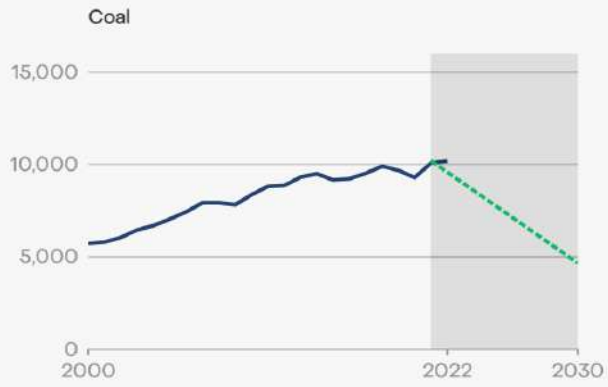
The 2020s is the implementation decade. The [IEA Net Zero Emissions scenario](#) shows that from 2021 to 2030 we need to raise wind and solar generation around five times (solar seven times and wind four times), other clean electricity needs to rise 54%, and this would halve coal power (–54%) and reduce gas power by 24%. That is the scale of the challenge. And ten years later in 2040, the world needs a net zero power sector. According to the IEA, that means not only an unabated coal power phaseout, but a near phaseout of unabated gas power as well.



# What needs to happen for 1.5 degrees?

## Electricity generation (TWh)

■ Generation (TWh) ■ IEA Net Zero pathway



Source: Annual electricity data, Ember, IEA (WEO 2022)





## Chapter 4 | Global Electricity Trends

# Data on the global electricity sector in 2022

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An overview of long term trends and the world's progress towards net zero.

### Chapter contents

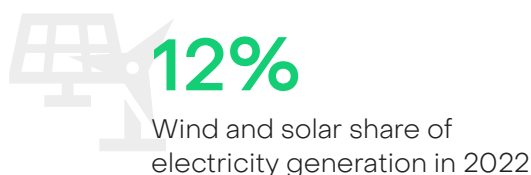
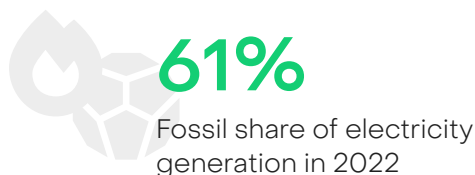
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# Global Electricity Generation

## Global Electricity Trends 2022

The global electricity generation mix is still dominated by fossil fuels, which provided 61% of electricity generation in 2022. Coal accounted for 36% (10,186 TWh), fossil gas for 22% (6,336 TWh) and other fossils for 3% (850 TWh) of global generation. Hydro remained the largest clean electricity source at 15% (4,311 TWh), and nuclear the second largest source contributing just over 9% (2,611 TWh). Wind and solar together reached a 12% share of global electricity (3,444 TWh), with wind at 7.6% (2,160 TWh) and solar at 4.5% (1,284 TWh). Bioenergy generated 2.4% (672 TWh) of global electricity, and other renewables 0.4%.



### Global electricity mix

Share of electricity (%)

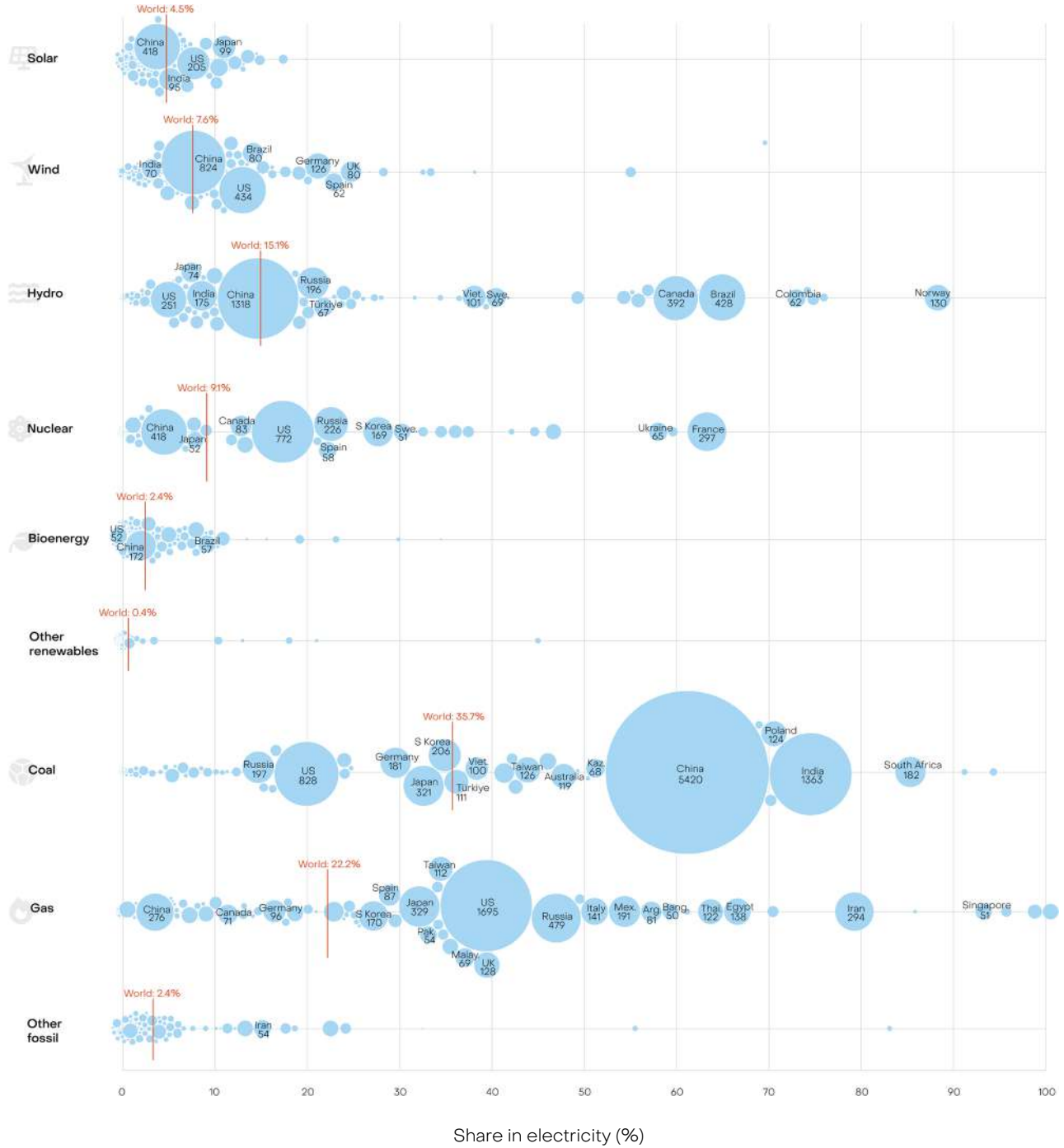
■ Solar ■ Wind ■ Hydro ■ Nuclear ■ Bioenergy ■ Other res ■ Other fossil ■ Gas ■ Coal



# Global Context

## Global electricity generation

Electricity generation (TWh, bubble size) and share of electricity (% x-axis)



Source: Ember

Note: 2022 data used where available, else 2021.

## Change in 2022

The most significant change in electricity generation in 2022 was the record year-on-year growth of solar and wind, rising by 245 TWh (+24%) and 312 TWh (+17%) respectively.

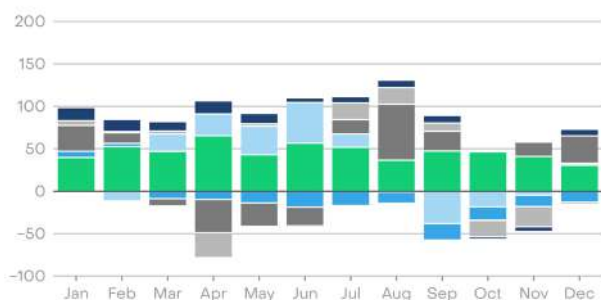
2022 also saw a historic fall in nuclear generation, with a decrease of 4.7% (-129 TWh) compared to the previous year. The fall was largely in the EU, which was affected by maintenance issues in France as well as plant closures in Germany and Belgium. Nuclear also fell significantly in Japan (-9.5 TWh) due to planned maintenance. Global hydro generation increased by 1.7% (+73 TWh), despite significant falls due to heatwaves in the EU and some other countries. In the context of volatile gas prices and security of supply concerns resulting from Russia's invasion of Ukraine, global gas generation remained almost flat, decreasing slightly by 0.2% (-12.3 TWh). Coal rose by 1.1% (+108 TWh).

These changes led to the global electricity mix shifting in favour of wind and solar. Combined, wind and solar provided 12% of global generation, up from 10% in 2021. Other clean electricity sources fell, with nuclear experiencing the largest share reduction (-0.7 percentage points), while hydro fell by 0.1 percentage points and bioenergy by 0.04 percentage points. Coal's share in the electricity mix fell slightly (-0.5 percentage points) to 35.7%. Similarly, gas share fell by 0.6 percentage points to 22.2%. In contrast, other fossil generation increased by 86 TWh, increasing its market share from 2.8% to 3%.

### Monthly changes in global electricity generation

Change in generation year-on-year (TWh)

■ Wind + Solar ■ Hydro ■ Nuclear  
■ Coal ■ Gas ■ Other

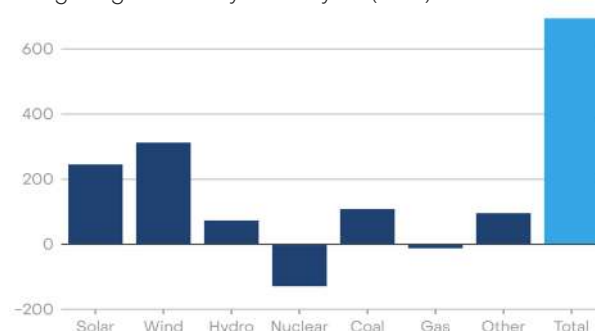


Source: Ember

Note: 2022 data used where available, else 2021

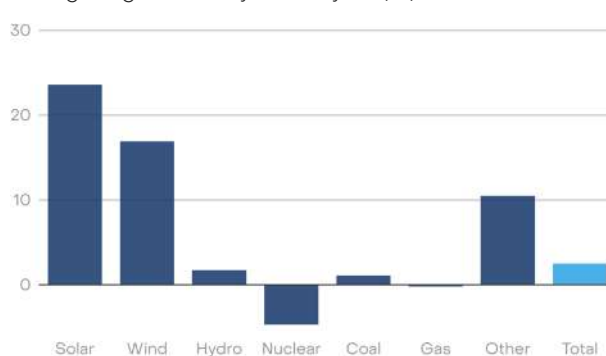
### Key changes in global electricity generation

Change in generation year-on-year (TWh)



### Key changes in global electricity generation

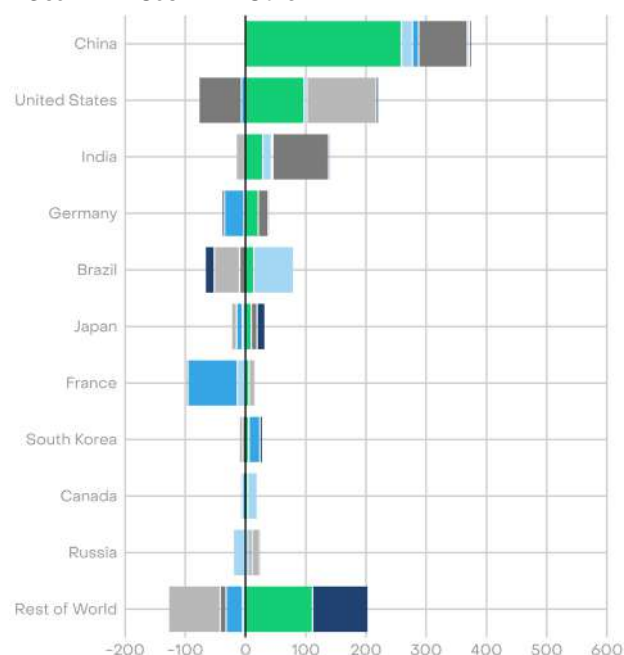
Change in generation year-on-year (%)



### Global electricity generation changes

Change in generation year-on-year (TWh)

■ Wind + Solar ■ Hydro ■ Nuclear  
■ Coal ■ Gas ■ Other



# Long-term Trends

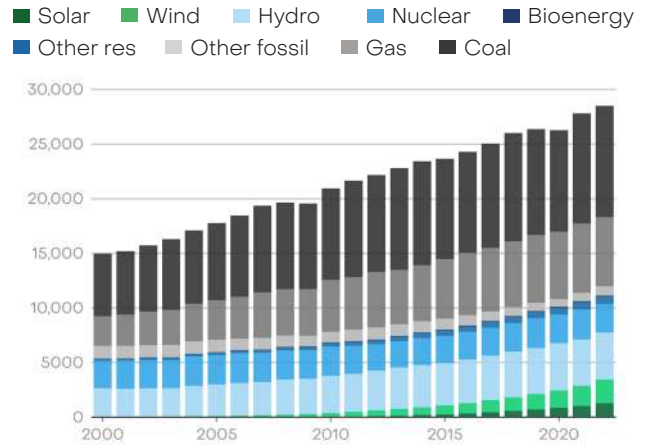
The world's reliance on fossil power has declined only slightly in the past two decades, from 64% in 2000 to 61% in 2022. During that time, coal generation grew in absolute terms from 5,719 TWh in 2000 to 10,186 TWh in 2022, even while its share of generation dropped from 38% in 2000 to 36% in 2022. Gas generation has increased by four percentage points since 2000 to account for 22% of global electricity in 2022. Other fossil fuels fell from 7.8% of generation to 3% over the same period.

In 2000, wind and solar accounted for almost no generation, growing over the past two decades to reach 12% in 2022. Solar has made a sprint start, as the fastest growing source of electricity for the last 18 years, closely followed by wind power. In comparison, other forms of low-carbon electricity have not been on a rapid growth trajectory. Bioenergy increased its share slightly over the same period, while hydro and nuclear fell in the global mix. Nuclear's share reduced the most, going from 17% of global electricity in 2000 to just 9.2% in 2022.

Since 2015, the year of the Paris Agreement, solar's share of global electricity has quadrupled, rising from 1.1% in 2015 to 4.5% in 2022. Wind's share more than doubled in the same period, from 3.5% in 2015 to 7.6% in 2022. Bioenergy generation rose only slightly in the global mix (+0.3 percentage points) while the shares of the other sources fell: coal from 39% in 2015 to 36% in 2022, gas from 23% to 22%, other fossil from 4.3% to 3%, nuclear from 11% to 9.2% and hydro from 17% to 15%.

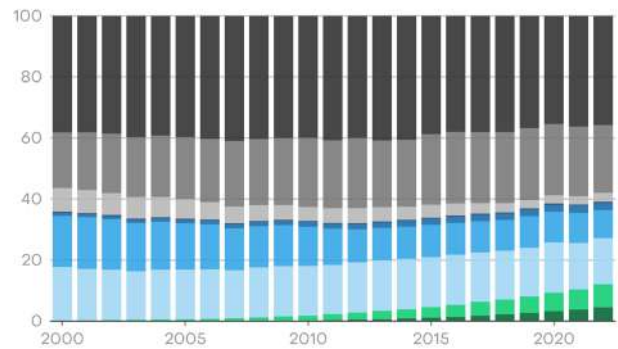
## Global electricity generation

Generation (TWh)



## Global electricity mix

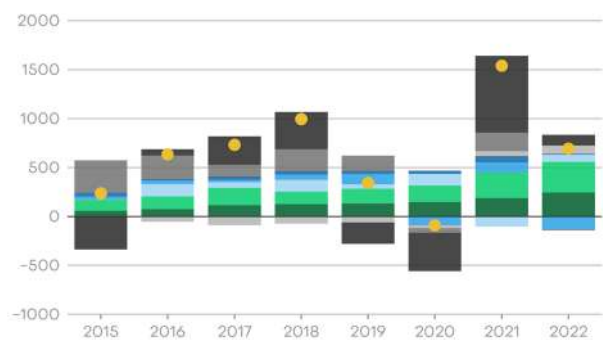
Share of electricity (%)



## Annual changes in global electricity generation

Change in generation year-on-year (TWh)

● Total



Source: Ember

Note: 2022 data used where available, else 2021



## Progress Towards Net Zero



There is universal agreement that the global electricity sector must be decarbonised for the world to keep global heating below 1.5C. This can be achieved in a number of ways. According to [the IEA Net Zero Emissions scenario](#), unabated coal plants must be phased out by 2035 in mature economies, and by 2040 in developing ones. Unabated gas (gas without carbon capture and storage) will produce only 5% (13 TWh) of the overall world's generation in 2035 and will have to be phased out by 2040. Wind and solar will form the backbone of global electricity generation, providing almost 70% of the world's electricity by 2050. By this time, nearly 90% of electricity will be produced by renewables. More detail on each electricity source can be found in chapter 5.

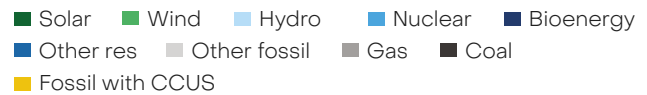
Impressive growth in wind and solar shows a glimpse of the future clean electricity system, but continued—if slowing—growth in fossil fuels is still holding back progress for a pathway aligned with 1.5C. According to the IEA, coal needs to fall by 8.3% annually between 2021 and 2030 and gas generation by 3% annually in the same period. Coal increased in 2022 while gas only fell slightly, but this may be the final year of fossil growth and the peak of power sector emissions (see chapter 3). In contrast, solar grew by 24% in 2022, close to the required annual rate between 2021 and 2030 of 25%, while wind saw the required rate of 17% in 2022. However, their growth is still from a relatively small base. Maintaining such high growth rates year-on-year will become harder as industries mature.

Other clean sources also need to increase their generation. Nuclear generation needs to rise by 3.8% annually, but it fell by 4.7% in 2022. Hydro must increase by 3.2%, but it grew only about half of the required rate. The IEA pathway sees bioenergy growing by 7.6% annually between 2021 and 2030, nine times faster than it did in 2022. However, pathways without bioenergy may be preferable given the emissions risks (see chapter 5).

It is clear that by 2030, the global power system will be unrecognisable from a decade ago: electricity will be cleaner, less dependent on fossil imports, and it will be relied on more for transport and heating. The 2020s are the decade of implementation. The task is herculean, but a 1.5 degree pathway is still possible.

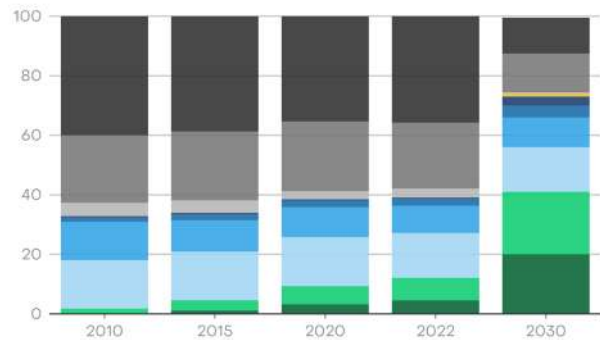
### Global electricity generation

Generation (TWh)



### Global electricity mix

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Global Electricity Demand

Global Electricity Trends 2022



Global electricity demand hit a record new high of 28,510 TWh in 2022. Major economies were responsible for the bulk of this demand: China for 8,840 TWh (31%), United States for 4,335 TWh (15%), the EU for 2,794 TWh (10%), India for 1,836 TWh (6%), Russia for 1,102 TWh (4%) and Japan for 968 TWh (3%). On average worldwide, the per capita demand was 3.6 MWh in 2022, with some major countries above the global per capita average (United States 13 MWh, South Korea 12 MWh, China 6.2 MWh, EU 6.3 MWh) and others far below (Bangladesh 0.6 MWh, India 1.3 MWh).

Electricity accounted for around 20% of final energy consumption in 2021. The power sector is the fastest-growing source of final energy demand, set to increase substantially as the world tackles the climate crisis by increasing electrification, alongside a growing population and improvements to standard of living. According to different [scenarios](#), electricity's share of final energy consumption may increase to between 30% and over 50% by 2050.

Estimates vary on how much electricity demand will grow by 2050. Some of the most respected estimates are given in the Stated Policies Scenario (STEPS), Announced Pledges Scenario (APS) and Net Zero Emissions Scenario by 2050 by the [IEA](#). Global electricity demand in 2050 is over 75% higher in the STEPS than it was in 2022, 120% higher in the APS and 150% higher in the Net Zero Emissions by 2050 Scenario. It is clear that higher ambition scenarios that rebuild the energy system around clean electricity will require far higher electricity demand than the current trajectory.

**28510 TWh**

Global total demand in 2022

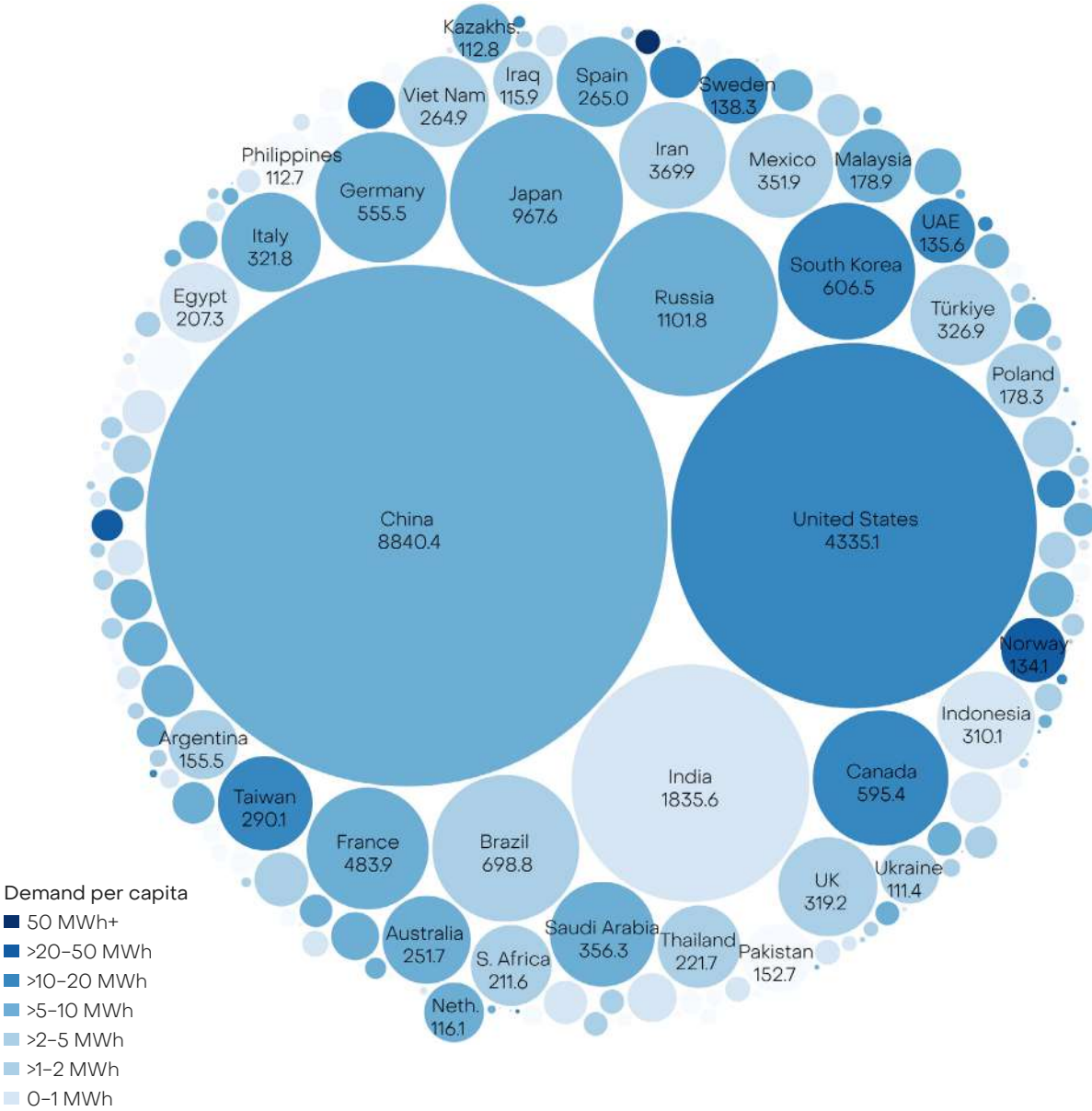
**3.6 MWh**

Demand per capita



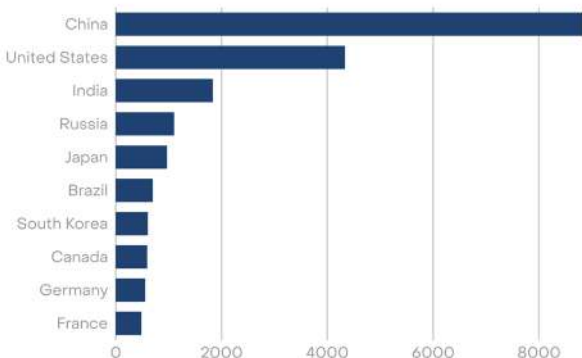
**Electricity demand**

Electricity demand (bubble size) and demand per capita (bubble colour)



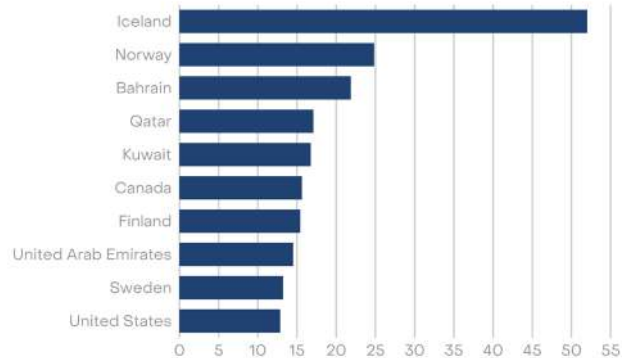
**Countries with highest demand**

Electricity demand (TWh)



**Countries with highest demand per capita**

Electricity demand per capita (MWh)





# Change in 2022

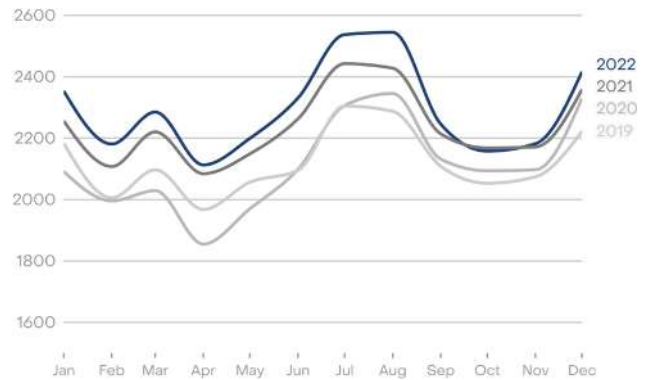
Global electricity demand increased by 694 TWh (+2.5%) in 2022, reaching 28,510 TWh, up from 27,816 TWh in 2021. Such an increase is broadly in line with the average historical demand growth for 2010–2021 of 2.6% and the average 2.7% demand growth since the Paris Agreement in 2015.

Wind and solar met 80% of demand growth in 2022, while all renewables together (wind, solar, hydro, bioenergy and other renewables) met 92% of the increase in demand. An increase in coal generation (+108 TWh) met the remaining increase in demand (8%) as well as the shortfall in nuclear and gas generation. Other fossil fuels also rose to cover the remaining shortfall (+86 TWh).

The growth in demand was not uniform across the world. China accounted for 54% of the global rise in demand; the US accounted for 21% and India accounted for 18% of global demand increase. In contrast, electricity demand fell in the EU by 87 TWh (-3%).

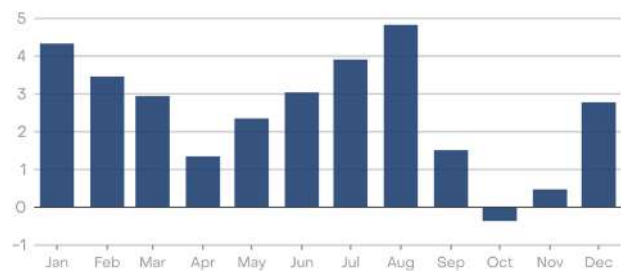
## Global electricity demand

Electricity demand (TWh)



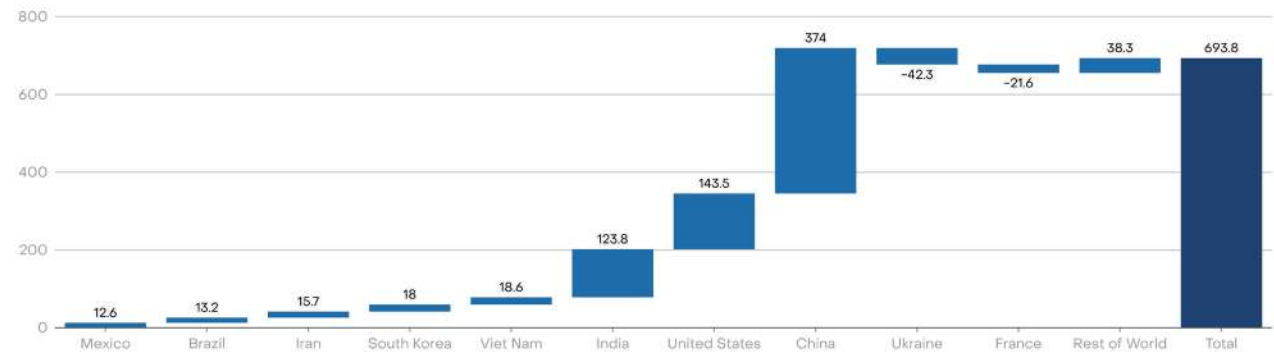
## Monthly changes in global electricity demand

Change in electricity demand year-on-year (%)



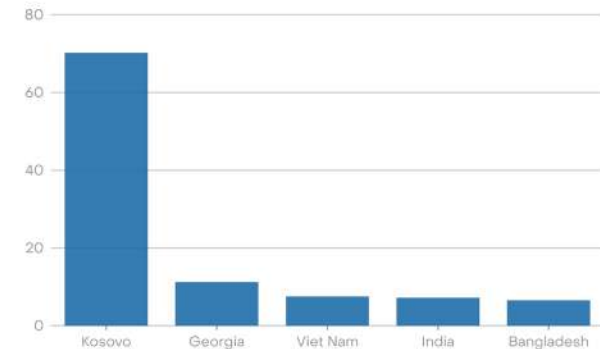
## Key changes in global electricity demand

Change in electricity demand year-on-year (TWh)



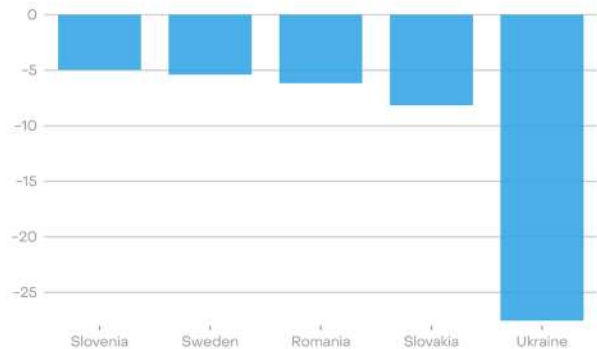
## Largest increases

Change in electricity demand year-on-year (%)



## Largest declines

Change in electricity demand year-on-year (%)



Source: Ember

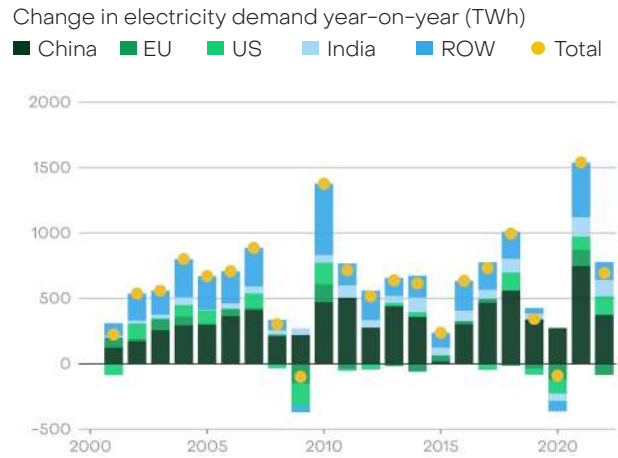
Note: 2022 data used where available, else 2021

# Long-term Trends

Since 2000, global electricity demand has almost doubled, increasing from 14,972 TWh in 2000 to 28,510 in 2022. Much of this increase was driven by demand increase in major growing economies. China particularly so, where electricity generation grew by more than six and half times in the last two decades, from 1,347 TWh in 2000 to 8,840 TWh in 2022. In India, demand has more than tripled in the last two decades from just 573 TWh in 2000 to 1,836 TWh in 2022. The majority of the increase in the global demand was met by coal, which led to an almost doubling of global coal generation. Other major economies where demand has been increasing include the US, Russia and Indonesia.

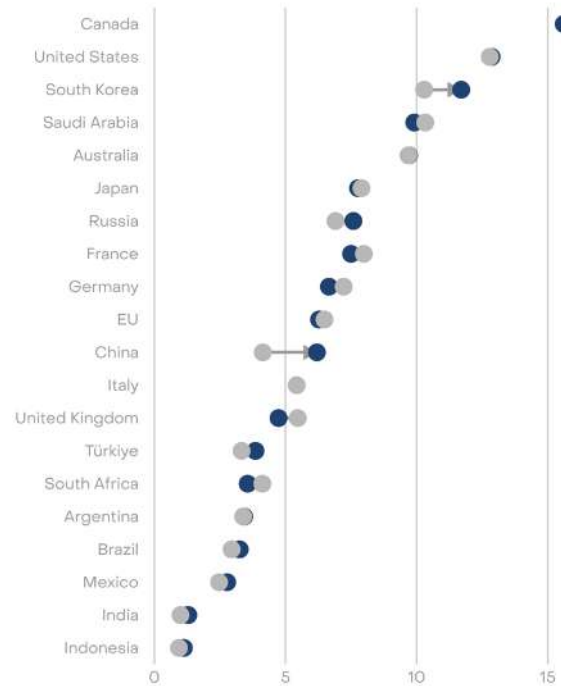
Since 2015, the year of the Paris Agreement, global demand has increased from 23,660 TWh to 28,510 TWh in 2022, an average 2.7% per year.

## Annual changes in global electricity demand



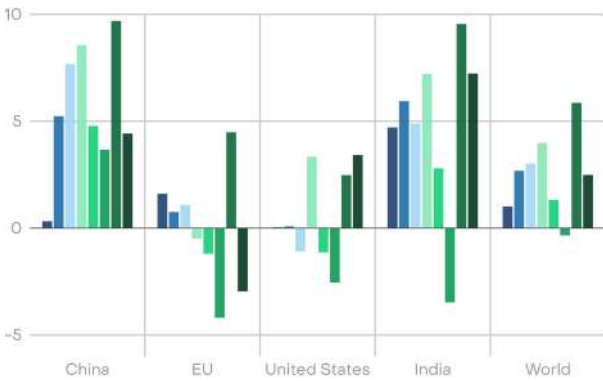
## Demand per capita, G20 countries

Electricity demand per capita (MWh)  
● 2015 ● 2022



## Annual changes in global electricity demand

Change in electricity demand year-on-year (%)  
2015 2022



Source: Ember

Note: 2022 data used where available, else 2021

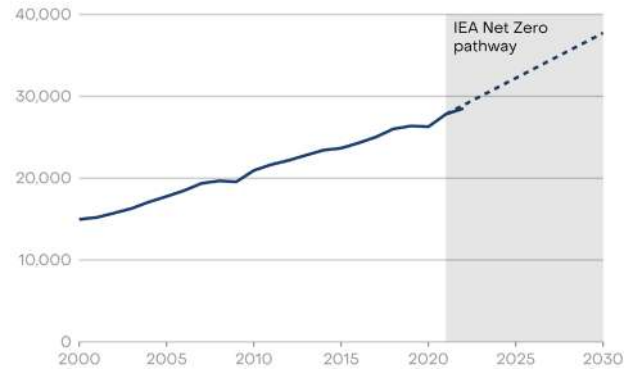
# Progress Towards Net Zero

Growth in electricity demand is a central part of any pathway to net zero, as clean electrification helps reduce emissions across sectors like transport, heating and industry. In the [IEA Net Zero Emissions scenario](#), electricity demand grows by 3.2% annually between 2021 and 2030, a rise from the average annual growth of 2.7% between 2015–2022.

Electrification increases the demand for electricity, but energy efficiency will also help to suppress the demand rises. Preventing runaway electricity demand growth is critical to meeting climate targets. The world is not yet in an era of unlimited clean electricity.

## Demand

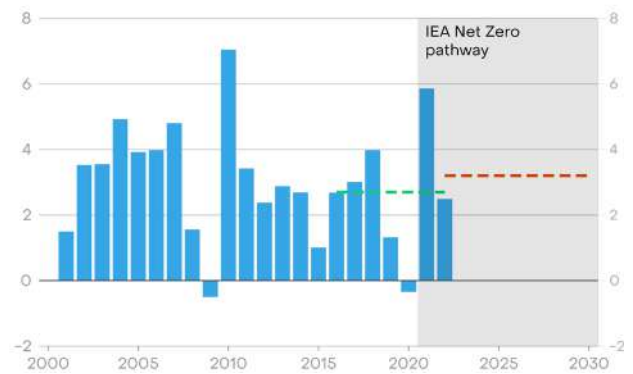
Electricity demand (TWh)



## Changes in electricity demand

Change in demand year-on-year (%)

■ YoY change    - - 2016–22 avg    - - Required YoY



Source: Ember

Note: 2022 data used where available, else 2021

# Global Power Sector Emissions

Global Electricity Trends 2022

---

The power sector is the biggest emitter from all sectors, responsible for about 40% of total global energy-related CO<sub>2</sub> emissions. In 2022, emissions from electricity generation increased to 12,431 million tonnes of CO<sub>2</sub>, reaching a new all-time high. To limit global heating to 1.5C, they should instead be falling fast. The top 10 absolute CO<sub>2</sub> emitters are responsible for generating 80% of global power sector emissions: China, US, India, EU, Japan, Russia, South Korea, Saudi Arabia, Indonesia and Iran.

The biggest emitters per capita are Bahrain, Qatar, Kuwait, Taiwan, United Arab Emirates, Saudi Arabia, South Korea, Kosovo, Australia and the US. Although global emissions intensity of electricity fell over recent years and currently stands at 436 gCO<sub>2</sub>/kWh, its lowest ever level, the global electricity emissions per capita has increased by 39% since 2000 to 1.57 tCO<sub>2</sub>.

**12431 mtCO<sub>2</sub>**

Global power emissions in 2022

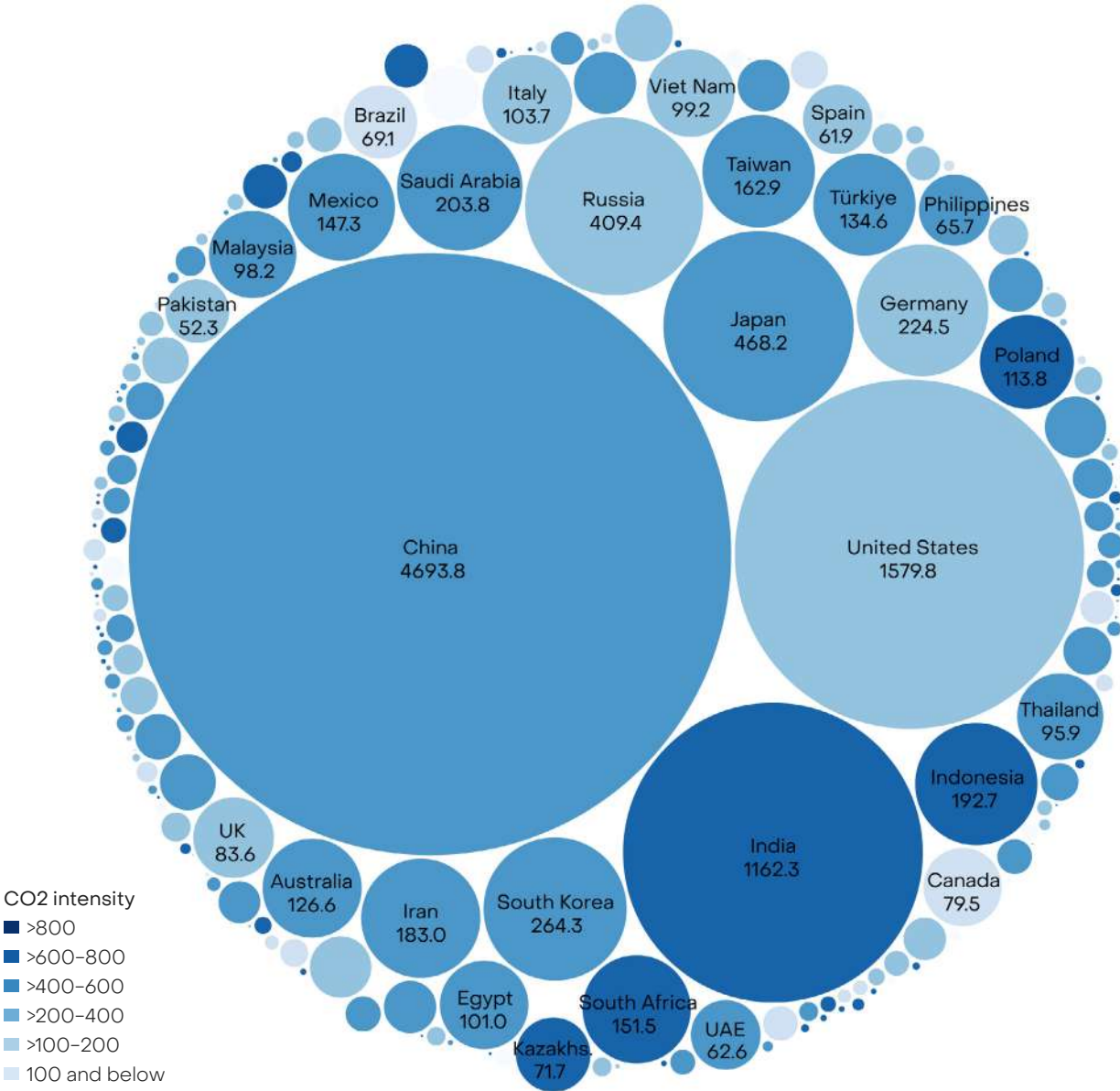
**436 gCO<sub>2</sub>/kWh**

Carbon intensity of generation

# Global Context

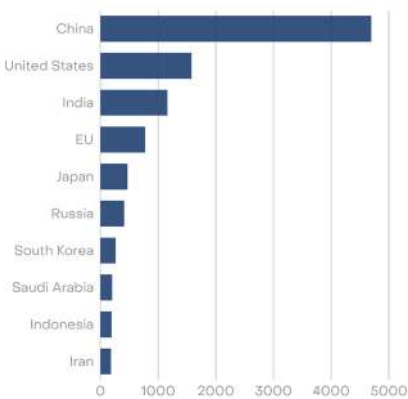
## Global power sector emissions

Power sector emissions (mtCO<sub>2</sub>, bubble size) and CO<sub>2</sub> intensity (gCO<sub>2</sub>/kWh, bubble colour)



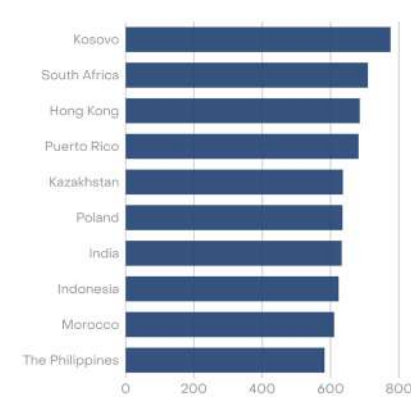
### Top 10 power sector emitters

Total emissions (mtCO<sub>2</sub>)



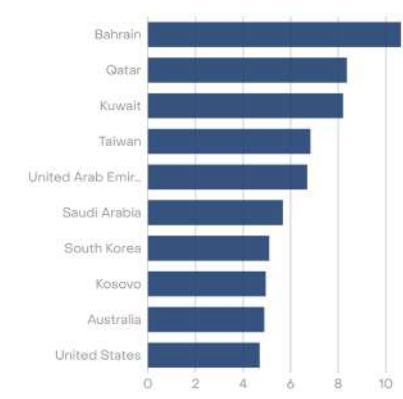
### Dirtiest electricity grids

CO<sub>2</sub> intensity (gCO<sub>2</sub>/kWh)



### Emission per capita

CO<sub>2</sub> emissions (tCO<sub>2</sub>/capita)



Source: Ember

Note: 2022 data used where available, else 2021

## Change in 2022

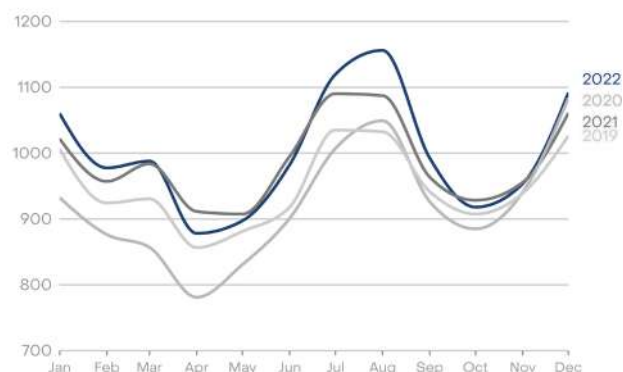
Global electricity emissions increased by 160 million tonnes of CO<sub>2</sub> (+1.3%), reaching 12,431 mtCO<sub>2</sub> in 2022. It was a smaller increase than in 2021 when emissions saw a record rebound due to the economic recovery from Covid-19 (+797 mtCO<sub>2</sub>, +7% year-on-year). Emissions intensity decreased slightly from 441 gCO<sub>2</sub>/kWh in 2021 to 436 gCO<sub>2</sub>/kWh in 2022, while emissions per capita increased from 1.55 tCO<sub>2</sub> to 1.57 tCO<sub>2</sub> per capita.

Emissions grew in China (+76 mtCO<sub>2</sub>) and India (+70 mtCO<sub>2</sub>) as demand growth was met in part by coal power. In Europe, shortfalls in nuclear and hydro were met in part by coal power, increasing emissions in Germany (+12 mtCO<sub>2</sub>) and Spain (+9.4 mtCO<sub>2</sub>). In the US, emissions rose (+4.6 mtCO<sub>2</sub>) as rising demand was partly covered by gas. In Mexico, emissions rose (+13 mtCO<sub>2</sub>) as the demand rise was largely met by coal and oil.

The biggest absolute drops in emissions were seen where clean generation increased beyond rising demand, including Brazil (-36 mtCO<sub>2</sub>), Chile (-6.3 mtCO<sub>2</sub>), Australia (-4.6 mtCO<sub>2</sub>) and Viet Nam (-10.5 mtCO<sub>2</sub>). In Ukraine, emissions fell (-14 mtCO<sub>2</sub>) due to the wartime decrease in electricity demand.

### Global power sector emissions

Emissions (mtCO<sub>2</sub>)



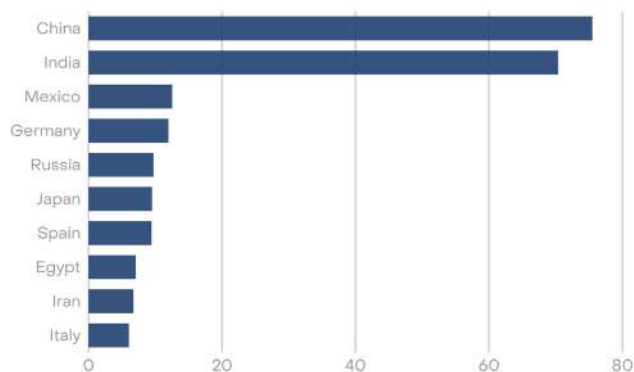
### Monthly changes in global electricity emissions

Change in emissions year-on-year (%)



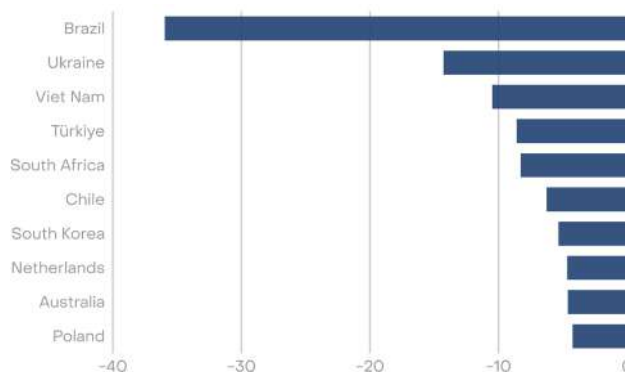
### Largest increases in emissions

Change in emissions year-on-year (mtCO<sub>2</sub>)



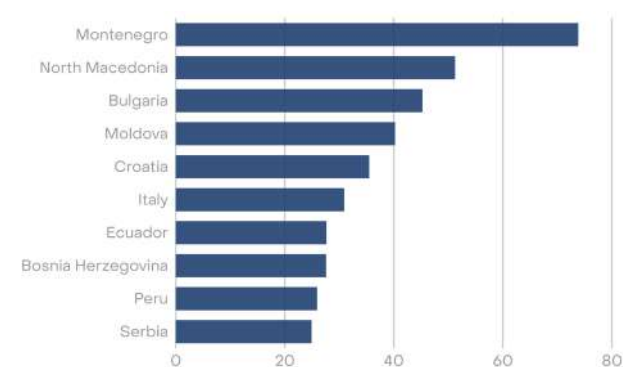
### Largest declines in emissions

Change in emissions year-on-year (mtCO<sub>2</sub>)



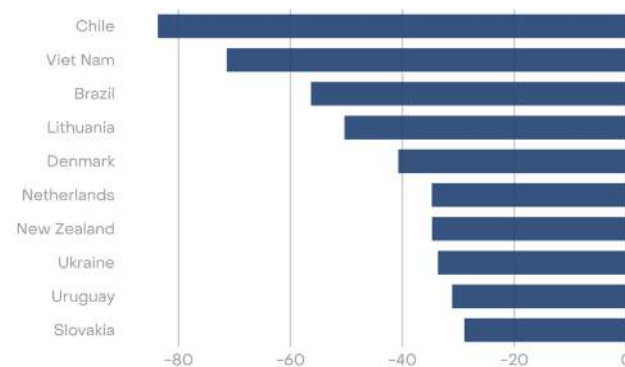
### Largest increases in CO<sub>2</sub> intensity

Change in CO<sub>2</sub> intensity year-on-year (gCO<sub>2</sub>/kWh)



### Largest declines in CO<sub>2</sub> intensity

Change in CO<sub>2</sub> intensity year-on-year (gCO<sub>2</sub>/kWh)





# Long-term Trends

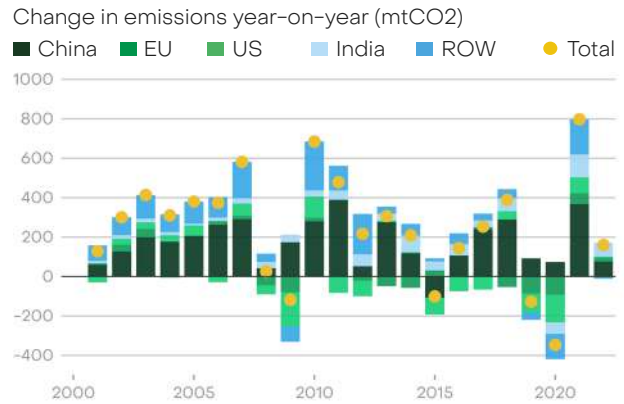
Since 2000, absolute power sector emissions have almost doubled, rising from 6,972 mtCO<sub>2</sub> in 2000 to 12,431 mtCO<sub>2</sub> in 2022. This equates to an average annual increase of 2.7%. Rapid economic growth across many regions has driven this increase, as global electricity demand has risen while the world maintains significant dependence on fossil fuels. China's growth is a large part of this, as its electricity generation increased by 6.5 times, from 1,356 TWh in 2000 to 8,858 TWh in 2022. This is nearly a third of the global generation, and has led to growth in China's absolute emissions of 415% (+3,782 mtCO<sub>2</sub>) from 2000 to 2022.

