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European Market Outlook for Battery Storage 2025-2029

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Foreword

Welcome to our European Market Outlook for Battery Storage 2025-2029

Though the battery energy storage revolution continued to unfold across Europe in 2024, setting yet another annual installation record, we also witnessed a substantial slowdown in market growth. While we anticipate demand to regain momentum in 2025, much will depend on policymakers implementing the right tools to unlock the immense potential of this strategically critical technology. One thing is certain, battery energy storage systems – from residential to commercial & industrial (C&I) to utility-scale – are the absolute short cut to delivering the flexible, electrified energy system that is foundational to EU energy security and competitiveness goals.

Our five-year outlook foresees significant BESS expansion in Europe – a sixfold increase to nearly 120 GWh by 2029, driving total capacity to 400 GWh, yet falls short of energy transition needs.

A 15% annual growth to 22 GWh of newly deployed BESS in 2024 expanded Europe's battery fleet to 61 GWh. That means that one-third of Europe's total installed batteries have been deployed in a single year. Yet, this growth curve has notably flattened compared to the 84-145% growth rates of the preceding three years. This market development was unsurprising. Residential solar and storage formed the backbone of BESS expansion during the energy crisis, and as retail energy prices declined and crisis-response incentive programmes waned, so did home solar and storage installation. Nevertheless, over 3 million home batteries have been connected to European grids within three years, shielding families and businesses from volatile energy prices, while reducing emissions.

Despite a 11% dip in demand for small home batteries, this solar residential rooftop partner remains the most popular BESS product, retaining a 50% market share by total capacity. Fortunately, strong growth in utility-scale BESS, now accounting for 40% of the market, has offset the residential downturn, marking a pivotal moment for battery storage applications. This year, we expect utility-scale storage to take the lead – a trend we anticipate will continue.

However, Europe's market remains highly concentrated, with Germany, Italy, and the UK accounting for more than two-thirds of 2024 demand, and the top five markets hosting nearly 80% of installed capacity. This must change. More European countries need to embrace the advantages of battery storage and even the leading markets must remove barriers that the sector is facing. Otherwise, the technology will remain far from tapping its potential, and slow down growth of renewables, as their value for investors decreases with wholesale power price increasingly turning negative and the general trend for curtailment of flexible renewables pointing upward.

While our five-year outlook foresees significant BESS expansion in Europe – a sixfold increase to nearly 120 GWh by 2029, driving total capacity to 400 GWh (EU-27: 334 GWh) – this remains far below the levels required to meet flexibility needs in a renewable-driven energy system. According to our Mission Solar 2040 study, EU-27 BESS capacity must reach 780 GWh by 2030 to fully support the transition.

This report outlines five key policy recommendations to unlock BESS deployment across the EU:

First, the European Commission must adopt an Energy Storage Action Plan within a broader Flexibility Package, to harmonise markets, remove regulatory barriers, and ensure storage is integral to national energy strategies. **Second**, grid connection procedures and pricing frameworks must be reformed to facilitate access, prioritise hybrid systems, and fairly allocate costs. **Third**, BESS must have full and fair access to electricity markets, with clear revenue streams, updated Guarantees of Origin frameworks, and permission to stack revenues. **Fourth**, balancing markets must become fully competitive and accessible to storage, through harmonised technical standards and transparent procurement. And **fifth**, Europe must enhance smart metering and data communication standards to enable real-time energy management and seamless BESS integration.

Recently, SolarPower Europe has also launched our **Battery Storage Europe Platform**, bringing BESS' critical role in EU energy security and competitiveness to the forefront of the EU agenda. Through this Platform, we're uniting industry and policymakers to improve the business case and regulatory environment for battery storage across Europe. The Platform is working to accelerate the implementation of existing legislation and complement it with a dedicated Energy Storage Action Plan and Flexibility Package to unleash the full potential of the battery storage revolution and ensure its essential contribution to Europe's clean and electrified energy future.

Enjoy reading our report,

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Methodology:
SolarPower Europe's five-year forecast consists of Low, Medium and High Scenarios. The Medium Scenario anticipates the most likely development given the current state of play of the market. The Low Scenario forecast is based on the assumption that policymakers halt solar and storage support and other issues arise, including negative policy changes, crisis situations. Conversely, the High Scenario forecasts the best optimal case in which policy support, financial conditions and other factors are enhanced.

