

European Electricity Review 2023

Ember's analysis of the EU electricity transition in 2022: what happened in 2022, what can we expect for 2023?

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About

The European Electricity Review analyses full-year electricity generation and demand data for 2022 in all EU-27 countries to understand the region's progress in transitioning from fossil fuels to clean electricity. It is the seventh annual report on the EU power sector published by Ember (previously as Sandbag). Our data is free and easily downloadable, and is available at annual and monthly granularity. We hope others also find the data useful for their own analysis.

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Highlights

4

Months of falling coal power generation since September.

+3%

Rise in EU fossil generation in 2022.

-20%

Predicted fall in EU fossil generation in 2023.

Executive Summary

Europe's electricity transition emerges from the energy crisis stronger than ever

Coal generation has been falling since the start of winter, and as the electricity transition heats up, falling fossil fuel power—especially gas—is set to be the story of 2023.

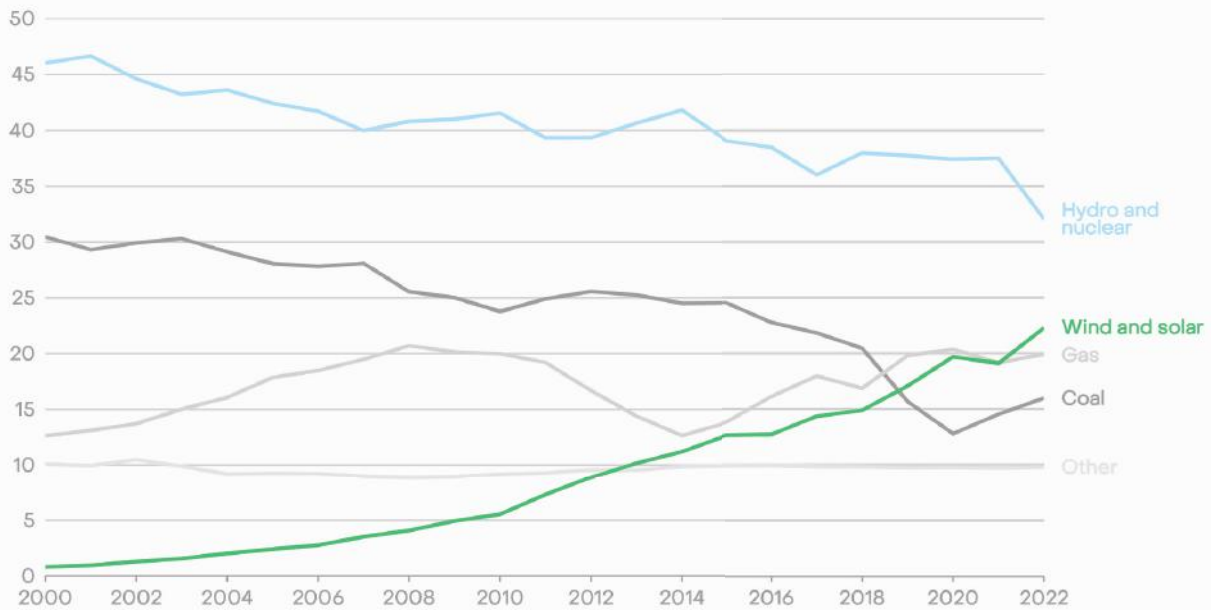
Europe's political response to Russia's invasion of Ukraine in 2022 was to accelerate its electricity transition. There is now a focus on rapidly cutting gas demand—at the same time as phasing out coal. This means a massive scale-up in clean energy is on its way.

In 2022, wind and solar generated a record fifth of EU electricity (22%), for the first time overtaking fossil gas (20%), and remaining above coal power (16%).

However, the shift away from fossil fuels was put on hold by the twin crises in Europe's electricity system in 2022. A 1-in-500 year drought across Europe led to the lowest level of hydro generation since at least 2000, and there were widespread unexpected French nuclear outages just as German nuclear units were closing. This created a large 185 TWh gap in generation, equal to 7% of Europe's total electricity demand in 2022. Five-sixths of the gap was made up by more wind and solar generation and a fall in electricity demand. But the remaining sixth was met by increased fossil generation. Since coal was less expensive than gas, coal accounted for the majority of the increase, rising 7% (+28 TWh) in 2022, compared to 2021. As a result, EU power sector emissions rose by 3.9% (+26 MtCO₂) in 2022 compared to 2021. Gas generation was almost unchanged (+0.8%), and because gas was already more expensive than coal in 2021, there was no further switching from gas into coal in 2022.

EU wind and solar generated more than gas for the first time

Share of electricity generation (%)



Source: Annual electricity data, Ember

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It could have been much worse: wind, solar and a fall in electricity demand prevented a much larger return to coal. In context, the rise was not substantial: coal power increased by just 1.5 percentage points to generate 16% of EU electricity in 2022, remaining below 2018 levels. The 28 TWh rise in EU's coal generation added only 0.3% to global coal generation.

2023 will be quite the opposite. Hydro generation will rebound, French nuclear units will return, wind and solar deployment will accelerate, and electricity demand will likely continue to fall over the coming months. In 2023, Europe is set to witness a huge fall in fossil fuels— of coal power, yes, but especially gas power.

01

Europe's coal power is now falling

Coal generation fell in all four of the final months of 2022. It dropped by 6% (-9.6 TWh) from September to December compared to the same months in 2021. This was primarily caused by falling electricity demand. The 26 coal units brought back as emergency standby ran at just 18% average utilisation throughout Q4 2022; nine of the 26 units did not provide any generation. These standby additions

added only 0.9% to EU coal generation in 2022. Despite importing 22 million tonnes of extra coal throughout 2022, the EU only used a third of this and the surplus two-thirds remained unused. Perhaps most encouragingly, countries remain as committed to phasing out coal as they were before the crisis.

02

Electricity demand started to fall fast

EU electricity demand has begun to fall fast—dropping by 7.9% in Q4 2022 compared to the same period the previous year—close in scale to the 9.6% fall witnessed in Q2 2020 when Europe was in lockdown. This trend was observed in all EU countries. Prior to October, the fall was much less notable. All three months of Q4 2022 were warmer than in 2021, but weather alone would not explain such large falls. It is likely that temporary cuts were driven largely by affordability concerns, alongside solidarity by many citizens to cut energy demand in a time of crisis and improvements in energy efficiency. The transition will ultimately bring a major rise in demand through electrification. And with the step up in heat pumps, EVs and electrolysers in 2022, it is apparent that this change will happen quickly. We must not allow the current fall in demand to slow down the roll-out of clean energy.

03

Solar's surge is only just starting

Solar generation rose by a record 39 TWh (+24%) in 2022, helping to avoid €10 billion in gas costs. This was due to record installations of 41 GW in 2022, 47% more than was added in 2021. Twenty EU countries achieved their highest ever share of solar electricity. The Netherlands was the leader, producing 14% of its power from solar—overtaking coal generation for the first time. Greece ran solely on renewables for five hours in October and is expected to reach its 2030 solar capacity target of 8 GW by the end of 2023, seven years early. For the first time, wind and solar reached over a fifth (22%) of EU electricity in 2022.

04

Gas generation set for a record fall in 2023

Fossil generation rose 3% in 2022. Based on the latest industry projections, this will not be repeated in 2023. EDF forecasts many of its French nuclear plants will return in 2023 (and many are already back online already), Europe's wind and solar industry groups show solar and wind generation should rise by about 20%, hydro stocks have nearly normalised and electricity demand will likely continue to fall in the short term. The only brakes will be the fall in nuclear as Germany completes its phase-out. Based on these indications from the industry, Ember estimates that fossil generation could plummet by 20% in 2023, double the previous record from 2020. Coal generation will fall, but gas generation will fall the fastest, since it is expected to remain more expensive than coal until at least 2025 based on current forward prices. The power sector is likely to be the fastest falling segment of gas demand during 2023, helping to bring calm to European gas markets as Europe adjusts to life without Russian gas.

“Europe has avoided the worst of the energy crisis. The shocks of 2022 only caused a minor ripple in coal power and a huge wave of support for renewables. Any fears of a coal rebound are now dead.

Europe's clean power transition emerges from this crisis stronger than ever. Not only are European countries still committed to phasing out coal, they are now striving to phase out gas as well.

The energy crisis has undoubtedly sped up Europe's electricity transition. Europe is hurtling towards a clean, electrified economy, and this will be on full display in 2023. Change is coming fast, and everyone needs to be ready for it.”

Dave Jones

Head of Data Insights, Ember



Shifting to clean electricity by 2035

Transforming Europe's electricity sector will be a critical part of building a new energy system that addresses the triple crisis of climate, energy security and affordability.

Action this decade is critical, not only to address the immediate fossil fuel crisis, but to quickly bend the curve on emissions. This is a necessity if Europe is to make a fair contribution to the goals of the Paris Agreement. Decarbonising and expanding Europe's electricity supply is the most effective way to displace fossil fuels across the economy, reducing reliance on imported energy. The good news is all the technologies required to supercharge the transition are available and affordable, with wind and solar power forming the backbone of the transition.

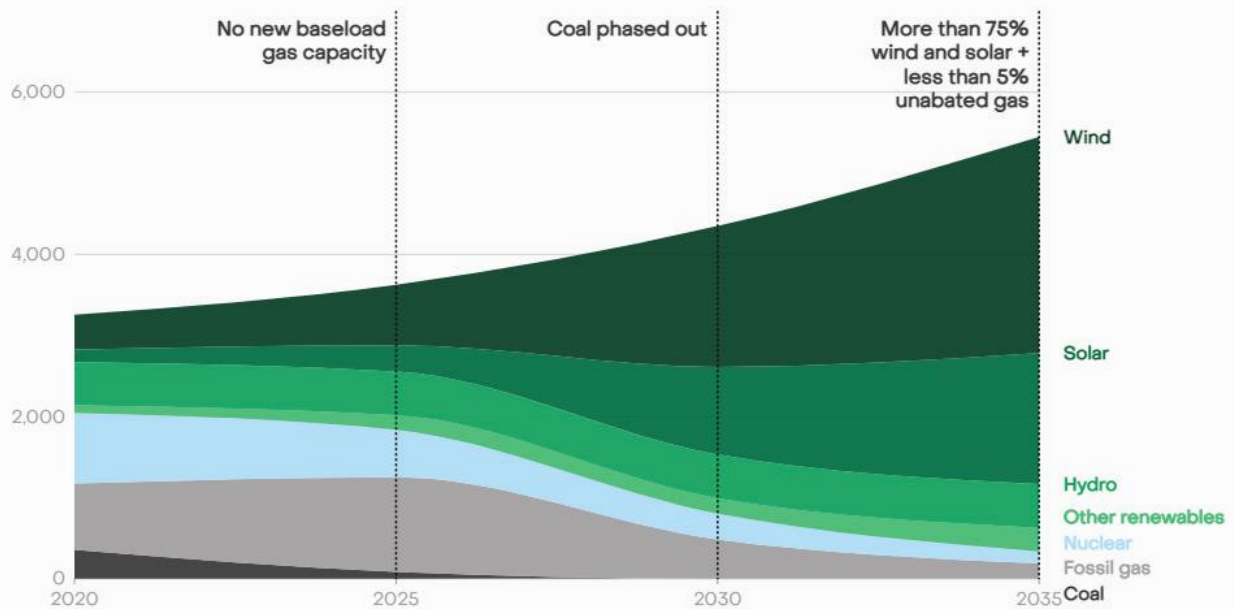
There is ample evidence that Europe must achieve a fully decarbonised power system by the mid 2030s for a pathway that keeps 1.5C in reach. This conclusion is reached both by the [IEA Net Zero roadmap](#) and [an assessment of the latest climate models](#) used by the IPCC. The UK and Germany are already aiming for completely decarbonised power by 2035 and the G7 have set a similar [target](#), however a unified signal from Europe and the EU is lacking.

[Modelling by Ember](#) shows that this is possible. Europe can achieve a clean power system by 2035; at no extra cost above stated plans and without compromising security of supply.

Making this vision a reality will require investment above and beyond existing plans, as well as immediate action to address barriers to the expansion of clean energy infrastructure. Such a mobilisation would boost the European economy, cement the EU's position as a climate leader and send a vital international message that these challenges can be overcome.

1.5C pathways to clean power by 2035 in Europe

Power generation by technology (TWh)



Source: New Generation, Ember, 2022

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Chapter 2 | The Big Picture

Insights

The biggest stories of 2022: the return to coal that wasn't, winter demand collapse and solar's surge. And looking forward, 2023 should be the year that the full scale of the transition becomes clear.

Following Russia's invasion of Ukraine, it was immediately obvious that Europe's energy system would have to change forever. Some expected that this new geopolitical landscape would mean that the transition from fossil fuels to clean power would be put on pause. Instead, the EU made an ambitious energy transition an immediate priority, central to its response to multiple emerging crises. Across Europe, the cost of fossil fuel reliance came into focus, with attention on how this fed into security vulnerabilities and cost of living increases, as well as unprecedented disasters stemming from extreme weather. Annual power sector data reflects the impact of these crises, but indicators looking towards the next year suggest that 2022 was the start of a profound shift that will continue long beyond the emergency responses of the moment.

Insight 1: The fallacy of Europe's "return to coal"

The background to Europe's "return to coal"

When Russia invaded Ukraine in February 2022, it quickly became apparent that Europe was facing a gas crisis. There were numerous, rapid responses at an EU and Member State level to mitigate the risks and reduce the scale of the crisis. Among a host of other measures, these included reactivating coal units, importing more coal and diversifying fossil fuel supplies. Combined with rising coal generation at the start of summer (the EU's coal burn in March was 35% higher than in March 2021), this created international speculation that Europe was "returning to coal".

Coal power has been in structural decline in the EU for the past decade. Even with the rise in 2022, coal generation was still 37% below 2015 levels, producing just 16% of the EU's electricity. The temporary uptick in 2022 was a small bump in the path to phasing out coal in Europe, with a wider view showing why it is inaccurate to say Europe "returned to coal".

The winter coal surge did not materialise

EU coal generation fell in each of the last four months of 2022, compared to the same months in 2021. In September it fell by 2%, October by 13%, November by 7% and December by 2%. Across the fourth quarter of 2022, this meant a fall of 7% in EU coal generation. Gas generation fell even further over the same period, by 10%.

The fall in coal power this winter was due to a major decrease in electricity demand. This can be attributed to the efforts of households and industry to reduce electricity consumption, combined with mild weather. Had French nuclear power not seen reduced generation persist well into December, the falls in coal in Q4 would undoubtedly have been even greater. Insight 2 provides more detail on this decline in demand.

EU ends 2022 with four months of falling coal generation

Year-on-year change in electricity generation (TWh)



Source: Monthly electricity data, Ember

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Across the year, total EU coal generation rose by 7% in 2022 compared to 2021. There were large rises in coal generation earlier in the year, as high as 35% in March 2022 versus March 2021. While many commentators speculated this early trend could continue into winter, the opposite happened.

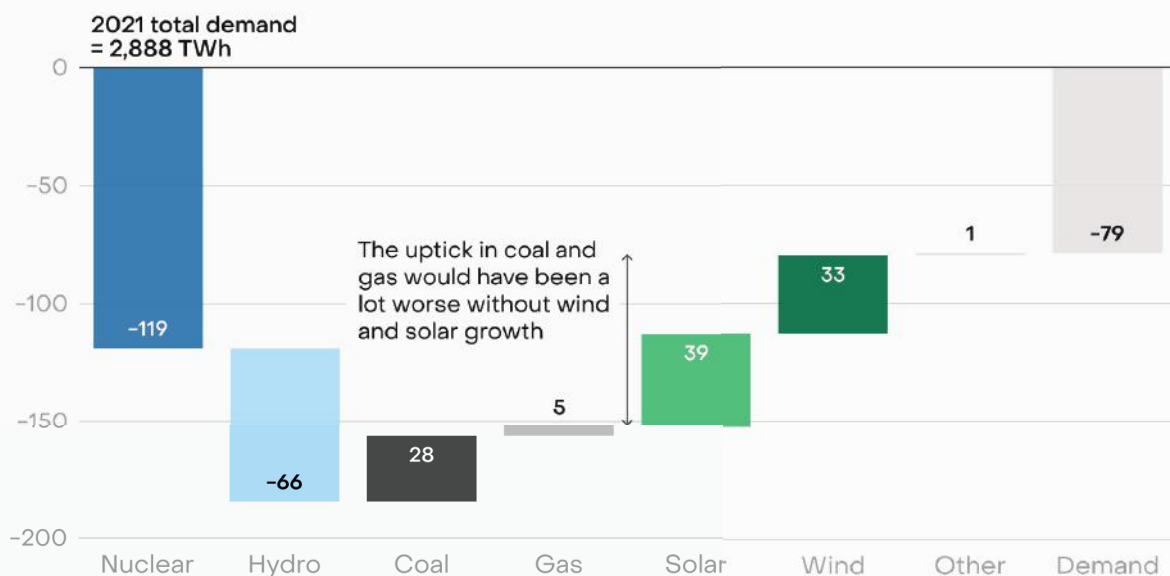
Low hydro and nuclear generation drove rise in coal burn

Understanding coal's 7% rise as part of the response to the shortfall in nuclear and hydro puts it into perspective. Nuclear and hydro generation in 2022 fell by 185 TWh compared to the previous year, six times more than coal's rise in generation (28 TWh). To give some context of the scale, 185 TWh is equal to 7% of the EU's total generation in 2022.

Five-sixths of the gap from nuclear and hydro was met by increased wind and solar generation and falling electricity demand, whereas only one-sixth was made up from increased coal generation. Gas generation was almost unchanged (+0.8%).

The EU's coal generation rose due to a sizeable nuclear and hydro deficit

Year-on-year change in EU-27 generation for 2022 (terawatt hours)



Source: Monthly electricity data, Ember
'Other' includes bioenergy, other renewables, other fossil fuels and net imports

While any rise in coal causes understandable alarm, coal had a relatively minor role in responding to these shortfalls. And given that these are not recurring factors, 2023 is likely to play out very differently [see Insight 4].

The shortfall in hydro power

In 2022, Europe faced its [worst drought in at least 500 years](#), pushing hydro generation to its lowest level since at least 2000.

Hydro generation was 66 TWh below 2021, leading to a 19% year-on-year fall, from 349 TWh in 2021 to 283 TWh in 2022. 2021 was slightly wetter than average, however hydropower generation in 2022 was 50 TWh below the 2000–2021 average.

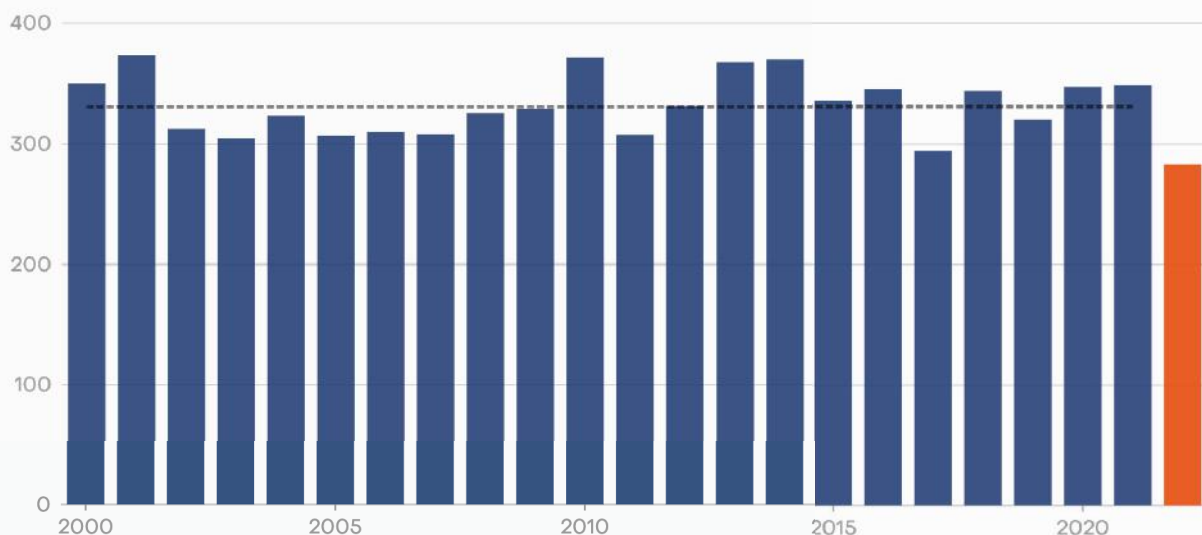
The Alpine region was the worst hit, with generation 9% below the lowest year so far this century. The Iberian region saw the fourth lowest level of hydro generation this century, and the Nordic region saw generation slightly above average. Of the 50 TWh shortfall against average 2000–2021 levels, 15 TWh was in Italy, 13 TWh in France and 11 TWh in Spain.

The situation is now almost remediated. By September 2022, hydro generation was back to the levels seen in 2021. 2023 has started with hydro stocks only slightly lower than the historical averages.

A particularly bad year for hydro power in Europe

Electricity generation (TWh)

Dotted line = 2000–2021 average



Source: Annual electricity data, Ember

The shortfall in nuclear power

EU nuclear power fell by 16% (119 TWh) in 2022. Of this fall, 69% was in France from outages, and 27% of it was as a result of German nuclear plants.

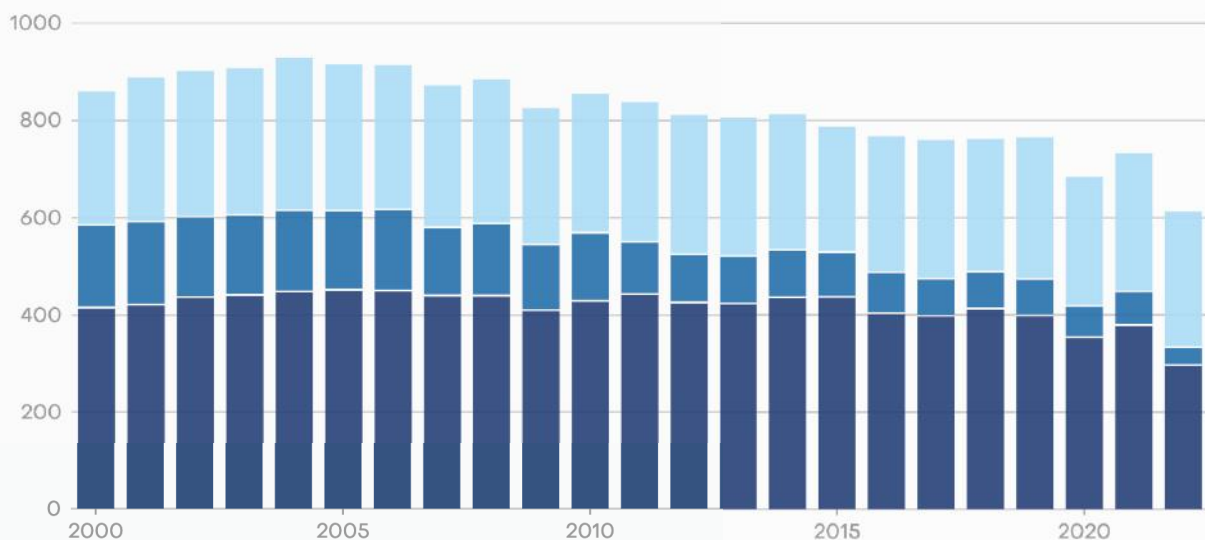
In 2022, [a record number of French nuclear reactors went offline](#), resulting in the lowest output in 30 years. This was 82 TWh below 2021 levels, leading to a 22% year-on-year fall, from 379 TWh in 2021 to 297 TWh in 2022. The situation improved towards the end of the year when a slew of reactors returned to the market. By January 9th of 2023, 72% of total capacity was operational (44 GW), compared to just 48% on average across 2022.

Germany's nuclear generation almost halved from 69 TWh in 2021 to 37 TWh in 2022, following units closing in December 2021. The final units will come offline in April 2023.

EU nuclear power generation dropped significantly in 2022

TWh

■ France ■ Germany ■ Rest of the EU



Source: Annual electricity data, Ember

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Two-thirds of France's nuclear and hydro shortfall was made up by other countries

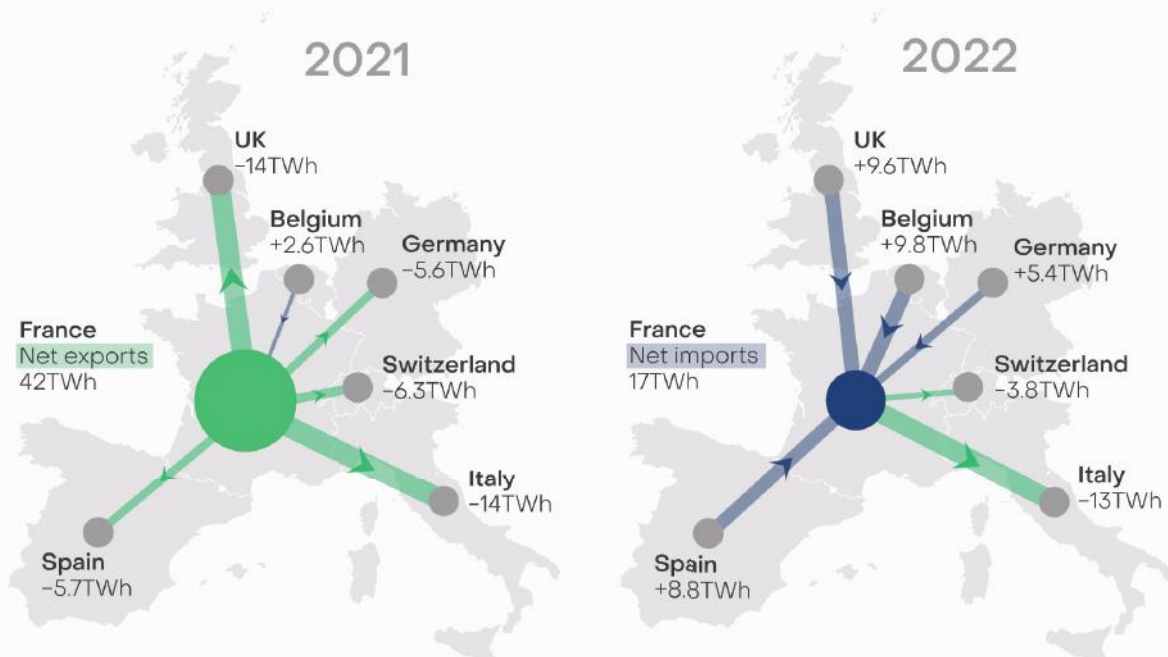
France is historically the biggest exporter of electricity in Europe. However, for the first time since at least 2000, France became a net importer with total flows switching by 59 TWh. Germany, Spain and the UK all flipped from being net importers from France to net exporters to France for the first time since at least 2015.

That means almost two-thirds (59 TWh) of the 96 TWh fall in France's year-on-year nuclear and hydro generation was replaced by imported electricity from other countries. Coal generation in Spain rose by 3 TWh, but with 15 TWh more electricity sent to France than in 2021. Without France's issues, it is highly likely that coal generation would not have risen in Spain. In Germany, coal rose by 17 TWh, but 11 TWh more electricity was sent to France than in 2021; France undoubtedly contributed to some of the rise in German coal generation.

With these changes, 2022 highlighted how important interconnectors are helping to achieve security of supply.

France's nuclear and hydro deficit turned it from an exporter to an importer of electricity

Lines and values represent net imports in electricity between France and each neighbouring country (TWh)



Source: Annual electricity data, Ember

Gas-to-coal switching played little role in coal's rise in 2022

Switching from gas-fired generation back to dirtier coal played little part in coal's rise in 2022. Gas generation for 2022 as a whole was almost unchanged (+0.8%) from 2021.

From July 2021, when Russia first began curtailing European gas flows, the gas price rose significantly above coal. This led to switching from gas to hard coal generation in 2021. Consequently, there was little coal-gas switching in 2022, because most of it had already happened.

