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European Electricity Review 2026

The EU’s electricity transition reached a new milestone in 2025 with wind and solar generating more power than fossil fuels.

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About

The European Electricity Review analyses full-year electricity generation and demand data for 2025 in all EU-27 countries to understand the region's progress in transitioning from fossil fuels to clean electricity. It is the tenth 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.

Key highlights

30%	369 TWh	14
Wind and solar generated a record 30% of EU electricity, higher than fossil power for the first time on record.	EU solar generation reached a record 369 TWh in 2025, 20% higher than last year.	In 2025 wind and solar generated more electricity than fossil fuels in 14 of the 27 EU countries.

A major milestone in the EU's transition to clean power

In 2025, the EU took an enormous step forward towards a clean power system backed by wind and solar. For the first time, wind and solar produced more electricity than fossil fuels in the EU. Homegrown renewables remained nearly half of EU power, as record-breaking solar worked in tandem with wind.

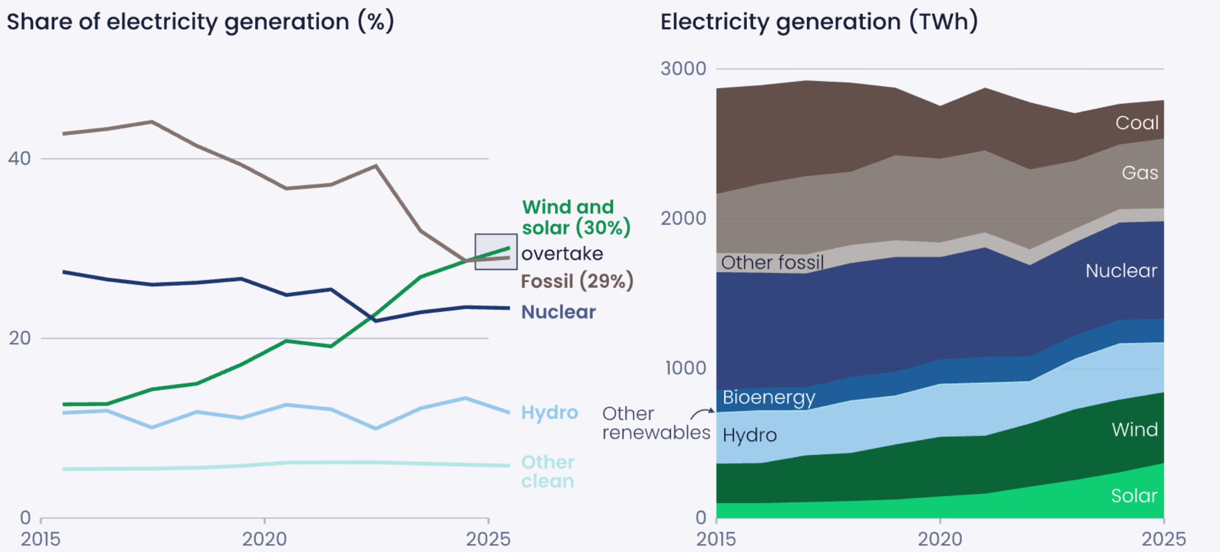
In 2025, the EU's energy priorities focused on cutting energy costs for households and businesses. The European Commission's Affordable Energy Action Plan correctly diagnoses the root cause of Europe's high energy prices: its dependence on costly imported fossil fuels. In the power sector, coal is nearly on its way out, reaching a new historic low in 2025 after years of steep decline. However, the EU is still significantly dependent on gas. An increase in gas generation amid a decline in hydro in 2025 pushed up the EU's fossil gas import bill by 16% and led to price spikes in electricity markets.

The stakes of the EU continuing to make progress on energy transition remain starkly clear. For the EU, risks of energy blackmail from fossil fuel exporters loomed large in 2025. Investing in homegrown renewables is a key strategy to lower that risk, as geopolitics continue to destabilise.

The EU agreed on [legislation to ban imports of Russian gas] by the end of 2027 in December 2025. However, new fossil dependencies have emerged with a rise in imported US LNG. Heavy reliance on a single supplier threatens EU security and weakens bargaining power in geopolitical negotiations and [trade disputes].

Expanding batteries, enhancing the grid and scaling up demand flexibility can unlock greater shares of solar and wind in the mix. Not only will this improve security, they are also crucial to ensure predictable and stable prices.

Wind and solar overtake fossil power in the EU for the first time in 2025



Source: Yearly electricity data, Ember
Other clean includes bioenergy and other renewables. Fossil includes coal, gas and other fossil.

01 **Wind and solar generated more power than fossil fuels in 2025**

Wind and solar reached 30% of EU electricity, higher than fossil power (29%) for the first time on record, and up from 20% just five years prior. By 2025 wind and solar generated more power than all fossil sources in 14 of the 27 EU countries.

02 **Solar's astounding growth continues across the EU**

Solar generated more EU power than ever before in 2025 (369 TWh), growing by more than 20% for the fourth year running to 13% of EU electricity, higher than coal and hydro. Solar grew in every EU country and accounted for more than a fifth of electricity in Hungary, Cyprus, Greece, Spain and the Netherlands.

03 **Renewables provided nearly half of EU power**

Early 2025 was less windy and rainy but sunnier than early 2024. The same weather conditions that caused an annual drop in hydro (-12%) and wind (-2%) boosted solar generation, with renewables providing nearly half of EU power (48%). Wind remained the second largest EU electricity source at 17% of EU power, above gas.

04 **Gas increased in the EU, driving prices up**

Gas generation rose by 8% compared to 2024, largely due to reduced hydro output. This pushed the EU power sector's gas import bill up to €32 billion — 16% higher than the previous year. Price spikes during peak gas-use hours drove the annual increase in wholesale electricity prices across 21 EU countries in 2025.

05 **Coal is increasingly marginal in the EU**

Coal power fell to a new historic low of 9.2%. In 19 EU countries, coal power is at less than 5%. Over the past decade the reduction in coal was not matched by an equal increase in gas or other fossil fuels.

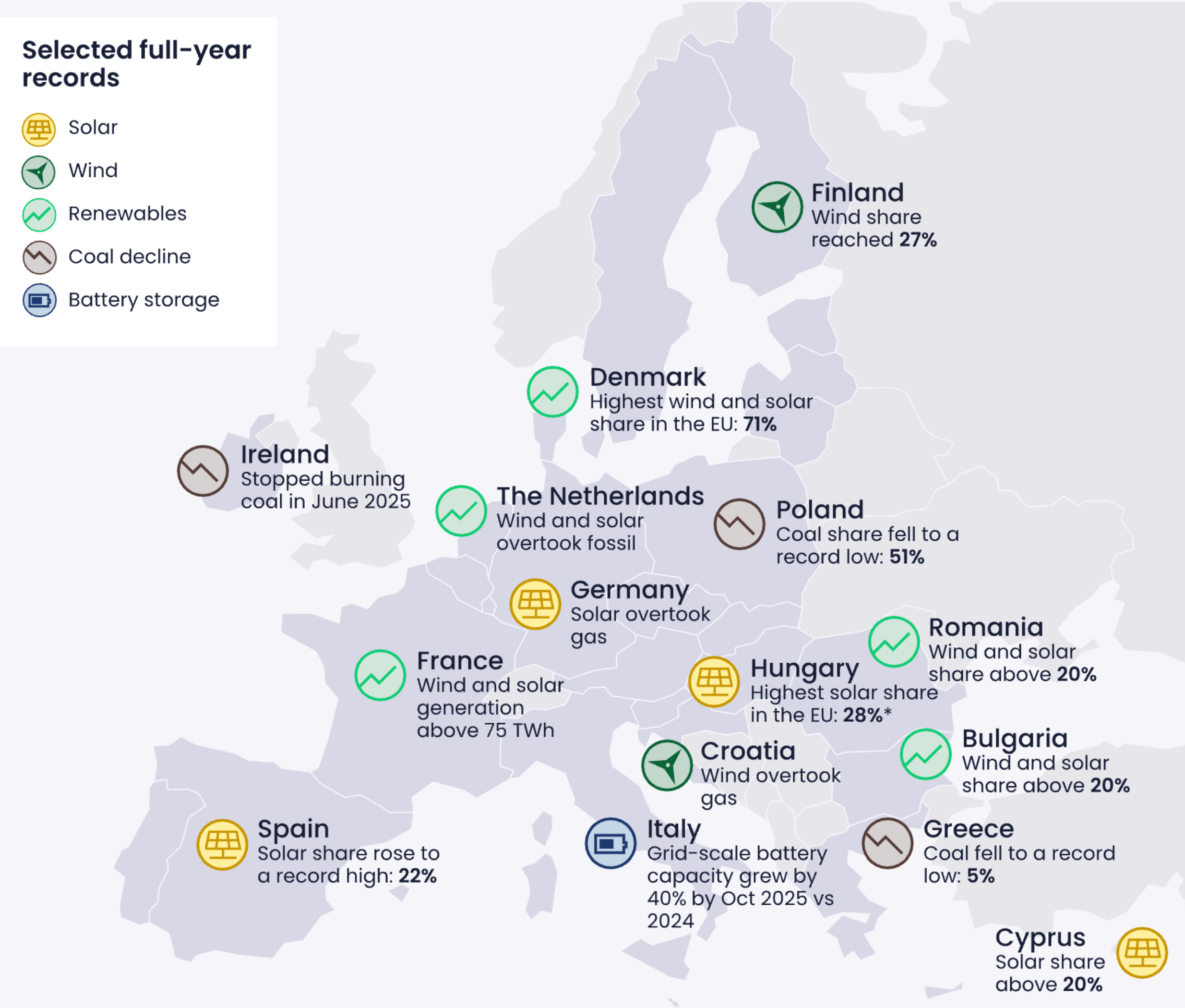
06 **The surging battery pipeline can limit the EU's costly gas use**