The geographical scope of this report includes the EU-27, the United Kingdom, and Switzerland.

Segmentation for BESS: Residential (<20 kWh); Commercial and Industrial (20 kWh to 1,000 kWh); Utility-scale (>1,000 kWh). For residential and commercial BESS, segmentation is based on the type of PV system coupled with the storage device. Industrial and utility-scale BESS can be either stand-alone or hybridised with industrial and large-scale power plants. SolarPower Europe's methodology includes only grid-connected battery storage systems.

Segmentation for solar PV: Residential (<10 kW), except for Switzerland, Germany and Austria where the segmentation is extended to <20 kW; Commercial (<250 kW); Industrial (<1,000 kW); Utility-scale (>1,000 kW, ground-mounted). SolarPower Europe's methodology includes only grid-connected solar PV systems.

Installed PV capacity is always expressed in DC. All figures are based on SolarPower Europe's best knowledge at the time of publication.

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European battery storage market grows at slower pace in 2024; growth rates expected to accelerate in coming years thanks to utility-scale segment

21.9 GWh

21.9 GWh batteries installed in Europe in 2024: 11th consecutive record-breaking year

15%

15% annual European batteries market growth: inflection point toward next stronger growth phase

400 GWh

400 GWh total European batteries capacity forecast by 2029: more than six-fold expansion, but our High Scenario reaches 600 GWh

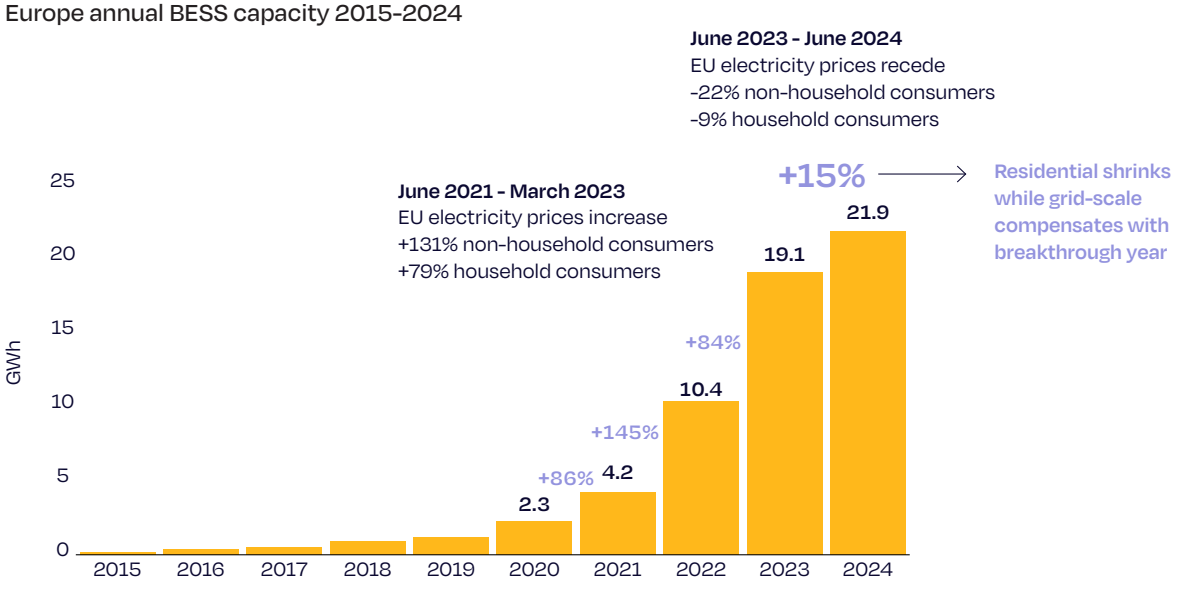
In 2024, Europe[1] installed 21.9 GWh of battery energy storage systems (BESS), marking the eleventh year of record-breaking annual additions since 2013, when our records began. The latest additions take the total running European battery fleet to 61.1 GWh at the end of 2024. However, the annual growth rate slowed down to 15% in 2024 after three consecutive years of doubling newly added capacity (see Fig. 1). This deceleration was expected, as the astounding surge observed during 2021-2023 was predominantly driven by the household segment as a direct response to the energy price crisis. In 2024, electricity prices receded, and major support schemes were phased out, triggering a decline in the residential segment. This reduction was compensated by the large-scale segment, which underwent strong growth in 2024. This year marked a turning point for the battery market, when changing dynamics on power prices, support schemes and borrowing costs had a very visible effect on installations.