The rise in emissions over the last two decades has been relatively steady year-on-year, with exceptions in 2009, 2015, 2019 and 2020 when emissions fell. In 2009 emissions **decreased** by 118 mtCO<sub>2</sub> (-1.3%) as the result of the economic recession, leading to lower demand as well as an increase in renewable electricity sources. In 2015, the year of the Paris Agreement, emissions and economic growth had **decoupled** and emissions fell by 101 million tonnes of CO<sub>2</sub> as major economies China and the US lowered their emissions by deploying more clean power sources. In 2019, slower economic growth and relatively mild weather conditions in major economies slowed the rise in demand, which was met entirely by clean sources. This led to **emissions** falling by 127 mtCO<sub>2</sub> (-1.1%). In 2020, the impacts of the Covid-19 pandemic led to reduced economic activities, with global emissions falling by 346 mtCO<sub>2</sub> (-2.9%) as a result.

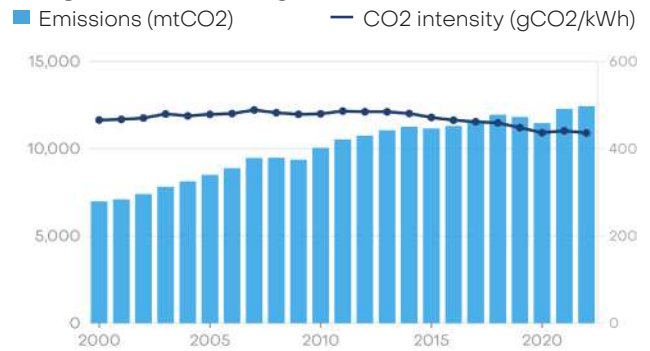
Global emissions intensity of electricity decreased by just 6% between 2000 and 2022, while demand per capita increased by 48%.

Since 2015, the year of the Paris Agreement, emissions have increased from 11,161 mtCO<sub>2</sub> to 12,431 mtCO<sub>2</sub>, which is equivalent to an average annual rise of 1.6%.

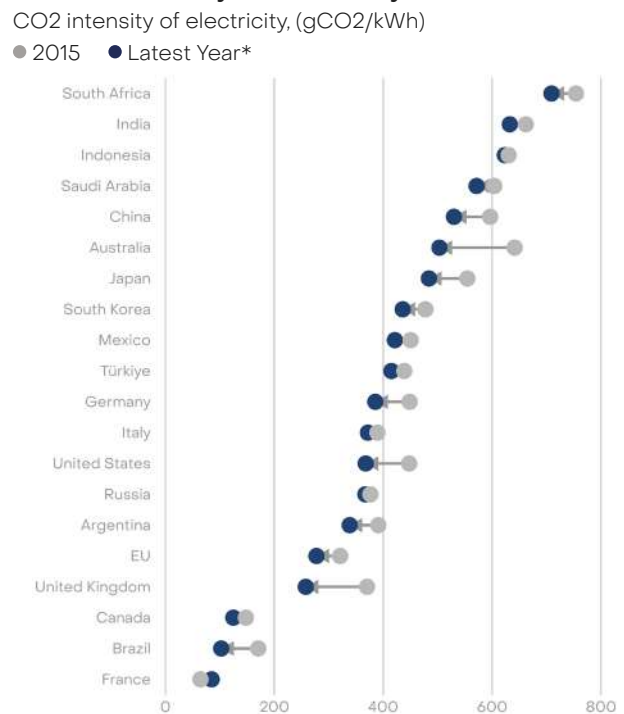
## Annual changes in global electricity emissions



## Long-term trends in global electricity emissions



## Carbon intensity of electricity, G20 countries



Source: Ember

Note: 2022 data used where available, else 2021

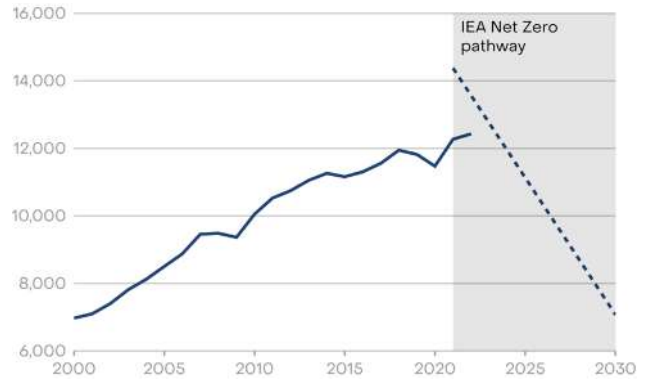
# Progress Towards Net Zero

To align with the [IEA Net Zero Emissions scenario](#), advanced economies must decarbonise their electricity generation by 2035 and the rest of the world by 2040.

We are not yet seeing the declines needed for those milestones, which require emissions from the power sector to fall by more than 7% per year from 2021 to 2030 and a completely decarbonised power sector by 2040. However, 2022 may be the peak of power sector emissions (see chapter 3). How fast emissions then decline will depend on wind and solar continuing their meteoric growth. There are certainly positive signs as major economies like the G7 continue substantial investment programs to achieve their commitments to clean power by 2035, and more countries recognise the benefits of wind and solar for clean, secure and affordable energy.

## Emissions

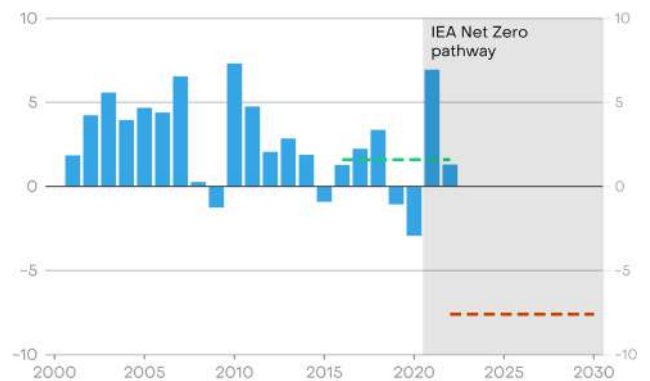
Emissions (mtCO<sub>2</sub>)



## Changes in emissions

Change in emissions year-on-year (%)

■ YoY change    - - 2016-22 avg    - - Required YoY



Source: Ember

Note: 2022 data used where available, else 2021



## Chapter 5 | Electricity Source Trends

# Analysis of the different global electricity sources in 2022

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The following pages run through a more detailed analysis of the changes in supply of electricity in 2022, and over a longer-term trend.

We have ordered the sections according to the fastest growing sources of electricity.

### Chapter contents

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72 Solar

77 Wind

82 Hydro

87 Coal

92 Bioenergy

97 Gas

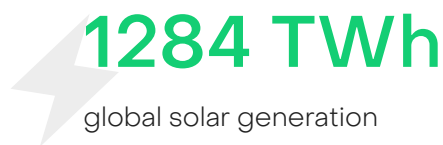
102 Nuclear

# Solar

## Global Electricity Trends 2022

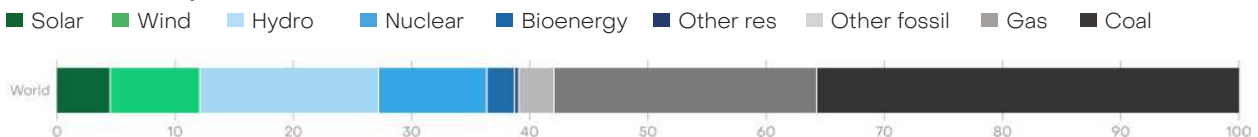


Solar power produced 4.5% (1,284 TWh) of global electricity in 2022. China generates the most electricity from solar at 418 TWh (4.7% of its electricity mix), while Chile has the highest percentage of solar in its electricity mix (17%, 14 TWh) ahead of the Netherlands (15%, 18 TWh) and Australia (13%, 33 TWh).



### Global electricity mix

Share of electricity (%)

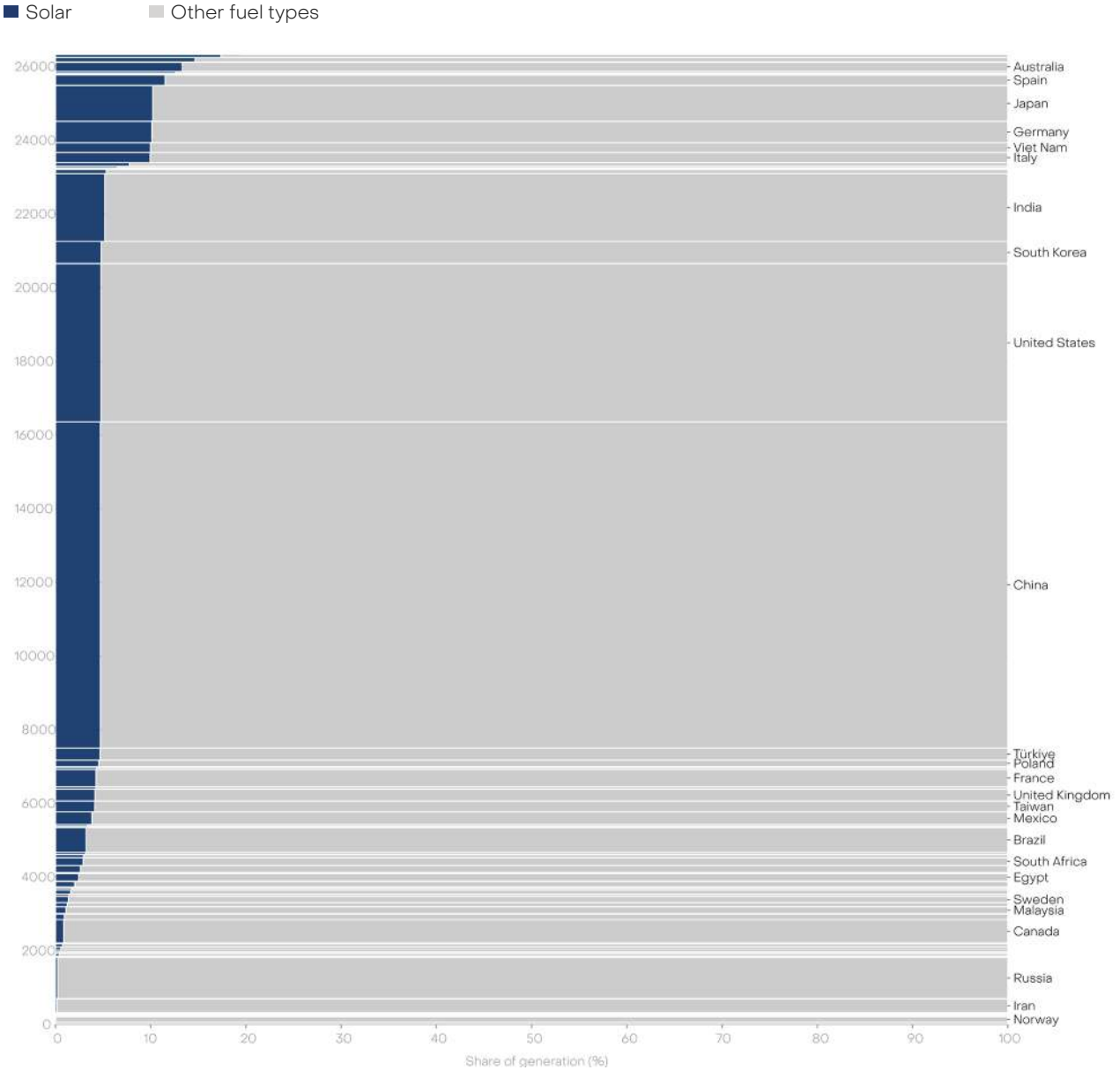


### Role of solar

Solar provides clean power that can be deployed quickly and locally to the demand source. As such, together with wind, it will form the backbone of the future electricity system by providing nearly 70% of global electricity by 2050. New solar power produces the cheapest electricity in history, according to the [IEA](#).

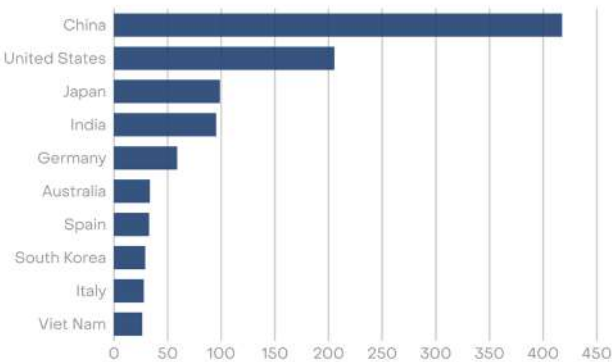
Major players in solar power

Electricity generation (TWh, y-axis) and share of electricity (% x-axis)



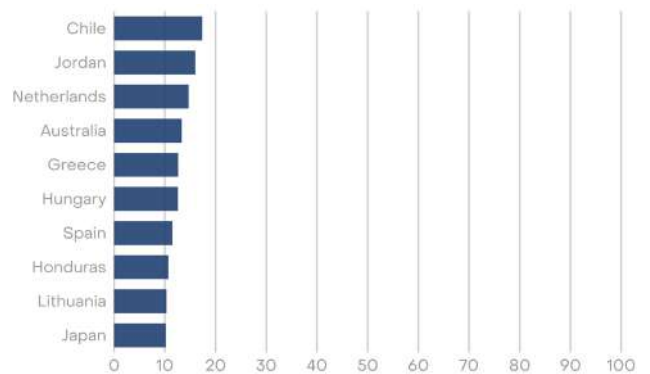
Largest solar generators

Electricity generation (TWh)



Highest shares of solar power

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Change in 2022

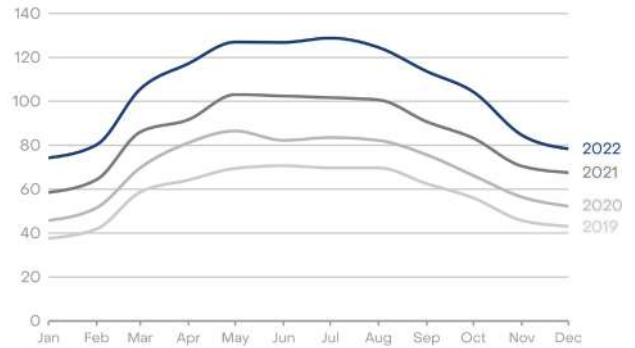
Global solar electricity generation rose by 24% (+245 TWh), from 1,039 TWh in 2021 to 1,284 TWh in 2022. This was the 18th year in a row that solar was the fastest growing electricity source by year-on-year percentage change. Solar's share in the global electricity mix grew by 0.8 percentage points, from 3.7% in 2021 to 4.5% in 2022.

The global rise in solar power was driven by a significant rise in China (+91 TWh, +28%) accounting for 37% of the worldwide increase. Solar generation increases in the US (+41 TWh, +25%) accounted for a further 17% of the global rise. Other regions with notable increases include the EU (+40 TWh, +24%), India (+27 TWh, +39%) and Japan (+10 TWh, +11%).

Solar generation more than doubled from 2021 in Kenya, Lithuania and Poland. The few countries with falling solar generation only recorded small falls of less than 10% (South Africa -6.6%, Switzerland -6.6%), caused by weather conditions rather than structural changes.

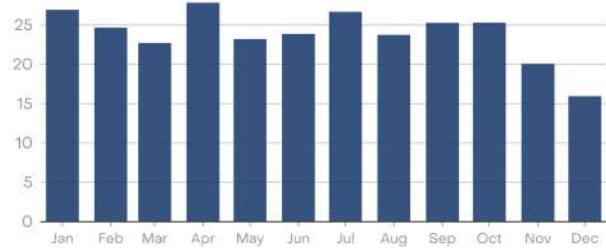
## Global solar generation

Electricity generation (TWh)



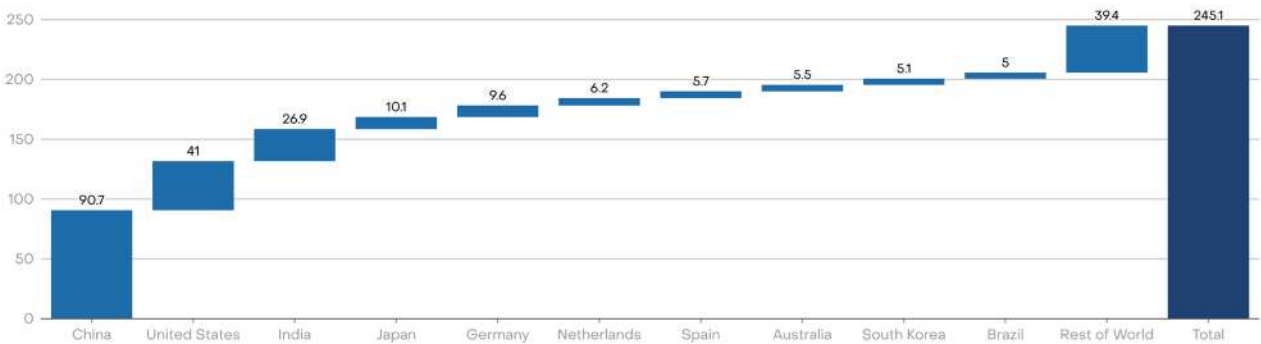
## Monthly changes in solar generation

Change in generation year-on-year (%)



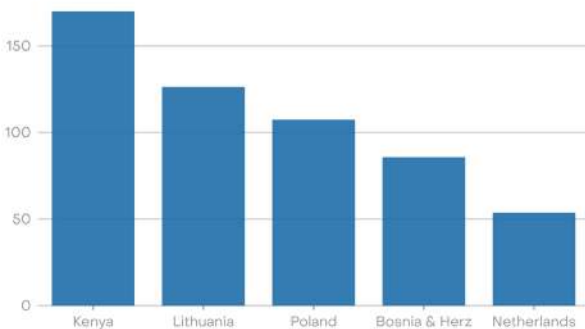
## Key global changes in solar generation

Change in generation year-on-year (TWh)



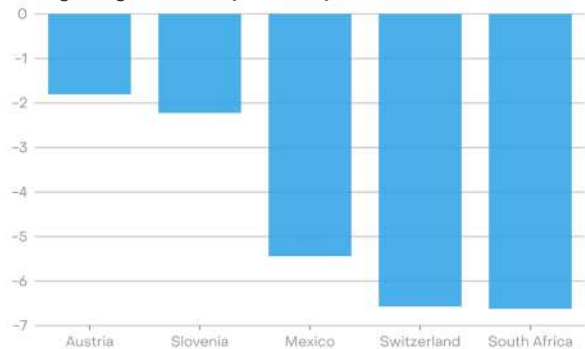
## Largest increases

Change in generation year-on-year (%)



## Largest decreases

Change in generation year-on-year (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Long-term Trends

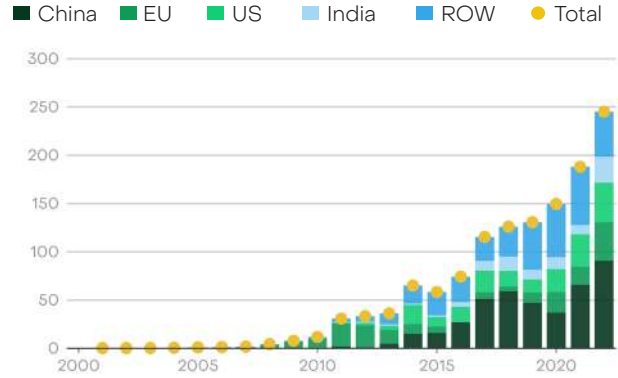
Over the last two decades, solar generation has gradually increased to become a significant part of the global electricity mix. In 2000, solar generated only 11 TWh. By 2022, it had increased to 1,284 TWh. As a result, the share in the electricity mix has shot up from 0.01% in 2000 to 4.5% in 2022.

Most solar growth has occurred in the last few years. During early years of deployment, solar increased from near zero in 2000 to 255 TWh in 2015. At this point, it had reached a market share of 1.1%. Although the absolute increases were still relatively small, this growth equated to a relatively high annual growth rate of 44%.

Since the Paris Agreement in 2015 we have seen absolute increases accelerate, getting bigger every year. The broad and fast-paced adoption of solar worldwide means that solar grew by 1,029 TWh in this period. The annual growth rate slowed to 26% during 2015–2022, but solar still represents the fastest-growing source of electricity. 2022 saw a year-on-year increase of 24% (+245 TWh). Since the Paris Agreement in 2015, solar’s market share has grown to 4.5%, with growth across all G20 countries.

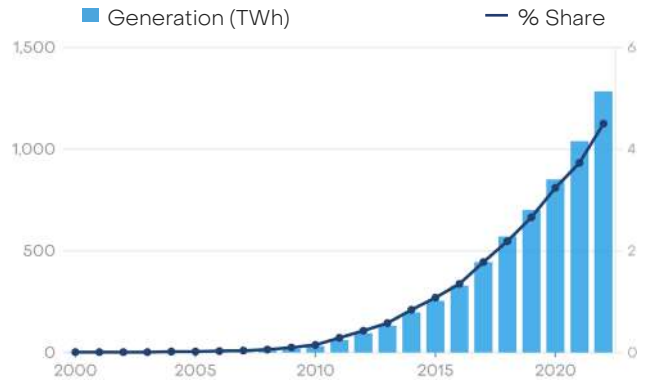
## Annual changes in solar generation

Change in generation year-on-year (TWh)



## Long-term trends in solar generation

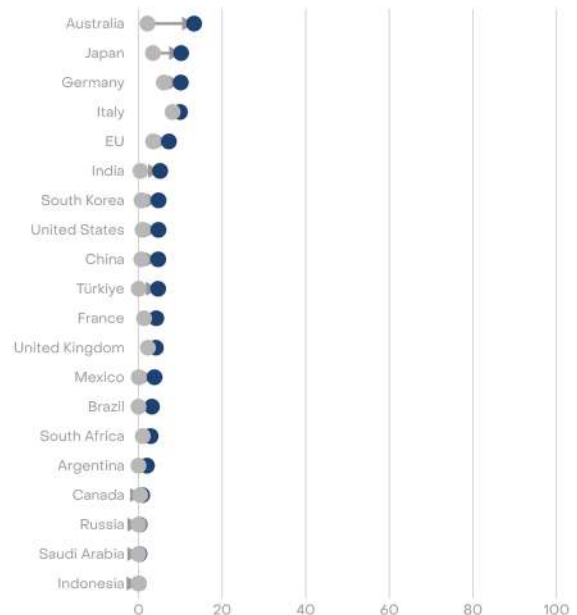
Electricity generation (TWh) and share of electricity (%)



## Solar share, G20 countries

Share of electricity (%)

● 2015 ● Latest year\*



Source: Ember

Note: 2022 data used where available, else 2021

\*Saudi Arabia and Indonesia use 2021 data.

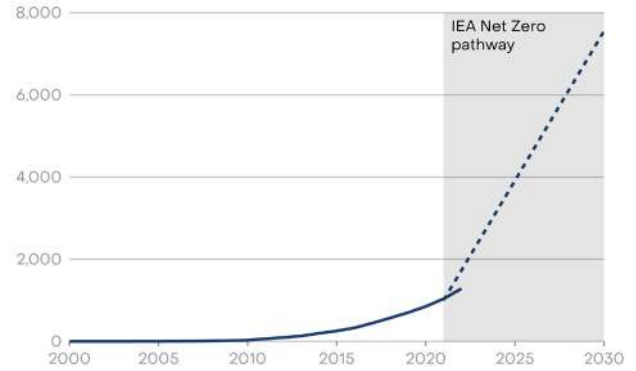
# Progress Towards Net Zero

Solar generation needs to rise to 7,552 TWh by 2030 to keep global heating to 1.5C, as per the [IEA Net Zero Emissions scenario](#). The pathway requires solar to grow by 25% annually from 2021 to 2030, and would see solar's share of global electricity generation reach 20% in 2030, up from 4.5% currently.

To align with the net zero pathway, solar power therefore needs to sustain the rate of growth seen between 2015 and 2022. This would mean increasing by 25% every year throughout the rest of the decade. To achieve this growth, countries need to continually increase their annual solar deployment targets. For example, in 2023 this would require 318 TWh in additional solar generation, while in 2030 the world would need to be adding at least 1,500 TWh of solar generation annually.

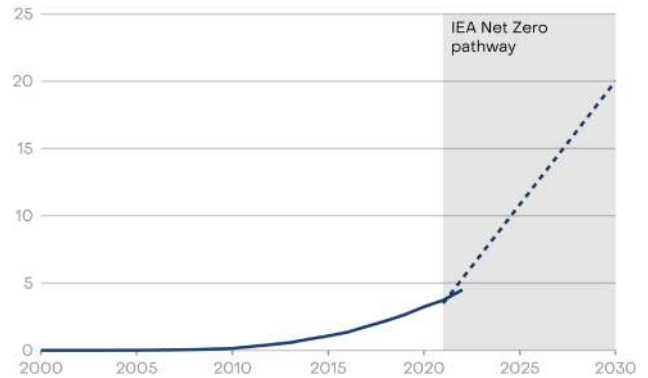
## Solar generation

Electricity generation (TWh)



## Solar share

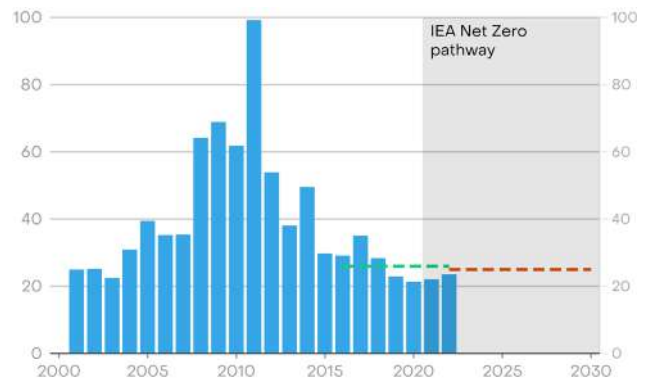
Share of electricity (%)



## Changes in solar generation

Change in generation year-on-year (%)

■ YoY change    - - 2016-22 avg    - - Required YoY



Source: Ember

Note: 2022 data used where available, else 2021

# Wind

## Global Electricity Trends 2022

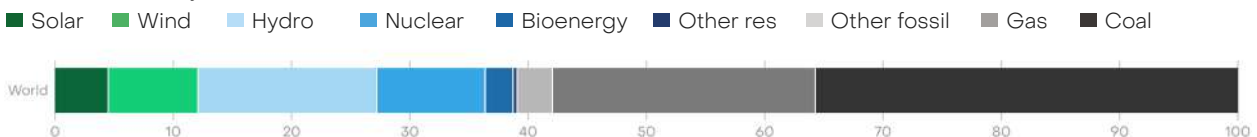


Wind power produced 7.6% (2,160 TWh) of global electricity in 2022. China is the biggest generator of wind power at 824 TWh, (9.3% of its electricity mix), while Denmark has the highest wind generation by percentage share at 55% (19 TWh). Germany has both the third highest generation of any country (126 TWh) and the sixth highest share in the mix at 22%.



### Global electricity mix

Share of electricity (%)

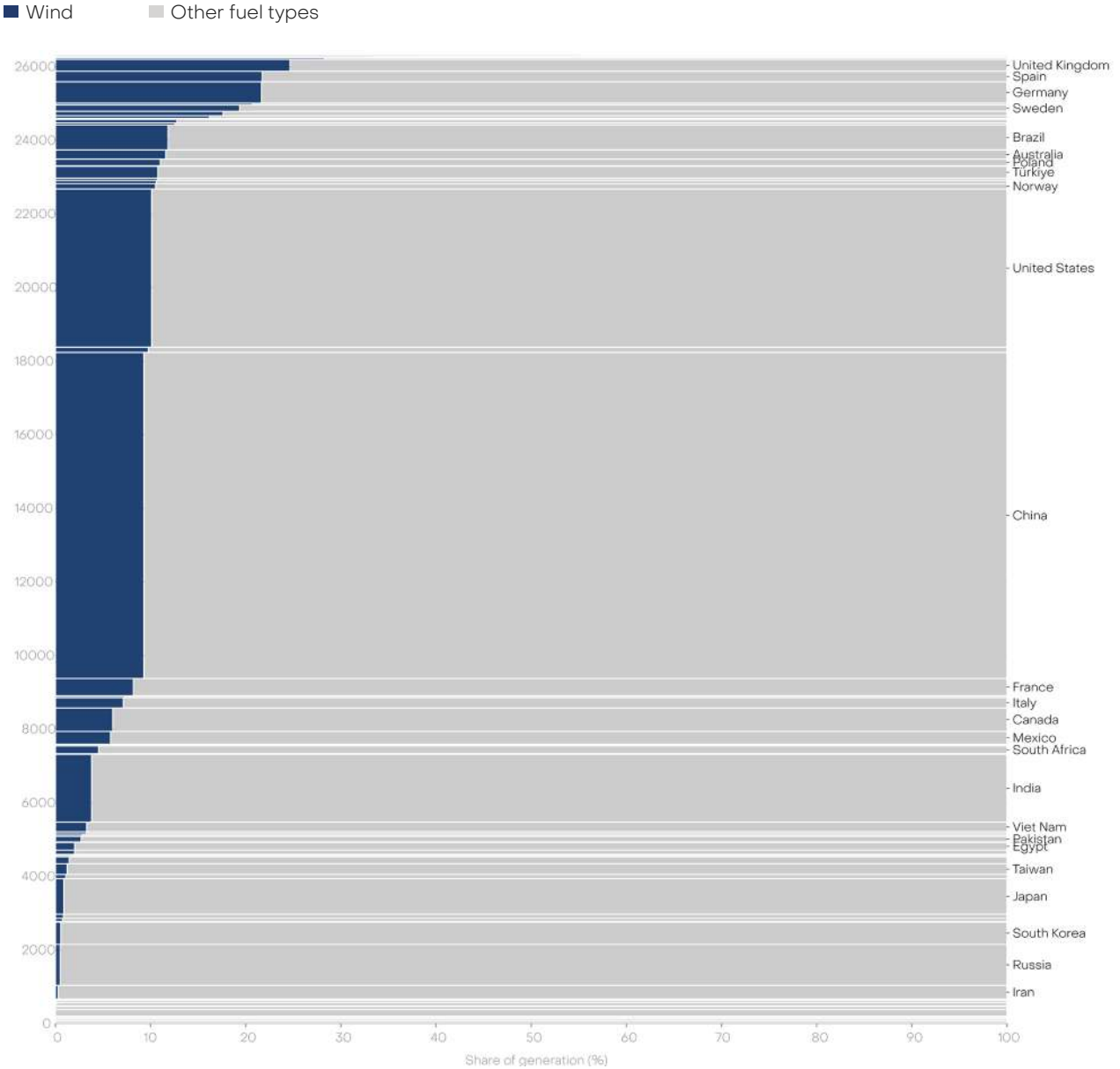


### Role of wind

Wind generation, alongside solar, is key to reducing emissions in the electricity sector. Both sources will form the backbone of the future electricity system by providing nearly 70% of global electricity by 2050. Therefore, rapid scale-up is required this decade.

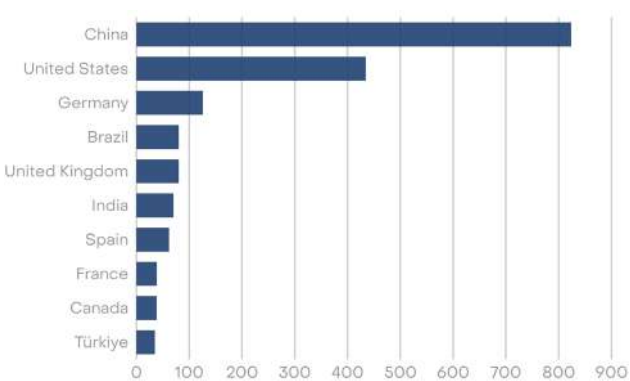
Major players in wind power

Electricity generation (TWh, y-axis) and share of electricity (% x-axis)



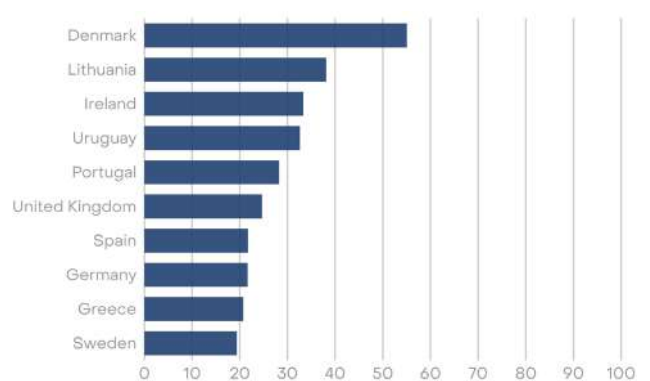
Largest wind generators

Electricity generation (TWh)



Highest shares of wind power

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021



# Change in 2022

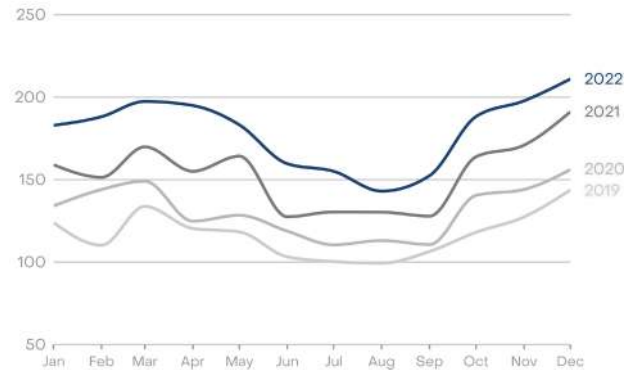
In 2022, wind was the electricity source with the largest absolute increase. Global wind electricity generation increased by 17% (+312 TWh), from 1,848 TWh in 2021 to 2,160 TWh in 2022. Only solar recorded higher relative growth. Wind's share in the global electricity mix also grew by one percentage point, from 6.6% in 2021 to 7.6%.

Wind power growth in China accounted for more than half of the global increase (+168 TWh, +26%). However, wind power rose across the globe. The US (+56 TWh, +15%) and the EU (+34 TWh, +8.8%) recorded significant increases in wind generation, and so did the UK (+15 TWh, +23%), Brazil (+8.5 TWh, +12%) and Viet Nam (+6.3 TWh, +262%) among many others.

Ukraine experienced a decline in wind generation due to the impact of the war, with much of its wind capacity in regions affected by hostilities, according to the [Ukrainian Association of Renewable Energy](#). Only a few other countries with very low levels of wind generation had declines.

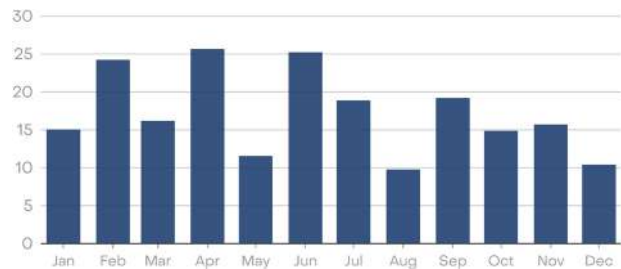
## Global wind generation

Electricity generation (TWh)



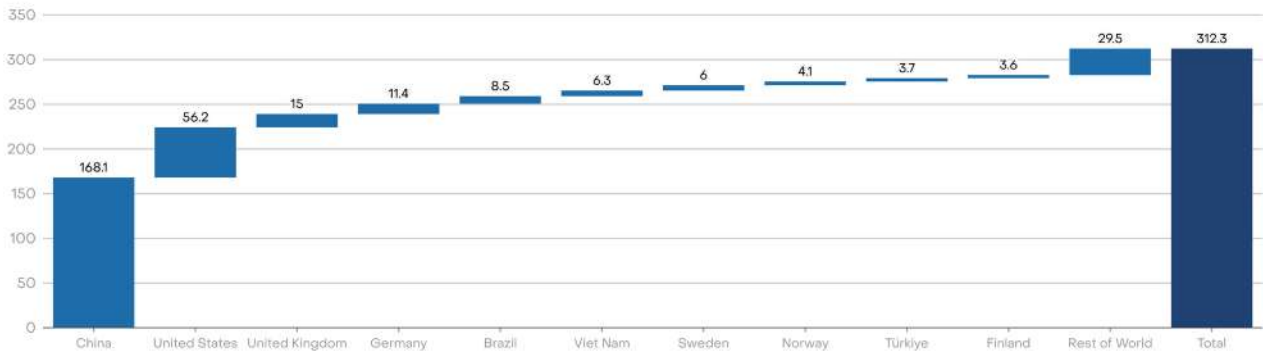
## Monthly changes in wind generation

Change in generation year-on-year (%)



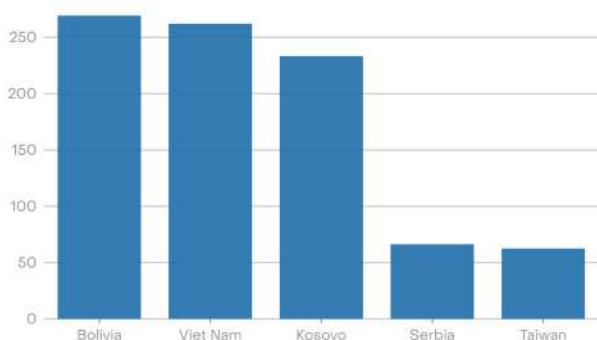
## Key global changes in wind generation

Change in generation year-on-year (TWh)



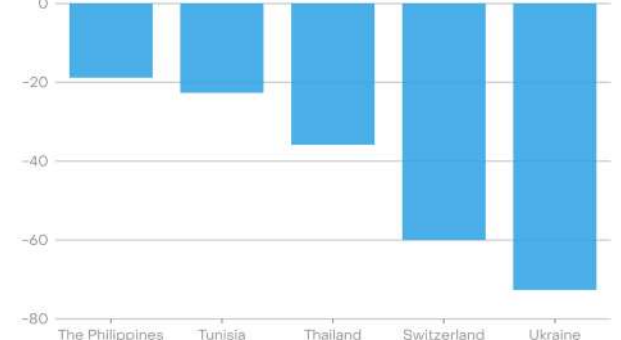
## Largest increases

Change in generation year-on-year (%)



## Largest decreases

Change in generation year-on-year (%)



Source: Ember

Note: 2022 data used where available, else 2021

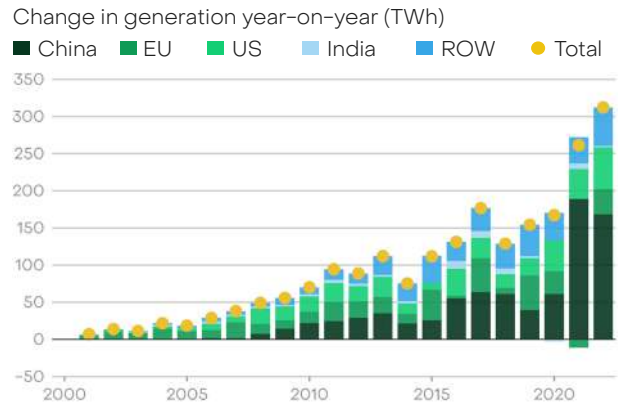
# Long-term Trends

Wind generation has increased rapidly in the last two decades. In 2000, wind generation was 31 TWh with a global share of power of only 0.2%. In 2022, wind generation was 2,129 TWh higher, reaching 2,160 TWh. Consequently, the market share has increased to 7.6%.

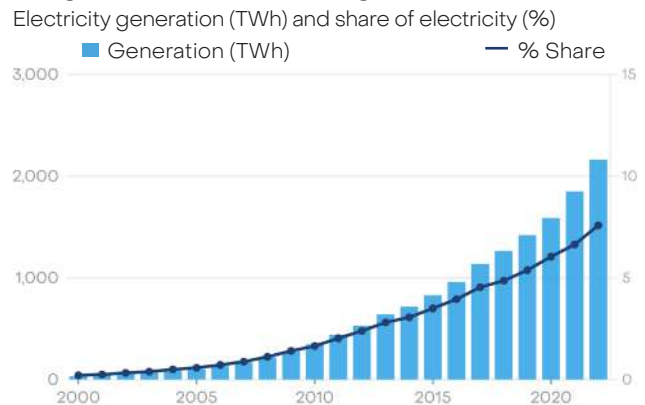
Similar to solar generation, wind generation has accelerated dramatically in recent years. Between 2000 and 2015, generation grew at a relatively high annual rate of 24%. However, absolute increases remained small, with wind generation reaching 828 TWh and a 3.5% share of global generation in 2015. Since then, absolute growth has increased significantly, to add an additional 1,332 TWh in just seven years. Relative growth has slowed, with wind generation recording an annual growth rate of 15% during this period. 2022 saw slightly higher growth, with wind generation increasing by 17% (+312 TWh).

Remarkably, wind's market share has grown in all G20 countries during that period. In Germany and the UK, wind power now accounts for over 20% of generation (22% and 25% respectively) and is even higher for smaller countries like Denmark (55%), Ireland and Uruguay (both 33%).

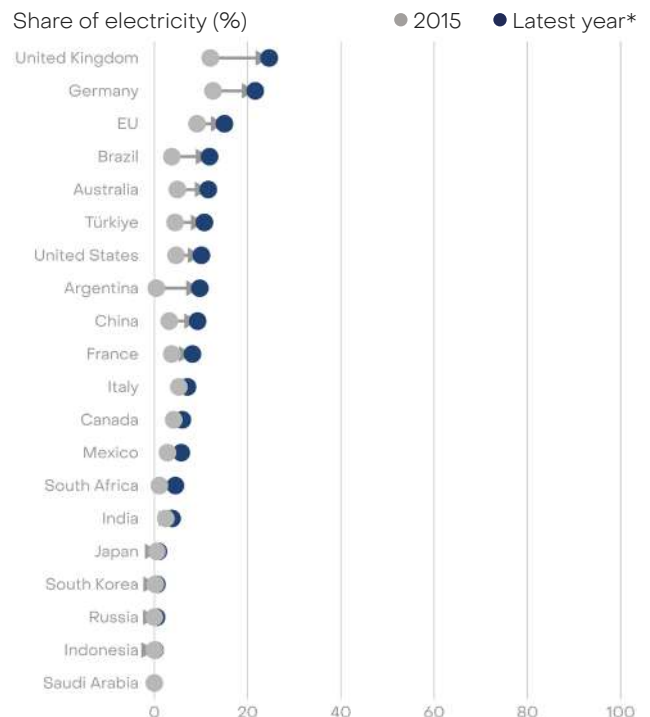
## Annual changes in wind generation



## Long-term trends in wind generation



## Wind share, G20 countries



Source: Ember

Note: 2022 data used where available, else 2021

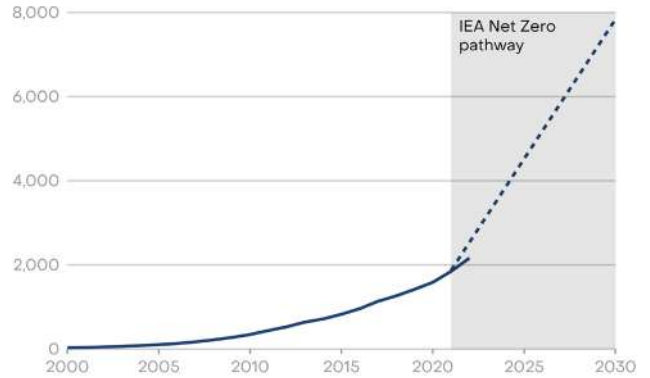
\*Saudi Arabia and Indonesia use 2021 data.

# Progress Towards Net Zero

For a 1.5C power sector pathway, wind generation needs to increase to 7,840 TWh by 2030, as per the [IEA Net Zero Emissions scenario](#). This would require an increase of 17% per year from 2021 to 2030, reaching 21% of global generation. In 2022, wind achieved this growth rate, but from 2015 to 2022, average yearly growth was slightly lower at 15%.

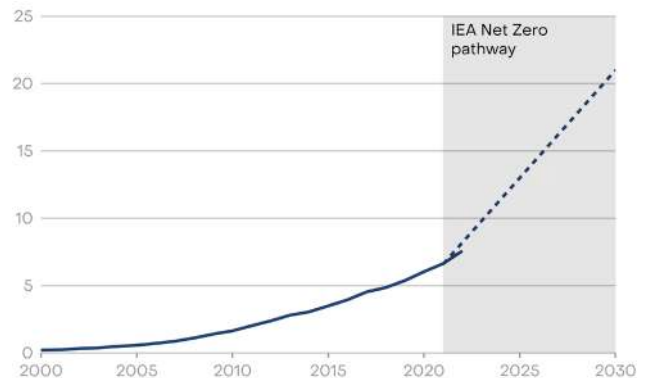
## Wind generation

Electricity generation (TWh)



## Wind share

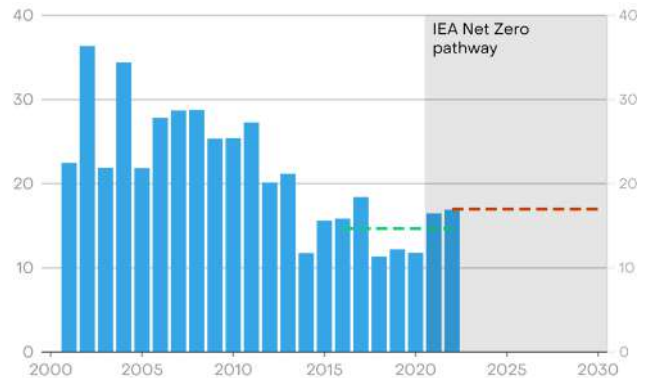
Share of electricity (%)



## Changes in wind generation

Change in generation year-on-year (%)

■ YoY change    - - 2016-22 avg    - - Required YoY



Source: Ember

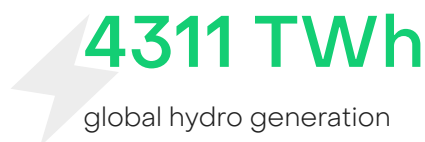
Note: 2022 data used where available, else 2021

# Hydro

## Global Electricity Trends 2022

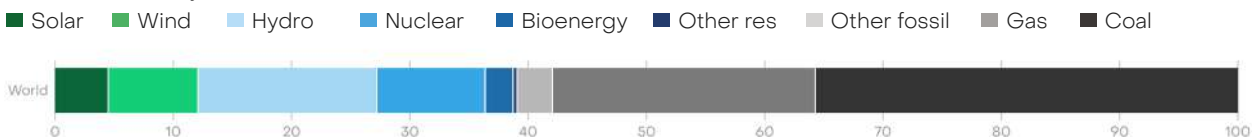


Hydro power produced 15% (4,311 TWh) of global electricity in 2022. China produces the most electricity from hydro, at 1,318 TWh (15% of its energy mix), while Paraguay has the highest percentage share of hydro in its electricity mix (99.7%, 40 TWh). Hydro dominates the electricity system of some major electricity producers: Brazil produces 63% (428 TWh), Canada 61% (392 TWh) and Norway 88% (130 TWh) from hydro.



