European Electricity Review 2022

Ember's analysis of the EU electricity transition in 2021 reveals a paradigm shift as new wind and solar replaced costly gas instead of dirty coal

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About

The European Electricity Review analyses full-year electricity generation data for 2021 in all EU-27 countries to understand the region's progress in transitioning from fossil fuels to clean electricity. It is the sixth annual report on the EU power sector published by Ember (previously as Sandbag).

The report compares electricity generation in 2021 to benchmark pre-pandemic levels in 2019, providing the first insight into how the gas crisis is affecting the region's power sector after its recovery from the pandemic.

The report compares electricity data from 2021 to both 2020 and 2019. The comparison to 2019 is a far more accurate measure of the EU's overall progress in the transition from coal to clean electricity, than the year-on-year headline figures, which have swung down and then back up again because of the Covid-19 pandemic.

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Disclaimer

The information in this report is complete and correct to the best of our knowledge, but if you spot an error, please email info@ember-climate.org

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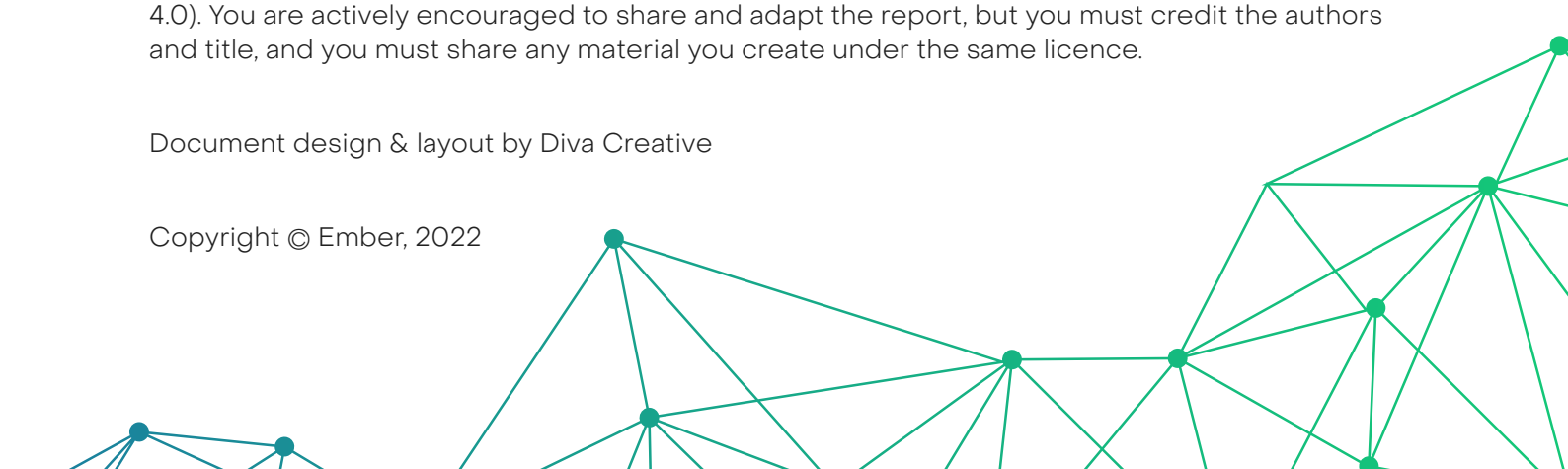

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Executive Summary

Gas crisis interrupts EU coal exit

‘Paradigm shift’ as new renewables replace costly gas instead of dirty coal

The gas crisis created a paradigm shift for the EU’s electricity transition. Historically, Europe’s growing renewables replaced coal power, the most emissions-intensive fuel. However, as a result of soaring gas prices in the second half of 2021, new renewables replaced fossil gas instead. The interruption to the EU’s coal phase-out slowed emission reductions.

Renewables now replacing costly gas - not dirtier coal

Change in EU-27 electricity generation, annual average in terawatt hours

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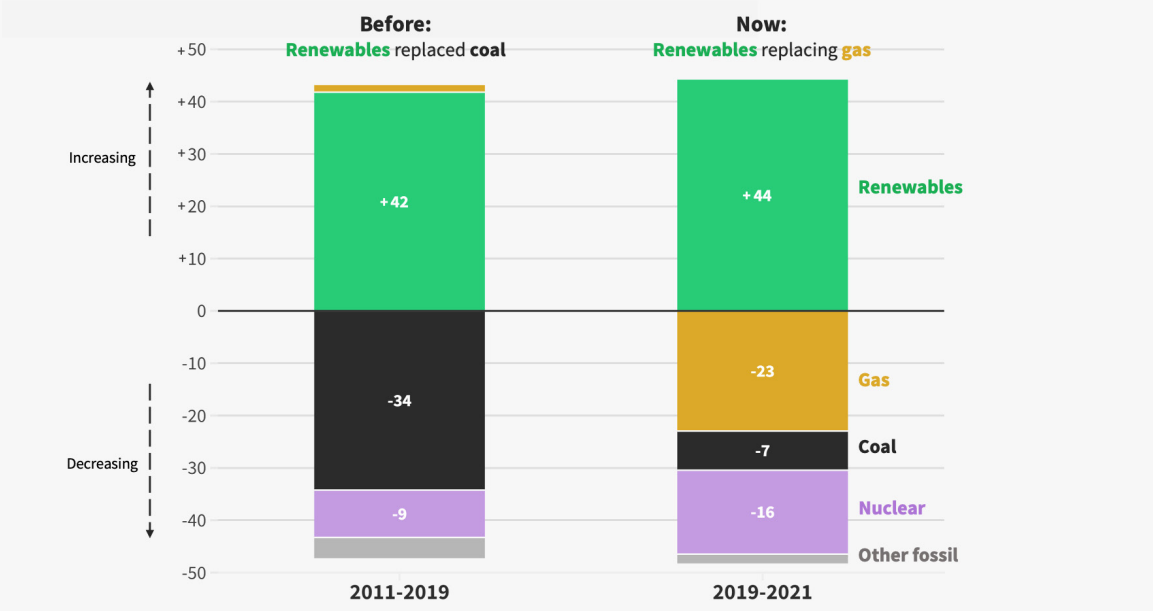


Source: Ember's European Electricity Review 2022

With market prices indicating that the gas crisis will continue for at least the next two years, Europe's climate goals could be at risk if countries fail to step up renewables deployment and legislate to close coal plants.

01

Renewables predominantly replace gas, not coal

Europe's renewable electricity continues to expand, with average annual growth of 44 TWh in the last two years. More than half (52%) of this new renewable generation since 2019 replaced gas power, and a third replaced nuclear, while only a sixth replaced coal. However, prior to this, from 2011 to 2019, over 80% of new renewables replaced coal. Over the last two years, coal generation only declined in countries that closed coal power stations like Spain (-42%) and Greece (-43%), but this was mostly offset by increases in Poland (+7%). Increased nuclear outages and plant closures also reduced the extent to which coal generation fell.

02

Emissions fell at half the rate required for 1.5°c

Between 2019 and 2021, EU power sector emissions declined at less than half the rate required for 1.5°c. The shift from fossil fuels to clean power is not happening fast enough. Coal, the dirtiest fuel, has declined just 3% since 2019, compared to 29% in the two years prior. Spain delivered the largest emissions reductions in the last two years, while Poland was by far the largest drag on overall progress. Fossil fuels still accounted for 37% of EU electricity production in 2021, down from 39% in 2019, while renewables generated 37% and nuclear 26%.

03

Wind and solar delivered throughout the energy crisis

Despite claims to the contrary, EU wind and solar power delivered throughout the energy crisis, setting new records every month in the second half of 2021 except September. Wind and solar power reached another new record in 2021 (547 TWh), for the first time generating more electricity than gas (524 TWh), despite modest growth due to lower wind speeds. Solar, in particular, is booming across both the north and south of Europe, producing 27% more power in 2021 than in 2019, and doubling in the Netherlands and Spain in that period.

“The gas crisis is a paradigm shift for the EU’s electricity transition. Action is needed to ensure Europe’s coal phase-out stays on track. Legislation is the only way to guarantee that coal plants are closed by 2030; volatile gas prices have made it clear that you cannot rely on market forces alone.

It is a huge wake-up call. Both coal and gas need to go; and fast. The benefits to the economy and the climate are clearer by the day. Keeping 1.5°c within reach requires a massive step up in renewables to ensure that all fossil fuels are off the grid by 2035. Now is the moment to double down on Europe’s transition to clean electricity.”

Charles Moore
Europe Lead, Ember

Chapter 2

Headline Trends

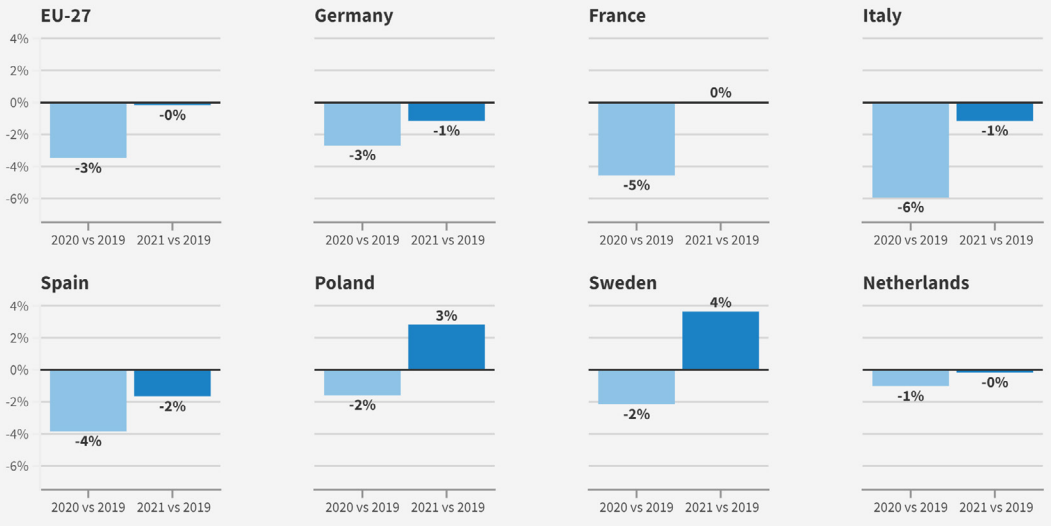
Electricity demand

EU-wide demand returned to pre-pandemic levels

In 2021, the impact of the Covid-19 pandemic on EU electricity demand was quite limited. This is in sharp contrast to 2020, when the pandemic's impact on electricity demand – and subsequently on electricity production – was the major driver of EU electricity system developments. Electricity demand fell during lockdowns in 2020, especially in the first wave of the pandemic, as offices closed, factories were shuttered and people were confined to their homes.