Narrowing the scope to the European Union (EU), 18.5 GWh of BESS were installed across the bloc in 2024, equivalent to 85% of existing installations on the continent. As consequence, EU total operating battery storage capacity reached 49.1 GWh at the end of 2024.

Figure 1

Europe breaks another battery storage record in 2024, though growth curve flattened after 4 years of extraordinary growth around the energy crisis

Europe annual BESS capacity 2015-2024



1 The scope of this report considers 'Europe' as all EU-27 Member States, the United Kingdom, and Switzerland

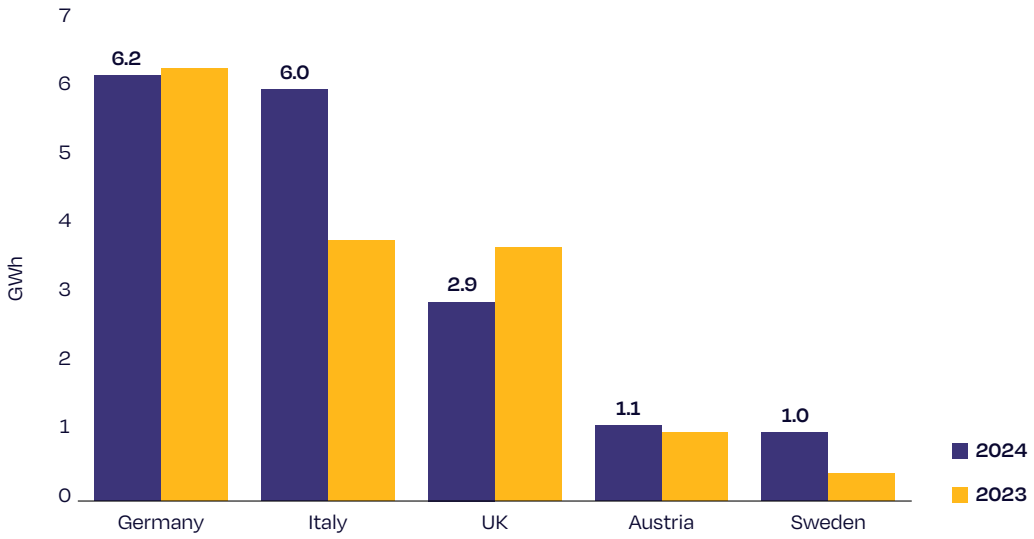
Germany, Italy and the United Kingdom continue to lead the market and deliver almost 70% of the annual capacity

In 2024, Europe's top three battery storage markets – Germany, Italy, UK – solidified their dominance, with Austria and Sweden closing the 'top 5' ranking (see Fig. 2). 2024 marked the first year when reaching the GWh scale of annual installations was required to access the top 5. Germany maintained its leading role despite a drop in residential installations and the slow uptake of larger batteries. Italy's home battery segment also decreased, but the large-scale segment's capacity surge brought the market to new heights. The UK experienced a temporary slump due to project delays at the large-scale level, but remained at a higher altitude than Austria and Sweden, which both reached the GWh scale for the first time thanks to a very strong growth in the residential and commercial and industrial (C&I) market. Altogether, the top 5 markets added 78% of 2024 installed capacity in Europe, highlighting the strong concentration of battery deployment in a select few countries.

Figure 2

Germany dominates European annual battery market, while Italy is close behind and the UK temporarily slumps