Battery deployment accelerated significantly in 2025, with grid-scale projects announced across the EU. With this acceleration, batteries' role in meeting evening demand could rapidly grow, reducing reliance on fossil generators and lowering wholesale prices when electricity is in high demand.

This milestone moment shows just how quickly things are changing in the EU's power sector. Wind and solar generated more of the EU's electricity than fossil fuels for the first time in 2025, providing nearly a third of power. The next challenge will be to put a serious dent in the EU's reliance on expensive, imported gas. By investing across the power system to harness the potential of batteries, grids and electrified tech, the EU can make use of homegrown renewable power to stabilise prices and insure against energy blackmail.

Beatrice Petrovich
Senior Energy Analyst, Ember

EU countries set new clean energy records in 2025



Source: Yearly electricity data, Ember

Renewables includes solar, wind, hydro, bioenergy and other renewables. Figures in bold indicate the share of total electricity generation in the country; solar includes behind-the-meter generation.*Among EU countries with solar generation > 1 TWh in 2025. Explore all data records: ember-energy.org/electricity-data-explorer

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Chapter 1 - 2025 at a glance

The EU power sector in 2025

Wind and solar produced more electricity than fossil fuels in the EU for the first time, thanks to record solar growth and despite an increase in gas power generation. Renewables provided nearly half of EU power in 2025, similar to 2024, with solar generation working in tandem with wind. Coal continued its terminal decline, falling to a new historic low.

Renewables provided nearly half of EU power in 2025

	2024 Electricity generation (TWh) **Share of generation (%)**	2025 Electricity generation (TWh) **Share of generation (%)**	Change 2024-2025 Generation (TWh) **Percentage change (%)**	Change 2024-2025 TWh	Average change 2015-2025 **Compound annual growth rate (%)**
Total renewables	1326 TWh **47.9%**	1331 TWh **47.7%**	5.3 TWh **0.4%** ▲		
- Solar	307 TWh **11.1%**	369 TWh **13.2%**	62 TWh **20.1%** ▲		**13.9%**
- Wind	485 TWh **17.5%**	473 TWh **16.9%**	-12 TWh **-2.5%** ▼		**6%**
- Hydro	370 TWh **13.4%**	327 TWh **11.7%**	-43 TWh **-12%** ▼		**-0.3%**
- Bioenergy	158 TWh **5.7%**	156 TWh **5.6%**	-2 TWh **-1.1%** ▼		**0.4%**
- Other renewables*	7 TWh **0.2%**	7 TWh **0.2%**	0.2 TWh **2%** ▲		**-0.4%**
Nuclear	650 TWh **23.5%**	652 TWh **23.4%**	3 TWh **0.4%** ▲		**-1.9%**
Total fossil	792 TWh **28.6%**	809 TWh **29.0%**	17 TWh **2%** ▲		
- Coal	271 TWh **9.8%**	257 TWh **9.2%**	-14 TWh **-5%** ▼		**-9.6%**
- Gas	432 TWh **15.6%**	466 TWh **16.7%**	34 TWh **8%** ▲		**1.7%**
- Other fossil**	89 TWh **3.2%**	86 TWh **3.1%**	-3 TWh **-3%** ▼		**-3.9%**
Net imports	-12 TWh	-22 TWh	-10 TWh		
Electricity demand	2755 TWh	2770 TWh	15 TWh **0.6%** ▲		**-0.3%**

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

The EU gets more power from wind and solar than fossil fuels in 2025

The EU's transition to clean power reached a tipping point in 2025 as wind and solar generated more electricity than fossil sources for the first time. Wind and solar generated 30.1% of EU electricity in 2025 (841 TWh), while all fossil power sources generated 29.0% (809 TWh).

Over the past decade, wind and solar have shown a consistent upward trend. This accelerated in the past five years, when their share of EU power increased by over 10 percentage points (from 19.7% in 2020 to 30.1 % in 2025). This is in stark contrast with the decline in fossil power over the same period, falling by almost 8 percentage points from 36.7% of the EU power in 2020 to 29.0% in 2025. The other two major clean power sources, hydro and nuclear, remained stable or slightly declined over the past five years.

For the majority of EU countries, wind and solar have become central in the electricity mix. In 2025, wind and solar generated more electricity than all fossil sources in 14 of the 27 EU countries. Two countries achieved this milestone for the first time in 2025: the Netherlands and Croatia. In the Netherlands this was due to strong solar growth (+31% compared to 2024), whereas Croatia's result was pushed by strong growth in solar and wind output (+57% and +19% compared to 2024, respectively). Largely thanks to strong growth in solar generation, formerly coal-heavy countries such as Greece, Bulgaria and Slovenia are very close to reaching this tipping point.

Wind and solar surpass fossil fuels in half of EU countries in 2025

Share of electricity generation (%)

In the countries highlighted in green, wind and solar generate more electricity than fossil

Source: Yearly electricity data, Ember • Other includes nuclear, hydro, bioenergy and other renewables. Countries are ordered by the year wind and solar generation overtook fossil generation, then by the gap between wind and solar and fossil generation

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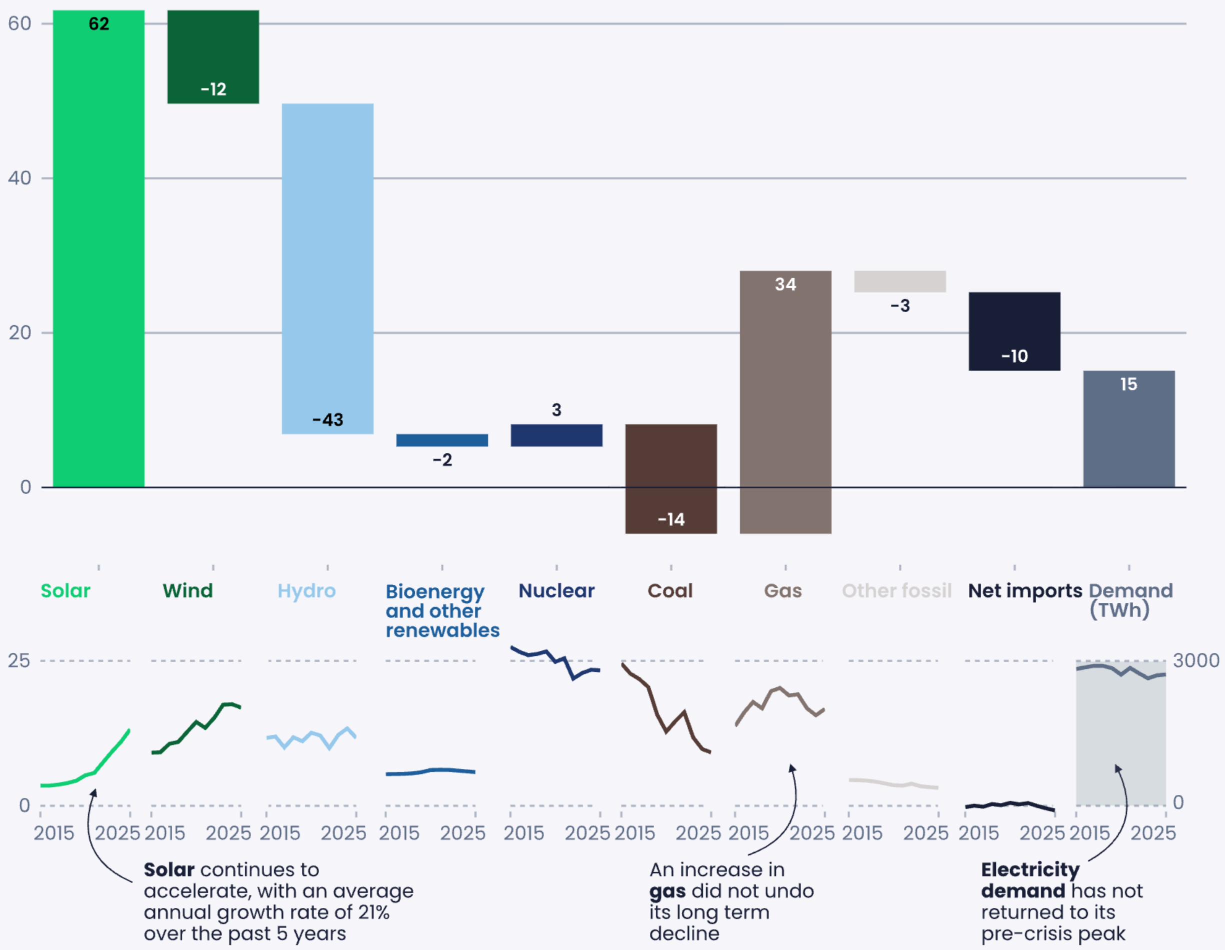
Solar breaks another record, growing by a fifth

A record annual increase in solar generation is behind the milestone moment for EU homegrown power. Solar grew by 62 TWh (+20.1%) compared to 2024 – an increase comparable to the annual electricity production of three French nuclear power plants.