EU-27 electricity demand is back to pre-pandemic levels

Change in electricity demand (%)

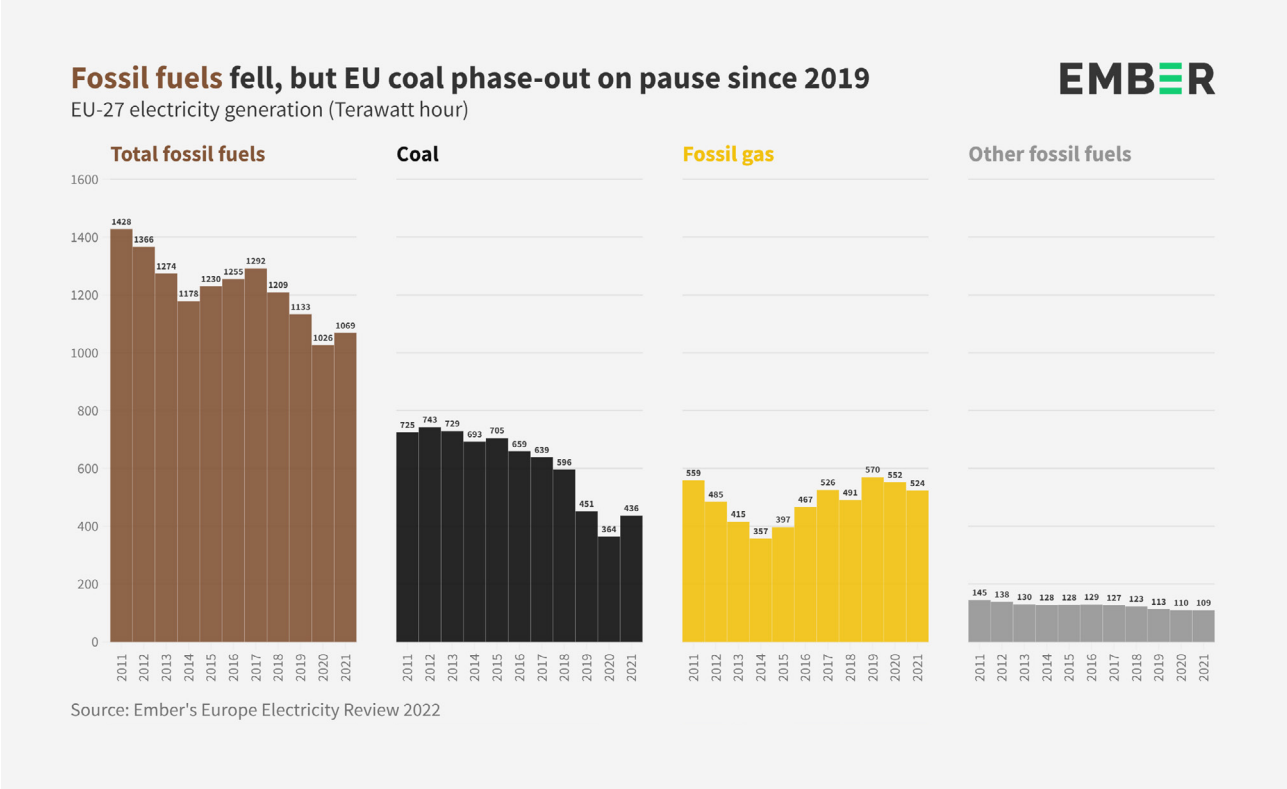


Source: Ember's Europe Electricity Review 2022. The countries displayed are the seven largest electricity consumers in the EU, accounting for 75% of the total.

After falling 3.5% (-100 TWh) between 2019 and 2020, electricity demand recovered nearly all of these losses in 2021, rising 3.4% (+95 TWh) year-on-year and reaching almost the same levels seen before the pandemic in 2019. Overall though, 2021 was a colder year than 2019, which would normally imply higher demand in 2021 all else equal. This indicates that underlying (weather-corrected) electricity demand has yet to fully bounce back from the pandemic.

Demand recovery varies at a national level

Despite EU-wide electricity demand returning to near pre-pandemic levels, the trends vary considerably at a national level. Electricity demand remained notably weaker than pre-pandemic levels in Spain (-2%), while it grew strongly in Poland (+3%), Sweden (+4%) and Denmark (+7%).



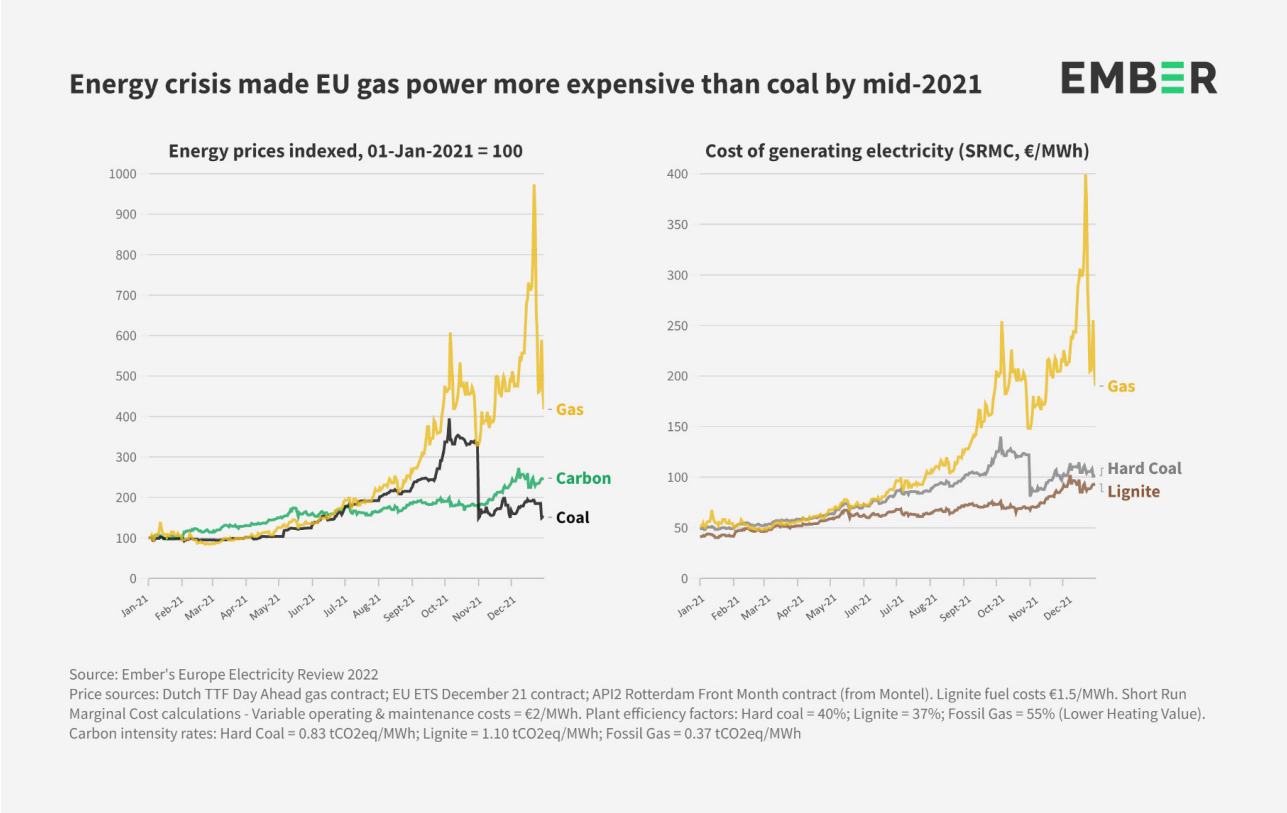
Fossil Fuels

Fossil fuel power grew in 2021 but remains below pre-pandemic levels

In 2021, EU-27 electricity generation from fossil fuels rose 4% (+43 TWh) year-on-year to 1069 TWh. This was primarily due to a 95 TWh (+3%) rise in electricity demand, which recovered after falling during the pandemic.

Electricity generation from fossil fuels remained 6% lower (-64 TWh) than before the pandemic in 2019, as a result of continued growth in renewables (especially wind and solar) over the two-year period.

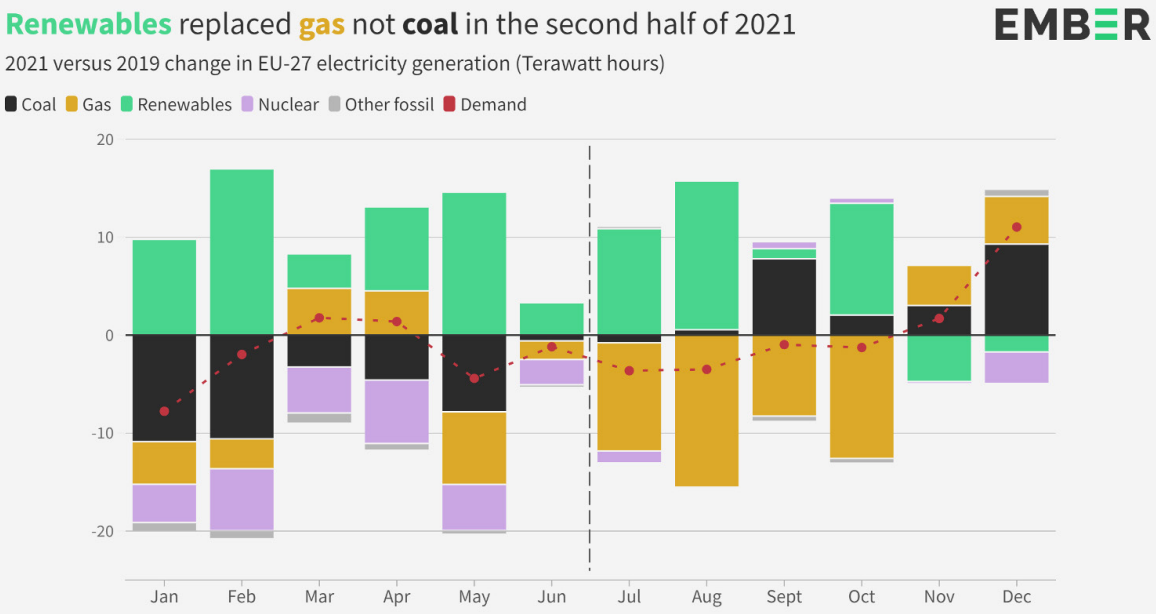
Fossil fuels still accounted for 37% of EU electricity production in 2021, down from 39% in 2019. Fossil gas power hit a 3-year low, generating 18% of EU electricity (524 TWh). Coal generated 15% of EU electricity (436 TWh) and has fallen just 3% since 2019, compared to 29% in the two years prior.



Energy crisis made gas power more expensive than coal by mid-2021

The price of fossil fuels soared in 2021, which upended the electricity market. A combination of factors caused gas prices to rise 585%, resulting in one of the largest energy price shocks since the OPEC oil embargo of 1973. While gas was the main mover, the price of coal and carbon also increased sharply.

Consequently, the cost of generating electricity from fossil gas plants increased almost sevenfold, leading to skyrocketing electricity prices across Europe. From July, the cost of generating electricity from fossil gas was more expensive than coal. The gap widened as the year progressed, despite rising carbon prices, as the gas price exploded.



Source: Ember's European Electricity Review 2022. Monthly data presented here is net electricity generation, whereas annual data elsewhere in the report is gross electricity generation. Therefore, there will be slight differences between aggregated monthly and the annual data.