Europe top 5 BESS markets 2023-2024



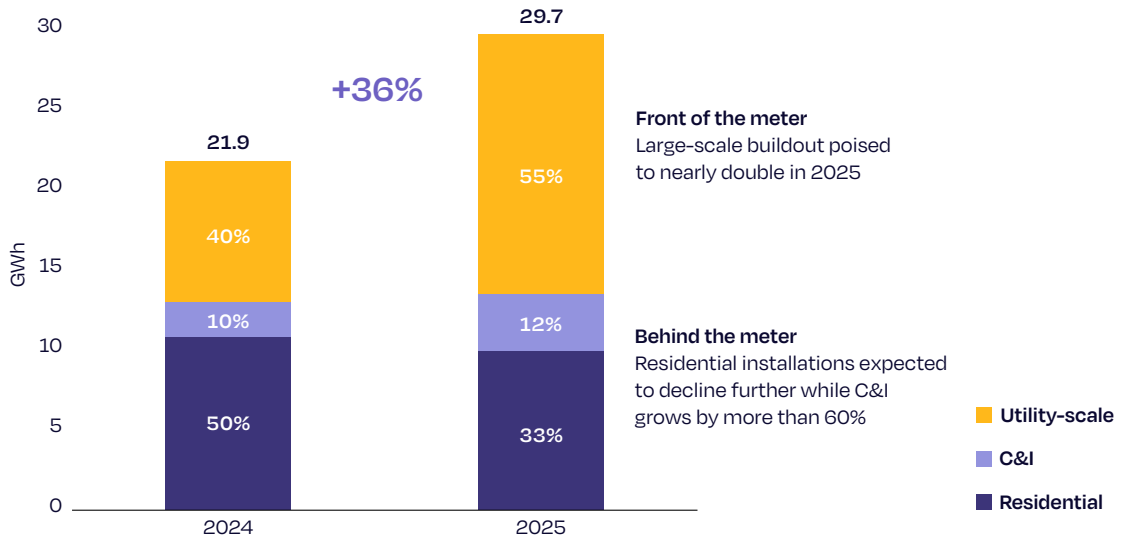
Large-scale batteries expected to become the European market's trailblazer in 2025, re-accelerating total installations to 36% annual growth

With 29.7 GWh deployed in 2025 under the Medium Scenario, the battery market is expected to regain speed with a 36% annual growth, installing in a single year about half of the total operating fleet at the end of 2024 (see Fig. 3). The utility-scale battery market is projected to almost double in Europe in 2025, compensating an overall stagnation in the behind-the-meter (BTM) segment. Household battery installations are poised to decline again, while the C&I segment continues to grow though far below its true potential. The energy security imperative, the integration of more renewables, strong climate commitments, favourable economics against conventional power generators, and new aid schemes, are all factors pointing to an unstoppable growth in the large-scale segment over the coming years. However, improved regulatory and financial conditions are needed to boost the small-scale segment, to support energy independence and resilience for citizens and businesses.

Figure 3

European annual battery market expansion set to speed up again in 2025, driven by utility-scale

Europe annual BESS installed capacity 2024-2025



Further driven by the utility-scale segment, by 2029 the annual European BESS market will be five times as large as 2024

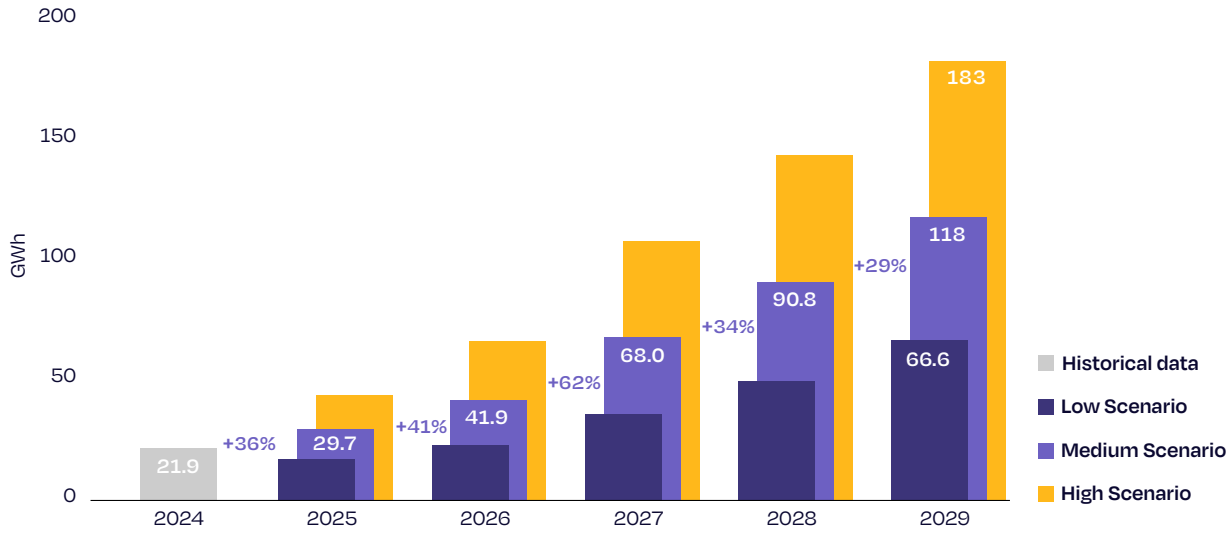
Beyond 2025, under current market and regulatory conditions, our Medium Scenario anticipates a sharp growth trajectory, with annual deployments increasing by 41.9 GWh (+41%) in 2026 and 68 GWh (+62%) in 2027 (see Fig. 4). As the market begins to mature toward the end of the decade, annual growth rates are expected to decelerate. Nevertheless, we project continued strong expansion, with deployments reaching 90.8 GWh in 2028 (+34%) and 118 GWh in 2029 (+29%), reaching an installation volume over five times larger than in 2024.

