Making clean power flexy

As Europe’s energy transition accelerates, clean flexibility is crucial to integrate increasing levels of wind and solar into the power system.

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About

This report provides an overview of clean flexibility in the EU, focusing on battery storage and demand side flexibility as two key enablers in the transition towards a clean power system. The paper analyses the current state-of-play in the EU regarding these solutions, examines outlooks for future deployment and presents relevant policy options to help accelerate their roll-out.

Executive Summary

Time for flex

Clean flexibility will unlock system-wide decarbonisation as more wind and solar is deployed across the EU.

As renewables grow rapidly in the EU, system flexibility needs are increasing. Flexibility is needed to balance the grid when weather dependent generation, such as wind and solar, exceeds or falls short of the amount of power being used. Making sure that flexibility is supplied by clean sources, rather than fossil fuels, is an essential part of keeping decarbonisation on track for EU targets.

Two clean sources in particular are often overlooked: battery storage and demand side flexibility. These are ready to deliver now and have the potential to make a significant difference to a clean power system, both immediately and longer term.

01 Overlooked forms of clean flexibility offer alternative to fossil fuels

System flexibility has historically been provided by fossil fuels, combined with cross-border imports and exports and hydropower. However, alternatives are available and gaining momentum. Battery storage in the EU doubled in the space of one year to 16 GW at the end of 2023, and awareness of the potential of demand side flexibility is growing.

02 EU flexibility needs will double by 2030

EU power system flexibility needs will double by 2030. Rapid deployment of flexibility is needed to keep pace with growing renewables, expected to rise to 66% of EU electricity by 2030. The growth in wind and solar brings a pressing need to manage system variability across different time scales.

03 Battery storage and demand side flexibility neglected in national plans

Despite the urgent need for a more flexible power system, explicit 2030 targets for both storage and demand-side flexibility are lacking in national policy documents. However, latest official assessments and industry forecasts suggest that batteries could offer a considerable amount of short term flexibility in 2030, although they overlook the potential of demand side flexibility.

The EU has succeeded in deploying a lot of renewables quickly, hitting a major milestone last year as wind overtook gas generation. However, wind and solar deployment is only one part of shifting the EU's power system and economy away from fossil fuels.

The signs of insufficient flexibility are already appearing. Negative prices and high curtailment of peak summer solar power in certain EU countries discourage further investment in solar power. The power system's canary in the gold mine is singing and although not currently wide-spread, problems will continue to grow if solutions to integrate growing levels of renewables are not implemented.

Luckily, these solutions already exist. It is now crucial that clean flexibility becomes a priority, including urgently scaling up battery storage, demand side flexibility and cross-border interconnection, as well as better incorporating clean flexibility into future system planning.

"A system based around wind and solar has to be flexible. Making sure that flexibility is supplied through clean solutions is absolutely critical to building a secure, cheap and decarbonised power system. Luckily, we already have tools at our disposal. Batteries, demand side flexibility and grids will be the connecting fabric of an agile and cost-effective clean power system."

Beatrice Petrovich
Senior Energy and Climate Analyst,
Ember

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What is clean flexibility?

No clean energy system without clean flexibility

Wind and solar are becoming the backbone of Europe's power system. Storage, demand side flexibility and grid enhancements are crucial to put that renewable power to use.

Increased levels of wind and solar in the power mix bring cost, climate and energy security benefits. However, other parts of the system that can complement wind and solar are needed to deliver those advantages. This is where clean flexibility comes in.

A smarter power system

Within a power system, there are many sources of supply and demand which must be constantly matched to ensure the stability of the grid and reliable power supply. System flexibility is defined as the ability of a power system to manage this variability and the unpredictability of demand and supply across all timescales and locations.

Energy transition will change how this needs to be managed. As the volume of weather-dependent renewable generation grows, the variability of supply also increases. Electrification will also have an impact, with power demand set to increase as more of the EU's economy electrifies. This will change consumption patterns, creating new, higher daily and seasonal peaks.

Balancing across time scales
In a highly renewable system, flexibility is required at different time scales to account for changes in weather and power use.

As more power is supplied by solar, it will need hourly and daily back-up for when it is less sunny. Low wind periods are more likely to happen across days or weeks, requiring flexibility of the same scale to match. On the other hand the system needs to be able to accommodate times when it is very sunny or windy, and renewable generation is higher than demand. These peaks can overload the grid if that power is not locally consumed or stored.

Balancing at the level of seconds and minutes is also needed to operate the grid safely by maintaining stable frequency. There is also a need for longer term balancing across the year and particularly between seasons. This is to respond to differences in demand, such as heating or cooling requirements, as well as seasonal patterns of generation fluctuations due to weather changes. To some extent, cross-border interconnection and seasonal complementarity between wind and solar production can help balance renewable generation across longer periods, but a suite of clean flexibility options will help keep the grid stable.

A new mode of a flexibility for a new system

Europe's power system is evolving. Historically, grid operators have balanced power demand and supply by using fossil fuel plants that could quickly be ramped up or down depending on need, known as 'peakers'. This was coupled with solutions such as electricity imports and exports, pumped hydro storage and dispatchable hydropower.

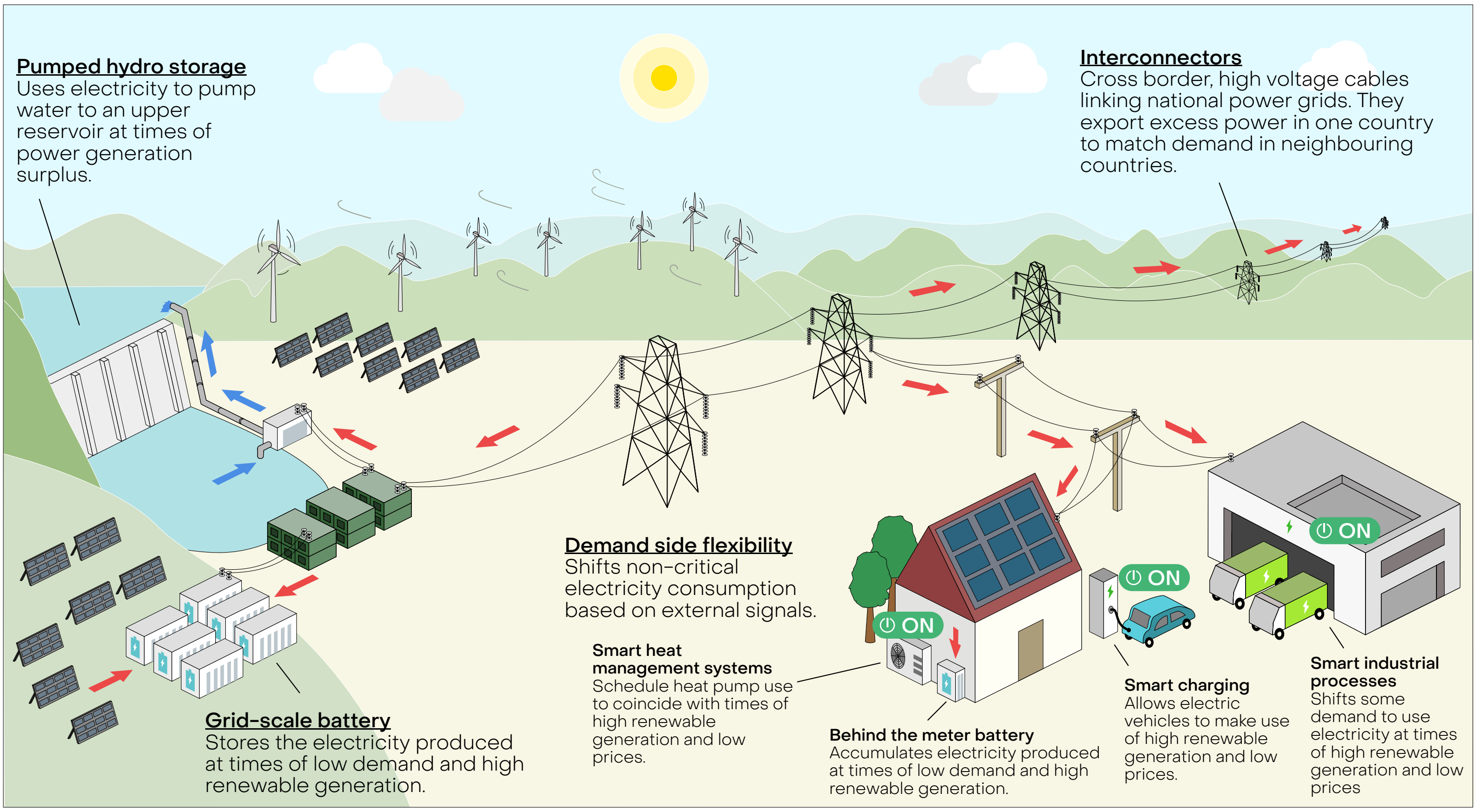
However, this is set to change. Fossil fuels are already playing a diminishing role in the EU's power system. As this trend continues, a new version of flexibility will be needed to make the transition to a clean system. Solutions such as battery storage and demand side flexibility (DSF) are emerging and offer increasing potential to replace fossil flexibility in the coming years.