Renewables replaced gas not coal in the second half of 2021

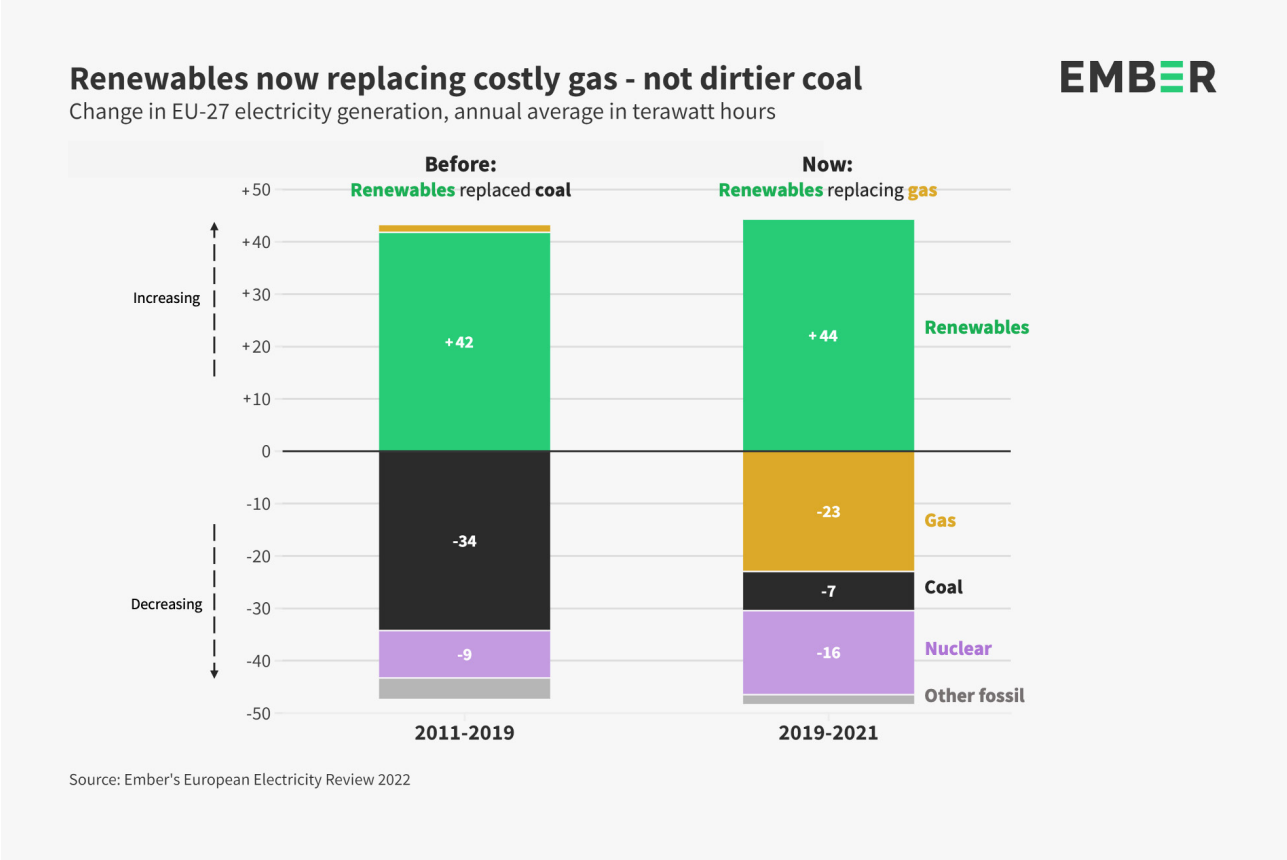
Using 2019 as the baseline, the growth in renewables output predominantly replaced coal in the first half of 2021. However, in the second half of the year, with fossil gas power more expensive than coal, new renewable output replaced fossil gas instead. Furthermore, the second half of 2021 saw some direct replacement of fossil gas with coal, equivalent to approximately 5% of total coal power generation in 2021.

Paradigm shift as new renewables replaced gas – not coal

The new pricing dynamic meant that new renewables predominately replaced expensive fossil gas instead of more emissions-intensive coal generation.

Europe's renewable electricity continues to expand, with average annual growth of 44 TWh in the last two years. More than half (52%) of this new renewable generation since 2019 replaced gas, and a third replaced nuclear, while only a sixth replaced coal. However, prior to this, from 2011 to 2019, over 80% of new renewables replaced coal. Increased nuclear outages and plant closures since the end of 2019 also reduced the extent to which coal generation fell.

The largest falls in fossil gas compared to 2019 were seen in the Netherlands (–17 TWh / –24%) and Spain (–15 TWh / –18%), the two countries with the strongest growth in renewable generation (primarily wind and solar), but there were also notable declines in Belgium (–17%) and France (–14%).



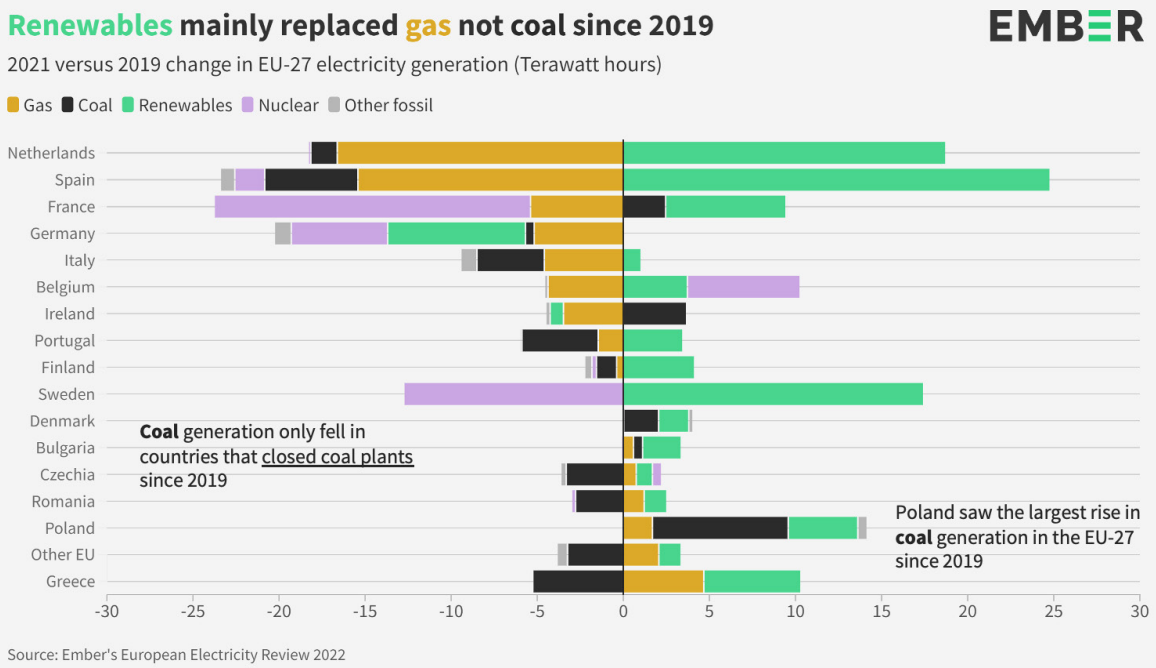
Coal power only declined in countries that closed coal power plants

Although new wind and solar growth since 2019 has predominantly replaced fossil gas, a number of countries have managed to decrease their coal burn. Coal power output in Spain has almost halved since 2019, following the closure of 6.5GW of coal capacity – over half of the fleet – in the last two years.

It is a similar story across the other countries where coal has fallen – the declines have mostly been driven by coal plant closures. In the last two years, Czechia, Greece, Italy, Romania and Portugal all retired about 1 - 2GW each (including power plants retired at the end of 2019). The closures in Portugal made it only the 4th country to go completely coal-free.

Unfortunately, the impact of coal closures in some countries was mostly offset by the increased use of existing coal power stations elsewhere in the EU.

Most notably, Poland's coal power output has increased 7% (+8 TWh) since 2019, as local production increased at the expense of imports from EU neighbours. Poland even became a net exporter of electricity from August 2021 after 53 continuous months of imports. Ireland's coal power output also increased sharply as coal replaced gas, which was exacerbated by a string of gas plant outages.



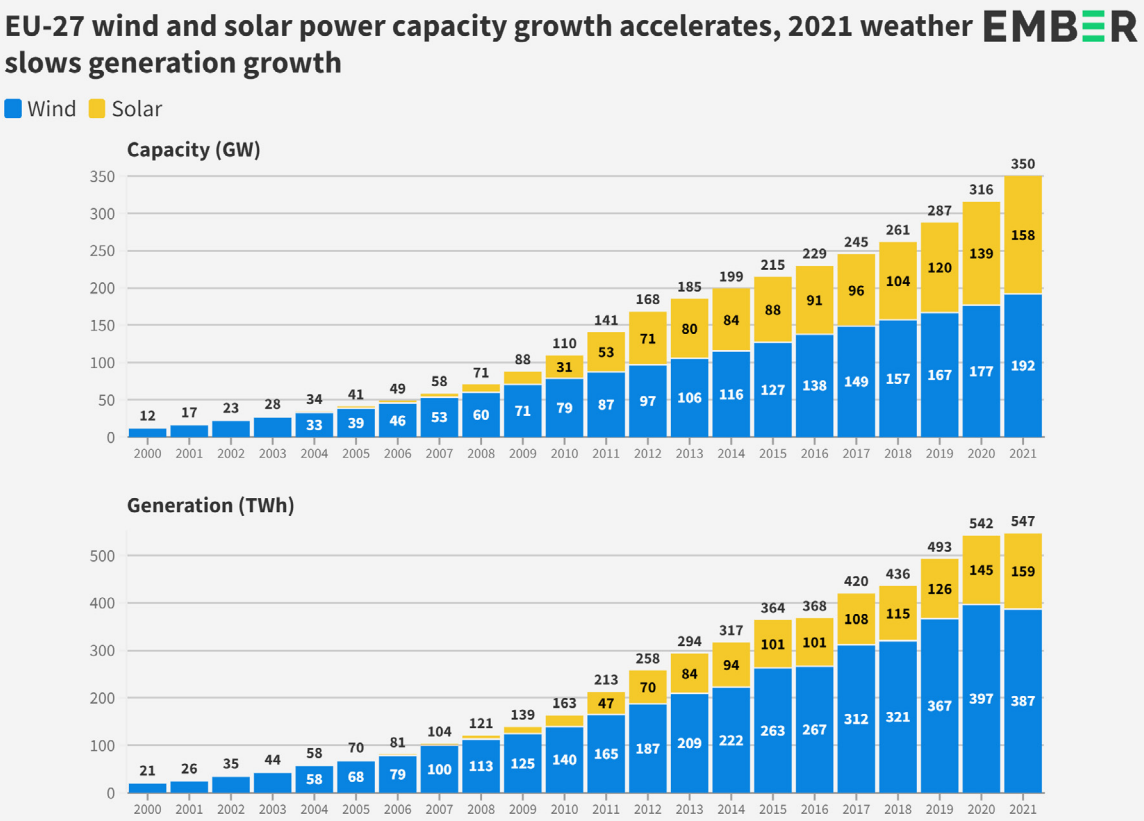
Renewables

Renewables break new records but growth slows

In 2021, electricity generated from renewable sources in the EU reached a new high of 1068 TWh, a 1% increase (+12 TWh) year-on-year, and a 9% (+88 TWh) increase compared to 2019. Renewables accounted for 37% of EU electricity production in 2021, up from 34% in 2019.

Wind and solar power have been responsible for the majority of the renewables growth since 2019. Wind and solar output reached another new record in 2021 (547 TWh), for the first time generating more electricity than fossil gas (524 TWh). Wind and solar generated 19% of EU electricity in 2021, up from 17% in 2019.