The contribution of large-scale batteries, which already provide 55% of new capacity in 2025, is expected to further increase. By 2029, the share of grid-scale BESS will grow to 68% of annual additions, with the BTM segment providing less than a third of the capacity. By that year, the large-scale segment will deliver over 80 GWh, 5 times more than in 2025.

Figure 4

European battery growth to intensify reaching almost 120 GWh by 2029, five times larger than in 2024

Europe annual BESS market scenarios 2025-2029



Total battery capacity in Europe projected to expand steeply, reaching 400 GWh by 2029, but needs to grow faster to meet flexibility needs

Examining the projected growth of the BESS fleet in Europe, our Medium Scenario foresees robust expansion through 2029. In 2025 alone, cumulative BESS capacity is expected to increase by 50%, surpassing the 90 GWh mark (see Fig. 5). Looking ahead, current trends indicate a compound annual growth rate (CAGR) of 45%, driving total installed capacity to reach around 400 GWh by the end of 2029. Under this scenario, the operational BESS fleet in Europe is set to expand more than sixfold within just five years.

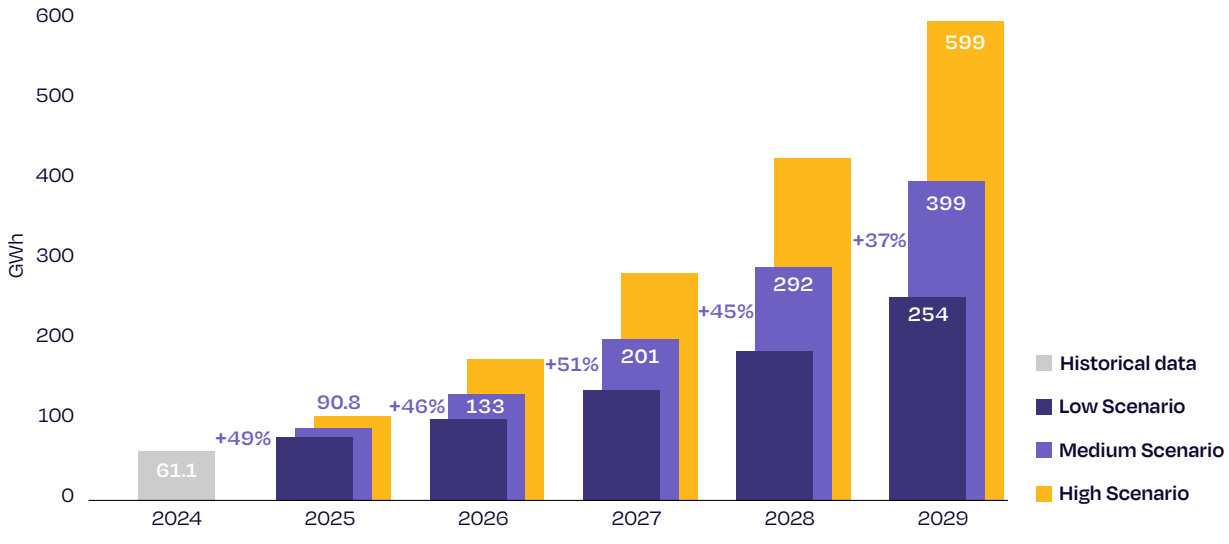
The optimistic High Scenario, boosted by improved policy and market conditions, envisions significantly larger battery additions until 2029, with a much steeper CAGR of 55%, bringing the total operational fleet to approximately 600 GWh by 2029 – 200 GWh more than the Medium Scenario and better aligned with the increased flexibility needs of the European energy system in 2030. On the other hand, the Low Scenario – which anticipates continued permitting and grid bottlenecks, delays in auctions and aid schemes, stagnant electrification and the participation of reserve fossil-fuel based power plants in flexibility markets – reflects a much more subdued market outlook, with less than 80 GWh installed by the end of 2025 and just surpassing 250 GWh by 2029, corresponding to a CAGR of 34%.