What's in the clean flexibility toolkit?

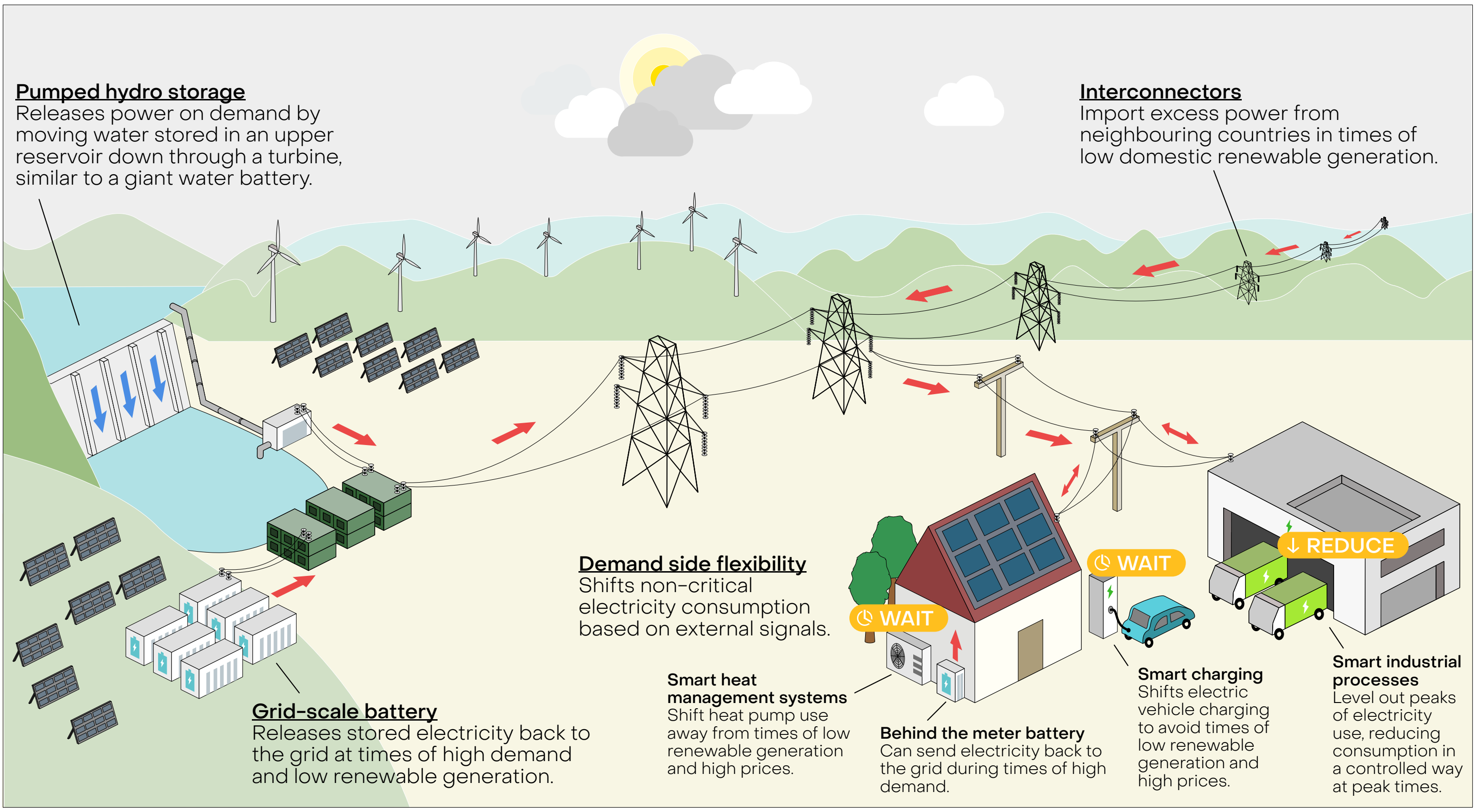
What is clean flexibility?

In the electricity grid, demand and supply need to match at any time to avoid blackouts. Clean flexibility is a suite of solutions that balance the grid when weather-dependent generation, such as wind and solar, either exceeds or falls short of electricity demand. Flexibility ensures that excess clean power is not wasted, but rather harnessed for later use, moved to where it is needed or matched with consumption. These solutions already offer an alternative to fossil power, which has been historically used to balance the grid.

If renewable generation is higher than electricity demand...



If renewable generation is lower than electricity demand...



Source: Ember
Graphic by Reynaldo Dizon

Grids

Grids are the enabling factor of a clean power system, connecting electricity to where it is needed. They are already a key provider of flexibility, but their role is set to grow.

Interconnectors between countries allow electricity to move across borders in a matter of minutes, balancing geographic variations in wind and solar generation between countries. Interconnections play a central role in providing flexibility: at the EU level they could cover 15% of the daily and 33% of the monthly flexibility needs by 2030.

Within a country's borders, transmission and distribution grids also ensure renewable generation is integrated and delivered to where it is needed most. Focus on smart grids is also growing, increasing the use of data and software in power networks to better match supply and demand in real time.

Storage

While grids shift electricity across geographies, storage shifts electricity across time. Storage technologies accumulate the electricity produced at times of high wind or solar production and shift it to when it is needed the most.

While various storage technologies exist, lithium-ion batteries and pumped hydro storage are currently the most widely deployed technologies in the EU. These account for virtually all (>95%) operating storage capacity in the EU in 2022.

Lithium-ion batteries can be deployed at grid-scale, connected to the transmission grid, or at smaller scale in a residential or commercial building to enhance consumption of energy produced on site. This is known as behind-the-meter.

The costs of batteries are rapidly declining, and lithium-ion batteries have become increasingly cost competitive thanks to a significant drop in raw material costs. Battery costs are expected to drop even further as industrial capacity for their mass production is built up, and also as electric vehicle manufacturing hits another increase in scale.

Demand side flexibility

The third key source of clean flexibility acts on consumption patterns. Demand side flexibility (DSF) is created by consumers shifting their non-critical electricity use according to external signals, such as periods of low power prices.

DSF can materialise in different ways. Historically, the majority was procured using *peak shaving*, typically through large industrial users. This method manages short-term demand spikes by reducing consumption in a controlled manner, such as shutting off non-essential industrial processes. However, as more renewables come online and create times of low prices, the focus of DSF has moved to *demand shifting*: moving demand from times of high to low prices. For example, an electric vehicle could shift its charging to times of cheap peak solar generation around midday.

DSF can be implicitly or explicitly procured. Explicit DSF uses direct rewards for consumers who shift their demand, whereas implicit DSF relies on price signals or tariffs to incentivise consumers to move consumption away from peak times.

Developing technologies

Countries are also considering other low carbon forms of flexibility alongside this core toolkit, especially for mid- to long-duration flexibility needs. There is still debate on whether lithium-ion batteries are able to provide storage for longer time periods at a competitive cost. Pumped hydro storage and interconnection can contribute to longer duration flexibility needs and are already embedded in the wider system, both technologically and in terms of regulation and policy. However, further research into alternative technologies for long duration storage is needed to understand the most cost-effective and efficient route to manage the future power system. Potential areas for research include sensitive heat thermal storage, metal-anode or flow batteries.