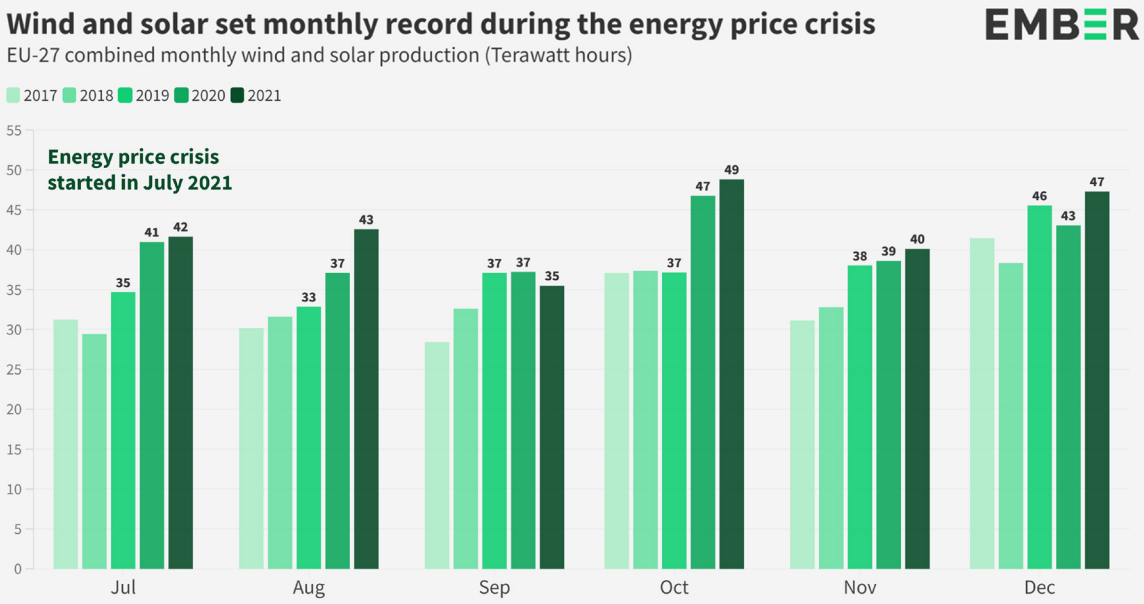
However, year-on-year wind and solar output growth of 1% was modest, due to lower wind speeds, which were below average across the EU, most notably in Germany. 2020 was also a windy year, especially the first quarter, amplifying the difference in 2021. EU wind power output saw a small fall year-on-year (-2% / -10 TWh), but this is equivalent to just 0.3% of total EU electricity production. A 10% (+14 TWh) increase in solar output, which is booming across Europe, more than offset the decline in wind, to ensure continued growth in wind and solar.



Source: Ember's Europe Electricity Review 2022. *2021 capacity estimate taken from IEA Renewables Data Explorer. 2000-2020 capacity data taken from IRENA.

It is not unexpected to see year-on-year variations in output from renewable sources like wind and solar. Modernised, flexible grids supported by long-term energy storage (such as green hydrogen) will ensure future energy security as the share of variable sources increases.

Installed wind and solar capacity across the EU continued to grow in 2021. Wind and solar capacity grew an estimated 8% (+15 GW) and 16% (+22GW) respectively.



Source: Ember's Europe Electricity Review 2022. Monthly data presented here is net electricity generation, whereas annual data elsewhere in the report is gross electricity generation. Therefore, there will be slight differences between aggregated monthly and the annual data.

Wind and solar delivered throughout the energy crisis

The electricity price crisis began in earnest in the second half of 2021, as fossil gas price rises accelerated. Despite claims to the contrary, wind and solar power have delivered throughout the crisis. EU wind and solar power output was the highest on record for each month in the second half of 2021 except September. Despite concerns raised about low wind output in particular, wind output alone grew 2% in the second half of 2021 compared to the same period in 2020.

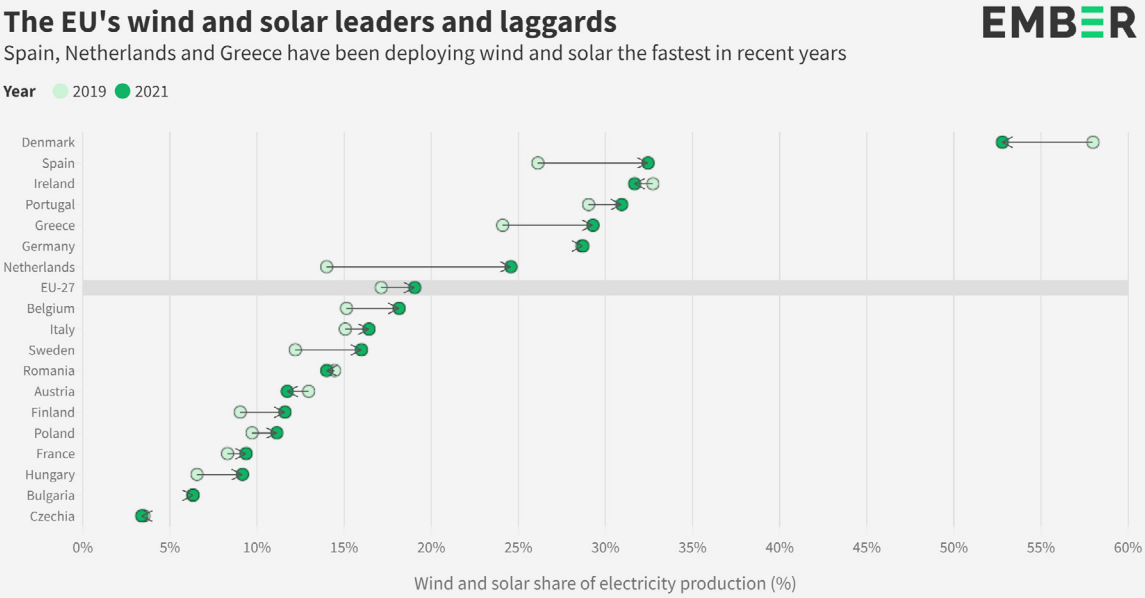
In reality, the extraordinary rise in fossil fuel prices, especially fossil gas, is by far the largest driver of the electricity price rises seen this year.

The EU has three new engines of wind and solar power growth

Spain, the Netherlands and Greece have become the new engines of EU wind and solar power growth. In each country, wind and solar power's market share grew by about 10 percentage points in just three years, after slow to minimal growth in the previous three years.

Wind and solar provided a third of Spain's electricity in 2021, and at least a quarter in the Netherlands and Greece. Together these countries have been responsible for over half of all growth in wind and solar output in the EU since 2019, despite accounting for just 16% of electricity demand.

Wind and solar growth in these countries is being driven by supportive policy frameworks, falling costs and ambitious targets. Both Spain and the Netherlands plan to provide about two-thirds of their electricity from wind and solar by 2030, with Greece targeting 50%. This is in sharp contrast to countries such as Poland and Italy, where renewables are still not expanding fast enough, or countries such as Bulgaria, Czechia and Romania which have failed to deploy almost any wind and solar.



Only modest changes for the other renewable sources

After seeing very limited growth since 2015, bioenergy grew 4% (+7 TWh) between 2019 and 2021, almost entirely driven by new biomass co-firing in coal power stations in the Netherlands. Hydro output was normal in 2021 and broadly unchanged year-on-year, but it was 9% (+28 TWh) higher than 2019 which was a relatively dry year.

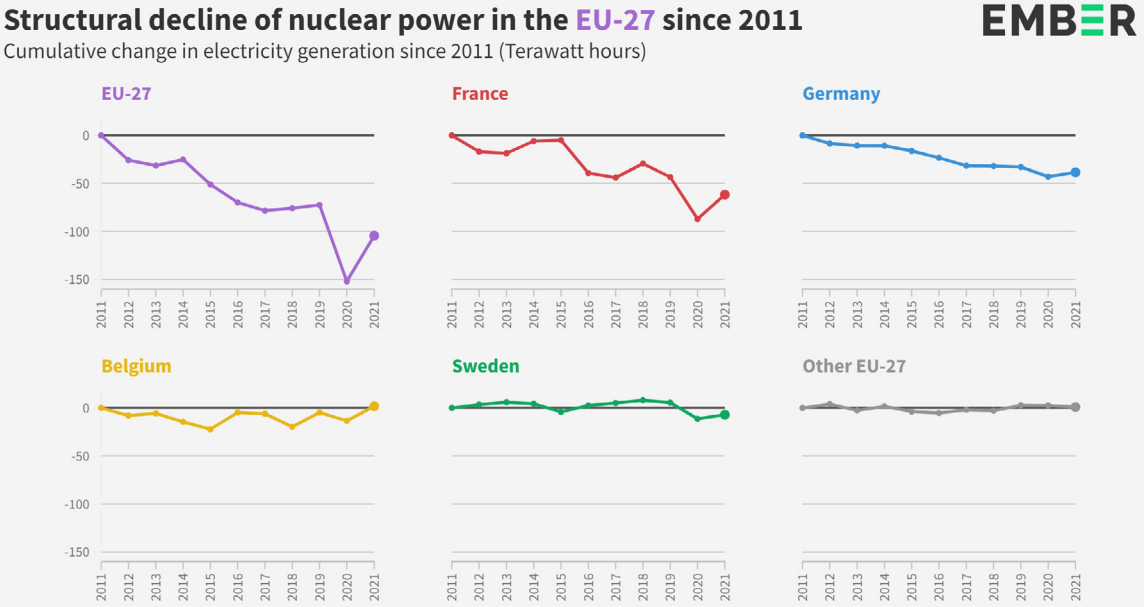
Note: bioenergy is treated as a renewable energy source in EU legislation, but recent scientific evidence shows that many forms of bioenergy risk significant carbon emissions.

Nuclear

Nuclear recovers from its pandemic slump but remains in long-term decline

In 2021, nuclear power stations in the EU produced 733 TWh of electricity. This was 7% (+47 TWh) more than 2020 as French and Belgian power plant availability improved. However, nuclear output remained 4% lower (-32 TWh) than in 2019, primarily caused by the planned closure of nuclear reactors. Nuclear accounted for 26% of EU electricity production in 2021, down from 29% ten years ago.

The declines in nuclear power output since 2019 were led by France (-18 TWh), Sweden (-13 TWh) and Germany (-6 TWh). All three countries have closed at least 1.8 GW of nuclear capacity since the end of 2019. This was only partially offset by improved output in Belgium (+7 TWh).



The long-term, structural decline of nuclear power in the EU has slowed power sector decarbonisation. Some of the growth in renewables output is needed to replace lost nuclear output, slowing down the replacement of fossil fuels. This trend looks set to continue in the near future.