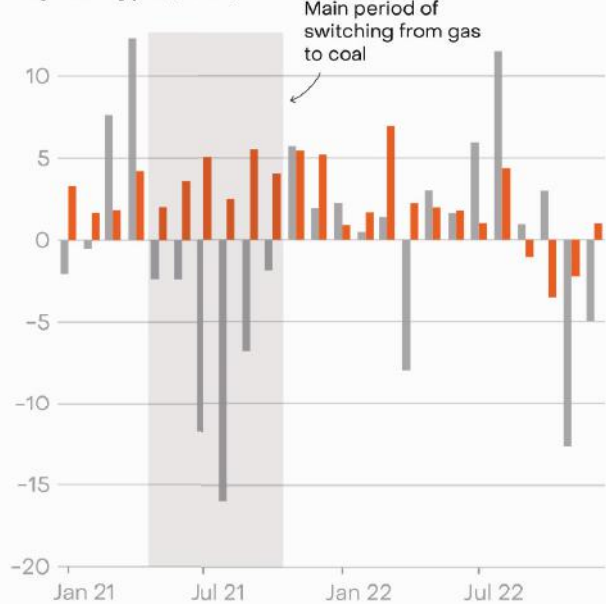
Little evidence of gas-to-coal switching in 2022; most happened in 2021 when gas prices initially surged above coal

Short run marginal costs by fuel type (€/MWh)

■ Hard coal ■ Gas



Year-on-year change in EU electricity generation by fuel type (TWh)



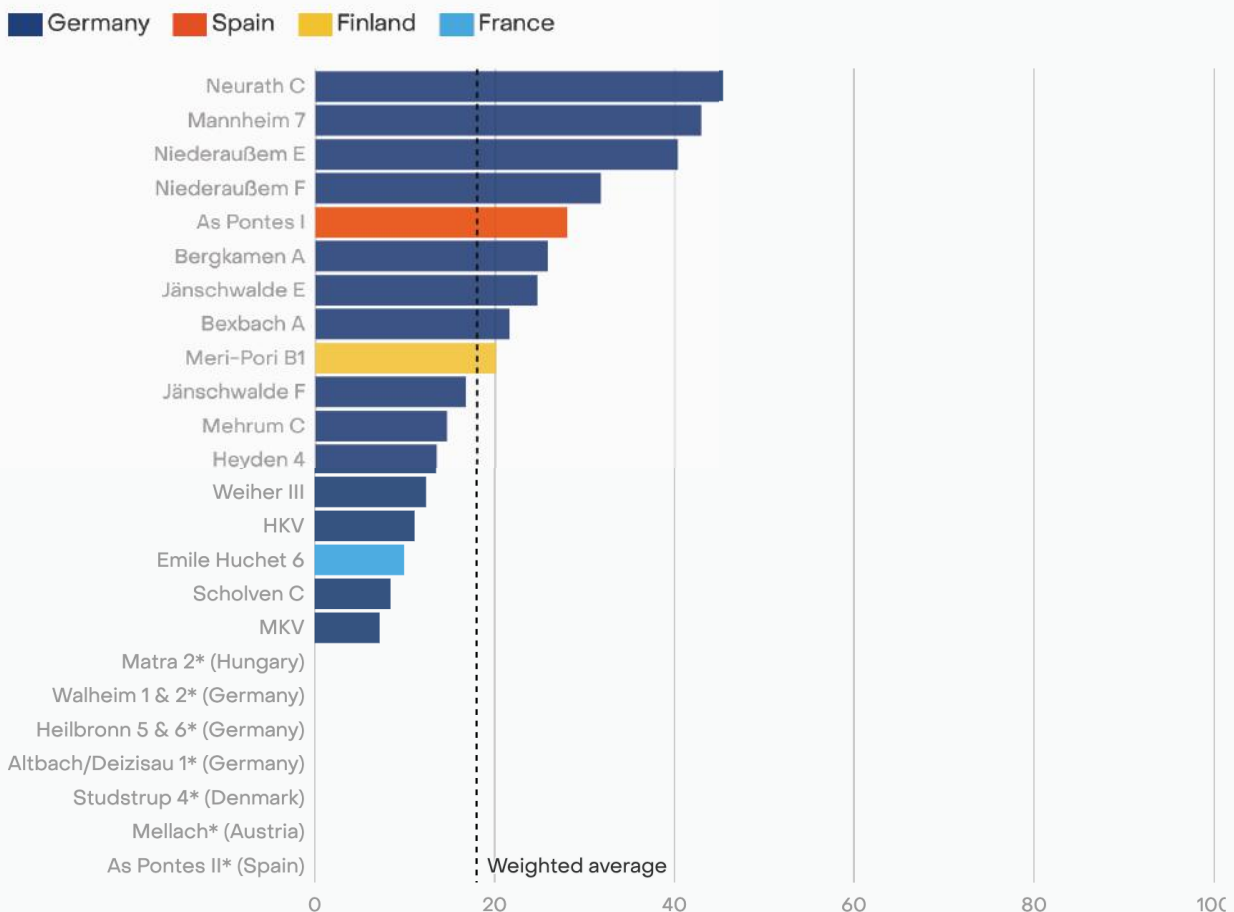
Source: API2 hard coal prices (front month), TTF (day ahead) and ETS-EUA (December contract) prices from Montel, monthly electricity data, Ember
 Variable operating and maintenance costs are not included in SRMC calculations

Reactivated coal units barely impacted the EU's coal generation

With Russia's invasion of Ukraine and associated [energy blackmail](#), Europe was compelled to activate temporary emergency measures to ensure energy security, especially for this current winter. These included the creation of strategic reserves by several governments, allowing coal plants to remain operational beyond scheduled shutdown dates or mothballed plants to be placed on standby.

Europe's 26 reactivated coal units have been operating at only 18%

Unit utilisation, October to December 2022 (%)



Source: ENTSO-E unit generation · Reactivated units include some previously due to close during Q4 2022 which received lifetime extensions
 *Not yet generating as of Dec 2022

In total, 26 coal units with 11 GW of capacity that should have been offline in the fourth quarter of 2022 were permitted to return to or remain in the market. These units span across seven countries, with 19 (73%) in Germany. The average utilisation of the 26 units during this period was just 18%. Since coming back online, these units have generated 4 TWh. That is predominately lignite generation in Germany. This represents only 0.9% of the EU's total 2022 coal generation of 447 TWh. EU coal power rose by 28 TWh in 2022, so only 14% of this rise can be attributed to the reactivation of these coal units.

A further 11 GW of plants in Italy and the Netherlands had load factor limits removed to enable them to run more if required. In the Netherlands, a law was passed in June 2022 revoking an order from December 2021 that limited coal plants to 35% capacity. Since then, the four remaining Dutch coal plants have generated at 45% capacity, lower than the 65% capacity over the same period in 2021. In Italy, capacity limits on coal plants were lifted in August 2022, lasting until March 2023. There was no observable change since this decree—coal units ran at an average of 30% capacity in 2022, the same as in 2021.

Two-thirds of the surge in imported coal was stockpiled, not burnt

Imports of thermal coal into the EU increased by 51% in 2022, as Europe sought to increase stock levels. Imports rose from 43 million tonnes (Mt) in 2021 to 65 Mt in 2022. However, Russian coal imports were banned in August 2022, resulting in an even larger pick-up in coal imports from other countries. Imports from South Africa and Australia rose sixfold from 2 to 13 Mt and 1 to 6 Mt respectively; from Indonesia they rose from near-zero to 6 Mt; from Colombia they rose by 80% from 8 to 14 Mt.

Although this increase was large, it led to some wildly exaggerated claims. In June, Indonesia's Ministry of Energy and Mineral Resources revealed a [plan to increase its coal production target](#) following a supposed request from Germany to buy up to 150 Mt from Indonesia. A later [communication](#) from the Indonesian embassy in Berlin stated the figure was only 5–6 Mt.

However, while coal imports rose by 22 Mt last year, hard coal power plants burned only 8 Mt more coal (excluding Poland, which mostly supplies its hard coal plants with domestic coal). Therefore, only just over a third of the extra coal that was imported was burned. The remaining two-thirds of the extra coal imported was implicitly added to stockpiles.

Europe's strategy was to replenish low stock levels from last winter, which began with relatively low stockpiles, and to enter this winter with extra high stockpiles. This was in case there was an emergency in the gas system during winter, although fortunately this scenario did not materialise. As a result, coal is now piling up. With stocks already high going into 2023, coal imports are unlikely to stay high.

The EU's hard coal stockpiles surged in 2022

Implied cumulative change in stocks since Q4 2016* (million tonnes)



Source: Kpler; monthly electricity data, Ember; Ember calculations
 *Calculated as the difference between imports and volume of coal burned each quarter; data excludes Poland

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Europe's coal phase-out is still very much alive

The restarting of coal plants is only a temporary, emergency measure. The majority of coal units in reserve facilities have only been granted permission to continue operating over this winter until the end of March 2023.

Germany is allowing its emergency reserve plants to be available until March 2024 but remains firmly committed to its coal exit plan. The government has [reiterated](#), "the coal exit in 2030 isn't wobbling at all. It is more important than ever that it happens in 2030." [RWE](#) has made this even more of a reality by agreeing to phase out all of its coal plants eight years earlier than expected, in—2030 instead of 2038. Romania also moved its coal exit date forward from 2032 to 2030.

The Netherlands and Czechia are not amending their respective coal phase-out dates of 2029 and 2033. France is only allowing the Emile Huchet 6 unit (595 MW) to be in reserve for this winter. And Austria has clearly stated that the Mellach plant is coming out of retirement “so that in an emergency it can once again produce electricity from coal (not gas)”.

These actions indicate that Europe has no intention of returning to coal. The consensus in Europe is that the only way to permanently extricate itself from the cost and security crises it faces is to get off all fossil fuels, both coal and gas, and to do so as quickly as possible.

Insight 2: Europe’s big fall in demand this winter

Towards the end of 2022, the EU saw a fall in electricity demand on the same scale witnessed during the deepest Covid-19 lockdowns. It was the reason why coal and gas generation fell in the final months of 2022. Falling electricity demand will be a major theme into 2023, and more work is needed to understand how structural this demand shift is, or if we can expect to see a rebound like with the economic recovery from the Covid-19 pandemic.

Europe saw a substantial fall in electricity demand of 7.9% in the fourth quarter of 2022, close in scale to that witnessed during the most extreme lockdowns, when demand fell by 10.2% in Q2 2020.

Electricity demand in the EU for October dropped by 10%, November by 9% and December by 7% year-on-year. Although these were less than the [falls in gas demand](#), which were 25% in October and 23% in November, the decreases in electricity demand necessitate a closer look.

Mild temperatures played a role in lower demand: October, November and December in 2022 were [warmer](#) by 1.9, 0.8 and 0.9 degrees celsius respectively across Europe compared to 2021. However, temperature explains only part of this fall in demand.

The fall in electricity demand in the last quarter of the year occurred at a similar magnitude in most EU countries. Likewise, the majority of countries had not seen a large demand fall in 2022 prior to Q4.

EU electricity demand was unusually low from September

TWh



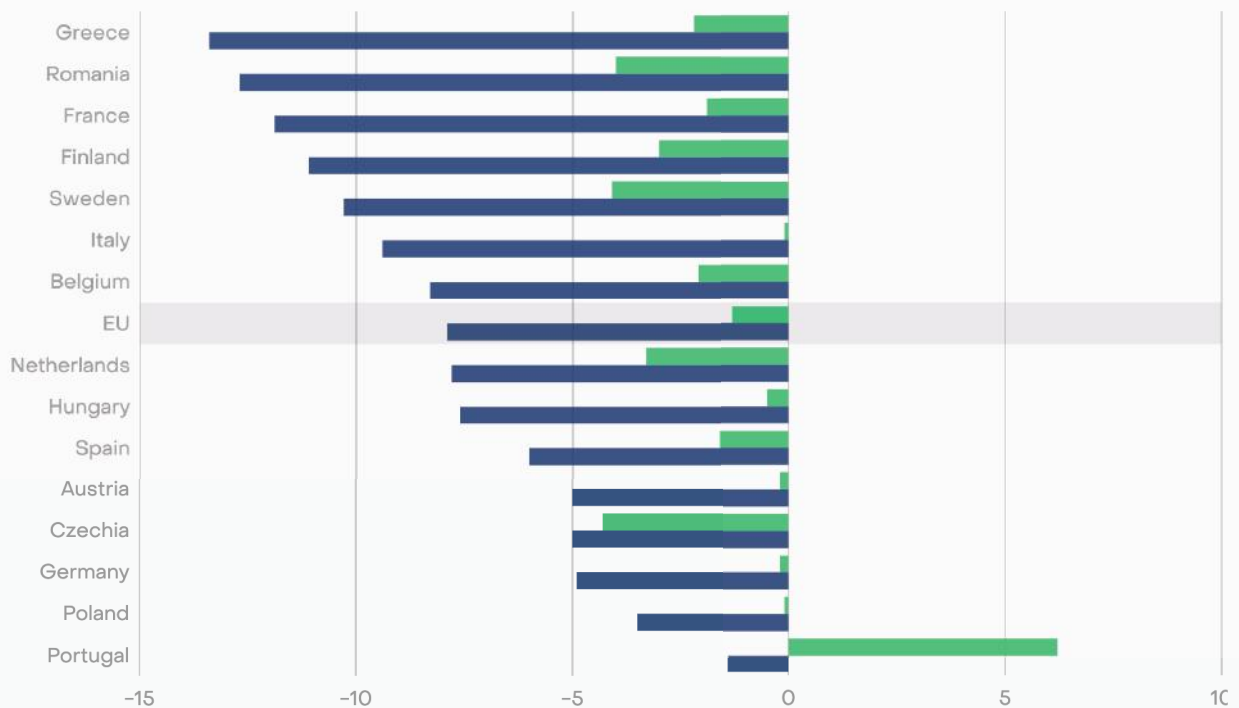
Source: Monthly electricity data, Ember

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Electricity demand dropped in winter across EU countries

Year-on-year change in electricity demand in 2022 (%)

■ Q1-Q3 ■ Q4



Source: Monthly electricity data, Ember · Only the largest 15 markets included in the graphic

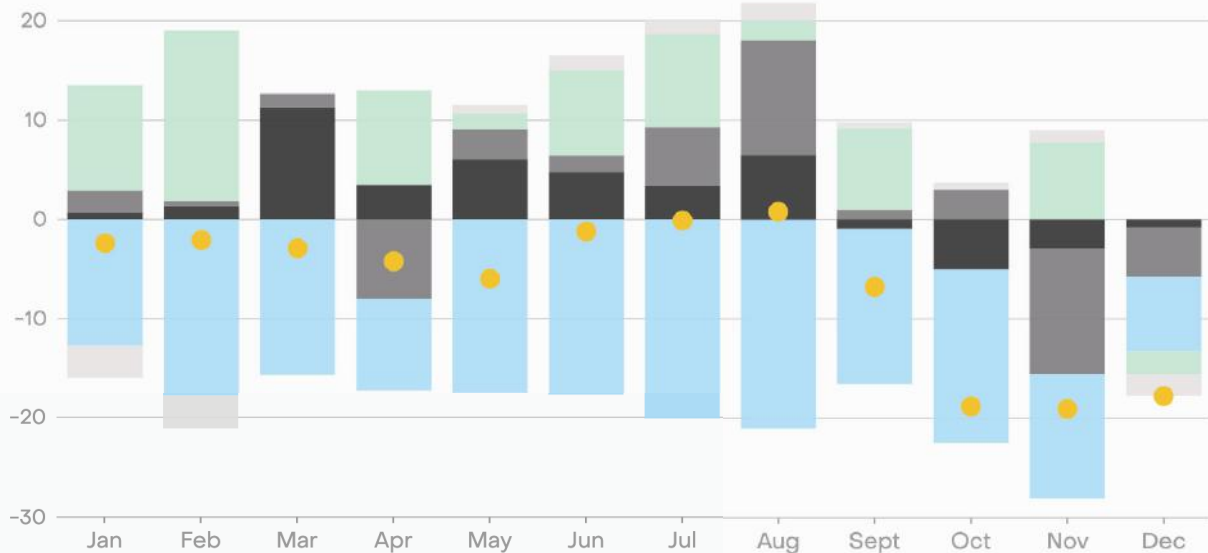
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The 8% drop in electricity demand in Q4 2022 was the primary factor in the 9% fall in coal and gas generation over the same period. Coal generation fell for four consecutive months, and gas generation for two. This was despite French nuclear availability remaining low until late December. Had French nuclear plants run at the same levels as 2021, the demand fall would have cut the EU's fossil generation twice as fast, by 18% in Q4.

Coal and gas power fell in winter with drop in electricity demand

Year-on-year change in electricity generation, 2022 (TWh)

Wind and solar Nuclear and hydro Coal Gas Other Demand



Source: Monthly electricity data, Ember

'Other' includes bioenergy, other renewables, other fossil fuels and net imports

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What does the demand fall tell us?

Broadly, the reasons behind the fall in demand are clear. Incidental actions reducing electricity demand over the winter have been [much discussed](#) in the press and elsewhere, but detailed quantification is challenging. Some of the reduction may be attributed to investments into efficiency. Some to reductions in industrial and commercial output. Much of it is likely to be a change in behaviour with cost-of-living challenges, electricity prices rising and actions in solidarity against Russia's invasion. Some of that is voluntary, as well as some mandated electricity demand reductions introduced for the winter by the [European Commission](#) in September 2022. These currently only apply until 31 March 2023.

It is hard to predict the permanence or longevity of the shift in demand. When the [European Commission](#) and the [IEA](#) analysed the ways to urgently reduce Russian gas imports in 2022, it was assumed that behaviour change related to energy savings, such as turning down heating thermostats, would be temporary and not sustained into 2023. There are multiple uncertainties related to forecasting future demand. Will summer equally see shifts in demand with changes to air conditioning use? Will the reductions grow as electricity bills rise further in 2023, or could demand quickly rebound back like it did following Covid-19 impacts? This fall in electricity demand is unprecedented, but these uncertainties complicate planning into the years ahead.

What is already evident though is that the crisis will spur faster electrification. [Heat pump sales doubled](#) in Poland, Italy, Austria and the Netherlands during the first half of 2022, [EV sales are high and rising](#), and [hydrogen electrolyzers saw a step change](#) in 2022. This shift may add to electricity demand faster this decade than many experts previously thought. One thing is certain: the current lull in electricity demand must not be an excuse to slow down the roll out of clean energy.

Insight 3: Solar shielded Europe from the energy crisis

Russia's invasion of Ukraine had a profound impact on Europe in 2022, with the resulting gas shortages and all-time-high fossil fuel prices pushing the continent into a cost of living crisis. While both wind and solar delivered through the energy crunch, for the first time generating more than a fifth of EU electricity in 2022 (22%), it was solar power that really shined, setting electricity generation records and saving billions in imported gas costs.

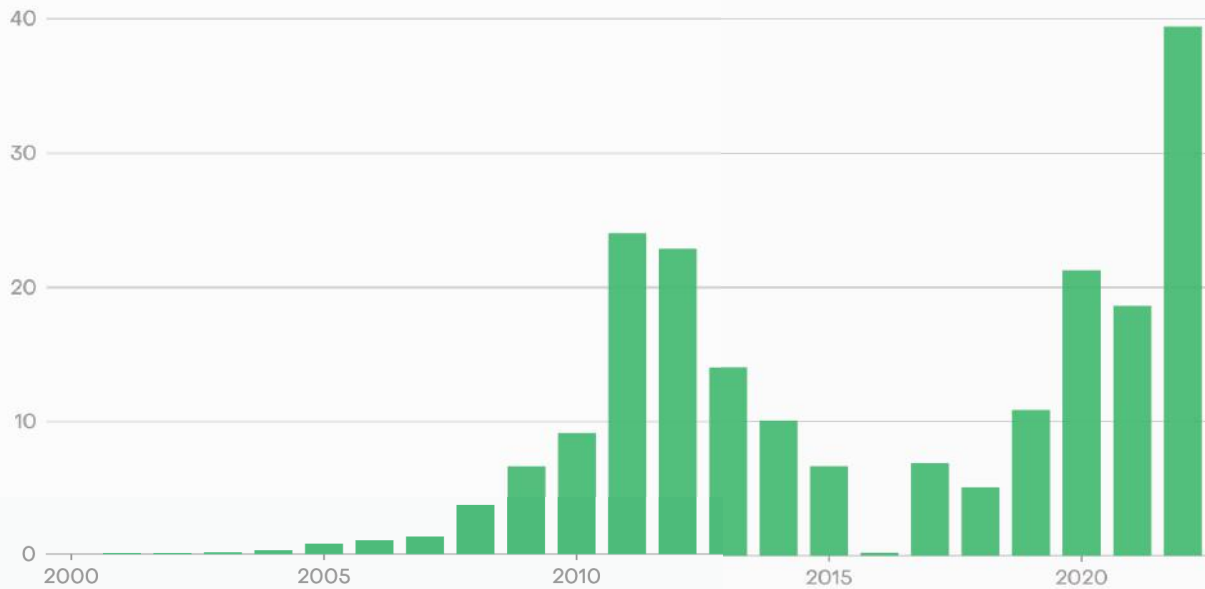
Solar set generation records across the continent

The year 2022 saw the largest ever absolute increase in solar electricity generation. It rose by 39 TWh (+24%), which was almost double the rise of any year so far.

That mirrored the 25% rise in capacity from 168 GW to 209 GW. New installations rose by a [record](#) 41 GW in 2022, which was 47% more than was installed in 2021.

Growth in EU solar generation doubled in 2022

Annual change in electricity generation (TWh)



Source: Annual electricity data, Ember

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Solar produced 7.3% (203 TWh) of EU electricity in 2022, up from 5.7% in 2021. Between May and August, 12% of the EU's power came from solar, exceeding 10% for the first summer in history. These four months were sweltering, setting new temperature records. As hydro generation fell short due to the drought and nuclear output was cut because of water temperature constraints, solar reliably delivered.

Effective policies drove solar growth

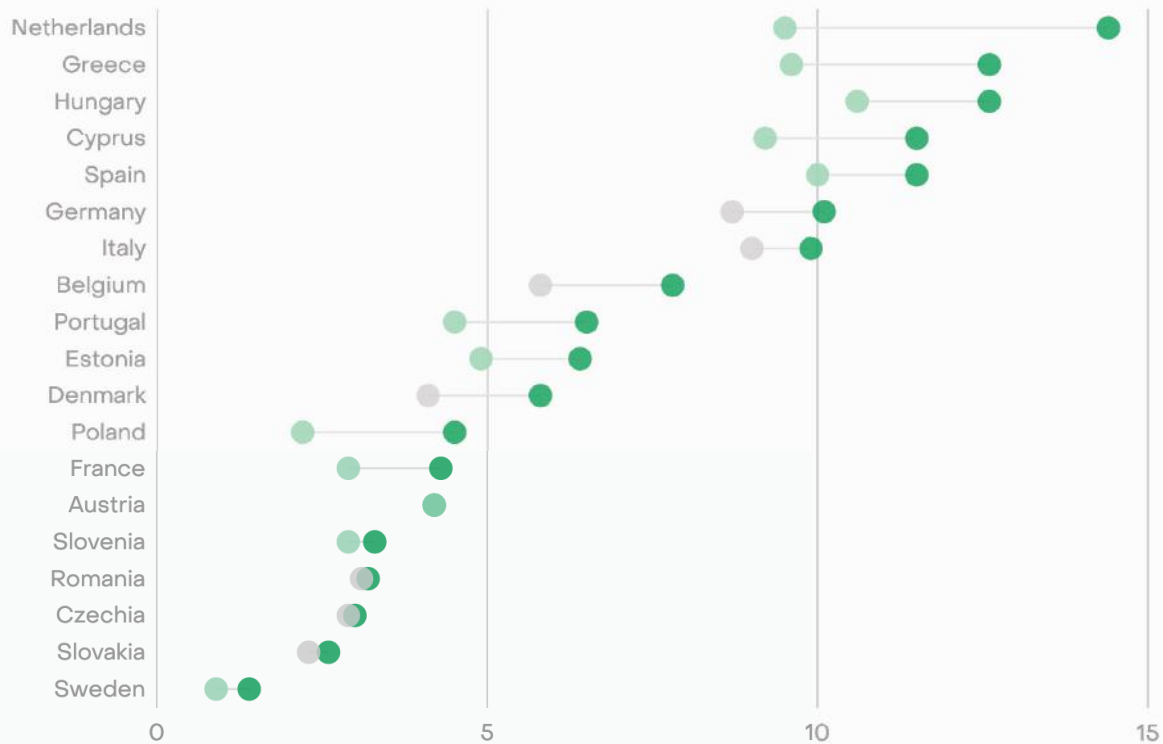
The Netherlands was the unquestionable solar energy leader of 2022, generating 14% of its electricity from the sun and surpassing previous leader Spain, typically a much sunnier country, by two percentage points (12%). For the first time, solar generation in both the Netherlands and Greece surpassed that of coal generation. Overall, twenty EU countries set new solar share records in 2022.

For 2022 solar capacity additions, the top five countries were Germany (7.9 GW), Spain (7.5 GW), Poland (4.9 GW), the Netherlands (4 GW) and France (2.7 GW)

20 EU countries set solar records in 2022

Share of electricity generation (%)

● 2022 ● Previous record (2021) ● Previous record (2020)



Source: Annual electricity data, Ember · Latvia, Lithuania and Luxembourg were excluded from the solar share in generation analysis due to electricity imports exceeding 30% of the demand

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The Netherlands has demonstrated how simple and effective policies drive solar growth. Since 2020, it has been supporting residential solar through net-metering. This enabled a rapid expansion of rooftop solar, with 1.8 GW of capacity added in 2022, 38% more than in 2021 (1.3 GW). Other solar segments are thriving as well, with one million consumers taking part in energy cooperatives. Commercial and utility-scale solar are subsidised by a tendering scheme, with 2.3 GW of these projects applying for financing in 2022 alone.

These supportive policies led to substantial growth in Dutch solar generation: rising from just 1% of the power mix in 2015 to 14% in 2022. In absolute terms, solar generation grew by 51% in 2022 alone (from 12 TWh to 17 TWh). Some barriers, such as grid congestion, are being swiftly removed by the government. The Netherlands also announced a rapid [offshore wind expansion plan](#) in response to Russia's invasion of Ukraine that puts the country in line with a target for a [100% clean power system by 2030](#). Solar deployment is expected to remain strong, with an 11 GW large-scale project pipeline and annual capacity additions expected to stay above 4 GW until 2026.

A spectacular example of the strength of renewables in 2022 also came from Greece, where the electricity grid ran [solely on renewables](#) for five hours in October. This was possible due to solar's share in power generation increasing from 9.6% in 2021 to 12.6%, placing Greece in second place on Europe's solar leaderboard. Greece added a record 1.3 GW in solar capacity, partly as a result of the [simplification of permitting](#), bringing its cumulative capacity to 5.5 GW. Similarly to other regions in Europe, grid congestion is emerging as a major bottleneck, and the government is tackling it through a grid expansion plan and a support scheme for energy storage units. The solar project pipeline is also strong, with around 3 GW of solar projects auctioned in 2022 alone. Greece is expected to reach its 2030 total installed solar target of 7.7 GW by the end of 2023, seven years early.

European citizens stepped up, deploying rooftop solar at scale

European governments quickly responded to Russia's invasion of Ukraine, [accelerating climate policies](#) and cutting both electricity demand and Russian fossil fuel imports. But in the shadow of top-level action, a quiet revolution started. European households massively invested in rooftop solar panels, adding 25 GW in 2022, 8 GW more than in 2021. Rooftop solar now represents 66% of the EU's total installed solar capacity of 209 GW.

New government initiatives helped accelerate rooftop solar's growth in 2022: Belgium provided [free solar panels](#) to households who could not afford them, and several states in Germany introduced a [rooftop solar obligation](#) on new buildings. The European Commission published its [EU Solar Energy Strategy](#), aiming to overcome workforce bottlenecks, accelerate rooftop solar deployment and streamline permitting.

Several governments also raised their [2030 renewable energy targets in 2022](#), including [Estonia](#), [France](#), [Denmark](#), [Greece](#), [Ireland](#), [the Netherlands](#) and [Portugal](#).

Solar avoided billions in gas import costs

Without the record solar generation of 203 TWh, the EU would have required an additional 35 billion cubic metres (bcm) of gas imports to produce that electricity with gas. That is the equivalent of around 25% of the EU's Russian gas imports in 2021. Applying the average European benchmark TTF gas price for 2022 of €121/MWh, this equates to €49 billion in avoided gas costs. The year-on-year solar growth of 39 TWh alone delivered savings of 7 bcm and €10 billion.

Keeping the solar momentum going

It is crucial the EU maintains the momentum around solar and implements new measures in 2023 to enable even faster deployment. As Ember's [previous research](#) shows, permitting times for solar in some EU countries are double the two year limit set in the [Renewable Energy Directive](#). The European Council approved temporary emergency measures to limit permitting times in December 2022. Future amendments to the Renewable Energy Directive must also address a key bottleneck for industrial scale solar: grid connection times.