### Global electricity mix

Share of electricity (%)



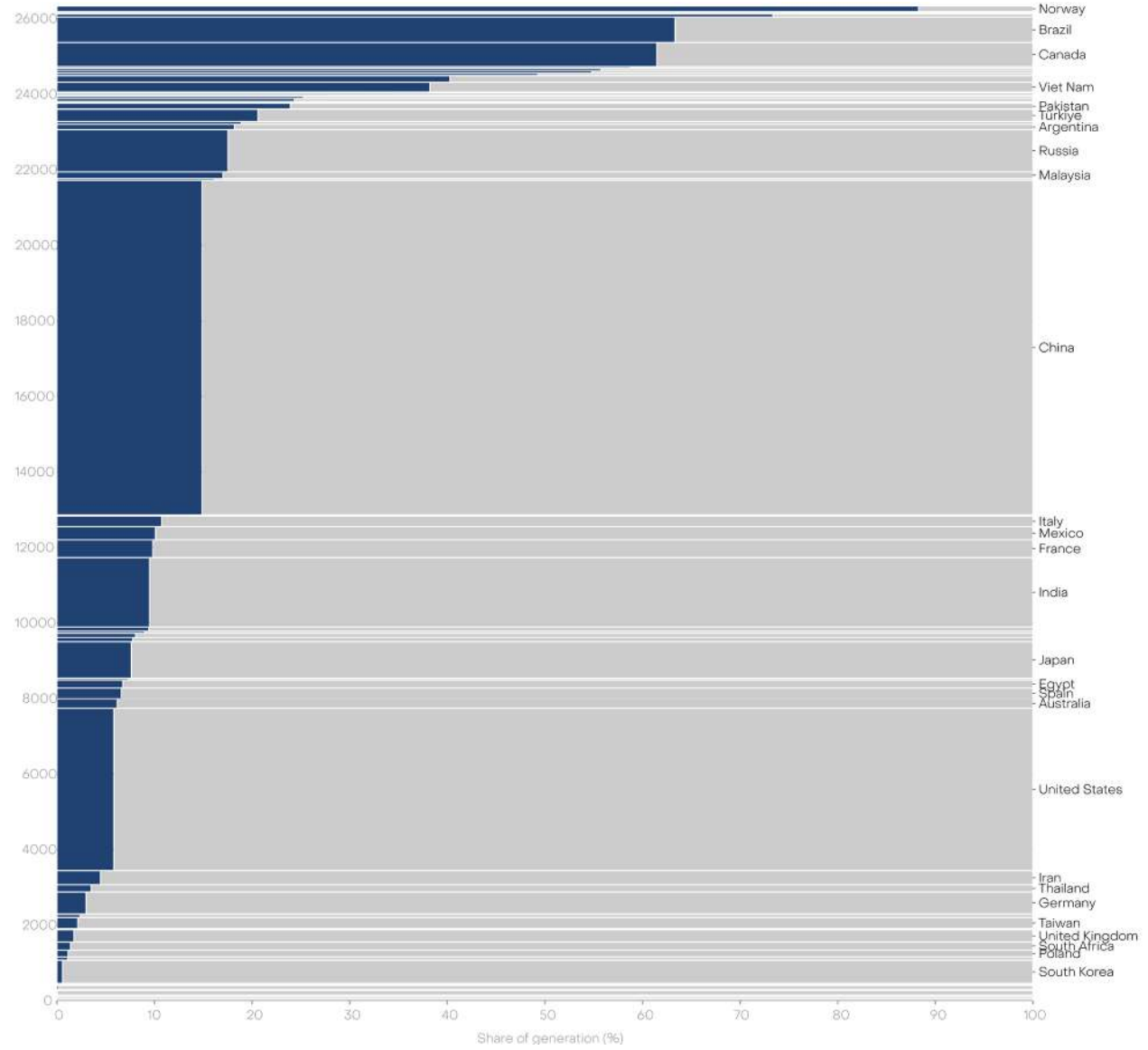
### Role of hydro

Hydro power has an important role in the global electricity mix. Not only is it currently the largest source of clean power, but it also provides flexibility to help accommodate the large influx of wind and solar. The world needs new hydro power plants, but in many regions hydro resources have already been maximised. In other regions where there is potential, the projects may come at too high an ecological and social cost.

### Major players in hydro power

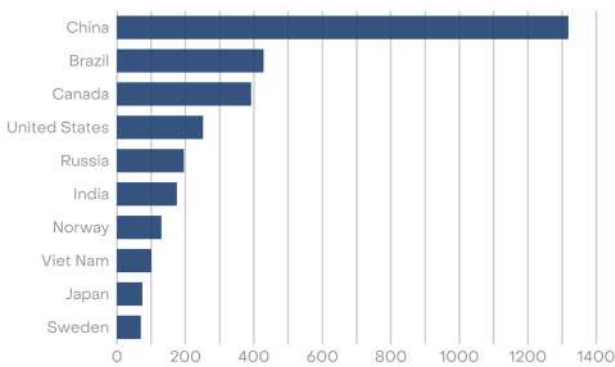
Electricity generation (TWh, y-axis) and share of electricity (% x-axis)

■ Hydro ■ Other fuel types



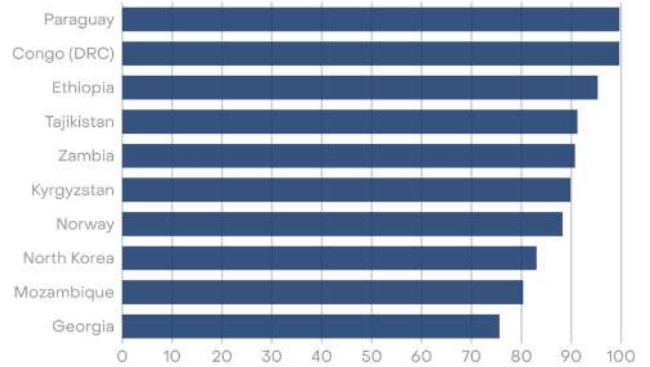
### Largest hydro generators

Electricity generation (TWh)



### Highest shares of hydro power

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

## Change in 2022



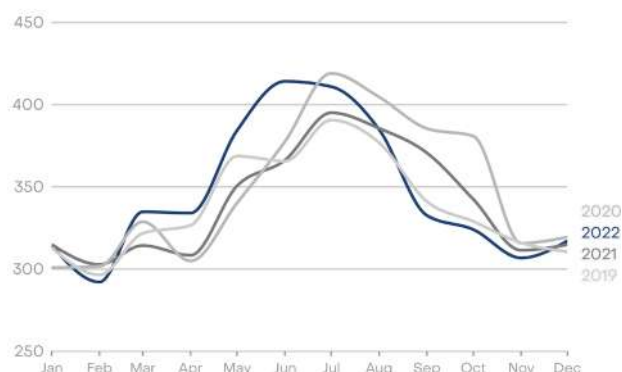
Global hydro electricity generation rose by 1.7% (+73 TWh), from 4,238 TWh in 2021 to 4,311 TWh in 2022. Due to strong demand growth, the share of hydro in the overall electricity mix fell by 0.1 percentage points, from 15.2% in 2021 to 15.1%.

Hydro rebounded in 2022, after a fall in 2021 for the first time in over a decade. Hydro still remains below the record-high generation seen in 2020 (4,340 TWh).

In 2022, the global increase was driven by increases in Brazil (+65 TWh, +18%), Viet Nam (+25 TWh, +33%), China (+18 TWh, +1.4%), Canada (+15 TWh, +3.9%), as well as increases in India (+14 TWh, +8.9%) and Türkiye (+11 TWh, +20%). However, many European countries were hit by historic droughts in the summer, causing hydro output to fall dramatically. The EU as a whole saw hydro generation fall by 66 TWh (-19%). Russia's hydro generation also fell substantially, by 19 TWh (-8.9%). Southern Europe was hit hardest with generation falling the most in Italy (-15 TWh, -34%), France (-13 TWh, -23%) and Spain (-11 TWh, -37%).

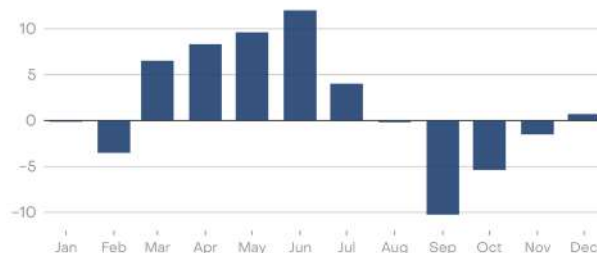
### Global hydro generation

Electricity generation (TWh)



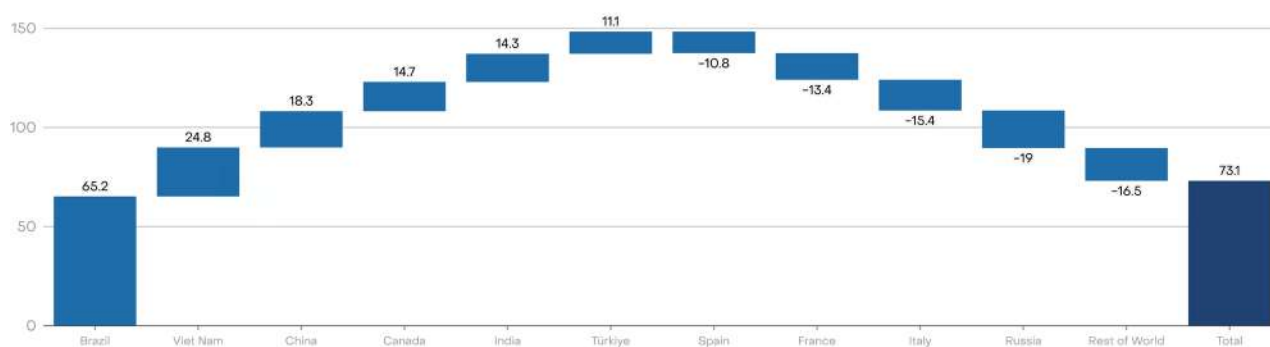
### Monthly changes in hydro generation

Change in generation year-on-year (%)



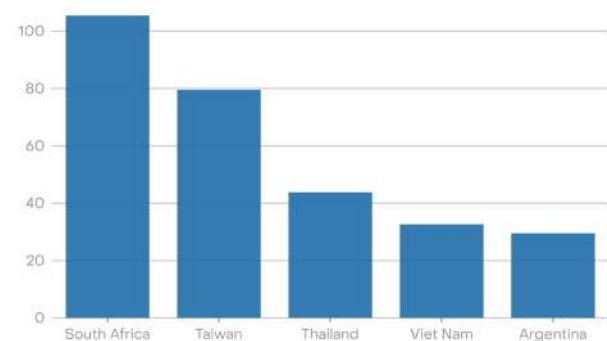
### Key global changes in hydro generation

Change in generation year-on-year (TWh)



### Largest increases

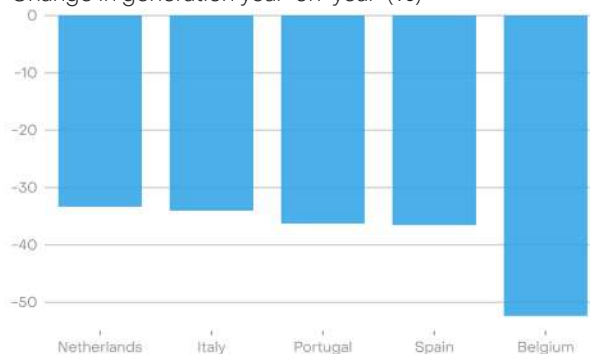
Change in generation year-on-year (%)



Source: Ember

### Largest decreases

Change in generation year-on-year (%)



Note: 2022 data used where available, else 2021

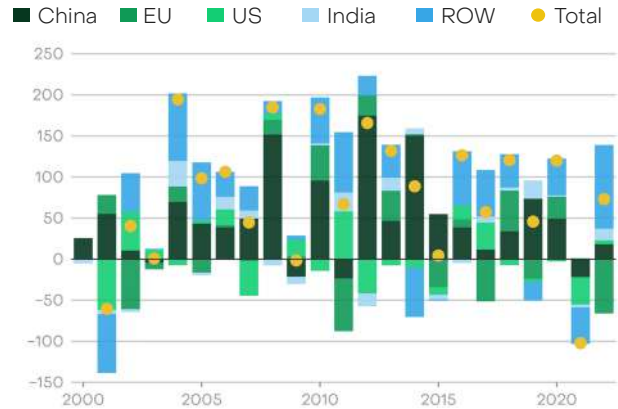
# Long-term Trends

Hydro generation has increased substantially over the last two decades, with stable growth (+1,690 TWh). However, its share in the electricity mix has fallen from 18% in 2000 to 15% in 2022, as its growth has not kept pace with rising electricity demand.

Since the Paris Agreement in 2015, the average year-on-year growth in hydro has been 1.6%. This is less than the annual growth rate from 2000 to 2015 of 2.6%. Hydro's share has fallen from 16% to 15% of global electricity generation since 2015. In most of the G20 countries, market share has remained stable or fallen. Only in Australia, Canada, South Korea, Russia and South Africa has the share of hydro generation in power increased since 2015.

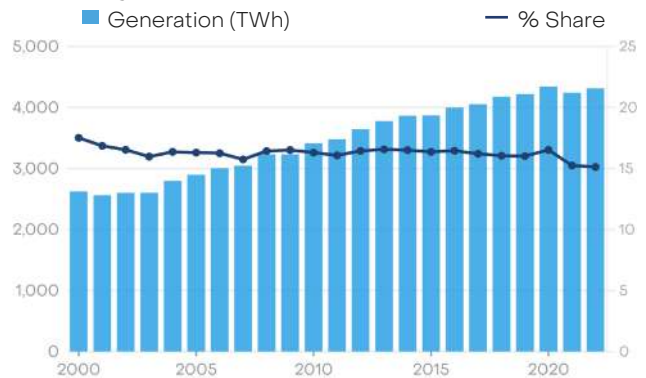
## Annual changes in hydro generation

Change in generation year-on-year (TWh)



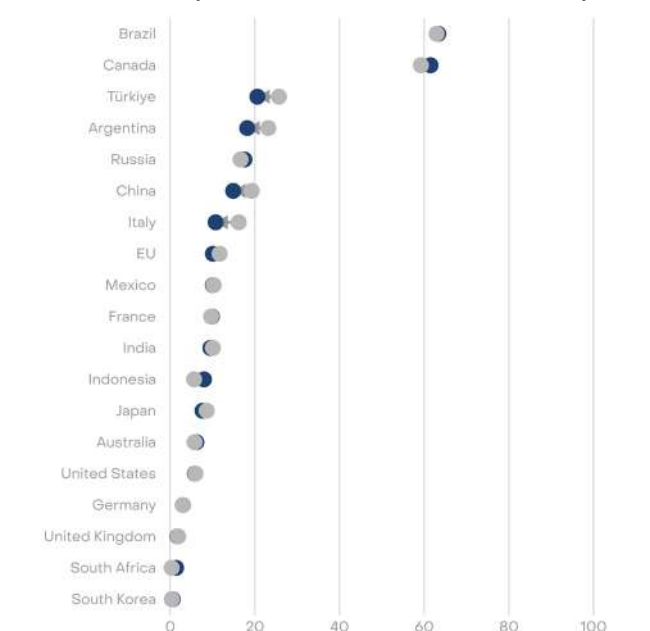
## Long-term trends in hydro generation

Electricity generation (TWh) and share of electricity (%)



## Hydro share, G20 countries

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

\*Saudi Arabia and Indonesia use 2021 data.





## Progress Towards Net Zero

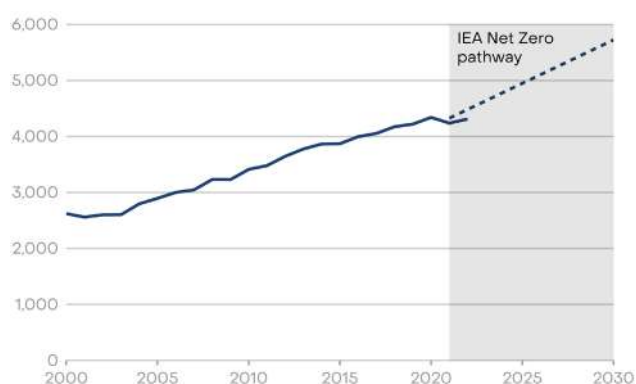


Hydro generation needs to rise by 3.2% annually between 2021 and 2030 according to the target outlined in the [IEA Net Zero Emissions scenario](#). This would maintain hydro's share of global generation at the current level. Since 2015, the average year-on-year growth for hydro power has been 1.6%. Therefore, to align with the net zero pathway, growth in hydro power would need to happen twice as fast.

Given that recent years have seen hydro generation in some regions affected by extreme weather, this rate of growth could present a challenge in years with heat waves and droughts. The [IPCC](#) notes the uncertainty around hydro conditions with some regions. Southern Europe, Australia and the southern United States among other regions could see generation drop by 20%, whereas other regions like India or northern Europe might experience an increase in hydro output. New solutions may mitigate this risk, such as floating solar panels, which can reduce evaporation and maximise hydro electricity generation.

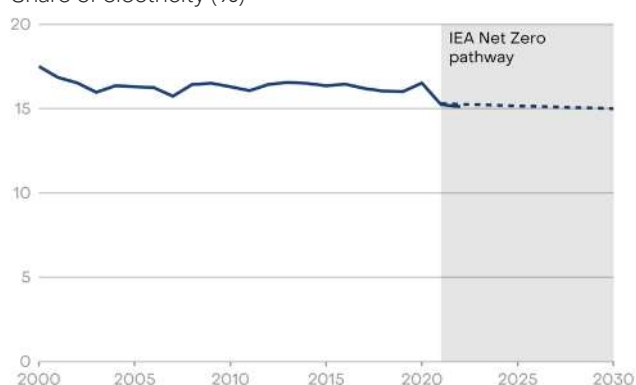
### Hydro generation

Electricity generation (TWh)



### Hydro share

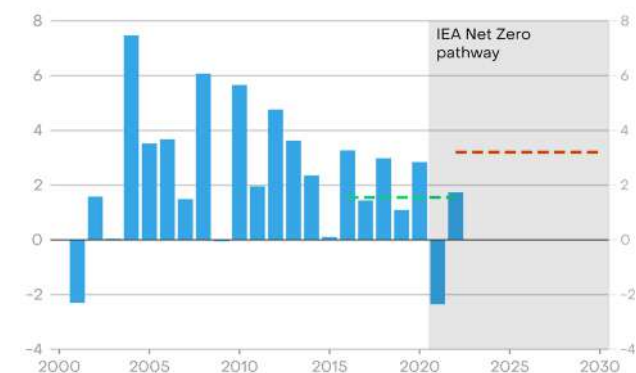
Share of electricity (%)



### Changes in hydro generation

Change in generation year-on-year (%)

■ YoY change    - - 2016-22 avg    - - Required YoY



Source: Ember

Note: 2022 data used where available, else 2021

# Coal

## Global Electricity Trends 2022

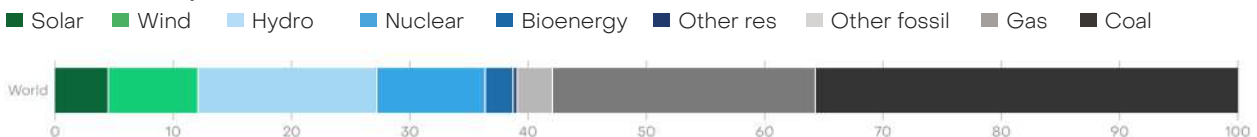


Global coal power generation reached an all-time record high of 10,186 TWh in 2022, producing 36% of global electricity in 2022. China produces by far the most electricity from coal of any country, generating 5,420 TWh of coal power (61% of its electricity mix). This is four times more than the second largest, India, at 1,363 TWh (74% of the mix). Kosovo has the largest share of coal in the power mix at 94% (10 TWh).



### Global electricity mix

Share of electricity (%)



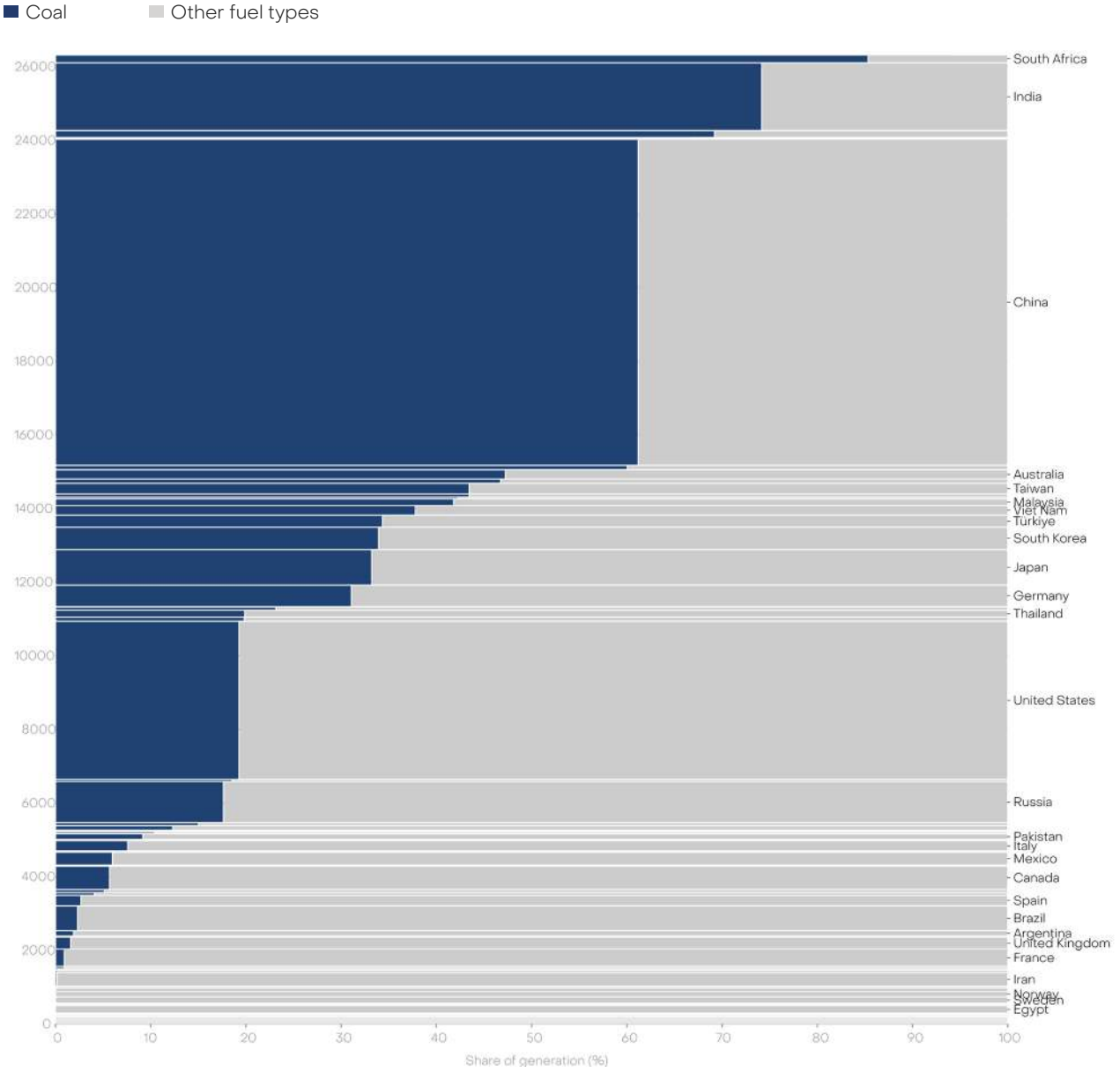
### Role of coal

Coal is the single largest contributor to emissions from the power generation sector. As such, its role has to be reduced rapidly in the next two decades so the world has a chance to limit global warming to 1.5C. As per the [IEA Net Zero Emissions scenario](#), unabated coal plants need to be phased out by 2030 in advanced economies and by 2040 in developing ones.

Global Context

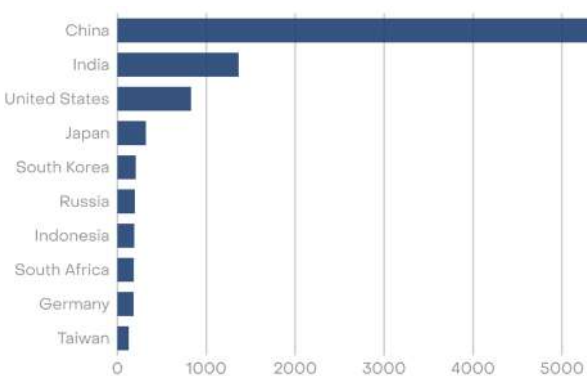
Major players in coal power

Electricity generation (TWh, y-axis) and share of electricity (% x-axis)



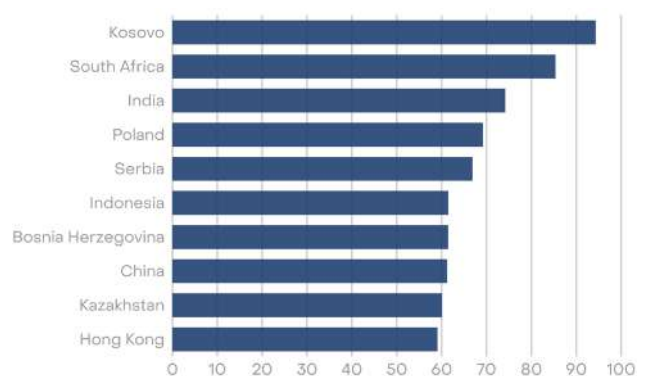
Largest coal generators

Electricity generation (TWh)



Highest shares of coal power

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Change in 2022

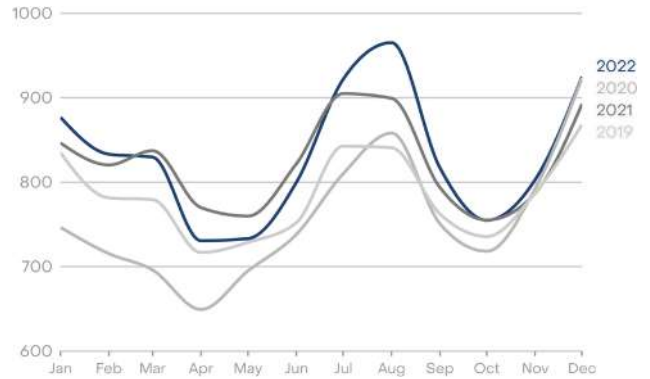
Coal generation rose by 1.1% (+108 TWh), from 10,078 in 2021 to 10,186 TWh in 2022. Although coal generation hit a record high, the share of coal generation dropped by 0.5 percentage points in 2022, down to 35.7% from 36.2% in 2021. This fall in share can be attributed to significant growth in wind and solar (+19%, +557 TWh).

Despite the record generation, coal's growth of 1.1% was much smaller than in 2021, when coal saw an increase of 8.4% as world economies eased Covid-19 restrictions.

Extreme temperatures in summer and winter pushed up power demand, driving monthly coal generation up. The largest increase was in August (+7.3%, +66 TWh). The largest increase came from India (+92 TWh), China (+81 TWh) and Germany (+17 TWh). Kosovo, Mexico, Spain and Italy had annual increases higher than 50%. The US showed the largest fall in coal generation (-70 TWh), followed by Viet Nam (-15 TWh). New Zealand and Portugal almost halted coal generation in 2022, showing yearly drops of 94% and 93%, respectively.

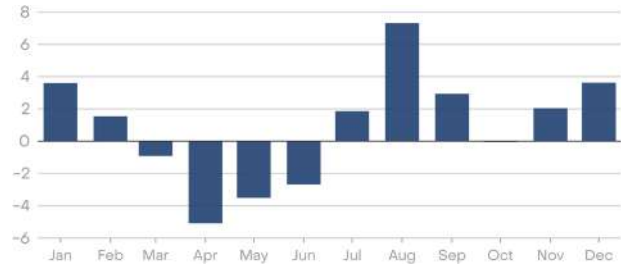
## Global coal generation

Electricity generation (TWh)



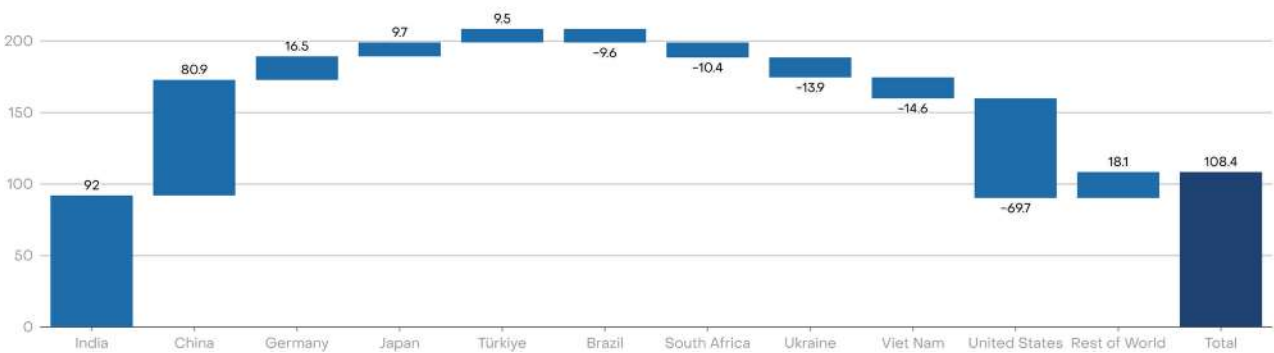
## Monthly changes in coal generation

Change in generation year-on-year (%)



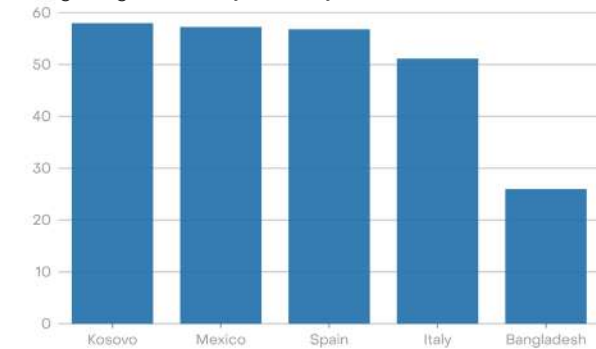
## Key global changes in coal generation

Change in generation year-on-year (TWh)



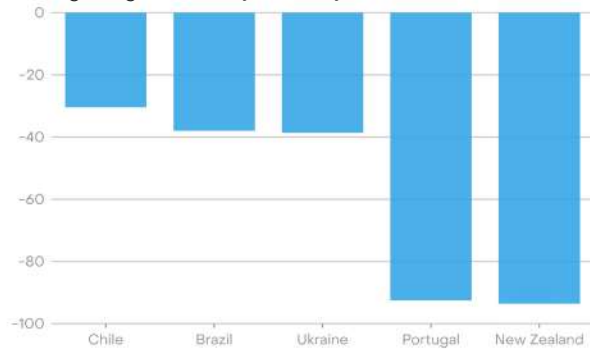
## Largest increases

Change in generation year-on-year (%)



## Largest decreases

Change in generation year-on-year (%)



Source: Ember

Note: 2022 data used where available, else 2021

## Long-term Trends

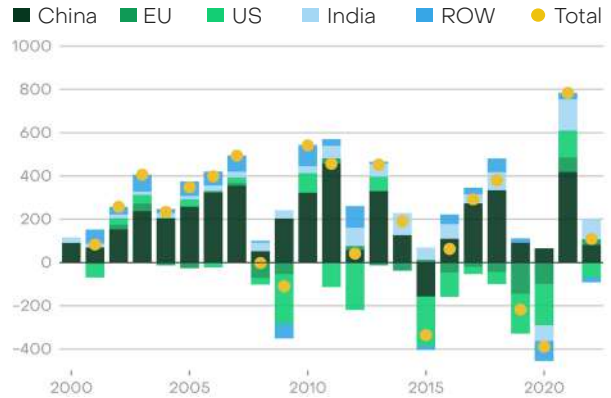
Over the last two decades, coal generation increased by 78%, from 5,719 TWh in 2000 to 10,186 TWh in 2022. However, the share of coal in the global power mix has fallen slightly (from 38% in 2000 to 36% in 2022). No other individual fuel source is larger than coal, though clean sources in aggregate exceeded coal generation in 2019.

Since the Paris Agreement, the rate of coal generation's annual growth has slowed, with an average growth rate of 1.5% from 2015 to 2022, half the average rate between 2000 and 2015 (+3.2%). From 2000 to 2015, the share of coal power in the electricity mix increased by one percentage point (from 38% to 39%). In 2022, the share had fallen to 36%.

Among G20 countries, South Africa has had the highest share of coal generation since 2015, followed by India as the second highest and China the third, showing no change in ranking. Most G20 countries have dropped their share of coal by varying degrees. The UK has had the largest fall in coal share, with a decrease from 23% in 2015 to 1.6% in 2022.

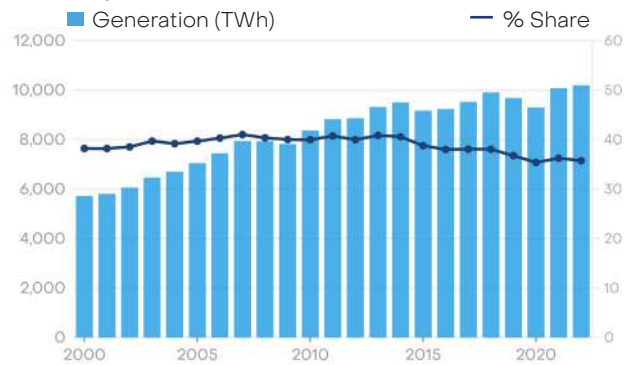
### Annual changes in coal generation

Change in generation year-on-year (TWh)



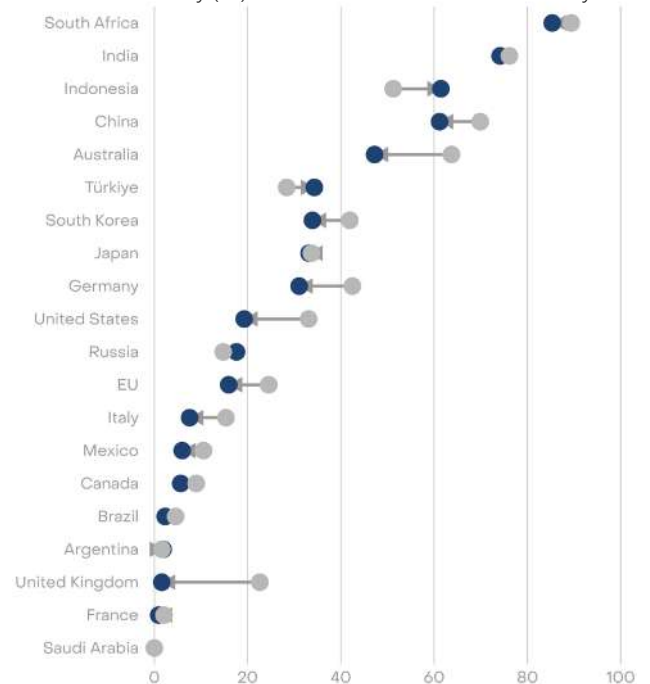
### Long-term trends in coal generation

Electricity generation (TWh) and share of electricity (%)



### Coal share, G20 countries

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

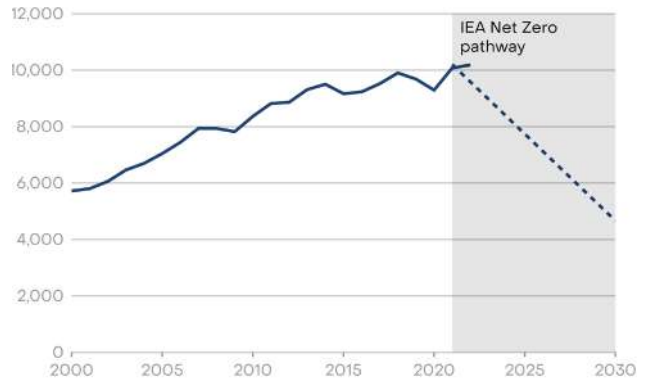
\*Saudi Arabia and Indonesia use 2021 data.

# Progress Towards Net Zero

According to the [IEA Net Zero Emissions scenario](#), the world needs to bring the share of coal in the power mix down to 12% by 2030, a decrease of 24 percentage points from the share in 2022 (36%). The IEA pathway requires coal to decline 8.3% every year from 2021 to 2030, whereas since 2015 coal has increased by 1.5% annually. To meet the requirements of the IEA pathway, OECD countries will need to phase out coal by 2030, with the rest of the world following by 2040.

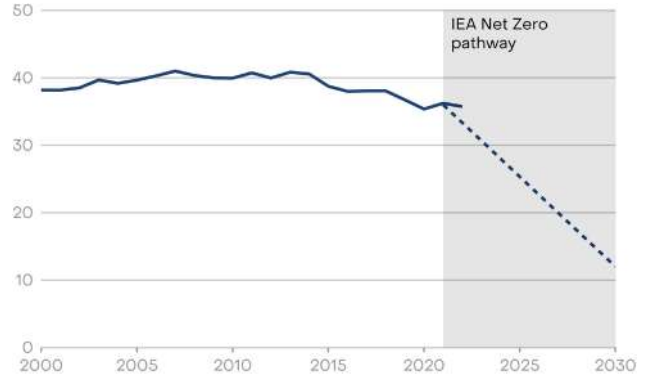
## Coal generation

Electricity generation (TWh)



## Coal share

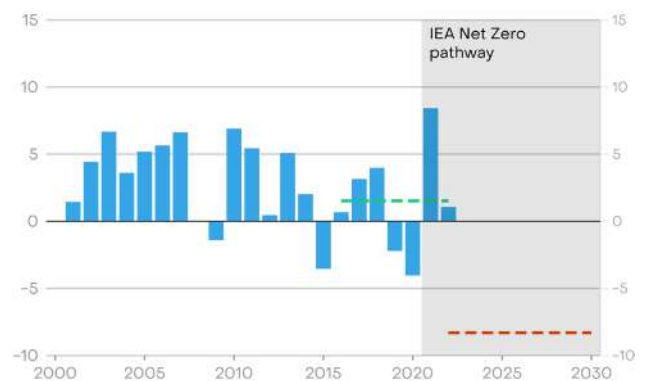
Share of electricity (%)



## Changes in coal generation

Change in generation year-on-year (%)

■ YoY change    - - 2016-22 avg    - - Required YoY



Source: Ember

Note: 2022 data used where available, else 2021

# Bioenergy

Global Electricity Trends 2022



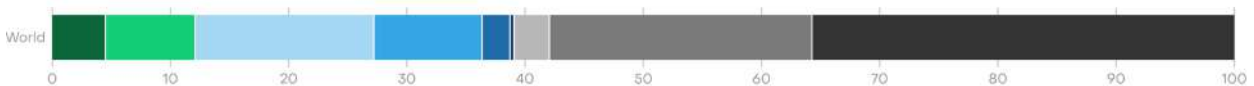
In 2022, 2.4% (672 TWh) of global electricity was generated with bioenergy. China was the largest producer, generating 172 TWh (1.9% of its electricity mix), followed by Brazil (57 TWh, 8.5% of the mix). Countries that rely on bioenergy the most are Finland (19% of total generation, 14 TWh) and the United Kingdom (11%, 35 TWh).



## Global electricity mix

Share of electricity (%)

Solar Wind Hydro Nuclear Bioenergy Other res Other fossil Gas Coal



## Role of bioenergy

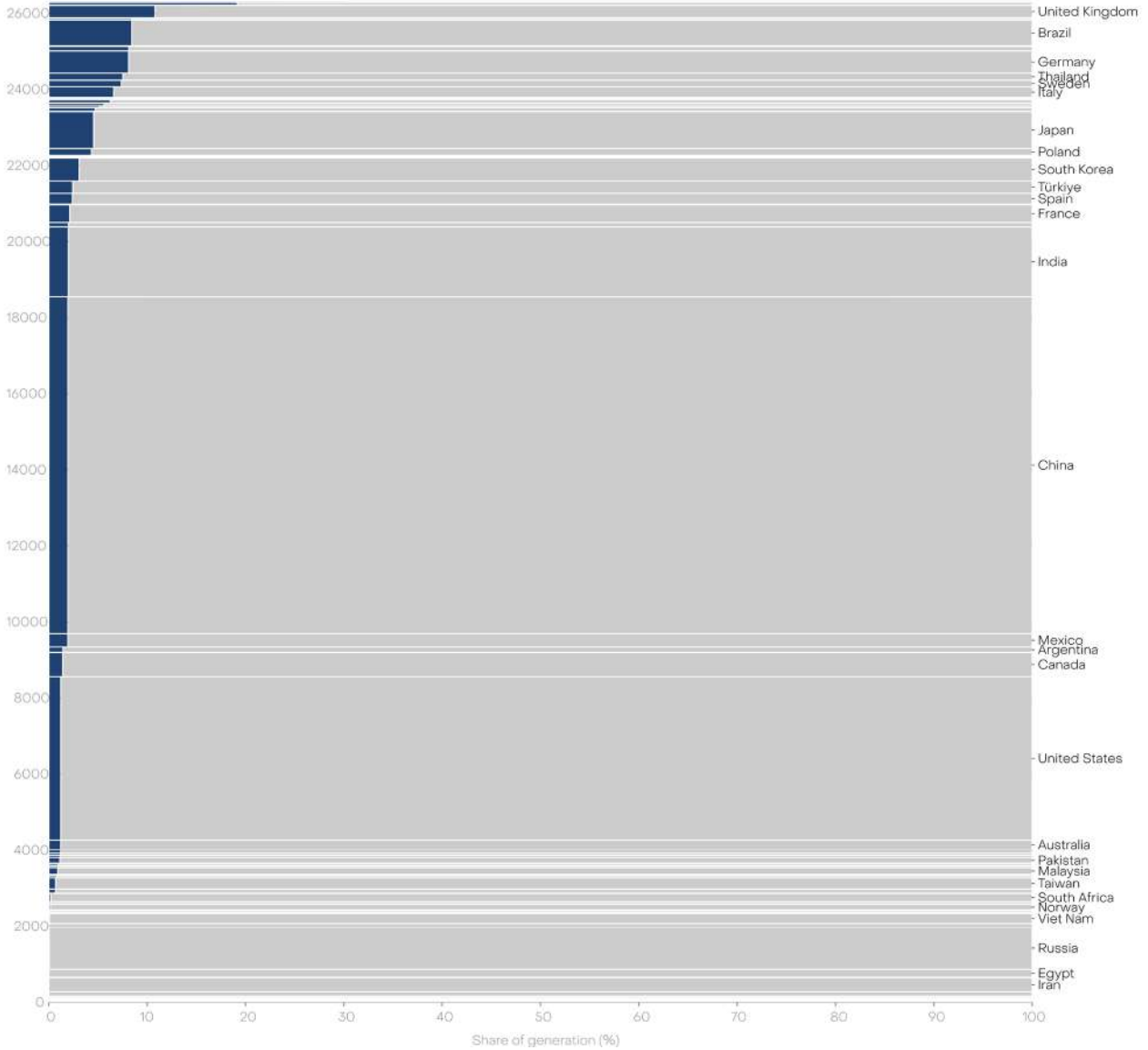
Although bioenergy is categorised as a renewable source in this report, its climate impact is highly dependent on the type of feedstock and how it was sourced. Scientific evidence is mounting that suggests that in some cases burning bioenergy for power contributes to climate change.



### Major players in bioenergy power

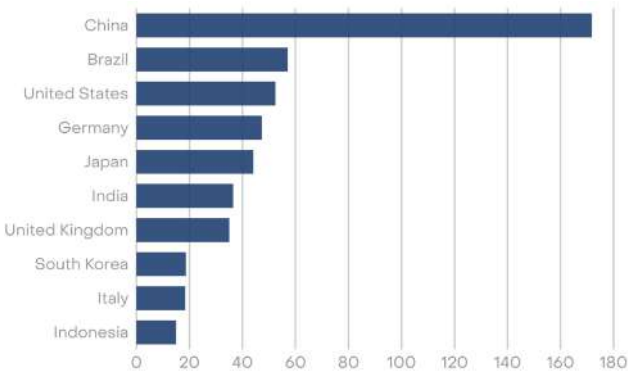
Electricity generation (TWh, y-axis) and share of electricity (% x-axis)

■ Bioenergy    ■ Other fuel types



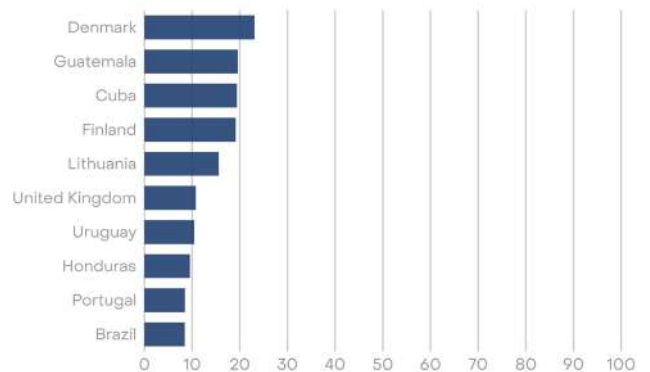
### Largest bioenergy generators

Electricity generation (TWh)



### Highest shares of bioenergy power

Share of electricity (%)



# Change in 2022

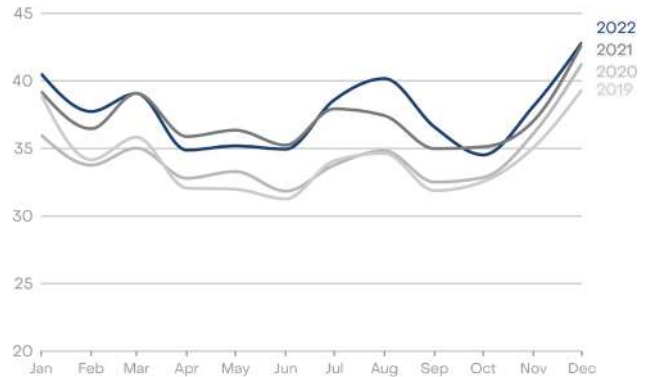
Bioenergy production slightly increased by 0.8% (+6 TWh), up from 666 TWh in 2021 to 672 TWh in 2022. This was the lowest annual absolute increase for bioenergy since 2001. The share of bioenergy in the global electricity mix remained unchanged at 2.4% in 2022.

The UK had the largest fall in absolute terms (-4.1 TWh), followed by the US (-1.9 TWh), and the Netherlands (-1.1 TWh). The decrease in the UK is particularly notable, as it was the first year that bioenergy production fell since 2000. The drop was also quite large in relative terms (-10%), dropping the share of bioenergy in the UK's power mix from 13% 2021 to 11% in 2022.

On the other hand, Japan increased production by 7.2 TWh (+19%), as it experienced annual power demand growth above 1% for the first time since 2010. South Korea also increased production, adding 3.6 TWh of bioenergy to the power mix (+24%) to meet rising demand while decreasing reliance on coal.

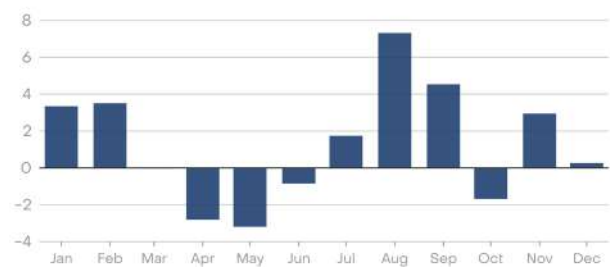
## Global bioenergy generation

Electricity generation (TWh)



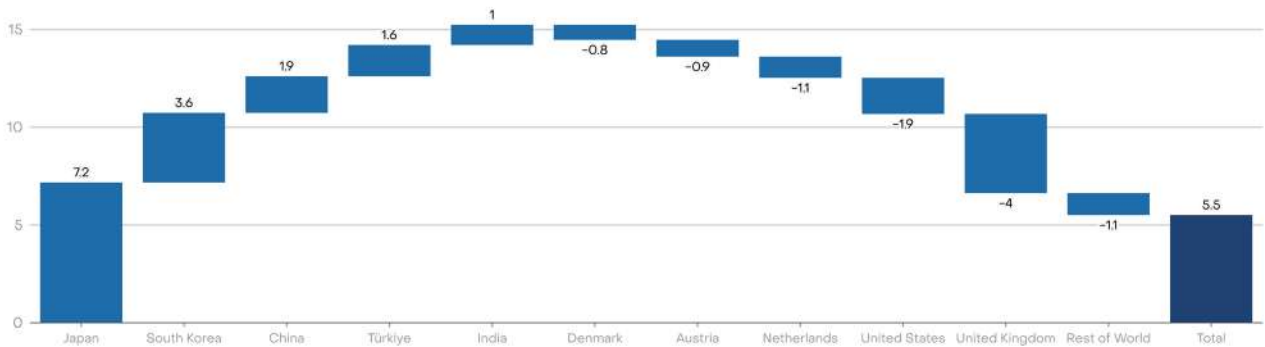
## Monthly changes in bioenergy generation

Change in generation year-on-year (%)



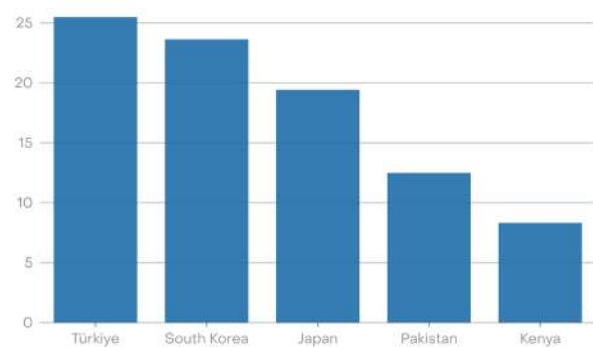
## Key global changes in bioenergy generation

Change in generation year-on-year (TWh)



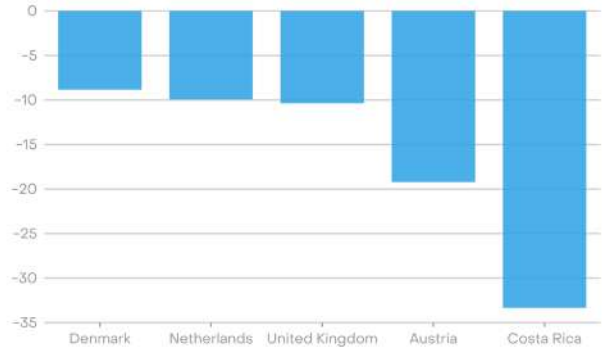
## Largest increases

Change in generation year-on-year (%)



## Largest decreases

Change in generation year-on-year (%)



Source: Ember

Note: 2022 data used where available, else 2021

## Long-term Trends

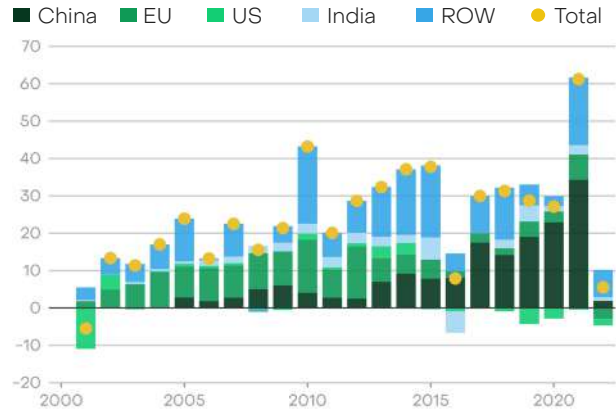
In the last two decades, bioenergy generation has increased 4.5 times, from 148 TWh in 2000 to 672 TWh in 2022. Consequently, the share of bioenergy in the global power mix went from below 1% in 2000 to 2.4% in 2022. There has been only one calendar year when bioenergy generation showed an annual decline: in 2001 production fell by 5.5 TWh (-3.7%). Since then, bioenergy generation has grown at an average annual growth rate of 8%. In 2022, the growth rate plummeted to 0.8%, as major producers like Brazil, United States and the UK reduced bioenergy generation.