Countries are also considering hydrogen-based power generation as a potential solution for managing several days of demand-supply mismatches. Flexible operation of electrolysers can use surplus renewable generation for the production of green hydrogen. Since hydrogen can be stored for long periods, it can act as a source of flexibility on longer time scales in combination with hydrogen-based power generation, although this technology is still in the nascent stages of development. Fossil gas power stations equipped with carbon capture and storage (CCS) are also potential sources of flexible low carbon power, although can only be employed at times of low renewable generation given they cannot store electricity. A gas CCS project has been granted planning approval in the UK. However, although the technology has existed for decades, overall little progress has been made. The cost of gas CCS and hydrogen technologies is still uncertain.

Putting the toolkit into action

Achieving climate targets and mitigating system costs will need all the tools in the clean flexibility kit. In particular, battery storage and DSF are key for providing daily flexibility, which is where the largest increase in system flexibility needs will come from as variable wind and solar continue to grow. Given their high potential but relative lack of attention from policy makers and energy system planners, the remainder of this report will focus solely on DSF and battery storage.

Why do we need clean flexibility?

Unlocking the benefits of the clean transition

Batteries and demand side flexibility, along with cross-border interconnection, are the key to a faster and cheaper energy transition.

Europe is in the midst of a paradigm shift away from an inefficient and expensive fossil-based system, to a fluid and nimble one backed by wind and solar.

The change to a responsive and clean system promises big benefits: delivering low cost renewable power across Europe, taking advantage of home-grown wind and solar resources, building a secure and distributed power system that is resilient to geopolitical threat and reducing carbon emissions to prevent an escalation of climate impacts.

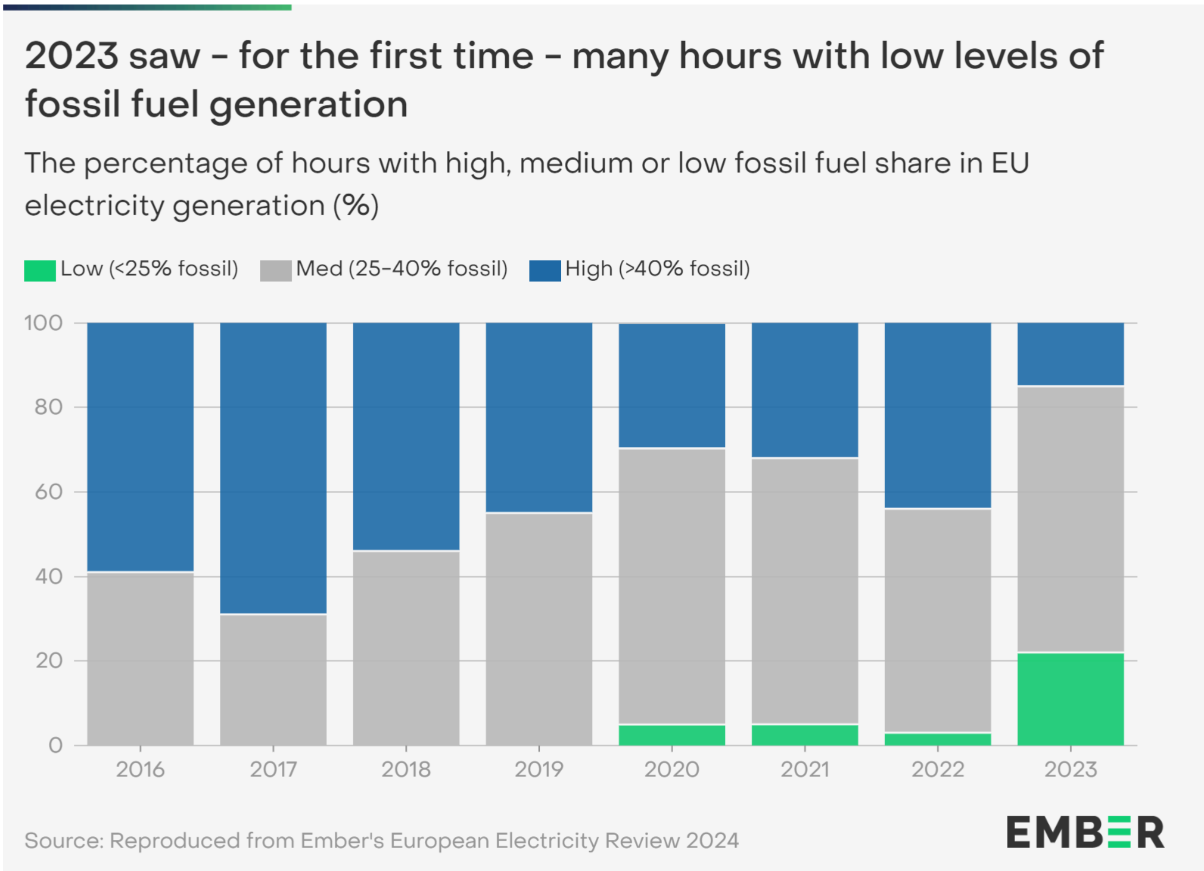
Clean flexibility will be the connective tissue of this new system, with its importance to the future energy system becoming increasingly clear. To deliver the benefits of the transition to wind and solar as quickly and efficiently as possible, batteries and demand side flexibility in particular need investment and clear policy planning now.

Clean flexibility unlocks benefits

Reducing fossil reliance
Clean flexibility reduces the need for fossil fuel backup in an electricity system dominated by renewables: the final piece of the puzzle in decarbonising power supply.

A rapid phase out of coal and gas power is necessary to achieve the EU's climate targets. This shift is already well on its way, with wind and solar providing more than a quarter (27%) of EU electricity in 2023 for the first time. This increased wind and solar generation is increasingly replacing baseload fossil generation, meaning that renewable sources now provide a sizable, stable share of the EU's power throughout the year. And this transition is clear even on a more granular level: in 2023, 24% of hours saw less than a quarter of electricity coming from fossil fuels, a large jump from just 4% of hours in 2022.

Clean flexibility sources can further help to reduce the hours when expensive fossil technologies such as gas power are used to fill the gap between supply and demand: batteries and demand side flexibility are the new peakers.