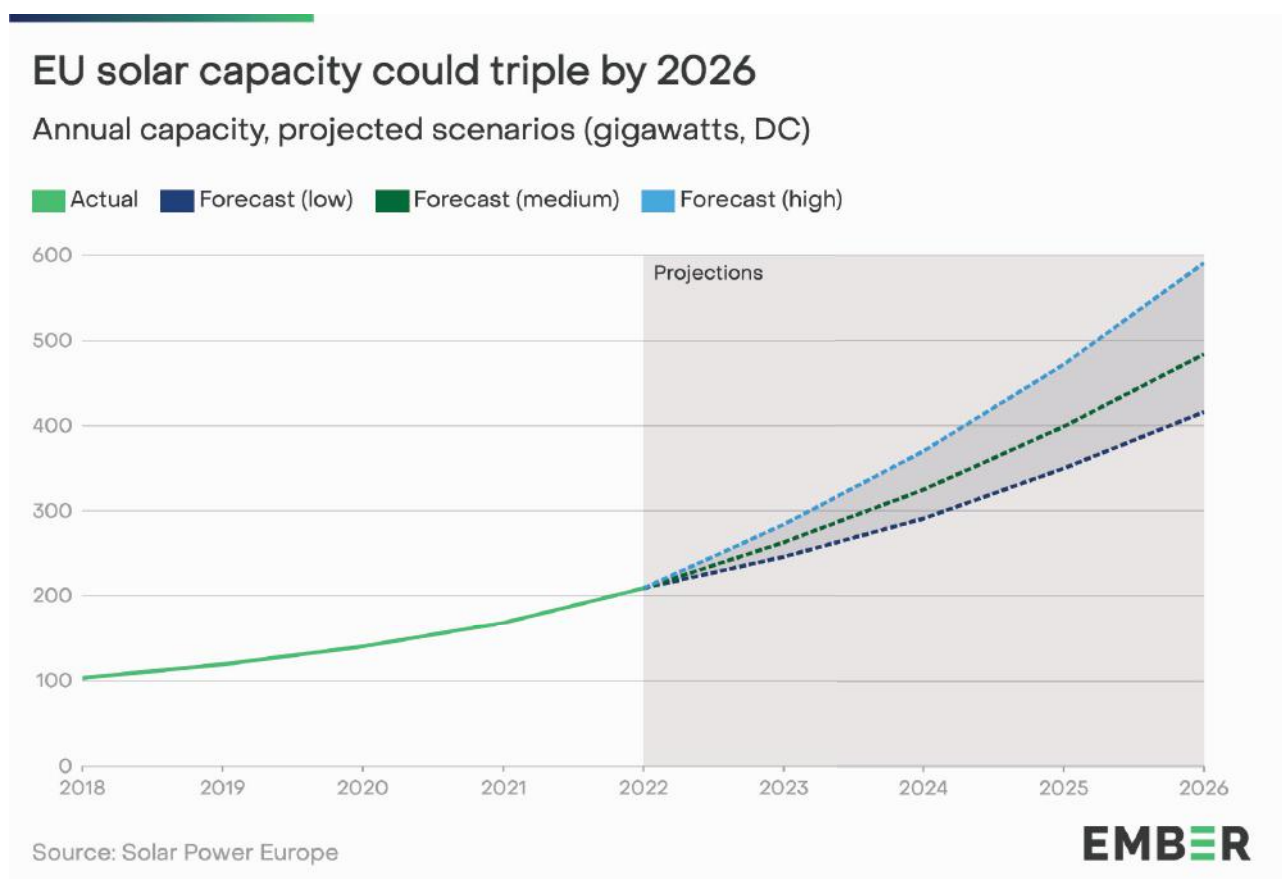
In 2022, many EU countries demonstrated that rooftop solar can ramp-up at speed. Now is the time for an EU-wide solar mandate on all new and renovated buildings, as well as existing non-residential buildings. While this would be a substantial initiative, these targets build on those already set in the [European Solar Rooftops Initiative](#) and would have an immediate impact on households in the coming winters.

The future is even brighter

In 2018, the EU had 103 GW of installed solar capacity. In just four years that doubled, reaching 209 GW at the end of 2022. Four years from now, and it is possible that solar will have tripled again to nearly 600 GW.

Solar Power Europe's latest [forecast](#) sees installed solar capacity growing by 54 GW in 2023 (medium scenario) and by up to 68 GW (high scenario). This is 30–65% higher than the record 41 GW installed in 2022. And this growth accelerates. By 2026, annual capacity additions are anticipated to reach 85 GW (medium) and 120 GW (high).

As part of its [REPowerEU plan](#) to expedite renewables deployment and replace fossil fuels, the European Commission has set solar capacity targets of 400 GW by 2025 and 740 GW by 2030. Solar Power Europe's high scenario shows that this is not ambitious enough, and capacity will reach 484 GW by 2026 and 920 GW by 2030—even under its medium scenario—and 591 GW by 2026 and 1184 GW by 2030 under its high scenario.



Solar growth has consistently exceeded expectations, and policies are continuously evolving to enable higher targets. The current ambition from REPowerEU and Solar Power Europe is aligned with and even overshooting the requirements for 1.5C. It is now imperative that these EU goals translate into local action. Member States must ensure that regulation and infrastructure is fit for purpose to enable the rapid rate of deployment of renewables that is not only necessary but inevitable.

Insight 4: Coal and gas generation to plummet in 2023

Coal generation rose by 7% in 2022, and gas generation rose by 0.8%. The increase in fossil generation of 3% was necessary due to two electricity crises in 2022: large-scale outages of France's nuclear power plants, and a 1-in-500 year drought.

However, 2023 will be a very different story, even as Germany completes its nuclear phase-out. French nuclear plants should return, even more solar and wind generation will be added, hydro should return to normal and electricity demand will continue to fall.

Much remains unpredictable in our current period of heightened economic, geopolitical and climate volatility. But if our assumptions below based on current indications come to fruition, fossil generation across the EU would plummet by 20% (211 TWh) in 2023. That would be almost double the record 11% drop seen in 2020 when Covid-19 struck.

What to expect for 2023

We assume that total nuclear generation will remain unchanged in 2023. In line with [EDF's announcement](#), we can expect French nuclear generation to rise by 40 TWh, however German nuclear phase-out will complete in April, knocking 30 TWh off 2023 production. German nuclear generation in 2022 was 37 TWh, but two (2.7 GW) units were given extensions until April 2023, at which point German nuclear generation falls to zero. We assume a 10 TWh decrease in other EU countries. Belgium's Tihange 2 (3 GW) will close on 31st January, although there should be increases elsewhere as Finland's [new](#) nuclear plant begins commercial operation.

We assume that hydro rises by 40 TWh. In 2023, hydro should rebound back to seasonal norms, which was 50 TWh higher than in 2022. But stocks entered the year a little lower, still lingering from lower rainfall in 2022.

The confirmed growth in capacity from 2022 into 2023 from WindEurope and Solar Power Europe, shows an increase 19% higher than the 72 TWh rise in 2022. Based on this, we assume that wind and solar rises by 86 TWh in 2023.

Electricity demand is perhaps the biggest uncertainty. Demand only began falling in earnest in 2022 in Q4, which recorded an unprecedented 8% fall. If we assume a 6% fall in Q1 2023, a 3% fall in summer 2023, with Q4 2023 the same as in 2022, then this would be a 3% total annual fall across 2023, or 84 TWh.

Across the EU power sector, this trajectory would mean a substantial decline in fossil generation, falling by 20% (211 TWh) in 2023.

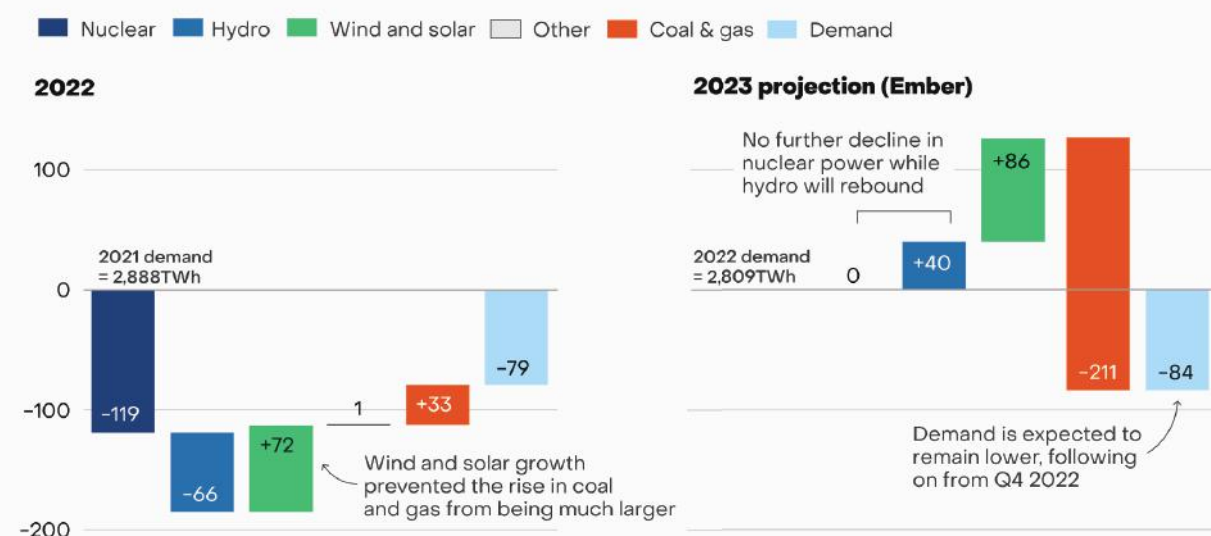
What this means for Europe

Gas generation will fall the fastest, as it is expected to remain more expensive than coal until at least 2025 (based on current forward prices). If total fossil generation falls by 20%, that means an even larger percentage fall in gas.

However, there will be many hours when gas power is not required, especially with even more wind and solar added and decreased demand. This means coal generation will very likely fall as well.

A big fall in fossil generation is expected in 2023

Year-on-year change in electricity generation, TWh



Source: Annual electricity data, Ember; Ember calculations
'Other' includes bioenergy, other renewables, other fossil fuels and net imports

The large fall in gas generation means the power sector is likely to be the fastest falling segment of gas demand during 2023, helping to bring calm to European gas markets as Europe adjusts to life without Russian gas. A decrease of 20% in EU gas generation would reduce the EU's economy-wide gas demand by 5%, thereby contributing to a more secure gas system in 2023.

The first two weeks of 2023, at the time of writing, had already seen a 29% fall in fossil generation compared to the same period in 2022, although the weather has been mild and windy across Europe.

Chapter 3 | EU Electricity Trends

Data on the EU's electricity sector in 2022

Data on the EU electricity sector in 2022, with an overview of changes and trends over the last two decades.

Electricity Demand

EU Electricity Trends 2022



At 2809 TWh, the EU represents 10% of global electricity demand. Germany has the highest electricity demand (556 TWh), accounting for almost 20% of total EU demand. Germany is followed by France (484 TWh), Italy (322 TWh) and Spain (265 TWh). The Nordic countries of Finland (15 MWh) and Sweden (13 MWh) have the highest demand per capita, while Romania (3 MWh) has the lowest.

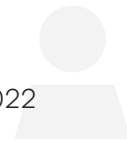
2,809 TWh

EU total demand in 2022



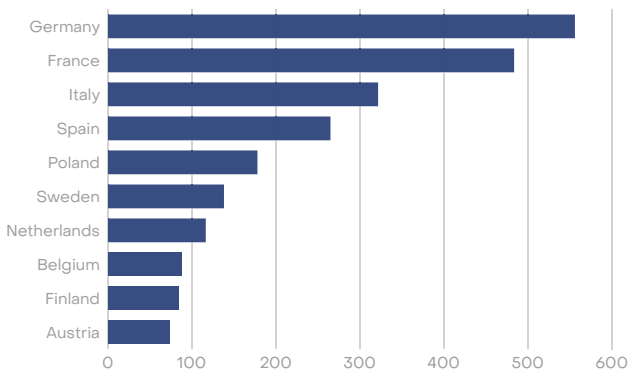
6.31 MWh

EU demand per capita in 2022



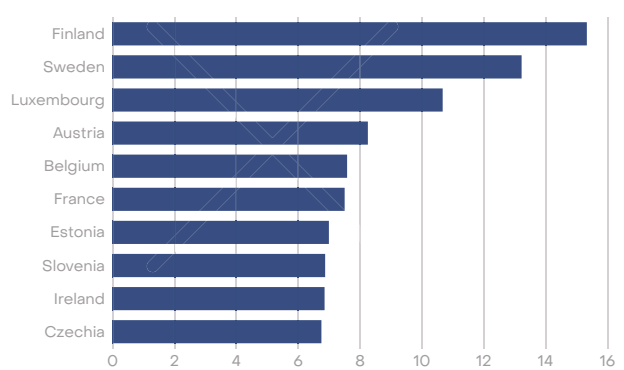
EU countries with highest demand

Electricity demand (TWh)



EU countries with highest demand per capita

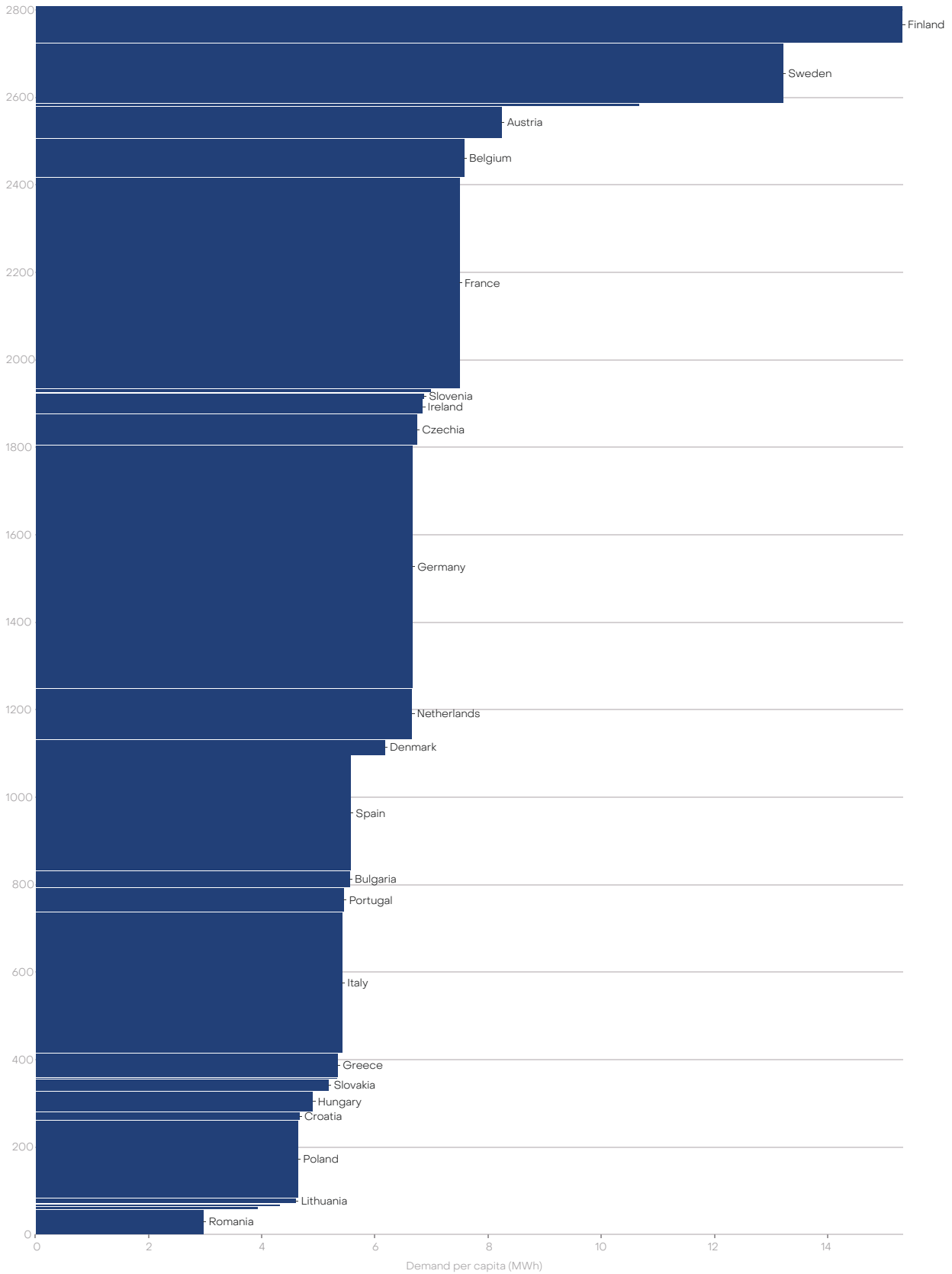
Electricity demand per capita (MWh)



Regional Context

Electricity demand across the EU

Electricity demand (TWh, y-axis) and demand per capita (MWh, x-axis)



Source: Ember

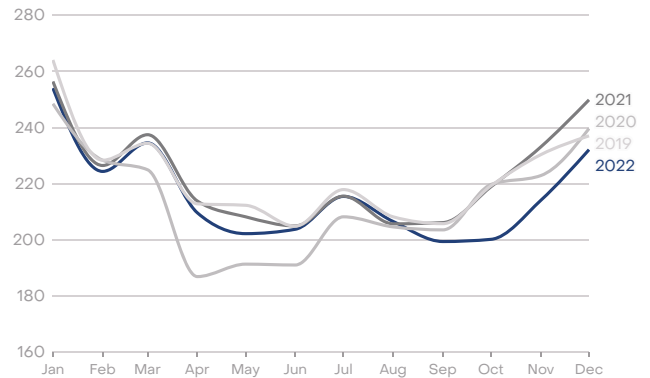
Note: uses full-year data for 2022 in all EU-27 countries

Change in 2022

From October 2022, EU electricity demand has seen large year-on-year falls. It fell by 8.5% in Q4 2022 compared to the same period in 2021. Earlier in the year, electricity demand was only slightly down. The fall in demand was primarily due to mild weather, alongside demand reduction measures driven in part by high electricity prices. Across the year as a whole, EU demand fell by 2.7% (-79 TWh), from 2888 TWh in 2021 to 2809 TWh in 2022. This follows a substantial increase in 2021 of 118 TWh (+4.2%) as demand rebounded from a pandemic low. France recorded the largest absolute reduction in demand in 2022 with demand falling by 22 TWh (-4.3%) to 484 TWh from 505 TWh. Slovakia saw the largest relative decrease with demand falling 8.1% (-2.5 TWh). Almost all EU countries experienced falling or stagnant demand in 2022. Malta, Cyprus, Ireland and Portugal were the exception, with demand growing between 3 and 6%.

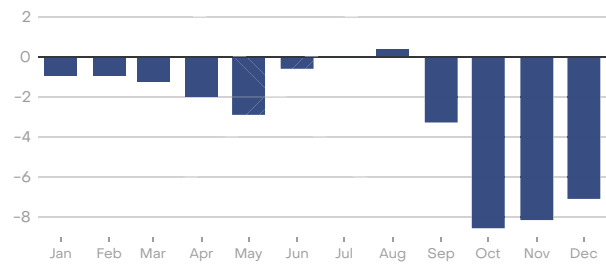
EU electricity demand

Electricity demand (TWh)



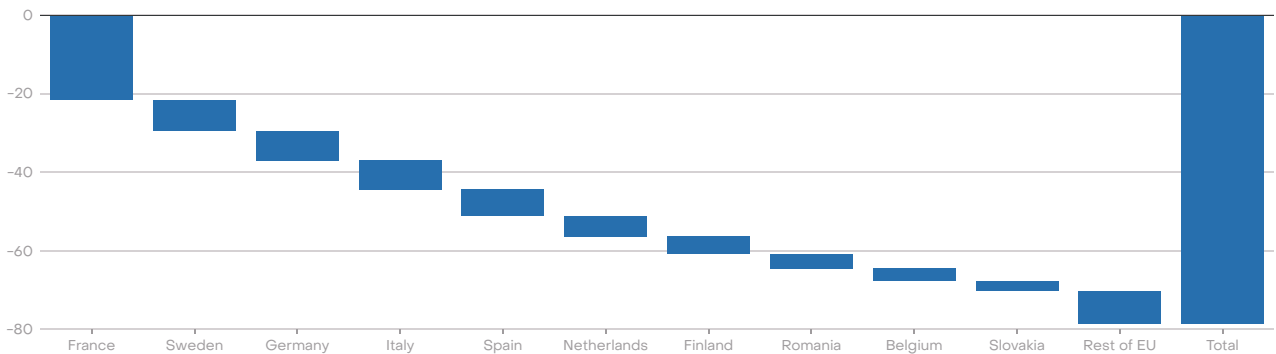
Monthly changes in EU electricity demand

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



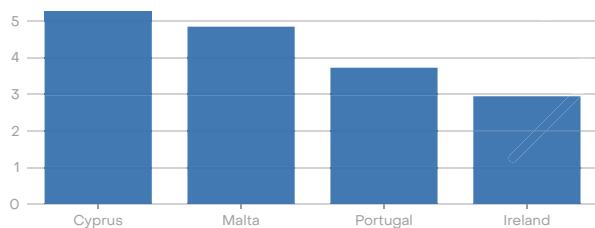
Key changes in EU electricity demand

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



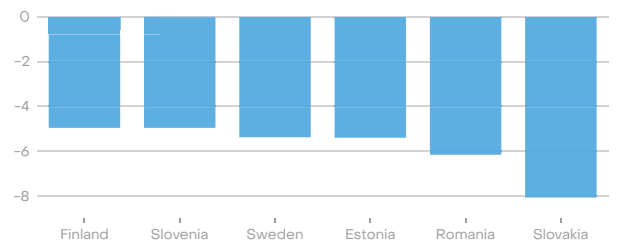
Largest increases

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



Largest declines

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



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Long-term Trends

Until the Covid-19 pandemic, EU electricity use has been largely stable since 2010, following recovery from the financial crisis. In 2020, the impact of the pandemic saw demand reductions comparable with those of the financial crisis, with a 110 TWh fall in power consumption (compared to a 151 TWh drop in 2009). In 2022, demand was 2% below what it was at the time of the Paris Agreement in 2015.

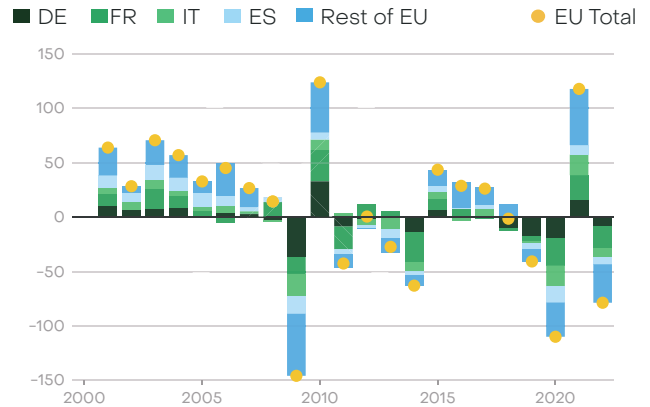
EU-wide electricity demand per capita has remained broadly flat over the last two decades. In 2000, it was 6.2 MWh, rising only slightly to 6.3 MWh 2022. However, this varies at the country level. Eastern European countries such as Hungary, Croatia, Poland and Lithuania have seen moderate increases whereas western European countries like Germany, Spain and France have seen demand per capita decline.

EU electricity demand is expected to increase this decade as electrification expands across sectors, which may happen quicker than expected in response to the energy crisis.

Demand savings, however, have so far kept track with these increases, and there are still many remaining opportunities for efficiency improvements.

Annual changes in EU electricity demand

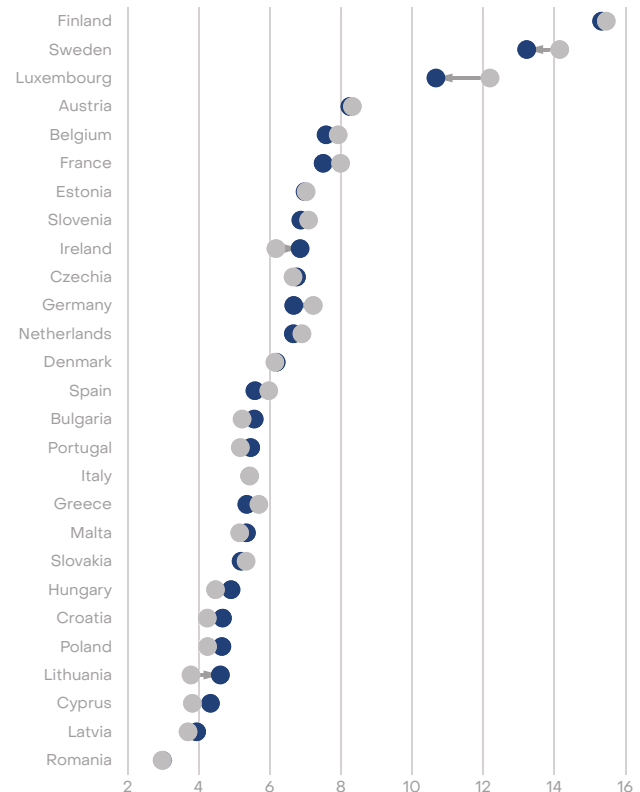
Change in electricity demand year-on-year (TWh)



Demand per capita, EU countries

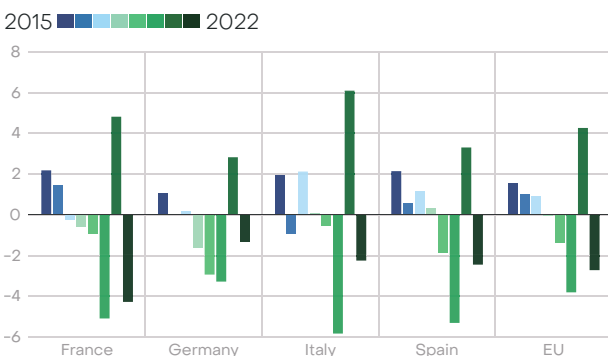
Electricity demand per capita (MWh)

● 2015 ● 2022



Annual changes in electricity demand across the EU

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



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Power Sector CO2 Emissions

EU Electricity Trends 2022

The EU has the world's fourth-most CO2 emitting power sector, considered alongside countries globally. It was responsible for 712 million tonnes of CO2 in 2022, which is 5.7% of the world's total power sector emissions. At 230 million tonnes, Germany has by far the highest total power sector emissions of any EU country ahead of Poland, Italy and Spain. Poland has the most carbon-intensive electricity at 692 gCO2/kWh, due to its heavy use of coal for electricity generation. Across the EU, carbon intensity of electricity production is 255 gCO2/kWh.