Growth of bioenergy generation has slowed since 2015, showing a lower average annual growth rate at 4.9%. Bioenergy's share has gone up only by 0.4 percentage points since 2015, from 2% to 2.4% in 2022.

Among G20 countries, the UK has the highest share of bioenergy in the domestic power mix. In 2000, its share was only 1.1%. By 2015, the share rose to 8.5%, although the increase has slowed, bringing the UK's share of bioenergy to 11% in 2022. Brazil and Germany have similar shares, with a consistent share of around 8% since 2015.

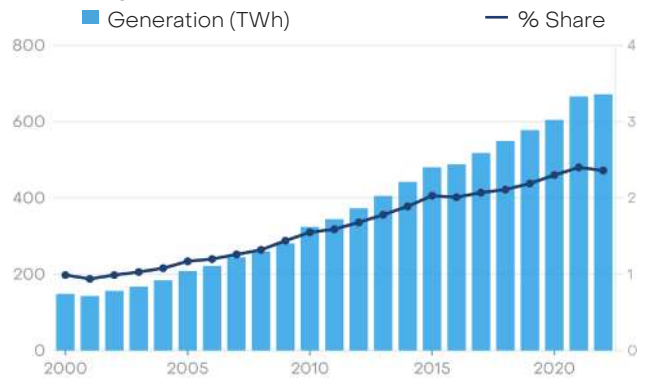
### Annual changes in bioenergy generation

Change in generation year-on-year (TWh)



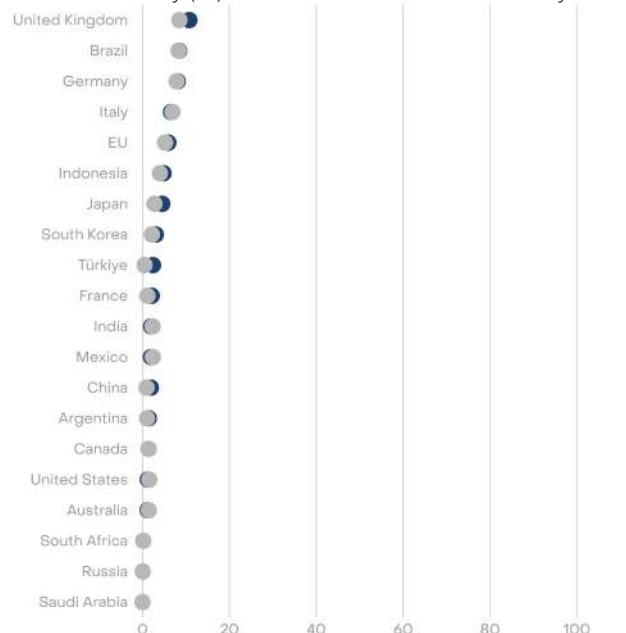
### Long-term trends in bioenergy generation

Electricity generation (TWh) and share of electricity (%)



### Bioenergy share, G20 countries

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

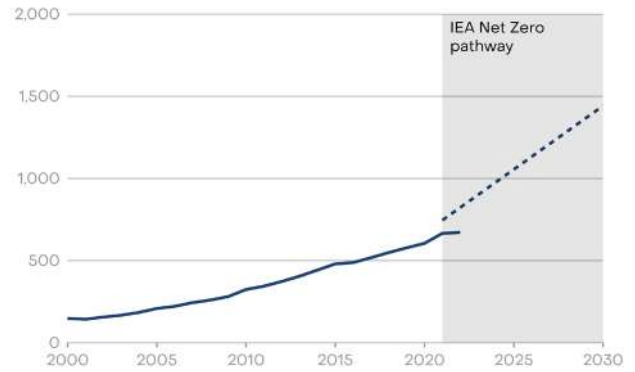
\*Saudi Arabia and Indonesia use 2021 data.

# Progress Towards Net Zero

Because of the climate risks associated with carbon-intensive feedstock, bioenergy should play a limited role in clean electricity transition. In the [IEA Net Zero Emissions scenario](#), bioenergy generation only accounts for 4% of global electricity generation in 2030. The [International Panel on Climate Change](#) suggested that bioenergy should be limited further to just 2% by 2040. Yet, the IEA Net Zero pathway suggests that bioenergy generation should double to 1,442 TWh by 2030 as the world phases out coal. To be on this pathway, global bioenergy generation would need to rise 7.6% every year from 2021 to 2030 compared to a growth rate of 4.9% since 2015.

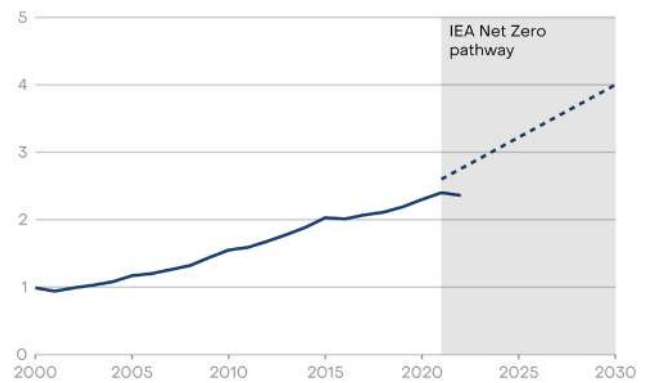
## Bioenergy generation

Electricity generation (TWh)



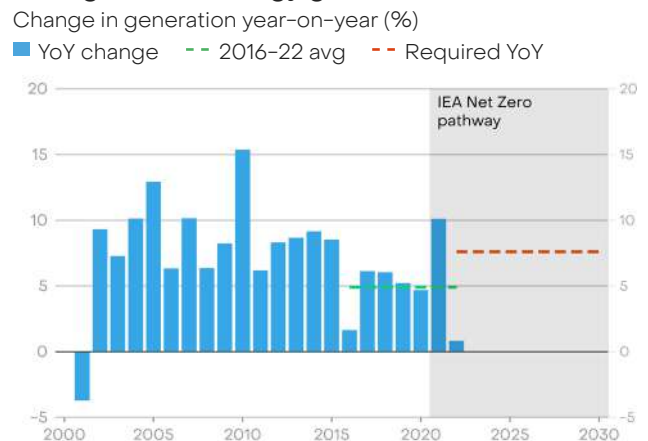
## Bioenergy share

Share of electricity (%)



## Changes in bioenergy generation

Change in generation year-on-year (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Gas

## Global Electricity Trends 2022

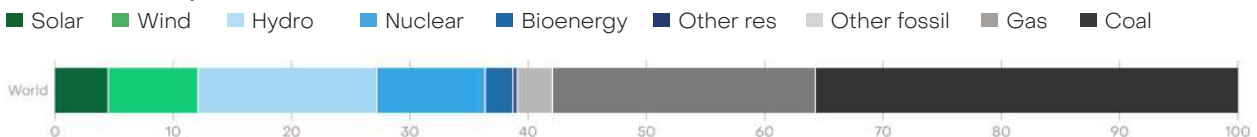


Fossil gas generation is the second largest source of electricity worldwide, responsible for 22% of global electricity generation. The US is the largest producer of electricity from gas at 1,695 TWh (39% of its electricity mix). This is more than three times larger than the next biggest generator Russia (479 TWh, 43% of its mix). Kuwait has the highest share of gas in the mix, with 99.9% (71 TWh) of its electricity from gas.



### Global electricity mix

Share of electricity (%)

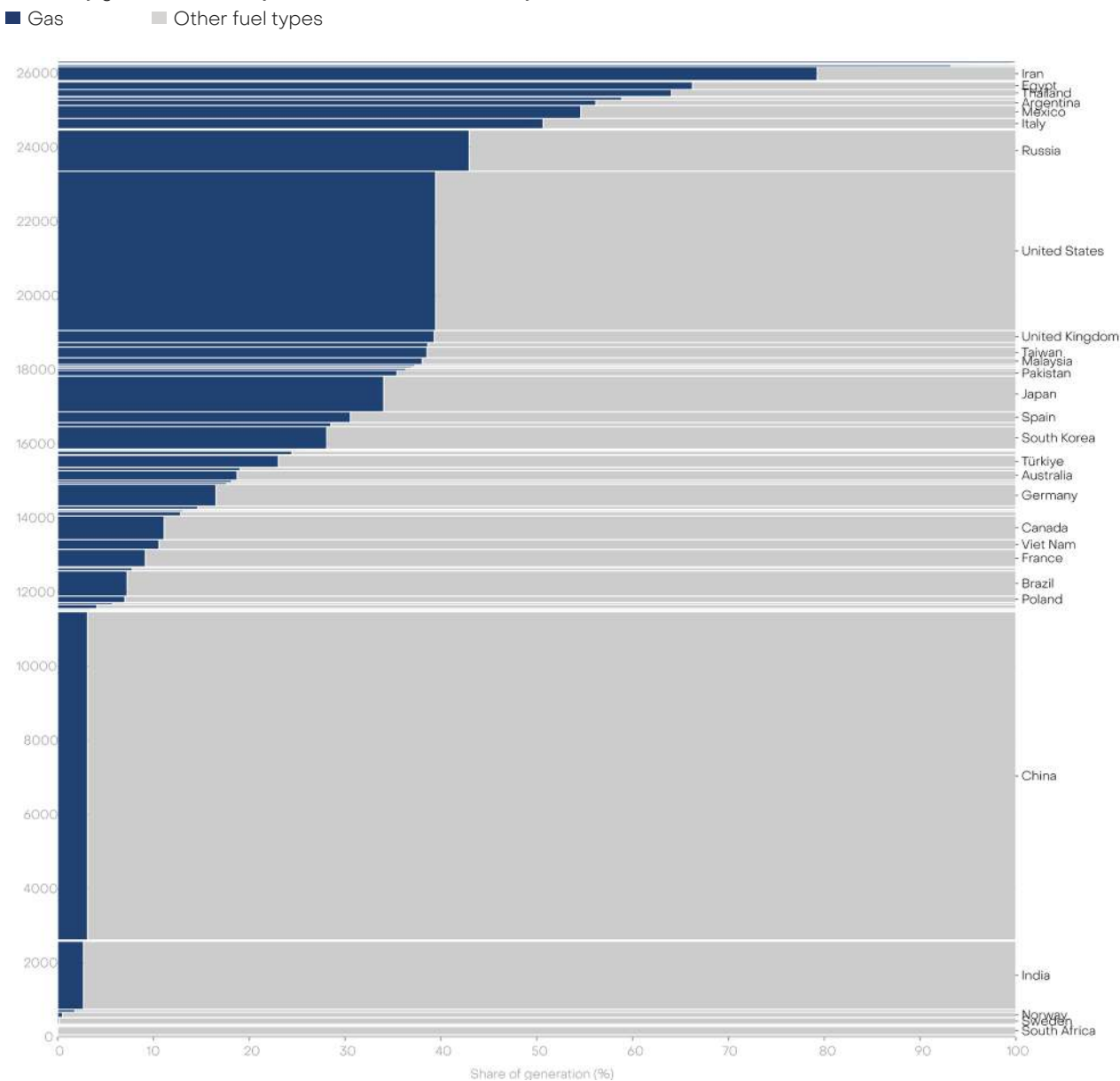


### Role of gas

Gas, after coal, is the second largest contributor to emissions from the power sector. In the mid-term it has a role helping with the power system flexibility to accommodate a large influx of wind and solar. However, unabated gas (gas without carbon capture and storage) will need to be phased out by 2040 in order to move to a clean power system.

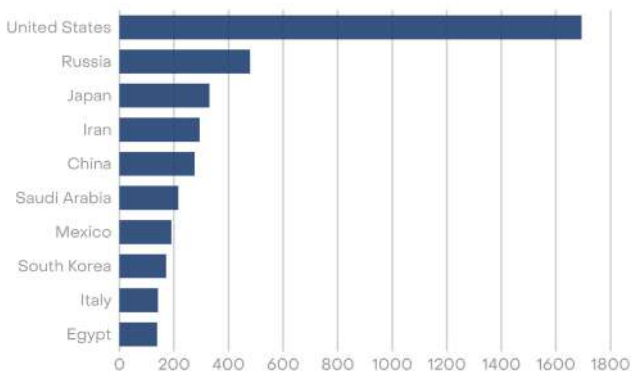
### Major players in gas power

Electricity generation (TWh, y-axis) and share of electricity (% x-axis)



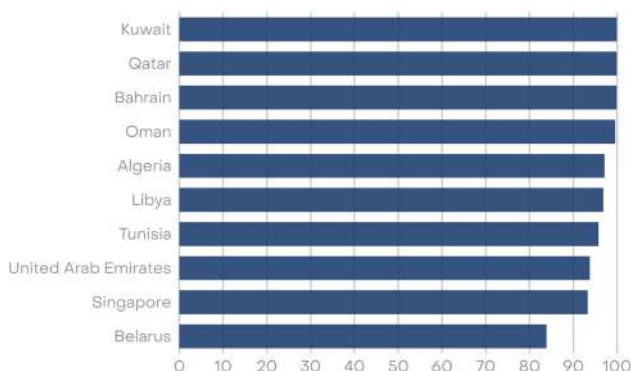
### Largest gas generators

Electricity generation (TWh)



### Highest shares of gas power

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Change in 2022

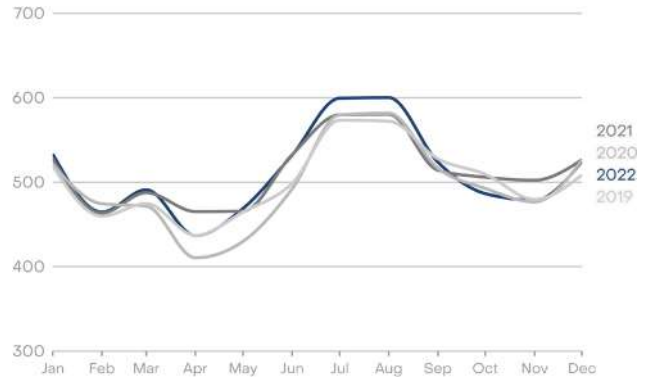
Despite supply chain disruptions after Russia's invasion of Ukraine and consequent price hikes, gas generation had only a marginal change. Down by 0.2% (-12 TWh), gas generation went from 6,348 TWh in 2021 to 6,336 TWh in 2022. The share of gas also decreased marginally from 23% in 2021 to 22% in 2022.

In the US, gas had a large increase of 116 TWh (+7.4%), driven by a rise in demand and a move away from coal. Some countries in western Europe also increased gas generation, with reduced nuclear generation in France forcing a 9.6 TWh (+29%) domestic increase, and the [Iberian mechanism](#) allowing Spain's generation to rise by 15 TWh (+22%) to export power to France.

Reasons for declines elsewhere were mixed. Brazil had a 42 TWh fall in gas (-46%), driven by a resurgence of hydro after a poor year in 2021. In Türkiye, many other sources of power increased, most notably hydro and coal, allowing gas to fall by 35 TWh (-32%).

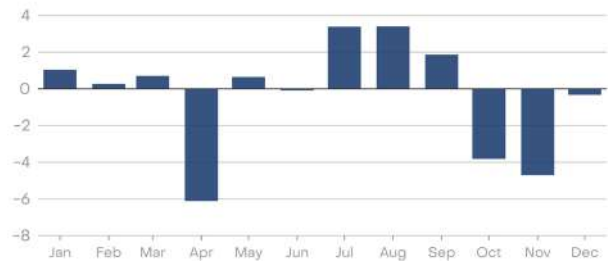
## Global gas generation

Electricity generation (TWh)



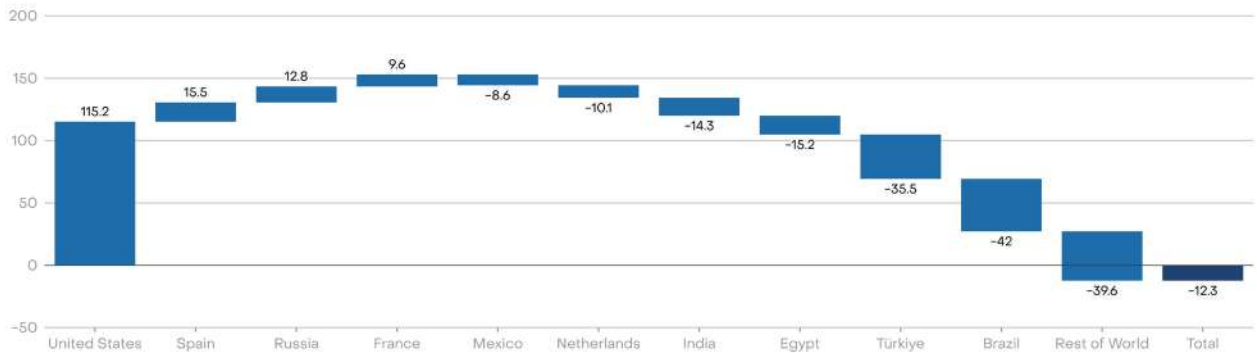
## Monthly changes in gas generation

Change in generation year-on-year (%)



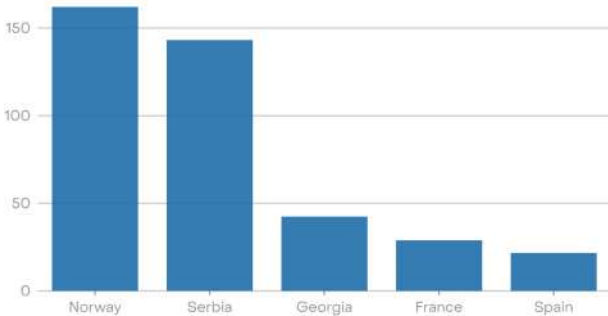
## Key global changes in gas generation

Change in generation year-on-year (TWh)



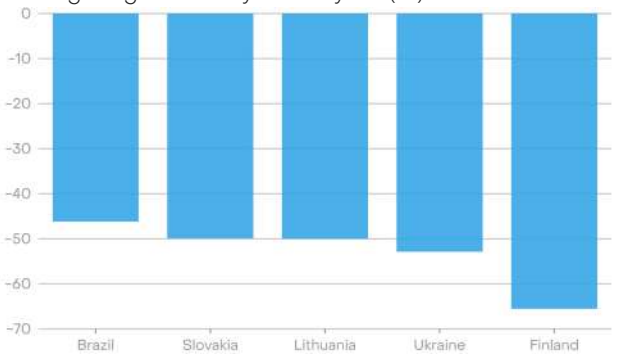
## Largest increases

Change in generation year-on-year (%)



## Largest decreases

Change in generation year-on-year (%)



Source: Ember

Note: 2022 data used where available, else 2021



## Long-term Trends

In the last two decades, gas generation has increased 2.3 times, from 2,718 TWh in 2000 to 6,336 TWh in 2022. In 2022, gas generation reached its second highest ever level, not far from the 2021 record of 6,348 TWh. The share of gas went up from 18% in 2000 to 23% in 2015, then slightly down to 22% in 2022.

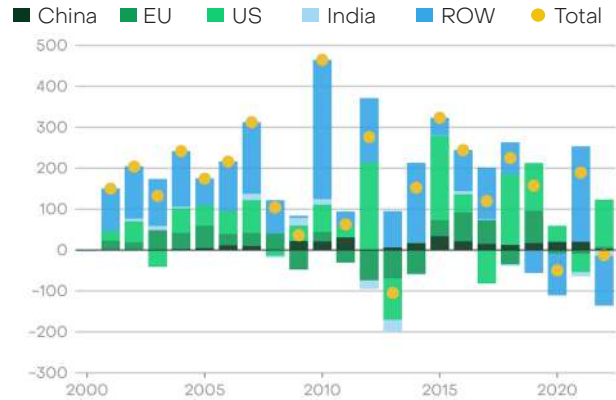
Over the past two decades, only three calendar years saw a drop in gas generation: 2013 (-2.1%, -105 TWh), 2020 (-0.8%, -50 TWh) and 2022 (-0.2%, -12 TWh). The fall in gas generation in 2022 was not as substantial as the two other years, but this hints at impacts from the global gas crisis.

From 2000 until the Paris Agreement in 2015, gas generation doubled, reaching 5,463 TWh in 2015. This translates to an average yearly growth rate of 4.8%. Since 2015, the rate of growth has slowed to 2.1% per year on average.

Half of the G20 countries have increased the share of gas in their power mix since 2015. Saudi Arabia is most notable, with the share of gas increasing from 46% in 2015 to 61% in 2021. Italy's gas share went from 39% in 2015 to 51% in 2022, Germany from 9.9% to 17%, France from 3.7% to 9.2%, the US from 33% to 40%, and South Korea from 22% to 28%. On the other hand, Brazil's gas share fell from 13% in 2015 to 7% in 2022, Türkiye's from 38% to 23%, India's from 4.9% to 2.7%, Japan from 40% to 34% and Russia from 49% to 43%.

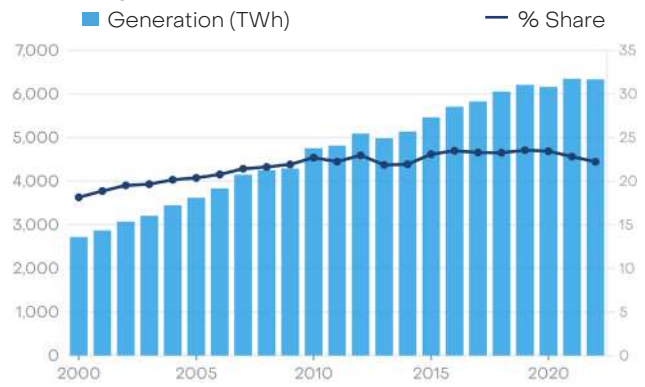
### Annual changes in gas generation

Change in generation year-on-year (TWh)



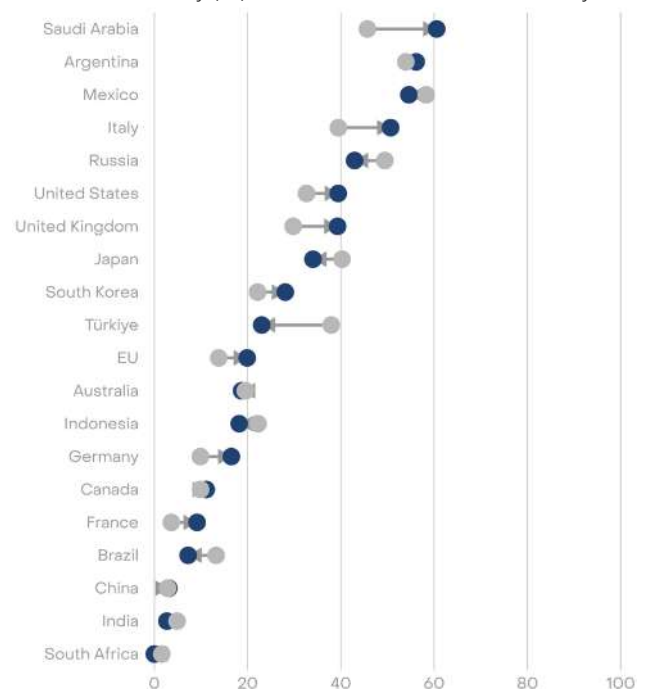
### Long-term trends in gas generation

Electricity generation (TWh) and share of electricity (%)



### Gas share, G20 countries

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

\*Saudi Arabia and Indonesia use 2021 data.



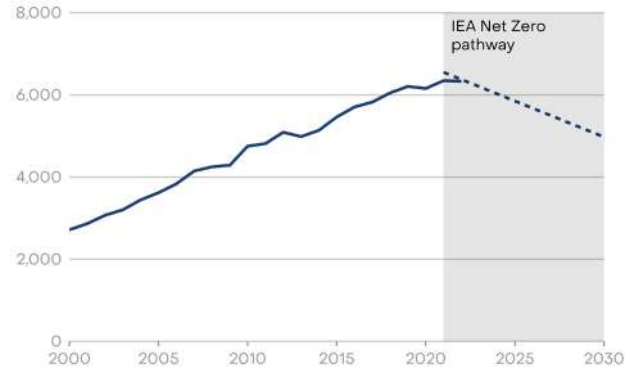
# Progress Towards Net Zero

According to the [IEA Net Zero Emissions scenario](#), the world must reduce gas generation to bring the total down to 4,977 TWh by 2030 to limit global temperature rise to 1.5C. Under this scenario, gas would account for 13% of the global power mix in 2030. To be on this path, gas generation must fall by 3% every year from 2021 to 2030.

Historically, gas generation has grown steadily, although its rate of growth has slowed since 2015. The gas crisis in 2022 may prove a turning point, as it revealed vulnerabilities of the global gas supply chain and prompted many countries to reconsider the role of gas in their power mix. If clean electricity growth accelerates, it has the potential to hasten the decline of gas in future years.

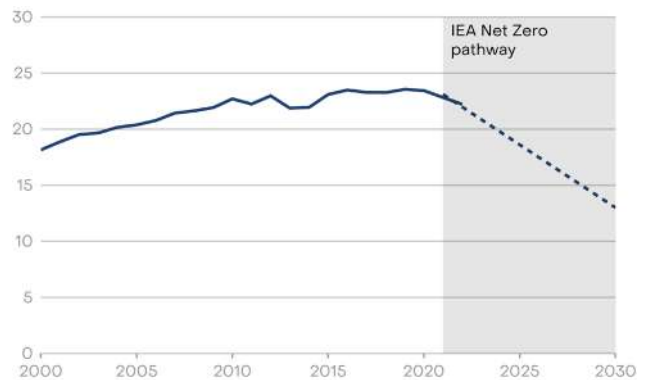
## Gas generation

Electricity generation (TWh)



## Gas share

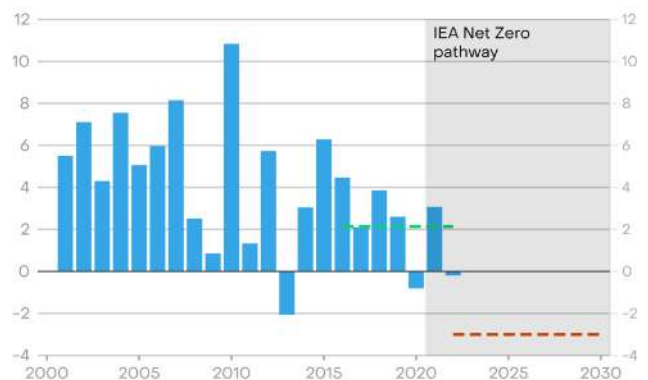
Share of electricity (%)



## Changes in gas generation

Change in generation year-on-year (%)

■ YoY change    - - 2016-22 avg    - - Required YoY



Source: Ember

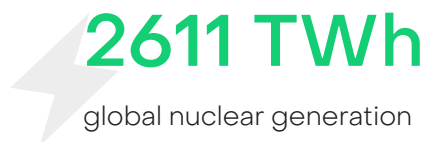
Note: 2022 data used where available, else 2021

# Nuclear

## Global Electricity Trends 2022

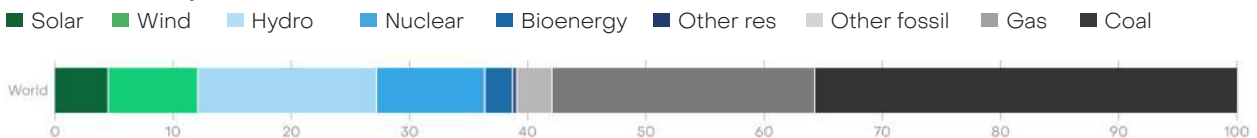


In 2022, nuclear power produced 9.2% (2,611 TWh) of global electricity. The US is the single largest nuclear power generator, accounting for 30% of global nuclear power production (772 TWh). Nuclear production in China was less than half that of the US, amounting to 418 TWh and 16% of global production. Countries that rely heavily on nuclear power are France (63%, 298 TWh), Slovakia (59%, 16 TWh), Ukraine (58%, 65 TWh), Belgium (47%, 44 TWh) and Hungary (45%, 16 TWh).



### Global electricity mix

Share of electricity (%)



### Role of nuclear

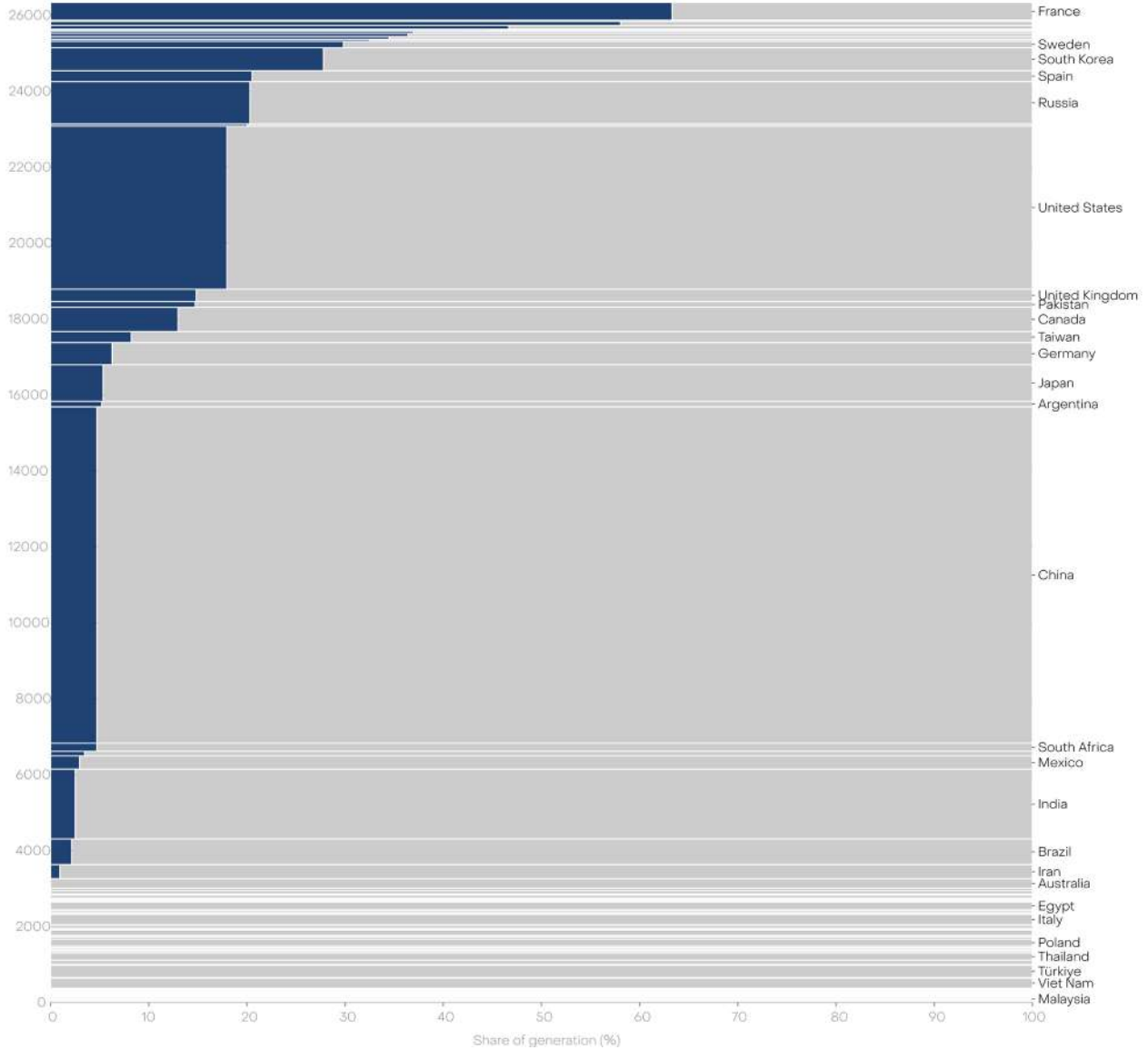
Nuclear power is an important source of firm zero-carbon energy, given the severity of the climate crisis and the necessity to quickly move off fossil fuels. Nuclear power capacity needs to increase significantly over the coming decades in line with growing electricity demand, but its share of global electricity generation is likely to remain similar to today.



### Major players in nuclear power

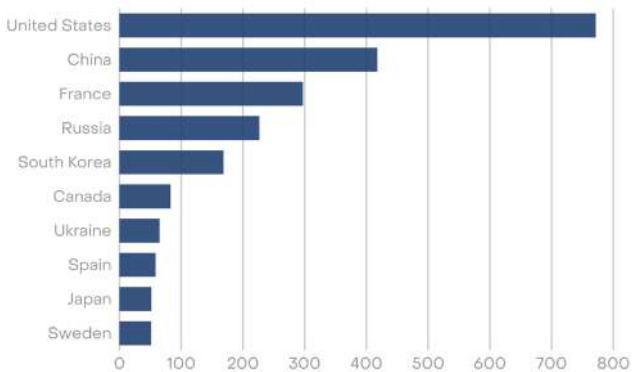
Electricity generation (TWh, y-axis) and share of electricity (% x-axis)

■ Nuclear    ■ Other fuel types



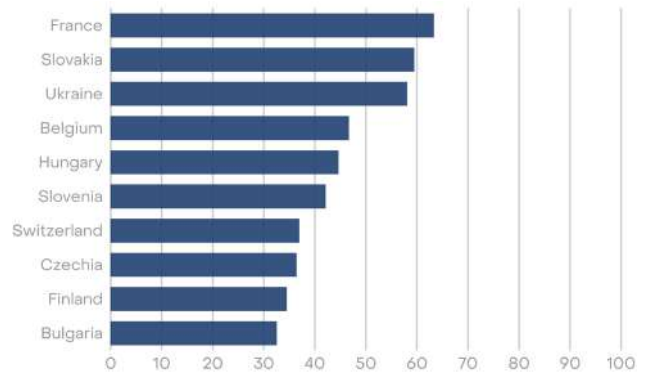
### Largest nuclear generators

Electricity generation (TWh)



### Highest shares of nuclear power

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

## Change in 2022



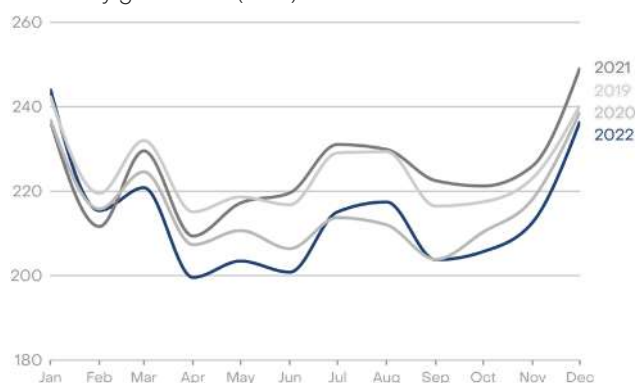
Global nuclear electricity generation fell by 4.7% (-129 TWh), from 2,739 TWh in 2021 to 2,611 TWh in 2022. Nuclear's share in the global electricity mix also fell by 0.7 percentage points, from 9.9% in 2021 to 9.2% in 2022.

The largest fall occurred in France, where many nuclear power plants were shut down for maintenance for longer than expected (-82 TWh, -22%). The second largest fall came from Germany's delayed nuclear phaseout (-47%, -33 TWh). The invasion of Ukraine forced several reactor shutdowns (-21 TWh, -25%). Among non-European countries, Japan had the largest fall in nuclear generation due to scheduled maintenance (-9.5 TWh, -15%), despite its shift in policy to [revive its nuclear industry](#).

Among countries that saw a jump in nuclear generation, South Korea had the largest increase of 18 TWh (+12%). China's nuclear generation went up by 10 TWh (+2.5%), with [Honyanhe 6](#) nuclear reactor coming online in May. Pakistan had the third largest increase in absolute terms and largest percentage change globally (+6.7 TWh, +43%).

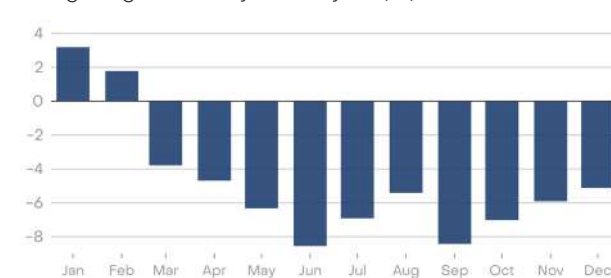
### Global nuclear generation

Electricity generation (TWh)



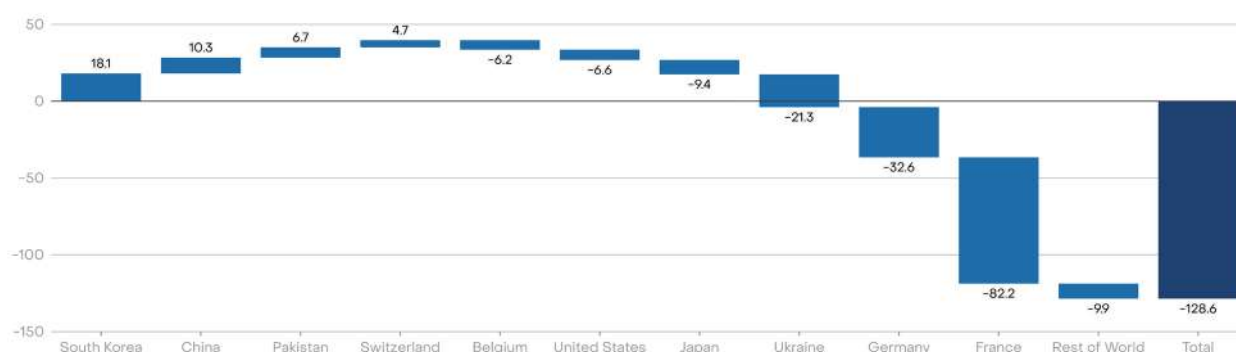
### Monthly changes in nuclear generation

Change in generation year-on-year (%)



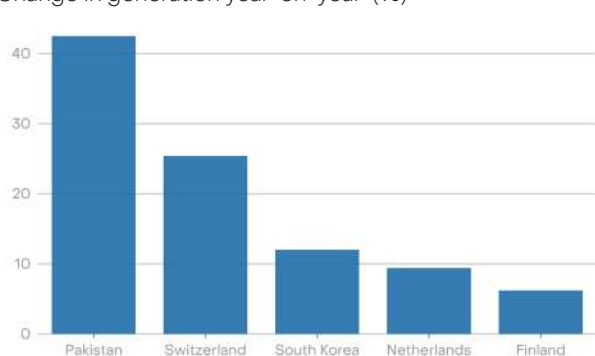
### Key global changes in nuclear generation

Change in generation year-on-year (TWh)



### Largest increases

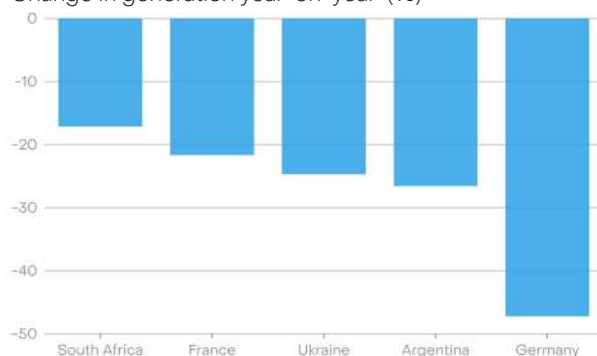
Change in generation year-on-year (%)



Source: Ember

### Largest decreases

Change in generation year-on-year (%)



Note: 2022 data used where available, else 2021

# Long-term Trends



In the last two decades, nuclear power has not seen significant growth. From 2000 until 2022, nuclear power increased only at about 0.2% annual growth rate on average. Nuclear share has gone down significantly as a result, dropping to 9.2% (2,611 TWh) in 2022 from 17% of the world's electricity (2,507 TWh) in 2000.

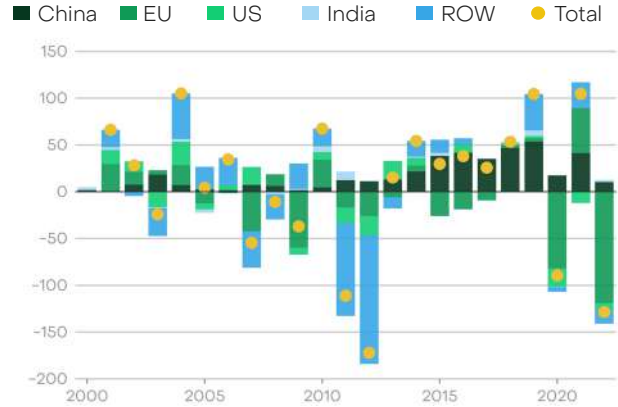
The fall in nuclear power in 2022 (-4.7%, -129 TWh) was the second largest year-on-year decrease the world has ever seen. Nuclear generation in 2022 (2,611 TWh) was even lower than 2020 (2,635 TWh), when the Covid-19 pandemic forced the world economy to a halt. The largest drop was seen in 2012 (-6.7%, -172 TWh), a year after the Fukushima nuclear disaster struck Japan.

After the large setback in 2012, nuclear generation regained momentum of growth for the next seven years until 2020, the year when the Covid-19 pandemic began. However, growth was still not strong enough to keep pace with rising global power demand. As a result, the share of nuclear in the global electricity mix has declined. In 2015, the share of nuclear power was at 11% and it has continued to fall, reaching 9.2% in 2022.

Among G20 countries, France has the highest share of nuclear power in its domestic power mix. France also showed the largest drop in the share of nuclear power, decreasing its share from 76% in 2015 to 63% in 2022. The drop in nuclear power reflects strong uptake of wind and solar as well as gas. South Korea, which has the second highest nuclear share amongst the G20, has seen a slight fall, down from 30% in 2015 to 28% in 2022.

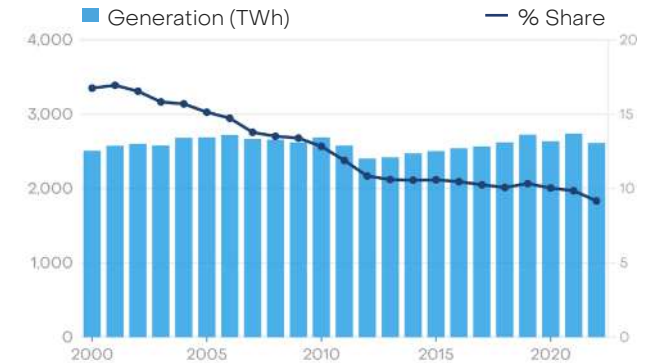
## Annual changes in nuclear generation

Change in generation year-on-year (TWh)



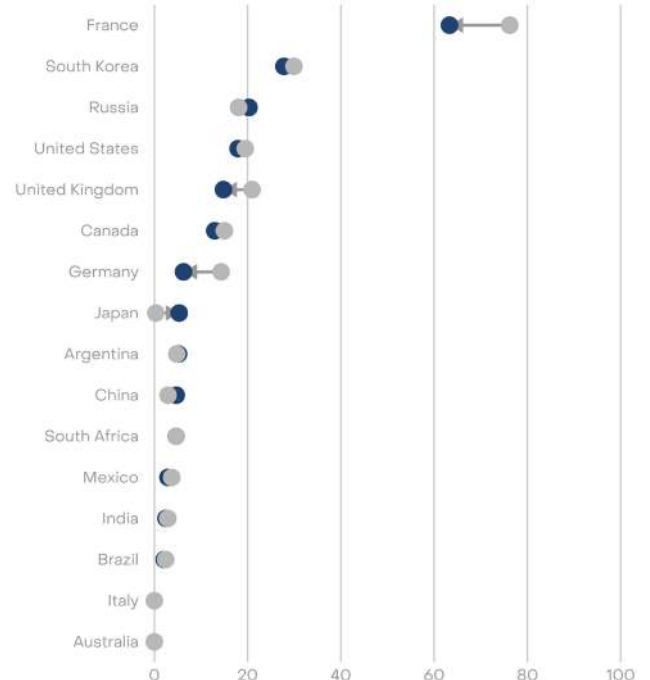
## Long-term trends in nuclear generation

Electricity generation (TWh) and share of electricity (%)



## Nuclear share, G20 countries

Share of electricity (%)



Source: Ember

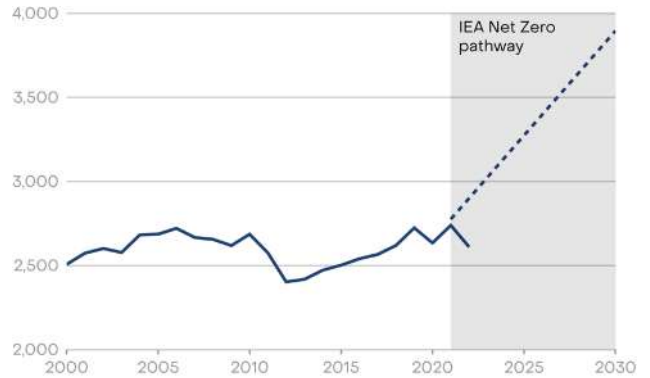
Note: 2022 data used where available, else 2021



According to the [IEA Net Zero Emissions scenario](#), nuclear power will play a limited role in the global power mix in 2030, keeping its share at about 10%. Yet, to meet the world's rising demand for power with zero-carbon energy source, the IEA pathway requires nuclear generation to grow by 3.8% annually from 2021 to 2030. From 2015 to 2022, the average growth rate was at just 0.6% and 2022 showed a 4.7% fall.

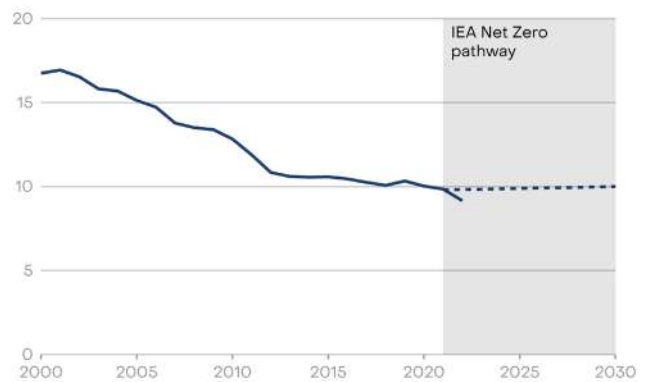
### Nuclear generation

Electricity generation (TWh)



### Nuclear share

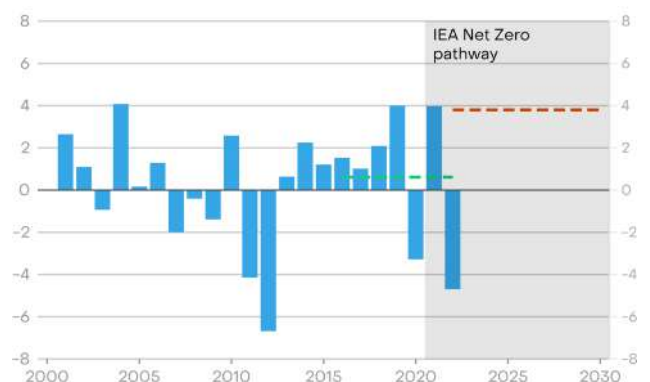
Share of electricity (%)



### Changes in nuclear generation

Change in generation year-on-year (%)

■ YoY change    - - 2016-22 avg    - - Required YoY



Source: Ember

Note: 2022 data used where available, else 2021

# Analysis of the ten largest power sector emitters in 2022

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This chapter provides a deeper analysis of what has happened in the countries and regions that are the world's top ten absolute CO<sub>2</sub> emitters. Collectively, they are responsible for around 80% of global emissions from the electricity sector.

We have ordered the sections according to the amount of carbon dioxide emissions produced from the electricity sector of the given country or region in 2022, or the previous year if no data is available.

## Chapter contents

---

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114	United States	139	South Korea
119	India	144	Saudi Arabia
124	European Union	149	Indonesia
129	Japan	154	Iran

# China

## Global Electricity Trends 2022



Last year, China produced the most CO<sub>2</sub> emissions of any power sector in the world. At 4,694 million tonnes of CO<sub>2</sub>, China accounted for 38% of total global emissions from electricity generation. In 2021, 19% of China's final energy consumption came from electricity: this is likely to grow rapidly with the electrification of other sectors like transport and heating. Given the scale of China's emissions, rapid decarbonisation of the global power sector will not be possible without the coal to clean power transition in China.

Although solar and wind have been the main drivers of additional power production in China, reliance on coal remains high. Coal alone made up 61% of China's electricity mix last year (5,420 TWh). Taking gas (3.1%, 276 TWh) and other fossil fuels into consideration, all fossil fuels accounted for 64% of China's electricity in 2022. Solar and wind together contributed 14% of the electricity mix (1,241 TWh). The share of wind (9.3%) is almost twice that of solar (4.7%). Other clean power sources in China include hydro (15%), nuclear (5%) and bioenergy (2%).

Due to its high reliance on fossil fuels, China's power sector emissions intensity (530 gCO<sub>2</sub>/kWh) was 22% higher than the global level of 436 gCO<sub>2</sub>/kWh. Moreover, China's per capita demand for power (6.2 MWh) was almost two times higher than the global level (3.6 MWh). As a result, China's per capita power sector emissions (3.3 tonnes CO<sub>2</sub>) were more than double the global average of 1.6 tonnes in 2022.

“China is the world's biggest coal power country but also the leader in absolute wind and solar generation. Choices being made about energy in the country have worldwide implications. Whether peaking fossil generation globally happens in 2023 is largely down to China.”