Focusing on the EU, total deployed BESS capacity in the Medium Scenario reaches 334 GWh in 2029. While this is an impressive growth from the 49.1 GWh operating in 2024, it remains significantly below the levels needed to meet increased flexibility needs in a renewable-dominated and electrified energy system. To adequately accompany this transition, BESS capacity in the EU should grow to 780 GWh by 2030 and 1.8 TWh by 2040, according to SolarPower Europe's Mission Solar 2040 study.[2] Even in the High Scenario, the EU appears to be falling short of the trajectory towards the achievement of these volumes, reaching slightly over 500 GWh by 2029, just one year before the end of the decade.

Figure 5

European battery fleet on track to reach 400 GWh by 2029 but High Scenario lies 200 GWh above

Europe cumulative BESS market scenarios 2025-2029



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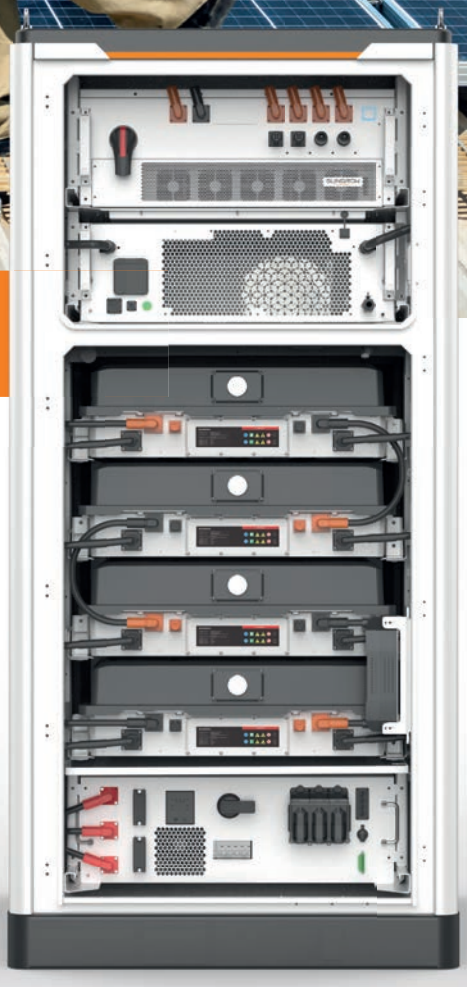

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How can European policymakers help the battery storage sector

Battery storage systems are essential for strengthening the EU's energy security and competitiveness by enhancing flexibility, providing ancillary services to secure the grid, maximising the use of renewable energy, and effectively dealing with energy price volatility that stems from the EU's reliance on imported fossil fuels. As Europe transitions to a decarbonised energy system with more renewable energy, storage must be fully integrated into the market rules, structures, planning of electricity system needs, and regulatory frameworks. A robust and coherent EU energy storage strategy is needed to support the effective deployment of BESS, alongside other storage and flexibility solutions, across utility-scale, commercial & industrial, and residential electricity systems.

1

Adopt an EU Energy Storage Action Plan as part of wider EU Flexibility Package

The EU currently lacks a cohesive and forward-looking strategy for the large-scale deployment of energy storage solutions. According to SolarPower Europe's Mission Solar 2040 study, battery storage will provide 27% of EU daily flexibility needs by 2030 and 39% by 2040 in an electrified, flexible energy system. That makes batteries one of the strongest solutions to respond to grid needs, absorbing excess electricity and meeting excess demand. The top five EU battery markets in 2024 – Germany, Italy, Austria, Sweden, and Ireland – deliver 81% of the annual installed capacity, with Germany and Italy alone installing 66%. Clearly, the majority of EU countries need to accelerate rapidly on storage development.

To address this strategic shortfall, the European Commission should adopt an Energy Storage Action Plan, as part of a wider EU Flexibility Package. This plan would complement the EU Grid Package and provide a clear, coordinated roadmap for the deployment and integration of storage systems across all Member States. The Energy Storage Action Plan should address barriers to hybrid assets, tackle the double imposition of grid charges, and taxes and levies in some Member States, ensure batteries can stack flexibility revenues, and address challenges in the battery supply chain.