Wasting no clean power

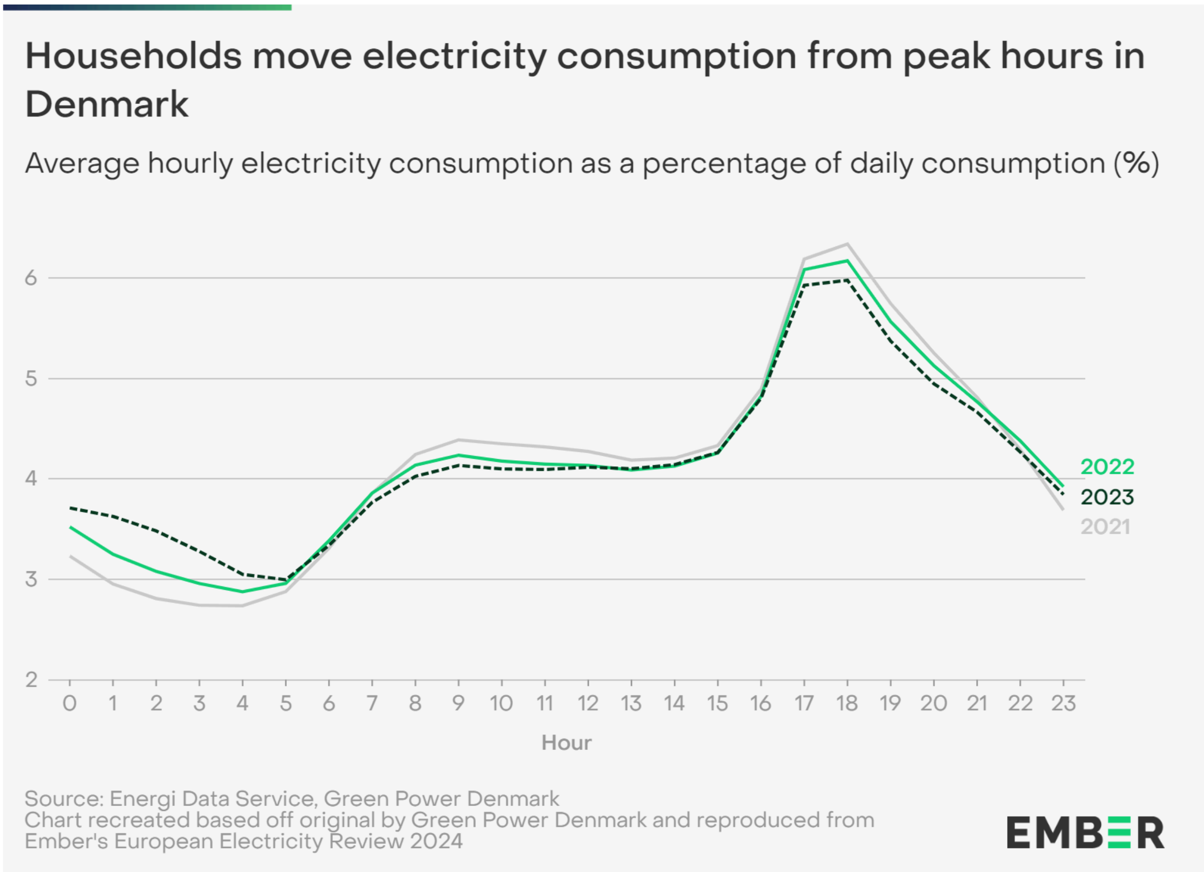
As more wind and solar is added, times when the grid cannot manage the excess renewable generation are becoming more common, leading to curtailment – when network operators must restrict the output of renewable generators to avoid overloading the grid. This situation is made worse by the fact some baseload generators, such as inflexible coal and nuclear plants, are unable to ramp down quickly. Curtailment is not only a waste of clean energy but also negatively impacts investment cases for renewable power. It also increases system costs for consumers as renewable generators are paid to turn down whilst expensive fossil fuel plants are often paid to turn on closer to the demand centres.

As more wind and solar is added, hours when generation surpasses demand will occur more frequently and curtailment will increase unless sufficient clean flexibility is added. By 2030 excess wind and solar power could amount to 118 TWh/year, around 6% of their expected generation in the European Commission's REPowerEU plan. Battery storage and DSF can reduce curtailment, which helps stabilise renewable generators' income and also lowers network investment needs. In the UK, batteries could cut curtailment costs by 80% annually.

Reducing bills

Batteries can reduce price volatility and lower system costs at peak times. This is in contrast to continued reliance on fossil power, which exposes consumers to the risk of price spikes. Just 350 MW of operating battery assets would have saved French consumers around €75 million in one day during the energy crisis when prices reached record levels of over €2000/MWh.

Clean flexibility can offer immediate cost savings for consumers too. One of the principal benefits of DSF is that it returns money to the pockets of consumers in exchange for their flexibility. In Denmark, the introduction of time-varying tariffs, an implicit form of DSF, has incentivised households to shift consumption away from more expensive morning and evening peaks. In the UK, over winter 2022/23, the Demand Flexibility Service paid consumers £3.2/kWh on average for shifting their electricity consumption away from peak times, allowing them to earn around ten times more than the average unit cost of electricity for domestic bills in 2023.



Reducing emissions
Clean flexibility also reduces system-wide carbon emissions. Batteries could displace up to 2 gigatonnes of greenhouse gas emissions per year by 2030 from the global power sector, equivalent to half of the EU's total CO2 emissions in 2022. Full deployment of DSF in the EU by 2030 could reduce carbon emissions by 8% compared to a no-DSF scenario and save consumers €300 billion annually.

Operating the grid efficiently

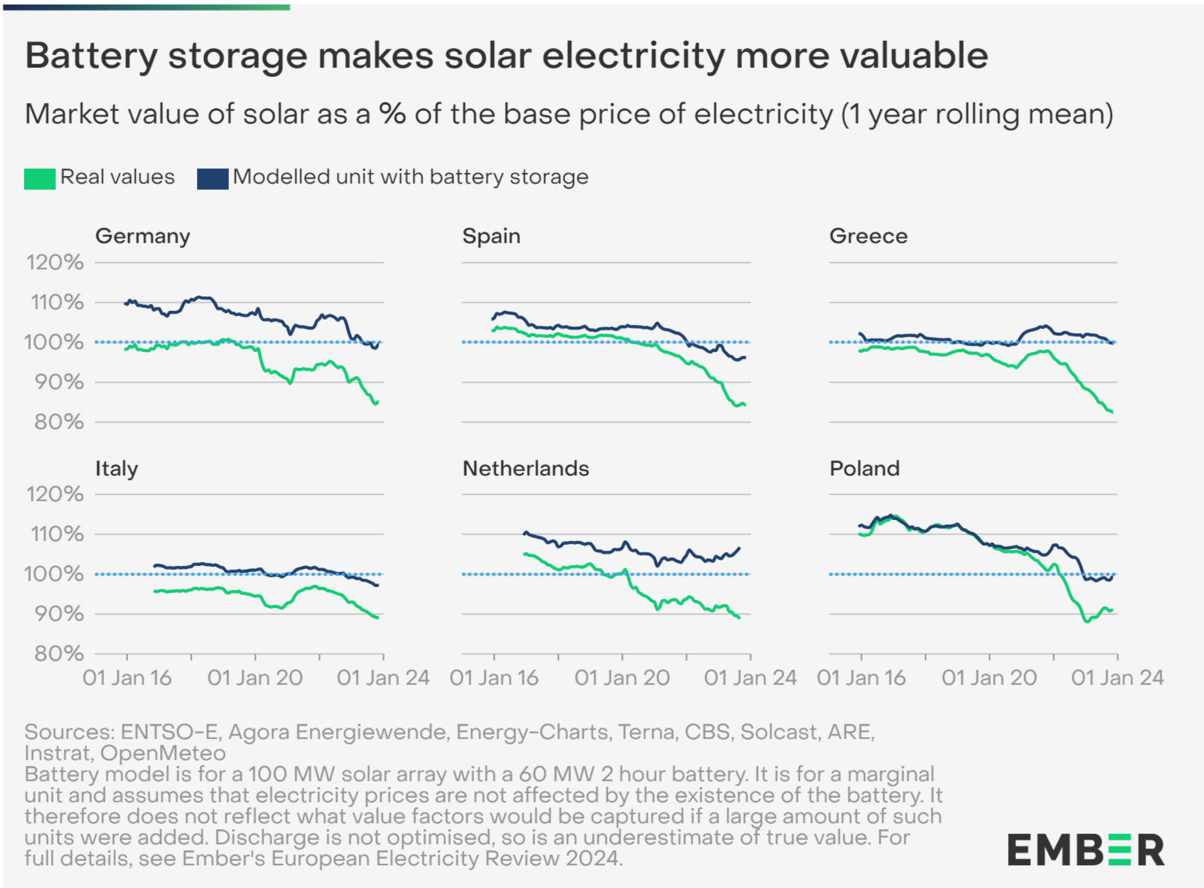
Storage and DSF can help existing infrastructure go further, addressing pressure points that might otherwise require more investment. In Germany, some large batteries are already officially labelled as "grid boosters", allowing better use of existing power lines. 450 MW of battery grid boosters are currently being built with an additional 500 MW recently approved. In France, DSF is already used to alleviate stress on the grid. It is procured through its own specific auction under a scheme designed to provide demand response capacity on days of highest voltage on the electrical system. In 2023, 2.7 GW was procured.

Increasing solar's value

Installing batteries alongside solar can also make solar electricity more valuable.

Falling utility solar capture rates – the price received for solar electricity compared to the baseload price – is a phenomenon which is already here and set to worsen this summer as more solar is added to the system.

Storage solutions help alleviate instances of low capture rates and low revenues for solar generators. During times of high solar generation they take up excess electricity, reducing the volume flooding the grid during low price periods. By releasing this stored energy strategically, it gives solar power plants more control over the price they command for their power, and helps them avoid selling for low prices in the middle of the day.