In total, solar generated a record 369 TWh in 2025, more than double the output in 2020 (145 TWh). The rapid solar growth in 2025 continued a trend of strong expansion, with an average annual growth in generation of 21% over the past five years: far beyond any other energy source.

Solar grows more than any other power source in the EU in 2025

Annual change in EU electricity generation in 2025 (TWh)
Long term trend in share of electricity generation (%) and demand (TWh), 2015-2025

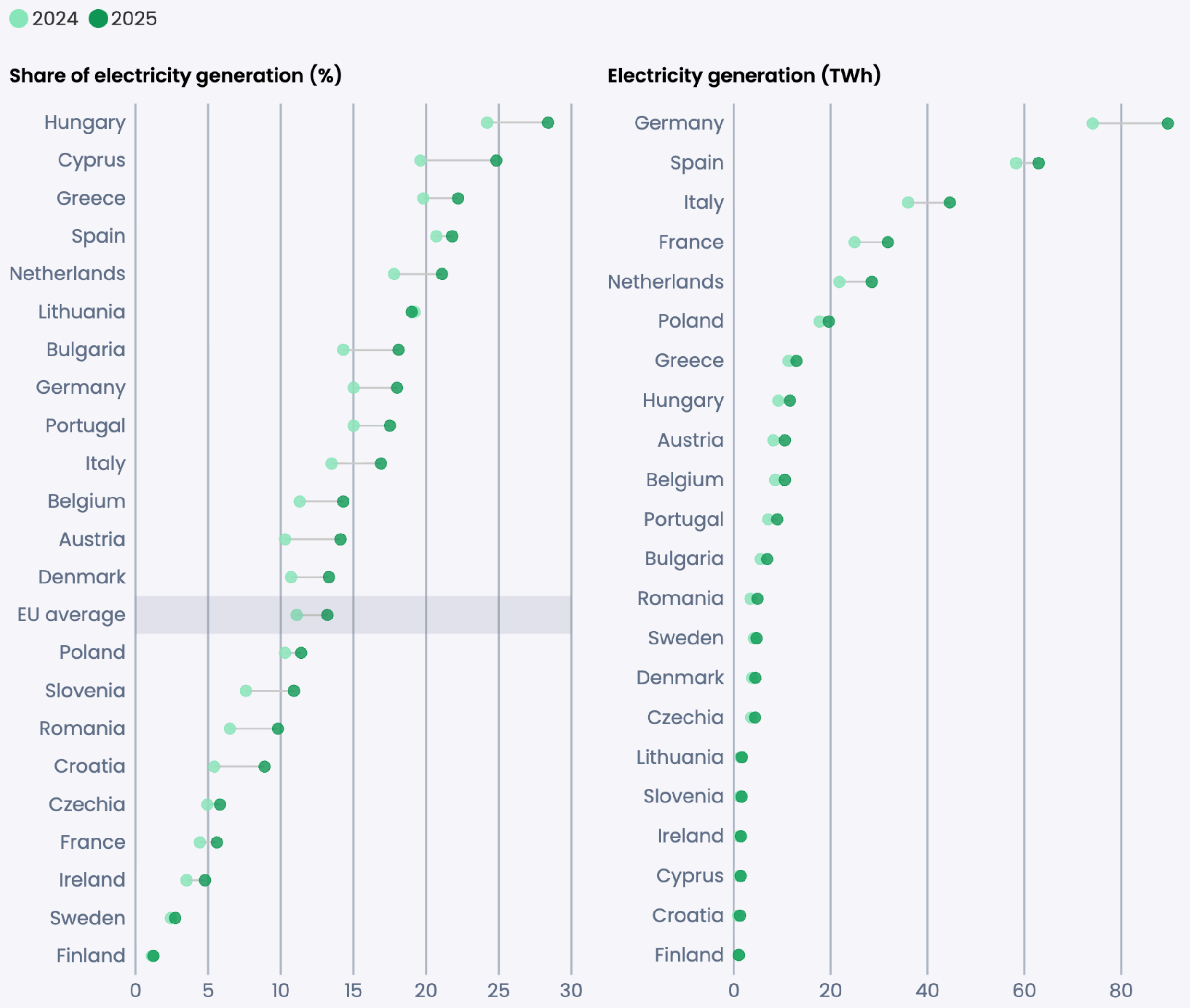


Source: Yearly electricty data, Ember

Record growth in solar power is predominantly due to an expanding EU fleet. Solar capacity grew by 65.1 GW in 2025, nearly equally split between utility-scale solar farms and new rooftop installations. This is a 19% increase in total cumulative installed capacity within a single year, more than any other energy source.

In 2025, all EU countries saw growth in solar generation compared to the year before. Solar's share in the EU's annual electricity generation increased to an all-time high of over 13%, with Hungary, Cyprus, Greece, Spain and the Netherlands recording solar shares above 20%. This is more than double the global average in the first half of 2025 (8.8%). Out of the top ten countries with the highest solar shares across the globe, seven are in the EU. In June 2025, solar became the largest EU power source for the first month ever.

Solar power is growing in every EU country



Source: Yearly electricity data, Ember
Graphic excludes countries with solar generation lower than 1 TWh in 2025: Estonia, Latvia, Luxembourg, Malta and Slovakia.

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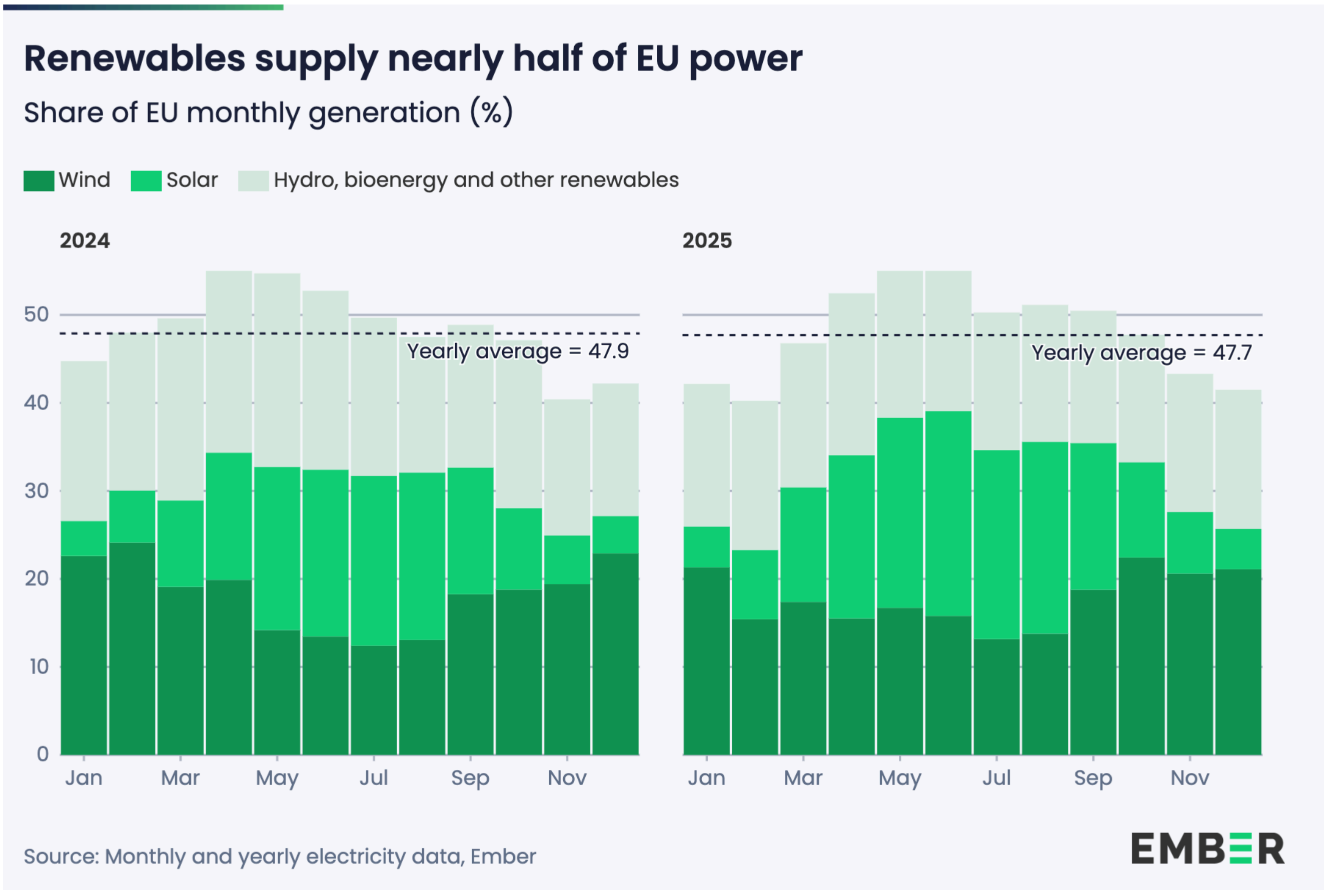
Renewables provide nearly half of EU power, staying stable through unusual weather conditions