By recognising storage systems under EU funding mechanisms and grid planning processes, the EU can unlock their full potential, not only in stabilising energy supply and maximising renewable energy utilisation but also in reinforcing the resilience and autonomy of the European energy system.

A Single Market for BESS is key to reducing costs, scaling deployment, and accelerating innovation. By harmonising regulations and removing barriers to cross-border energy flows, BESS can participate seamlessly in all EU energy markets, lowering the costs of storage and accelerating energy system innovation (see Box 1).

In line with their flexibility needs assessment, Member States must commit to setting clear storage targets within their National Energy and Climate Plans (NECPs), ensuring that energy storage plays an integral role in national decarbonisation and energy security strategies.

Energy storage must also take centre stage in the EU's upcoming Energy Security Strategy. Together with electrification, battery storage reduces Europe's dependency on fossil fuels and provides resilience to disturbances in the energy system.

Box 1

The need for a Single Market for battery storage deployment

The EU Single Market is critical for economic growth, facilitating the free movement of goods, services, capital, and labour. This framework is particularly important in the energy sector, where BESS are key to grid optimisation, reducing fossil fuel dependency and enhancing renewable energy integration. However, the current fragmented regulatory landscape hinders BESS efficiency, increases costs, and limits scalability across Member States.

Key barriers and solutions

- **Harmonising network codes:** differing national network codes hinder BESS integration. Aligning EU TSOs and DSOs with CEN-CENELEC standards (EN 50549-1/-2) and creating a unified list of BESS connection requirements would facilitate smoother cross-border deployment and operational consistency.

- **Streamlining permitting and connection processes:** inconsistent permitting and connection procedures across Member States create delays. A standardised EU-wide permitting and connection framework would reduce administrative burdens, lower costs, and accelerate deployment.

- **Standardising safety regulations:** varied national fire safety regulations force manufacturers to adapt products for each market. Introducing and enforcing EU-wide harmonisation of BESS fire safety standards through the framework set by the Battery Regulation will ensure cost-effective, compliant, solutions and improve safety and consumer confidence.

- **Ensuring interoperability:** the lack of standardised communication protocols in the Demand Response Implementing Regulation (DRIR) causes market fragmentation. Adopting pan-European APIs and protocols like IEEE 2030.5 would enhance data exchange between DSOs, TSOs, and Distributed Energy Resources (DERs), improving efficiency and market integration.

Addressing these challenges would leverage the benefits of battery storage at all levels. At the front-of-the-meter level, large-scale storage (or the aggregation of distributed assets) is critical for grid stability, peak demand management, and renewable energy integration. As such, a unified Single Market would reduce infrastructure costs, increase investment, and enable efficient cross-border electricity trading. At the behind-the-meter level, distributed storage optimises self-consumption, reduces grid dependency, and supports demand-side flexibility. Standardised regulations across the EU would enhance affordability, drive adoption, and improve consumer access to energy markets.

2 Ensure grid connection procedures and grid pricing accommodate storage

High connection fees, slow approval times, and administrative complexity remain significant barriers to BESS deployment. Grid operators, therefore, must enhance transparency and streamline processes to accelerate the integration of BESS into electricity grids, whether as part of hybrid systems (see Box 7 in Chapter 2) or standalone units. Grid connection processes must also be simplified, and European countries need fair network tariffs for battery storage.

As a critical initial step, grid operators must publish grid hosting capacity maps, displaying both available grid capacity and existing connections of renewable energy and storage assets. This level of visibility is essential for solar and storage developers as it helps them identify suitable locations for BESS integration or hybridisation with renewable sources, ultimately reducing project risks and delays. In response to the reform of the Electricity Market Design, system operators are required to provide users with the necessary information for an efficient access and utilisation of the system. This includes transparently publishing data on the capacity available for new connections within their operational area, with a high level of spatial granularity. To achieve this, the information should be made available on a single national platform in the form of a grid hosting capacity map, similar to the approach taken in Denmark, Flanders (Belgium), and France. For instance, French transmission system operator RTE recently introduced a national TSO map that outlines available battery connection capacity at the substation level. As more than 60% of substations show less than 5 MW of available capacity, the map also underscores the urgent need for proactive grid reinforcement across Europe. To support effective investment and optimise grid planning for BESS, regularly updated and standardised maps are crucial. These maps will not only guide grid development but also facilitate a more efficient and reliable energy transition.