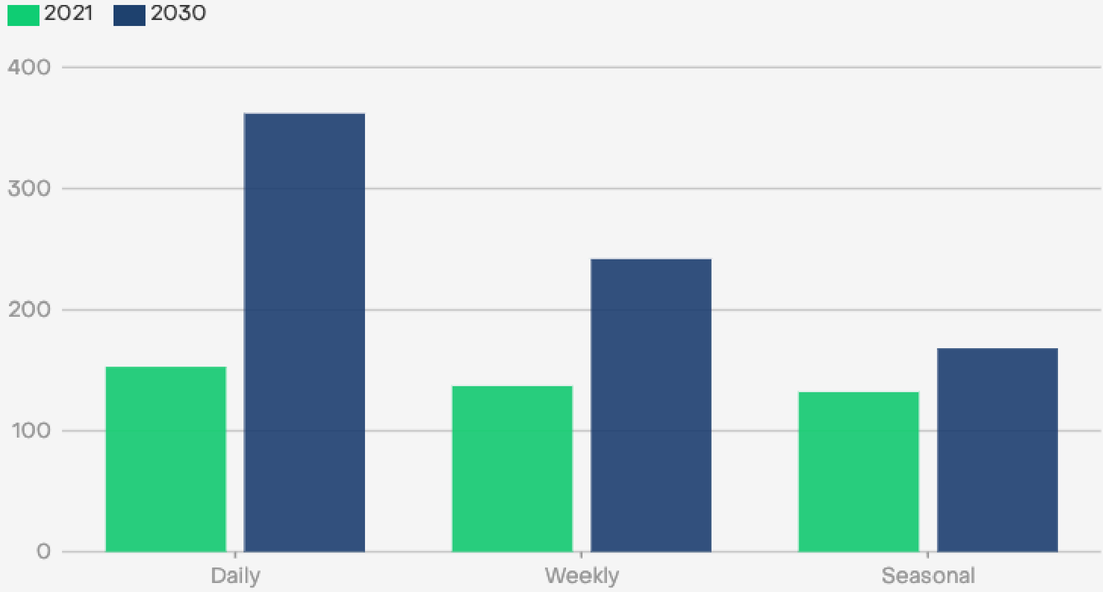
EU flexibility needs could double by 2030

EU power system flexibility needs could double by 2030, with rapid deployment required to keep pace with the growth of renewables and electrification. The need for daily flexibility in particular is expected to grow rapidly in the next six years, underlining the importance of on-the-ground deployment of battery storage and DSF in the very near term.

The rise in flexibility needs is tied to increasing ambition in wind and solar. Based on the updated draft National Energy and Climate Plans (NECPs) and other national announcements, Ember estimates that renewables are on course to generate 66% of EU electricity by 2030, with eight Member States expected to exceed 80% renewables generation. In 2023, renewables accounted for 44% of EU electricity generation, with wind and solar alone responsible for 27%.

A renewable-based system needs more flexibility

Daily, weekly and seasonal flexibility needs for Europe (terawatt hours)



Source: ACER/EEA
2030 annual data from the policy scenarios for delivering the European Green Deal.
Europe includes EU27, UK, Western Balkans, Switzerland and Norway.

Battery storage and DSF already provide flexibility in the EU

Batteries and DSF are already deployed in the EU. Batteries have seen recent rapid growth, driven by a few key countries. DSF remains an under-utilised option, often held back by regulation. For both technologies, open and readily available data to track their development is lacking.

Recent rapid growth of batteries

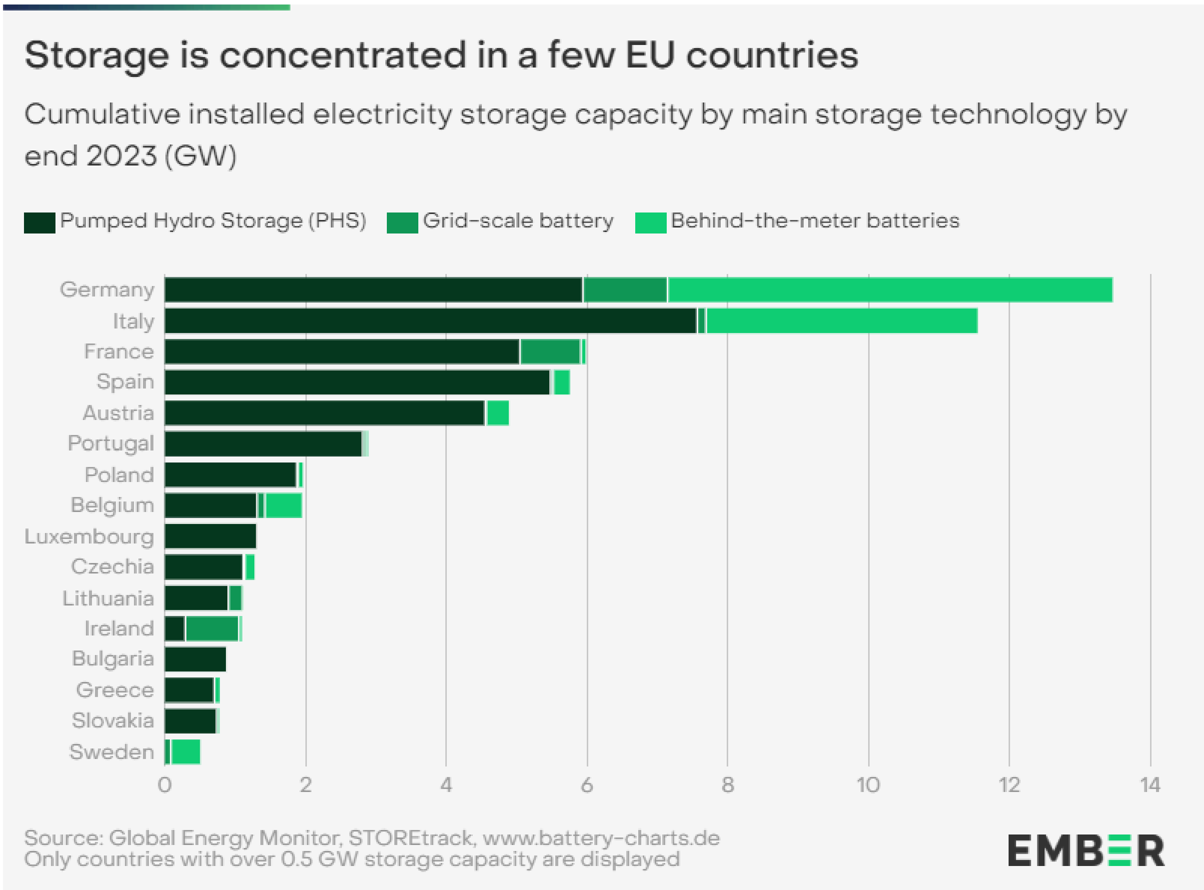
Batteries have been growing rapidly in recent years. While pumped hydro storage has historically made up most of EU storage capacity, with 40 GW currently installed, battery growth means this status quo is about to change.

Battery capacity starts to take off

Installed battery capacity doubled to 16 GW in the EU in 2023. Currently, this capacity is concentrated in a small number of countries. More than 70% of EU grid-scale batteries are found in France, Ireland and Germany, whilst Italy and Germany account for the majority of behind-the-meter batteries. Other countries must now follow, particularly those where a high penetration of renewables, such as Spain and the Netherlands, is already causing problems with price cannibalisation and curtailment.

Battery growth in 2023 was predominantly due to a rise in behind-the-meter batteries, accounting for around 70% of additions. Batteries located in buildings have become the largest source of storage in Germany at over 6 GW, surpassing pumped hydro storage. Further growth is expected in the grid-scale segment, especially in Italy and Germany, which have the most significant project pipeline for new grid-scale batteries.

Batteries' performance over longer time frames has also been improving, with 4-hour duration expected in the short-term future across Europe and new storage tenders creating demand for projects up to 8-hour duration.