Renewables provided nearly half of EU electricity in 2025 (47.7%, 1331 TWh). Despite unusual weather conditions, the renewable share remained stable compared to 2024 (47.9%).



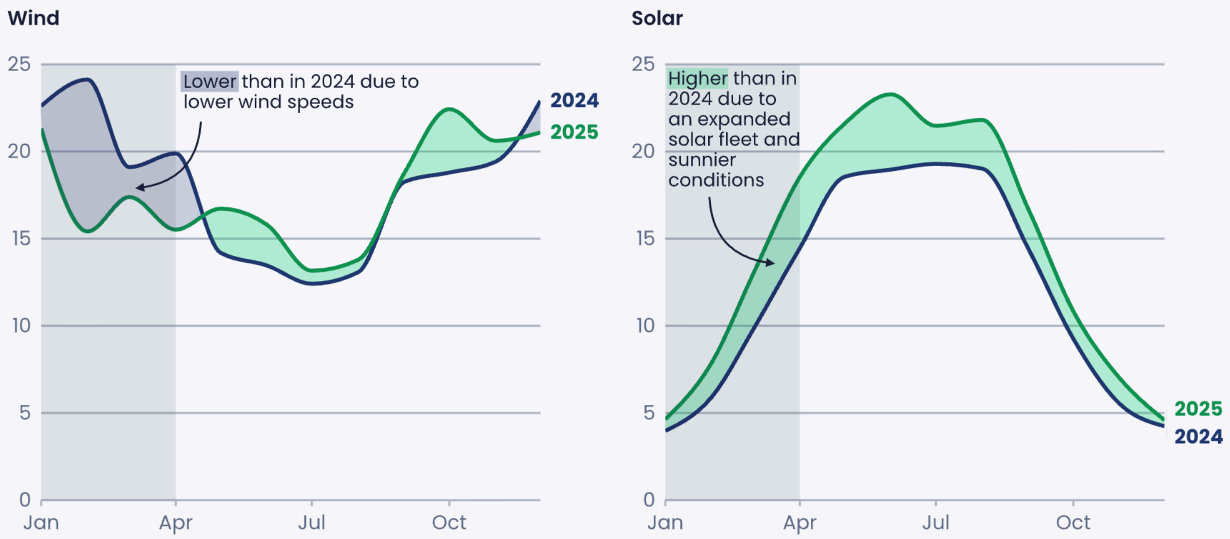
Renewables stayed stable because the same weather conditions that caused a drop in wind and hydro output boosted solar generation. Unusually warm temperatures over the north Atlantic (+3-4°C over the long-term average) led to a dry and low-wind first quarter of 2025. Cumulative rainfall in Northern Europe was 33% lower and average wind speeds fell by 23% in January-March compared to the average in the last five years.

A larger EU wind fleet, thanks to 5.3 GW of new wind commissioned in the first half of 2025, was not enough to compensate for the exceptionally low wind speeds at the start of the year. Wind production was 18% lower in the first four months of 2025 compared to the same period in 2024.

However, solar generation thrived due to exceptionally sunny conditions in Northern Europe, helping balance the drop in wind generation in the first four months of 2025. The average irradiation was 6% higher than the previous five years. Sunnier conditions particularly improved solar output in Belgium and in the Netherlands, where weather alone boosted output by 26% and 21%, respectively, and had a positive impact on Germany (+15%) and France (+10%) too. Improved solar conditions contributed 7 TWh, or about 11% of the EU's year-on-year growth in solar generation, with the rest coming from the structural increase in capacity.

Unusual weather in the EU led to a dip in wind in early 2025, but solar stepped up

Share of electricity generation, 2024 and 2025 (%)



Source: Monthly electricity generation, Ember

The boost in solar power was well timed to help with the peak in electricity consumption for air conditioning during summer heatwaves. While daily power demand grew by up to 14% during the June-July 2025 heatwave, overall EU demand remained stagnant in 2025. It rose by only 15 TWh (+0.6%) from 2024 and remained 4% below 2019 levels.

Later in the year, thanks to a return to normal wind conditions and the fleet expansion, wind remained the second largest EU electricity source at 16.9% of EU power, generating more than gas (16.7%).

Gas increases but does not recover to pre-crisis levels

After reaching a recent high of 569 TWh in 2019, gas power generation in the EU declined for five consecutive years, falling to 432 TWh in 2024. Gas power increased in 2025 (+34 TWh, +8%, compared to 2024), but it remained 18% lower than its pre-energy crisis peak. Gas remained lower than wind power for the third year running.

The increased gas generation, combined with higher gas prices (+5.6% in 2025 compared to 2024), meant that the EU spent €32 billion to import fossil gas for power generation in 2025, 16% more than in 2024. This is the first annual increase in the EU gas import bill since the 2022 energy crisis, with Italy and Germany paying the most.

Not every EU country experienced a gas power increase in 2025, however. Gas power increased in 15 of the 27 EU countries, with Spain (+9.7 TWh, +19%), Italy (+6.5 TWh, +5.5%) and Germany (+4.3 TWh, +5.4%) alone accounting for 60% of the increase. In all cases, an important driver was lower hydro domestically and abroad.

In Germany, gas replaced hydro as a dispatchable fuel to meet demand in hours with low solar and wind production. In fact, the hours with the largest increase in gas coincided with the biggest fall in generation from domestic hydro and a decrease in net imports, in particular from France, Switzerland and Austria – all experiencing a fall in hydro on a similar scale to Germany.

In Spain, the impact of a drop in hydro generation was exacerbated by an increased use of gas power plants for grid services, such as voltage control, after the Iberian blackout in April 2025. This increased gas use for grid services in Spain is however expected to be temporary as long-awaited rule changes were approved in June 2025, allowing generators other than gas plants to participate in voltage control services starting from January 2026. Many of the grid services provided by gas in Spain's power system can equally be provided by clean alternatives.

Coal nears its end across the EU

Coal declined yet again in 2025, bringing the end of the most polluting fuel even closer in the EU. Coal remained below a tenth EU power (9.2%), generating 257 TWh, a new historic low. This is a remarkable change considering that ten years prior coal represented nearly a quarter of EU electricity generation (24.6%), generating 705 TWh. Coal's importance in the EU mix is far below the global average (33.1% in the first half of 2025).

Coal is becoming increasingly marginal across the bloc: 20 EU countries have zero or less than 5% coal in their power mix (three more than in 2024). Ireland stopped burning coal in June 2025. In April, Finland de facto phased coal out ahead of the country's mid-2029 deadline to exit coal. Strong wind growth helped to fill the gap, reaching the highest share of Finnish electricity on record in 2025 (27%).

Over the past decade, as coal use declined, gas did not rise to fill the gap. In each of the 22 EU countries that ever had coal in their generation mix, the reduction in coal over the last ten years was not matched by an equal increase in gas or other fossil fuels.

The EU's remaining coal power is highly concentrated in just two countries, Germany and Poland, which accounted for more than 74% of the EU's coal generation in 2025. However, coal fell even here compared to 2024: by 3.2% and 6.6% in Germany and Poland, respectively. In Germany and Poland coal fell to an all-time low in 2025 (103 TWh and 87 TWh).