**Małgorzata Wiatros-Motyka**

Senior Electricity Analyst, Ember

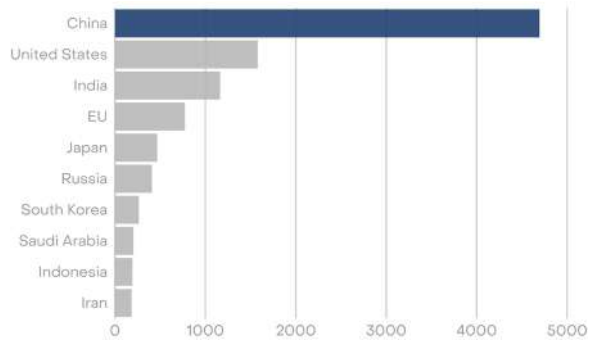




# Global Context

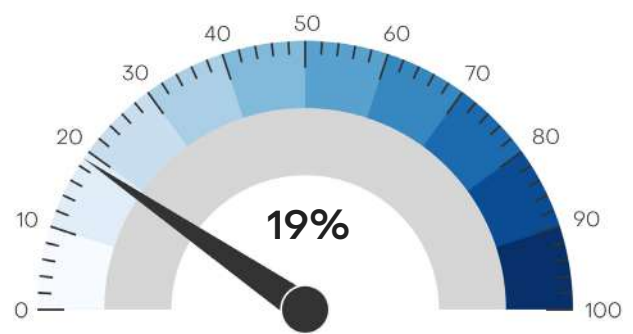
## Top 10 power sector emitters

CO2 emissions (million tonnes)



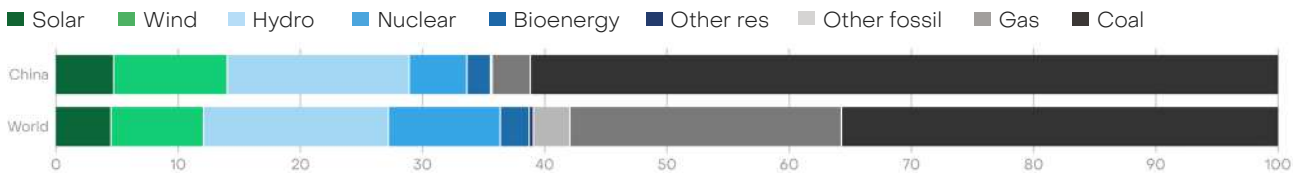
## China's electrification

Electricity as a percentage of final energy consumption (%)



## China vs world - electricity mix

Share of electricity (%)

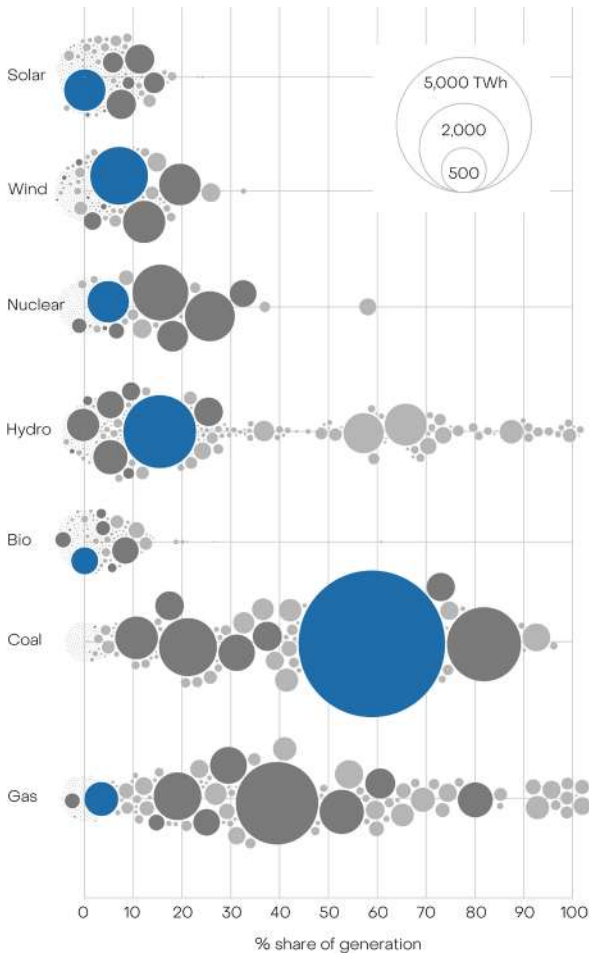


## China vs world - sources of electricity

Share of electricity (%)

Bubble size represents electricity generation (TWh)

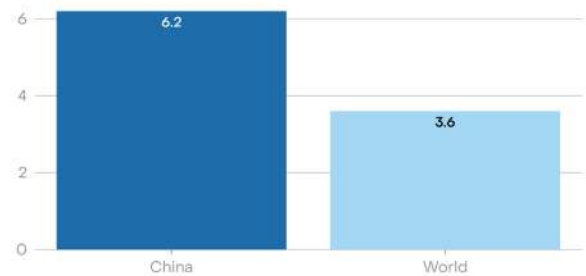
● China ● Top 10 emitters ● Other countries



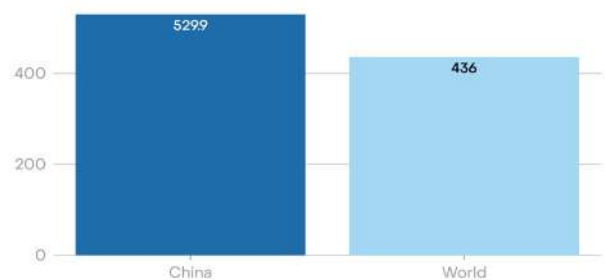
## China vs world - emissions and demand

● China ● World

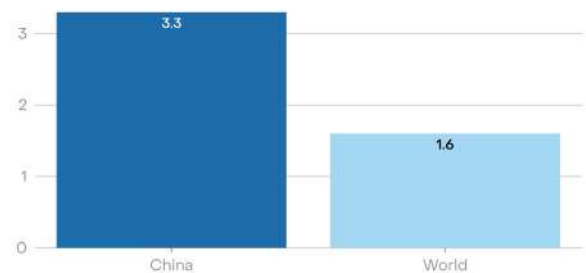
### Demand per capita (MWh)



### CO2 intensity (gCO2/kWh)



### Emissions per capita (tCO2)



Source: Ember

Note: 2022 data used where available, else 2021

## Change in 2022



China's power demand increased by 4.4% in 2022, below the average growth rate since 2010 (6.5%), as China's zero-COVID policy continued to impact demand. Despite this, China's demand increase of 374 TWh was more than half the total global demand increase.

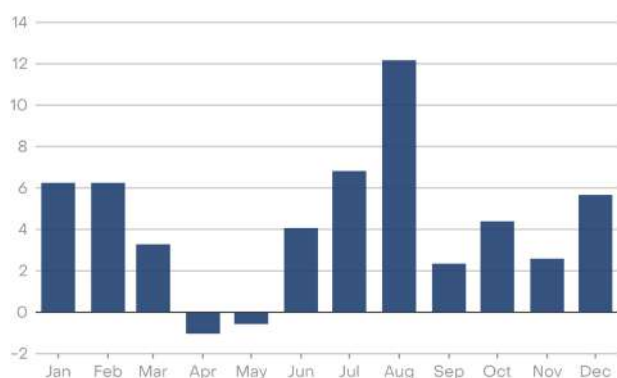
China's clean power growth has been strong, but below the rise in demand. As a result, coal generation hit an all-time high in absolute terms this year, rising by 1.5% (+81 TWh) to meet 22% of the overall demand increase. However, strong growth in clean power pushed the share of coal (61%) down by two percentage points compared to 2021. Gas generation rose by 1.3% (+3.5 TWh).

In 2022, wind and solar generation saw enormous 26% growth (+259 TWh), with China accounting for almost half of the world's additional generation from the two sources. The year-on-year rise in solar and wind power met 69% of China's net demand increase in 2022. While solar and wind grew at a similar rate, the share of wind (9.3%, 824 TWh) was still about two times higher than solar (4.7%, 418 TWh).

Nuclear generation grew 2.5% (+10 TWh), significantly below the average annual growth rate in the last decade (+16%). Hydro was up by only 1.4% (+18 TWh) amid droughts in the summer and winter, and had its lowest share in generation since 2011 (15%).

### China's monthly changes in emissions

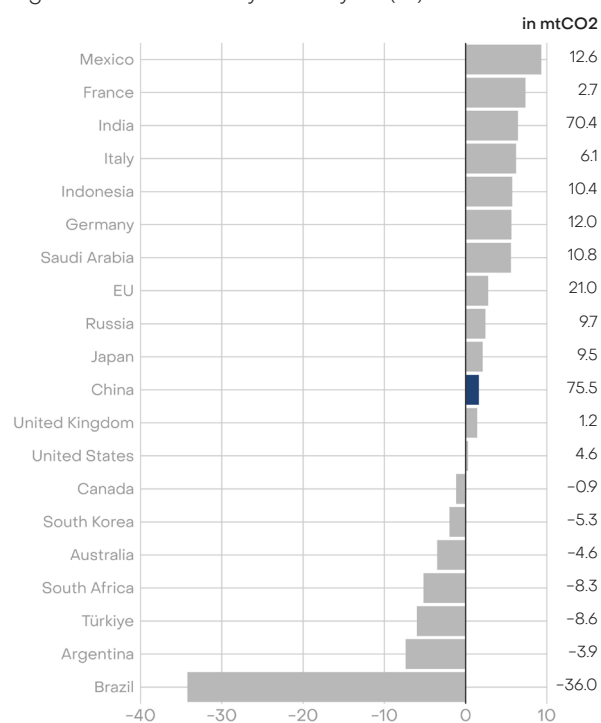
Change in CO2 emissions year-on-year (%)



Source: Ember

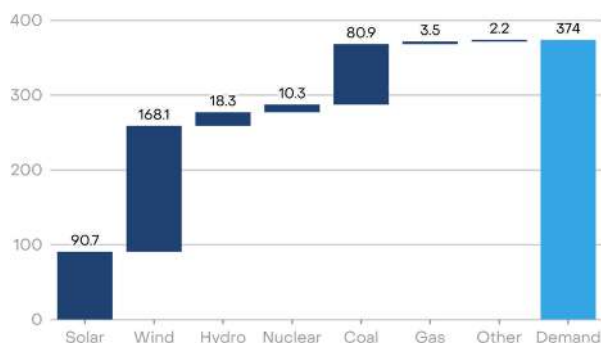
### G20 changes in power sector emissions

Change in CO2 emissions year-on-year (%)



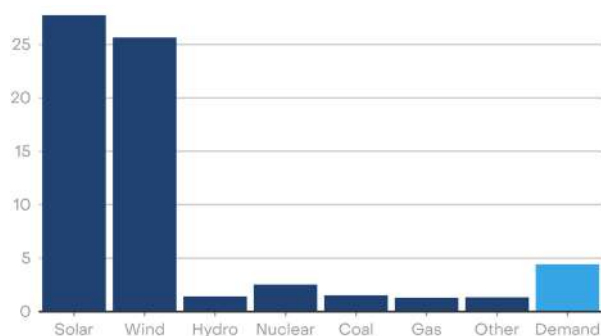
### China's change in electricity generation

Change in generation year-on-year (TWh)



### China's change in electricity generation

Change in generation year-on-year (%)



Note: 2022 data used where available, else 2021

## Long-term Trends



Over the last two decades, power demand rose sixfold in China. Total power demand in 2022 was 8,840 TWh, a huge jump from 1,347 TWh in 2000. To meet the scale of China's demand rise, coal generation has risen steadily, hitting a record high in 2022. As a result, China's total power sector emissions in 2022 were five times higher than in 2000 (+415%, +3,872 MtCO<sub>2</sub>). Global power sector emissions rose much less, increasing by 78%.

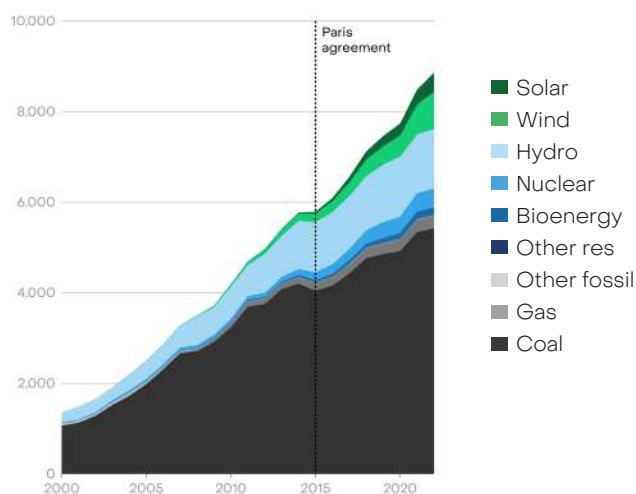
Despite this rise in power demand, the share of coal has fallen by 17 percentage points from 78% in 2000 to 61% of China's electricity in 2022. Coal's share has been steadily declining in the last two decades thanks to rapid deployment of clean power sources. In absolute terms, however, coal generation in 2022 (5,420 TWh) was five times higher than it was in 2000 (1,060 TWh).

The rate of solar and wind growth in China is staggering. In 2015, wind and solar share was 3.9%. Since then, wind and solar have seen a fivefold increase in absolute generation, accounting for nearly half of the global change in wind and solar generation and reaching 14% of China's electricity generation.

China's emissions intensity of electricity generation has declined by 21% since 2000, reaching 530 gCO<sub>2</sub>/KWh in 2022. However, China's total power sector emissions (4,694 MtCO<sub>2</sub>) increased five times since 2000 due to rising demand and increased coal generation.

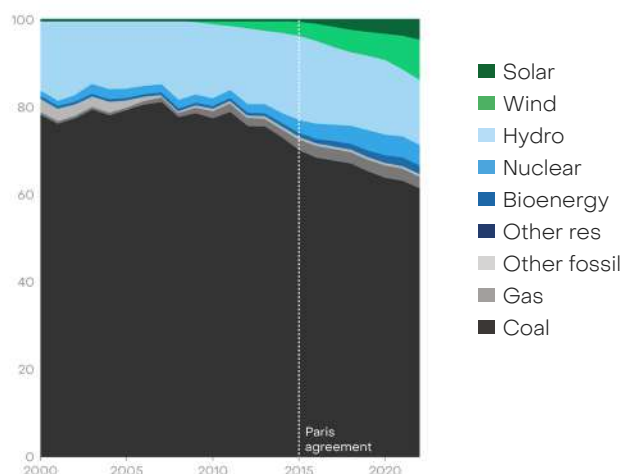
### China's electricity generation

Electricity generation (TWh)

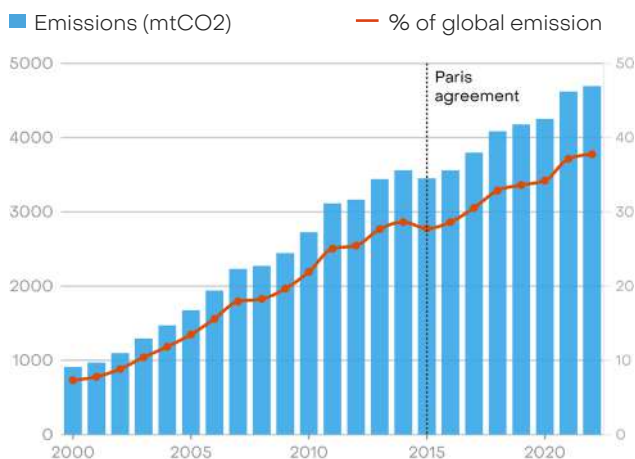


### China's electricity mix

Share of electricity (%)



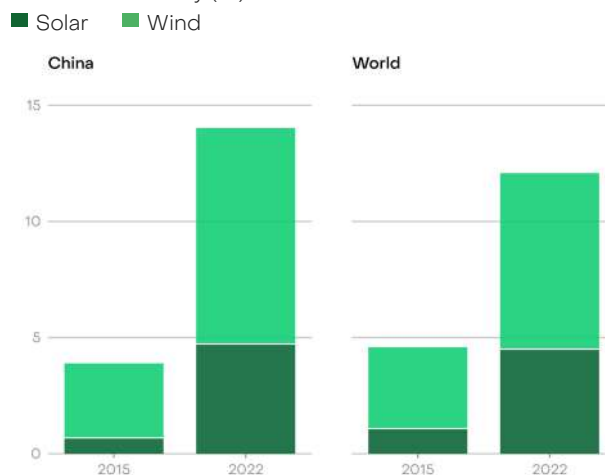
### China's power sector emissions



Source: Ember

### China vs world - wind and solar share

Share of electricity (%)



Note: 2022 data used where available, else 2021

## Progress Towards Net Zero

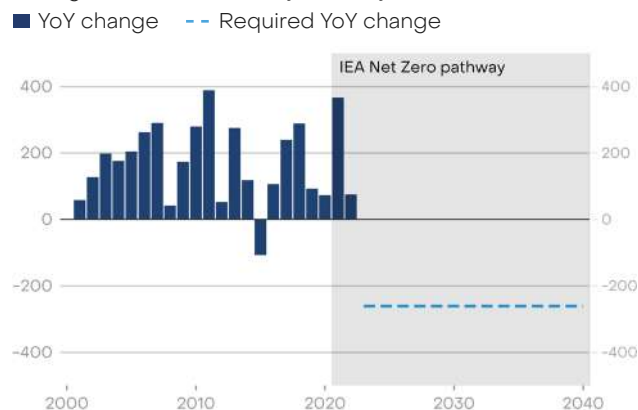


China needs to generate all its electricity from clean sources by 2040 to achieve a net zero emissions power sector, per the [IEA Net Zero Emissions scenario](#). That would mean reducing power sector emissions by 261 million tonnes of CO<sub>2</sub> every year until 2040. Since 2015, China's power sector has added an average 177 million tonnes of CO<sub>2</sub> emissions every year. Reversing this trend is a great challenge, but rapid build up of wind and solar generation has moved China closer to satisfying and exceeding new electricity demand with additional low carbon electricity rather than coal. Continuing this trend will be the key in the country's power sector and energy transition.

In September 2020, President Xi Jinping announced that China will aim to peak CO<sub>2</sub> emissions before 2030 and achieve carbon neutrality by 2060. The [IEA](#) declared that “a power sector dominated by renewables provides the foundation for China's clean energy transition.” China's [14th Five-Year Plan](#) and new [market reforms](#) seek to prioritise these efforts. Impactful policies like ‘Whole-County Rooftop Solar’ (see chapter 3) helped push solar to new levels in 2022. In the short term, there is a huge opportunity for solar to grow even faster. Major new solar manufacturing plants came online in China in 2022, [reportedly](#) increasing annual manufacturing capacity by 66%, which far exceeds the expectations for solar panel demand in 2023.

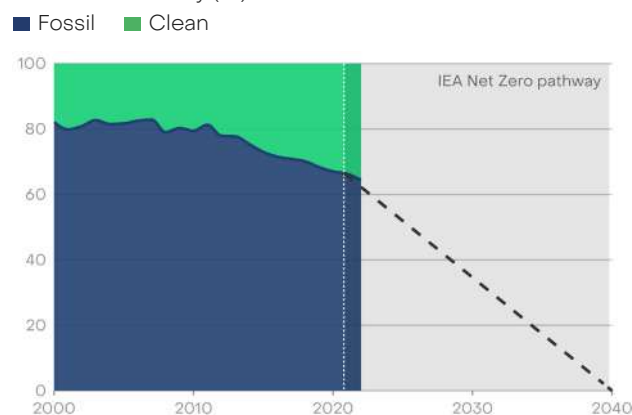
### China's power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (mtCO<sub>2</sub>)



### China's electricity mix

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# United States

## Global Electricity Trends 2022



The United States has the world's second most CO<sub>2</sub>-emitting power sector, responsible for 1,580 million tonnes of CO<sub>2</sub> in 2022, or 13% of total global emissions from electricity generation.

The US generates around 60% of its electricity from fossil fuels: 19% (828 TWh) from coal, 39% (1,695 TWh) from gas and 0.9% (40 TWh) from other fossil fuels. Wind and solar now make up 15% (644 TWh) of the electricity mix, with the rest coming from nuclear (18%, 772 TWh), hydro (5.9%, 251 TWh) and bioenergy (1.2%, 52 TWh).

The US has an emission intensity of 368 gCO<sub>2</sub>/kWh, below the global average of 436 gCO<sub>2</sub>/kWh. Annual demand per capita is 13 MWh, more than three times the world average of 3.6 MWh. Per capita power sector emissions in the US are also nearly three times the world average, with 4.7 tonnes of CO<sub>2</sub> per capita compared to 1.6 tonnes globally.

As the second largest global power sector emitter, efforts to reduce emissions through the build up of wind, solar and other clean electricity sources can have a large impact on the global effort to achieve net zero by 2050.

“The deployment of clean power is getting supercharged by the Inflation Reduction Act and Bipartisan Infrastructure Law. But the US still generates 60% of its electricity from fossil fuels, so there is a crucial need for more clean power. Coal power is already falling rapidly, and the US will soon see gas power fall rapidly. The US target for 100% clean power by 2035 is certainly within reach.”

**Dave Jones**

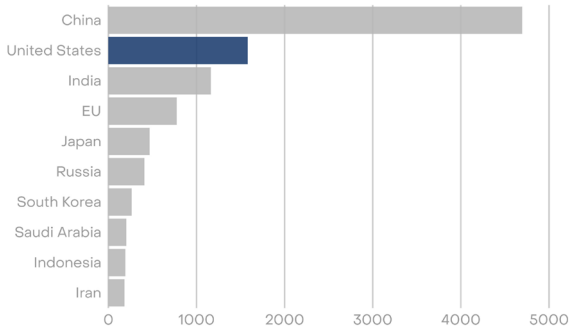
Head of Data Insights, Ember



# Global Context

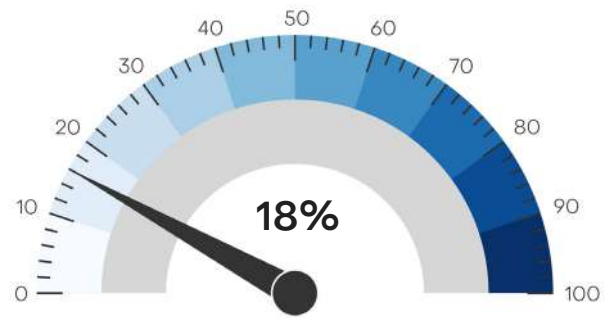
## Top 10 power sector emitters

CO2 emissions (million tonnes)



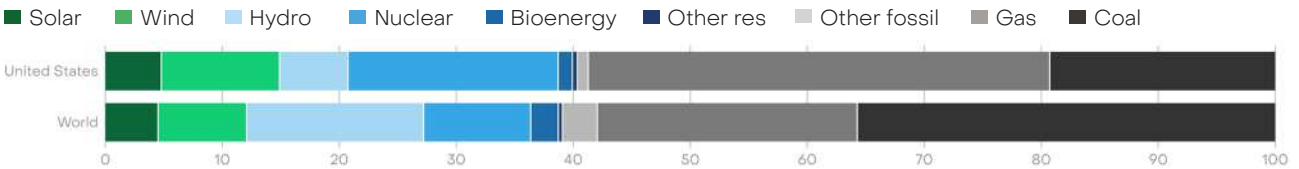
## USA's electrification

Electricity as a percentage of final energy consumption (%)



## USA vs world - electricity mix

Share of electricity (%)

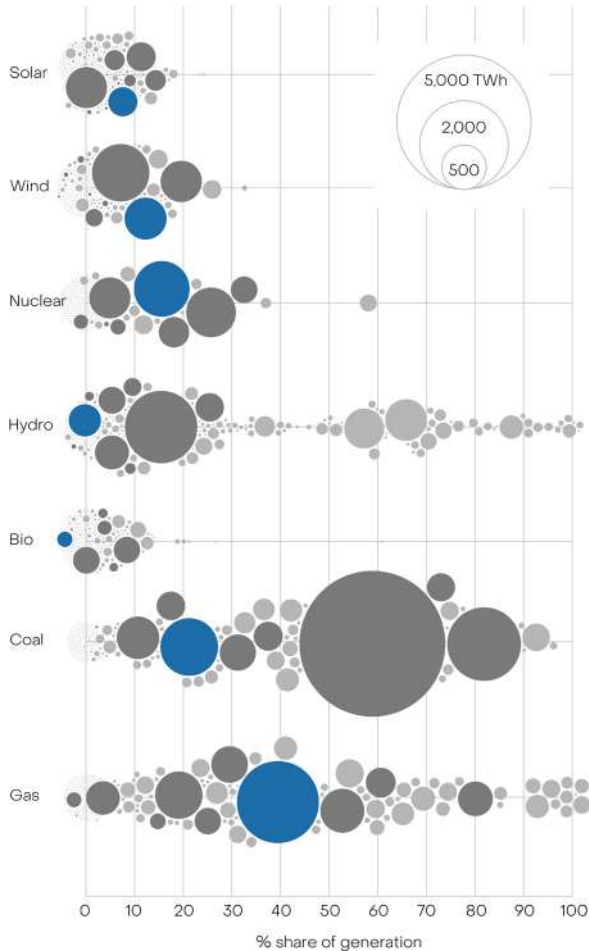


## USA vs world - sources of electricity

Share of electricity (%)

Bubble size represents electricity generation (TWh)

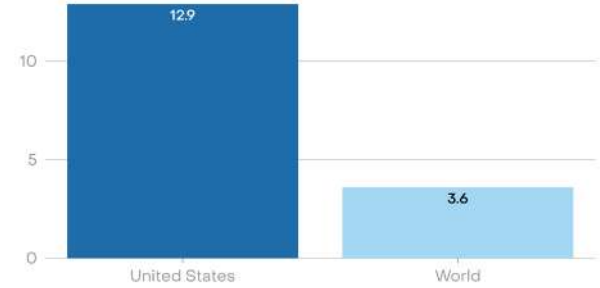
● USA ● Top 10 emitters ● Other countries



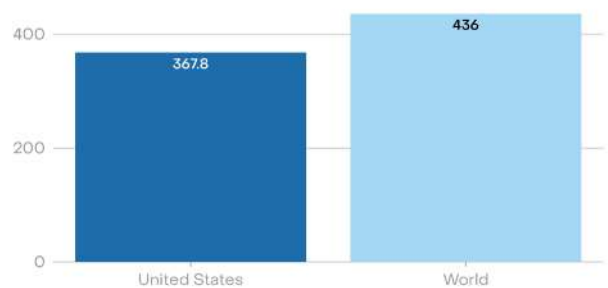
## USA vs world - emissions and demand

● USA ● World

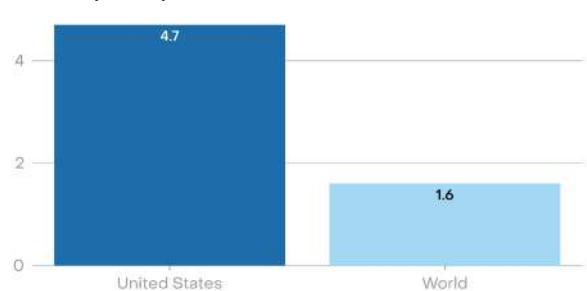
### Demand per capita (MWh)



### CO2 intensity (gCO2/kWh)



### Emissions per capita (tCO2)



Source: Ember

Note: 2022 data used where available, else 2021



## Change in 2022



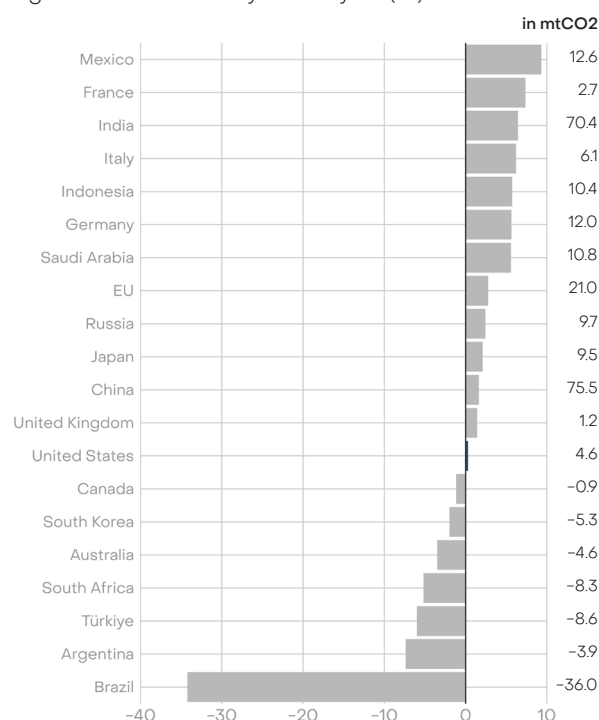
In 2022, US power sector emissions rose slightly by 0.3% (+4.6 million tonnes of CO<sub>2</sub>), below the global rise of 1.3%.

US electricity demand increased by 3.4% in 2022 (+144 TWh). This was higher than the global demand change of 2.5%, and significantly higher than the US average demand growth rate of 0.4% for 2010–2021. The rise was in part due to air conditioning during extensive summer heatwaves.

Gas generation saw the largest absolute increase, rising 115 TWh (+7.3%). This replaced some coal, which fell by 70 TWh (-7.8%). Wind generation grew by 15% (+56 TWh) and solar grew by 25% (+41 TWh), together meeting 68% of the increase in demand. Other electricity generation sources saw smaller changes: nuclear fell by 0.9% (-6.6 TWh), hydro rose by 1.9% (+4.6 TWh), while bioenergy, other fossil generation and other renewables remained largely stable. Wind and solar's shares increased slightly to 10.1% and 4.8% respectively. The share of gas also rose slightly to 39.5%. Coal had the largest change in share, falling 2.3 percentage points to generate 19.3% of electricity. Nuclear fell to 18%. The share of hydro and bioenergy remained stable.

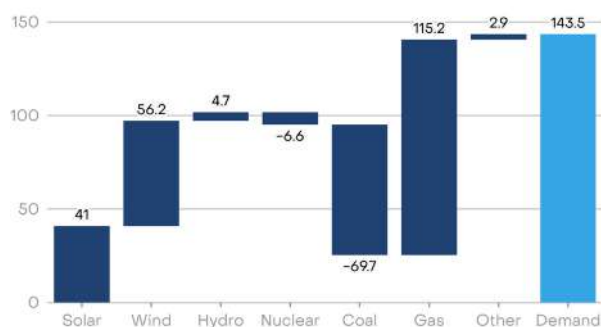
### G20 changes in power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (%)



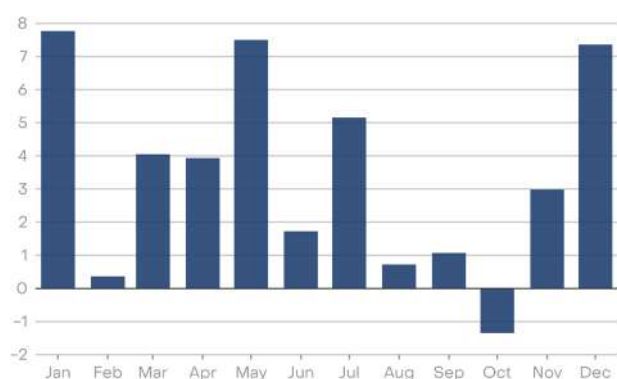
### USA's change in electricity generation

Change in generation year-on-year (TWh)



### USA's monthly changes in emissions

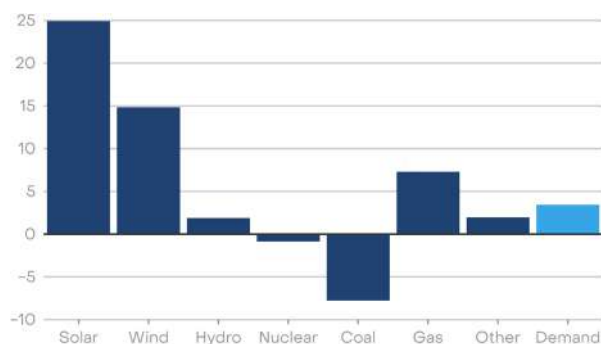
Change in CO<sub>2</sub> emissions year-on-year (%)



Source: Ember

### USA's change in electricity generation

Change in generation year-on-year (%)



Note: 2022 data used where available, else 2021

# Long-term Trends

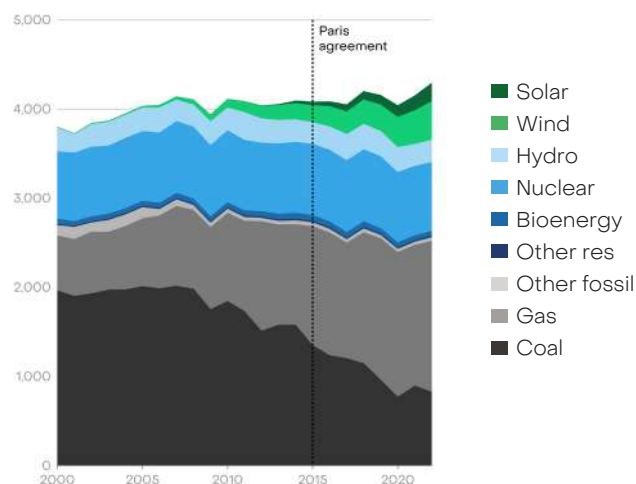
US electricity demand has grown by 13% (499 TWh) in the last two decades, from 3,836 TWh in 2000 to 4,335 TWh in 2022. Emissions intensity in 2022 (368 gCO<sub>2</sub>/kWh) was significantly below 2000 levels (533 gCO<sub>2</sub>/kWh), in part due to the recent build up of wind and solar as coal generation fell. Because of the cleaner grid, total annual power sector emissions decreased by 22% (-445 million tonnes of CO<sub>2</sub>) over the same period despite the increased demand.

Since the Paris Agreement in 2015, US power sector emissions have fallen by 14% (-248 million tonnes of CO<sub>2</sub>). Increased demand since 2015 has primarily been met by gas generation, which rose by 27% (+361 TWh). Gas generation also replaced some retiring coal plants. At the same time, wind grew by 128% (+244 TWh) and solar grew an astonishing 426% (+166 TWh), preventing an even larger rise of fossil generation.

The US transition to wind and solar is happening faster than the global average. Wind and solar now account for 15% of electricity production, up from just 5.6% in 2015. Globally, the share of wind and solar increased from 4.6% to 12.1% in the same period.

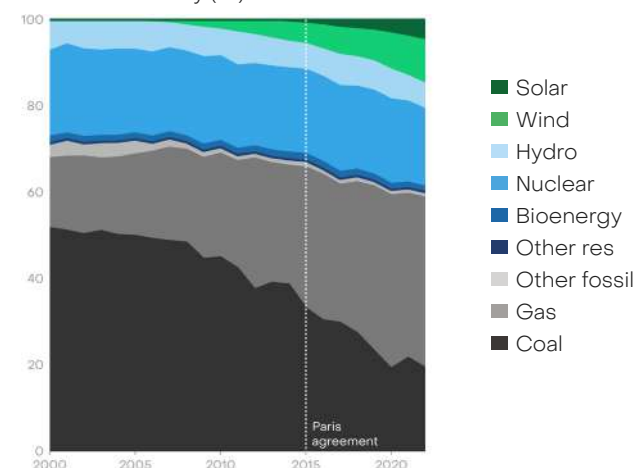
## USA's electricity generation

Electricity generation (TWh)

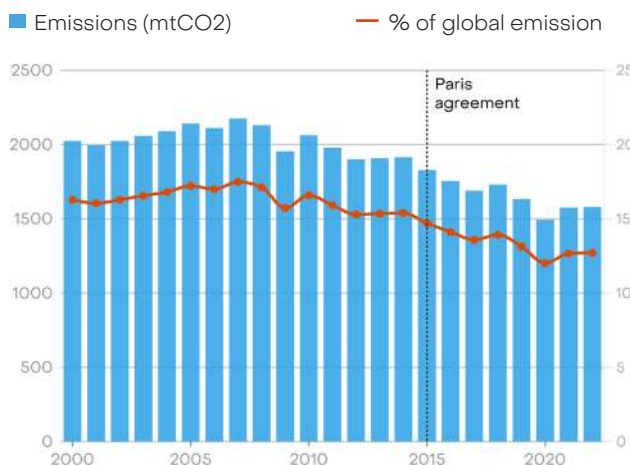


## USA's electricity mix

Share of electricity (%)



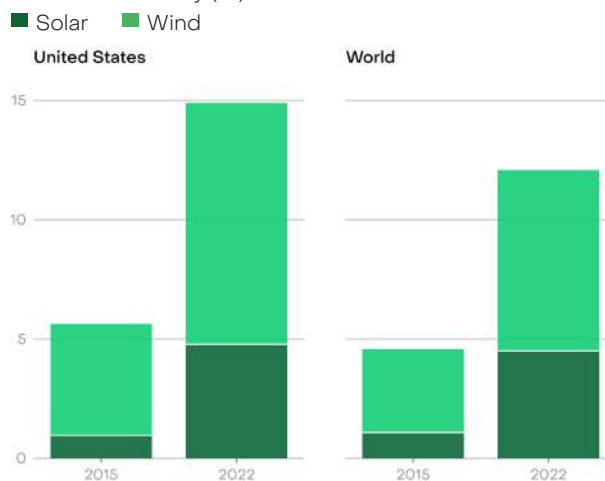
## USA's power sector emissions



Source: Ember

## USA vs world - wind and solar share

Share of electricity (%)



Note: 2022 data used where available, else 2021





## Progress Towards Net Zero

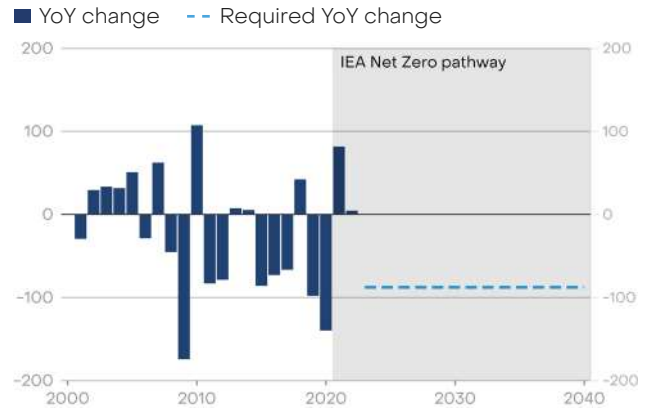


US power sector emissions need to fall to zero by 2035 from the current 1,580 million tonnes of CO<sub>2</sub> to align with the [IEA Net Zero Emissions scenario](#). To achieve this, emissions will need to fall by 122 million tonnes per year, more than three times as fast as the average decrease of 35 million tonnes annually since 2015.

The commitment by the United States to achieve '100 percent carbon pollution-free' electricity by 2035 should move it towards that trajectory. The Inflation Reduction Act (IRA) of 2022 provides the stimulus to make that commitment a reality. It represents the single largest investment in climate and energy in American history, [according to the US Department of Energy](#). In a report published this year, Evergreen Action and NRDC (Natural Resources Defense Council) presented [new modelling](#) that details how setting ambitious carbon pollution standards for new and existing power plants under the Clean Air Act would be a crucial next step.

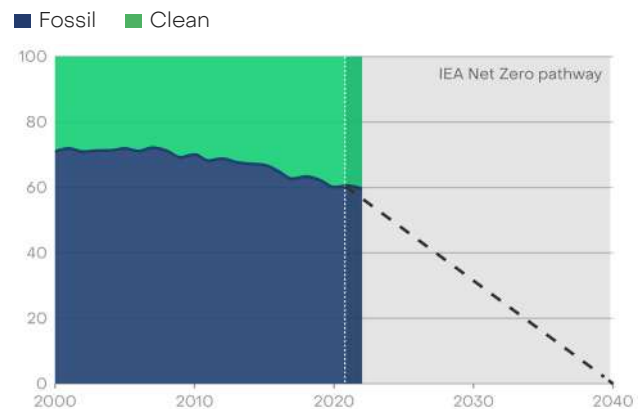
### USA's power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (mtCO<sub>2</sub>)



### USA's electricity mix

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# India

## Global Electricity Trends 2022



India had the third largest power sector emissions in the world in 2022, behind China and the United States. In 2022, India produced 1,162 million tonnes of CO<sub>2</sub>, accounting for 9.4% of the world's total power sector emissions. India's per capita emissions, however, are half the global average (0.8 tCO<sub>2</sub> vs. 1.6 tCO<sub>2</sub>).

India's emissions are driven by high reliance on fossil fuels and a large population. The country has a low power demand per capita of 1.3 MWh, one third that of the global average (3.6 MWh). India's electricity generation, however, is 45% more carbon intensive (632 gCO<sub>2</sub>/kWh) than the global average (436 gCO<sub>2</sub> per kWh).

In 2022, India generated 77% (1,415 TWh) of its electricity from fossil fuels. Coal had the largest share at 74% (1,363 TWh), followed by gas (2.7%, 50 TWh), and other fossil (0.1%, 2.4 TWh). The share of wind and solar reached a record high of 9% (165 TWh), although still three percentage points behind the global average. Hydro generated 9.5% (175 TWh) of electricity, while nuclear and bioenergy accounted for 2.5% and 2%, respectively.

In 2022, India surpassed China to [become the world's most populous nation](#). As growth continues amid rapid economic development, so too will India's need for electricity. Meeting that with clean electricity would mean growing clean sources quickly and at a vast scale. Electricity provided 17% of India's final energy consumption in 2021, which is expected to increase as the electrification of sectors like transport, heating and industry accelerates.

“India's clean electricity transition journey has now reached a critical juncture. The country needs to build upon its recent solar power surge. It needs to ramp up renewable generation capacity to meet its growing demand, build enough storage capacity to meet peak demand and develop infrastructure to facilitate grid integration. These are all big challenges but they need to be addressed for India to achieve its 500GW non-fossil capacity by 2030 and ensure its coal-fired generation is closer to peaking.”

**Aditya Lolla**

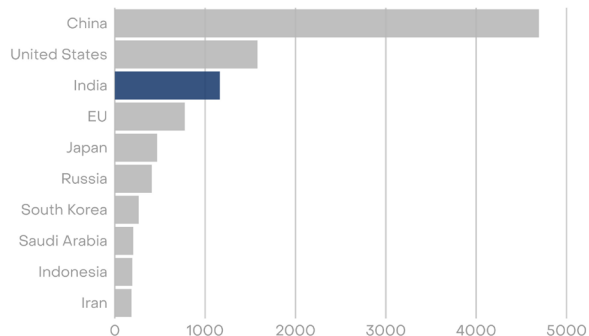
Senior Electricity Policy Analyst, Ember



# Global Context

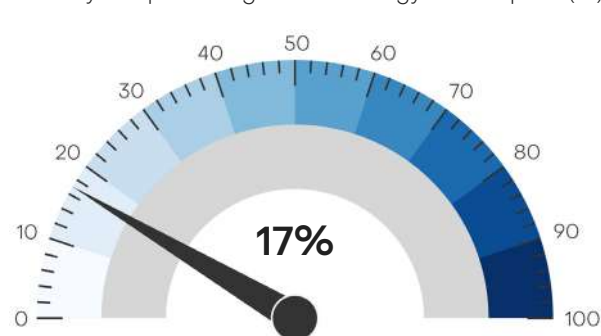
## Top 10 power sector emitters

CO2 emissions (million tonnes)



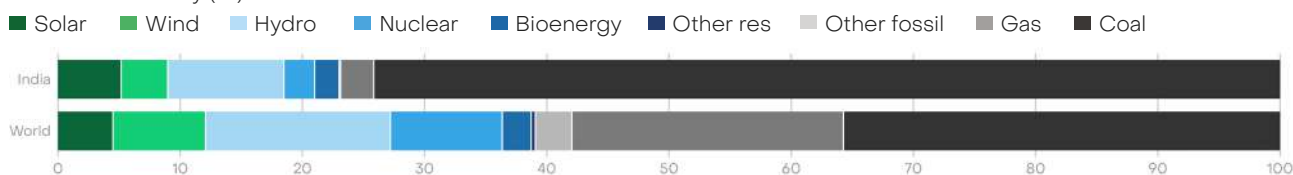
## India's electrification

Electricity as a percentage of final energy consumption (%)



## India vs world - electricity mix

Share of electricity (%)

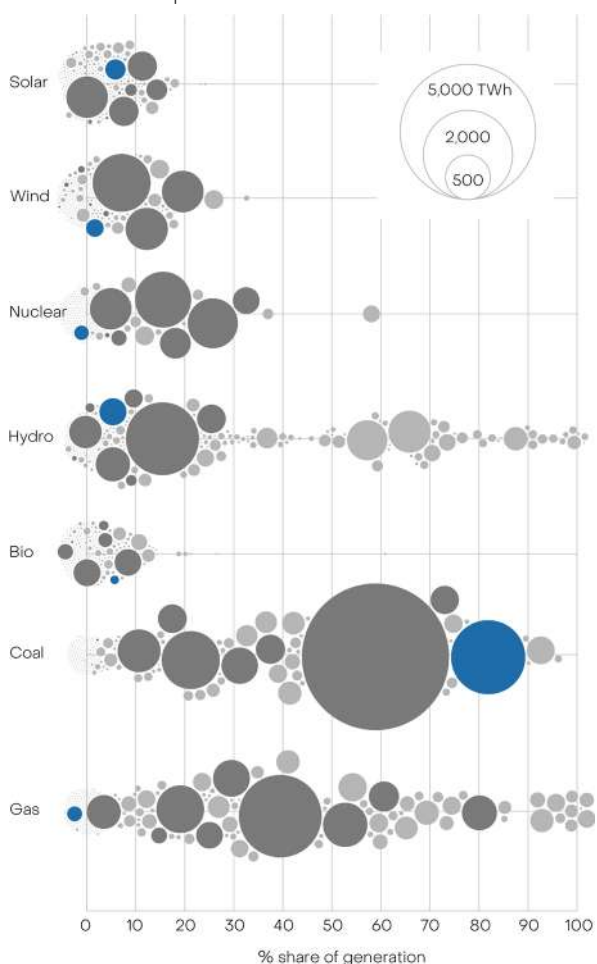


## India vs world - sources of electricity

Share of electricity (%)

Bubble size represents electricity generation (TWh)

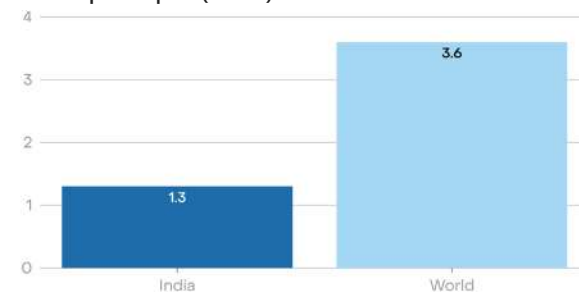
● India ● Top 10 emitters ● Other countries



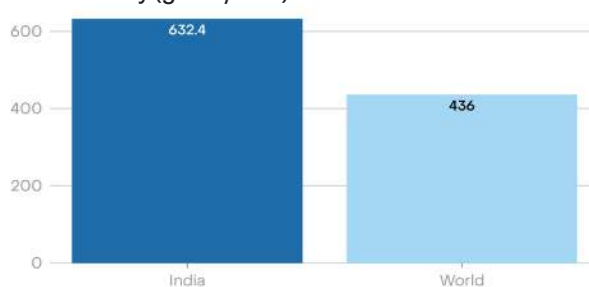
## India vs world - emissions and demand

● India ● World

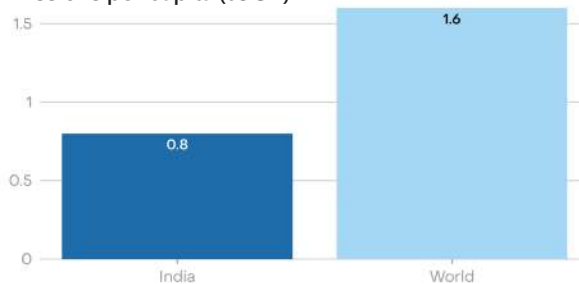
### Demand per capita (MWh)



### CO2 intensity (gCO2/kWh)



### Emissions per capita (tCO2)



Source: Ember

Note: 2022 data used where available, else 2021

# Change in 2022

In 2022, India's power sector emissions rose by 6.4% (+70 million tonnes of CO<sub>2</sub>) compared to 2021. India's year-on-year change in power sector emissions was much higher than its peer countries in the G20, including China (+1.6%). The emissions increase can be attributed to a number of factors, including a rise in electricity demand, and a large increase in coal generation.

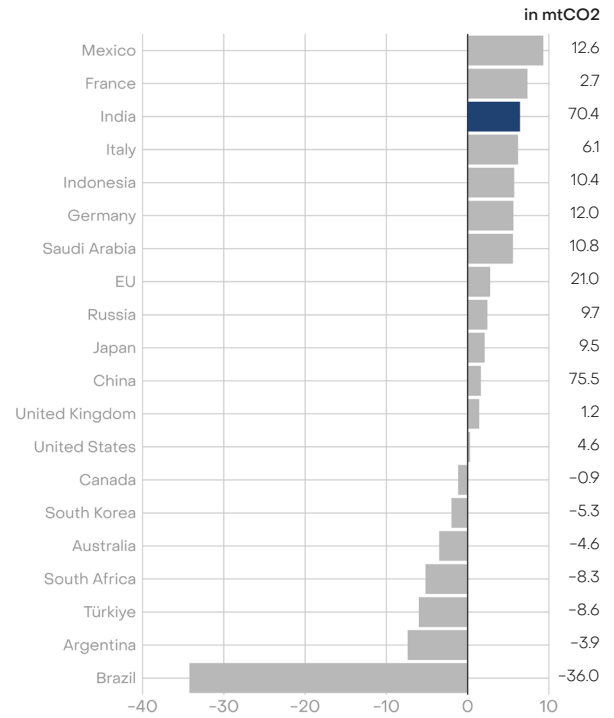
Up by 7.2%, (+124 TWh), India's power demand increase outpaced its average annual demand growth rate in the last decade (+5.7%) amid an economic rebound from the Covid-19 pandemic. This was also three times the global increase of 2.5%.

Coal generation saw the largest absolute increase among generation sources, rising by 7.2% (+92 TWh), which met 74% of the country's demand increase. The share of coal in India's power remained at 74%, showing no change since 2021. On the other hand, gas generation dropped by 22% (-14 TWh), reducing the share of gas to its lowest level in the last two decades.

While solar generation showed a remarkable increase of 39% (+27 TWh), growth in wind power was weaker at 2.9% (+2 TWh). Rise in wind and solar generation was only enough to meet a quarter of the increase in demand. Other clean sources showed a moderate increase, including hydro (+8.9%, +14 TWh), nuclear (+5.4%, 2.4 TWh) and bioenergy (+2.9%, +1 TWh).