712 mtCO2

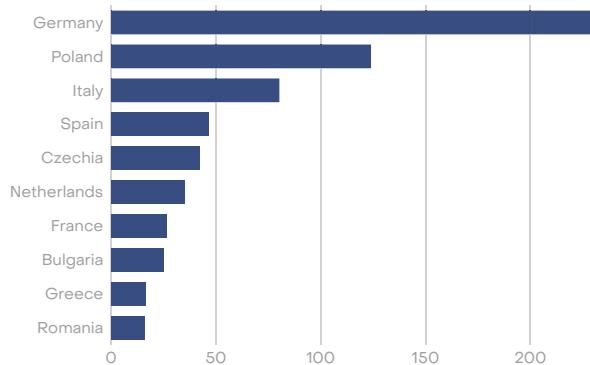
EU power emissions in 2022

255 gCO2/kwh

EU CO2 intensity in 2022

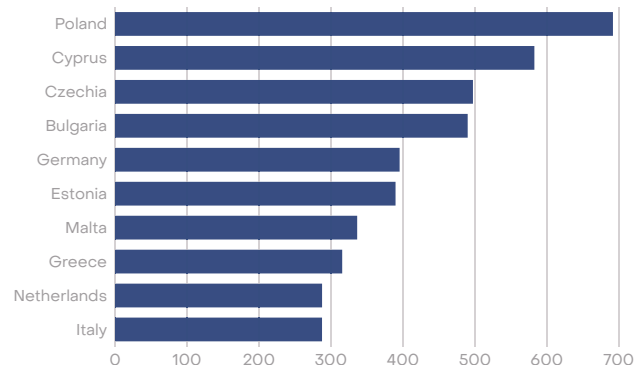
EU's largest power sector emitters

Total emissions (mtCO2)



EU's dirtiest electricity grids

CO2 intensity (gCO2/kWh)

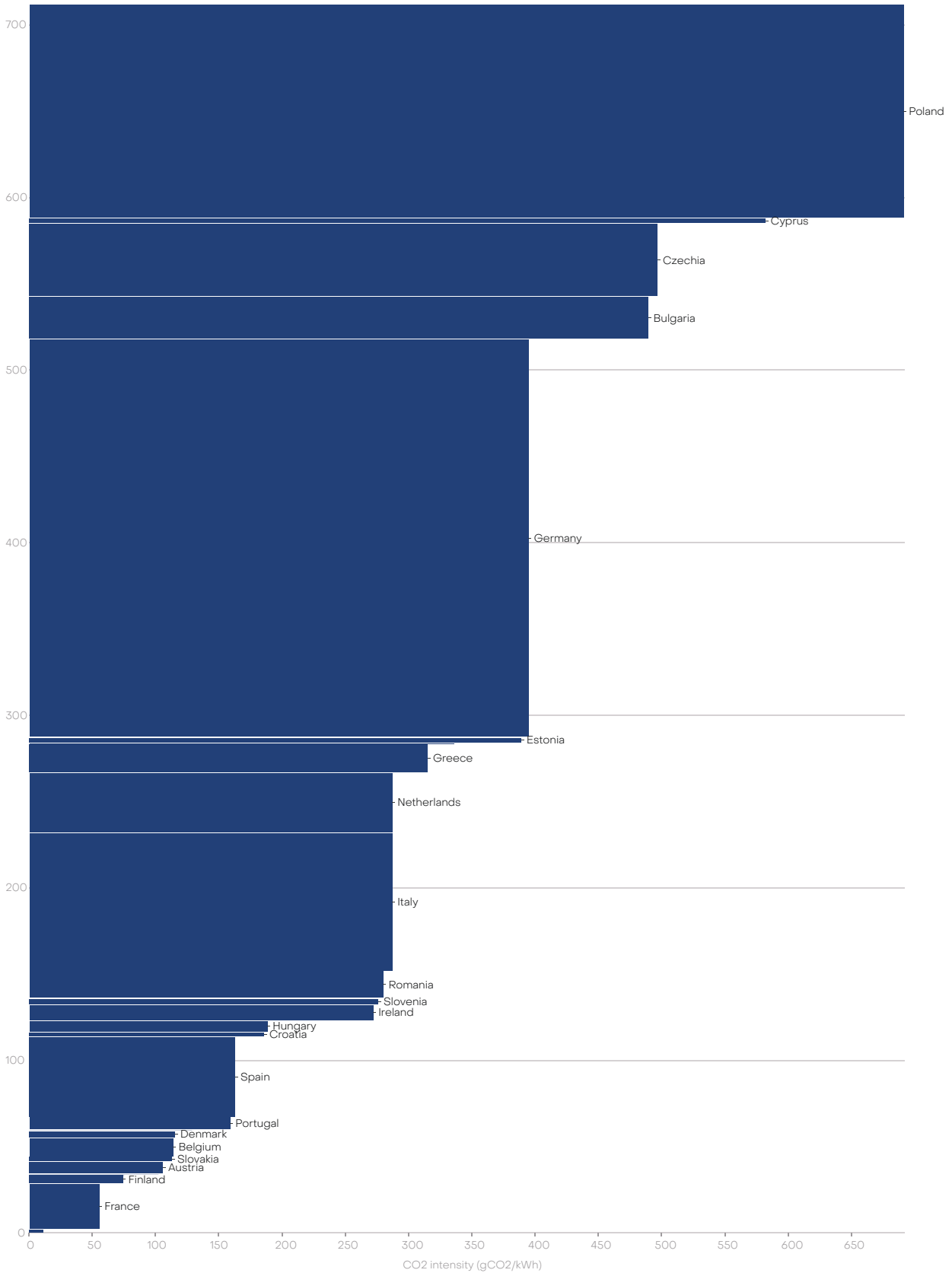




Regional Context

EU power sector emissions

Power sector emissions (mtCO₂, y-axis) and CO₂ intensity (gCO₂/kWh, x-axis)



Source: Ember

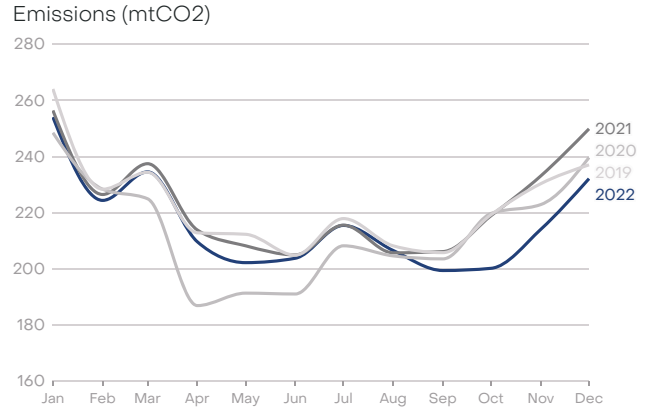
Note: uses full-year data for 2022 in all EU-27 countries

Change in 2022

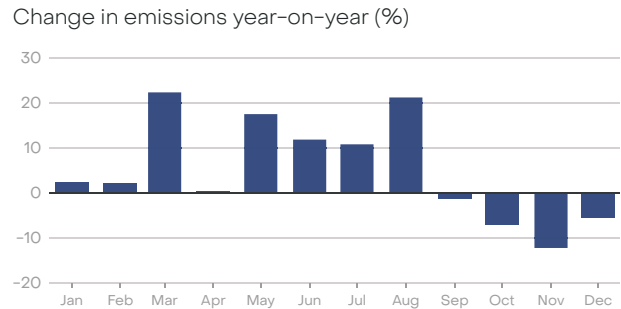
The last four months of 2022 saw year-on-year declines in EU power sector CO2 emissions, resulting from demand reductions and a reduction in fossil generation. Overall power sector emissions rose by 3.9% (+26 MtCO2) compared to 2021. This was despite year-on-year increases of over 20% for some months earlier in the year, as nuclear and hydro shortfalls required a large increase of fossil generation, and especially of coal generation.

The biggest absolute emissions increase was from Germany, producing 230 MtCO2 (+13 MtCO2, +6.1%). Other increases came from Spain (+7.6 MtCO2, +19%), Italy (+6.9 MtCO2, +9.3%) and Bulgaria (+4.7 MtCO2, +23%). The second biggest emitter, Poland, had the greatest reduction in emissions of all EU countries (-3.7 MtCO2, -2.9%).

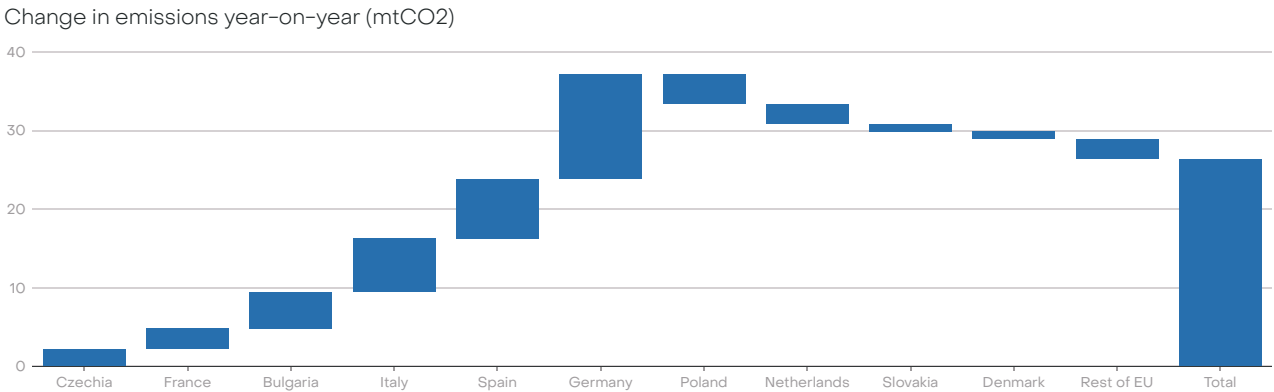
EU power sector emissions



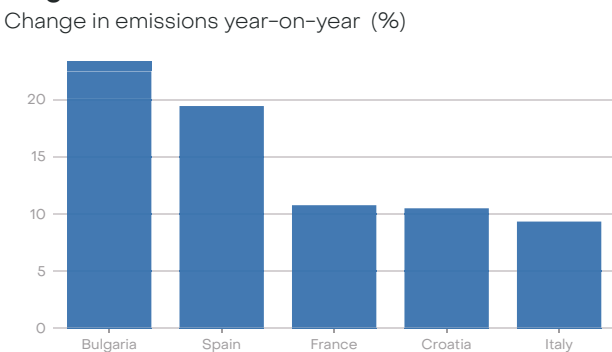
Monthly changes in EU electricity emissions



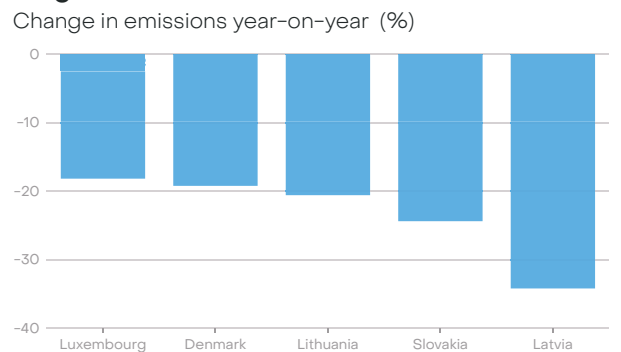
Key changes in EU electricity emissions



Largest increases



Largest declines



Long-term Trends

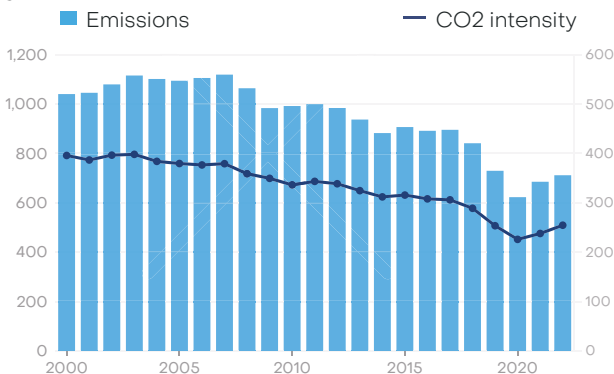
2022 marks the second year in a row of increasing emissions after the post-pandemic demand rebound in 2021 saw emissions rise by 10% (+62 million tonnes of CO₂), the largest ever year-on-year increase. However, the emissions rises in 2021 and 2022 followed three years of strong emissions reductions between 2018 and 2020.

The EU's carbon intensity of electricity generation in 2022 (255 gCO₂/kWh) is significantly lower than it was in 2000 (396 gCO₂/kWh). Wind and solar deployment has accelerated since 2010, and despite the decline in nuclear generation (-29% since 2000), the EU grid continues to get cleaner. Total EU emissions have fallen by 32% (-329 MtCO₂) since 2010.

Since the Paris Agreement in 2015, carbon intensity has fallen in every EU country (with the exception of France as a result of this year's nuclear shortfall). As a result, EU annual power sector emissions have decreased by 22% (-195 MtCO₂) over the same period.

Long-term trends in EU electricity emissions

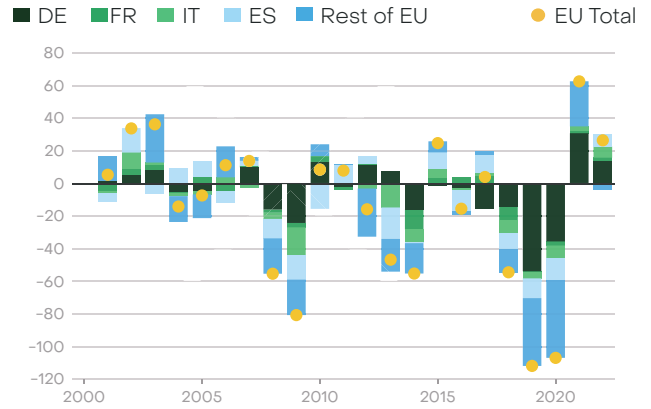
Emissions (mtCO₂, left axis) and CO₂ intensity (gCO₂/kWh, right axis)



Source: Ember

Annual changes in EU electricity emissions

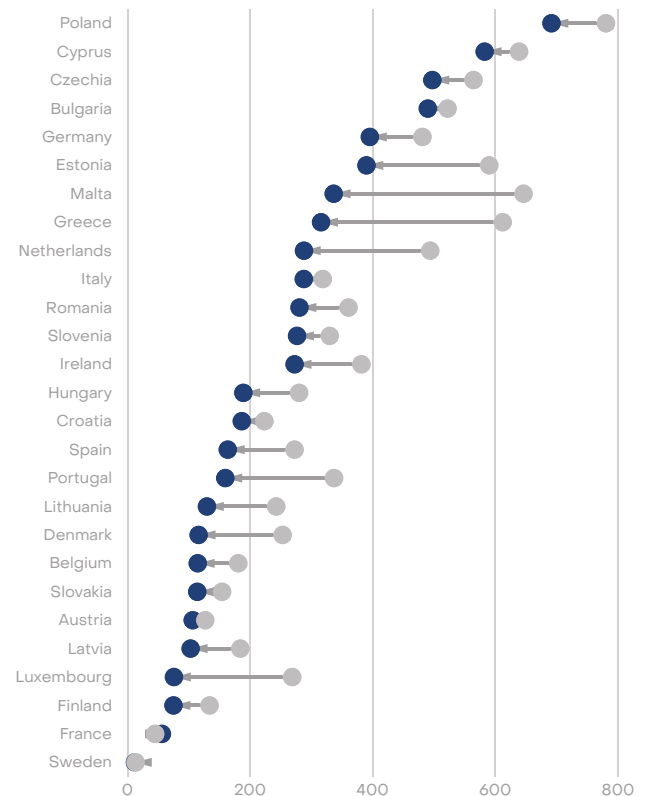
Change in emissions year-on-year (mtCO₂)



Carbon intensity of electricity, EU countries

CO₂ intensity of electricity, (gCO₂/kWh)

● 2015 ● 2022



Note: uses full-year data for 2022 in all EU-27 countries

Electricity Generation

EU Electricity Trends 2022

The EU was an early deployer of renewable power sources, and continues to be a leader in this area. A proposed 45% renewable energy goal for 2030 would see 69% of the EU's electricity generated from renewables by that year. Today however, EU electricity generation is still heavily reliant on fossil fuels. 39% (1,104 TWh) of its electricity is generated from coal, gas and other fossil sources. Coal produces 16% (447 TWh), gas 20% (557 TWh) and other fossil fuels 3.6% (100 TWh). Nuclear remains the single largest contributor to EU electricity at 22% (613 TWh) of the mix. 15% (420 TWh) is produced by wind and 7.3% (203 TWh) is produced by solar. Combined, wind and solar produce more electricity than any other fuel (22%, 623 TWh). The rest is produced by hydro (10%, 283 TWh), bioenergy (6%, 167 TWh) and other renewables (0.2%, 6.7 TWh).

2,795 TWh

EU total generation
in 2022

623 TWh

EU wind and solar generation
in 2022

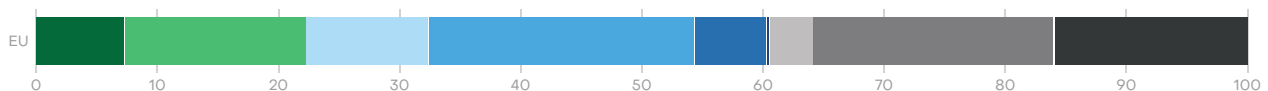
1,104 TWh

EU fossil fuels generation
in 2022

EU electricity mix

Share of electricity (%)

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

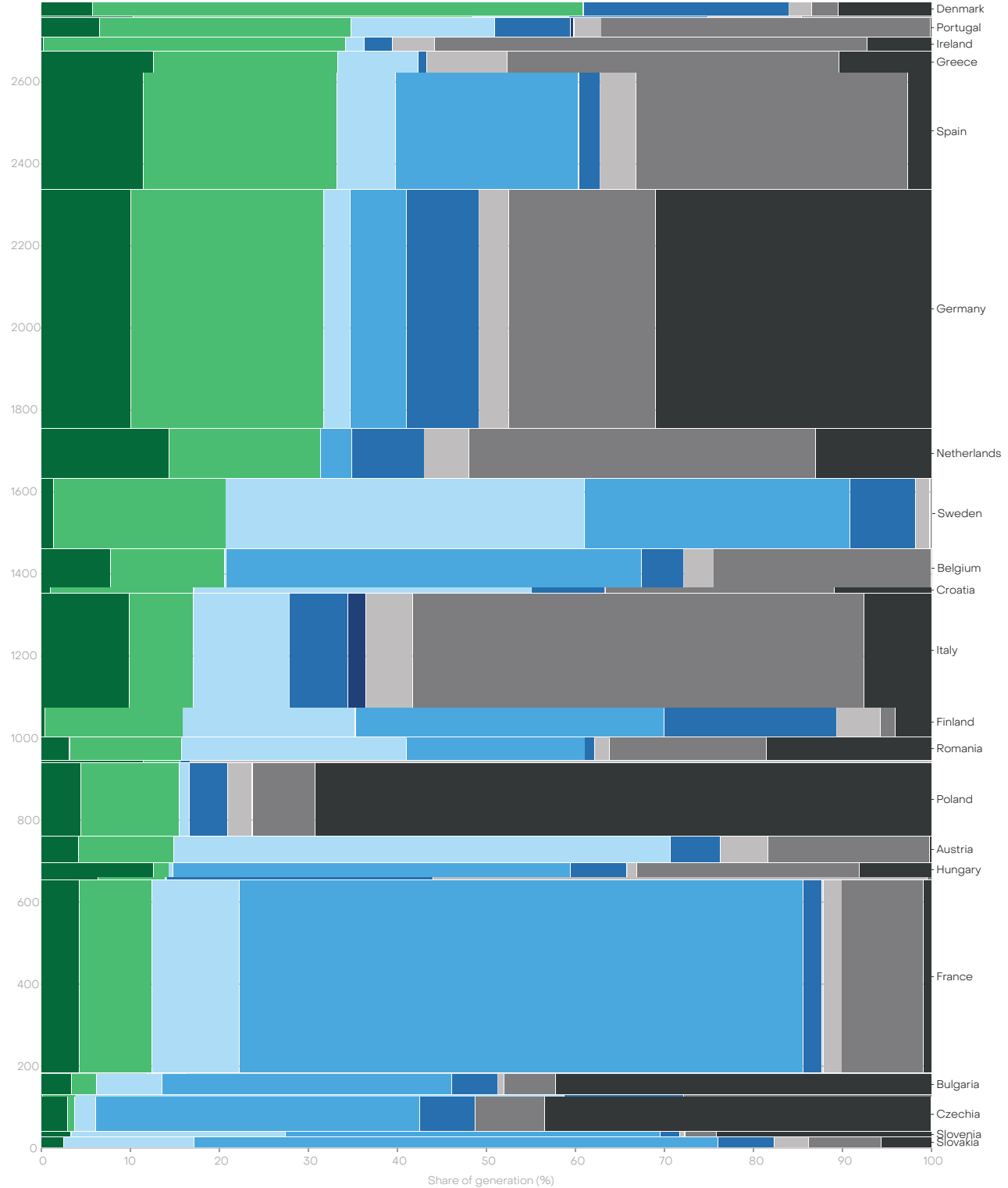


Regional Context

Electricity generation across the EU

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

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



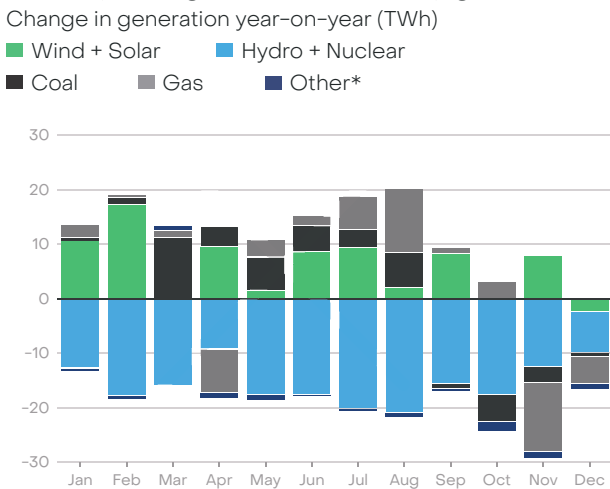
Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Change in 2022

In 2022, changes in EU electricity generation were dominated by historic falls in hydro and nuclear generation. Hydro generation was heavily impacted by prolonged heat waves in the summer, falling by 66 TWh (-19%). Outages and maintenance of French plants significantly decreased availability of nuclear generation throughout most of the year. German nuclear plant closures further reduced nuclear output. As a consequence, nuclear generation dropped 119 TWh (-16%) to its lowest share of the mix (22%) in 40 years. French nuclear alone was responsible for 82 TWh of the shortfall. Low hydro and nuclear output meant that despite lower electricity demand, fossil generation increased year-on-year. Coal was up 28 TWh (+6.7%) and gas was up 4.5 TWh (+0.8%). Wind and solar generation continued to grow, with wind up 33 TWh (+8.6%) and solar growing an impressive 39 TWh (+24%). This brought their market share to 22%, up from 19% in the previous year. Other fossil power, other renewables and bioenergy generation all remained largely stable.

Monthly changes in EU electricity generation

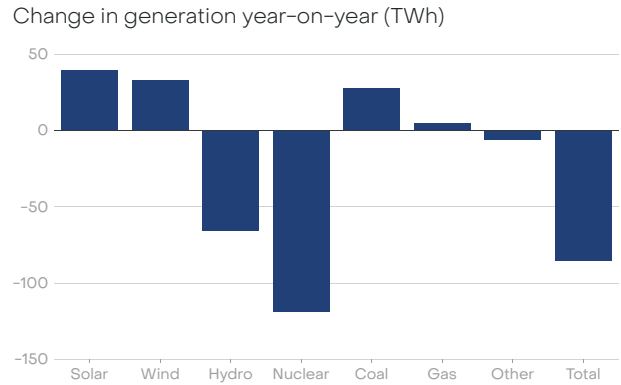


*Other includes bioenergy, other renewables and other fossil fuels.

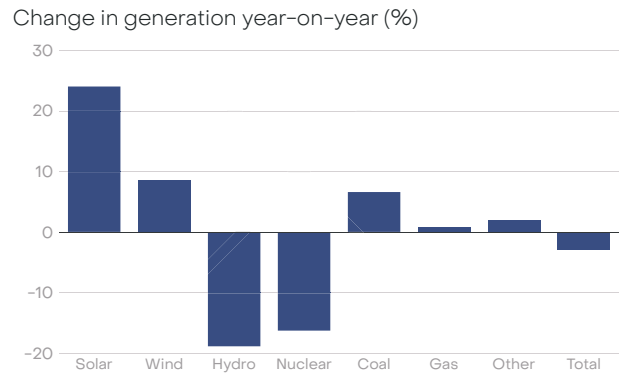
Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

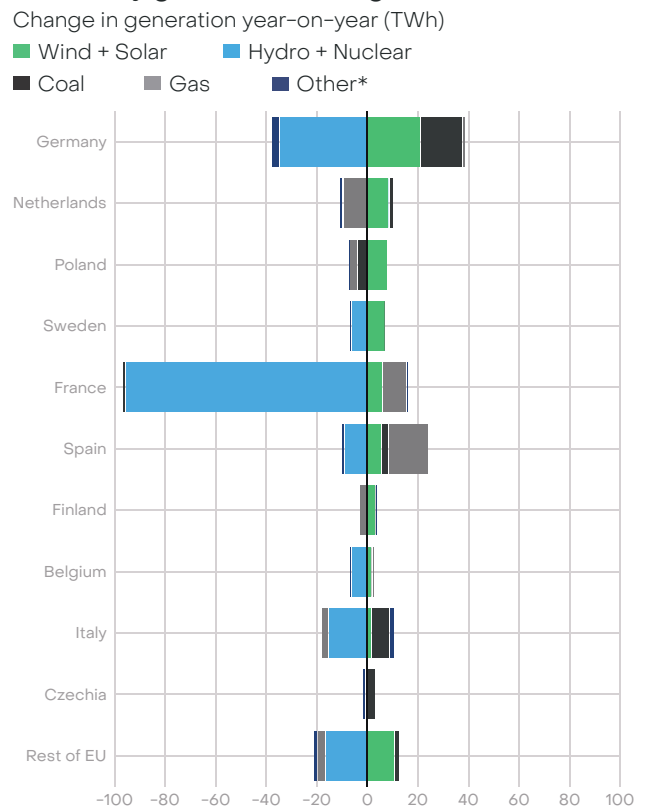
Absolute changes in EU electricity generation



Relative changes in EU electricity generation



Electricity generation changes in EU countries



Long-term Trends



The defining characteristic of the changes in EU electricity generation has been the growth of wind and solar generation as well as a reduction of coal.

Wind and solar generation has grown from just 13% (364 TWh) at the time of the Paris agreement to 22% (623 TWh) in 2022. In 2000, the share of wind and solar generation in the mix was less than 1%.

The growth of wind and solar has allowed the EU to reduce coal generation. In 2000, nearly a third of the EU's electricity was generated using coal (30%, 800 TWh). It had only declined slightly to 25% (705 TWh) by 2015. Since then, the acceleration of wind and solar build up has reduced coal to just 16% (447 TWh) of the electricity mix.

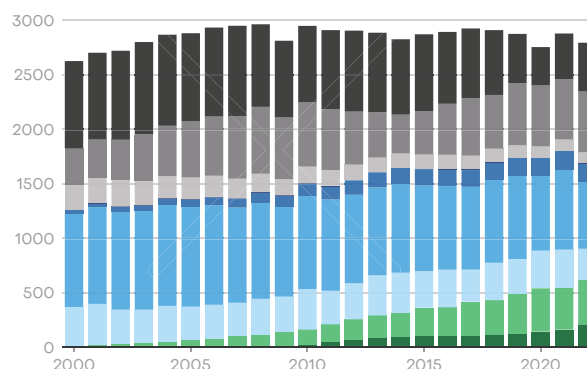
Coal generation has fallen substantially, and is likely to decline further in the coming years. However, the EU's second largest contributor to emissions from the power sector, fossil gas, has seen an increase over the last two decades. It grew from just 13% (331 TWh) in 2000 to 20% (557 TWh) of the mix in 2022. Gas has seen substantial increases since 2015, when it contributed only 14% (397 TWh) to EU electricity generation.

Despite falls in nuclear generation over the last two decades and since 2015, as well as the recent rise in gas generation, fossil generation as a whole has declined substantially. Electricity generated from clean sources now produces 61% (1,692 TWh) of the EU's electricity. Fossil fuels generate 39% (1,104 TWh). In 2000, they produced 48% (1,263 TWh) and 52% (1,361 TWh) respectively.

EU electricity generation

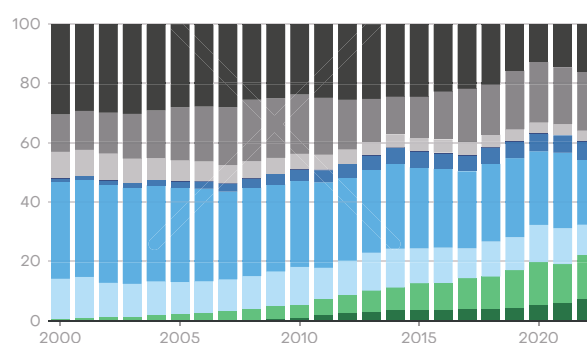
Generation (TWh)

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



EU electricity mix

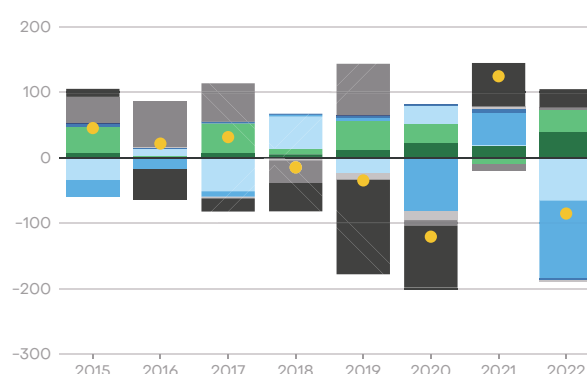
Share of electricity (%)



Annual changes in EU electricity generation

Change in generation year-on-year (TWh)

● EU total



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Chapter 4 | Electricity Source Trends

Data on EU electricity sources in 2022

Data on EU electricity generation from bioenergy, coal, gas, hydro, nuclear, solar and wind in 2022, with an overview of changes and trends over the last two decades.