In nearly every EU country, coal dropped to 5% or less - and it's not being swapped for gas

Share of electricity generation from coal, gas and other fossil in 2015 and 2025 (%)

Green highlight = 0% coal; blue highlight ≤ 5% coal share in 2025

How to read this chart

EU countries that had coal in their power mix in 2015, sorted by coal share in their 2025 generation (from lowest to highest). Malta phased out coal power in 1995; Cyprus, Estonia, Latvia, Lithuania and Luxembourg never had coal in their power mix.

Source: Yearly electricity data, Ember, Beyond Fossil Fuels

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Chapter 2 – Early signs of the impact of batteries

Batteries started to compete with gas power in 2025

In many EU countries, gas-heavy hours pushed up prices in 2025, while sunny and windy hours pulled them down. This creates a profitable opportunity for batteries to store clean power for use in fossil-reliant times of the day. Early evidence of this was visible in 2025, with a record battery pipeline hinting at a major acceleration.

Electricity prices increase during gas hours

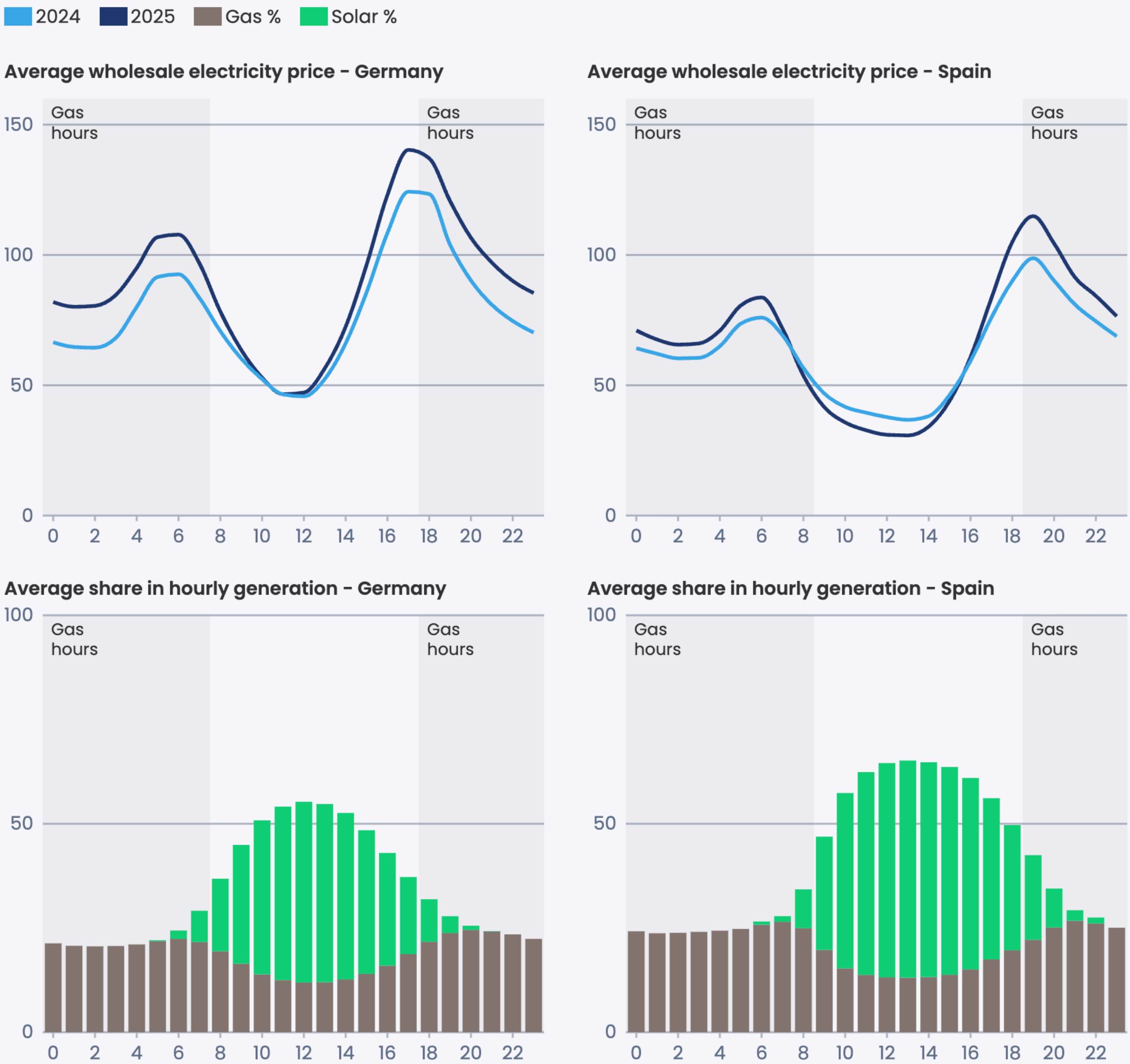
Wholesale electricity prices increased in 21 EU countries in 2025 compared to 2024, with annual rises ranging from 22% in Austria to 3% in Greece. The main cause of these price increases was sharp spikes during morning and evening hours. These are periods that align with the highest gas use, when more power from costly gas generators is needed to meet demand.

Burning fossil gas is typically the most expensive way to generate electricity. In 2025 the average cost of electricity from gas ranged between €101/MWh and €112/MWh across the EU. During peak gas-use hours in 2025, prices were on average 11% higher across the EU than in 2024. By contrast, in the hours when clean power (especially solar) was abundant, typically between 7am and 4pm, wholesale electricity prices rose by only 3%. In Germany, for instance, electricity prices jumped by 19% during high gas-use periods but grew only by 8% when solar generation was plentiful.

Hours with abundant wind and solar, which align with lower power prices, are common across the EU and are happening more often. In 2025, 19 EU countries experienced at least one hour when wind and solar combined accounted for over 70% of the country's hourly power generation, a significant increase from only two countries in 2020. Wind and solar together supplied more than half of electricity generation during at least one third of all hours in Denmark, Estonia, Germany, Greece, Lithuania, Luxembourg, the Netherlands, Portugal and Spain.

Solar is driving prices down, gas is driving them up

Average wholesale electricity price (€/MWh)
Average gas and solar share in hourly generation, in 2025 (%)



Source: Ember wholesale price dataset, Ember hourly generation data
Gas hour = hour when gas share of hourly generation is > 20% in 2025

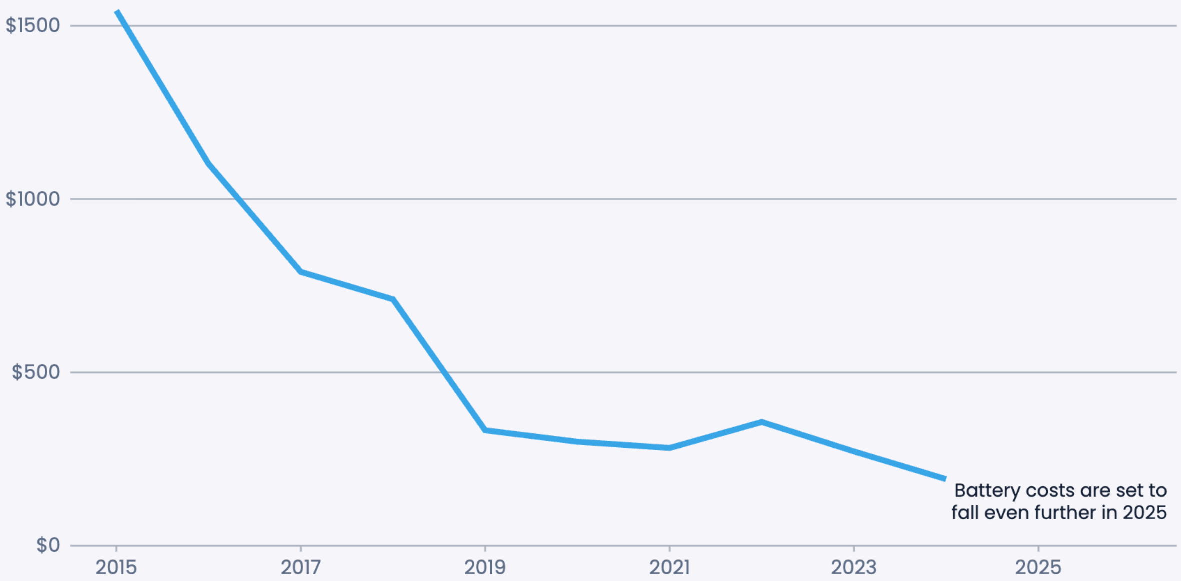
Record pipeline of battery projects can address price spikes

The widely interconnected European power system is already alleviating price spikes and stress on the grid by moving electricity to where it is needed the most. Higher connectivity and new cross-border electricity transmission lines, both in major demand centers and in more isolated regions such as the Nordics and Eastern Europe, could further mitigate both the frequency and the severity of the high price events.