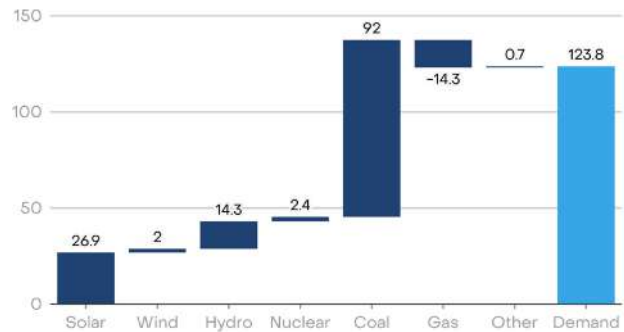
## G20 changes in power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (%)



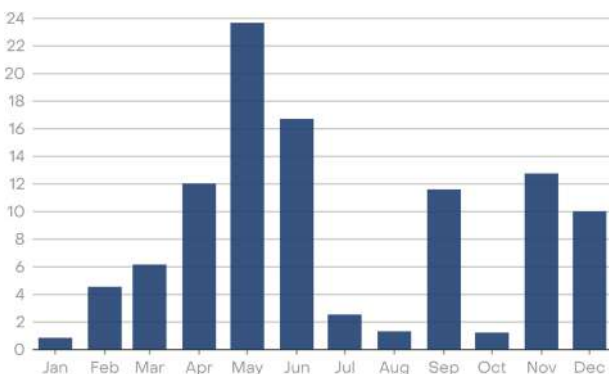
## India's change in electricity generation

Change in generation year-on-year (TWh)



## India's monthly changes in emissions

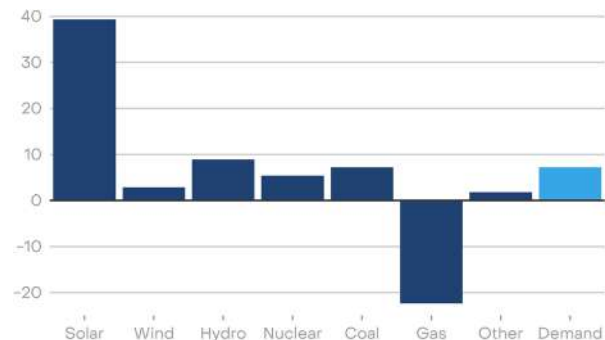
Change in CO<sub>2</sub> emissions year-on-year (%)



Source: Ember

## India's change in electricity generation

Change in generation year-on-year (%)



Note: 2022 data used where available, else 2021

# Long-term Trends



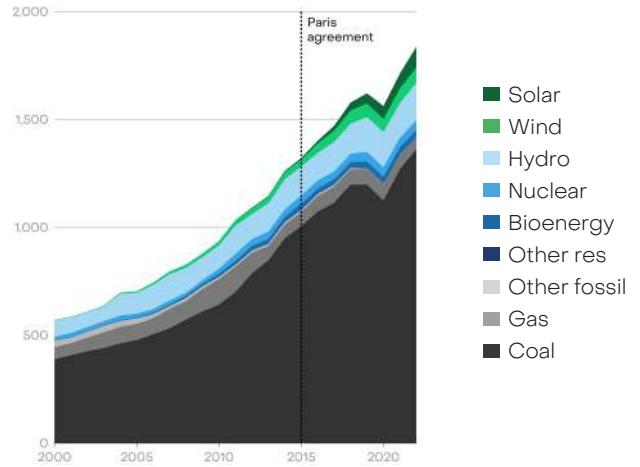
To fuel rapid economic growth, India's demand has more than tripled in the last two decades, from just 573 TWh in 2000 to 1,836 TWh in 2022. To meet this rising demand, coal generation jumped to 1,363 TWh, three and a half times higher than it was in 2000. As a result, India's power sector emissions increased 214% in comparison to 2000 (+792 MtCO<sub>2</sub>).

However, thanks to solar and wind deployment in the last decade, India's power sector emissions intensity fell slightly to 632 gCO<sub>2</sub>/kWh, below the level in 2000 (648 gCO<sub>2</sub>/kWh).

Wind and solar, as well as other low carbon sources are not yet growing fast enough to meet rapidly growing electricity demand, leading to continuously rising power sector emissions. Renewables are, however, rapidly increasing. In 2000, wind and solar accounted for only 0.3% of India's power generation, jumping to 9% in 2022. The growth in wind and solar power has been particularly high since the Paris Agreement in 2015, gaining six percentage points in share through to 2022.

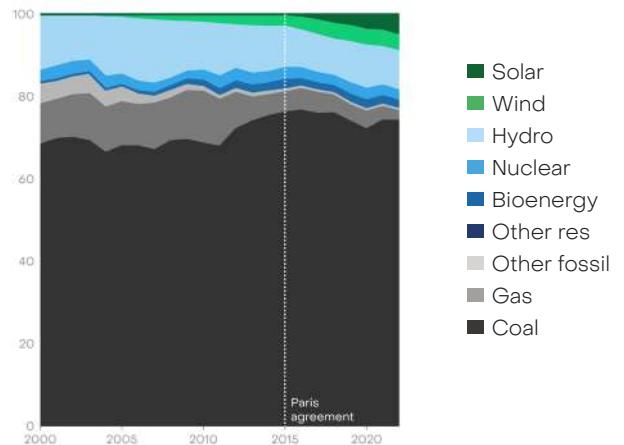
## India's electricity generation

Electricity generation (TWh)



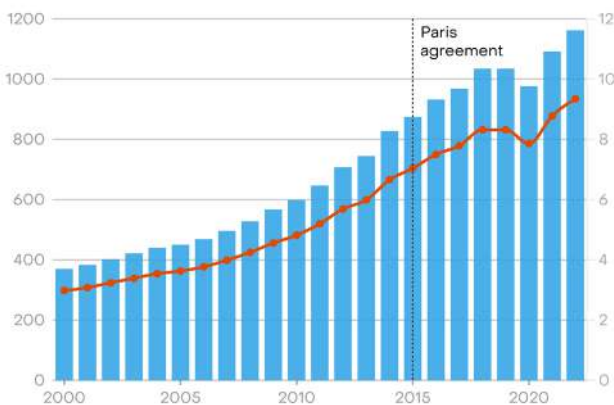
## India's electricity mix

Share of electricity (%)



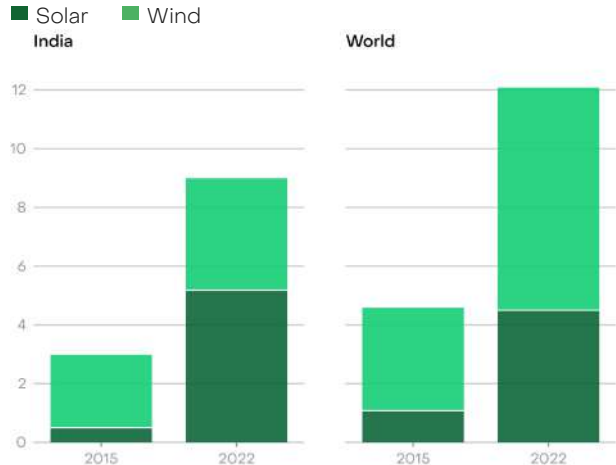
## India's power sector emissions

■ Emissions (mtCO<sub>2</sub>)      — % of global emission



## India vs world - wind and solar share

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

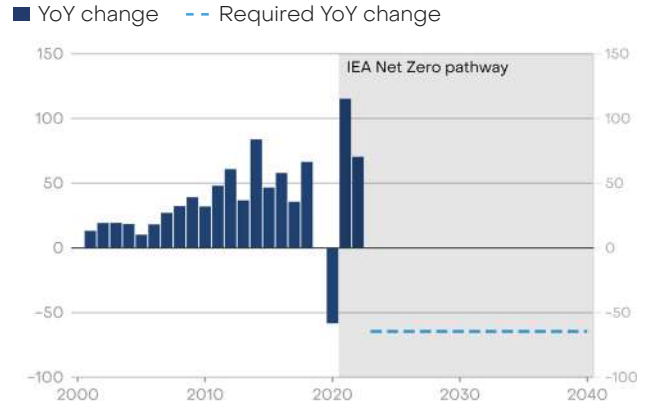
# Progress Towards Net Zero

To align with the [IEA Net Zero Emissions scenario](#) and reach a fully decarbonised power sector by 2040, India must reduce its power sector emissions by 65 million tonnes of CO<sub>2</sub> on average every year. Power sector emissions have been rising by 41 million tonnes of CO<sub>2</sub> annually since 2015. It is expected that India's emissions will continue to rise in the near-term, driven by rapid demand growth, but accelerating renewables deployment will eventually lead to emissions peaking and then declining.

At the COP26 held in Glasgow in 2021, India displayed its climate stewardship with its 'Panchamrit' commitments, targeting 500 gigawatts of non-fossil electricity capacity by 2030. Achieving these targets will, however, require tackling much stiffer challenges at the national and sub-national levels. According to a [recent analysis](#) by Ember and IEEFA, states like Karnataka and Gujarat made the most progress towards clean electricity transition, while others need to ramp up efforts to maximise their renewable energy generation potential.

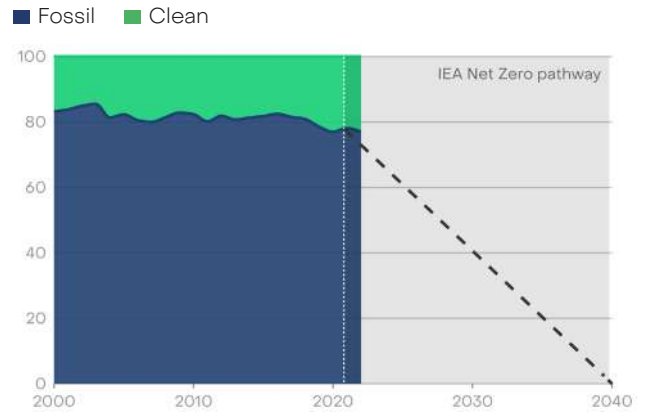
## India's power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (mtCO<sub>2</sub>)



## India's electricity mix

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# European Union

## Global Electricity Trends 2022



Combined, the EU has the world's fourth most CO<sub>2</sub>-emitting power sector, responsible for 775 million tonnes of CO<sub>2</sub> in 2022, which is 6.2% of the world's total power sector emissions.

The EU generates 39% (1,102 TWh) of its electricity from fossil fuels; 16% from coal (446 TWh), 20% from gas (556 TWh) and 3.6% from other fossil fuels (99 TWh). Wind and solar now make up 22% (624 TWh) of the electricity mix, with the rest coming from nuclear (22%, 613 TWh), hydro (10%, 282 TWh) and bioenergy (6%, 167 TWh).

Power generation in the EU has an emissions intensity of 277 gCO<sub>2</sub>/kWh, lower than the global average of 436 gCO<sub>2</sub>/kWh. However, the EU's annual demand per capita of 6.3 MWh is higher than the world average of 3.6 MWh. At 1.7 tonnes of CO<sub>2</sub>, the EU's per capita emissions from the power sector are just above the global average of 1.6 tonnes.

The EU is a critical region in the global transition to clean power. As the fourth largest power sector emitter, efforts to reduce emissions through the build up of wind, solar and other clean electricity sources will have a large impact on the global effort to achieve net zero by 2050.

“The EU started the race to renewables early but, as the world accelerates, it cannot afford complacency. In particular, the barriers preventing the rapid deployment of onshore wind power must be removed. Europe had an extremely challenging year in 2022 but should now seize the opportunity to double-down on renewables deployment and remain at the forefront of the global transition to a clean and prosperous economy. Europe must lead by example. It has a crucial role to play in supporting emerging economies to build clean power fast enough to outpace rapid demand growth, thus ensuring power sector emissions have peaked.”

**Sarah Brown**

Europe Programme Lead, Ember

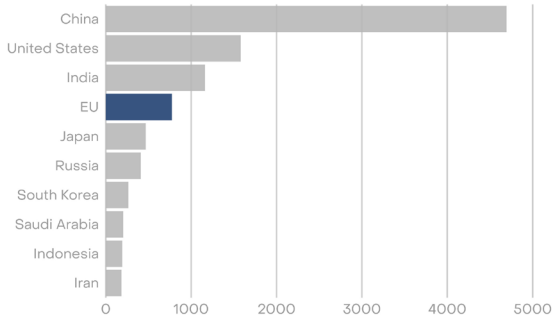




**Global Context**

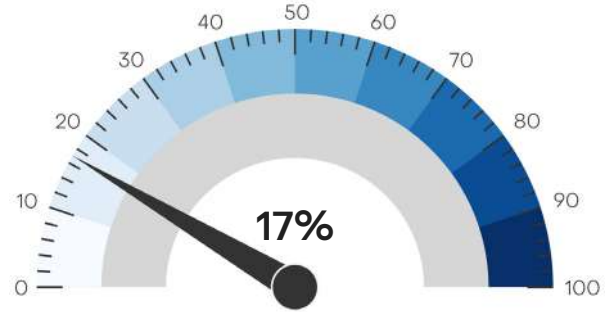
**Top 10 power sector emitters**

CO2 emissions (million tonnes)



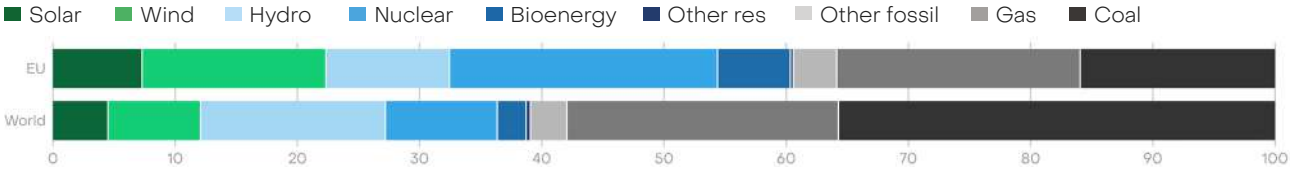
**EU's electrification**

Electricity as a percentage of final energy consumption (%)



**EU vs world - electricity mix**

Share of electricity (%)

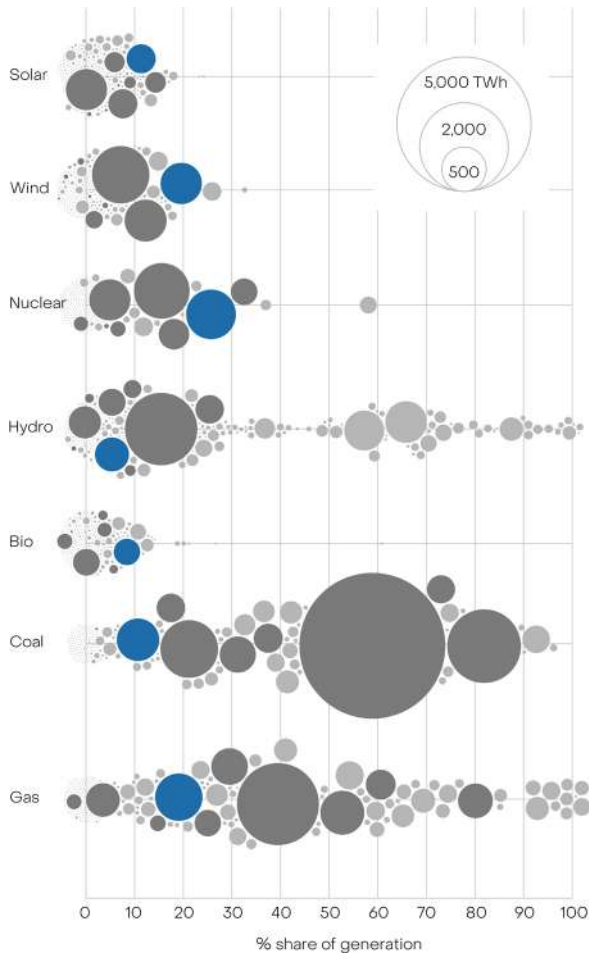


**EU vs world - sources of electricity**

Share of electricity (%)

Bubble size represents electricity generation (TWh)

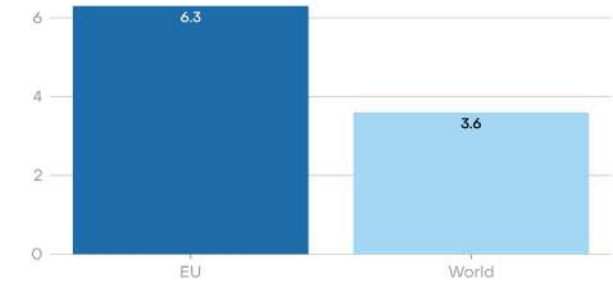
● EU ● Top 10 emitters ● Other countries



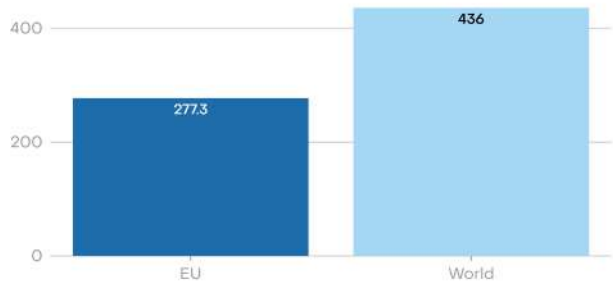
**EU vs world - emissions and demand**

● EU ● World

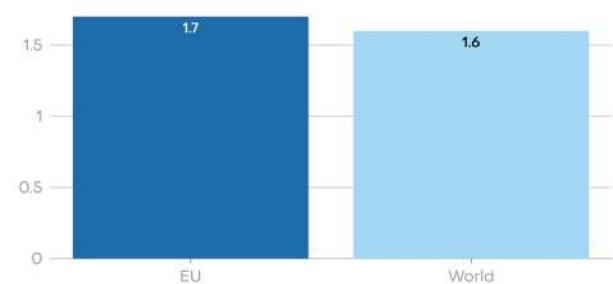
**Demand per capita (MWh)**



**CO2 intensity (gCO2/kWh)**



**Emissions per capita (tCO2)**



Source: Ember

Note: 2022 data used where available, else 2021



# Change in 2022

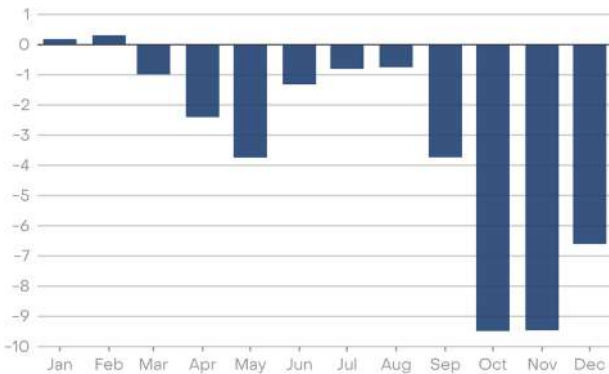
In 2022, EU power sector emissions rose by 2.8% (+21 MtCO<sub>2</sub>) compared to 2021. This is higher than the 1.3% increase in global power sector emissions, and resulted from a historic fall in nuclear and hydro power that was in part replaced by coal and gas, leading to an increase in emissions intensity from 262 to 277 gCO<sub>2</sub>/kWh.

Since 2010, EU demand has declined by an average of 0.5% per year, but in 2022, demand fell 3% (-85 TWh) even as it increased by 2.5% globally. This was due to mild weather, alongside demand reduction measures driven in part by high electricity prices.

Hydro power dropped by 19% (-66 TWh) due to hot weather and droughts. At the same time, nuclear generation fell by 16% (-119 TWh) with maintenance and outages of French nuclear causing the largest reductions, along with plant closures in Germany. Wind and solar increased by 8.8% (+34 TWh) and 24% (+40 TWh) respectively, with [record generation](#) in a number of EU countries. Combined, wind and solar met 40% (74 TWh) of the 185 TWh shortfall in hydro and nuclear generation. Coal generation increased by 6.4% (+27 TWh), meeting 15% of the hydro and nuclear shortfall. The rest was made up by a fall in electricity demand. Coal's share in the electricity mix increased by 1.4 percentage points to 16%, but remained at pre-pandemic levels. Gas generation also increased by 0.8% (+4.6 TWh), and its share increased to 19.9% (+0.8 percentage points).

## EU's monthly changes in emissions

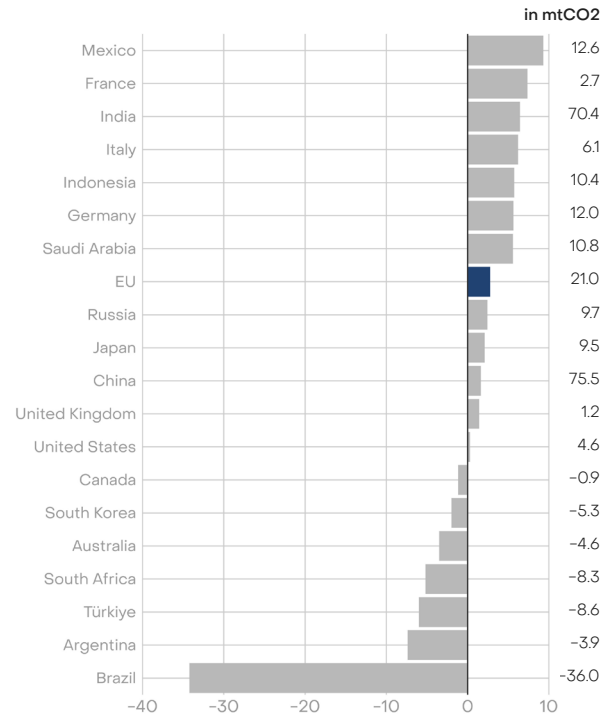
Change in CO<sub>2</sub> emissions year-on-year (%)



Source: Ember

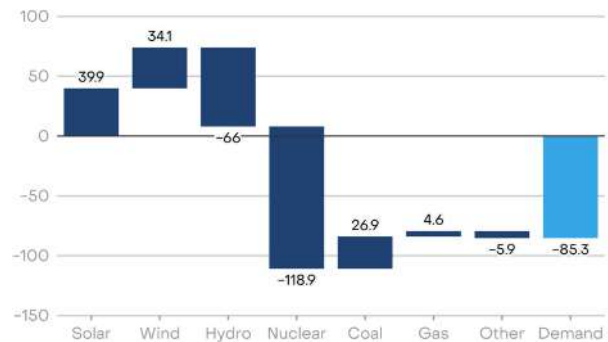
## G20 changes in power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (%)



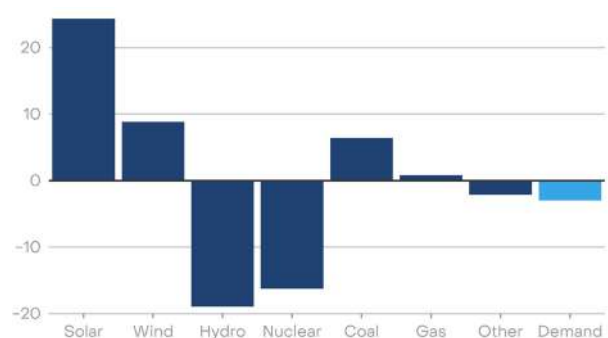
## EU's change in electricity generation

Change in generation year-on-year (TWh)



## EU's change in electricity generation

Change in generation year-on-year (%)



Note: 2022 data used where available, else 2021

# Long-term Trends



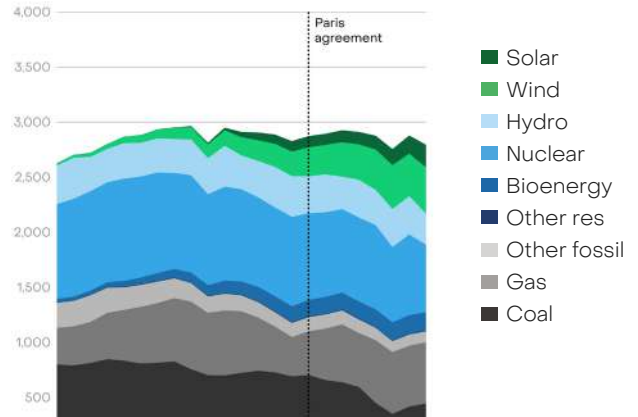
The EU's demand has grown by just over 6% in the last two decades, from 2,628 TWh in 2000 to 2,794 TWh in 2022. At the same time, the region's emissions intensity in 2022 (277g CO<sub>2</sub> per kWh) was significantly lower than in 2000 (383g CO<sub>2</sub> per kWh). This is due to the acceleration of wind and solar deployment since 2010, and despite the decline in nuclear generation since 2000. Emissions fell by 23% (-230 million tonnes of CO<sub>2</sub>) over the same period.

Since the Paris Agreement in 2015, EU emissions have decreased by 16% (-147 MtCO<sub>2</sub>). Declines in nuclear and coal have primarily been replaced by gas, which rose by 40% (+160 TWh), but the future is uncertain for gas consumption following Russia's invasion of Ukraine and the record high price volatility. An increase in wind and solar generation of more than 71% (260 TWh) from 2015 to 2022 prevented a larger rise in fossil generation.

The EU's transition to wind and solar is happening faster than the global average. Wind and solar now account for 22% of electricity production, up from just 13% in 2015. Globally, the share of wind and solar increased from 4.6% to 12.1% in the same period.

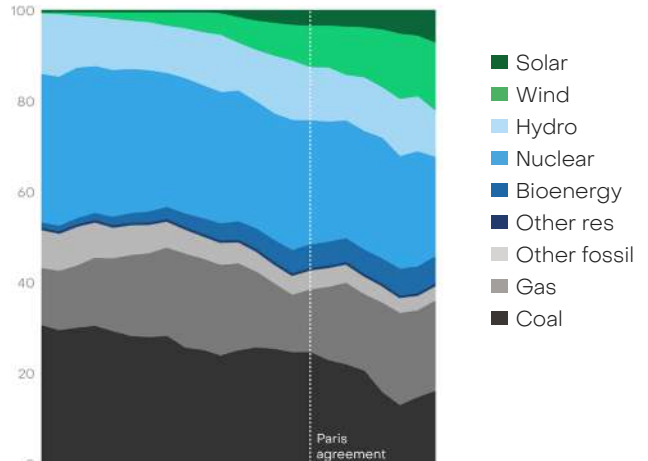
## EU's electricity generation

Electricity generation (TWh)



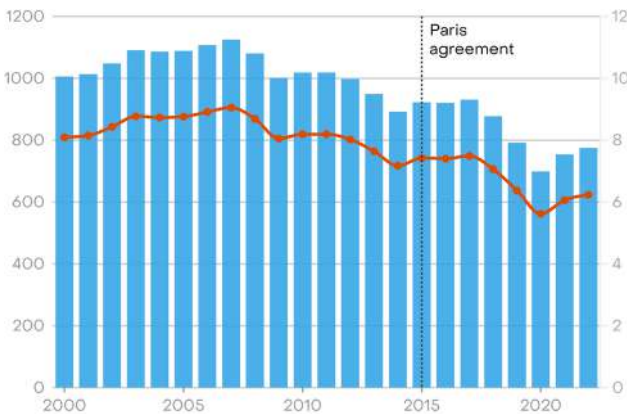
## EU's electricity mix

Share of electricity (%)



## EU's power sector emissions

■ Emissions (mtCO<sub>2</sub>)      — % of global emission

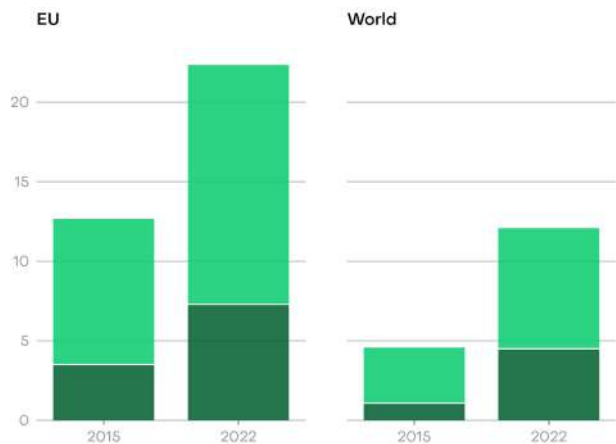


Source: Ember

## EU vs world - wind and solar share

Share of electricity (%)

■ Solar      ■ Wind



Note: 2022 data used where available, else 2021

# Progress Towards Net Zero



The EU needs to achieve a net zero emissions power sector by 2035 as set out by the [IEA Net Zero Emissions scenario](#). [Modelling by Ember](#) reveals that the least-cost pathway would see the EU generate 70–80% of electricity from wind and solar, and less than 5% from unabated gas power.

In the seven years since the Paris Agreement in 2015, emissions have decreased by an average of 20 million tonnes annually. To meet the net zero target, emissions need to fall almost three times as fast from the current 780 million tCO<sub>2</sub>e, at 60 million tonnes per year.

Since the presentation of the [Fit-for-55 package](#) in July 2021, a new energy reality has unfolded across Europe. The EU's response to the energy crisis, fuelled by the Russian invasion of Ukraine, has turbocharged the green transition with deployment of key clean technologies taking off at previously unprecedented levels. The European Commission's REPowerEU plan proposed [raising](#) the bloc's 2030 renewable energy target from 40% to 45%, a move overwhelmingly supported by the European Parliament.

Nations have [accelerated](#) the transition to clean power, putting the EU as a region on track for 63% renewable electricity by 2030. Some EU countries are targeting [more than 80% renewable electricity by 2030](#), including Germany and the Netherlands. Ember estimates that 2023 is set for a [record decline](#) in fossil fuels. By 2030, according to national plans, [just 17%](#) of EU electricity will come from fossil fuels and the majority of the region will have phased out coal. The EU power sector is therefore in a good position to achieve a trajectory aligned with 1.5C.

## EU's power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (mtCO<sub>2</sub>)



## EU's electricity mix

Share of electricity (%)

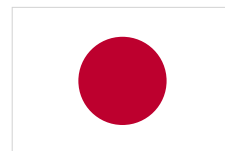


Source: Ember

Note: 2022 data used where available, else 2021

# Japan

## Global Electricity Trends 2022



Japan has the fifth largest power sector CO<sub>2</sub> emissions, responsible for 468 million tonnes of CO<sub>2</sub> in 2022. Japan accounts for 3.8% of the total global emissions from electricity generation. In 2022, Japan generated 71% of its electricity from fossil fuels: 33% (321 TWh) from coal, 34% (329 TWh) from gas and 3.8% (37 TWh) from other fossil fuels.

However, clean power development is also progressing. Solar accounted for 10% of Japan's total generation in 2022 (99 TWh). Wind accounted for only 0.9% (8.6 TWh). The rest came from hydro (7.6%, 74 TWh), nuclear (5.4%, 52 TWh), bioenergy (4.6%, 44 TWh) and other renewables (0.3%, 2.9 TWh).

Japan's power sector has an emissions intensity of 484 gCO<sub>2</sub>/kWh, which is slightly higher than the global average of 436 gCO<sub>2</sub>/kWh. Its annual demand per capita of 7.8 MWh is twice as high as the world average of 3.6 MWh. At 3.8 tonnes of CO<sub>2</sub>, Japan's per capita emissions from the power sector are over twice as high as the global average of 1.6 tonnes of CO<sub>2</sub>.

As the fifth largest power sector emitter, Japan plays an important part in the global energy transition. While Japan's reliance on fossil fuels remains high at 71%, solar generation is growing quickly, and the country has recently [committed to reopening nuclear plants](#). Wind power remains underdeveloped, with more efforts needed to decarbonise Japan's power sector.

“As Japan assumes the G7 Presidency this year, it faces quite a challenge on its hands with over two-thirds of its electricity still coming from fossil fuels. This is the highest of any G7 country, at a time when the G7 has made a commitment to a ‘fully or predominantly’ decarbonised power sector by 2035. The G7 will want to push harder on this in Hiroshima in May. Japan has an opportunity to scale up offshore wind to help deliver a true commitment towards clean power by 2035.”

**Małgorzata Wiatros-Motyka**

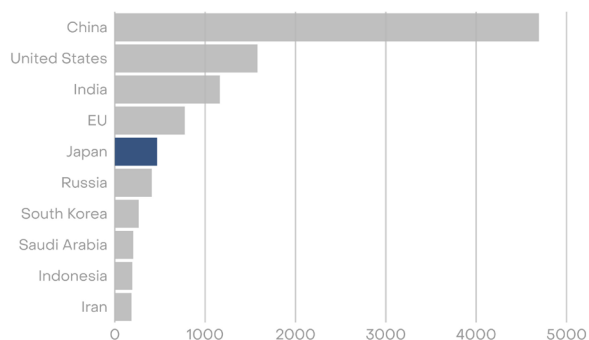
Senior Electricity Analyst, Ember



# Global Context

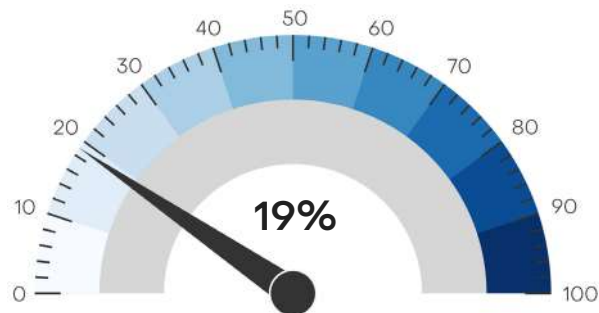
## Top 10 power sector emitters

CO2 emissions (million tonnes)



## Japan's electrification

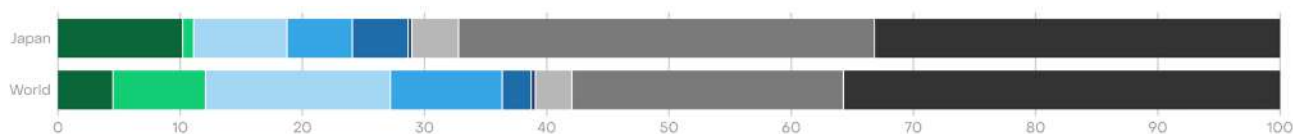
Electricity as a percentage of final energy consumption (%)



## Japan vs world - electricity mix

Share of electricity (%)

Legend: Solar, Wind, Hydro, Nuclear, Bioenergy, Other res, Other fossil, Gas, Coal

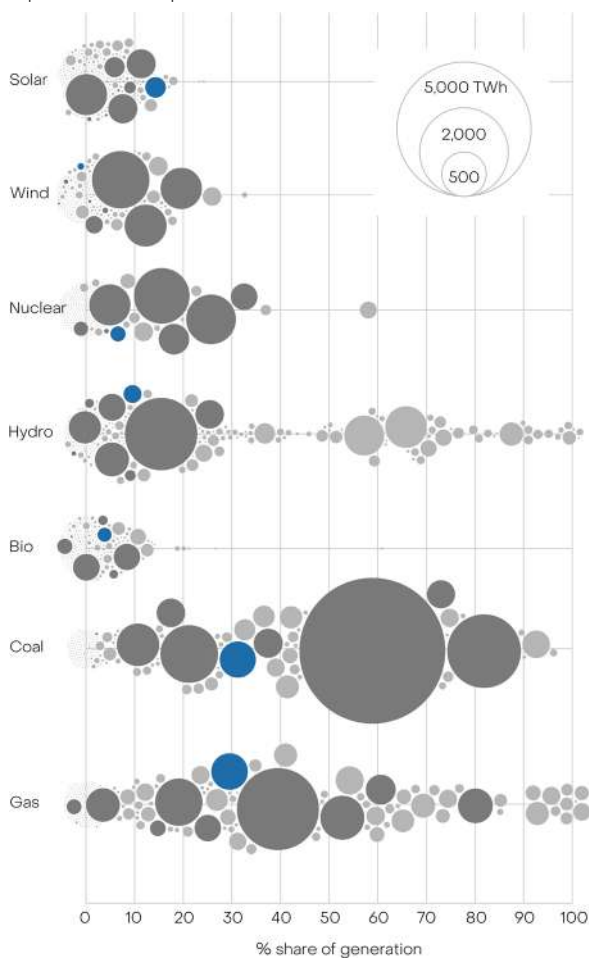


## Japan vs world - sources of electricity

Share of electricity (%)

Bubble size represents electricity generation (TWh)

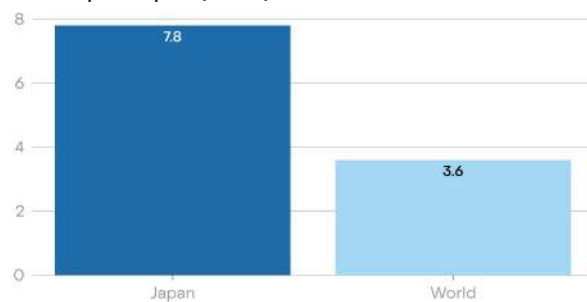
Legend: Japan (blue), Top 10 emitters (grey), Other countries (light grey)



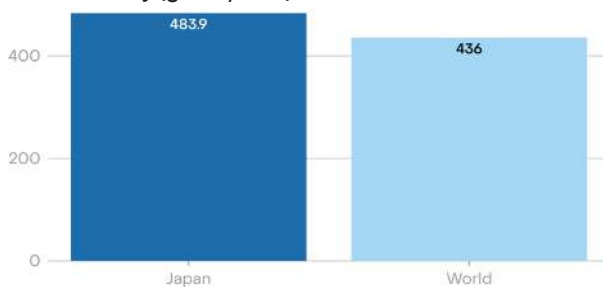
## Japan vs world - emissions and demand

Legend: Japan (dark blue), World (light blue)

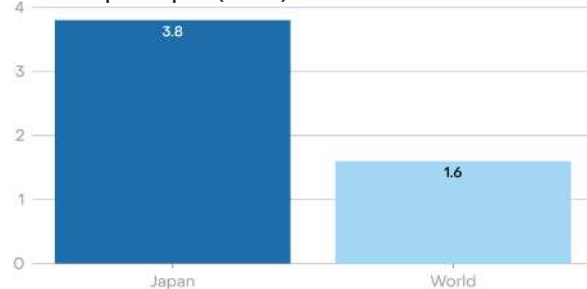
### Demand per capita (MWh)



### CO2 intensity (gCO2/kWh)



### Emissions per capita (tCO2)



Source: Ember

Note: 2022 data used where available, else 2021

## Change in 2022

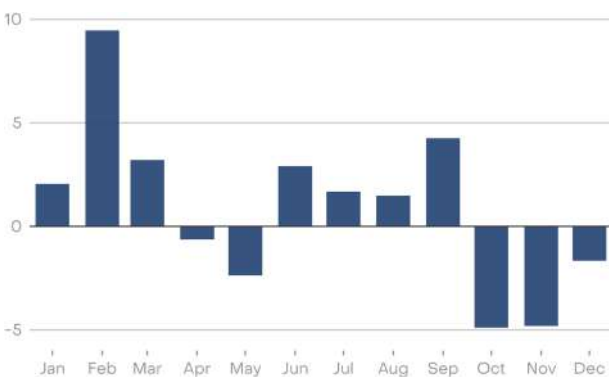
After a decade of falling electricity demand, in 2022, Japan saw the largest demand increase since 2010. With demand up by 1%, this increase was half the rate of the global demand increase of 2.5%. Extreme temperatures in January and heat waves during the summer contributed to this rise, in addition to the economic rebound after the easing of Covid-19 restrictions.

Japan's total power sector emissions increased in 2022 for the first time in a decade. Emissions increased by 2.1% (+9.5 million tonnes of CO<sub>2</sub>), compared to a change in global power sector emissions of +1.3%.

Growth in solar generation of 11% (+10 TWh) was enough to meet and exceed the 9.1 TWh of additional demand. Solar surpassed a 10% share in total generation for the first time. Fossil gas was down by 2.2% (-7.3 TWh), its fifth consecutive year of decline, with its share in power generation falling to 34%. Coal generation rose significantly by 3.1% (+9.7 TWh), largely to cover falls in nuclear generation and hydro. Despite [recent policy signals from Japan that it would revive the nuclear industry](#), nuclear generation was down by 15% (-9.5 TWh) in 2022 due to reduced availability for [maintenance](#). [Severe droughts](#) this year also led to a decline of 6.7% (-45 TWh) in hydro generation. Finally, lack of additional capacity deployment and low wind speeds led to a decline in wind generation (-4.4%, -0.4 TWh).

### Japan's monthly changes in emissions

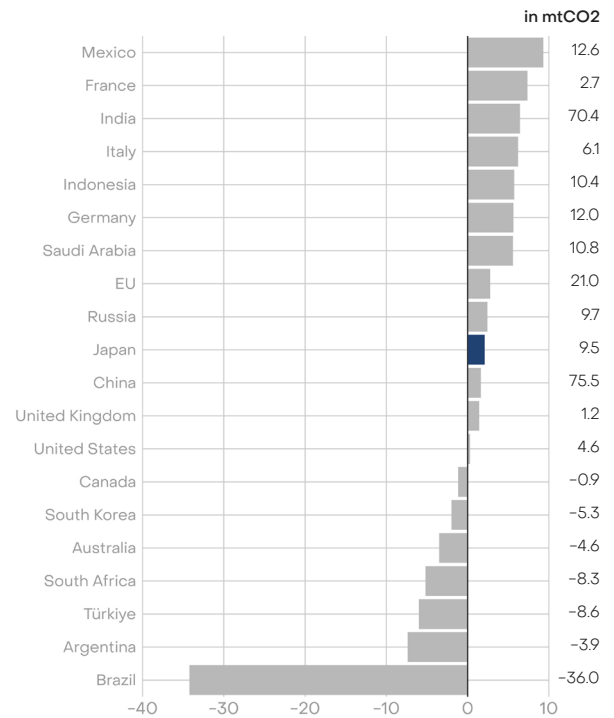
Change in CO<sub>2</sub> emissions year-on-year (%)



Source: Ember

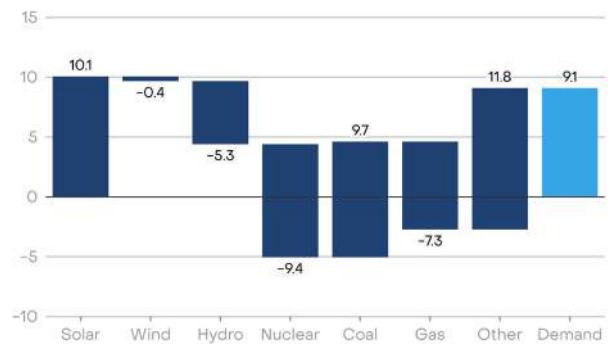
### G20 changes in power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (%)



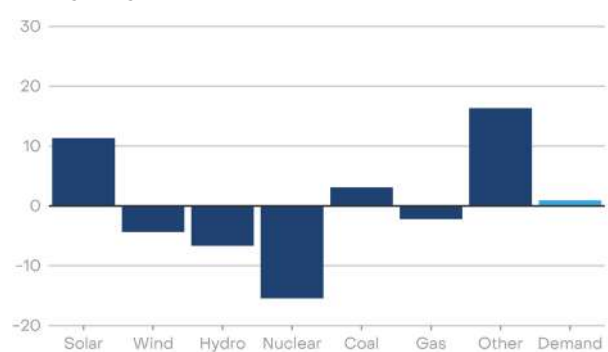
### Japan's change in electricity generation

Change in generation year-on-year (TWh)



### Japan's change in electricity generation

Change in generation year-on-year (%)



Note: 2022 data used where available, else 2021



# Long-term Trends

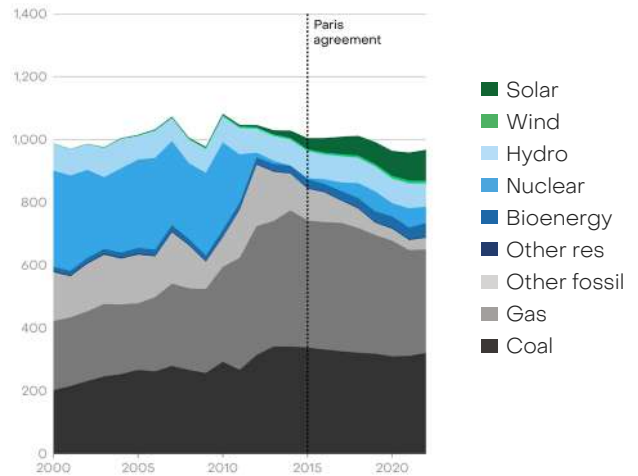
Over the last two decades, Japan's annual power demand has fallen by 2.1% from 988 TWh in 2000 to 967 TWh in 2022. Japan's declining demand is in stark contrast to the global trend. Globally, demand is up 90% in 2022 compared to 2000. Despite the decrease in power demand, Japan's total emissions have increased by 19% in the last two decades, largely due to the closure of nuclear power stations which resulted in higher reliance on fossil fuels.

Fossil fuels accounted for 71% of the power mix in 2022 compared to 59% two decades ago. In the 2000s, nuclear power reduced Japan's reliance on fossil fuels, generating 26% of total electricity in 2010. However, this came to a halt in the aftermath of the Fukushima nuclear disaster in 2011. Although nuclear power has seen a comeback in recent years, its share still remains at only 5.4%. As a result, Japan's power sector emissions intensity increased to 484 gCO<sub>2</sub>/kWh in 2022 compared to 397 gCO<sub>2</sub>/kWh in 2000.

Following the Paris Agreement in 2015, Japan has made progress on the development of clean power. Clean power's share has nearly doubled to 29%. Solar and wind combined now make up 11% of Japan's electricity generation, almost triple the share in 2015. The rise in clean power has resulted in annual power sector emissions dropping by 16% (-89 million tonnes of CO<sub>2</sub>) compared to 2015 levels.

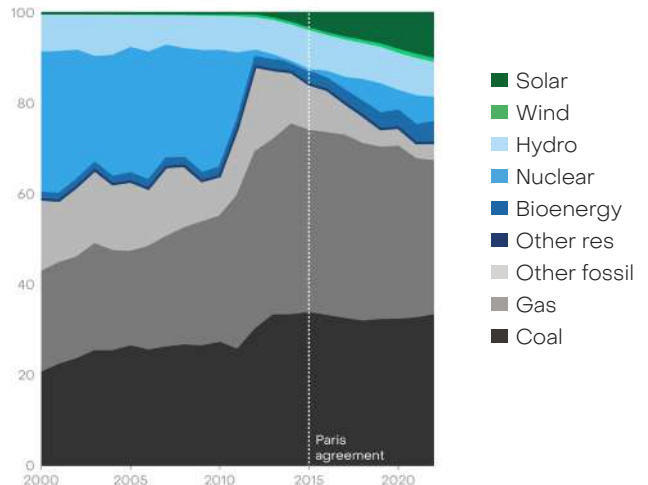
## Japan's electricity generation

Electricity generation (TWh)

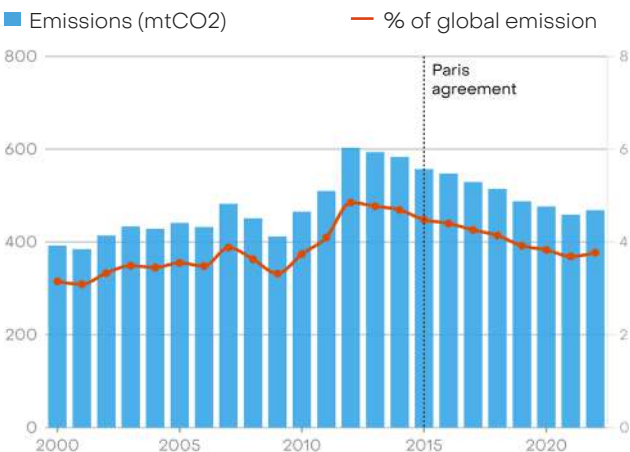


## Japan's electricity mix

Share of electricity (%)

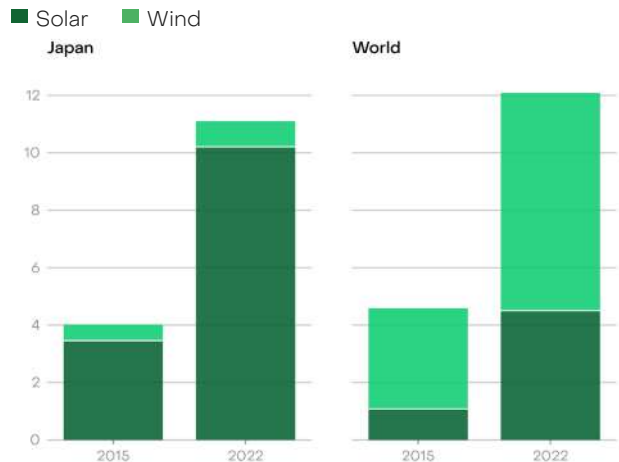


## Japan's power sector emissions



## Japan vs world - wind and solar share

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

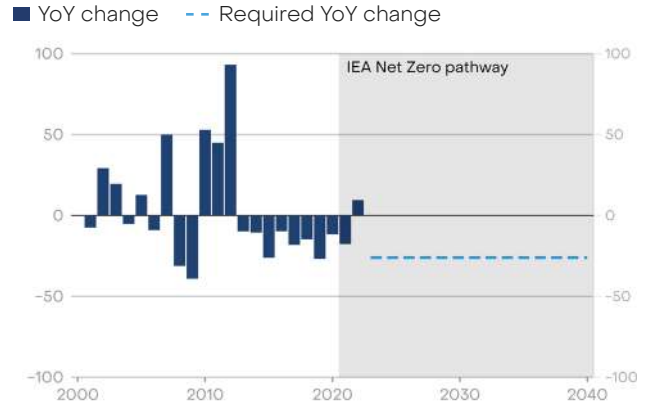
# Progress Towards Net Zero

Japan needs a net zero emissions power sector by 2035, as set out in the [IEA Net Zero Emissions scenario](#), to put it on course to deliver its [commitment](#) to economy-wide net zero by 2050. Japan will need power sector emissions to fall by 36 million tonnes annually. This is nearly three times the rate since 2015, with average annual emissions declining by 13 million tonnes of CO2 per year. To meet milestones from the IEA pathway, Japan would also need to increase its renewable targets, currently set at 59% by 2030.

In 2022, the G7 – including Japan – [committed](#) to a ‘fully or predominantly’ decarbonised power sector by 2035. However, compared to its counterparts Japan is [far behind](#) on renewables ambition. If implemented, the [Ministry of Economy, Trade and Industry’s \(METI\) Strategic Energy Plan](#) from October 2021 does see clean power increase as the country seeks to reactivate many of its idled nuclear reactors. However, its focus on ammonia co-firing will likely prove a [costly and ineffective way](#) to reduce emissions. More concerning, this distraction may also slow the transition in Southeast Asia, where a [cooperation agreement](#) will see Japan support ASEAN countries to adopt ammonia-coal co-firing.

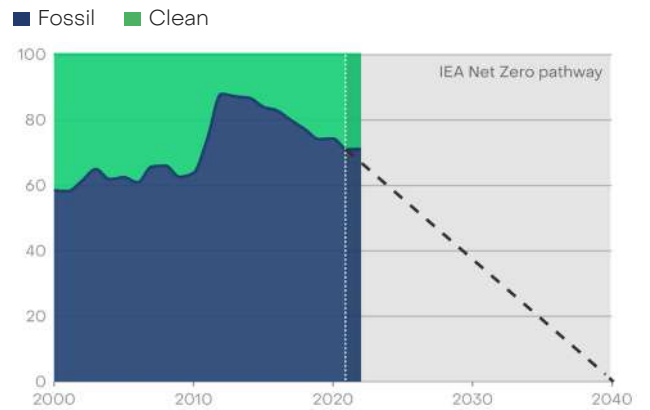
## Japan’s power sector emissions

Change in CO2 emissions year-on-year (mtCO2)



## Japan’s electricity mix

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021



# Russia

## Global Electricity Trends 2022

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Russia has the world's fifth most CO<sub>2</sub>-emitting power sector, responsible for 409 million tonnes of CO<sub>2</sub> in 2022, or 3.3% of total global emissions from electricity generation.