Solar

EU Electricity Trends 2022



Solar power produced 7.3% (203 TWh) of EU electricity in 2022. Germany is the biggest generator at 59 TWh (10% of its electricity mix), producing nearly twice as much as the second biggest generation Spain (33 TWh, 12%). The Netherlands have the highest percentage share of solar generation in their electricity mix with 14% (17 TWh), ahead of Greece (6.6 TWh, 13%) and Hungary (4.5 TWh, 13%).

203 TWh

EU solar generation in 2022

7.3%

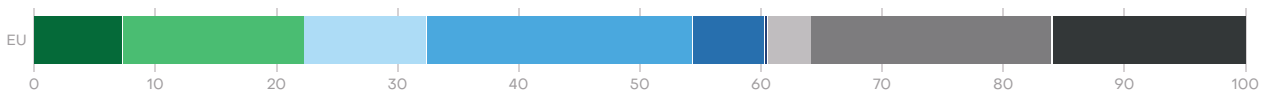
solar share in EU generation in 2022



EU electricity mix

Share of electricity (%)

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



Role of solar

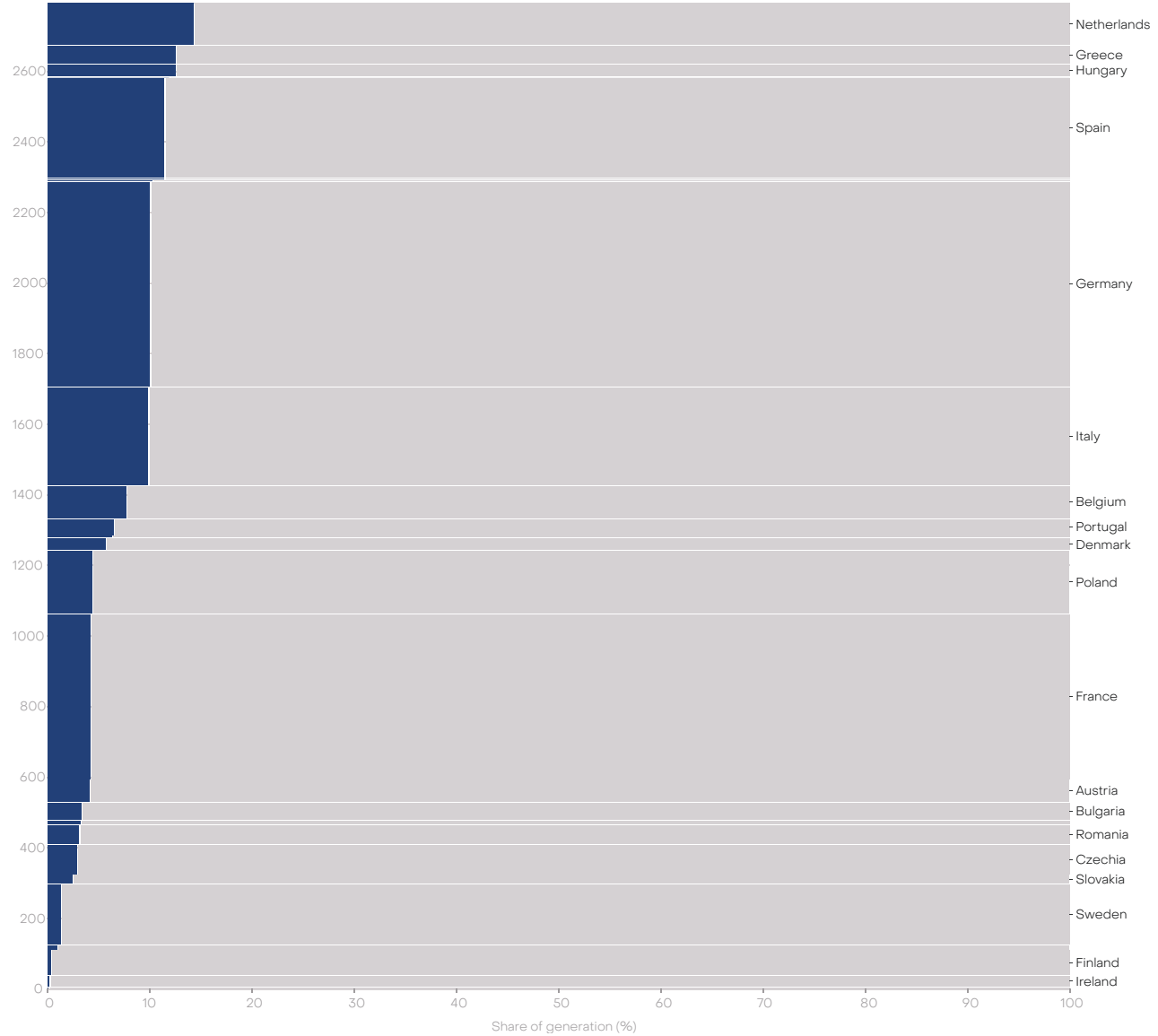
Solar provides clean power that can be deployed quickly and locally to the demand source. As such, together with wind, it will form the backbone of the future electricity system by providing nearly 70% of global electricity by 2050. New solar power produces the cheapest electricity in history, according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

Regional Context

Major players in solar power

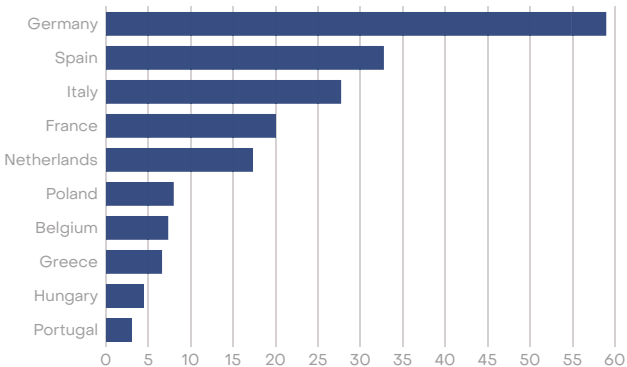
Electricity generation (TWh, y-axis) and share of electricity (% x-axis)

■ Solar ■ Other fuel types



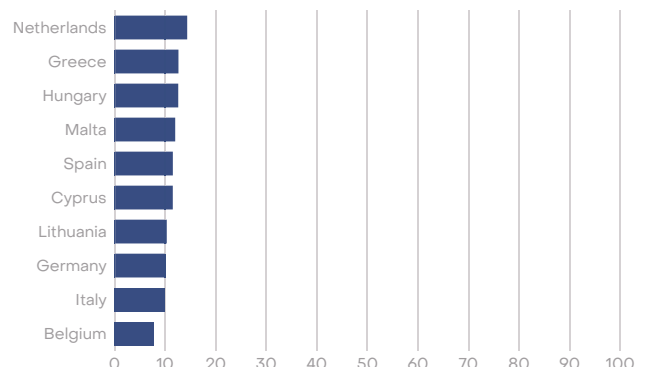
Largest solar generators in the EU

Electricity generation (TWh)



Highest shares of solar power

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Change in 2022

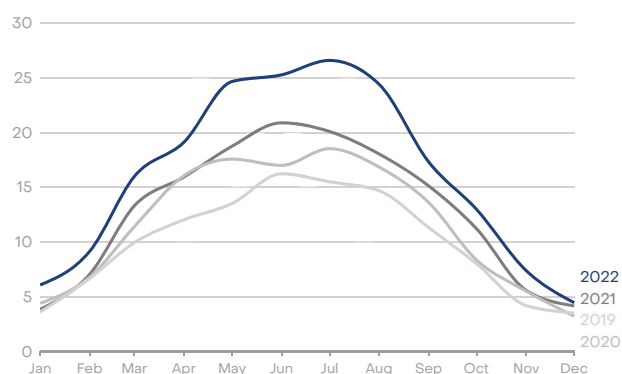


Solar electricity generation in the EU grew by 24% in 2022, from 164 TWh in 2021 to 203 TWh in 2022. This brought solar's share in the electricity mix to 7.3%, a 1.6 percentage point increase from the previous year (5.7%). The increased solar generation was due to a significant rise in Germany (+9.6 TWh, +20%) as well as substantial increases in Spain (+5.7 TWh, +21%), the Netherlands (+5.8 TWh, +51%), France (+4.3 TWh, +27%) and Poland (+4.1 TWh, +104%). Compared to the previous year, solar generation fell only in Austria (-0.05 TWh, -1.8%) and Slovenia (-0.01 TWh, -2.2%).

January saw the highest year-on-year percentage increase of 58%. May (+32%, +5.9 TWh), July (+32%, +6.5 TWh) and August (+35%, +6.4 TWh) all saw year-on-year increases above 30% and resulted in the largest absolute increases compared to last year.

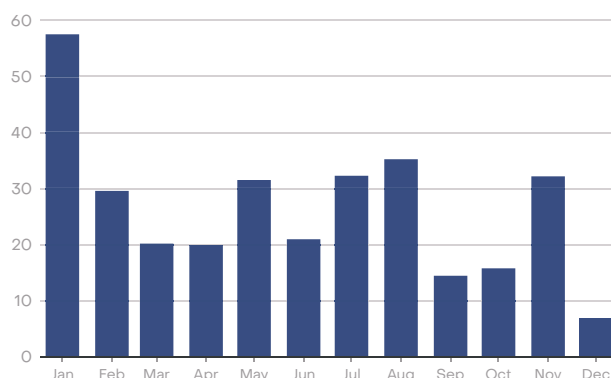
EU solar generation

Electricity generation (TWh)



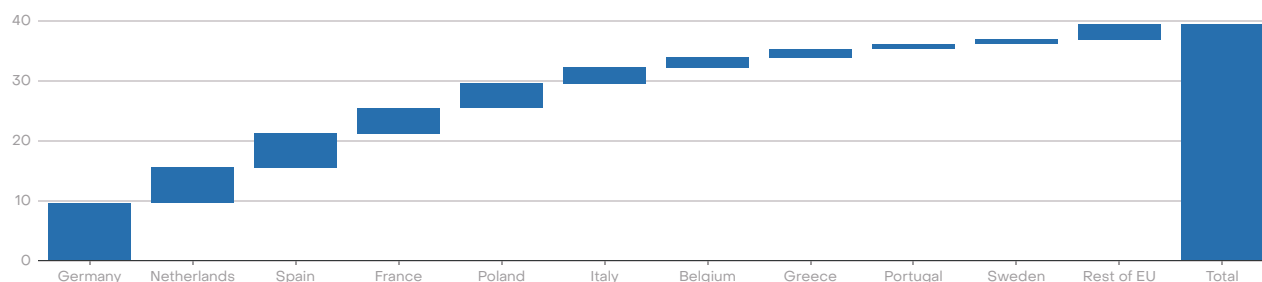
Monthly changes in EU solar generation

Change in generation year-on-year (%)



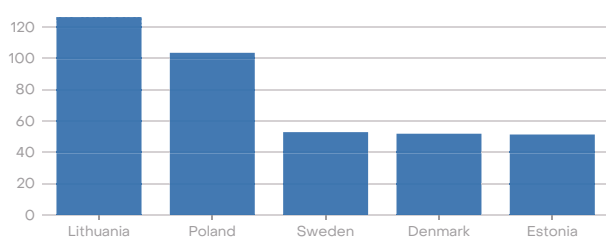
Key changes in EU solar generation

Change in generation year-on-year (TWh)



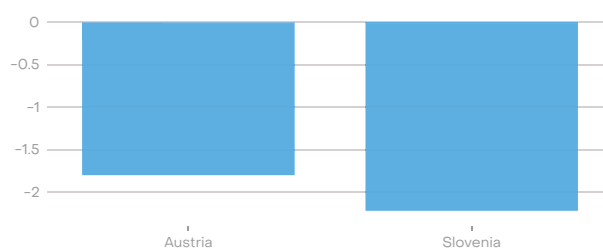
Largest increases

Change in generation year-on-year (%)



Largest declines

Change in generation year-on-year (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Long-term Trends

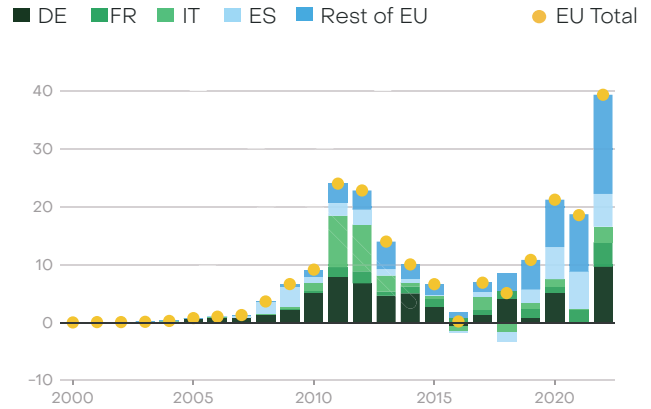
Solar generation rose in the overall EU electricity mix from 0% (0.1 TWh) in 2000 to 7.3% (203 TWh) in 2022.

Solar deployment in Germany and Italy drove strong growth in the early 2010, but following that growth fell, declining to nearly zero in 2016. However, solar has been growing at an average annual rate of 11% since the Paris Agreement in 2015. This represents slower growth than the upwards trend between 2000–2015 (+58% annually). 2022 saw a year-on-year increase of 24% (39 TWh). Solar’s market share has grown from 3.5% to 7.3% of EU electricity generation since 2015.

Countries like Hungary, the Netherlands and Cyprus have seen a remarkably quick integration of solar generation into their electricity mix. The share of solar in the Netherlands increased from only 1% (1.1 TWh) to 14% (17 TWh) since 2015. Hungary saw similar growth from 0.5% (0.1 TWh) to 13% (4.5 TWh) in the same period. Just like wind generation, solar has seen broad buy-in across the entire EU and grew in nearly all countries.

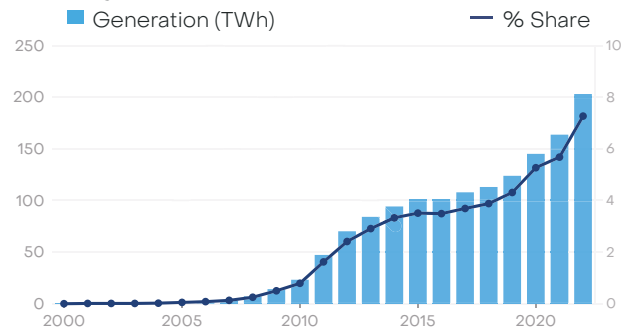
Annual changes in EU solar generation

Change in generation year-on-year (TWh)



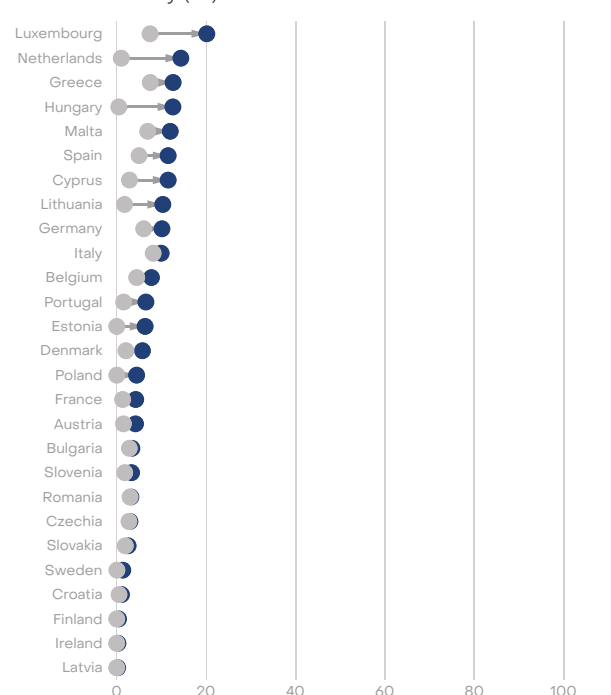
Long-term trends in EU solar generation

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



Solar share, EU countries

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Wind

EU Electricity Trends 2022



Wind power produced 15% (420 TWh) of EU electricity in 2022. Germany is the biggest generator at 126 TWh (22% of its electricity mix), ahead of Spain (62 TWh, 22%). Denmark has the highest percentage share with 55% of its electricity mix (19 TWh) ahead of Lithuania (38%), Ireland (34%) and Portugal (28%). Wind generation is currently the second largest clean source of electricity in the EU, but is set to continue to grow and surpass nuclear generation. There are now eight EU countries where wind produces more than 20% of electricity, and 16 countries with more than 10% share.

420 TWh

EU wind generation in 2022

15.0%

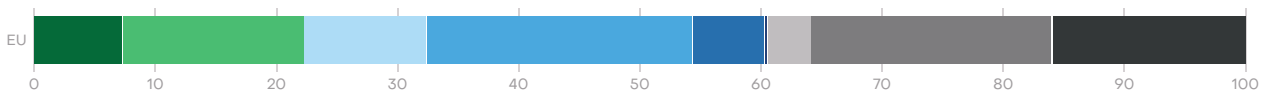
wind share in EU generation in 2022



EU electricity mix

Share of electricity (%)

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

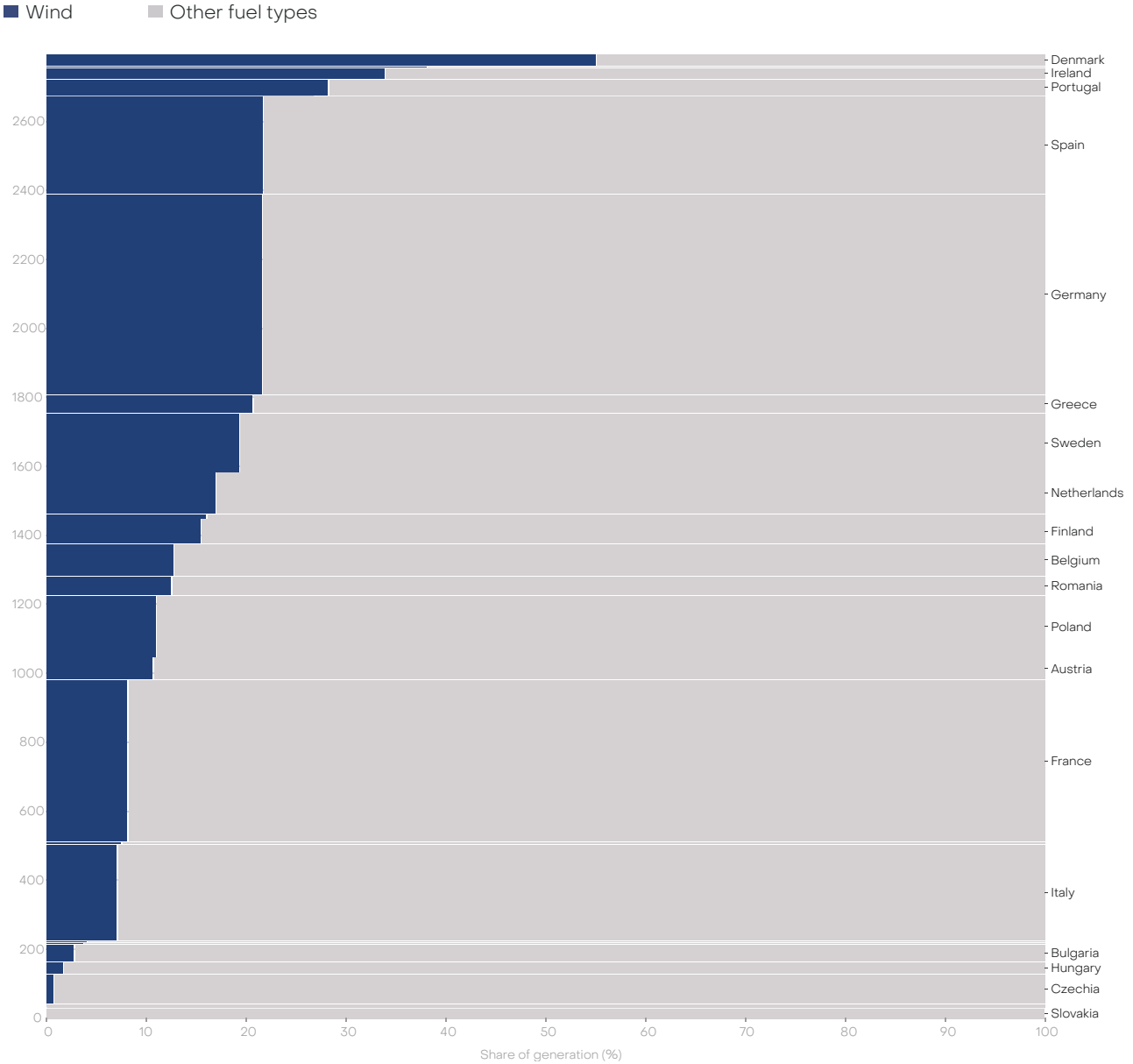


Role of wind

Wind, 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.

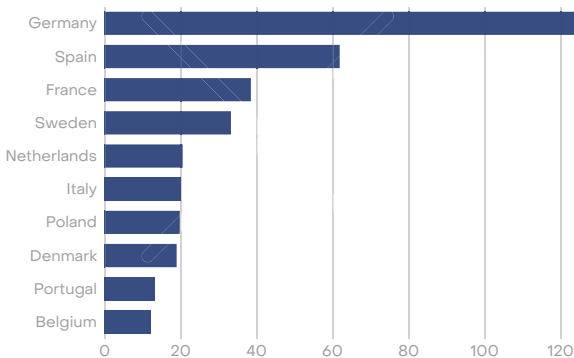
Major EU players in wind power

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



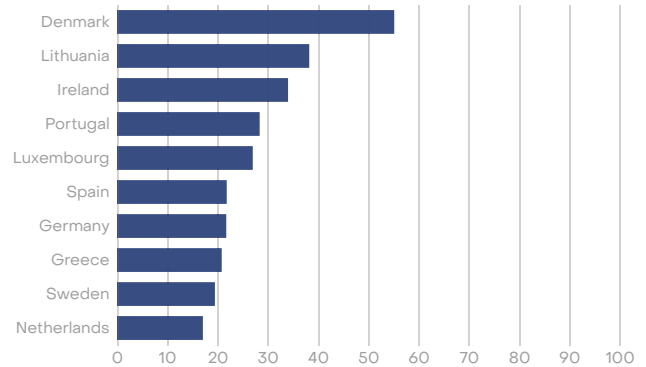
Largest wind generators in the EU

Electricity generation (TWh)



Highest shares of wind power in the EU

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Change in 2022

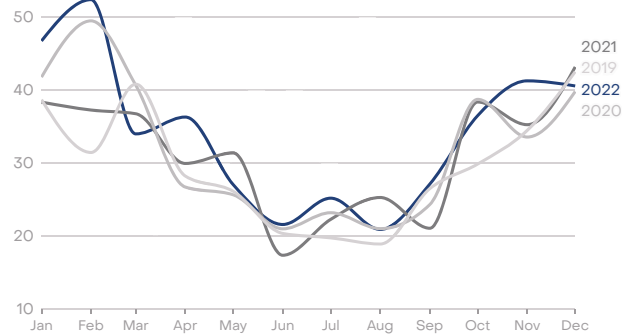
EU wind generation rose by 8.6% (+33 TWh), from 387 TWh in 2021 to 420 TWh in 2022. This more than makes up for last year's fall of 11 TWh, but is still lower than growth in 2015, 2017 and the largest year-on-year increase in 2019 of 47 TWh.

Share of wind power in the electricity mix also grew by 1.6 percentage points, from 13.4% in 2021 to 15% in 2022. The increase in wind power was driven by significant increases in Germany (+11 TWh, 10%) as well as Sweden (+6 TWh, 22%) and Poland (+3.5 TWh, 22%).

Italy, Hungary, Cyprus and Estonia saw some reductions in wind generation, but only with modest absolute falls that did not affect the overall balance of generation across the EU.

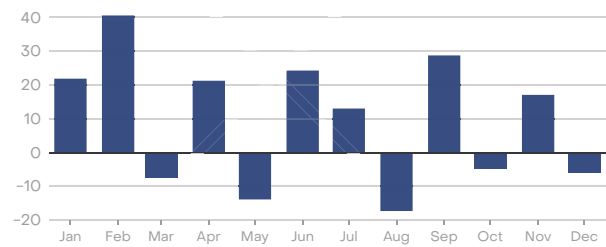
EU wind generation

Electricity generation (TWh)



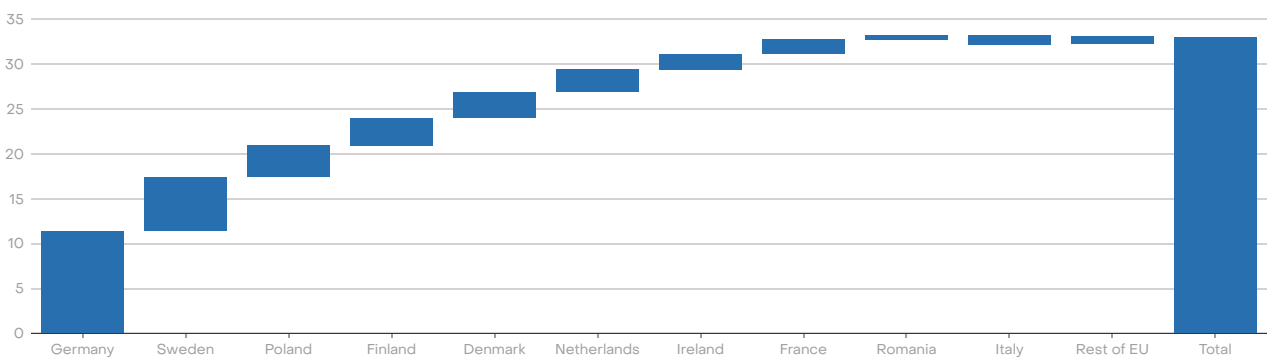
Monthly changes in EU wind generation

Change in generation year-on-year (%)



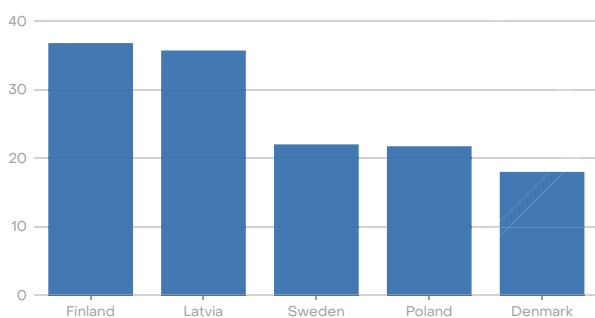
Key changes in EU wind generation

Change in generation year-on-year (TWh)



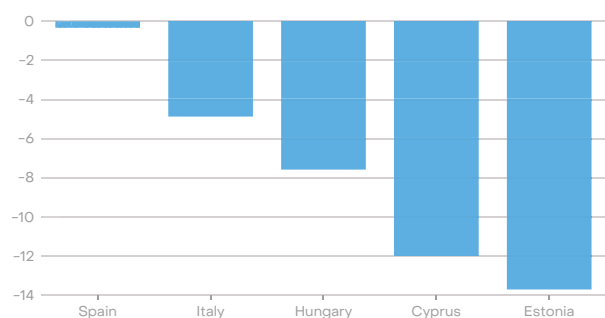
Largest increases

Change in generation year-on-year (%)



Largest declines

Change in generation year-on-year (%)



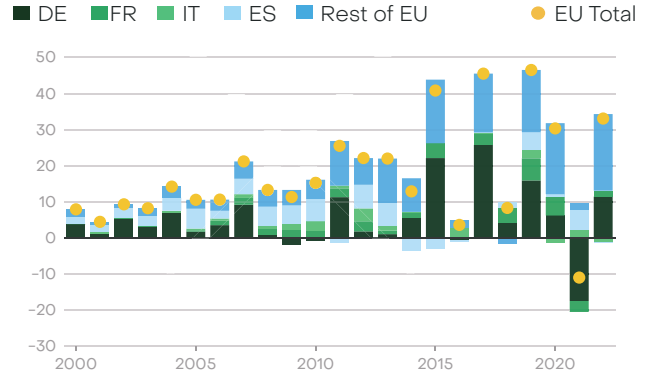
Long-term Trends

Wind generation has increased by 398 TWh in the last two decades (+1,873%) and has subsequently also risen in the overall electricity mix (from 0.8% of the EU's electricity mix in 2000 to 15% in 2022). There has been consistent growth in wind generation over the last 20 years with the exception of 2021. This was not a structural decline, but rather caused by bad wind conditions in the first half of the year that resulted in lower than usual generation.