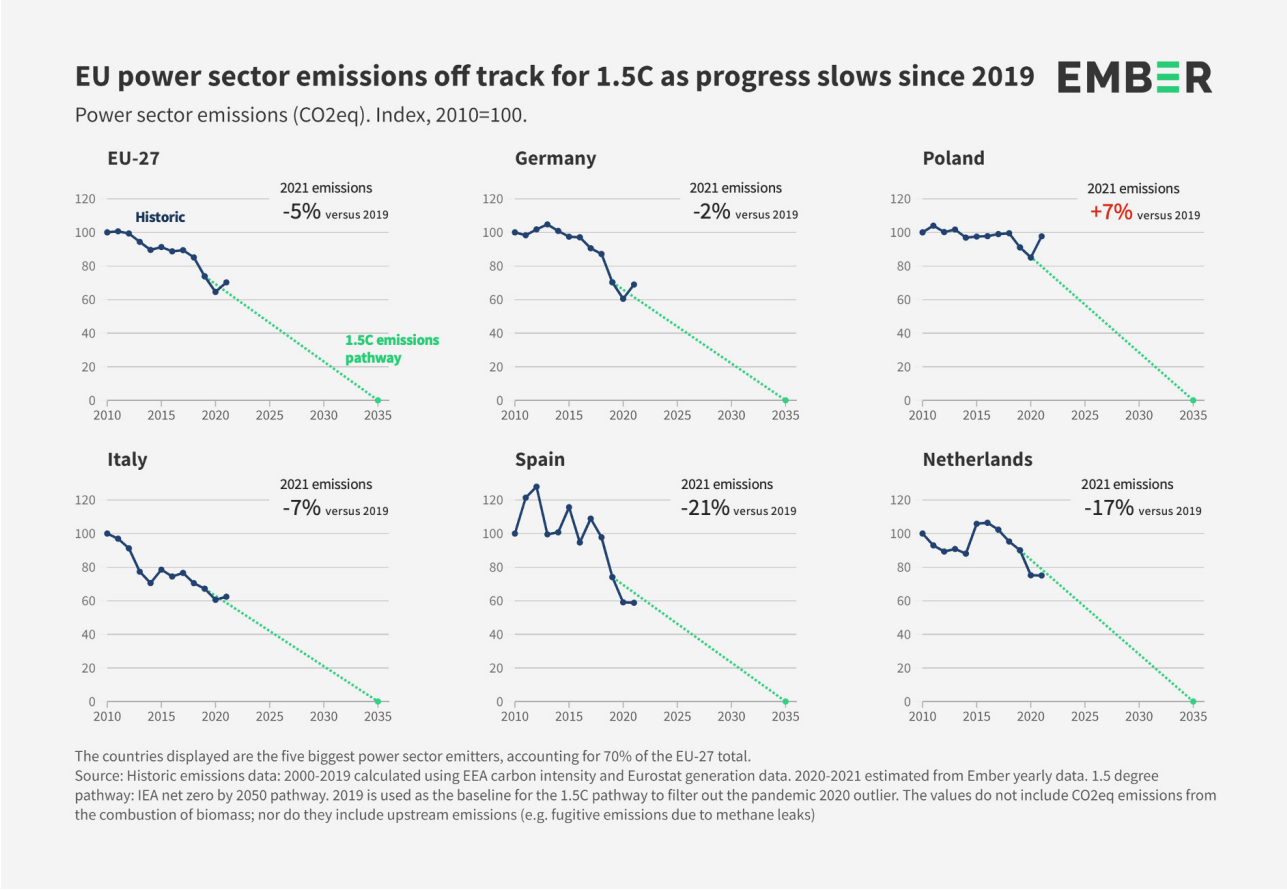
Emissions

EU power sector emissions are not on track for 1.5°c

According to the International Energy Agency (IEA), limiting global temperature rise to 1.5°c and avoiding the worst impacts of the climate crisis, will require power sector emissions to reach zero by 2035 in advanced economies (which includes the EU). Using 2019 as the baseline (to filter out the pandemic 2020 outlier), power sector emissions would need to decline at an average annual rate of 6% per year to reach zero emissions by 2035.

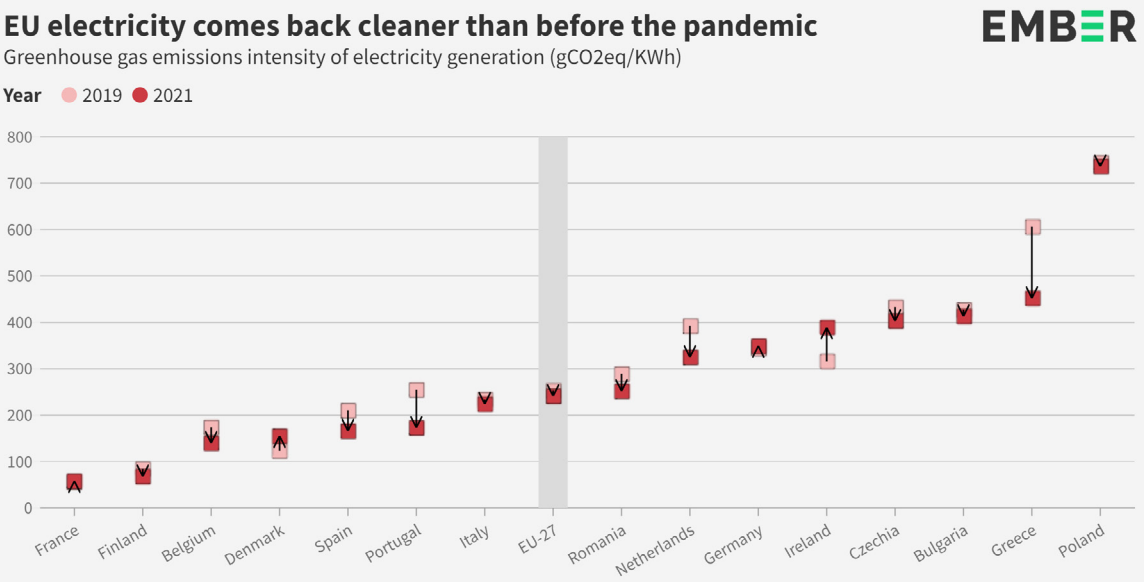
Ember estimates that (direct) greenhouse gas (GHG) emissions from the EU power sector were 700 MT CO2eq in 2021, equivalent to an average annual decline of just 2.5% per year since 2019. Therefore, EU power sector emissions fell at less than half the rate needed to stay on track for 1.5°c.

Emissions are not falling fast enough because clean power isn't replacing fossil fuels fast enough. And where it is, it's now replacing gas rather than more emissions-intensive coal, further slowing progress.



The countries displayed are the five biggest power sector emitters, accounting for 70% of the EU-27 total.
Source: Historic emissions data: 2000-2019 calculated using EEA carbon intensity and Eurostat generation data. 2020-2021 estimated from Ember yearly data. 1.5 degree pathway: IEA net zero by 2050 pathway. 2019 is used as the baseline for the 1.5C pathway to filter out the pandemic 2020 outlier. The values do not include CO2eq emissions from the combustion of biomass; nor do they include upstream emissions (e.g. fugitive emissions due to methane leaks)

Spain was the largest contributor to EU power sector emissions reductions, and most countries saw power sector emissions declines compared to 2019. Poland was a notable exception, and was by far the largest drag on overall progress, with emissions increasing 7% compared to 2019, although Bulgaria, Denmark and Ireland all posted large emissions gains due to coal increases.



Emissions intensity

EU electricity is cleaner than 2019

The emissions intensity of EU electricity generation (the amount of GHG emitted per unit of electricity) declined from 253gCO2eq/kWh in 2019 to 241gCO2eq/kWh in 2021. There remains a huge gulf between the cleanest and dirtiest electricity grids across the EU.

Chapter 3

Emerging Trends

The credibility of fossil gas as a transition fuel vanishes

The 2021 gas crisis created a paradigm shift for the EU's electricity transition. Skyrocketing fossil gas prices meant that new wind and solar replaced fossil gas rather than coal. With market prices indicating that the gas crisis will continue for at least the next two years, the prospects for fossil gas as a "transition fuel" in the power sector look severely damaged.

The gas crisis caused the EU electricity price spike

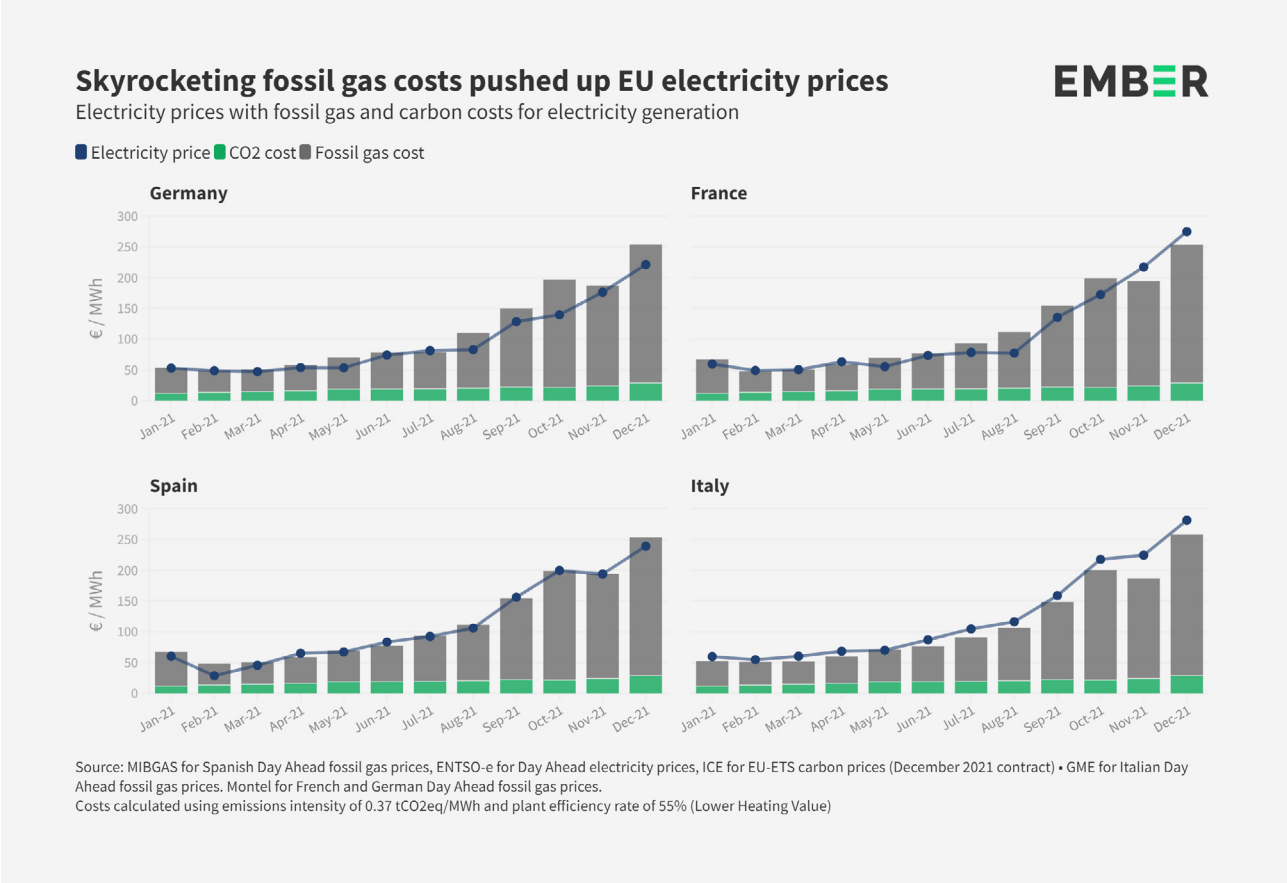
Fossil gas prices have risen exponentially in 2021. TTF day-ahead (the EU gas benchmark contract) was up 585% in December 2021 versus December 2020.

This unprecedented surge in fossil gas prices has been caused by a combination of factors:

- a cold northern hemisphere winter in early 2021 depleted fossil gas storage levels
- increased demand and prices in Asia and South America resulted in liquefied natural gas (LNG) being delivered there rather than to Europe
- global demand for gas rose as Covid-19 restrictions were lifted
- lower than expected fossil gas imports arrived into the EU from Russia

The cost of using fossil gas to generate EU electricity, including any associated carbon and variable operating costs, averaged €255/MWh in December 2021.