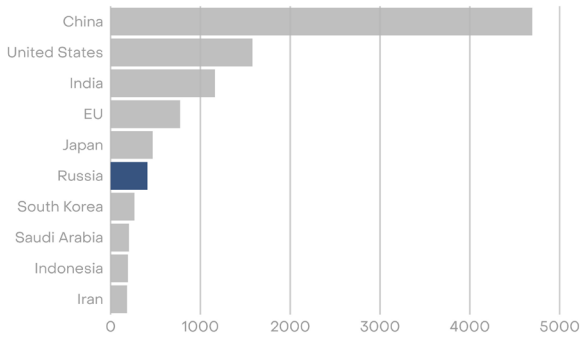
Russia generates 61% of electricity from fossil fuels: 18% (197 TWh) from coal, 43% (479 TWh) from gas and 0.7% (8.1 TWh) from other fossil fuels. Wind and solar only make up 0.7% (8.3 TWh) of the electricity mix. Hydro (18%, 196 TWh) and nuclear power (20%, 226 TWh) also play a big role.

Russia's emission intensity of 367 gCO<sub>2</sub>/kWh is lower than the global average of 436 gCO<sub>2</sub>/kWh. Annual demand per capita is 7.6 MWh, around twice the world average of 3.6 MWh. At 2.8 tonnes of CO<sub>2</sub> per capita, emissions from the power sector in Russia are higher than the global per capita average of 1.6 tonnes.

# Global Context

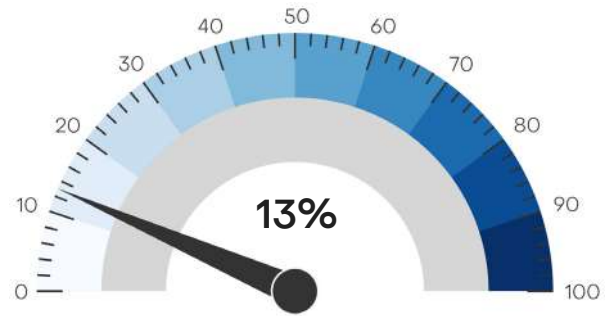
## Top 10 power sector emitters

CO2 emissions (million tonnes)



## Russia's electrification

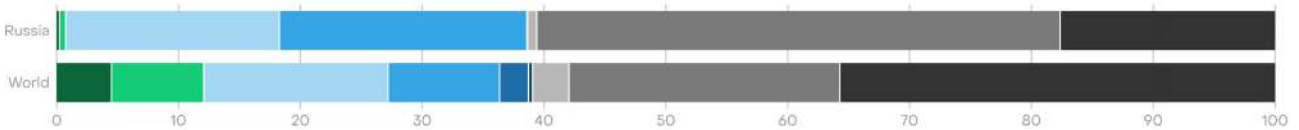
Electricity as a percentage of final energy consumption (%)



## Russia vs world - electricity mix

Share of electricity (%)

Legend: Solar, Wind, Hydro, Nuclear, Bioenergy, Other res, Other fossil, Gas, Coal

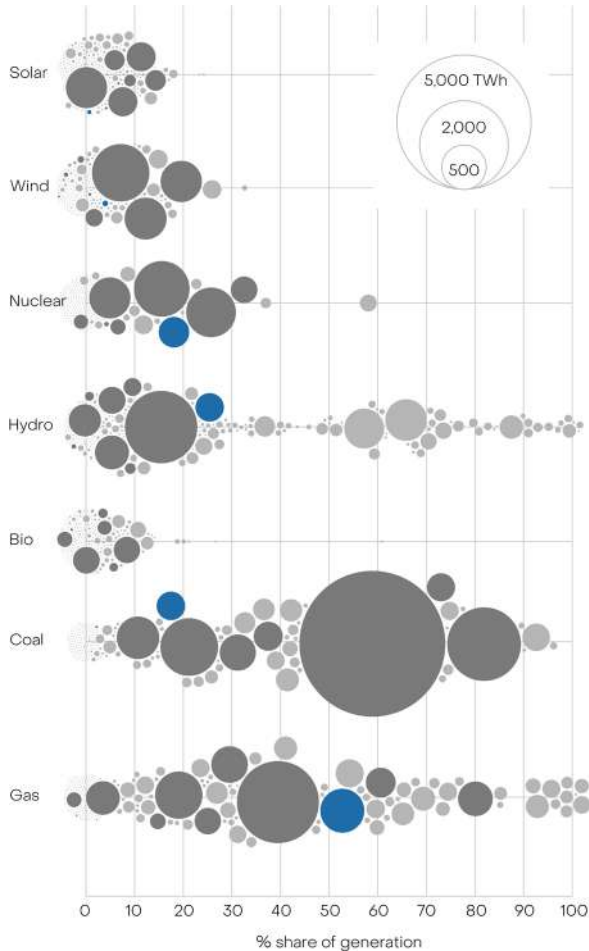


## Russia vs world - sources of electricity

Share of electricity (%)

Bubble size represents electricity generation (TWh)

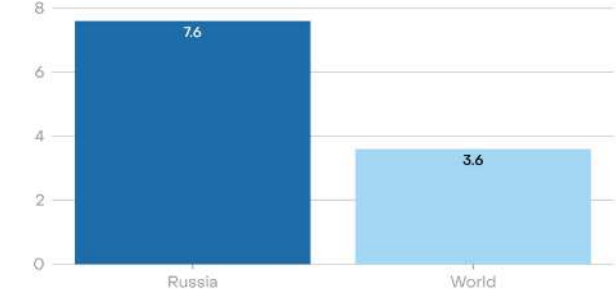
Legend: Russia, Top 10 emitters, Other countries



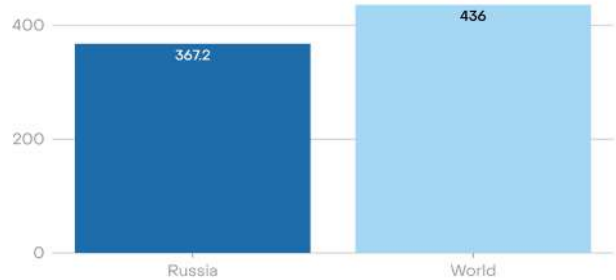
## Russia vs world - emissions and demand

Legend: China, World

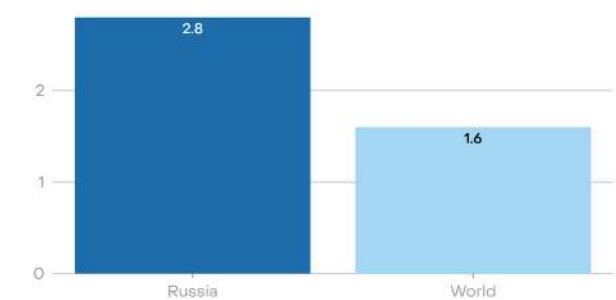
### Demand per capita (MWh)



### CO2 intensity (gCO2/kWh)



### Emissions per capita (tCO2)



Source: Ember

Note: 2022 data used where available, else 2021

# Change in 2022

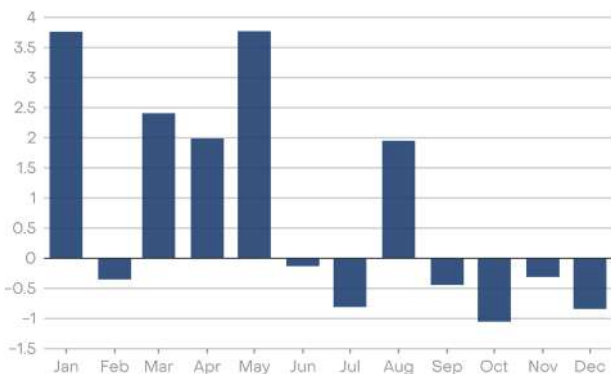
In 2022, Russia saw a small rise in electricity demand of 0.8% (+9.1 mtCO<sub>2</sub>), from 1,093 TWh in 2021 to 1,102 TWh. This was below the global demand change of 2.5% and also lower than Russia's average demand growth rate of 1.1% for 2010–2021.

Russia's power sector emissions increased by 2.4% (+9.7 million tonnes of CO<sub>2</sub>) to 409 million tonnes of CO<sub>2</sub>, eclipsing the previous record-high set last year. This increase was higher than the global rise in power sector emissions of 1.4%. Russia's emissions increase outpaced growth in electricity demand, which rose by 0.8% in 2022 (+9.1 TWh).

Hydro generation fell 8.8% (-19 TWh) compared to 2021 amid drought conditions. To meet higher demand, fossil generation rose, with gas power up 2.7% (+13 TWh) and coal up 2.4% (+4.5 TWh). Nuclear generation also grew a moderate 1.8% (+4 TWh). Wind generation grew 44%, but the relatively low absolute generation meant that only 1.7 TWh was added. Solar's growth was even lower, increasing by 0.3 TWh (+15%). These changes resulted in only minor shifts in Russia's electricity mix. The share of gas in the mix increased from 42% to 43%, while the fall in hydro generation reduced its share in the mix from 19% to 18%. Wind and solar were just 0.7% (+0.2 percentage points) of the mix.

### Russia's monthly changes in emissions

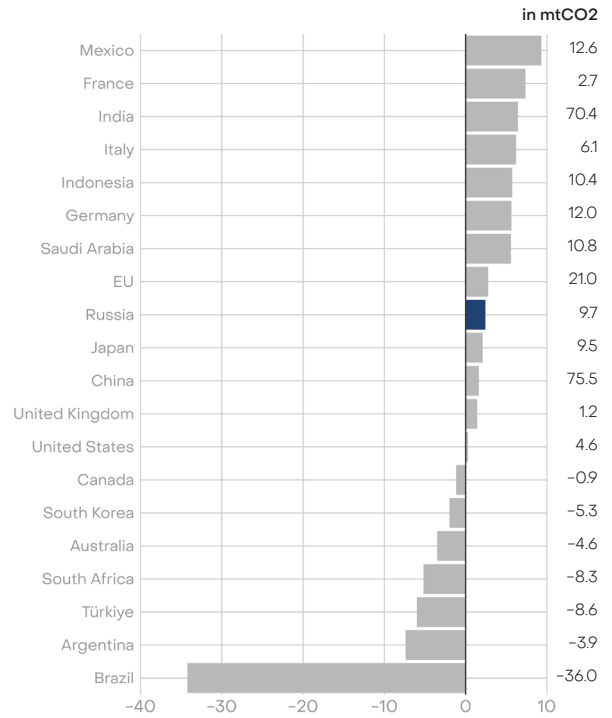
Change in CO<sub>2</sub> emissions year-on-year (%)



Source: Ember

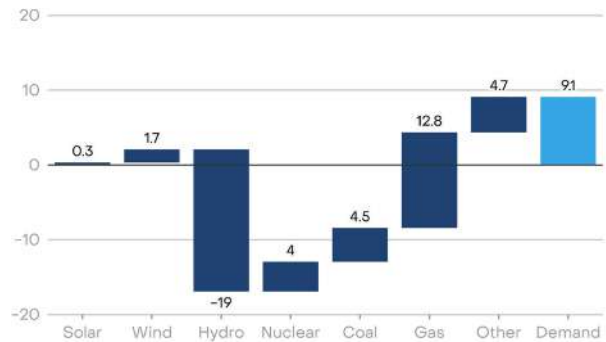
### G20 changes in power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (%)



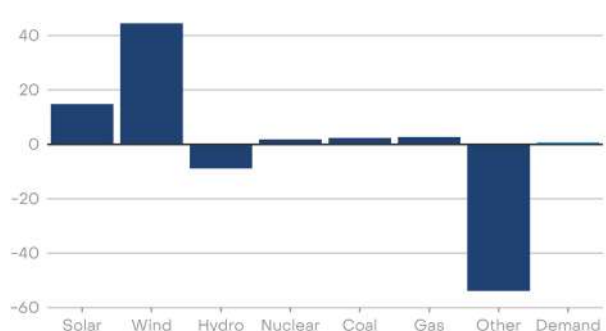
### Russia's change in electricity generation

Change in generation year-on-year (TWh)



### Russia's change in electricity generation

Change in generation year-on-year (%)



Note: 2022 data used where available, else 2021

# Long-term Trends

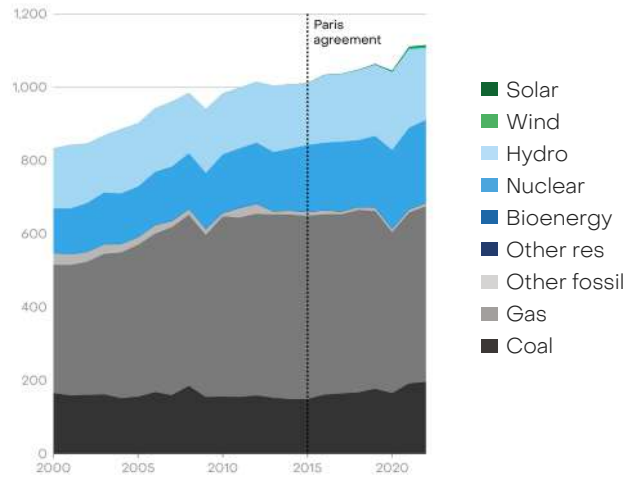
Russia's annual power demand has increased by 34% from 819 TWh in 2000 to 1,102 TWh in 2022. The growth is substantially lower than global demand change over the same period (+90%). Emissions from the power sector in Russia have also grown (+22%) since 2000.

There has been very little change in Russia's electricity mix over the last two decades. Additional demand has largely been met by increases in gas generation (+37%, +129 TWh), but its share of the electricity mix has remained nearly the same, at 43% (up from 42% in 2000). The role of other electricity sources in the mix also showed little change. As a result, emissions intensity today is just slightly lower (367 gCO<sub>2</sub>/kWh) compared to 2000 (402 gCO<sub>2</sub>/kWh).

Similarly, little change has occurred in the years since the Paris Agreement. Wind and solar share has risen from only 0.05% to 0.7%. Russia is being left behind as the global share of wind and solar increased from 4.6% to 12.1% in the same period. Russia's additional demand combined with the lack of clean power growth since 2015 meant that annual power sector emissions increased by 29 million tonnes.

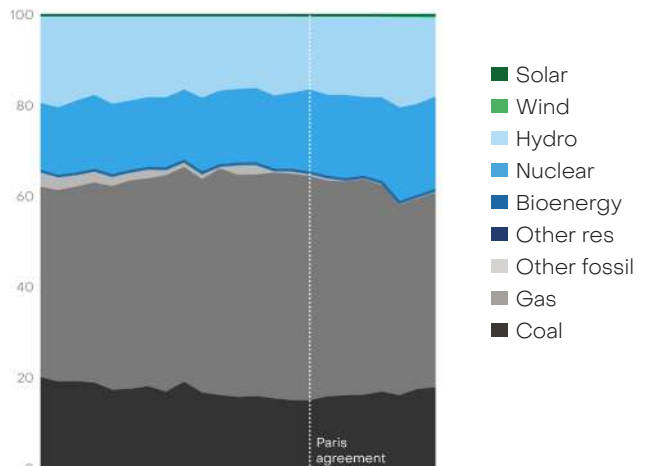
## Russia's electricity generation

Electricity generation (TWh)



## Russia's electricity mix

Share of electricity (%)



## Russia's power sector emissions

Emissions (mtCO<sub>2</sub>)      % of global emission

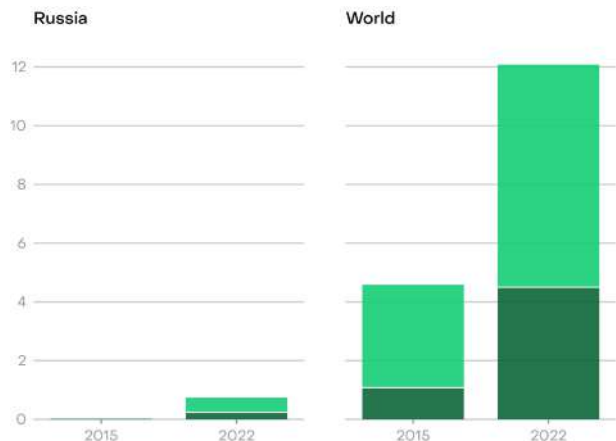


Source: Ember

## Russia vs world - wind and solar share

Share of electricity (%)

Solar      Wind



Note: 2022 data used where available, else 2021

# Progress Towards Net Zero

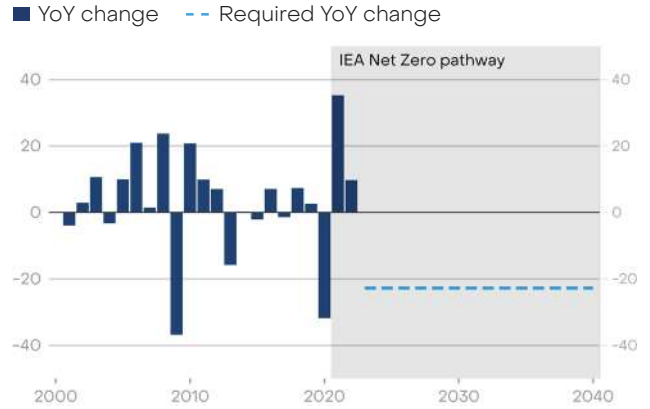
Russia's power sector emissions need to fall to zero by 2040 from the current 409 million tonnes of CO2 to align with the [IEA Net Zero Emissions scenario](#). For that target, emissions will need to fall by 23 million tonnes per year, reversing the trend since 2015, where emissions have grown an average of 4.1 million tonnes of CO2 per year.

In its 2020 nationally determined contribution, Russia pledged to keep emissions [30% below](#) 1990 level by 2030 using "the maximum possible absorptive capacity of forest and other ecosystems". It has not made any commitment to reduce emissions from the power sector.

Russia has a net zero emission target by [2060](#), which is less ambitious than many other developed economies and insufficient for limiting global heating to 1.5 degrees.

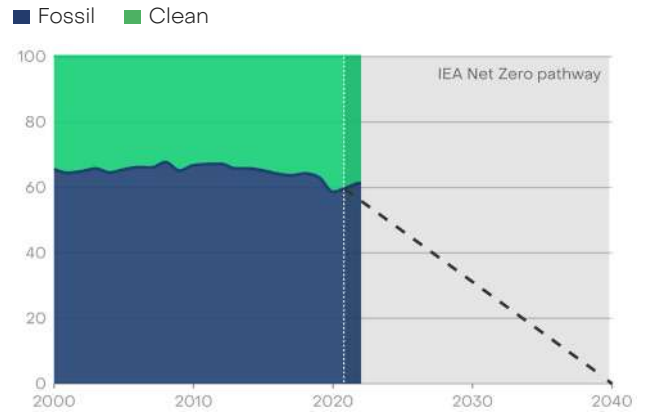
## Russia's power sector emissions

Change in CO2 emissions year-on-year (mtCO2)



## Russia's electricity mix

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# South Korea

## Global Electricity Trends 2022



South Korea has the world's sixth largest power sector CO<sub>2</sub> emissions. Responsible for 264 million tonnes of CO<sub>2</sub>, the country's power sector accounted for 2.1% of total global emissions from electricity generation in 2022. As one of the most advanced economies in Asia, South Korea has a higher responsibility to mitigate emissions contributing to the climate crisis. However, it is still lagging behind its OECD peers in terms of wind and solar development. In addition, South Korea's heavy reliance on imported fossil fuels heightens risks related to not only climate but also energy security.

South Korea generated 63% of its electricity from fossil fuels in 2022: 34% from coal (206 TWh), 28% from gas (170 TWh) and 1% from other fossil fuels (6 TWh). Nuclear was the largest clean power source, producing 28% of South Korea's electricity (169 TWh). Wind and solar accounted for 5.4% (32 TWh) of the electricity mix, with the rest coming from hydro (0.6%, 3.6 TWh) and bioenergy (3.1%, 19 TWh).

South Korea has an emissions intensity of 436 gCO<sub>2</sub>/kWh, which is identical to the global average. However, the country's annual demand per capita of 12 MWh is more than three times the world average of 3.6 MWh. Due to high demand for power, South Korea's per capita emissions from the power sector (5 tonnes of CO<sub>2</sub>) is triple the global average of 1.6 tonnes of CO<sub>2</sub>.

“Coal generation share hit its all-time low, bringing South Korea's power sector emission intensity down on par with the global level. This was a sign that decarbonisation is happening in South Korea, though it may be small. While emissions reduction must be accelerated and scaled up, recent downward adjustments in renewable targets are going to have the opposite effect.”

**Uni Lee**

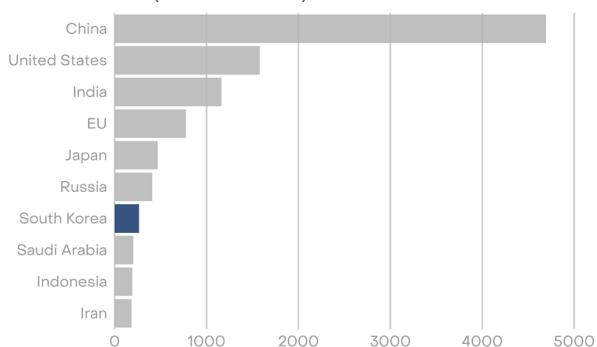
Data Analyst, Ember



# Global Context

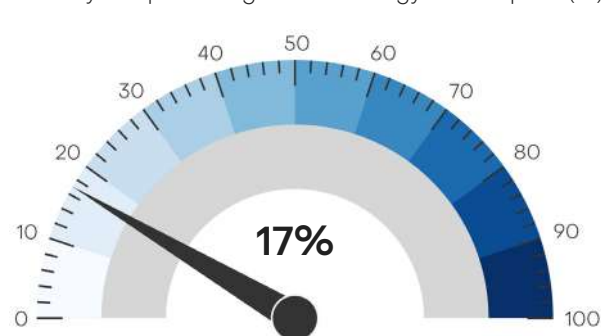
## Top 10 power sector emitters

CO2 emissions (million tonnes)



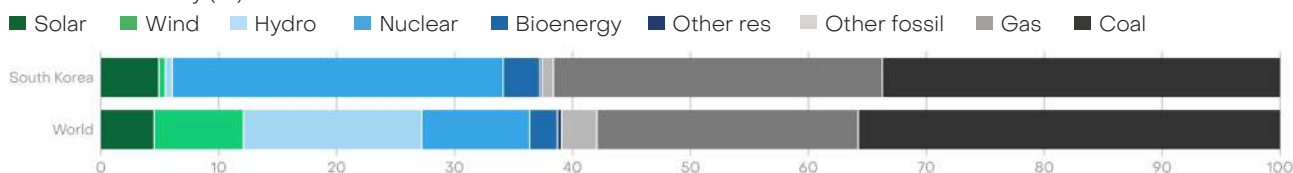
## South Korea's electrification

Electricity as a percentage of final energy consumption (%)



## South Korea vs world - electricity mix

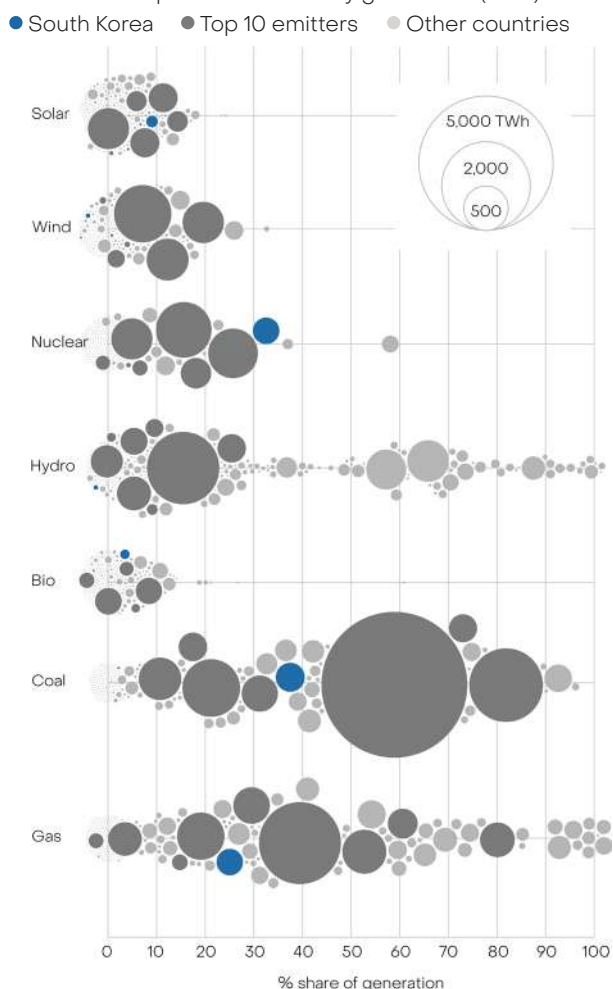
Share of electricity (%)



## South Korea vs world - sources of electricity

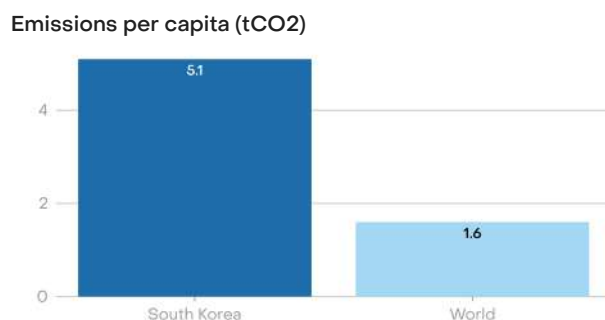
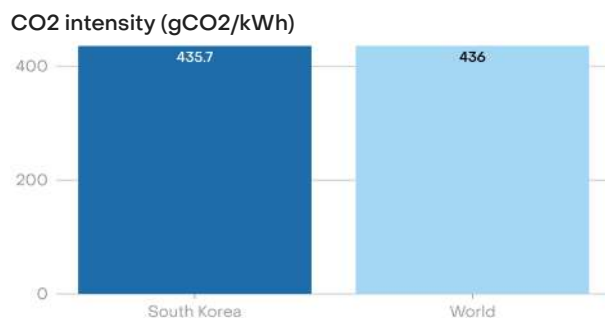
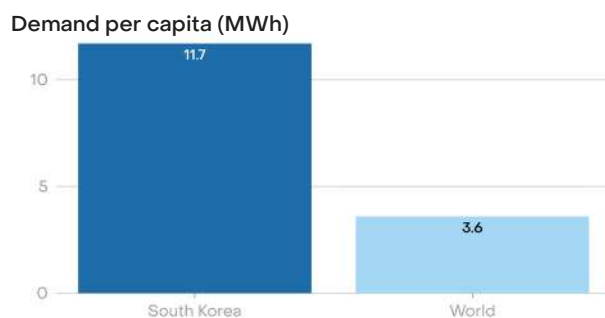
Share of electricity (%)

Bubble size represents electricity generation (TWh)



## South Korea vs world - emissions and demand

● South Korea ● World



Source: Ember

Note: 2022 data used where available, else 2021



# Change in 2022

Thanks to the rise in clean power and the fall in fossil fuel generation, South Korea's power sector emissions fell by 2% (-5.3 million tonnes of CO<sub>2</sub>) compared to 2021. In contrast, global power sector emissions were up by 1.3%. Consequently, the emissions intensity dropped to a historic low at 436 gCO<sub>2</sub> per kWh.

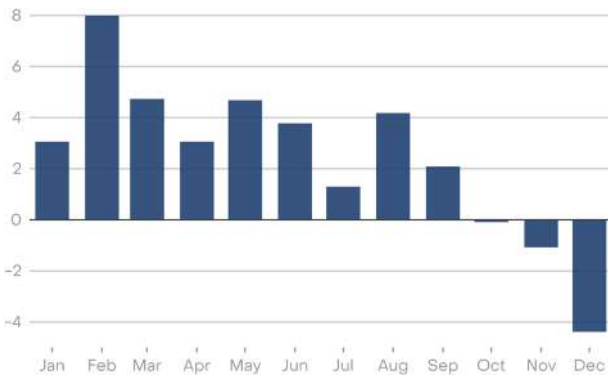
This year's fall in emissions is noteworthy as it occurred despite a rise in electricity demand of 3.1% (+18 TWh). This was roughly on par with the global demand change of 2.5%. A key driver of the demand increase were extreme temperatures in July, August and December, which led to an all-time high in peak demand.

Coal dropped by 2.1% (-4.4 TWh) and hit a historic low in the electricity mix at 34%. Gas fell by 2.7% (-4.7 TWh) and other fossil fuels by 15% (-1 TWh). The fall in fossil fuel generation can be attributed to rising prices of fossil gas and [national policies to curb coal power during seasons of high air pollution](#).

The increase in clean power generation (+14%, +28 TWh) was large enough to meet the entire demand increase (+18 TWh) and make up for the drop in fossil fuels (-10 TWh). Among clean power sources, nuclear saw the largest increase in absolute terms (+18 TWh), up by 12%. Scheduled [maintenance of nuclear power was cancelled](#), meeting the rise in demand while compensating for the fall in coal and gas generation. Solar (+21%, +5.1 TWh) and wind power (+6%, +0.2 TWh) also saw a substantial increase.

### South Korea's monthly changes in emissions

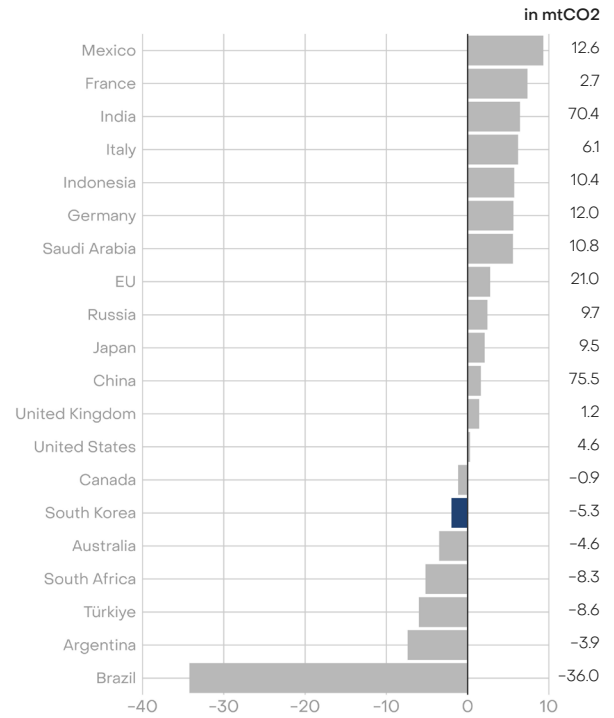
Change in CO<sub>2</sub> emissions year-on-year (%)



Source: Ember

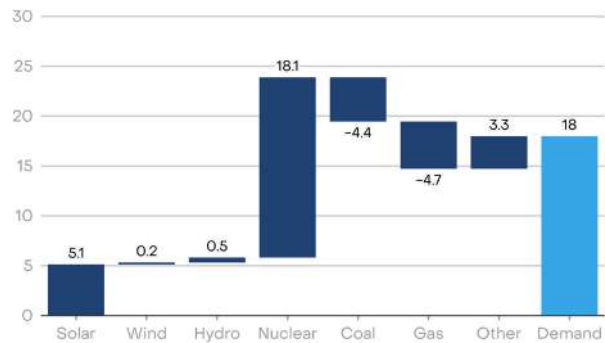
### G20 changes in power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (%)



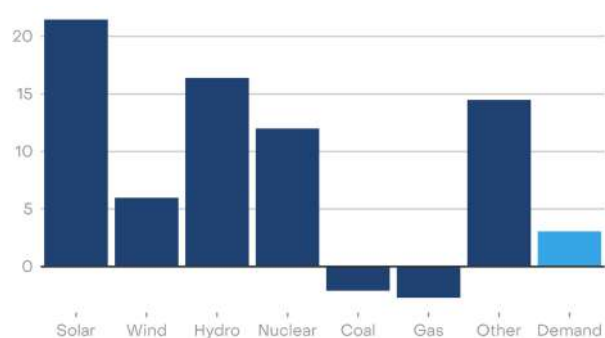
### South Korea's change in electricity generation

Change in generation year-on-year (TWh)



### South Korea's change in electricity generation

Change in generation year-on-year (%)



Note: 2022 data used where available, else 2021

# Long-term Trends



South Korea's power generation emissions intensity in 2022 (436 gCO<sub>2</sub>/kWh) was slightly lower than it was in 2000 (454 gCO<sub>2</sub>/kWh), reflecting its long-term trend of declining reliance on fossil fuels. However, across the last two decades clean generation has not grown fast enough to meet its demand increase, resulting in a doubling of power sector emissions to 264 million tonnes of CO<sub>2</sub>.

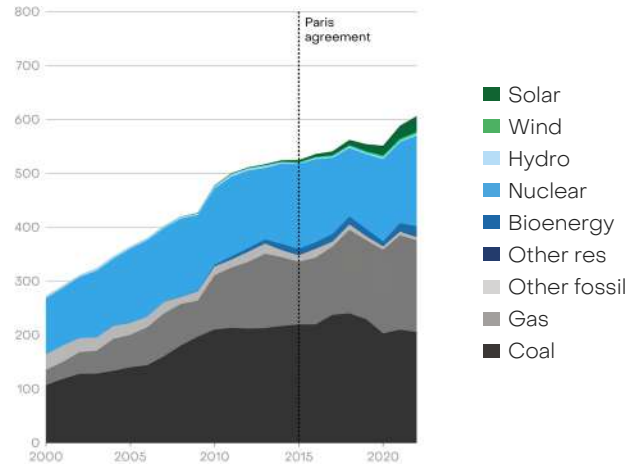
Since 2000, South Korea's power demand has more than doubled to 607 TWh. To meet this rising demand, fossil fuel generation has also more than doubled over the same period (+217 TWh). Gas generation saw a six-fold increase in the last two decades, tripling its share to 28%. Coal generation nearly doubled in absolute terms, but its share fell to 34%, down by five percentage points compared to 2000.

Clean power sources have grown at a slower rate than fossil fuels, with the share of clean generation dropping from 39% in 2000 to 37% in 2022. The share of nuclear power showed the largest decline in the fuel mix over that period. It fell by nine percentage points to 28% in 2022, although its absolute generation was up by 63%.

In 2015, wind and solar accounted for less than 1% of the total generation. Since then, wind and solar have grown to now make up 5.4% of the electricity mix. Still, South Korea's share of solar and wind is half that of both Japan and the global average, which reached 11% and 12% in 2022 respectively.

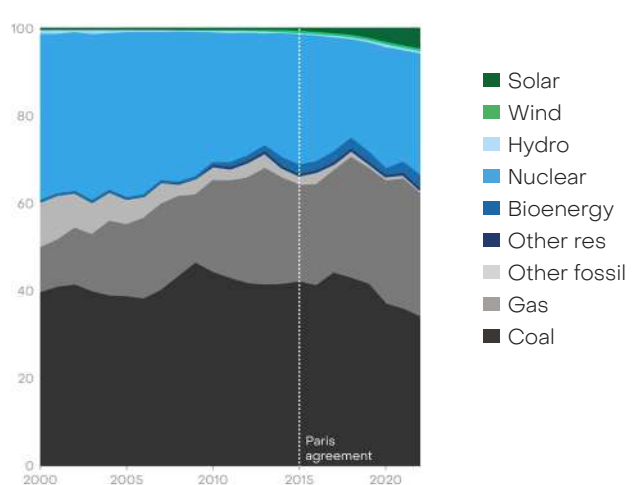
## South Korea's electricity generation

Electricity generation (TWh)



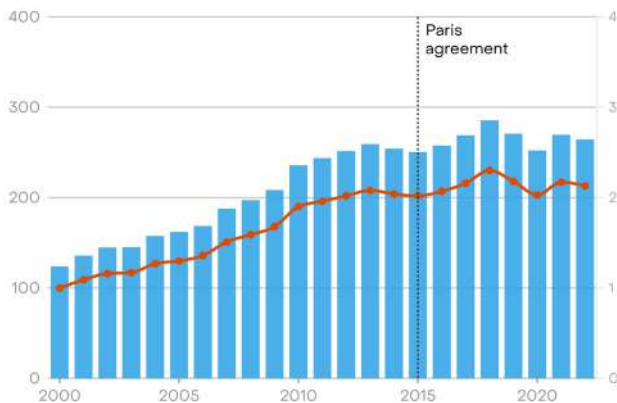
## South Korea's electricity mix

Share of electricity (%)



## South Korea's power sector emissions

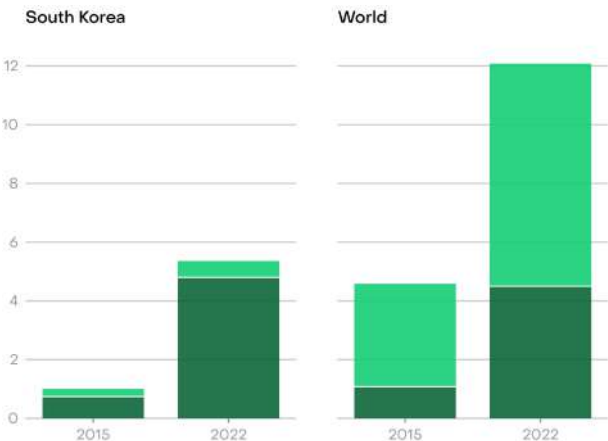
■ Emissions (mtCO<sub>2</sub>)      — % of global emission



## South Korea vs world - wind and solar share

Share of electricity (%)

■ Solar      ■ Wind



Source: Ember

Note: 2022 data used where available, else 2021

# Progress Towards Net Zero



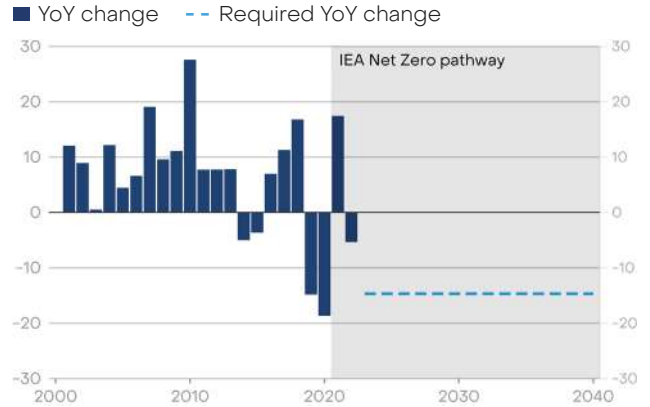
To be in line with the [IEA Net Zero Emissions scenario](#), South Korea needs to reach a net zero power sector by 2035. This means that South Korea needs to reduce power sector emission by 20 million tonnes of CO2 per year, starting in 2023. However, South Korea has been adding 2 million tonnes of CO2 per year since 2015. The upward trend in emissions increase must be reversed quickly.

Under the [Framework Act on Carbon Neutrality and Green Growth for Coping with the Climate Crisis](#), South Korea has set a target to reduce power sector emissions by 44% in comparison to 2018 levels, reaching 150 MtCO2 by 2030. In March, the government set out a [plan](#) to revise its power sector reduction target to 45.9%.

However, clean power targets in South Korea are much lower than what the IEA pathway recommends. In a recent announcement of the [10th Basic Plan of Long-Term Electricity Supply and Demand](#), South Korea set a target to bring the share of renewable and nuclear power up to 31% and 35% by 2036, respectively. To reach net zero, policy targets for clean power must be increased, along with regulatory and financial support for clean power producers.

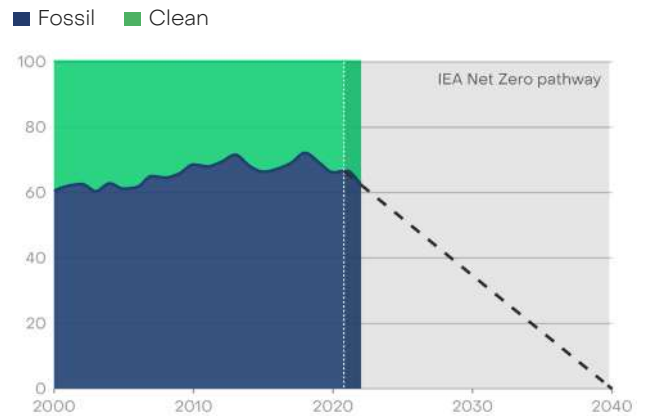
## South Korea's power sector emissions

Change in CO2 emissions year-on-year (mtCO2)



## South Korea's electricity mix

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Saudi Arabia

## Global Electricity Trends 2021

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2022 electricity data for Saudi Arabia is not yet available. This section will focus on data available for 2021. Saudi Arabia had the 8th highest emissions from the power sector in 2021. It was responsible for 204 million tonnes of CO<sub>2</sub>, the equivalent to 1.7% of global power sector emissions.

Saudi Arabia's electricity is almost entirely generated from fossil fuels (99.8%). Gas generation accounts for 61% of electricity (216 TWh) and oil generates 39% (140 TWh). The country generates no electricity from coal or nuclear power, and has almost no renewable generation. Saudi Arabia generates more electricity from oil than any other country.

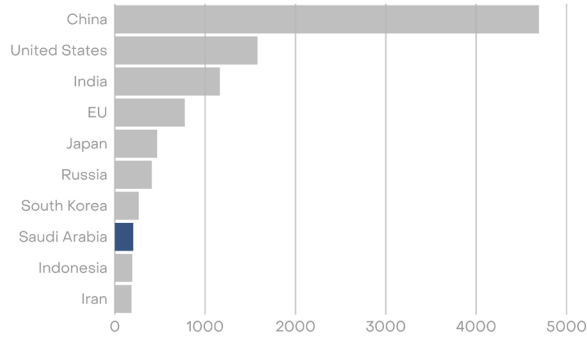
Compared to the global average (441 gCO<sub>2</sub>/kWh), Saudi Arabia has significantly higher emissions intensity of electricity (571 gCO<sub>2</sub>/kWh), and almost three times the demand per capita (9.9 MWh vs. 3.5 MWh). This means that per capita emissions from the power sector in Saudi Arabia are three and a half times higher than the global average (5.7 tCO<sub>2</sub> vs. 1.6 tCO<sub>2</sub>).

Saudi Arabia has committed to generating 50% of its electricity from renewables by 2030, from less than 0.2% in 2021. So far, implementation has lagged behind initiatives and promises by the Saudi government and the country remains with one of the lowest wind and solar shares among major economies.

**Global Context**

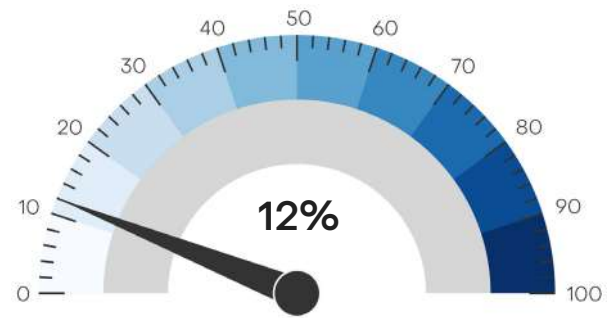
**Top 10 power sector emitters**

CO2 emissions (million tonnes)



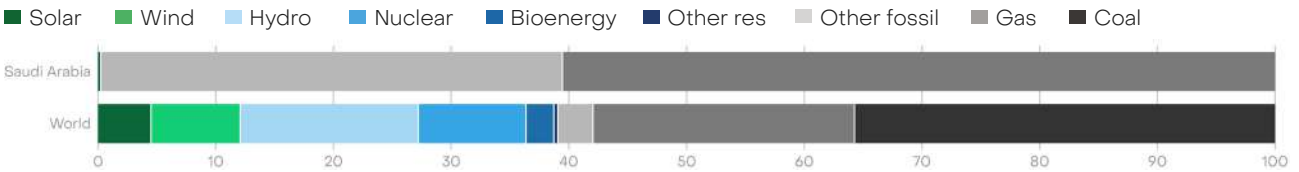
**Saudi Arabia's electrification**

Electricity as a percentage of final energy consumption (%)



**Saudi Arabia vs world - electricity mix**

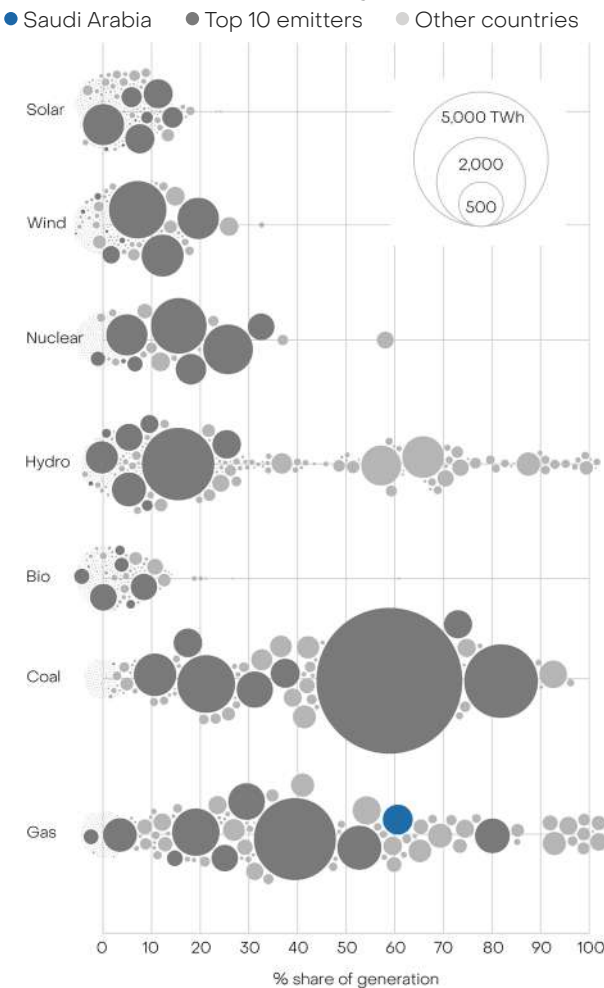
Share of electricity (%)



**Saudi Arabia vs world - sources of electricity**

Share of electricity (%)

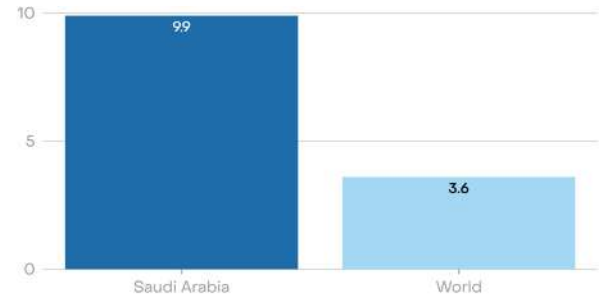
Bubble size represents electricity generation (TWh)



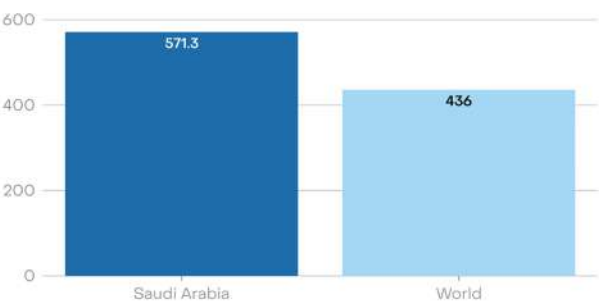
**Saudi Arabia vs world - emissions and demand**

● Saudi Arabia ● World

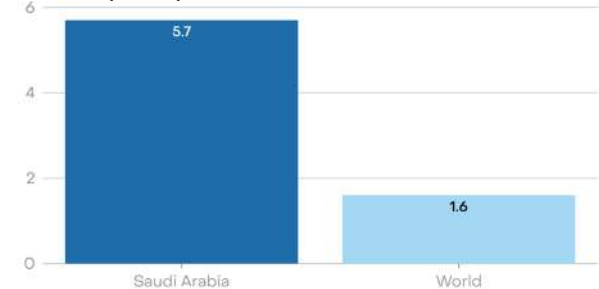
Demand per capita (MWh)



CO2 intensity (gCO2/kWh)



Emissions per capita (tCO2)



Source: Ember

Note: 2022 data used where available, else 2021

# Change in 2021

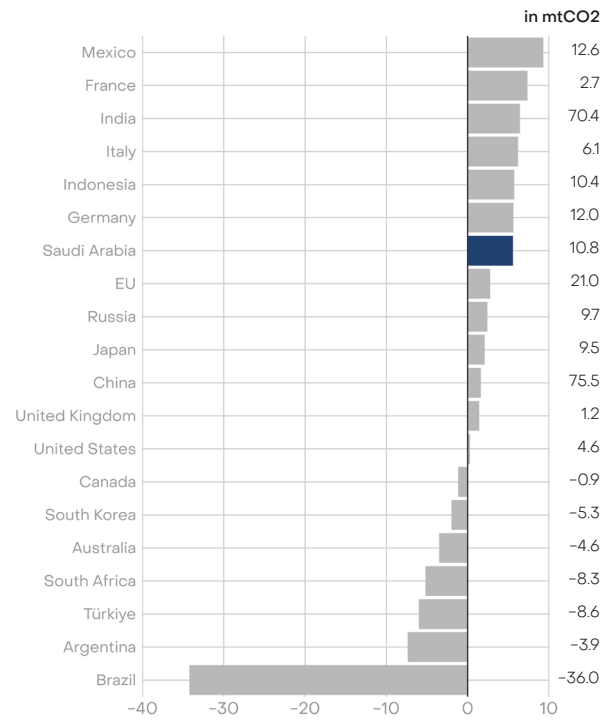
Saudi Arabia’s power sector emissions rose by 5.6% in 2021 (+11 million tonnes of CO2), growing faster than global power sector emissions which remained stable in 2021.

Saudi Arabia’s electricity demand rose by 5.5% (+19 TWh) in 2021, faster than the global increase of 5.9%. This was higher than the country’s average growth rate for 2010–2020 (3.7%).

Gas generation rose by 4.3% (+8.9 TWh), meeting half of the increase in electricity demand. This meant that gas generation set a new record high (216 TWh), rising past the previous high (207 TWh) in 2020. Other fossil generation (mostly oil) also increased significantly by 6.9% (+9.1 TWh). While solar generation increased by almost four times, this still only represented an increase of 0.6 TWh.