Since the Paris Agreement in 2015, wind has been growing an average of 6.9% annually. This represents a decline of the upwards trend between 2000–2015 (+18.3% annually). However, 2022 saw a year-on-year increase of 8.6% (33 TWh). Wind's market share has risen from 9.2% to 15% of EU electricity generation since 2015. This trend is consistent across most of the EU with a few exceptions in countries with Hungary and Cyprus as the only exceptions. Large increases in market share in Lithuania and Luxembourg are mostly explained by their low overall generation.

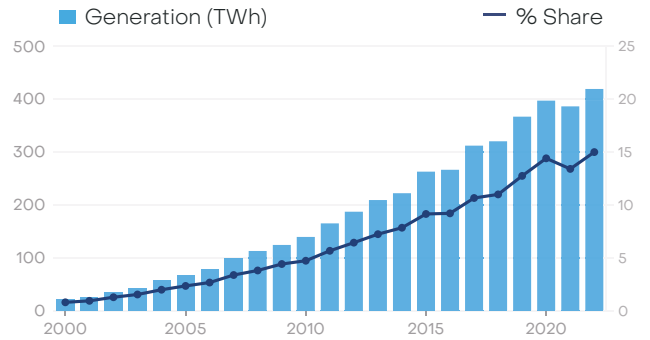
Annual changes in EU wind generation

Change in generation year-on-year (TWh)



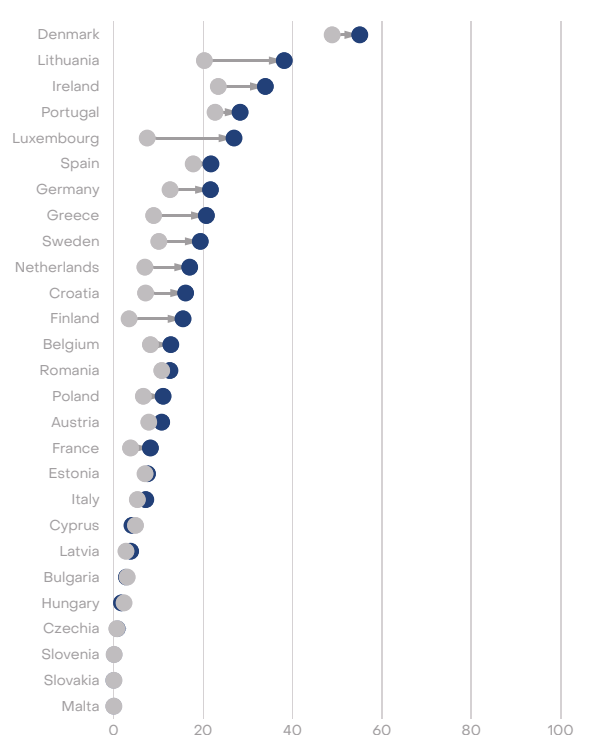
Long-term trends in EU wind generation

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



Wind share, EU countries

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Coal

EU Electricity Trends 2022



Coal power produced 16% (447 TWh) of EU electricity in 2022. Germany is the biggest coal generator (181 TWh, 31% of its electricity mix), while Poland has the highest percentage share at 69%, with a total output of 124 TWh. Poland, Czechia, Bulgaria and Germany all still produce more than 30% of their electricity from coal. More and more countries in the EU have either phased out or have committed to a phase-out of coal generation.

447 TWh

EU coal generation in 2022



16.0%

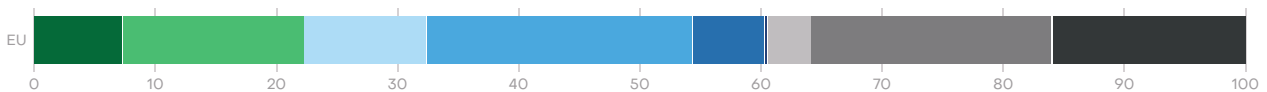
coal share in EU generation in 2022



EU electricity mix

Share of electricity (%)

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



Role of coal

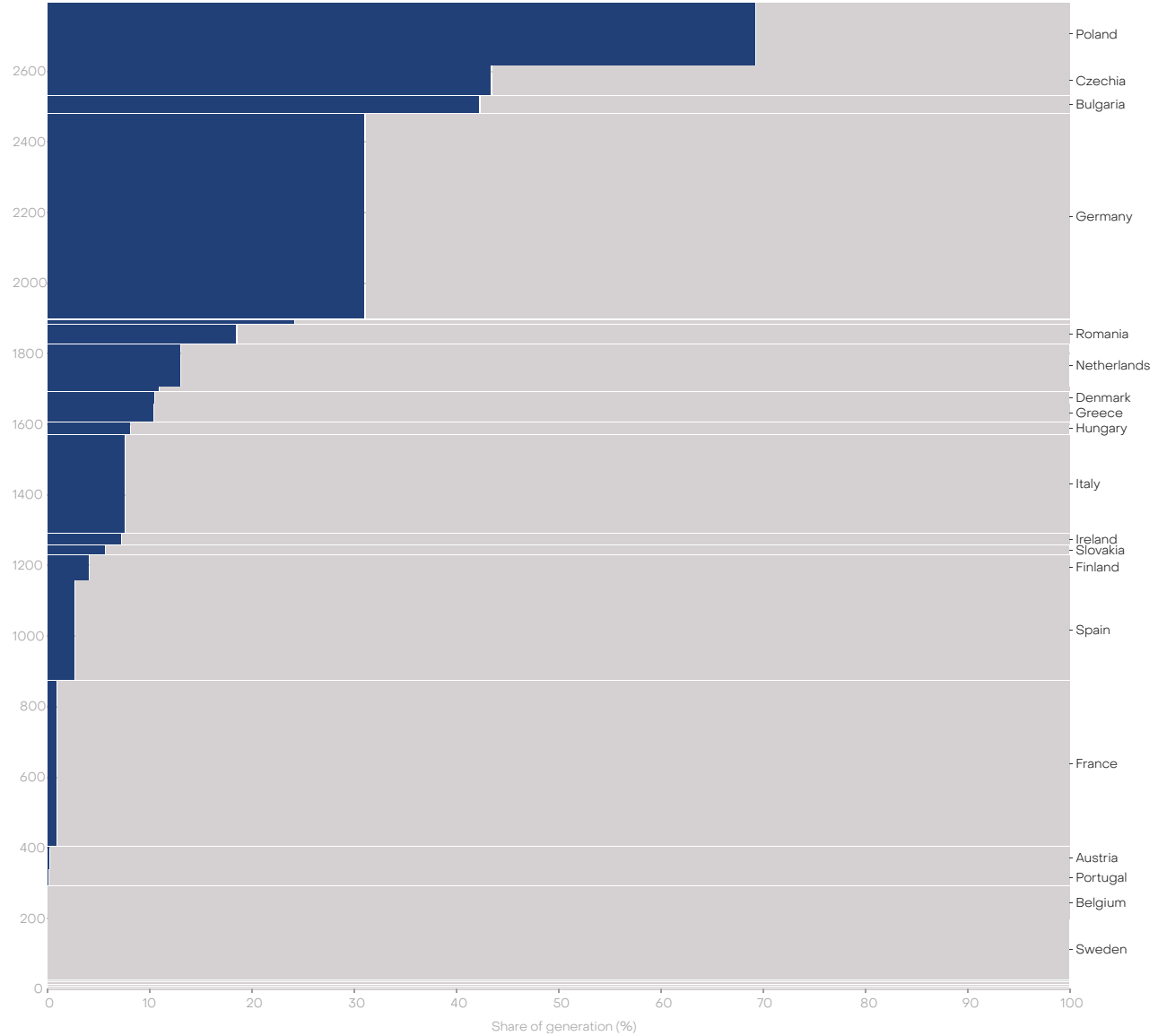
Coal is the single largest contributor to emissions from the power generation sector. As such, its role has to be reduced rapidly in the next two decades so the world has a chance to limit global warming to 1.5C. As per IEA Net Zero scenario, unabated coal plants need to be phased out by 2030 in developed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

Regional Context

Major EU players in coal power

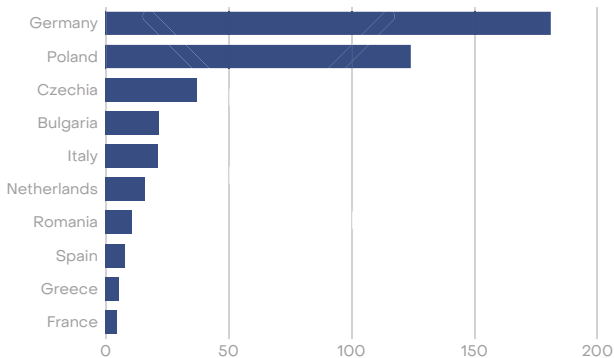
Electricity generation (TWh, y-axis) and share of electricity (% x-axis)

■ Coal ■ Other fuel types



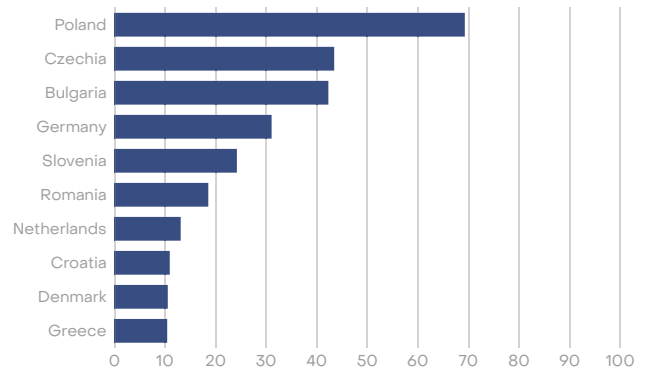
Largest coal generators in the EU

Electricity generation (TWh)



Highest shares of coal power in the EU

Share of electricity (%)



Source: Ember

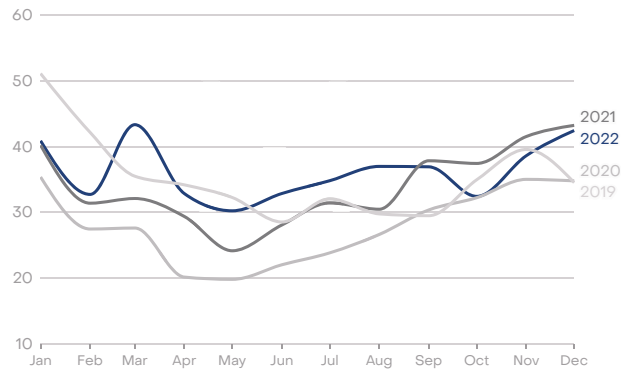
Note: uses full-year data for 2022 in all EU-27 countries

Change in 2022

EU coal electricity generation rose by 6.7% (28 TWh), from 419 TWh in 2021 to 447 TWh in 2022. This pushed coal's share in the EU electricity mix from 14.5% in 2021 to 16% in 2022. The increase was largely temporary, as coal met some of the reduction in nuclear and hydro generation. The largest increases were recorded in March and over the summer months. This trend was largely reversed by the Q4 2022. The last four months of the year saw coal generation below 2021 levels.

EU coal generation

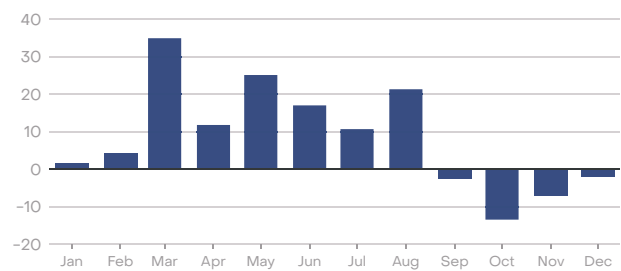
Electricity generation (TWh)



The rise in coal power was most noticeable in Germany (+17 TWh, +10%) with smaller rises in Italy (+7.2 TWh, +51%) and Bulgaria (+4.3 TWh, +25%). Portugal reduced coal power to near zero (-93%, -0.7 TWh) as it closed its last coal power plant. France, Denmark, Slovenia and Ireland also saw cuts to coal generation. Poland recorded the largest absolute decline with coal falling 2.5 TWh (-2.7%).

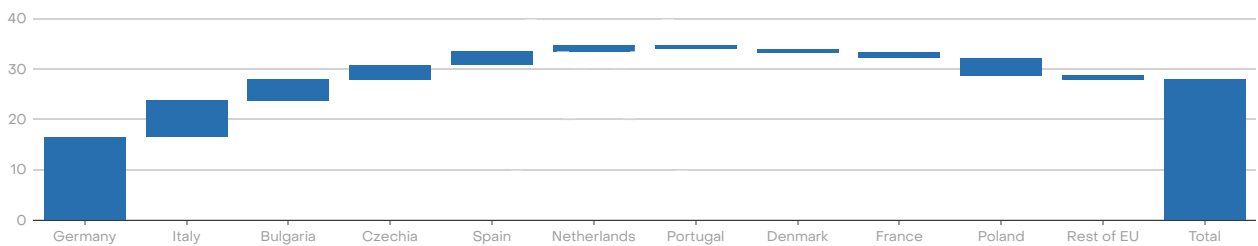
Monthly changes in EU coal generation

Change in generation year-on-year (%)



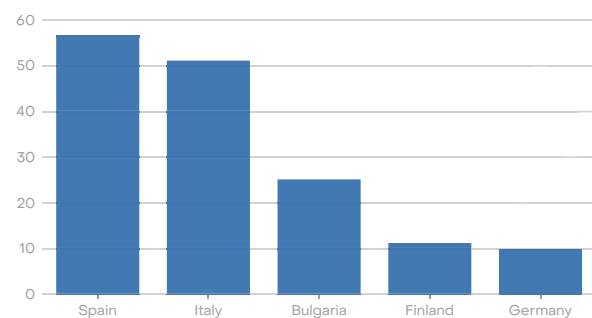
Key changes in EU coal generation

Change in generation year-on-year (TWh)



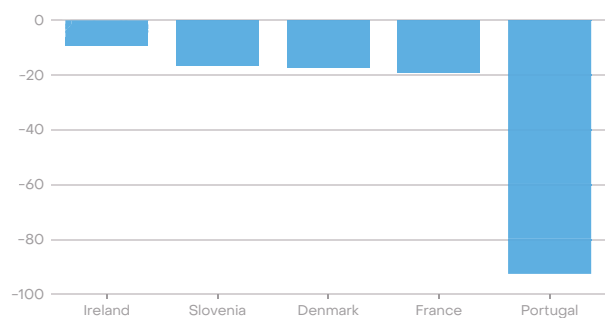
Largest increases

Change in generation year-on-year (%)



Largest declines

Change in generation year-on-year (%)



Long-term Trends

Coal generation has fallen by 353 TWh in the last two decades (-44%), going from 30% of the EU's electricity mix in 2000 to 16% in 2022.

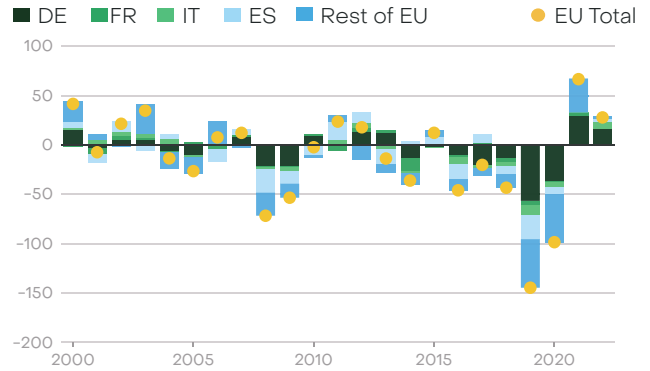
Despite increases in 2021 and 2022, coal power in 2022 was still 37% below 2015 levels. Coal's share has fallen from 25% to 16% of EU electricity generation since 2015.

Every EU country had a smaller share of coal in 2022 than in 2015. The biggest falls in generation share were in Greece (10%, down from 43%), Portugal (0.1%, down from 29%), the Netherlands (13%, down from 36%) and Spain (2.7%, down from 19%).

The use of coal for power generation is set to fall further. Coal phaseout targets, increased generation from wind and solar, as well as a rebound in French nuclear generation will reduce the need for the comparatively expensive fossil fuel.

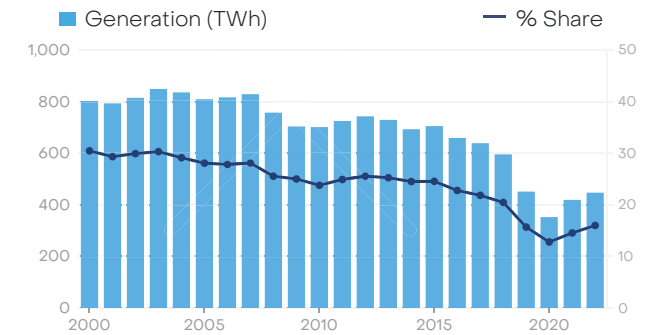
Annual changes in EU coal generation

Change in generation year-on-year (TWh)



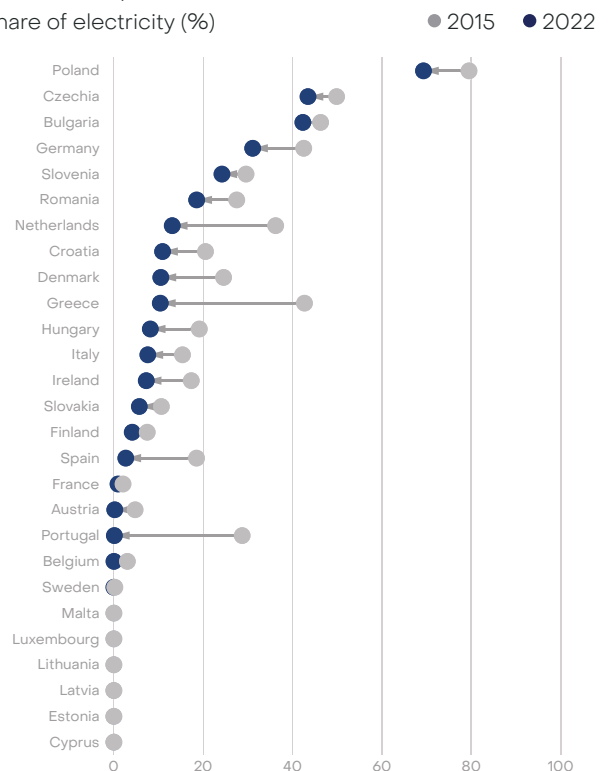
Long-term trends in EU coal generation

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



Coal share, EU countries

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Gas

EU Electricity Trends 2022



In 2022, gas power accounted for 20% of the EU's electricity production, with a total output of 557 TWh. Italy was the largest generator of gas power, producing 141 TWh, which represented 51% of its energy mix, the second largest gas share of any EU country. Malta had the highest percentage of gas power in its energy mix at 84%, with a total output of 1.8 TWh.

557 TWh

EU gas generation in 2022



19.9%

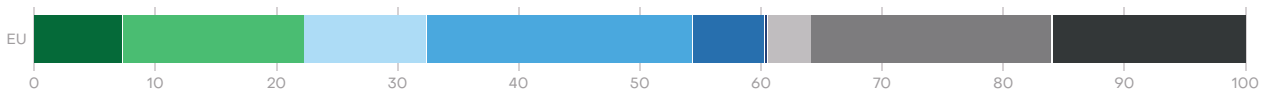
gas share in EU generation in 2022



EU electricity mix

Share of electricity (%)

Solar Wind Hydro Nuclear Bioenergy Other res Other fossil Gas Coal



Role of gas

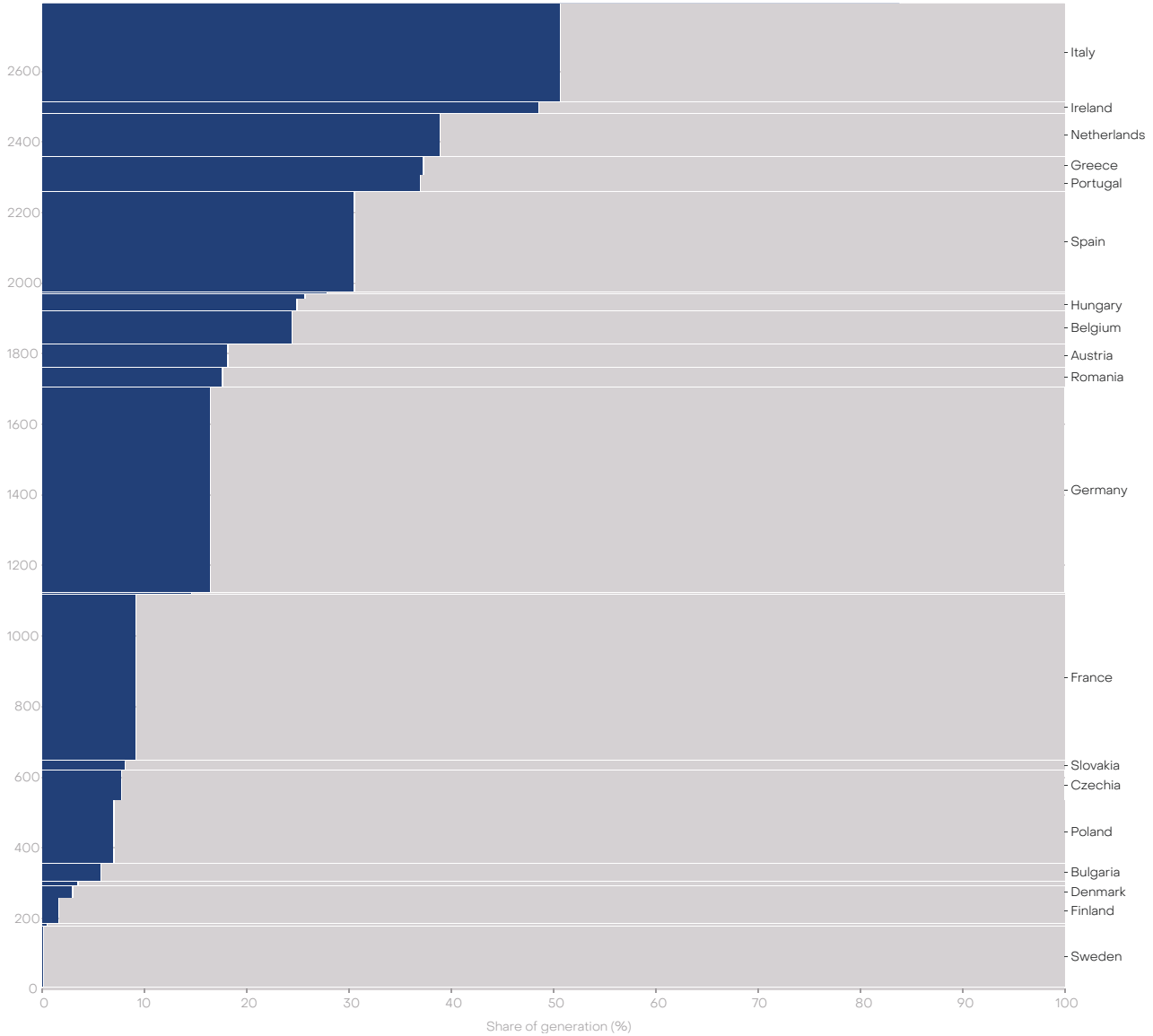
Gas, after coal, is the second largest contributor to emissions from the power sector. So, although it will play a useful role in the mid-term, helping with the power system flexibility to accommodate a large influx of wind and solar, unabated gas will need to be phased out by 2040, in order to move to a clean power system.

Regional Context

Major EU players in gas power

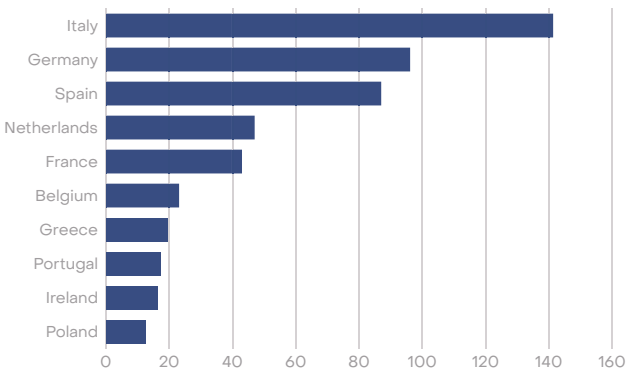
Electricity generation (TWh, y-axis) and share of electricity (% x-axis)

■ Gas ■ Other fuel types



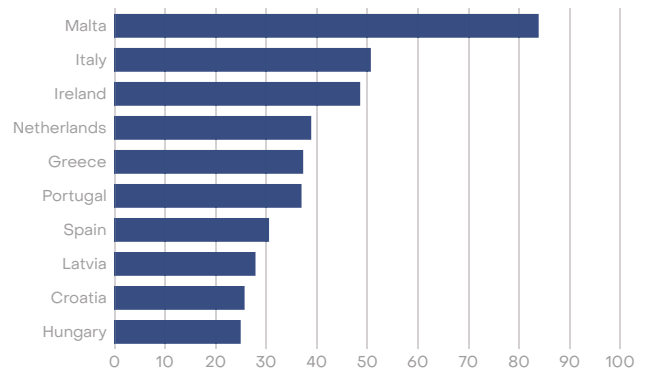
Largest gas generators in the EU

Electricity generation (TWh)



Highest shares of gas power in the EU

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Change in 2022



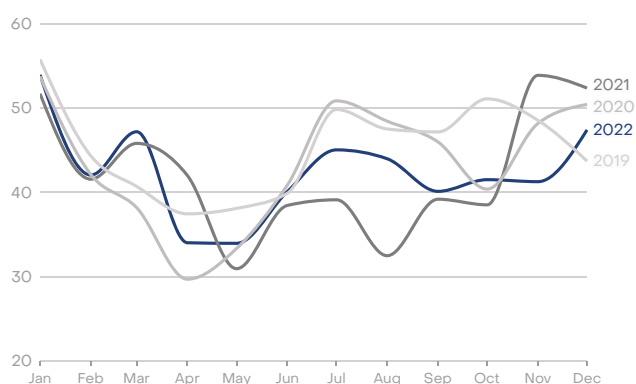
Gas electricity generation in the EU saw a slight increase of 0.8% in 2022 (+4.5 TWh). This brought the share of gas in the EU's electricity mix to 19.9%, a 0.7 percentage point increase from the previous year (19.2%). Despite the high cost of gas generation in 2022 as the global energy crisis drove up gas prices, several countries still experienced growth.

The largest increases were seen in Spain (+16 TWh, 22%) and France (+9.6 TWh, 29%). Gas generation in these countries likely would not have risen without large losses of nuclear power in France that resulted in lower exports to Spain.

There were small gas power falls in Poland, Greece, Italy and Finland, and a larger fall in the Netherlands (-9.7 TWh, -17%) which saw increased wind and solar power replace gas power.