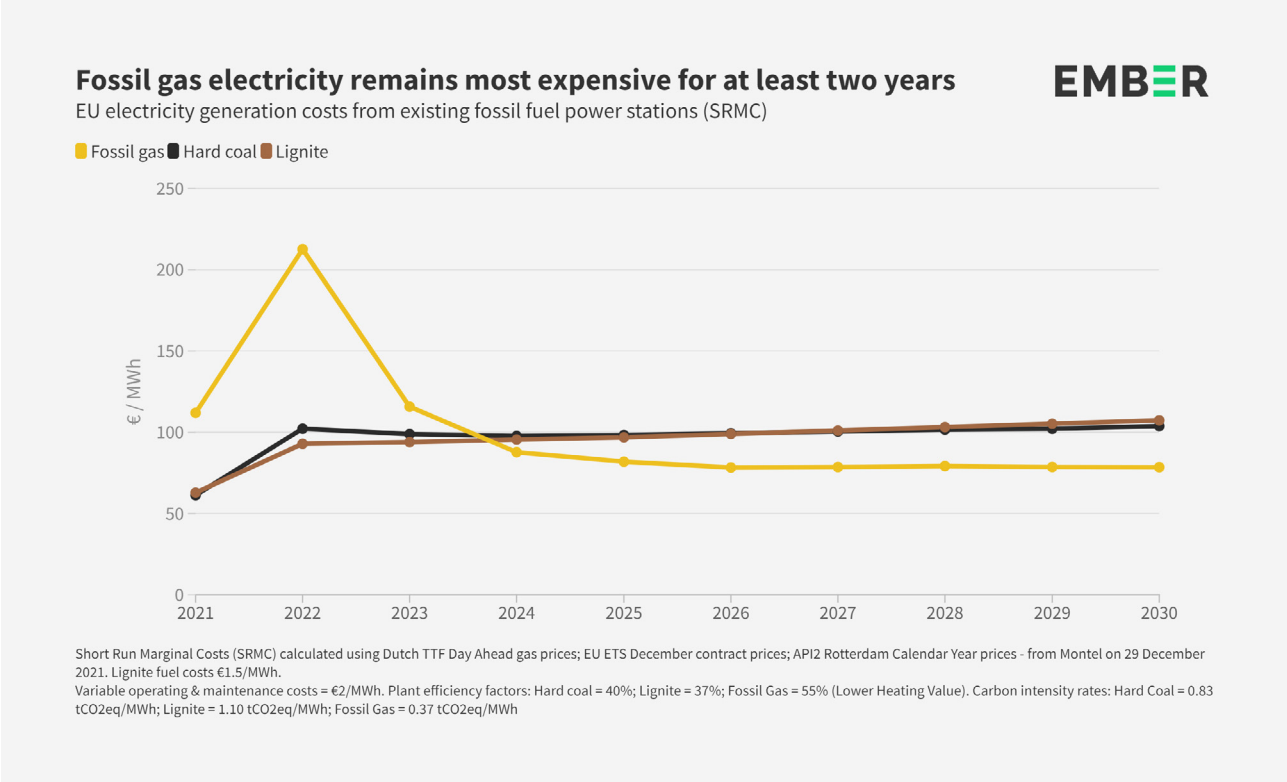
This is an almost sevenfold increase year-on-year. Consequently, electricity prices also soared. Record monthly wholesale power prices were seen across the EU in December 2021. France (€275/MWh); Germany (€221/MWh); Greece (€235/MWh); Italy (€281/MWh); Hungary (€246/MWh); Spain (€239/MWh); and the Netherlands (€238/MWh).



The colossal increase in the costs of fossil gas electricity generation is overwhelmingly due to the underlying cost of the gas itself. While the price of emitting a tonne of carbon (in the EU-ETS) rose from €33/tonne (1 January) to a record high of €89/tonne (8 December), this only adds €21/MWh to the cost of producing electricity using fossil gas and equates to 10% of the increase in gas generation costs in 2021.

The gas crisis could extend beyond 2023

Future gas prices indicate that the crisis is expected to continue for at least the next two years. The TTF Dutch gas calendar year 2022 and 2023 contracts were trading at €90/MWh and €42/MWh respectively at the end of December. At these levels, fossil gas will remain the most expensive method of generating electricity – more than both hard coal and lignite.



The ongoing supply issues and deepening geopolitical unrest have resulted in legitimate concerns that the gas crisis will have a longer-term impact. Some energy analysts believe that the gas crisis will remain until 2025. This significantly increases the risks associated with continued dependence on volatile imported fossil gas for electricity generation as opposed to accelerating the transition to domestic clean electricity.

The gas crisis has made renewables even more competitive

Wind and solar power were already cheaper than fossil gas for electricity generation before the gas crisis hit and they have become even more cost-competitive since, despite global commodity prices increasing their production costs. The International Energy Agency (IEA) recently confirmed that '**higher natural gas and coal prices have improved the competitiveness of wind and solar PV, despite historic equipment price increases due to high commodity and energy prices**'.

Furthermore, with the advancements in storage technologies and the associated cost reductions, wind and solar combined with storage will progressively challenge fossil gas for the provision of flexible as well as bulk electricity generation, as wind and solar become the backbone of Europe's future electricity system.

The time to transition away from fossil gas is now

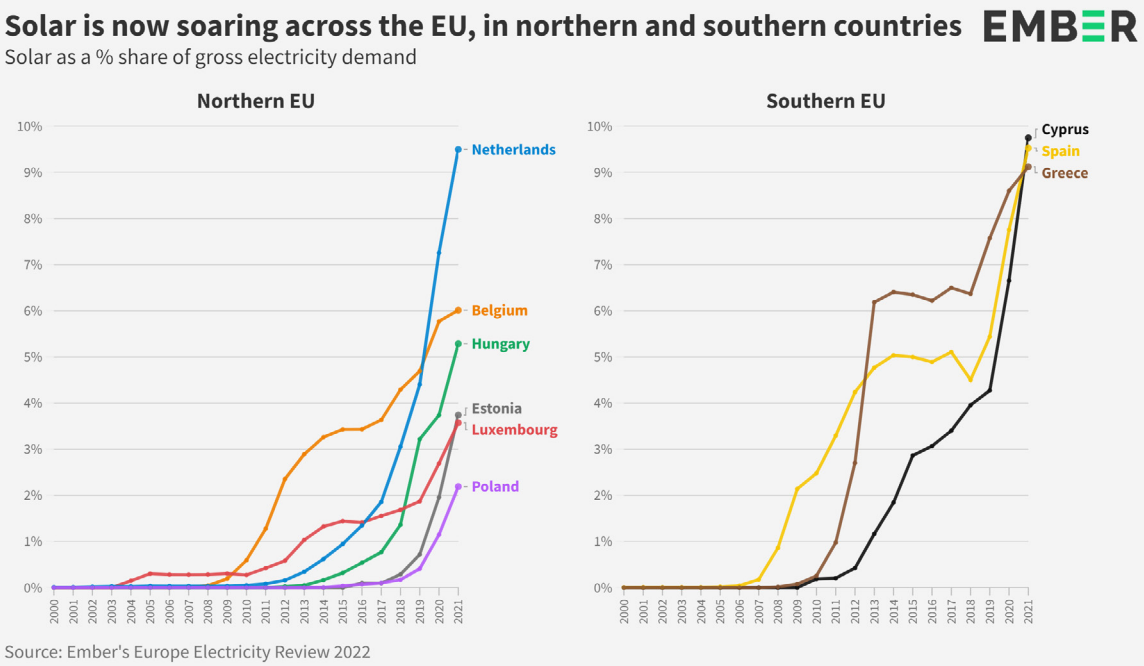
The crisis has provided a powerful reminder that as long as Europe remains reliant on imported fossil fuels it is exposed to volatile energy prices. Coupled with an expensive and uncertain outlook for fossil gas power and further increases in the competitiveness of domestic alternatives such as wind, solar and clean flexibility solutions, the prospects for fossil gas as a transition fuel look severely damaged.

Many countries were relying on renewables to replace more emissions-intensive coal while ignoring their gas problem, but with gas more expensive than coal, market forces alone can no longer be guaranteed to drive this forward. There is now increased urgency to phase out both fuels on economic as well as climate grounds. Renewables will need to be deployed at sufficient scale to rapidly replace both coal and gas.

To limit global warming to 1.5°c, advanced economies (including the EU) must reach zero emissions in the power sector by 2035. Accelerated deployment of renewables in conjunction with increased investment in energy efficiency offers a way out of both the energy and climate crises. In the wake of the crisis more countries look likely to choose this path rather than sticking with fossil gas.

Solar's moment has arrived

For the first time across Europe, wind and solar power combined (547 TWh) generated more electricity than gas (524 TWh). In a year of below average wind speeds, the growth in solar power was vital for passing this milestone: solar produced over 25% more power in 2021 than in 2019 and now produces 6% of Europe's electricity. Many European countries have now laid the foundations for rapid growth in solar, and not just in southern Europe where solar potential is the highest. However, progress across Europe is extremely uneven, with some countries yet to embrace solar.



Solar begins to soar across much of Europe

Spain's solar story is a textbook example for other countries in Europe to follow, almost doubling solar generation since 2019 from 15 TWh to 26 TWh. Spain has the sunshine and the policy framework for this acceleration to continue, and its Minister for the Ecological Transition, Teresa Ribera, has won plaudits for enabling coal areas to directly transition to a growing solar industry. On current plans, solar is set to provide nearly 30% of Spain's electricity generation by 2030 (up from 10% currently).

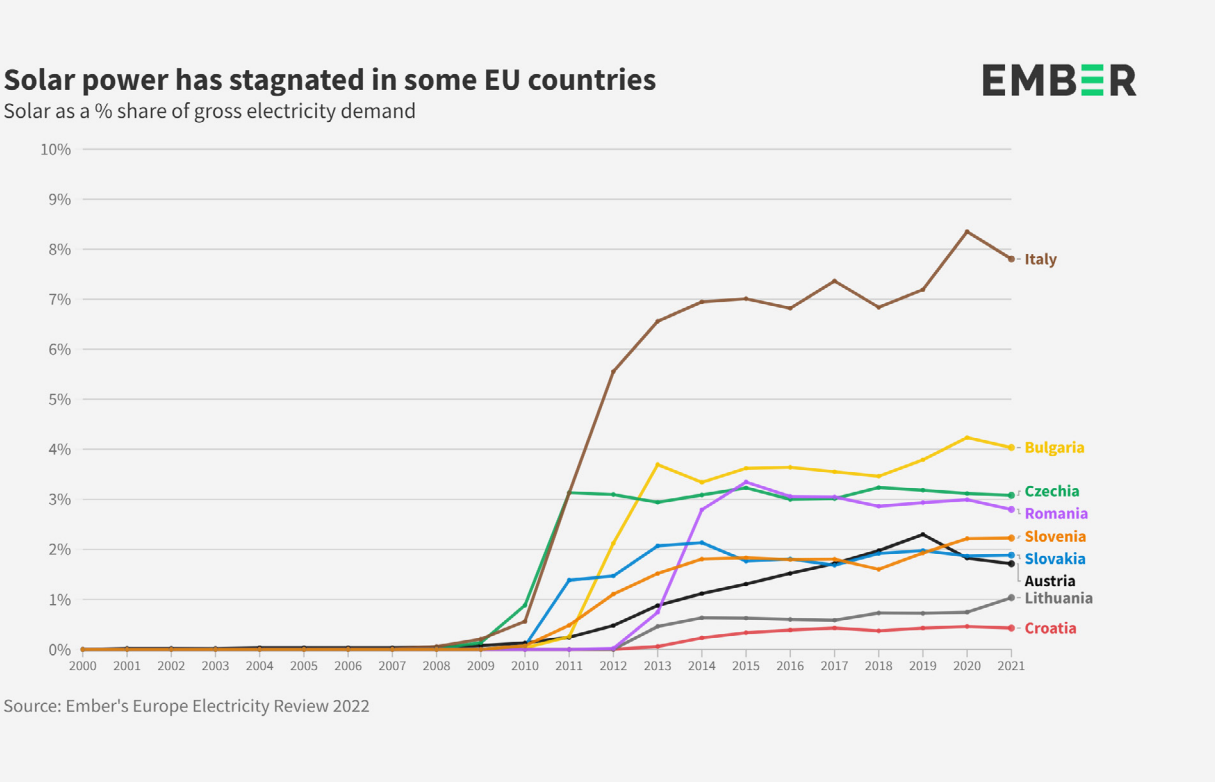
Further North, Europe's growth in solar generation has been driven by the Netherlands (+6 TWh / +115% since 2019). Almost 10% of the country's power demand was met by solar in 2021 and it has ambitious plans for further growth this decade, despite being a higher latitude country. Taken together, Spain and the Netherlands account for half of Europe's solar growth since 2019.