Batteries with solar

In some European countries, combining rooftop solar with behind-the-meter batteries is already common. This helps alleviate distribution grid congestion and increases the amount of self-produced electricity households can use. Italy saw growth in residential storage thanks to a generous incentive scheme for building renovation. Private battery systems bundled with rooftop solar accounted for 2.9 GW capacity as of June 2023. By the end of 2023 capacity had reached almost 3.9 GW. In Germany, over 80% of new home solar installations have battery storage systems.

Developers are increasingly looking at co-locating storage next to grid-scale renewables projects, which can increase the value and efficiency of the installation. The number of storage projects co-located with renewables reached about 300 MW in Europe in 2023. Although co-located storage is attracting increasing market interest, more must now be done to encourage and enable this set-up given the drastic falls in solar capture rates seen over the last year or so.

Dedicated support schemes boost growth
New dedicated support schemes for batteries are also helping bring them to market. At least 1.8 GW of batteries have already been contracted and subsidised in Europe through dedicated auctions that provide financial support and stable revenue streams for new capacity of standalone or co-located battery storage. Upcoming auctions could procure over 15 GW across Europe by 2030. In particular, by February 2024 grid operators in Greece and Spain had already procured 0.7 GW and 0.8 GW of batteries and Italy's new storage auction mechanism is expected to procure 9 GW of mostly pumped hydro storage and lithium-ion batteries, starting from the end of 2024.

Recent successes show that energy storage systems can also competitively provide reserve capacity to the grid. One example is Poland, where in the latest capacity mechanism auction in December 2023 (for delivery in 2028) almost a quarter of the capacity (1.7 GW) was awarded to battery storage projects. This is a significant step up from 2022, when 3% of the capacity was allocated to battery storage. In total, more than 5 GW of grid-scale batteries have been contracted across existing capacity mechanisms in Europe.

DSF remains underutilised but attention is growing

The current contribution to system flexibility from DSF remains low. In many countries, DSF faces significant barriers to entry under regulatory and market conditions designed for large fossil fuel power plants rather than smaller, distributed sources of flexibility. However, awareness of its potential is growing.

It is difficult to place a single number on the volume of DSF in use across EU Member States but certain statistics can be used as an indicator of the state-of-play. One of these is smart meter penetration across countries which ACER tracks in its annual market monitoring report. Without a smart meter installed, flexible tariffs are not available to consumers as their usage cannot be accurately measured and they therefore cannot be rewarded for providing flexibility. As of 2022 (the latest data available), 13 countries were marked as completed (meaning over 80% of consumers equipped with smart meters). However, 10 remain at less than 20%, five of which are at 0%, highlighting a large discrepancy in the progress of Member States.

Alongside the electricity wholesale market, there are other services such as capacity mechanisms and frequency response services which contribute to the reliable operation of a power system. These are technology neutral in theory but not in practice, meaning participation for demand response and energy storage is often limited. Eligibility requirements and product design features are often targeted at fossil fuels, which have traditionally dominated these services. Not all EU countries have capacity mechanisms, but of the eight that do, only four (Belgium, France, Ireland and Poland) have contracted DSF for future years, with volumes ranging from 7-10% of total procured capacity.

Data transparency

Cost-effective system planning including clean flexibility will depend on improvements to data transparency. While there are signs of increased implementation of batteries and DSF, data availability is limited and inconsistent.

This creates real barriers to a swift and cost-effective energy transition. It is not straightforward to comprehensively assess a country's flexibility mix or track its evolution over time. More transparency on the current and planned deployment of flexibility sources would enable informed policy decisions, increase stakeholder engagement, build confidence in the technologies and provide up-to-date inputs to power system planning, including grid development plans.

One improvement to this comes via the proposed reform of the EU's Electricity Market Design (EMD) which requires member states to assess the flexibility needs of their electricity system, taking into account all existing and planned flexibility investments. The reform asks member states to set indicative objectives for storage and DSF and envisages support schemes dedicated to clean flexibility.

Room for improvement for storage data

Data quality on storage varies by technology. Due to the longer history of pumped hydro storage facilities and their bigger size, open data on operating capacity and project pipelines for Europe's "water batteries" are readily available.

A “one-stop-shop” for open, up-to-date and consistent data on European battery storage capacity does not yet exist. Data on large-scale batteries is scattered in reports on planning, permitting and grid connection requests. Industry associations gather data on battery storage facilities, but full data access is normally restricted to their members, and updates are normally released on an annual basis. This makes it challenging to track up-to-date battery rollout.

One notable best practice for data transparency concerns battery systems in Germany where almost all behind-the-meter storage installations must be entered into a market register of the German Federal Network Agency. The Battery Charts project tracks and visualises these installations, updating the information monthly and including details such as size, technology type and location.

Along with capacity data transparency issues, granular data on charging and discharging volumes of battery storage (electricity injected and absorbed) is scattered amongst disparate grid operator sources. This makes it challenging to assess their contribution to power system flexibility needs, such as their role in meeting peak demand hours and reducing curtailment of renewable energy. It is encouraging that Eurostat has started reporting data on charges and discharges from European batteries, although only with partial coverage of EU countries, annual granularity and a more than one year lag.

Data on DSF use is scattered and inconsistent

Unlike supply-side generation, which is recorded as it is produced, DSF appears as a change in demand, making it harder to measure and correctly attribute to active demand-side management. DSF is not a physical generator with a name-plate capacity that can be recorded. Instead, consumers (or aggregators working on their behalf) bid the volume of flexibility they are able to provide into various markets.

Tracking the use of DSF is challenging for several reasons. Often, the markets that DSF are bidding into are technology-agnostic, and transmission system operators do not publish information on the types of winning capacity. When information is reported, it is often scattered amongst reports concerning the various markets and flexibility services that DSF partake in, such as capacity mechanisms and frequency response. In addition, the services in which DSF can participate are not consistent amongst countries as different rules and entry requirements exist across Member States.

Outlook for clean flexibility in Europe

Promising potential for further deployment of batteries and DSF

The key role battery storage will play in providing future flexibility is generally acknowledged, whilst DSF remains overlooked.

Explicit 2030 targets for both storage and DSF are lacking in national policy documents and strategies. However, scenarios in energy network plans and industry forecasts suggest that batteries could offer a considerable amount of short term flexibility in 2030. The potential of DSF is still often left unnoticed.

Limited existing targets

Despite the urgent need for a more flexible power system, there is a general lack of projections and targets for storage and DSF deployment in national policy documents.

Eleven draft revised National Energy and Climate Plans (NECPs), out of the 26 submitted, quantify deployment by 2030 for either pumped hydro storage or battery storage, or storage technologies in general. However, this is rarely a binding target. Only Spain has an explicit technology-neutral storage target in the draft revised NECP, supported by a dedicated energy storage strategy. Belgium, Bulgaria, Cyprus, Greece, Hungary, Italy, Portugal and Romania quantify battery deployment by 2030 or 2025 in their NECPs, but with varying levels of political commitment. Only four countries provide a quantitative target for demand-side flexibility via smart-meter roll-out or demand-side response.

NECPs are not the only policy documents to provide plans on storage and DSF. In fact some countries have or are consulting on a storage strategy, such as Spain and Germany. Bulgaria, Poland and Romania earmarked investment in battery storage in their Recovery and Resilience Plans.

However, NECPs act as roadmaps for policymakers and investors, so their omission of clean flexibility is worrying. The plans due in June 2024 have an important role as Europe now faces a possible two-year planning gap when it comes to flexibility goal setting. According to the latest EU Electricity Market Reform, indicative national objectives for energy storage and demand response will not be due until early 2026.