Using batteries to store renewable energy for later use at times of high demand is another solution to lowering price spikes, and one that could be rapidly scaled up thanks to the favourable economics of battery projects. An average 20% annual decline in battery costs over the last decade, combined with large and widening intraday price spreads, made investing in battery storage more financially attractive than ever in 2025.

Battery costs fell by a fifth per year on average since 2015, improving the business case

Total installed project cost* - global ($/kWh)



Source: IRENA • *Costs of a fully installed and commissioned battery storage project, prices in $/kWh of usable capacity. Expressed in real terms (2024 prices).
Another major cost decline expected in 2025 based on Ember's research.

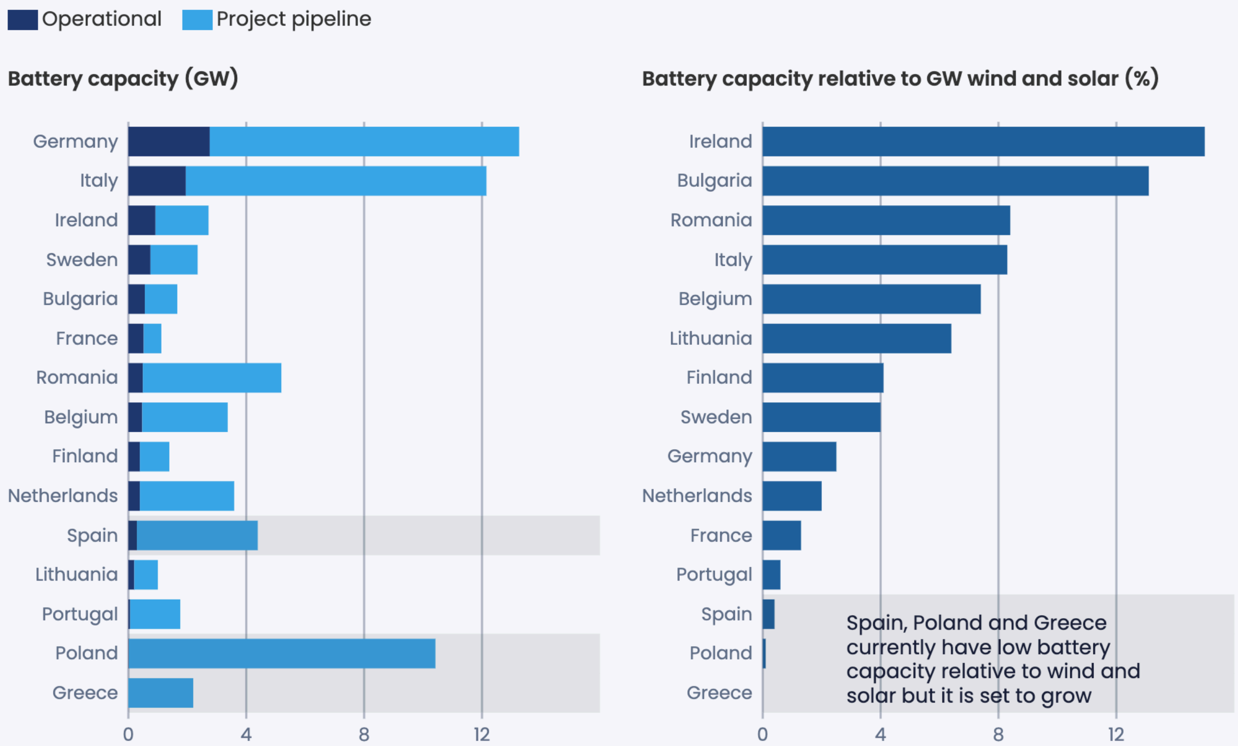
The improved business case has already boosted battery deployment: in 2025 EU large batteries exceeded 10 GW. This is more than double what it was just two years ago, at 4 GW in 2023.

While nearly half of EU grid-scale batteries are still concentrated in just two countries (Italy and Germany), 2025 saw clear signs of acceleration across the bloc. Battery projects started construction or were announced in most EU countries. In 2025, the grid-scale battery pipeline reached record levels in countries like Greece, Spain and Poland where operating grid-scale battery capacity remains especially low compared to installed wind and solar.

Germany and Poland lead the EU battery storage pipeline, followed by Italy. If all projects in the pipeline go ahead, capacity would exceed 40 GW, a ten times growth from 2023 levels, and would be less geographically concentrated. A big jump in the value of Chinese batteries imports to the EU in the first 11 months of 2025 is a sign of the strength of the pipeline.

Large batteries set to grow across the EU, especially where battery capacity is low relative to solar and wind

EU countries ranked by operational grid-scale battery capacity (GW) and by battery capacity relative to installed wind and solar (%)



Source: European Energy Storage Inventory, Ember monthly capacity data
Countries with battery pipeline < 0.5 GW excluded. Pipeline includes announced, permitted and in-construction projects. Solar includes utility-scale installations only.

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Early signs of batteries starting to meet demand in gas hours

Italy is one of the battery leaders in the EU, hosting 1.9 GW large batteries (about 20% of total EU operating capacity). Strong growth came in 2025: capacity increased by 0.7 GW from January to October (+40% compared to 2024). A robust pipeline of projects hints at rapid growth to come, with 10 GW of new battery projects in construction, permitted or announced as of December 2025.

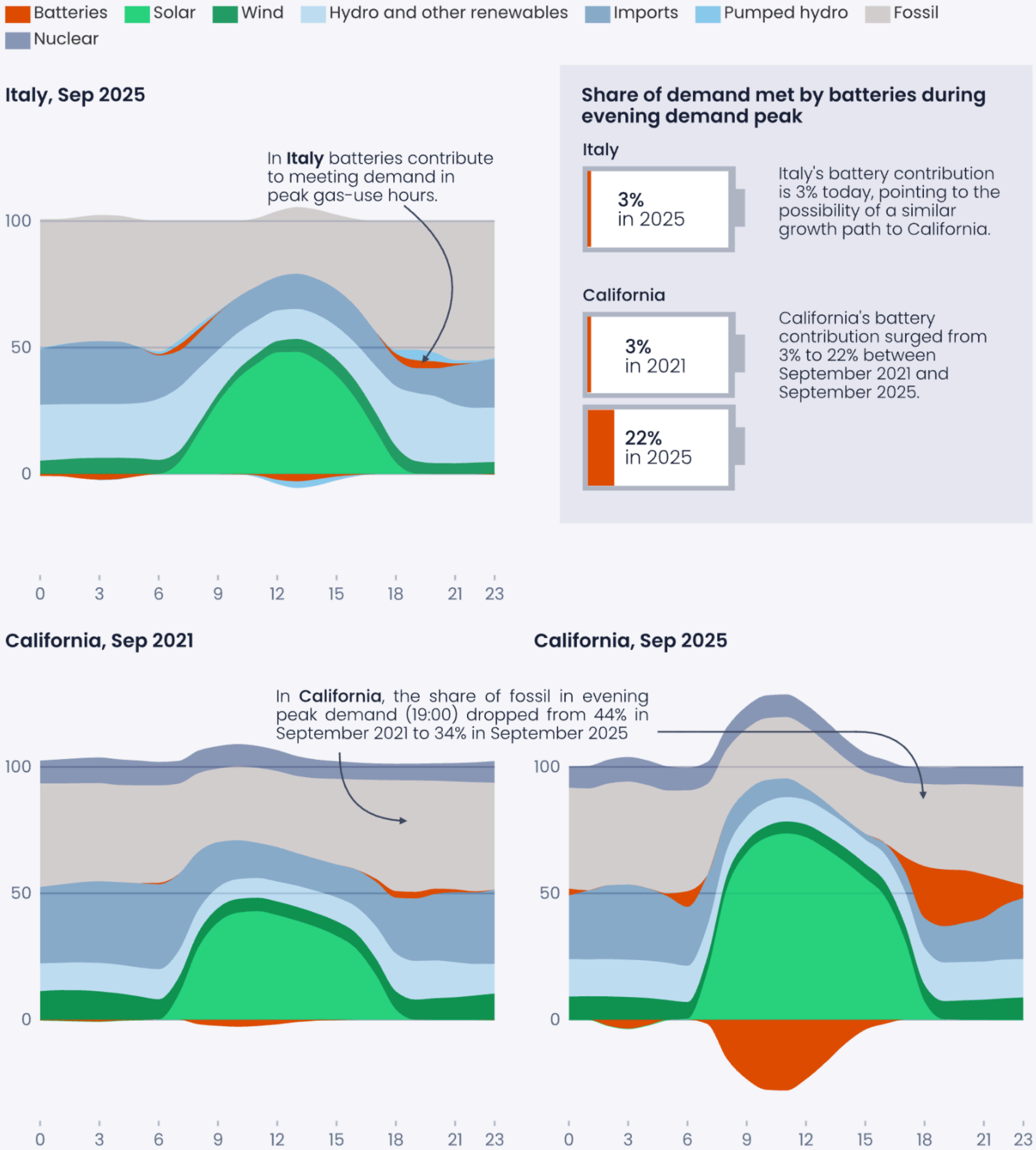
In 2025, Italy's batteries contributed to meeting demand during peak gas-use hours, a trend that could rapidly accelerate as that pipeline is built. In September 2025, large-scale battery systems discharged an average of 1.1 GW during the early evening hours (7–8 pm). This accounted for only 3% of demand in those hours, compared to fossil power's 52% share. However, with the delivery of the development pipeline, battery capacity could quickly grow by nearly six times, meet higher shares of demand during peak gas-use hours and reduce the country's high reliance on expensive gas.