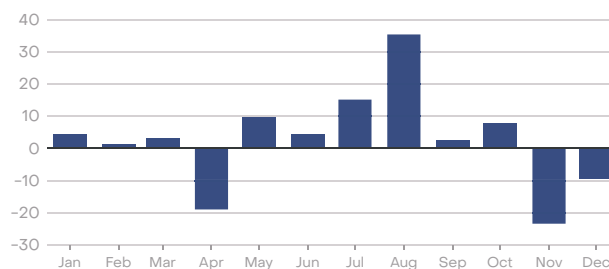
EU gas generation

Electricity generation (TWh)



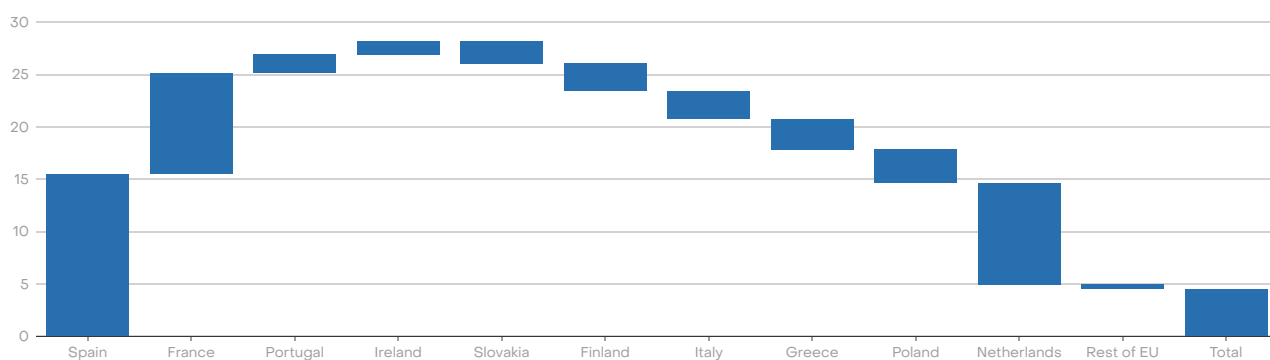
Monthly changes in EU gas generation

Change in generation year-on-year (%)



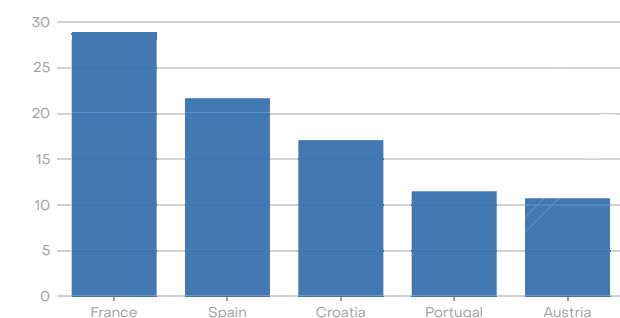
Key changes in EU gas generation

Change in generation year-on-year (TWh)



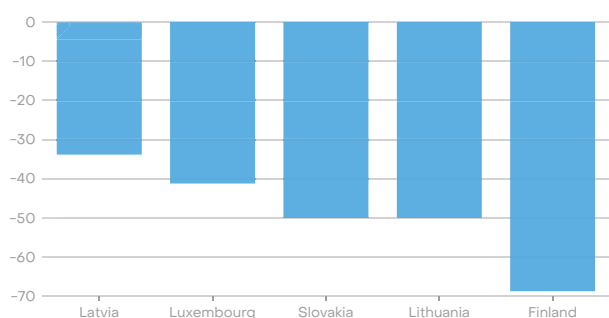
Largest increases

Change in generation year-on-year (%)



Largest declines

Change in generation year-on-year (%)



Long-term Trends

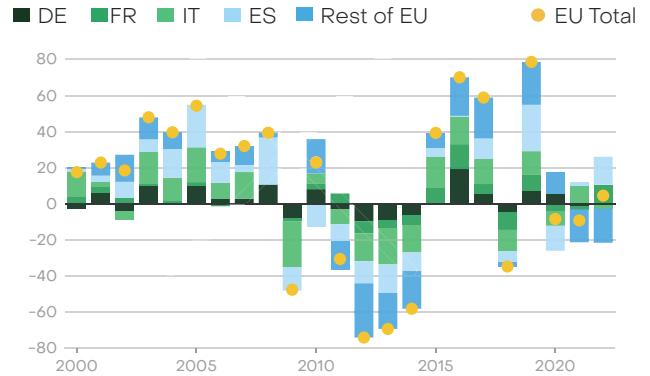
Annual gas generation has substantially increased by 225 TWh in the last two decades (+68%). As a result, the share in the electricity mix has increased from 13% in 2000 to 20% in 2022. It is the only fossil fuel that has seen growth over the past two decades. In the same period, coal generation was cut in half.

Since the Paris Agreement in 2015, gas has been growing by an average of 5% annually. This represents an acceleration of the growth trend between 2000–2015 (1.2% annually). The increase in 2022 of only 0.8% is slower than recent trends. The market share of gas has increased from 14% to 20% of EU electricity generation since 2015.

While there are several countries that have reduced their reliance on gas since 2015, some countries with high electricity demand such as Germany, Italy, Spain and France have seen gas generation take a more important role. In Italy, the share of gas in the mix increased from 39% to 51% (+30 TWh), while Germany saw an increase from 10% to 16% (+32 TWh).

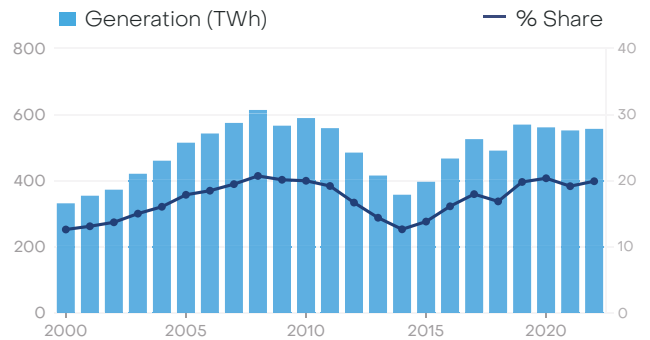
Annual changes in EU gas generation

Change in generation year-on-year (TWh)



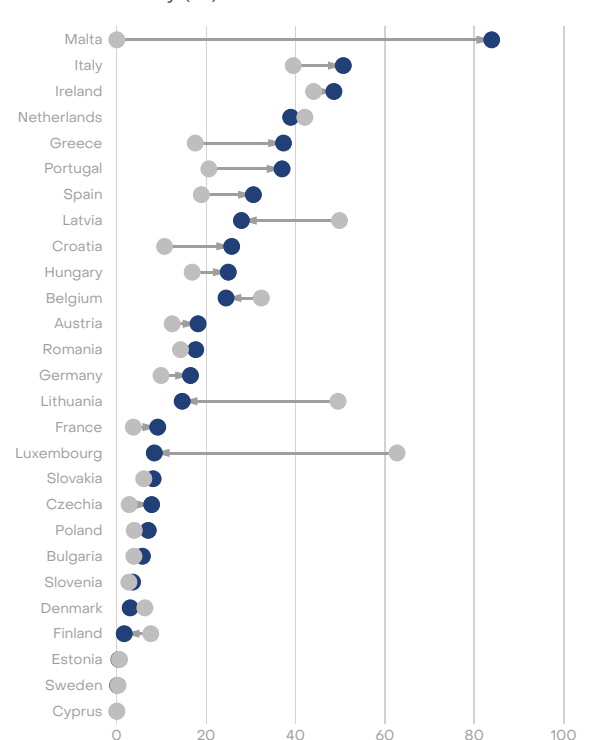
Long-term trends in EU gas generation

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



Gas share, EU countries

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Hydro

EU Electricity Trends 2022



In 2022, hydro power generation accounted for 10% of the EU's electricity production, with a total output of 283 TWh. Sweden was the largest generator of hydro power, producing 69 TWh (40.2% of its electricity mix), ahead of France (46 TWh, 9.8%) and Austria (36 TWh, 56%). Austria's share of 56% was the highest share of hydro power in its electricity mix among EU countries.

283 TWh

EU hydro generation in 2022

10.1%

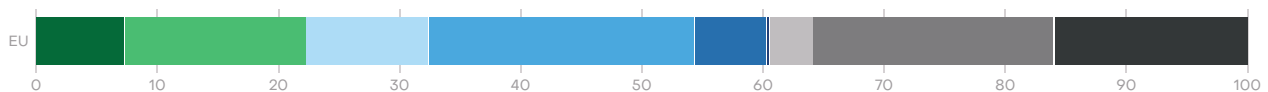
hydro share in EU generation in 2022



EU electricity mix

Share of electricity (%)

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



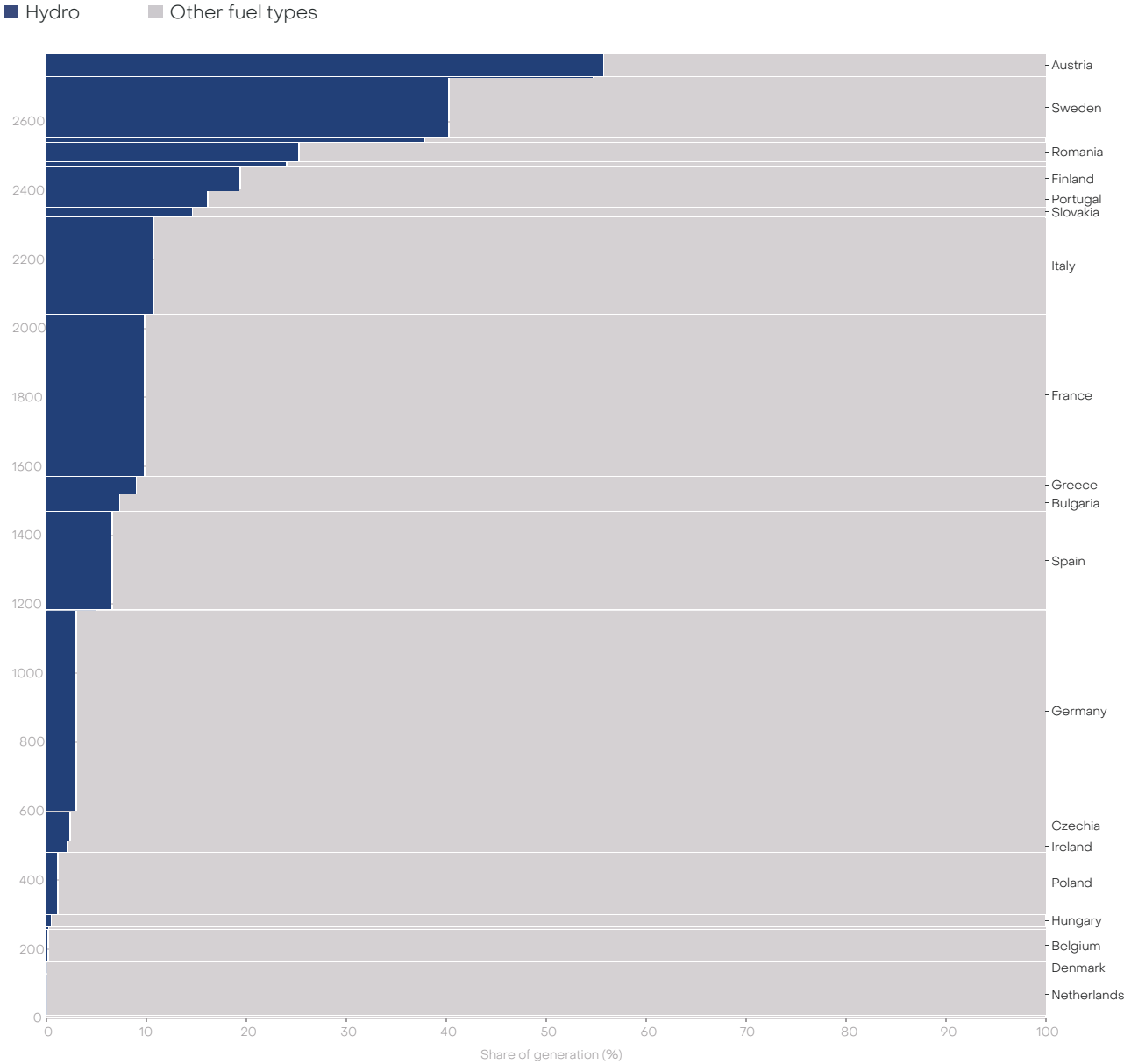
Role of hydro

Hydro power has an important role in the current energy 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, and in other regions where there is potential, the projects may come at too high an ecological cost.

Regional Context

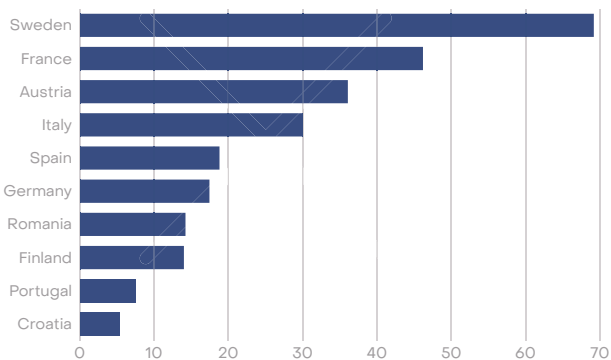
Major players in EU hydro power

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



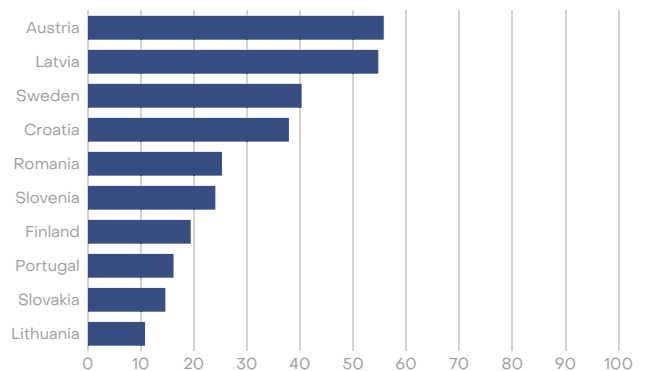
Largest hydro generators in the EU

Electricity generation (TWh)



Highest shares of hydro power in the EU

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

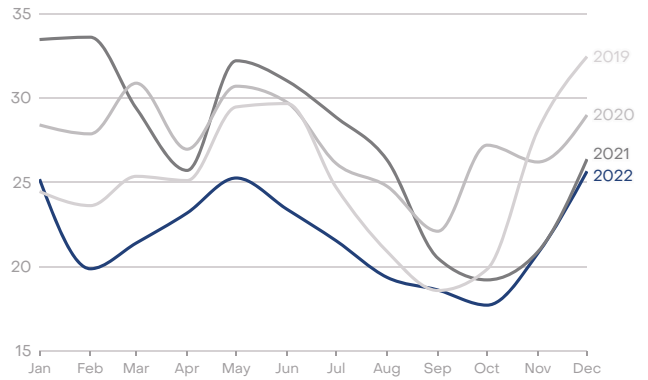
Change in 2022

A drought-stricken summer in 2022 meant that EU hydro generation fell to the lowest level since at least 2000. It fell by 19%, with a total decrease of 66 TWh from 349 TWh to 283 TWh. As a result, the share of hydro power in the electricity mix fell by 2% from 12% in 2021 to 10% in 2022.

The Alps and Iberia were particularly affected by the drought. Italy, France and Spain all saw hydro output fall by more than 10 TWh. This represented reductions of 34% (Italy), 23% (France) and 37% (Spain). However, the Nordic region was also impacted. Lithuania (+0.07 TWh) and Latvia (+0.06 TWh) were the only EU countries to see any rise in hydro generation, but only recorded small increases.

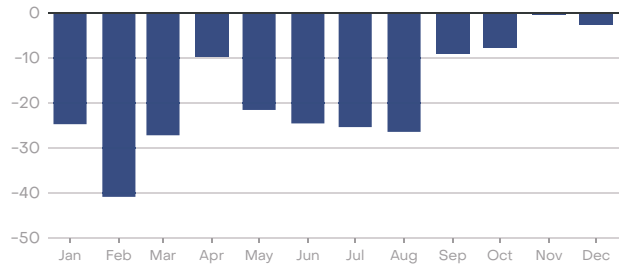
EU hydro generation

Electricity generation (TWh)



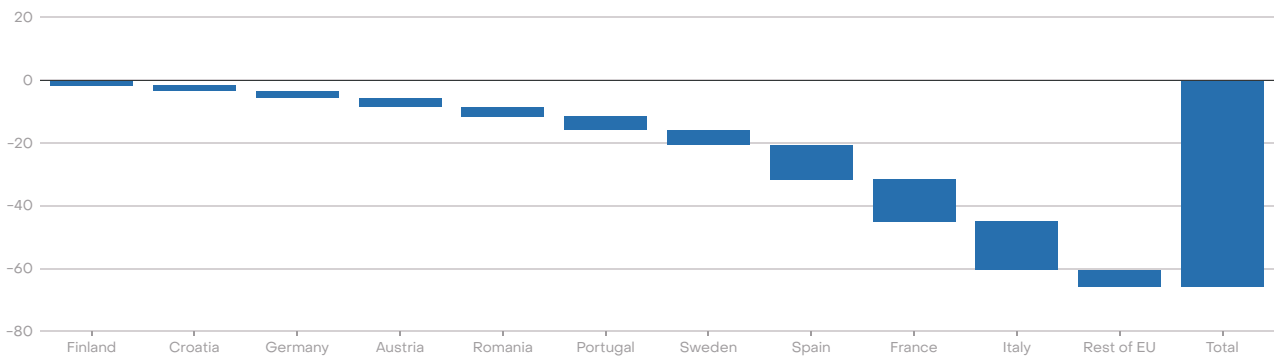
Monthly changes in EU hydro generation

Change in generation year-on-year (%)



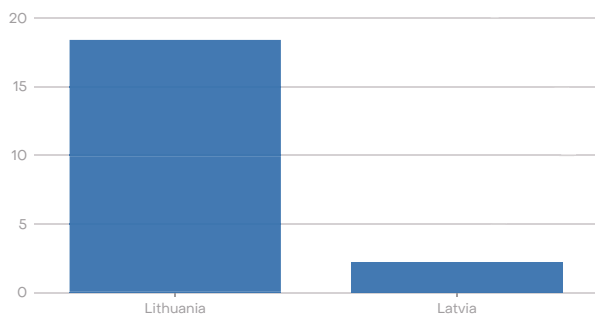
Key changes in EU hydro generation

Change in generation year-on-year (TWh)



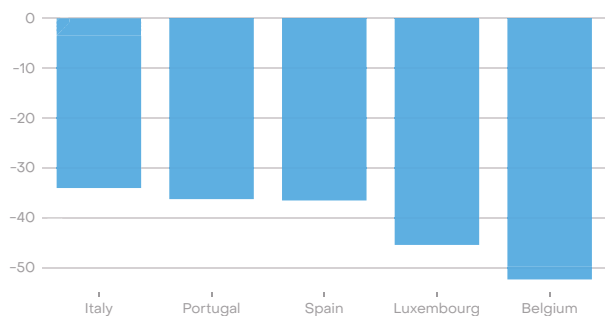
Largest increases

Change in generation year-on-year (%)



Largest declines

Change in generation year-on-year (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

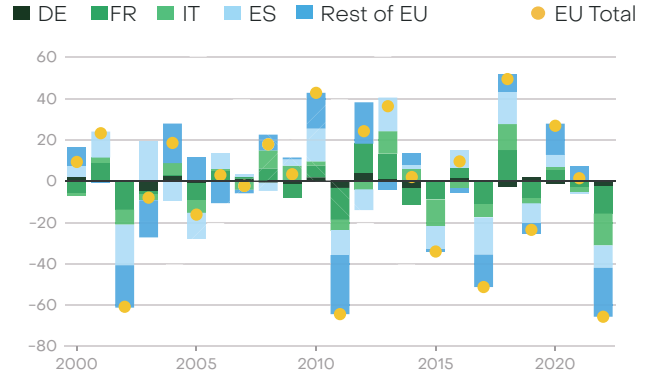
Long-term Trends

Hydro capacity has remained almost unchanged since 2000, with very little added or closed since. The only factor impacting generation is precipitation. Hydro generation in 2022 was 19% lower (-67 TWh) than in 2000. The 67 TWh fall is nearly equivalent to the fall just seen in 2022 of 66 TWh. Despite the large falls in 2022, hydro's 10% share of generation was not substantially lower than the market share in 2000 of 13%.

Similarly, there have been no structural changes since the Paris Agreement in 2015. Growth from clean sources has largely been concentrated on the build up of wind and solar generation.

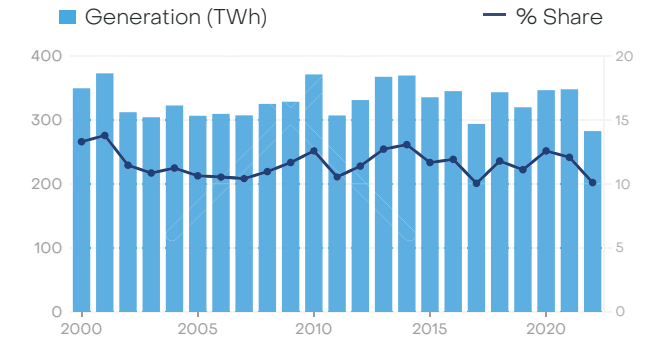
Annual changes in EU hydro generation

Change in generation year-on-year (TWh)



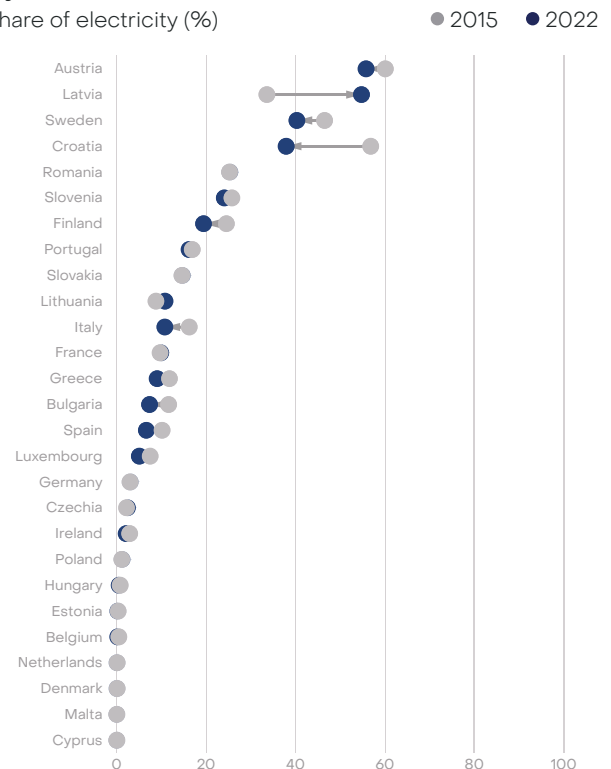
Long-term trends in EU hydro generation

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



Hydro share, EU countries

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Nuclear

EU Electricity Trends 2022



In 2022, nuclear accounted for 22% of the EU's electricity production, with a total output of 613 TWh. France was the largest generator of electricity from nuclear generation, producing 297 TWh. It is also the country with the highest share of nuclear power in its electricity mix at 63%.

613 TWh

EU nuclear generation in 2022



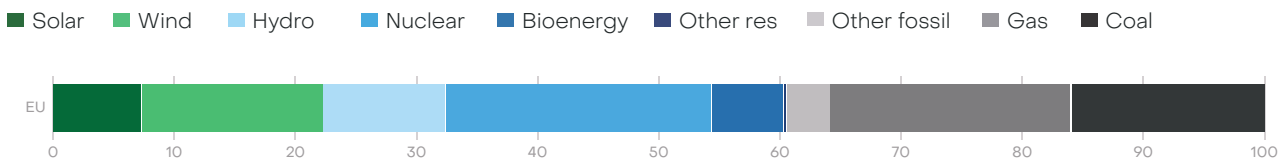
21.9%

nuclear share in EU generation in 2022



EU electricity mix

Share of electricity (%)



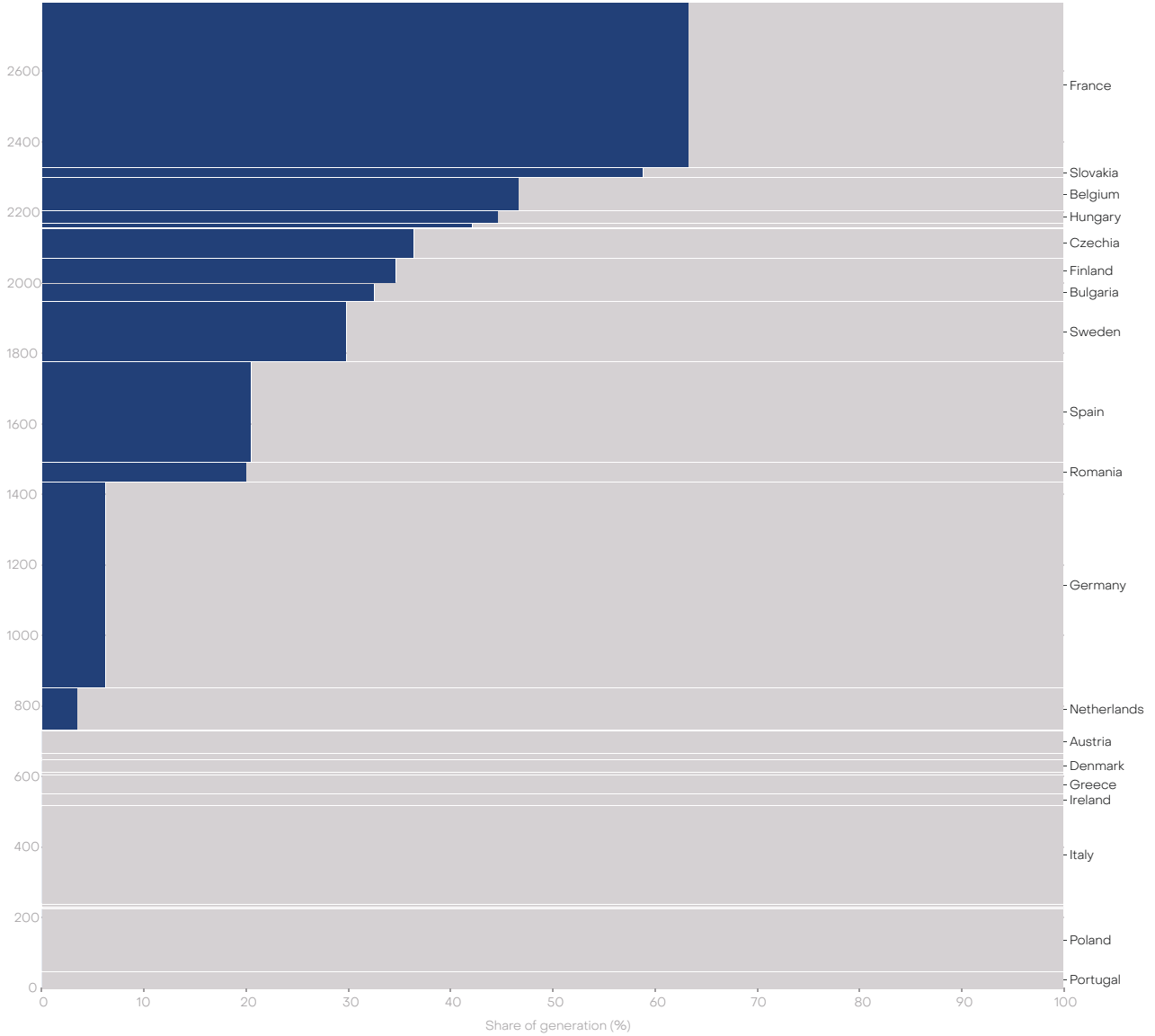
Role of nuclear

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 EU players in nuclear power

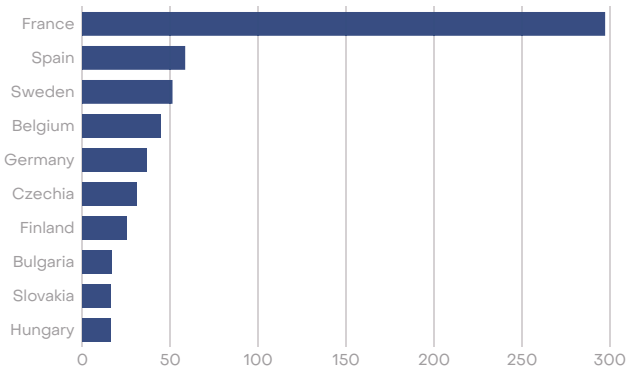
Electricity generation (TWh, y-axis) and share of electricity (% , x-axis)

■ Nuclear ■ Other fuel types



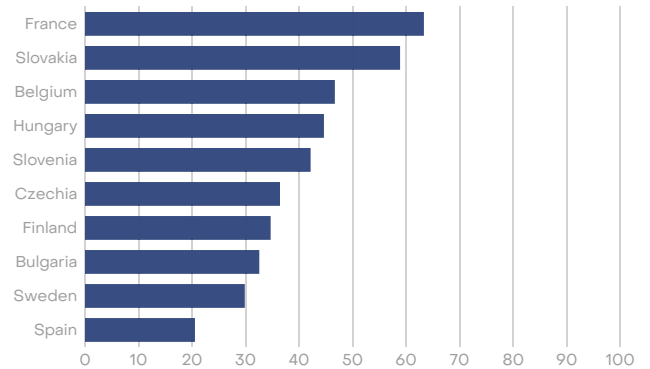
Largest nuclear generators in the EU

Electricity generation (TWh)



Highest shares of nuclear power in the EU

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Change in 2022

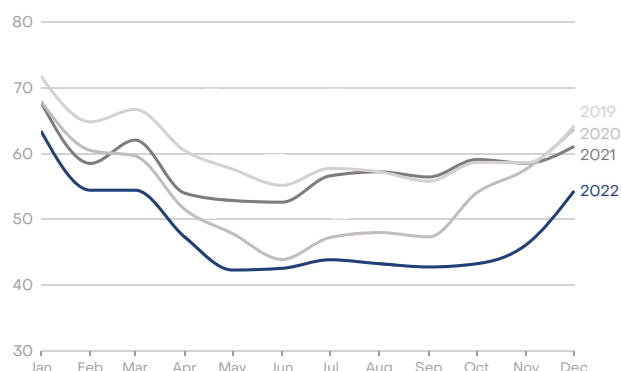


In 2022, nuclear generation in the EU saw its largest ever year-on-year decline, falling 16%, a total of 119 TWh compared to 2021 (from 732 TWh to 613 TWh). Consequently, the share of nuclear generation in the electricity mix fell by 3.5 percentage points to 21.9% from 25.4% in 2021. Spain (+1.9 TWh, 3.3%), Finland (+1.5 TWh, 6.2 %) and the Netherlands (+0.4 TWh, 9.4%) saw the largest increases in 2022, although these were still relatively modest.