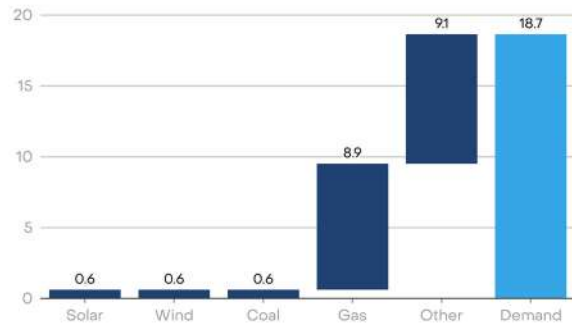
## G20 changes in power sector emissions

Change in CO2 emissions year-on-year (%)



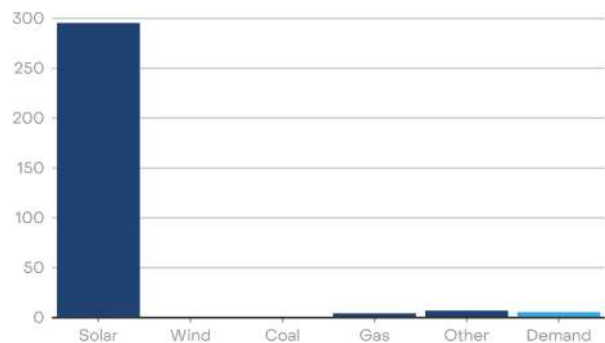
## Saudi Arabia’s change in electricity generation

Change in generation year-on-year (TWh)



## Saudi Arabia’s change in electricity generation

Change in generation year-on-year (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Long-term Trends



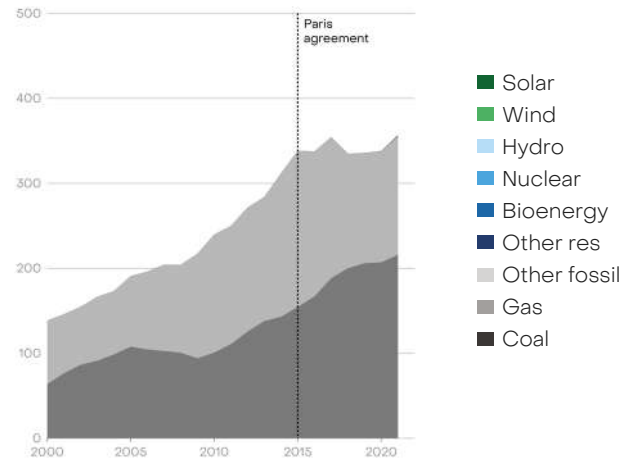
Saudi Arabia's electricity demand has more than doubled in the last two decades, from 139 TWh in 2000 to 356 TWh in 2021. As its electricity generation mix has remained almost entirely fossil-based, its emissions intensity has improved only slightly from 603 gCO<sub>2</sub>/kWh to 571 gCO<sub>2</sub>/kWh. The demand increase, combined with few changes in the emissions intensity of the grid, meant that power sector emissions more than doubled from 84 million tonnes of CO<sub>2</sub> in 2000 to 204 million tonnes of CO<sub>2</sub> in 2021.

Saudi power sector emissions have remained largely stable, falling by just 0.3% (-0.6 Mt of CO<sub>2</sub>) from 2015 to 2021. Increases in electricity demand since 2015 were met primarily with gas generation growth (+40%) instead of more carbon intensive oil, which fell by 24%.

In the almost total absence of renewables in the mix, emissions are not yet falling. Solar accounts for 0.2% of Saudi Arabia's electricity. This is compared to rapid growth elsewhere in the world: from 2015 to 2021 solar and wind more than doubled from 4.6% (1,083 TWh) to 10.4% (2,887 TWh) of global electricity.

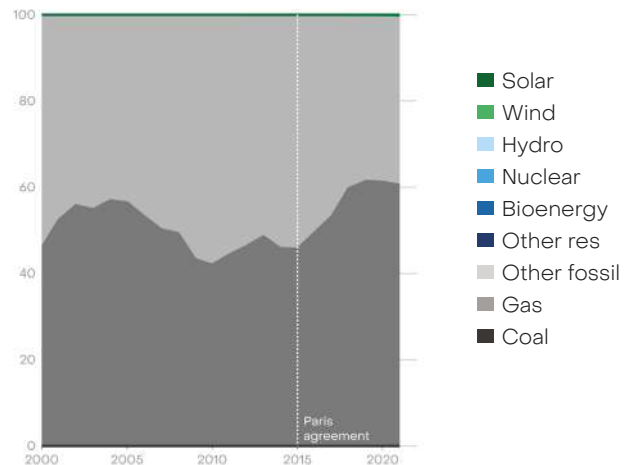
## Saudi Arabia's electricity generation

Electricity generation (TWh)

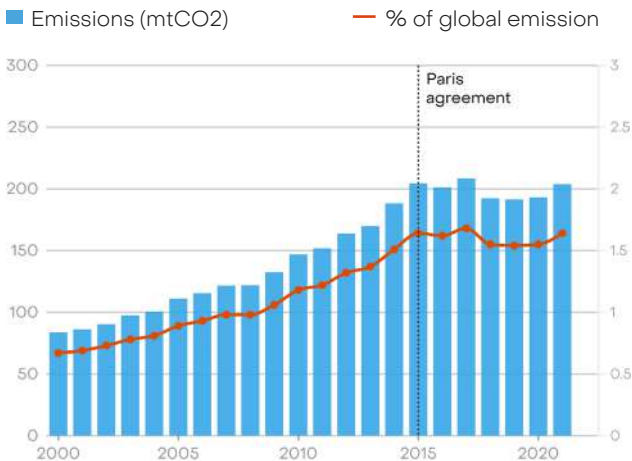


## Saudi Arabia's electricity mix

Share of electricity (%)



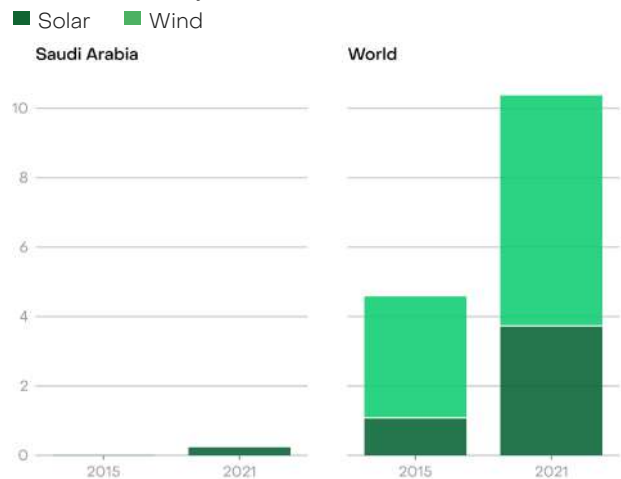
## Saudi Arabia's power sector emissions



Source: Ember

## Saudi Arabia vs world - wind and solar share

Share of electricity (%)



Note: 2022 data used where available, else 2021



# Progress Towards Net Zero



Saudi Arabia needs to generate all its electricity from clean sources by 2040 to achieve a net zero emissions power sector, per the [IEA Net Zero Emissions scenario](#).

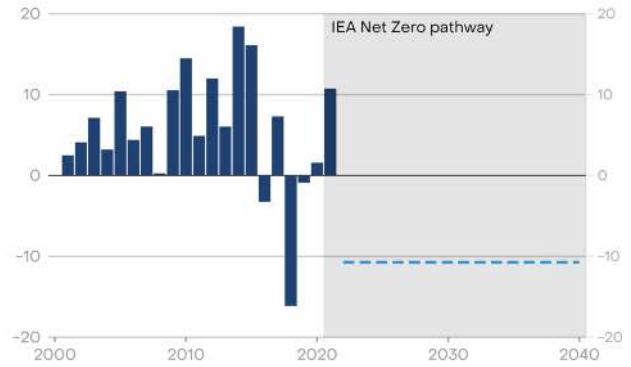
Saudi Arabia's power sector emissions in 2021 were broadly unchanged from 2015. For power sector emissions to fall to zero by 2040 from the current 204 million tonnes of CO<sub>2</sub>, emissions would need to fall 11 million tonnes per year.

Saudi Arabia has committed to generating 50% of its electricity from renewables by 2030, from near-zero today. This could be a trajectory for 100% clean power by 2040. However, it now needs to rapidly turn commitment into action to make this a reality.

## Saudi Arabia's power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (mtCO<sub>2</sub>)

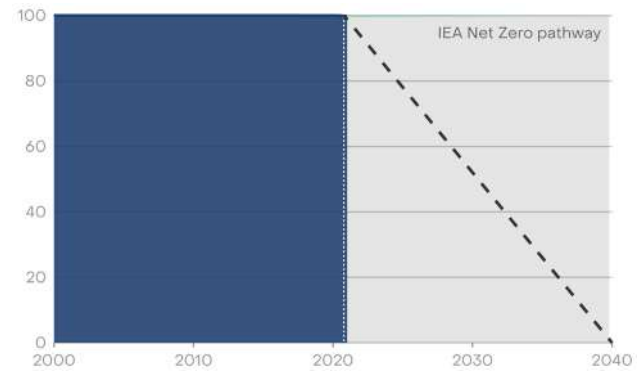
■ YoY change    - - Required YoY change



## Saudi Arabia's electricity mix

Share of electricity (%)

■ Fossil    ■ Clean



Source: Ember

Note: 2022 data used where available, else 2021

# Indonesia

## Global Electricity Trends 2021



2022 electricity data for Indonesia is not yet available. This section will focus on data available for 2021. Indonesia had the world's 9th highest power sector emissions in 2021, at 193 million tonnes of CO<sub>2</sub>. In 2021, this represented 1.6% of global emissions from the power sector.

Fossil fuels generate 82% of Indonesia's electricity. The largest contribution comes from coal at 61% (190 TWh) of the total power mix in 2021. Gas generation produced 18% (56 TWh) and other fossil fuels 2.1% (6.7 TWh). Combined, renewables produced just 18% of electricity. Hydro produced 8% (25 TWh) of electricity, and bioenergy 4.9% (15 TWh). Other renewables, mostly geothermal, produced 5.2% (16 TWh). Wind (0.4 TWh) and solar (0.2 TWh) both only contributed 0.1%.

As a consequence, Indonesia's emissions intensity is one of the highest worldwide, at 623 gCO<sub>2</sub>/kWh compared to global emissions intensity of 441 gCO<sub>2</sub>/kWh in 2021. However, its annual demand per capita of 1.1 MWh is only a third of the global average of 3.5 MWh per capita. This means that despite the high emissions intensity, the emissions per capita (0.7 tonnes of CO<sub>2</sub>) are only half of the global average of 1.6 tonnes of CO<sub>2</sub>.

Electricity provided 13% of Indonesia's final energy consumption in 2021, which is expected to increase as the electrification of sectors like transport, heating and industry accelerates.

“Despite the slow progress of renewable energy deployment in Indonesia over the past years, recent international support – such as the Asian Development Bank's Energy Transition Mechanism and the Just Energy Transition Partnership (JETP) – has provided the necessary resources to propel the country's adoption of renewable energy sources and to phase out coal-fired power plants. With this support, it is now the time for Indonesia to demonstrate its commitment and take the necessary steps to peak power sector emissions by 2030 and fulfil its renewable energy ambitions.”

**Małgorzata Wiatros-Motyka**

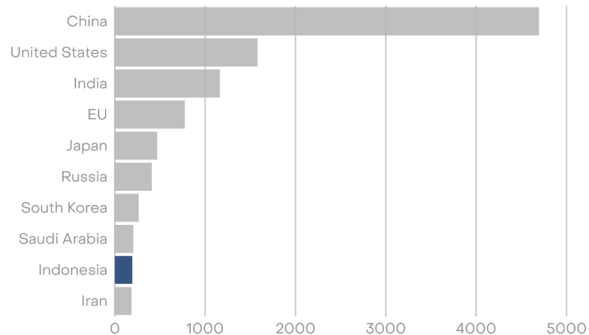
Senior Electricity Analyst, Ember



# Global Context

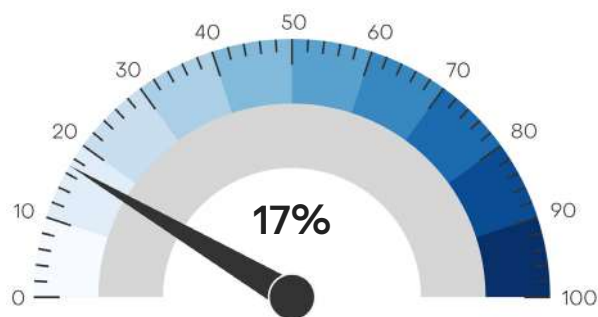
## Top 10 power sector emitters

CO2 emissions (million tonnes)



## Indonesia's electrification

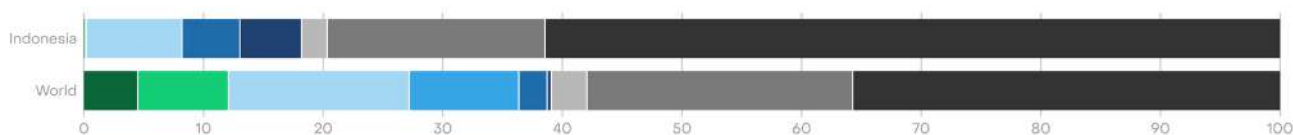
Electricity as a percentage of final energy consumption (%)



## Indonesia vs world - electricity mix

Share of electricity (%)

Legend: Solar, Wind, Hydro, Nuclear, Bioenergy, Other res, Other fossil, Gas, Coal

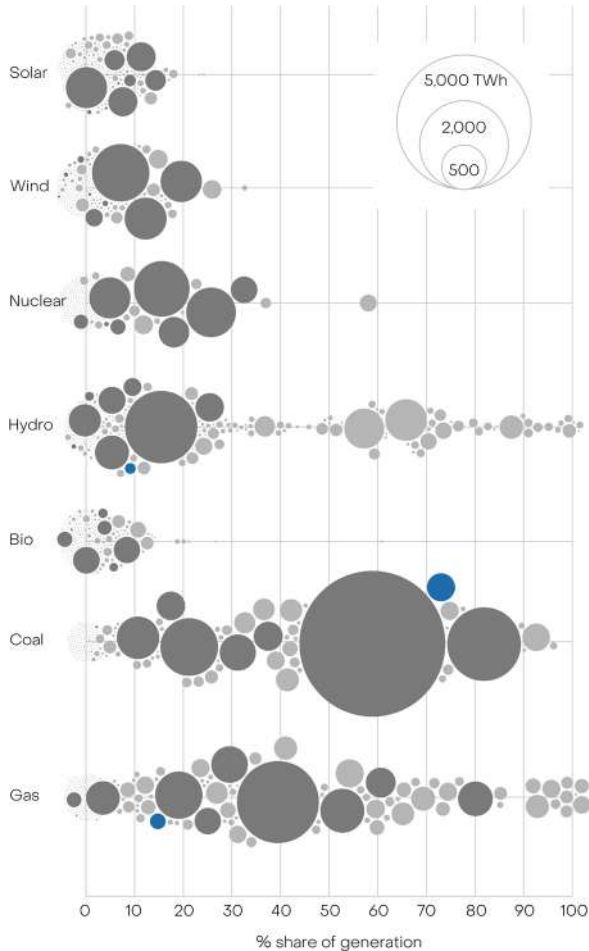


## Indonesia vs world - sources of electricity

Share of electricity (%)

Bubble size represents electricity generation (TWh)

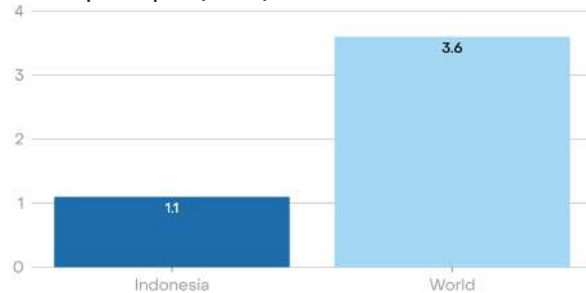
Legend: Indonesia, Top 10 emitters, Other countries



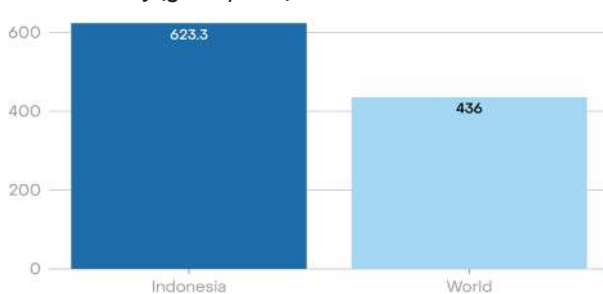
## Indonesia vs world - emissions and demand

Legend: Indonesia, World

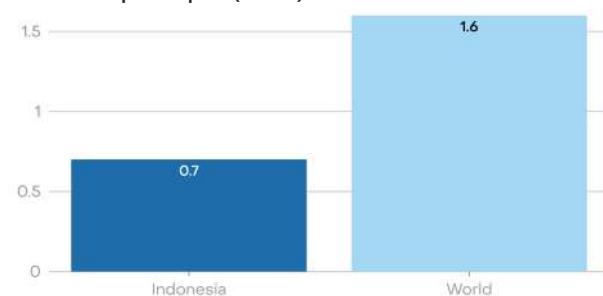
### Demand per capita (MWh)



### CO2 intensity (gCO2/kWh)



### Emissions per capita (tCO2)



Source: Ember

Note: 2022 data used where available, else 2021

# Change in 2021

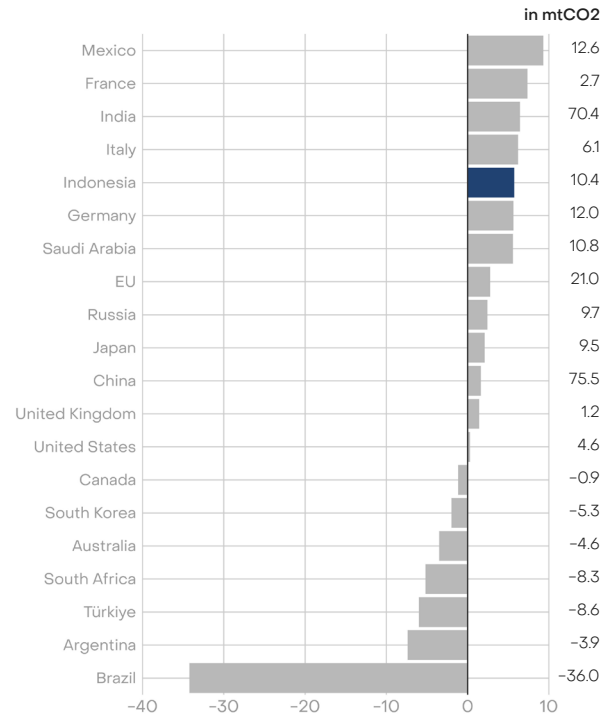
Indonesia's electricity demand in 2021 was 5.7% (+17 TWh) higher than in 2020. This was slightly lower than the global demand change in 2021 of 5.9%, and higher than Indonesia's average demand growth rate between 2010 and 2020 of 2.6%.

As a result of the demand growth and the high share of fossil generation in the mix, Indonesia's power sector emissions increased by 5.7% (+10 million tonnes of CO<sub>2</sub>). This was slightly below the global increase of emissions in 2021 of 7%.

Coal, gas and bioenergy satisfied most of the additional demand. Coal generation increased by 5% (+9.1 TWh) and gas generation grew by 9.7% (+5 TWh). Bioenergy grew by 21% (+2.6 TWh). Hydro only saw a small absolute increase (+1.5%, +0.4 TWh), as did other renewables (+2.2%, +0.3 TWh). Solar generation increased by 12% — a 0.02 TWh increase, given Indonesia's low levels of solar generation. Wind generation fell slightly by 6.4% (-0.03 TWh).

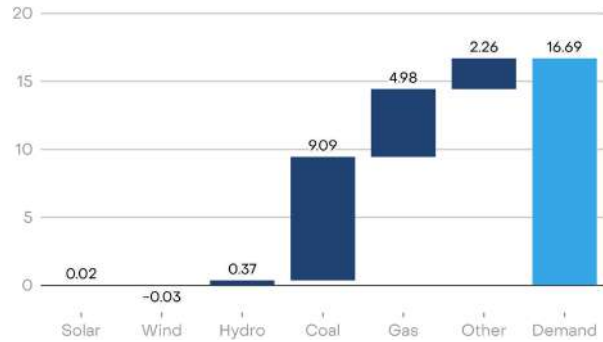
## G20 changes in power sector emissions

Change in CO<sub>2</sub> emissions year-on-year (%)



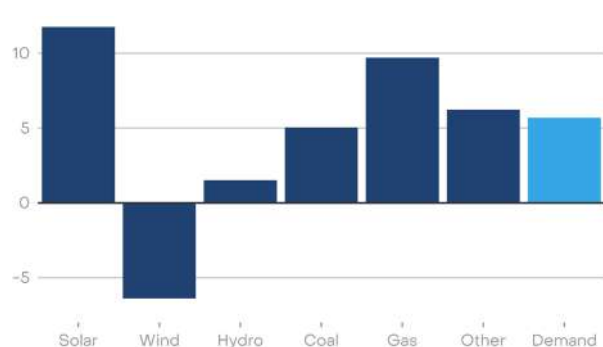
## Indonesia's change in electricity generation

Change in generation year-on-year (TWh)



## Indonesia's change in electricity generation

Change in generation year-on-year (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Long-term Trends

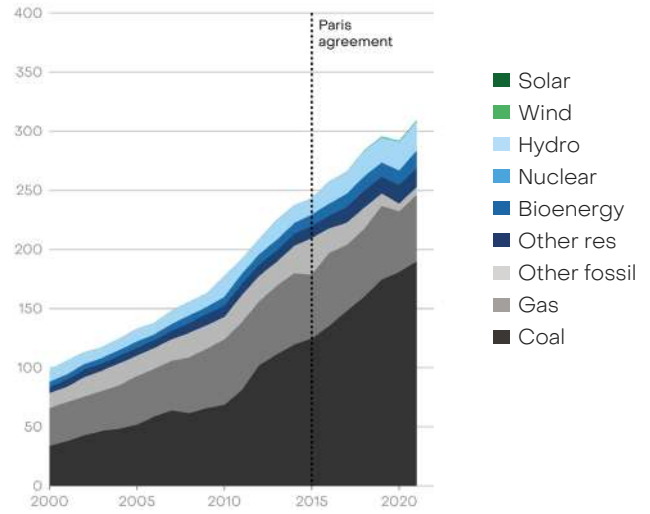
Indonesia has experienced strong demand growth over the last two decades. Its electricity demand more than tripled since 2000 (+216%, +212 TWh) from just 98 TWh in 2000 to 310 TWh in 2021. In the same period, global demand increased by 86%. Emissions intensity of electricity production increased from 548 gCO<sub>2</sub>/kWh in 2000 to 623 gCO<sub>2</sub>/kWh in 2021 due to the increased use of coal power in the electricity mix. As a consequence of demand growth and the higher intensity fuel mix, emissions from the power sector were almost four times larger in 2021 (193 MtCO<sub>2</sub>) than in 2000 (54 MtCO<sub>2</sub>).

Since the Paris Agreement in 2015, Indonesia's power sector emissions have increased by 26% (+39 MtCO<sub>2</sub>). The country has significantly reduced its use of other fossil fuels (mostly oil) for power generation (-78%, -24 TWh), but increasing coal use since 2015 (+52%, +65 TWh) still dominates the trajectory of the power sector.

Indonesia's transition to wind and solar lags significantly behind the world average. Only 0.2% of generation came from wind and solar in 2021 (up from 0% in 2015). During the same period, global wind and solar share increased from 4.6% to 10.4%.

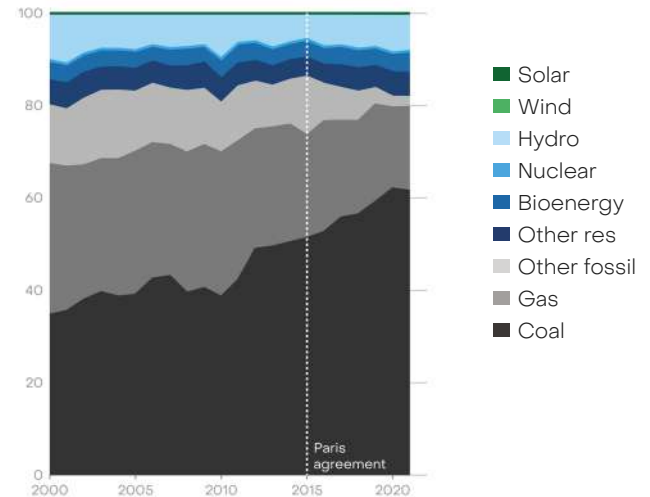
## Indonesia's electricity generation

Electricity generation (TWh)

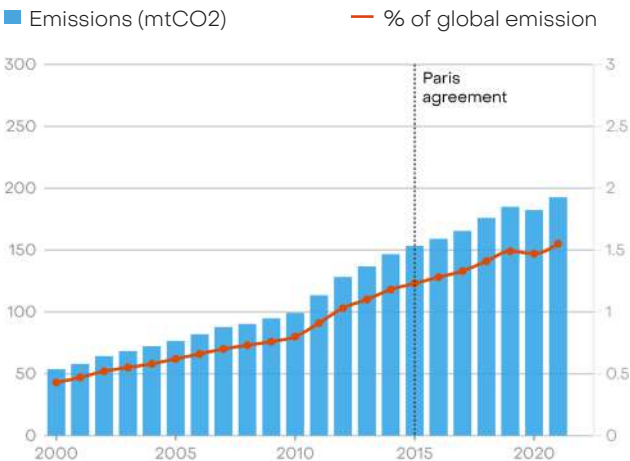


## Indonesia's electricity mix

Share of electricity (%)



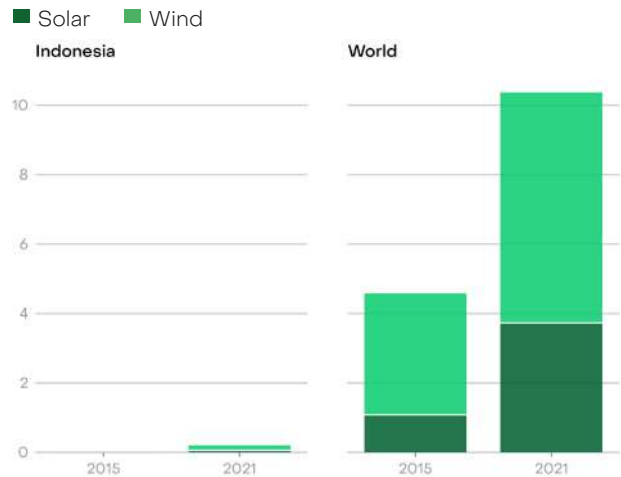
## Indonesia's power sector emissions



Source: Ember

## Indonesia vs world - wind and solar share

Share of electricity (%)



Note: 2022 data used where available, else 2021

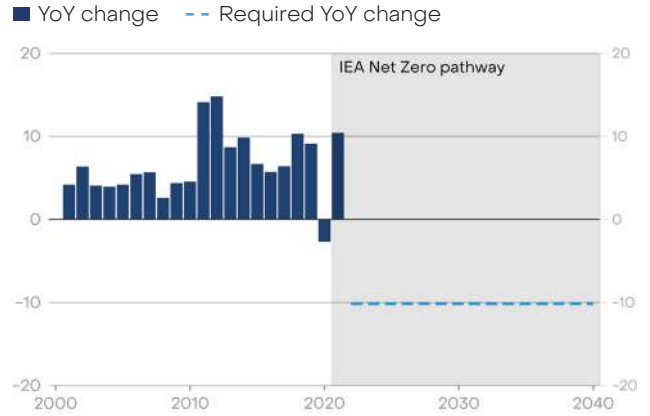
# Progress Towards Net Zero

To reach zero emissions from the power sector by 2040, in line with the [IEA Net Zero Emissions scenario](#), Indonesia's emissions need to fall 10 million tonnes per year. This is in contrast to an average annual rise in power sector emissions of 6.5 million tonnes that the country has seen since 2015. The continued use of coal to meet new electricity demand and the slow build up of wind and solar are significant hurdles that Indonesia will need to overcome.

In 2022, Indonesia secured a [Just Energy Transition Partnership](#) that will provide \$20 billion over the next three to five years to accelerate a just energy transition. [Analysis by Ember](#) shows that the JETP commitment to cap power sector emissions at 290 million tonnes of CO2 is broadly consistent with the Announced Pledge Scenario from the [IEA](#), which aligns with the government's target to achieve Net Zero Emissions for all sectors by 2060. However, it falls short of a pathway aligned with the IEA's more ambitious NZE pathway.

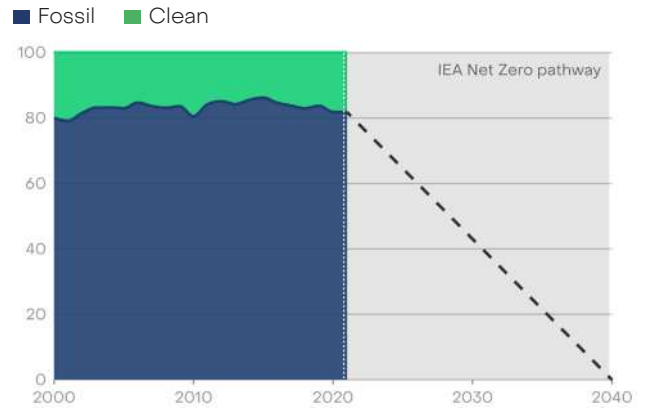
## Indonesia's power sector emissions

Change in CO2 emissions year-on-year (mtCO2)



## Indonesia's electricity mix

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Iran

## Global Electricity Trends 2022

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Iran had the world's tenth most CO<sub>2</sub>-emitting power sector, responsible for 183 million tonnes of CO<sub>2</sub> in 2022, or 1.5% of total global emissions from electricity generation.

Iran generates around 94% of its electricity from fossil fuels: 79% (294 TWh) from gas, 15% (54 TWh) from other fossil fuels and 0.2% (0.7 TWh) from coal. Hydro now makes up 4.5% (17 TWh) and nuclear 1% (3.5 TWh). Wind and solar make up just 0.5% (1.8 TWh) of the electricity mix.

Iran's electricity has an emission intensity of 494 gCO<sub>2</sub>/kWh, higher than the global average of 436 gCO<sub>2</sub>/kWh. Annual demand per capita is 4.2 MWh, which is also higher than the world average of 3.6 MWh. Per capita emissions in Iran are nearly a third higher than the world average, with 2.1 tonnes of CO<sub>2</sub> per capita compared to 1.6 tonnes globally.

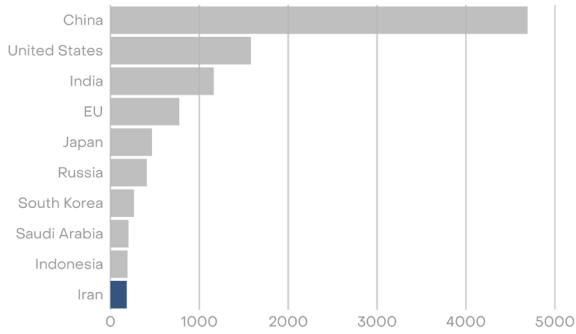
As the 10th largest global power sector emitter, efforts to reduce emissions through the build up of wind, solar and other clean electricity sources can have a large impact on the global effort to achieve net zero by 2050.



# Global Context

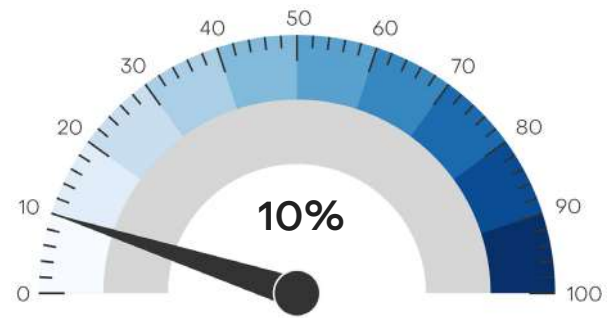
## Top 10 power sector emitters

CO2 emissions (million tonnes)



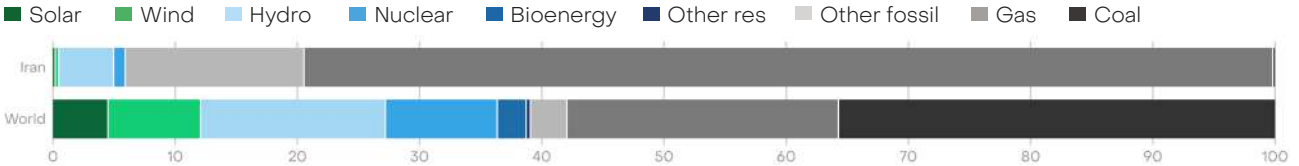
## Iran's electrification

Electricity as a percentage of final energy consumption (%)



## Iran vs world - electricity mix

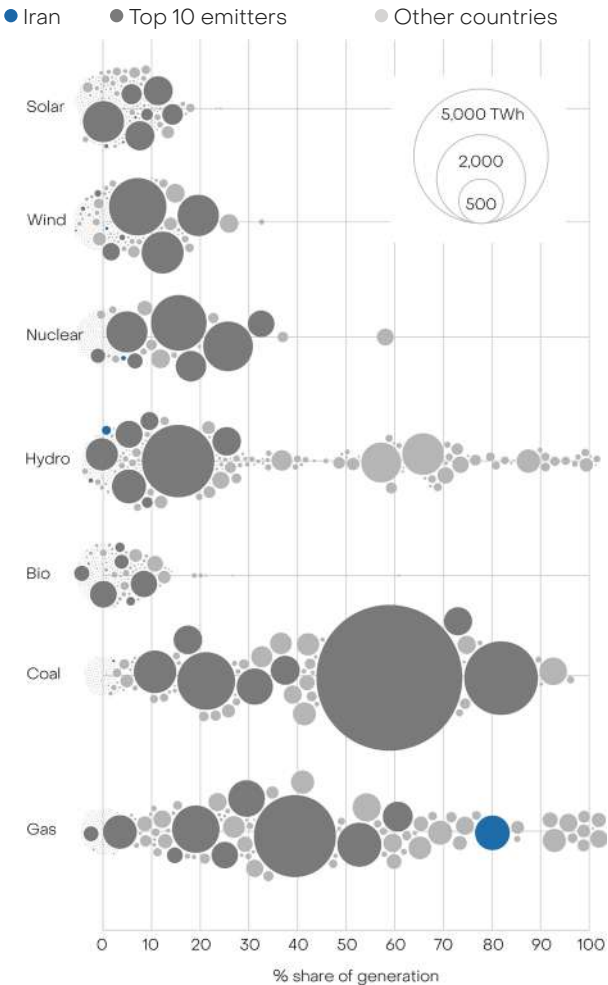
Share of electricity (%)



## Iran vs world - sources of electricity

Share of electricity (%)

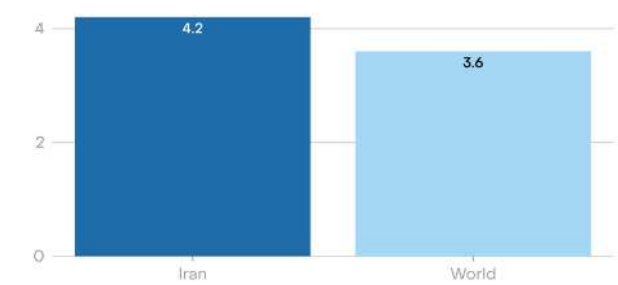
Bubble size represents electricity generation (TWh)



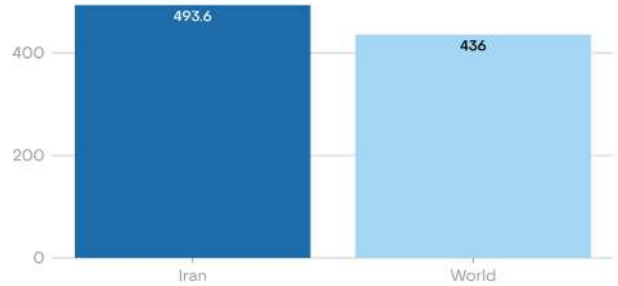
## Iran vs world - emissions and demand

● Iran ● World

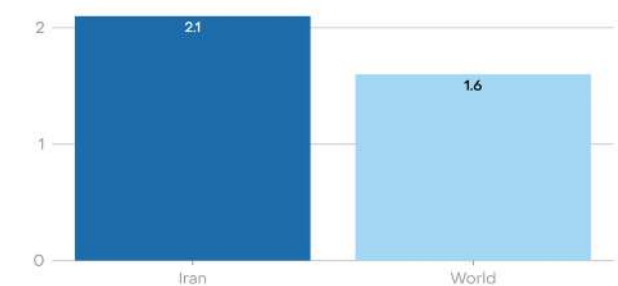
### Demand per capita (MWh)



### CO2 intensity (gCO2/kWh)



### Emissions per capita (tCO2)



Source: Ember

Note: 2022 data used where available, else 2021

## Change in 2022



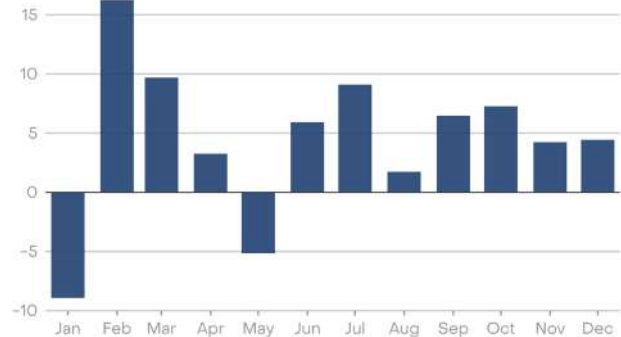
Iran’s electricity demand increased by 4.4% in 2022 (+15.7 TWh). This was significantly higher than the global demand increase of 2.6%, but only slightly higher than Iran’s average demand growth of 4% for 2010–2021.

Due to its heavy reliance on fossil fuels and a rise in demand, Iran’s power sector emissions rose by 3.8% in 2022 (+6.7 million tonnes of CO2), far above the global power sector emissions rise of 1.3%.

Gas generation saw the largest absolute increase, rising 5.7 TWh (+2%). Other fossil fuels saw the largest percentage increase at 12% (+5.6 TWh). Gas and other fossil fuels together met 72% of the increase in demand. Hydro also grew by 12% (+1.7 TWh), meeting 11% of the increase in electricity demand. The remaining increase in demand was met by net imports, which increased by 2.8 TWh.

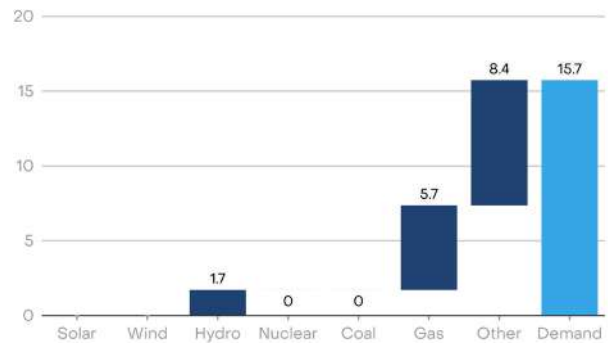
### Iran’s monthly changes in emissions

Change in CO2 emissions year-on-year (%)



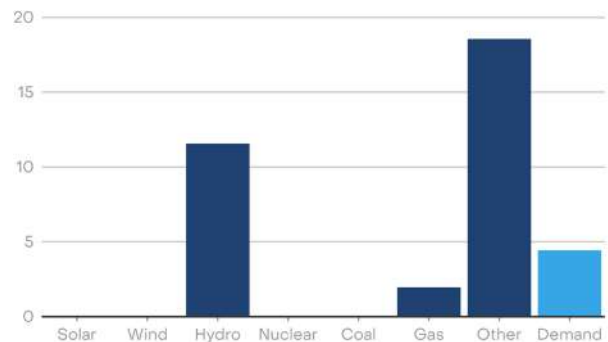
### Iran’s change in electricity generation

Change in generation year-on-year (TWh)



### Iran’s change in electricity generation

Change in generation year-on-year (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Long-term Trends



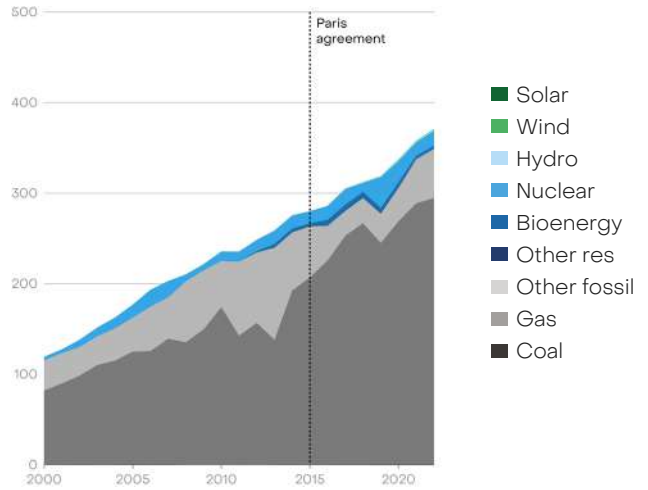
Iran's electricity demand has grown by 212% (+251 TWh) in the last two decades, from 119 TWh in 2000 to 370 TWh in 2022. This is considerably faster than the global demand increase of 90% over the same period. Emissions intensity in 2022 (494 gCO<sub>2</sub>/kWh) was slightly below 2000 levels (535 gCO<sub>2</sub>/kWh), due to increases in hydro and wind and the introduction of solar into the mix. Because of the majority fossil fuel grid, total annual power sector emissions have increased by 187% (+119 million tonnes of CO<sub>2</sub>) over the same period, roughly in line with the demand increase.

Since the Paris Agreement in 2015, Iran's power sector emissions have risen by 29% (+42 million tonnes of CO<sub>2</sub>). Increased demand since 2015 has primarily been met by gas generation, which rose by 42% (+87 TWh) to meet growing electricity demand. At the same time, hydro grew by 25% (+3.4 TWh) and nuclear grew fractionally by 1.1% (+0.04 TWh), displacing other fossil fuels which fell by 3.5% (-2 TWh) in the same period.

Iran's transition to wind and solar is significantly slower than the global average. Wind and solar now account for 0.5% of electricity production, up from just 0.05% in 2015. Comparatively, the global share of wind and solar increased from 4.6% to 12.1% in the same period.

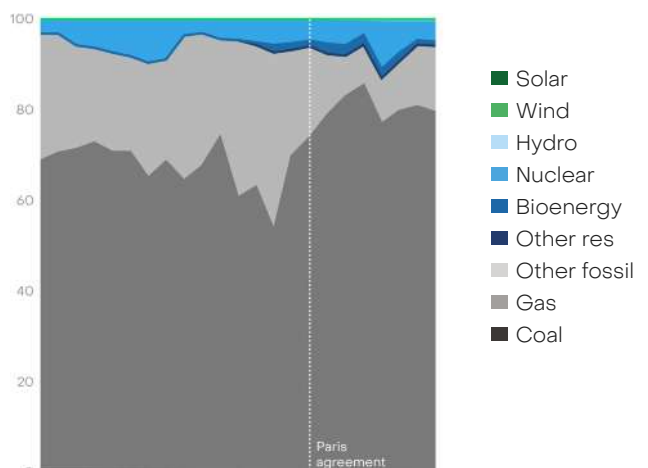
## Iran's electricity generation

Electricity generation (TWh)

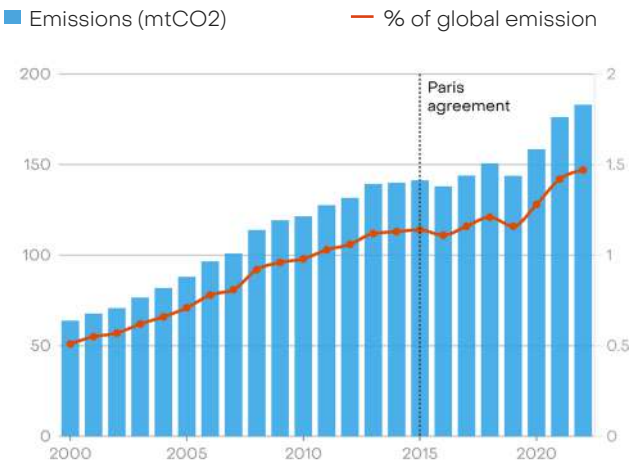


## Iran's electricity mix

Share of electricity (%)

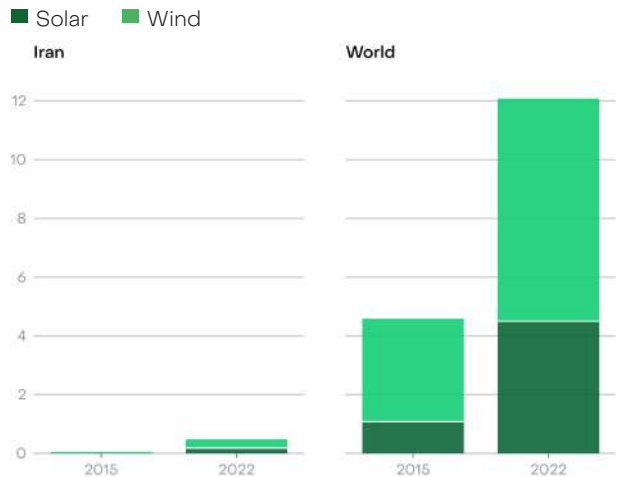


## Iran's power sector emissions



## Iran vs world - wind and solar share

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

# Progress Towards Net Zero

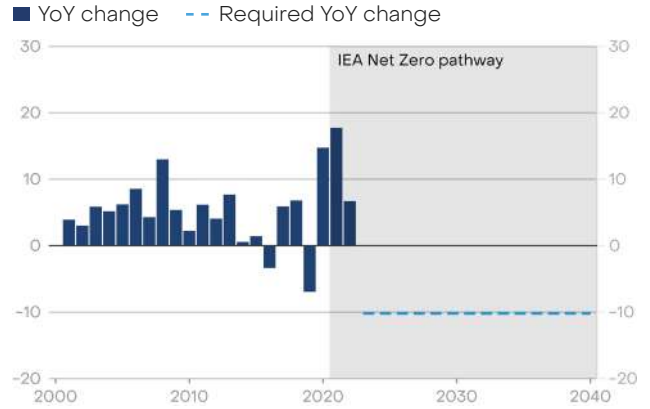


Iran's power sector emissions need to fall to zero by 2040 from the current 183 million tonnes of CO2 to align with the [IEA Net Zero Emissions scenario](#). For that target, emissions will need to fall by 10 million tonnes per year, reversing the average annual increase of 6 million tonnes seen since 2015.

Iran has so far not submitted a target date for [achieving net zero emissions](#). Its current electricity mix is dominated by fossil fuels (94%). Although there were plans to add [10 GW](#) of renewable electricity capacity between 2022–2025, the country faces difficulties in accessing finance due to a number of sanctions. [According to some experts](#), this is hindering renewable electricity projects.

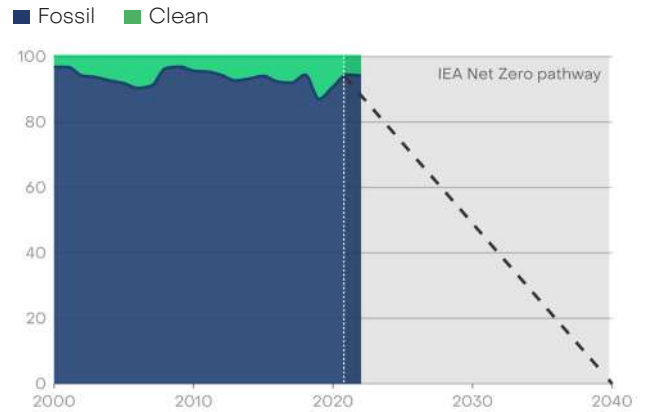
## Iran's power sector emissions

Change in CO2 emissions year-on-year (mtCO2)



## Iran's electricity mix

Share of electricity (%)



Source: Ember

Note: 2022 data used where available, else 2021

## Conclusion

# 2022 – a turning point in the electricity transition

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**The electricity sector is not yet seeing the emissions declines needed for 1.5C, but change is coming fast.**

Emissions rose in 2022 where they should be falling fast. For emissions to fall, first the increase in demand must be met by clean electricity sources. Then clean sources must continue to grow to replace fossil fuels and bring emissions down. Although this didn't happen last year, there are strong signs that 2022 was a turning point in the global electricity transition. If that's the case, then 2022 could be the all-time peak of power sector emissions.

Following the energy crisis and security of supply concerns due to the Russian invasion of Ukraine, many governments rethought their dependency on fossil fuels. This shift could have a lasting and fundamental impact on the pace of energy transition globally. Wind and solar are being prioritised not only because they are clean, but also because in many countries they are cheaper and more secure than fossil fuels. [Investment](#) in low carbon energy technology surpassed \$1 trillion in 2022—for the first time matching the investment in fossil fuels. This is a good sign but investment must triple by the end of this decade to put the world on track for 1.5C.

Much remains to be done to build on the momentum of wind and solar growth. Lowering permitting times and solving grid connection bottlenecks are parts of the solution. Increasing financing in the clean electricity sector will also be crucial, with help from historic emitters to developing nations that can help them to transition from coal to clean.

Acting now brings the most benefits. Investing in renewables will rapidly pay for itself with cheaper electricity. Moreover, securing clean electricity decades ahead of net zero will unlock the most affordable and effective pathways to economy-wide decarbonisation.

However, the electricity transition is not yet accelerating at the pace required to avoid the worst effects of the climate crisis.

There is so much to gain if we succeed, but even more to lose if we fail.

## Supporting materials

# Methodology

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## Data sources

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This report analyses annual power generation and import data for 215 countries from 2000 to 2021, with 2022 data included for 78 countries representing 93% of global power demand. Data is collected from multi-country datasets (EIA, Eurostat, BP) as well as national sources (e.g China data from the National Bureau of Statistics). The latest annual generation data is estimated using monthly generation data. Annual capacity data is collected from GEM, IRENA and WRI. A detailed methodology can be accessed [here](#). All the data can be viewed and downloaded freely from Ember's website.

## Acknowledgements

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