From a low base, Poland has seen impressive growth in solar, more than doubling since 2019 (from 1 TWh to 4 TWh). Indeed, Polish wind and solar combined (20 TWh) have now overtaken gas generation (16 TWh). However, recent changes in government support for residential solar means growth may slow in 2022. Hungary (+67% / +1 TWh) has also seen growth and now meets over 5% of its demand with solar.

Following its neighbour's impressive increase, Portugal is now beginning to catch up with Spain and making the most of a similar latitude, with almost 4% of demand met by solar. The first auctions for floating solar farms on Portuguese reservoirs are happening, and promise a new way to utilise solar technology.

Solar stagnates in some countries

After rapid growth in solar, supported by government incentives in the early 2010s, Italian solar growth has plateaued (+7%, +2 TWh since 2019). It may surprise some observers of the European electricity transition that Italy's absolute growth is now slower than long-time renewable laggard Poland (see below +451%, +3 TWh).

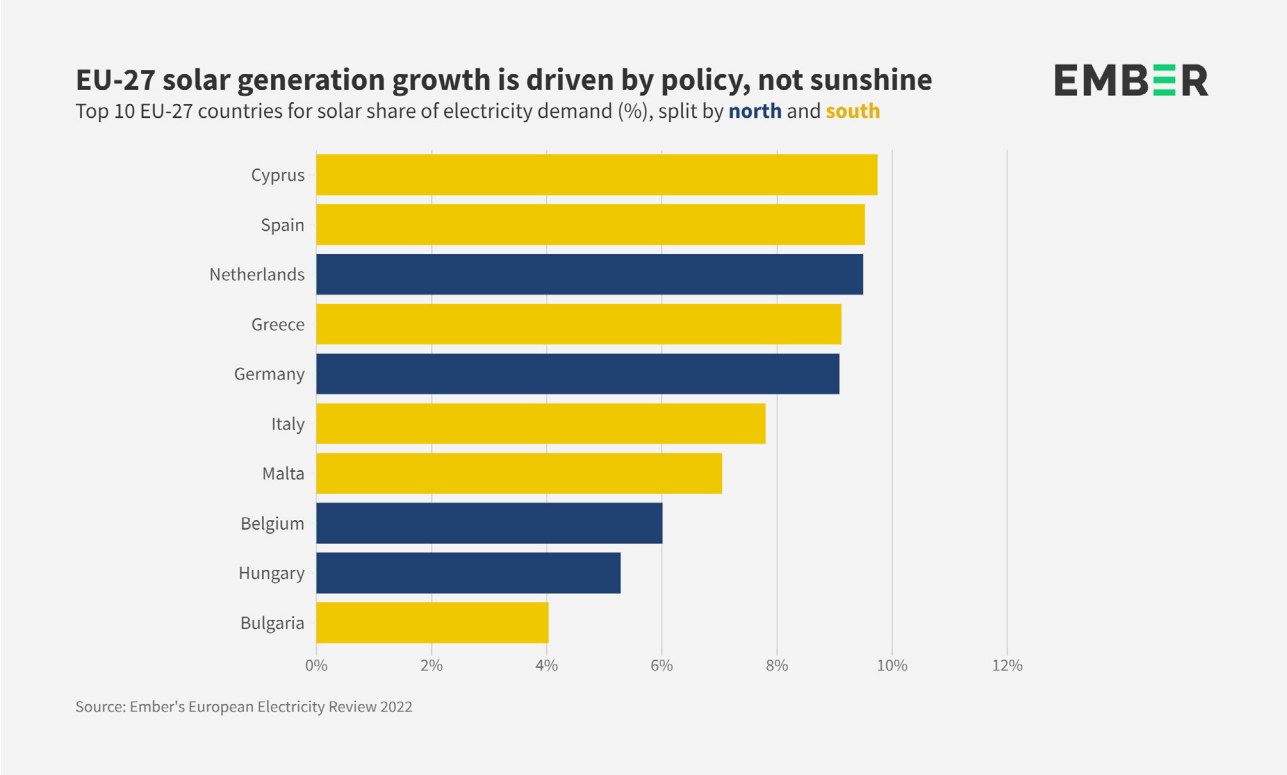


Much of this stagnation in Italy is due to delays in securing planning rights, and the Italian government is attempting to streamline the process.

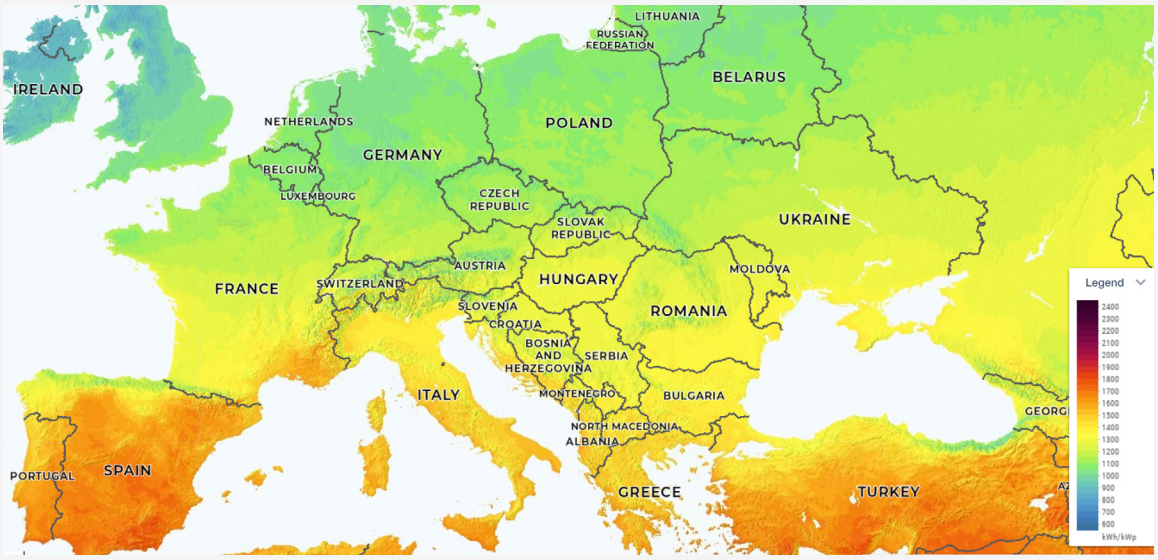
Czechia and Romania are notably larger countries with almost no growth in solar since 2019, and little over the last decade. Kick-starting solar industries in these countries would bring jobs, help lower bills as the energy crisis continues, and will be essential to ensure one fossil fuel (coal) isn't replaced with another (fossil gas) now that both countries are targeting coal phase-outs in the early 2030s.

Where solar power is successful is due to policy, not just sunshine

Countries with both higher irradiance (Spain and Cyprus) and lower irradiance (Netherlands and Germany) are now generating around a tenth of their national power demand from solar. Government policy, if sustained, can help create a market for solar anywhere in Europe.



With cheap solar power now appearing across Europe, we expect more countries to raise their solar power targets. For example, Germany's new coalition agreement recently raised the country's solar ambitions, with a new target of 200GW by 2030. This is a significant step up from its current capacity of ~ 59GW, which met 9% of electricity demand in 2021. Across the continent, solar's moment has arrived – if governments choose to embrace it.



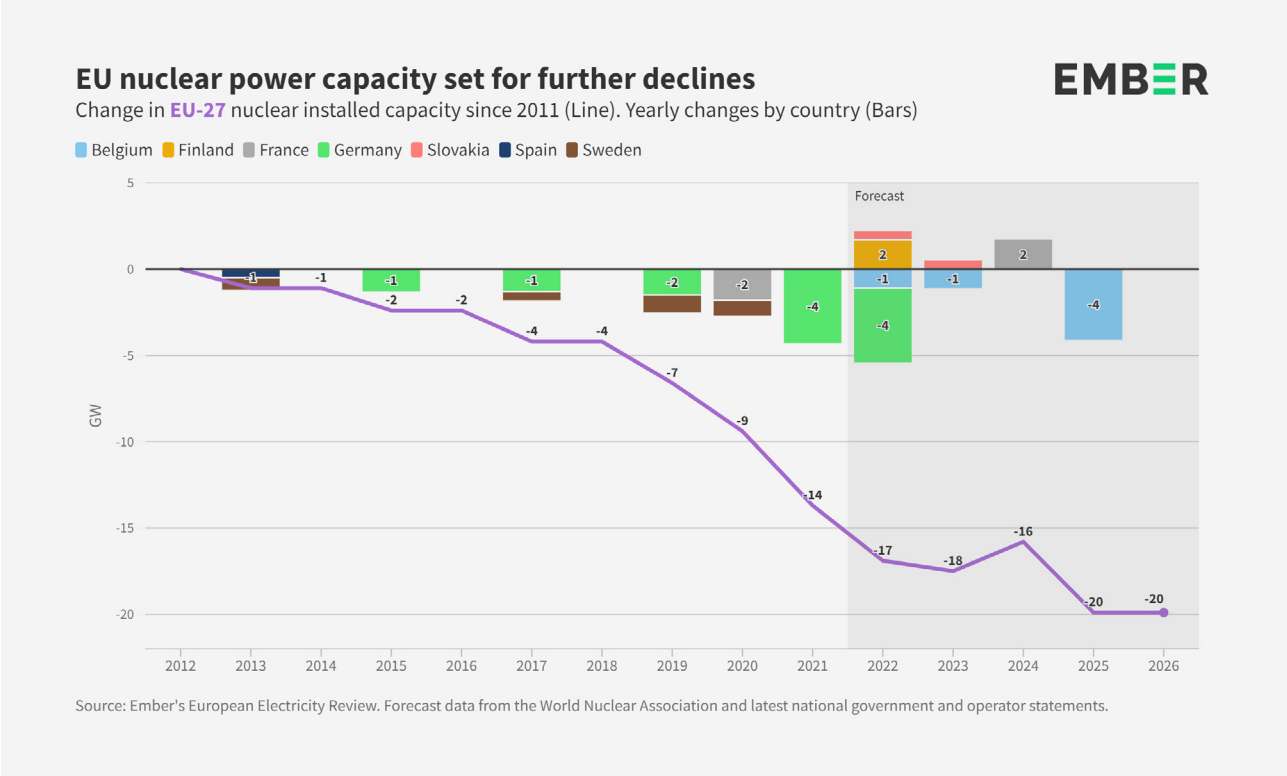
Southern Europe shows the largest solar potential (as shown in the Global Solar Atlas) – but some countries in the north are now getting significant generation from solar too

Source – Global Solar Atlas – Global tilted irradiation at optimum angle (kWh/m2). GSA 2.6 (July 2021). Licensed under the Creative Commons 4.0 Attribution International license

EU nuclear decline is slowing progress in the power sector

A third of recent wind and solar growth replaced nuclear not fossil

The structural decline of nuclear power output has slowed emissions reductions in the EU power system. The last ten years have seen rapid growth in wind and solar (+334 TWh), while EU nuclear power output has declined by 105 TWh. Consequently, almost a third of wind and solar power growth in the last decade has replaced lost nuclear output, rather than fossil fuels, which has slowed decarbonisation efforts.