California offers a case study of what could play out in Italy. California's grid-scale battery capacity in 2021 matched Italy's current level (2 GW), but then soared to 13 GW within four years. Italy would follow this trajectory if ongoing projects are delivered. In 2025, California's batteries routinely supply almost a fifth of electricity demand during evening peaks, increasingly limiting the need for gas. In fact, in just four years, California's share of fossil in the evening demand peak dropped from 44% in September 2021 to 34% in September 2025, while battery's contribution surged from 3% to 22% over the same period. This suggests that EU countries deploying batteries to store abundant clean power could similarly reduce their reliance on costly gas.

Deploying more battery capacity could displace more gas power generation and lower wholesale electricity prices at times when electricity is in high demand. Solar or wind power stored in a battery and shifted to the evening could cost around €64/MWh in Italy (see Methodology). This is a competitive price compared to the cost of producing electricity with a typical gas power plant which averaged €111/MWh in Italy in 2025 and typically set the electricity price in EU power markets. By outcompeting expensive gas-fired power plants and increasing competition among suppliers to meet demand, batteries can reduce the market power of existing price-setting generators and lower wholesale electricity prices.

In just four years, Italy’s battery storage could resemble California’s today

Share of demand met by source in Italy and California in September, hourly average (%)



Source: Hourly generation data, Ember, gridstatus.io
Negative shares for batteries and pumped hydro indicates charging from the grid

Batteries can limit waste of clean power

As solar installations take off across Europe, increasing battery use can ensure that as many solar kilowatts as possible get put to use.

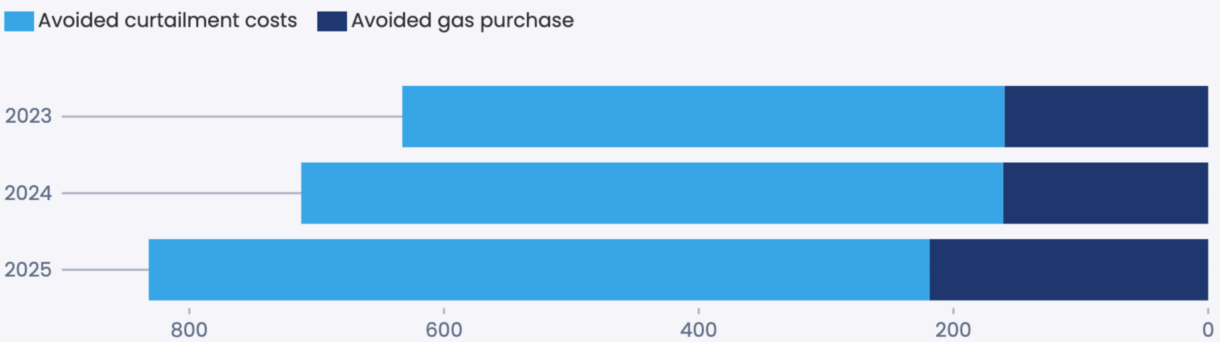
Curtailment, where grid operators intentionally limit the output of a generator, is generally due to physical constraints in the grid or limitations in operating the grid. Where curtailment takes place, there is an opportunity to capture that power for later use through battery storage. Batteries that charge using low-priced abundant clean power — which would otherwise be wasted — stand to profit, as periods of high renewable curtailment typically align with the lowest prices, sometimes even turning negative. In 2025, seven EU countries recorded negative prices in 5% or more of all hours.

Germany, the largest EU producer of solar power, is one country where batteries could help capture a significant amount of wasted solar and wind production. Germany curtailed about 3.1% of their total solar generation in 2025, up from 1.9% in 2024, while monthly wind curtailment remained at an average of 4.8% into 2025. Overall, Germany curtailed an estimated 9.6 TWh of wind and solar generation in 2025, nearly 4% of the total generation of these fuels.

If Germany's battery announced projects (equivalent to 10.5 GW/26.3 GWh) had absorbed this otherwise wasted generation, it could have avoided one third of the curtailment in 2025, avoiding about €0.8 billion in redispatch costs (€613 million) and gas purchase (€219 million). This could have alleviated consumer bills, since redispatch costs are passed to consumers via grid fees included in the electricity bill. Making use of that electricity through batteries would have also reduced gas generation by 3.7% (3 TWh) over the full year. These benefits would have outstripped the necessary cost of investment in batteries. To deliver those annual savings of €0.8 billion, the additional investment in batteries is estimated at €145 million per year over the technology's lifetime. The cost-benefit ratio for investing in batteries improves further given that they would be used for additional grid stabilization services, and would be used over a period of many years.

Storing wind and solar energy could have saved €830 million in 2025 in Germany

Potential avoided costs through storing rather than curtailing wind and solar power in Germany since 2023 (€ million)



Source: Netztransparenz, Shnetz, Avacon, Marktstammdatenregister, Ember monthly capacity data, Ember hourly elecitricity data, Montel • Assuming a stock of 26.3 GWh of batteries with a round-trip efficiency of 90%. If a curtailment occurs in any hour it is stored until the battery stock is fully charged. Batteries then discharge when there are no curtailments, replacing generation from gas.

The potential benefit of capturing curtailed power is substantial in those countries where a rapid solar expansion was not yet matched by a similar deployment of batteries, such as Greece, Poland or Spain. The lack of a clear regulatory framework is one of the factors that has slowed down battery storage development, but this started to change in 2025. For instance, Spain approved new rules to fast-track battery deployment, as part of a package to future-proof the Spain power grid and address key vulnerabilities identified after the Iberian blackout.

A smarter system can capture the full benefits of homegrown wind and solar power

Homegrown wind and solar are becoming the backbone of Europe's power system. Electricity storage, together with grid enhancements and demand flexibility, is crucial to put increasingly abundant renewable power to use and displace costly imported fossil power.

Policy action can accelerate a cost-effective transformation of the EU power system. To swiftly capture the full benefits of renewable power, EU member states and governing institutions need to put the following priority actions on top of the policy agenda in 2026:

Implement rules for clean flexibility

- Remove barriers to battery deployment in national legislation — such as streamlined permitting for co-located assets, ending double grid charging, clear rules and technical standards
- Implement a clear framework to reward consumers for their demand flexibility to lower consumer bills and provide grid stability

- Collaborate to accelerate permitting for key cross-border power lines and secure finance for a stronger power grid, implementing a new planning approach in line with the proposed Grids Package
- Member States must immediately implement non-wire solutions that can rapidly increase grid capacity
- The European Commission must ensure Member States implement existing rules and be held accountable for non-compliance.

Boost smart electrification through clear policy signals and support

- Put in place a clear policy for electrifying transport, heating, and industry, starting with the forthcoming Electrification Action Plan. Electrification can halve fossil import dependence and unlock investments in wind and solar.
- Support investment in heat pumps and other electric technologies through state aid and by rebalancing taxes and energy costs.
- Use electrification strategies to reward the rollout of smart electric technologies that adjust their consumption in response to electricity prices, opening access to cheap clean electricity
- Implement permitting reforms at the national level to enable renewables to meet rising electrification demand.

Improve energy security

- Prioritise the quick delivery of legislation to ban Russian gas and LNG imports by 2027, while avoiding a shift of the dependency to imported LNG that exposes EU consumers to global price shocks and unstable suppliers.
- Secure power lines against sabotage and deploy new interconnectors to protect against disruption from blackouts and attacks, especially in regions with the highest risk of incidents..
- Government, energy, financial and military stakeholders should collaborate to strengthen and protect grids and renewables.

Appendix A

Methodology

Generation, imports and demand

Annual data from 1990 to 2024 is gross generation, published primarily by Eurostat with wind generation data from IRENA. 2025 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 1990 to 2024 are also published by Eurostat, with recent data estimated in the same manner as generation. 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, Eurostat and directly reported national transmission system operators. In some cases data is published on a monthly lag; here we have estimated recent months based on relative changes in previous years. These cases are flagged in the dataset. Monthly published data is often reported provisionally, and is far from perfect. Every effort has been made to ensure accuracy, and where possible we compare multiple sources to confirm their agreement.