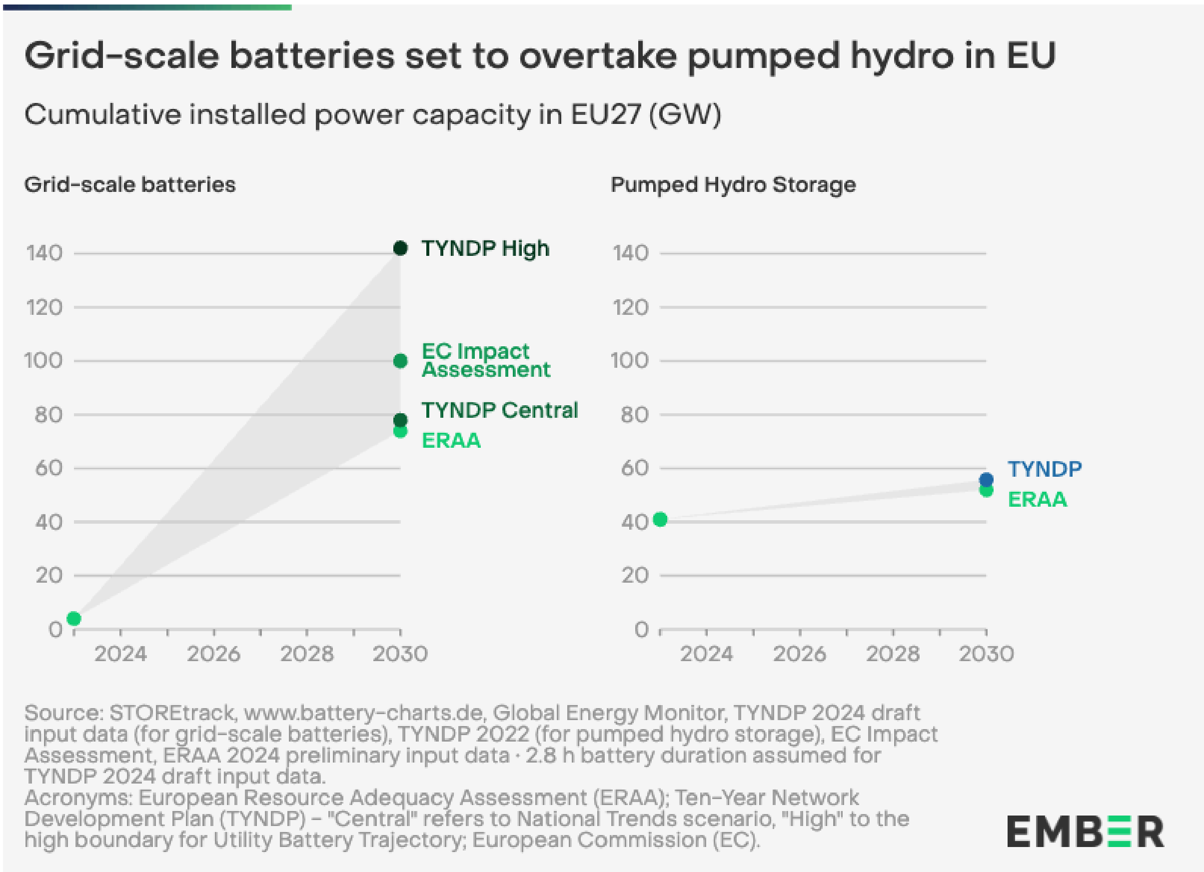
Where will batteries be in 2030?

Installed battery capacity has seen substantial acceleration in the last few years and forecasts look set for this to continue. Europe's storage association, EASE, and LCPDelta forecast the EU will have 102 GW of total battery capacity by 2030, including behind-the-meter systems. This is six times more than 2023. This is an astonishing increase, even compared with other fast-growing clean technologies: solar capacity is forecast to grow 3.5 times by 2030 to 902 GW, whilst wind capacity is expected to increase by 1.5 times to 393 GW.

Grid-scale batteries have the highest growth potential: EASE and LCPDelta forecast a 14-fold growth to 57 GW grid-scale batteries by 2030. European grid operators expect even higher growth potential and doubled the expected EU grid-scale battery capacity by 2030 in the latest European Resource Adequacy Assessment jumping to 74 GW from 38 GW in the previous year's study. This is higher than the expected 53 GW of pumped hydro storage in 2030 and represents a more than 18-fold increase compared to current capacity, reflecting the increased competitiveness and confidence in the technology.

If utility solar will be increasingly coupled with grid-scale batteries, the storage capacity could be even higher. In the draft assumptions for the latest European network planning exercise (TYNDP 2024), widespread coupling between battery and solar in the deviation scenarios means that EU grid-scale batteries could reach up to 142 GW in 2030, assuming an average 2.8 hour battery duration, in line with the latest grid operators' forecasts. This is almost double that forecasted by grid operators in the central National Trends scenario, based on 2019 NECP data.

The European Commission also foresees substantial battery growth: in their latest Impact Assessment for Europe's 2040 Climate Target they expect 100 GW of batteries to be installed in the EU by 2030. Deployment of battery storage is projected to accelerate after 2030, reaching 135 to 200 GW in 2040.



Demand side flexibility remains neglected

Whilst grid operators seem to be increasingly confident in battery storage, DSF assumptions in ENTSO-E modelling remain generally low. The European Resource Adequacy Assessment 2024 sees 24 GW of explicit market-available DSF in the EU by 2030 coming from 17 Member States, with the other 10 countries having no access to explicit DSF. This capacity does not include volumes secured through capacity mechanisms or participating in other ancillary services.

A study from Europe's smart energy association, SmartEn, found DSF could provide around 160 GW and 130 GW of upward and downward flexibility respectively in the EU by 2030. This is four to five times the capacity projected by ENTSO-E in the European Resource Adequacy Assessment 2024, and corresponds to about 10% and 8% of the EU's total demand respectively.

Electrification unlocks further potential for clean flexibility

As more final energy demand is electrified, the potential for clean flexibility grows. Heating and cooling account for the majority of household energy use, alongside electric vehicle charging for relevant households. With the projected increase in household electrification, this has the potential to become a large source of flexibility. However, the increase in electrified demand must be managed smartly, ensuring it is as flexible as possible, otherwise the higher demand risks putting further strain on the grid at times of peak load.

Electrified flexibility can be accessed in different ways. Smart charging enables the power demand of electric vehicles and heat pumps to be shifted to times of lower cost, helping avoid the creation of new peaks from this extra electricity demand, and saving consumers money as they can benefit from dynamic time-of-use tariffs.

As vehicle-to-grid technology develops, electric vehicles will be able to act as behind-the-meter batteries, charging at times of low demand and discharging back to the grid when demand is high. Depending on the regulatory and market situation, these electrified products can also be aggregated and bid into day-ahead markets or services such as frequency response or capacity reserve, where they can shift their demand to earn further revenues.

As more devices are electrified, it is crucial the surrounding infrastructure and wider environment enables these to be used flexibly. For example, more households buying electric vehicles will not increase system flexibility without certain conditions in place. Alongside the electric vehicles, charging infrastructure must be capable of following price signals, known as ‘smart charging’. Households must also have smart-meters installed and be on dynamic time-of-use tariffs to benefit from charging off-peak, and data sharing protocols must be in place between all involved parties.

Aligning storage and DSF deployment with climate goals

Despite strong expected growth, even faster deployment might be needed to align with EU climate targets. In a study conducted prior to the EU's response to the gas crisis and Russia's war on Ukraine, EASE estimated that the EU-wide energy storage capacity needs to double for the EU to reach its climate objectives, and calls for 200 GW of storage by 2030 to replace 55 GW of gas turbine flexibility.

The optimal mix of clean flexibility sources will, however, vary across countries. While detailed flexibility assessment exercises have been conducted for some countries (such for the Pentalateral Forum countries) or for the EU, by 2026, each EU country will have to assess their flexibility needs and set indicative objectives for DSF and storage. This new flexibility target-setting exercise will be guided by a EU-wide methodology developed by ENTSO-E and EU DSO, which should be ready by early 2025. However, as renewable generation is evolving faster than expected, early planning and implementation of clean flexibility will be key to integrate increasing levels of wind and solar, and countries should aim to carry out these assessments as soon as possible.

Policy Recommendations

Enabling a clean power system

Clean flexibility is an essential enabler of a clean power system, and it is now its time to shine.

While wind and solar are the backbone of the energy transition, they cannot decarbonise the power system alone. To effectively integrate skyrocketing volumes of renewable generation into Europe's power system, attention must now also turn to clean flexibility.

Cross-border interconnection, transmission and distribution grids, storage and demand-side flexibility will all have important roles to play in balancing periods of variable renewable output. They are all existing and proven technologies, especially for managing minutes and hours of demand-supply mismatches. Further research into long duration storage technologies is also needed to ensure the future clean power system works as effectively and efficiently as possible.