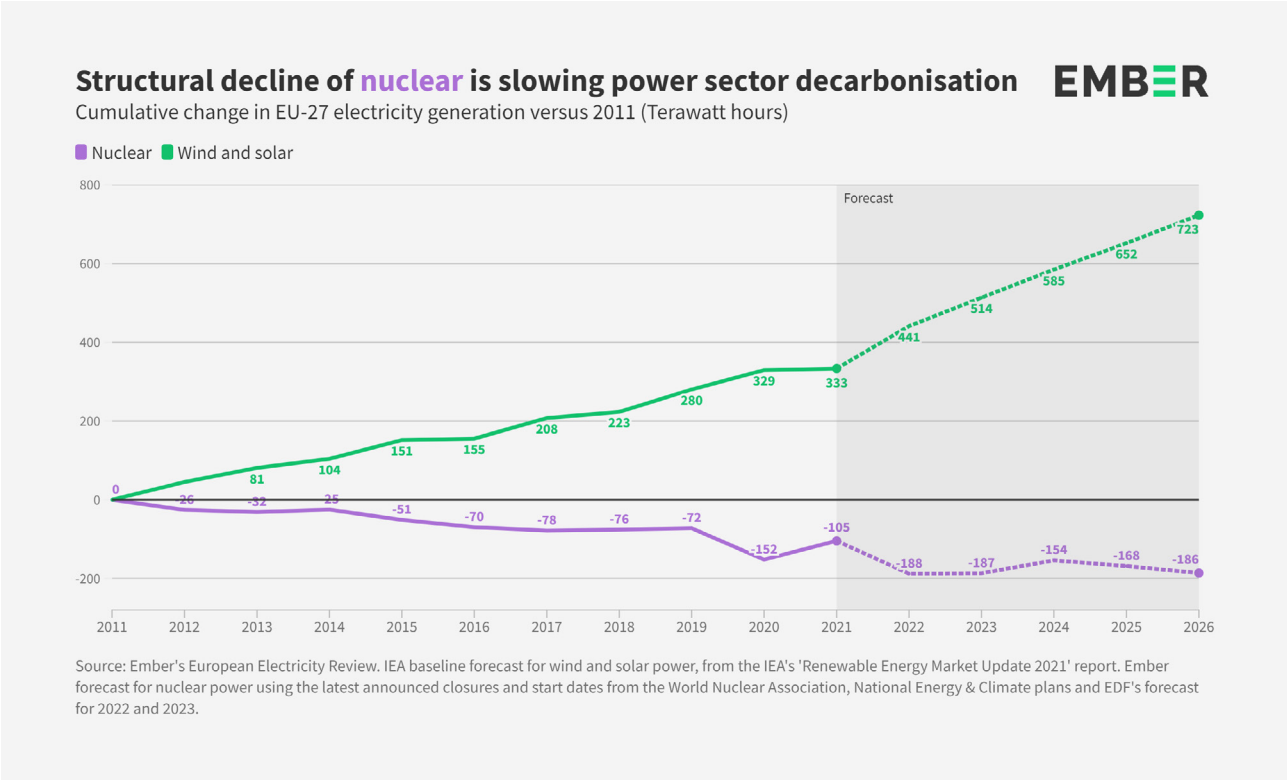
Nuclear power production set to fall further in the next 5 years

This trend looks set to continue in the next five years. At the end of 2021, half of the remaining nuclear reactors in Germany closed (4 GW), and the rest will close at the end of 2022. In December 2021, the Belgian government agreed in principle to close its nuclear power plants (6 GW) by 2025, with reactor shutdowns beginning this year. Furthermore, French nuclear output looks set to fall sharply in 2022, by an estimated 50 TWh as extended outages at five reactors were announced after faults were detected.

The losses will be only partially offset by new reactors starting operation in Finland, Slovakia and France in the coming years.

Nuclear's impact should ease after 2022 as wind and solar accelerate

Using the IEA baseline forecast for EU wind and solar power output, and Ember's forecast for nuclear output, overall we estimate that over 75% of the growth in wind and solar power output in 2022 will replace declining nuclear output, not fossil fuels. From 2023, nuclear output should broadly stabilise – provided no further nuclear issues are identified or closures are announced – and strong wind and solar growth will rapidly drive down fossil fuels instead.



Source: Ember's European Electricity Review. IEA baseline forecast for wind and solar power, from the IEA's 'Renewable Energy Market Update 2021' report. Ember forecast for nuclear power using the latest announced closures and start dates from the World Nuclear Association, National Energy & Climate plans and EDF's forecast for 2022 and 2023.

If nuclear remains in structural decline, policy makers will need to ensure that wind and solar deployment plans and further efficiency measures are sufficiently ambitious to both replace lost nuclear output and phase out fossil fuels at the speed required to stay on track for 1.5°c.

Chapter 3

Concluding remarks

Relying on fossil gas is no longer a credible energy strategy

While future prices indicate that the gas crisis may abate by 2023, there's a growing risk that it will extend further into the 2020s. The crisis has laid bare the inherent risks of energy strategies overly reliant on fossil gas as a "transition fuel". Similarly, the crisis is an important reminder that carbon pricing and market forces alone cannot guarantee a timely coal phase-out.

To ensure that coal is phased out by 2030, as is required to stay on track for 1.5C, it is essential that policymakers legislate to close coal power stations by this date. In parallel, they should also bring forward a policy framework which will secure clean energy infrastructure and efficiency investments at the speed and scale required to phase out both coal and fossil gas from electricity supply and deliver a clean electricity grid across Europe by 2035.

Chapter 4

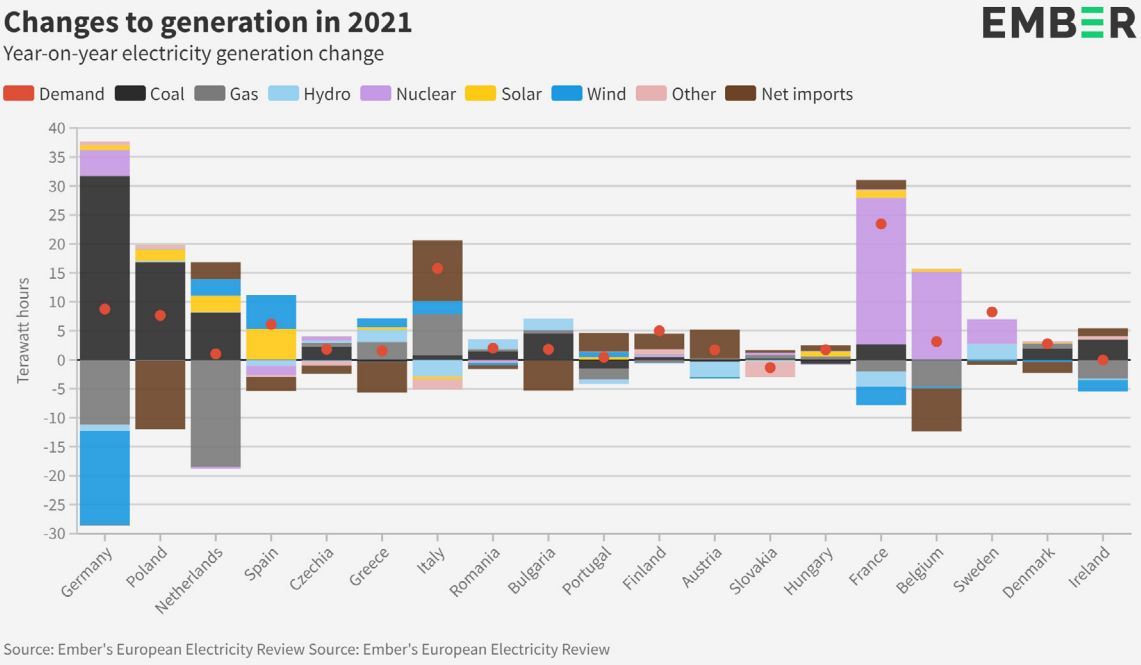
Methodology

Generation

A complete country-by-country methodology is available for download here.

The data in this report is curated by Ember. The full dataset is available to download. Please address any data queries to data@ember-climate.org

Annual data from 2000 to 2019 is gross generation, published by EUROSTAT. More recent data is an estimate of gross generation, based on net generation gathered from monthly data. This estimate is calculated by applying absolute changes in net generation to the most recent gross baseline.



Source: Ember's European Electricity Review Source: Ember's European Electricity Review

Monthly data is gathered from a number of sources, including both centrally reported ENTSO-E data and directly reported national transmission system operators. In some cases data is published on a monthly lag; here we have estimated recent months based on relative changes in previous years. These cases are flagged in the dataset.

Monthly published data is often reported provisionally, and is far from perfect. Every effort has been made to ensure accuracy, and where possible we compare multiple sources to confirm their agreement. In the case of Malta we were not able to gather monthly data of a high enough quality for publication, so we have repeated the 2019 EUROSTAT value for recent years.

Capacity

Historic (2000–2020): Annual installed capacity data is taken from two sources: IRENA and Global Energy Monitor (GEM). All capacity data for coal and gas is from GEM. Unit level coal and gas data is aggregated to create annual totals by country. All data for renewable sources, nuclear and other fossil is taken directly from IRENA. Other fossil data is incomplete for some countries, as IRENA's data contains some undefined capacity that couldn't be mapped to a fuel. All captive and off grid capacity is included, as well as on-grid installations.

Forecast (2021): 2021 installed capacity estimates for wind and solar were taken from the IEA Renewables Data Explorer, using the accelerated case. Nuclear forecast capacity data (2022–2026) was taken from the World Nuclear Association.

Emissions

Historic (2000–2019) direct greenhouse gas emissions from the power sector in the EU and by country are calculated as the product of greenhouse gas emission intensity of electricity generation from the **European Environment Agency (EEA)** and **Eurostat's gross electricity production**. 2020 and 2021 EU direct greenhouse gas emissions from the power sector are estimated by calculating the percentage change in emissions between 2019 and both 2020 and 2021 using standard emissions factors and Ember's generation dataset – and then applying the calculated percentages to the historic EEA/Eurostat dataset described above.

The standard (direct) emissions factors are as follows:

- Hard coal 830gCO2eq/KWh
- Lignite 1100gCO2eq/KWh
- Fossil gas 370gCO2eq/KWh
- Other fossil fuels 700gCO2eq/KWh.

The standard emissions factors reproduce recent historic emissions at an EU level, however, for a number of reasons these values will not be completely accurate at a country level. In particular, thermal plant efficiency and the carbon content of fuels varies by country, therefore country estimates have a lower confidence than the EU-wide estimates.

N.b. due to the methodology used by the EEA for the historic dataset, the values do not include CO2eq emissions from the combustion of biomass; nor do they include upstream emissions (e.g. fugitive emissions due to methane leaks).

Emissions intensity

Historic (2000-2019) data from the European Environment Agency (EEA). 2021 is estimated using the same approach used for emissions described above.

N.b. due to the methodology used by the EEA for the historic dataset, the values do not include CO2eq emissions from the combustion of biomass; nor do they include upstream emissions (e.g. fugitive emissions due to methane leaks).

Definition of renewable energy

In this report, for ease of comparison with EU targets, 'Renewables' mean all technologies treated as renewable in the EU Renewable Energy Directive i.e. wind, solar thermal and solar photovoltaic, geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas. However, recent scientific evidence shows that many forms of bioenergy risk significant carbon emissions. Given the availability of risk-free alternatives to generating electricity such as wind and solar, countries should aim to minimise or eliminate the inclusion of large-scale bioenergy in the power sector.

Electricity generation costs

The following values have been used to calculate fossil fuel generation costs.

- Plant efficiency rates – Fossil gas: 55% (Lower Heating Value); Hard coal: 40%; Lignite: 37%
- Carbon intensity – Fossil gas: 0.37 tCO2eq/MWh; Hard coal: 0.83 tCO2eq/MWh; Lignite: 1.10 tCO2eq/MWh.
- Variable operating and maintenance costs for Short Run Marginal Costs – Fossil gas, hard coal and lignite: €2/MWh.
- Fuel prices – Fossil gas: Dutch Title Transfer Facility (TTF); Hard coal: API2 Rotterdam coal; Lignite: €1.50/MWh

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