Hourly data has in most cases been sourced from ENTSO-E. Alternative sources have been used where ENTSO-E has been observed to supply incomplete data, such as missing generation from distributed solar or industrial thermal generation. These can be found in the per-country source list below.

A more detailed description can be found in our methodology.

Below is a list of countries included, and sources for monthly data:

- Austria: ENTSO-E, Eurostat, solar from E-Control GmbH
- Belgium: ENTSO-E
- Bulgaria: ENTSO-E
- Croatia: ENTSO-E with solar adjusted using a bespoke methodology to account for missing behind-the-meter
- Cyprus: Eurostat; hourly data used in analysis from Cyprus Transmission System Operator
- 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: Gas and solar from Energy-Charts; all other fuels from Agora Energiewende; flow data from ENTSO-E; yearly gas generation data from the Energy Institute
- Greece: ENTSO-E
- Hungary: Solar data before 2020 from Eurostat; solar data since 2025 from Mavir; other fuels from ENTSO-E
- Ireland: Generation and flow data from Sustainable Energy Authority of Ireland; no hourly data used in analysis
- Italy: Bioenergy, wind and solar from Terna, hydro is also taken from Terna and scaled using Eurostat to account for pumped hydro; other fuels from ENTSO-E; flow data from Terna
- Latvia: solar from AST; other fuels from ENTSO-E
- Lithuania: ENTSO-E

- Luxembourg: ENTSO-E
- Malta: Eurostat; no hourly data available for use in analysis
- Netherlands: Monthly data pre-2021 from Statistics Netherlands (CBS), post-2021 from the nationaal energie dashboard; hourly data pre-2021 data is based on ENTSO-E and CBS, post-2021 from the nationaal energie dashboard
- Poland: Solar data from ARE via Instrat pre-2021; other fuels from ENTSO-E; pre-2021 hourly solar data used in analysis modelled based on capacity from Instrat and insolation data from Open-Meteo
- Portugal: ENTSO-E, solar is adjusted using Eurostat
- Romania: ENTSO-E with solar adjusted using a bespoke methodology to account for missing behind-the-meter
- Slovakia: ENTSO-E
- Slovenia: ENTSO-E, solar is adjusted using Eurostat
- Spain: ENTSO-E with solar adjusted using a bespoke methodology to account for missing behind-the-meter; flow data from Red Eléctrica
- Sweden: ENTSO-E; hourly solar data used in analysis from Elstatistik

The annual increase in solar generation in 2025 is compared to the equivalent annual electricity production from France's nuclear plants, assuming a 68% capacity factor and an average plant capacity of 3.3 GW.

Power price data

Wholesale electricity prices are average day-ahead spot prices per MWh sold per hour, cleaned and sourced from ENTSO-E and semopx. Load-weighting is applied to compute average power prices for countries with multiple price zones: Italy, Sweden, Denmark. These are the prices paid to electricity generators, and are not the same as retail electricity prices or total costs to end users. No price analysis for Cyprus and Malta due to lack of reliable price data.

Average power price in peak gas hours for Germany is the simple average of hourly prices during hours when gas share of hourly generation is larger than

20% in 2025. Average power price in hours with plentiful solar generation for Germany is the simple average of hourly prices during hours when solar share of hourly generation is larger than 20% in 2025.

For the EU, the average power price in hours with plentiful solar generation is the simple average of hourly prices during between 7 am and 4 pm, while the average power price in peak gas use hours is the simple average of hourly prices during between 0-6 am and 5-11 pm.

Gas import bill for the EU power sector

It assumes plant efficiencies of 50% (Higher Heating Value) for gas, this value then multiplied by fuel costs. These are taken from day-ahead TTF prices for gas, unless specific country market data is available, see Methodology for details.

Import dependencies are derived from Eurostat data. Values are carried over from 2023, which represents a conservative approach as indigenous production is generally in decline across the EU.

Weather data

For irradiation: population weighted average of Germany, Netherlands, Belgium, France, Denmark, Ireland and Sweden.

Wind speed: population weighted average of Germany, Netherlands, Belgium, France, Denmark, Ireland and Sweden.

Battery storage data

The source for battery capacity is the Real-time Energy Storage Dashboard available on European Energy Storage Inventory, retrieved on 16th December 2025, filtering for "electrochemical storage" in the technology category. As a time step is not available, it is assumed that the retrieved data points reflect the deployment and project pipeline as of mid-December 2025. As the EU battery market has been experiencing fast growth, deployment data are likely to be a conservative estimate. The dataset reports total storage power installed capacity (measured in GW) by country, representing maximum power that can be discharged by all the country's batteries at a given time, starting from a fully charged state. It is assumed that the European Energy Storage Inventory includes only front-the-meter, grid-scale battery capacity, while it excludes behind-the-meter battery capacity (e.g. home battery). Project pipeline is computed as the sum of the following categories: in-construction, permitted, announced.

The battery capacity as a percentage of total installed solar and wind capacity is computed as follows:

- Battery capacity in GW, refers to operational grid-scale installations only. Behind the meter batteries (such as home batteries) are excluded
- Solar capacity in GWdc and wind capacity are both taken from Ember's monthly wind and solar capacity dataset. For reference we used either the date corresponding to the snapshot of the JRC database or the latest available date. For countries where monthly data was not available an average growth factor based on the subset of available data from European countries was computed and applied to the latest yearly installation numbers. Utility-scale solar capacity is estimated from total installed solar capacity according to Ember research on market segmentation.

Battery economics

Ember analysis suggests that shifting electricity in time with a battery costs $55/MWh (€49/MWh) in Italy, based on the following assumptions:

- Utilization 90%

- 120$/kWh capex (based Italy's MACSE storage tender in October 2025)

As the cost of charging electricity during hours of peak clean power production in Italy could be as low as €14/MWh (Italy power prices averaged €14/MWh between 11am and 14pm in September 2025), time-shifted solar or wind could cost around €64/MWh. This is lower than the cost of producing electricity with a typical gas power plant which averaged €111/MWh in Italy in 2025. Gas is typically the most expensive source of electricity, and currently sets the price in EU power markets.

The annual investment in battery capacity to deliver Germany's current battery pipeline is computed based on the following assumptions:

- 10.5 GW battery pipeline based on European Energy Storage Inventory (retrieved on 16 December 2025), converted in GWh assuming a 2.5-hour duration
- €111/kWh all-in capex for utility-scale battery storage outside China and the US, based on Ember's insight, converted into EUR.
- A 20-year lifetime, which is now the standard design life of the battery, as LFP technology has enabled higher cycle life.

Curtailment data

For Germany curtailment data the baseline used is the monthly for downward redispatch volumes from the Bundesnetzagentur (BNetzA). To derive an hourly profile for offshore, we used redispatch volumes from the four German TSOs and applied the shape of their hourly redispatch to reach the total monthly values. For onshore and solar we filtered redispatch volumes from Avacon, Bayernwerk, e.dis and SH Netz for curtailed onshore and solar generation and fitted the shape to the BNetzA's monthly total values. For both time series, we included a weighting towards hours with high wind or solar generation, based on the assumption that curtailments increase with the amount of wind generation. Costs per hour of renewable redispatch were taken from the BNetzA as well.

Costs for the import of gas use the same values as Ember's European electricity prices and costs data tool. Since the time series for total redispatch volumes and cost of renewable curtailments end in September 2025 the missing months were projected using historical ratios of curtailments to total generation and the partial curtailment volumes mentioned above. For the costs an average of the most recent years was used.

For curtailments as a share of generation the sum of curtailments of solar and wind was divided by the sum of solar and wind generation plus the sum of curtailments for each month. The share of combined curtailments of combined generation was split along the ratio of wind and solar curtailment per month.

Avoided redispatch costs and gas purchase costs thanks to additional battery storage

For the gas displacement in Germany, we assumed the following: A battery stock of 26.3 GWh, based on the latest capacity pipeline from the European Energy Storage Inventory, with a round-trip efficiency of 90%. If a curtailment occurs in any hour, the battery is charged by that amount instead of up to its maximum storage capacity. It then discharges as soon as the curtailment ends and displaces generation from gas in a 1-to-1 ratio. The displaced gas-fired generation is then multiplied by the day-ahead gas prices to calculate the amount in EUR. The costs of avoided curtailments are calculated from the sum of curtailments stored in batteries times the cost of redispatch per MWh for renewable energies.

The battery strategy is left intentionally simple and is not optimised with real-time price information and revenue streams from other services (frequency response and other ancillary services to the grid). It also does not force the battery stock to conform to the observed from mature battery markets, such as California, of charging during midday and discharging in the evening, but rather prioritises a reduction in curtailment volumes.

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