Europe needs clear policy direction and the removal of existing regulatory barriers to ensure clean flexibility solutions can be rolled out at the pace needed to match a world of growing electrified demand and rapid wind and solar expansion.

Key recommendations

Act fast

Rapid deployment of battery storage and DSF
Rising levels of wind and solar are resulting in increased periods of electricity price cannibalisation and curtailment of renewable energy.

The problem will only get worse as more renewables are added *unless* sufficient clean flexibility sources can be added alongside to store excess power at times of high generation. In particular, battery storage and demand side flexibility are well placed to tackle this issue as they can be deployed quickly given the right environment.

Put clean flexibility high on the political agenda
The Commission and Member States must acknowledge the importance of clean flexibility and ensure it takes its rightful place alongside the focus on renewables and grid expansion.

This must happen sooner than the next planned checkpoint: the latest Electricity Market Design reform will require Member States to assess their flexibility needs and set non-fossil flexibility objectives by 2026. Given the current pace of renewables growth, this would be too long to wait. The Council Conclusions of the May 2024 Energy Council are a key opportunity to recognise the crucial role of clean flexibility in delivering a secure and decarbonized energy for the EU.

Improve planning

Keep system planning in step with clean tech rollout
Countries should commit to producing comprehensive clean flexibility strategies as soon as possible in order to plan their transition away from reliance on fossil flexibility and ensure the integrated and complementary deployment of clean flexibility technologies. This should include quantitative targets, which are an opportunity to signal political commitment and boost confidence for investors.

Include flexibility in NECPs
Given the possible two-year lag before non-fossil targets are officially due, the NECPs are an important interim direction-marker. Countries should provide details of future flexibility plans in their NECPs due in June 2024 and, where this assessment is unavailable, commit to a process that will achieve this as soon as possible.

Plan for blended assets
A simple way to start planning for clean flexibility is to consider the potential for blended assets, for example, co-location of solar with batteries, and the incorporation of clean flexibility into spatial planning when identifying renewable acceleration areas.

Reduce waste of renewable power

Expand caps for curtailment
Renewable curtailment is rising, leading to higher costs and wasted clean energy. Currently, grid operators must only keep curtailment below 5% in countries where renewable generation accounts for less than 50% of the electricity mix. As renewable penetration increases, a curtailment cap for countries over the 50% threshold should be introduced.

Introduce targeted market services
New markets must be deployed to tackle the growing levels of curtailment across Europe, in particular constraint markets at distribution level can help manage local grid congestion due

to variation in renewable generation. As the number of these local markets increases, service management platforms, such as GOPACS in the Netherlands, can help increase access to and coordination of flexibility services.

Deploy batteries to match renewables
Targeted and accelerated grid connection access for batteries or co-located renewables can also help ease grid congestion and reduce the growing problem of renewable curtailment.

Level the playing field for clean flexibility

Market design fit for a distributed power system
The power system was designed with large, centralised, fossil-fuel generators in mind and many frameworks still make it more difficult for smaller, distributed sources of flexibility on both the supply and demand side to participate.

Addressing the lack of legal frameworks for market access in many Member States, and the restrictive requirements for participation in capacity markets, constraint management and ancillary services such as frequency response, will open up routes to market for these distributed resources.

The design of these mechanisms should also promote low-carbon flexibility, for example, through lowering the carbon cap in capacity mechanisms. Additional specific support schemes can be introduced where needed, as envisaged in the latest Electricity Market Design reform.

Include clean flexibility in modelling used for planning
Power system modelling exercises that underpin system planning and security of supply assessment, at European and national level, including the European Resource Adequacy Assessment and the Ten-Year Network Development Plan, should take account of the need to reduce reliance on fossil flexibility to achieve the EU's climate targets and the potential of clean substitutes. As the energy system becomes more complex, modelling methodologies must adequately represent clean flexibility sources, including via better access to open and accurate input data.

Improve data transparency

Improve data collection and reporting across the system
As Europe's power system moves towards a more decentralised, digitalised and smart energy system, data will be key to managing system needs and improving planning.

Currently, there is limited visibility on the rollout of battery storage, demand-side response measures and consumer participation. Whilst ensuring privacy and commercial confidentiality, more data transparency would help system operators, flexibility providers, investors and consumers to maximise their efficiency and cost-effectiveness. Open data on network congestion, renewable energy curtailment, real-time generation mix, demand-side flexibility deployment, installed and planned energy storage capacity, facilitate investment decisions.

Ensure open data for use in target setting and planning
Member States and national regulatory authorities should make such data publicly available, as recommended by the European Commission. Data on existing and planned flexibility sources will be key for the new flexibility target-setting exercise established by the latest EU Electricity Market Reform.

Bring consumers onboard

Empower participation through incentives
Consumers will be a crucial part of the energy transition. As the potential for demand-side flexibility increases, it is important that citizens and SMEs are empowered to participate. Households and businesses must be incentivised and rewarded for providing flexibility, for example through time-of-use tariffs that lower their bills for electricity used at off-peak times.

Take a people-first approach
Measures to ensure participation must cause minimal disruption to people's daily lives. Steps must be taken to ensure low-income households, who often have the lowest access to technologies which allow consumer flexibility, such as EVs and heat pumps, are not left behind or adversely affected.

Energy communities can help enable households to take part in the energy transition, whilst also acting as intermediaries, with aggregators providing flexibility services for the grid.

Align enabling infrastructure with clean flexibility needs
As more devices are electrified, it is crucial the surrounding infrastructure and wider environment, particularly lower-voltage distribution grids, enables them to be used flexibly. Ensuring that heat management and electric vehicle charging infrastructure are 'smart' as standard ensures that customers can benefit from the possible savings that these technologies provide.

Methodology

Battery storage - historical data sources
Data on large-scale batteries are scattered in reports on planning, permitting, grid connection requests, which might not always be consistent across each other and overtime. Ability to track deployment varies a lot by country, might be partial (e.g. reporting only power capacity and not energy capacity or duration of a facility) or challenging in the case of behind-the-meter systems due to their distributed nature, as reckoned in the EnTEC review of storage facilities in the EU.

Industry associations gather data on battery storage facilities, but full data access is normally restricted to their members, and updates are normally released on an annual basis.The European Association for Energy Storage (EASE) and LCPDelta curate a proprietary dataset on battery storage capacity in Europe, including operating capacity and projections (STOREtrack), and disclose a snapshot in their annual monitoring and outlook report on the European storage market. SolarPower Europe produces an annual outlook on European residential battery storage installations, which offers a good proxy for country-level behind-the-meter battery storage.

Data on grid-scale and behind-the-meter battery capacity by country are taken from STOREtrack and, in the case of Germany, from www.battery-charts.de.

Pumped hydro storage — historical data sources
Data on pumped hydro storage capacity by country are taken from Global Energy Monitor's Global Hydropower Tracker (May 2023 release). The Global Hydropower Tracker is a worldwide dataset of hydropower facilities. The tracker catalogues hydroelectric power plants with capacities of 75 megawatts (MW) or more. It includes all facilities at this capacity threshold for operating, announced, pre-construction, under construction, and shelved units.

Capacity market results
Data retrieved from Terna , Forum Energii, ACER.

Battery and DSF scenarios

Every year, ENTSO-E carries out an adequacy assessment of the European grid to model possible events which can adversely impact the balance between supply and demand: the European Resource Adequacy Assessment (ERAA). ERAA 2024 input assumptions on battery storage and DSF are national grid operators' best estimates at the time of data collection (November 2023-February 2024) and are available in the ENTSO-E Pan-European Market Modelling Database (PEMMDB). PEMMDB is one of the most comprehensive scenarios for clean flexibility resources. It includes projections for grid-scale battery storage, small scale battery storage, DSF and electrolyser power capacity projections (GW) by European country for 2026, 2028, 2030, 2035; battery storage energy capacity (GWh) by European country for 2026, 2028, 2030, 2035. Only capacity participating in the day ahead or intraday power market are included in the PEMMDB, capacity reserves are not included.

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