The closure of nuclear plants in Germany led to a decline in generation of 33 TWh (-47%). The heatwave in the summer of 2022 saw reduced output from some French nuclear plants, due to high temperatures in rivers used for cooling. Planned maintenance reduced nuclear output further. Consequently, French nuclear generation fell by 82 TWh (22%), a reduction of nearly 3% of the EU's total annual electricity generation.

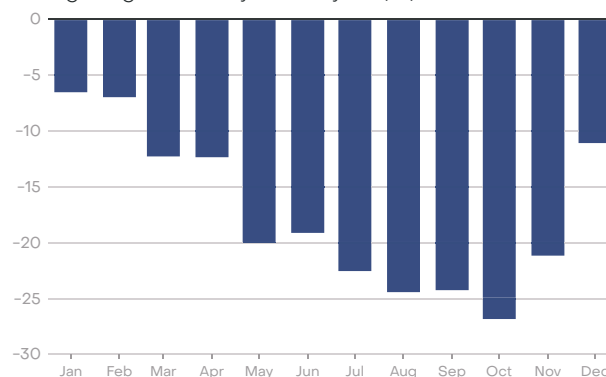
EU nuclear generation

Electricity generation (TWh)



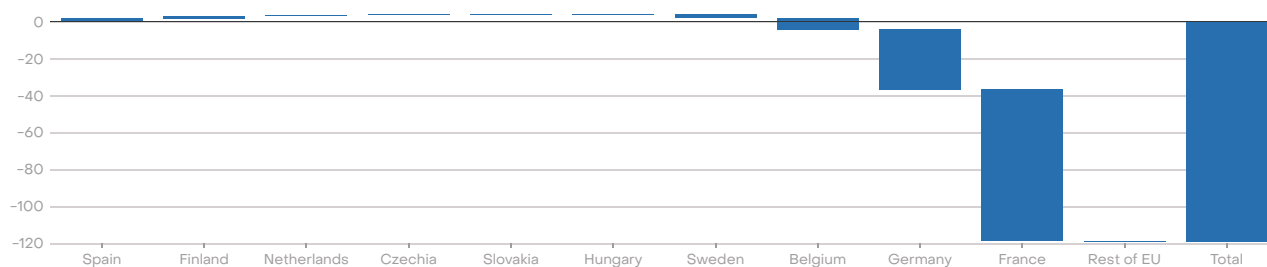
Monthly changes in EU nuclear generation

Change in generation year-on-year (%)



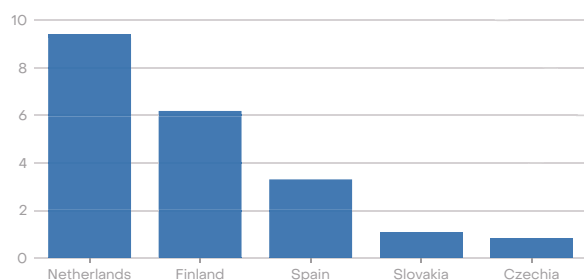
Key changes in EU nuclear generation

Change in generation year-on-year (TWh)



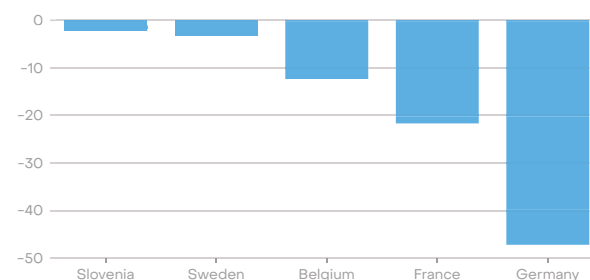
Largest increases

Change in generation year-on-year (%)



Largest declines

Change in generation year-on-year (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Long-term Trends

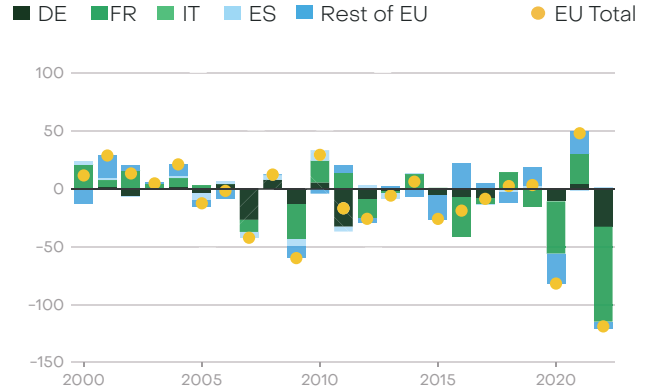


Between 2000 and 2022, nuclear generation fell by 29%. Likewise, its share in the EU electricity mix fell from 33% in 2000 to 22% in 2022. This is due to near-zero nuclear plants coming online, a wave of closures of older nuclear power plants and widespread temporary outages of existing French power plants in 2022.

Since the Paris Agreement in 2015, EU nuclear generation has been falling an average of 3.5% annually. This represents an acceleration of the downwards trend between 2000–2015 (–0.6% annually). 2022 saw a substantial decrease of 16% (119 TWh). Nuclear’s market share has fallen from 27% to 22% of EU electricity generation since 2015.

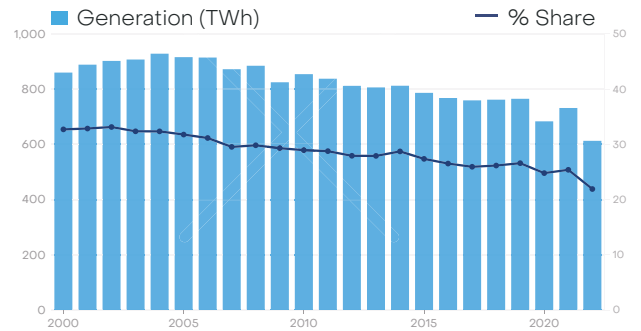
Annual changes in EU nuclear generation

Change in generation year-on-year (TWh)



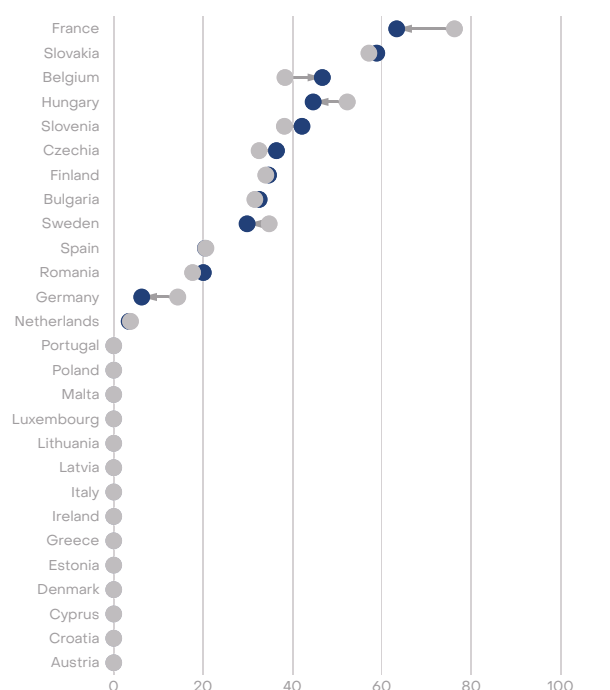
Long-term trends in EU nuclear generation

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



Nuclear share, EU countries

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Bioenergy

EU Electricity Trends 2022



In 2022, bioenergy accounted for 6% of the EU's electricity production, with a total output of 167 TWh. Germany was the largest generator of electricity from bioenergy in the EU by a considerable margin, producing 47 TWh, or 8.1% of its energy mix. Italy was the second largest generator, producing 18 TWh. Estonia had the highest percentage of bioenergy power generation at 30%, with a total output of 2.5 TWh.

167 TWh

EU bioenergy generation in 2022



6.0%

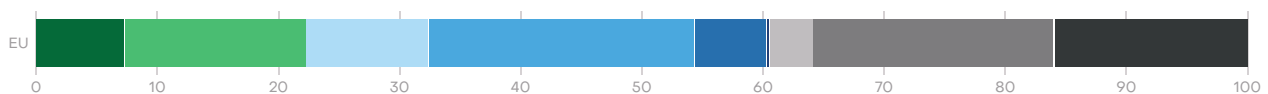
bioenergy share in EU generation in 2022



EU electricity mix

Share of electricity (%)

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



Role of bioenergy

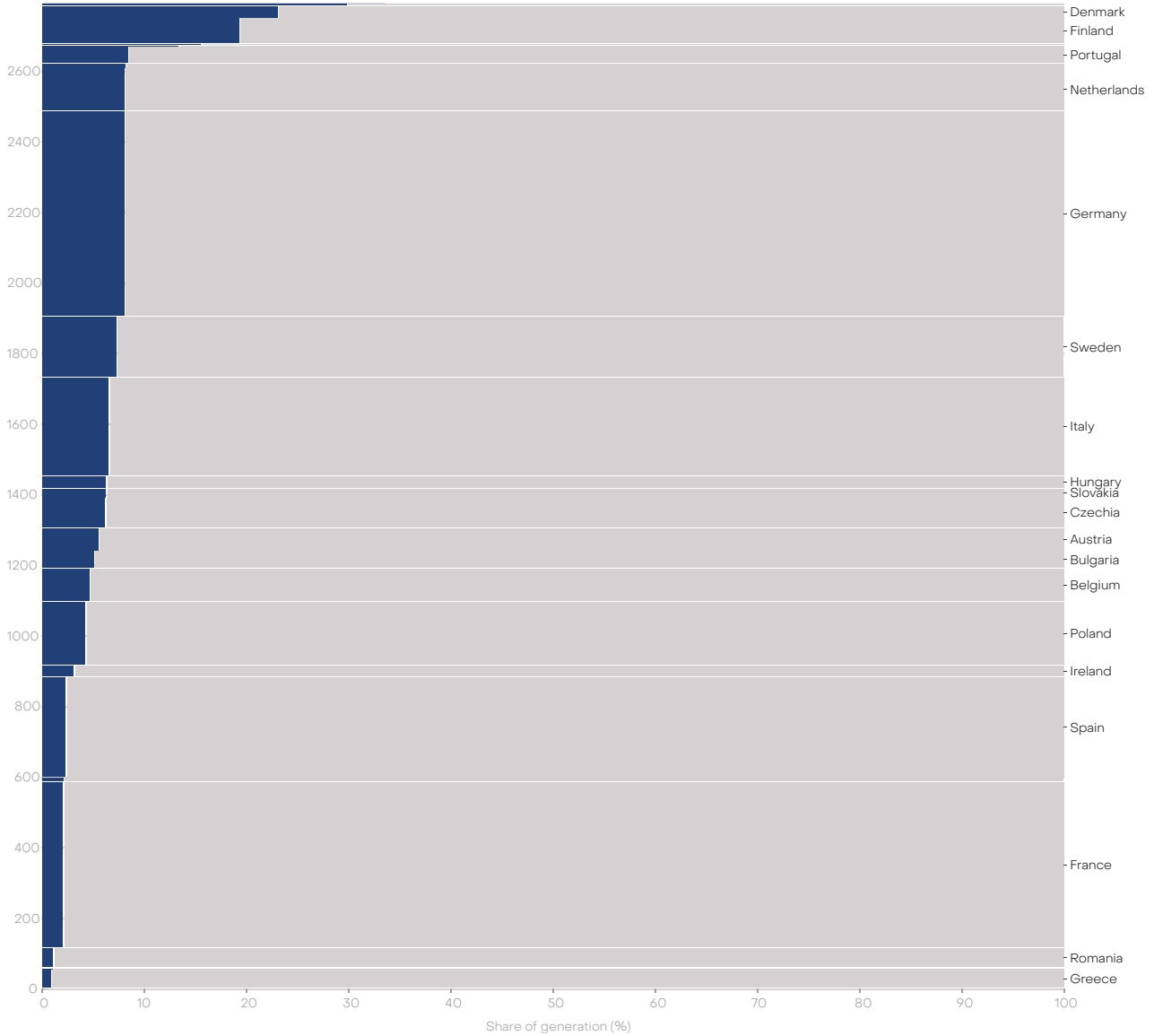
Bioenergy has been widely assumed to be carbon neutral, but recent scientific evidence shows that many forms of bioenergy are a major risk of significant carbon emissions. Given these risks, countries should aim to minimise or eliminate the inclusion of large-scale bioenergy in the power sector.

Regional Context

Major EU players in bioenergy power

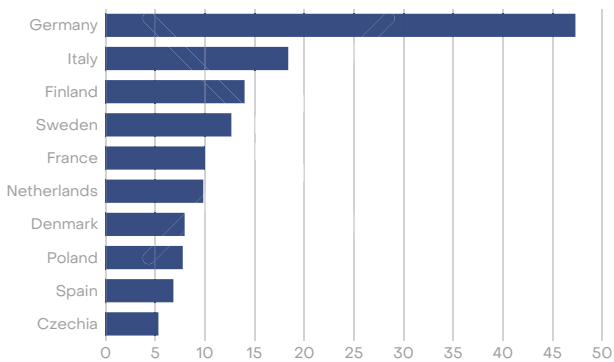
Electricity generation (TWh, y-axis) and share of electricity (% x-axis)

■ Bioenergy ■ Other fuel types



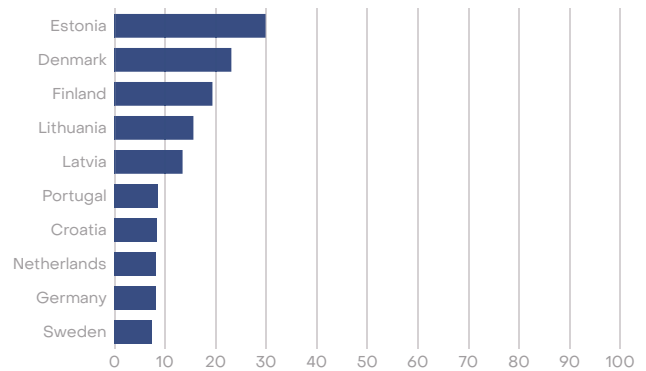
Largest bioenergy generators in the EU

Electricity generation (TWh)



Highest shares of bioenergy power in the EU

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

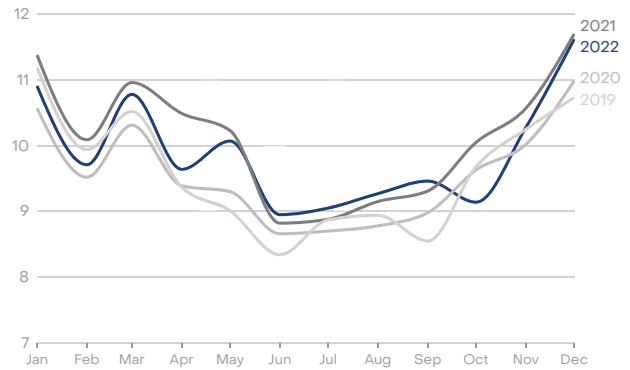
Change in 2022

Bioenergy generation in the EU declined slightly by 1.6% (-2.8 TWh) in 2022. This was the first fall in EU bioenergy electricity generation since 1996. However, it comes after a moderate rise in 2021 (+4.2 TWh, +6.7%).

Poland, Sweden, Italy, Denmark, Austria and the Netherlands saw the largest absolute reductions in generation. Estonia saw an increase of 41%, resulting in a small rise of 0.7 TWh. Higher generation in France, Finland and Germany led to an additional small offset that prevented an even larger EU-wide reduction.

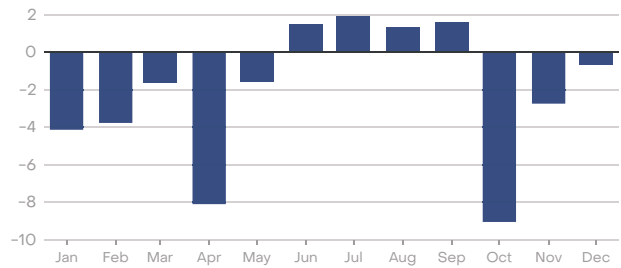
EU bioenergy generation

Electricity generation (TWh)



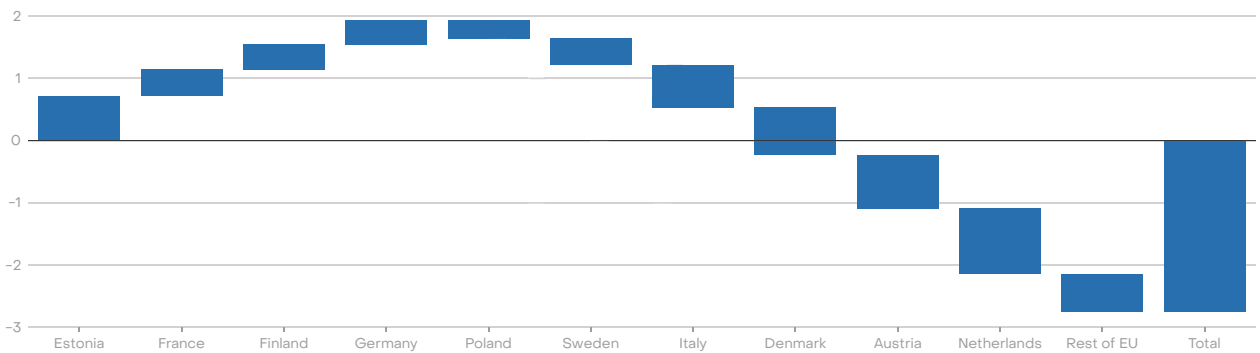
Monthly changes in EU bioenergy generation

Change in generation year-on-year (%)



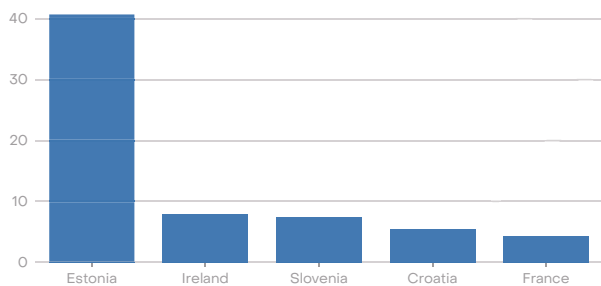
Key changes in EU bioenergy generation

Change in generation year-on-year (TWh)



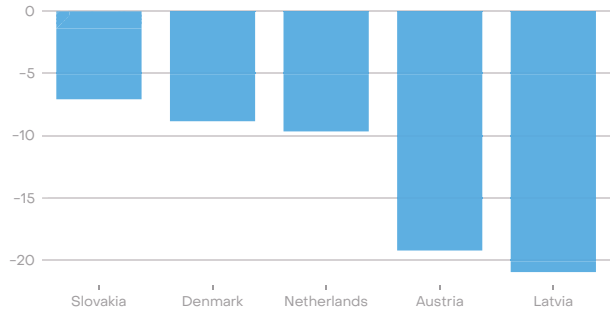
Largest increases

Change in generation year-on-year (%)



Largest declines

Change in generation year-on-year (%)



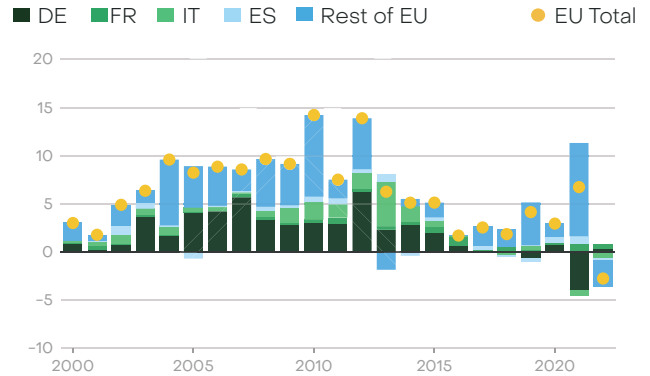
Long-term Trends

Bioenergy generation has increased more than fivefold since 2000, from 30 TWh to 167 TWh in 2022, rising from around 1.2% of the EU's electricity mix in 2000 to 6% in 2022. However, the rise has slowed dramatically. Generation in 2022 was only 12% higher than in 2015.

Since the Paris Agreement in 2015, bioenergy generation has been growing an average of 1.6% annually. This is significantly slower than the average annual EU growth rate of bioenergy of 11% between 2000–2015. Bioenergy's market share has seen a slight increase from 5.2% to 6% of EU electricity generation since 2015. Estonia has seen the biggest increase in market share since 2015, with bioenergy rising from 8% to 30% of Estonia's electricity mix.

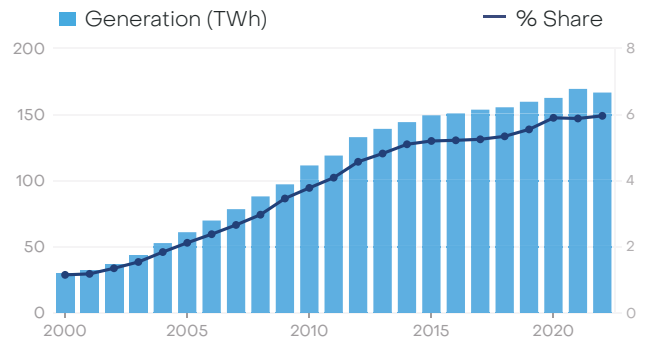
Annual changes in EU bioenergy generation

Change in generation year-on-year (TWh)



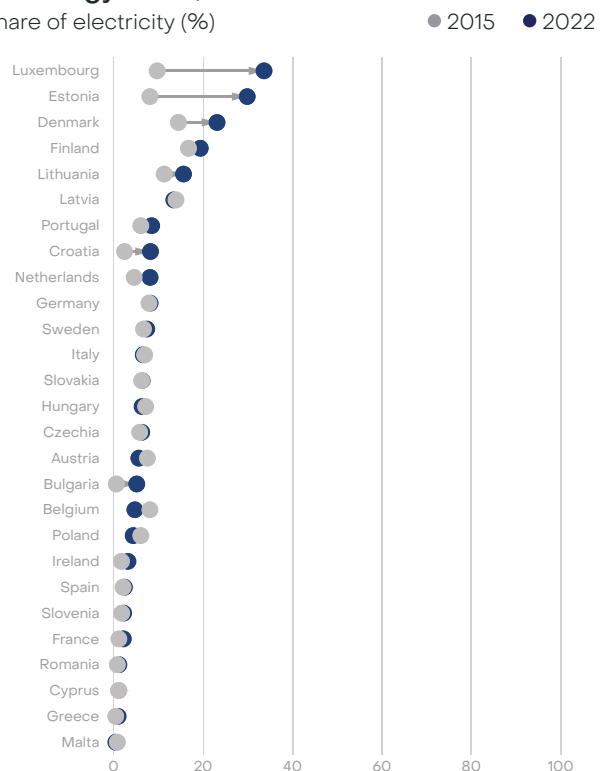
Long-term trends in EU bioenergy generation

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



Bioenergy share, EU countries

Share of electricity (%)



Source: Ember

Note: uses full-year data for 2022 in all EU-27 countries

Conclusion

An accelerator year for the EU's transition to clean power

There is no doubt that 2022 was an extremely challenging year for the EU. Russia's invasion of Ukraine created massive shockwaves and caused an unprecedented energy crisis, which in turn fuelled a crippling hike in living costs. One outcome has been a rush to cut dependence on Russian fossil fuel imports.

This can only be achieved through an accelerated clean energy transition. It became abundantly clear that fossil fuels are not the solution. Instead, they cause skyrocketing electricity prices and energy insecurity. Coal power did increase year-on-year, but this was due to hydro and nuclear issues rather than any appetite to revitalise the role of coal. Some coal-fired units may have been placed on standby for the winter but this is a short-term, emergency measure, resulting in minimal generation. The anticipated coal resurgence failed to materialise and current high stock levels will limit coal import requirements for 2023. Europe's coal phase-out is well and truly still alive.

Electricity demand dropped significantly in the fourth quarter of 2022 due to both mandated and voluntary energy savings and mild weather. However, we do not know how long this will last and, ultimately, the transition will increase electricity demand. This higher consumption must be met through renewable energy sources.

So it is extremely encouraging that 2022 saw record generation and capacity additions for wind and solar. Both played a critical role in mitigating the impact of the energy crisis— from a financial, security and climate perspective—with solar leading the charge. And the outlook is even brighter with acknowledgement that even more ambitious targets are achievable over the coming years.

The transition will gain even more momentum in 2023 and beyond. It is not only necessary but inevitable. The EU must now step up to ensure the right policies, investments and infrastructure are in place to enable this.

Supporting materials

Methodology

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.

Generation, imports and demand

Annual data from 2000 to 2020 is gross generation, published by [Eurostat](#).¹ 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.

Net imports from 2000 to 2020 are also published by Eurostat, with recent data estimated in the same manner as generation.² Demand is calculated as the sum of generation and net imports, and validated against direct demand figures published by ENTSO-E.

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.

-
1. Gross generation includes all electricity produced by a power plant, including the power it consumes to operate. Net generation is the electricity metered leaving the power plant and entering the grid, and is always smaller than gross.
 2. Flows between countries are published only in recent data, and as such are summed to produce annual data without any conversion. As such, in a small number of figures, summed values for net flows will not perfectly equal values for net imports.

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.

Below is a list of countries included, and sources for recent monthly data. A complete country-by-country methodology for all countries, including those outside of Europe, is available for download [here](#).

- **Austria:** ENTSO-E
- **Belgium:** ENTSO-E
- **Bulgaria:** ENTSO-E
- **Croatia:** ENTSO-E
- **Cyprus:** Eurostat
- **Czechia:** ENTSO-E
- **Denmark:** ENTSO-E
- **Estonia:** ENTSO-E
- **Finland:** Biomass, gas, hydro, solar and wind from Eurostat; other fuels from ENTSO-E
- **France:** ENTSO-E
- **Germany:** Biomass and gas from [Agora](#); other fuels from ENTSO-E
- **Greece:** ENTSO-E
- **Hungary:** Solar data before 2020 from Eurostat; other fuels from ENTSO-E
- **Ireland:** [Sustainable Energy Authority of Ireland](#)
- **Italy:** Biomass and solar from [Terna](#); other fuels from ENTSO-E. Flow data from Terna
- **Latvia:** ENTSO-E
- **Lithuania:** ENTSO-E
- **Luxembourg:** Eurostat
- **Malta:** Eurostat
- **Netherlands:** [Statistics Netherlands](#)
- **Poland:** Solar data from ARE via [Instrat](#); other fuels from ENTSO-E
- **Portugal:** ENTSO-E
- **Romania:** ENTSO-E
- **Slovakia:** ENTSO-E
- **Slovenia:** ENTSO-E
- **Spain:** ENTSO-E. Flow data from [e-SIOS](#)
- **Sweden:** ENTSO-E

Emissions

Note: this methodology differs slightly from our global methodology, in that it uses emissions factors more specific to EU countries. As a result, figures provided in this report will differ slightly from those we report elsewhere.

We report emissions values by fuel type, and emissions intensity by country. These values are calculated by multiplying our generation numbers by the below emissions factors:

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

These factors are calculated with reference to data on the greenhouse gas emission intensity of electricity generation from the [European Environment Agency \(EEA\)](#) and gross electricity production and electricity production by fuel type from [Eurostat](#). These factors reproduce recent historic emissions at an EU level, but for a number of reasons will not be completely accurate at country level. In particular, thermal plant efficiency and the carbon content of fuels varies by country.

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 is calculated as total emissions divided by total generation.

Short Run Marginal Cost (SRMC) of generation

SRMC is calculated as the cost of fuel per MWh of generation, plus the cost of carbon credits (EU-ETS) per MWh. Variable operating and maintenance costs are not included.

The following plant efficiency rates have been applied:

- Gas plant efficiency rate = 55% (Lower Heating Value)
- Coal plant efficiency rate = 40%

Coal (API2), gas (TTF) and CO₂ (EU-ETS) prices are provided by Montel.

Solar and gas savings

All solar capacity data is in gigawatts (DC)

1 Net Calorific Value = 0.9 Gross Calorific Value

Calorific value of Russian gas = 37.83 MJ/m³

1 billion cubic metre = 10.5 Terawatt hours



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