The EU should ensure grid connection frameworks reflect the benefits of hybrid systems, combining different renewables and/or storage. Asset developers should have the possibility to agree with grid operators on a grid connection capacity in private grid connection agreements. This allows them to optimise BESS integration and usage of the grid, following best practices from Spain and Austria. Hybridisation of existing renewables projects with BESS, which has not required an increase in the grid connection capacity, should be prioritised in grid queues. This allows for a more efficient use of connection points. However, such prioritisation should be limited to cases where system needs have been clearly demonstrated.

To complement these steps, connection fees should follow a shallow cost allocation approach, where developers only pay for direct connection costs and grid operators cover broader reinforcements. This model, successfully implemented in France, ensures that costs are distributed fairly across all users rather than placing the full burden on individual developers. In contrast, the deep cost allocation approach in Denmark, which requires generators to pay for extensive grid reinforcements, raises costs and slows deployment.

Grid price signals, such as time-of-use tariffs and local flexibility markets, are crucial for ensuring that BESS contribute effectively to grid needs. These signals incentivise BESS operators to charge and discharge at optimal times, aligning with periods of high demand or surplus generation. This helps balance the grid, reduce peak loads, and integrate more renewable energy. Time-of-use tariffs encourage energy use when it is cheaper, while local flexibility markets reward services like frequency regulation and voltage support, creating a responsive and efficient energy system.

Additionally, the EU should provide guidance on removing excessive charges on battery storage, which provides flexibility services. In some Member starts, gas power plants usually don't pay grid tariffs when they offer volumes to imbalance markets. Neither should storage systems, independent of their size. The guidance should outline how storage assets help the system and therefore their contribution (also in terms of cost savings for the system) should be reflected in the grids charges by removing double-charging of storage, eliminating any tariffs on consumption and grid export. This will lower the financial barriers and accelerate the integration of BESS in hybrid systems, in line with the requirements of RED II, which should have been implemented three years ago.

3 Ensure BESS can access fairly all markets for electricity and have visibility on revenues

BESS remains underutilised in many EU energy markets due to inadequate financial support mechanisms and restrictive participation rules. EU Member States can promote a fairer and more efficient market environment for BESS deployment by following the steps below.

Ensure swift implementation across all Member States of the new market design provisions related to flexibility needs assessments and support schemes for non-fossil flexibility solutions. This will enhance revenue visibility for BESS, facilitate greater integration of renewable energy sources, and support more efficient grid management.

Encourage hybrid solar PV + BESS participation in renewable energy auctions by allowing them to participate in traditional renewable auctions on a level playing field. Contracts-for-difference must be settled based on energy production rather than energy injection. This will allow the asset operator to receive the CfD for the PV asset while generating additional market-based revenues from the BESS. These extra revenues will eventually lead to lower bids from developers and reduce the support costs for society.

Guarantees of Origin (GOs) frameworks should be updated to ensure that renewable electricity stored in batteries is properly tracked and certified. Today, the industry lacks appropriate frameworks. Certifying stored renewable electricity will enable industrial decarbonisation through hybrid power purchase agreements and certified renewable-based electricity.

Allow batteries under government support to stack revenue streams. Additional revenues can come from co-location with solar PV or from participating in different markets. Restrictive rules on the use of co-located BESS, as observed in Member States such as Germany, Portugal, and Spain, should be removed.

Adjust capacity market design to fairly account for BESS duration and co-optimisation with solar PV in derating factors. This will ensure storage technologies are competitively valued alongside conventional energy assets, including when the battery is co-located to a renewable plant.

4 Ensure competitive participation in balancing markets

The EU must ensure TSOs procure balancing services in market-based procedures in which batteries can compete on a level playing field. This requires transparency and competitive access. Some EU markets still rely on bilateral contracts that limit fair competition and exclude smaller storage assets.

In the 2026 review of the **Electricity Balancing Guideline, the Commission must harmonise and simplify technical requirements and prequalification procedures for all balancing market products, including Frequency Containment Reserve (FCR)**. Harmonised and fair access procedures, open to large and small assets, including aggregated BESS, will increase liquidity and reduce imbalance prices.

To support full market integration, **the EU must resolve the remaining inconsistencies between national rules, even in regions using shared balancing platforms like MARI and PICASSO**. Differences such as restrictions on price bidding in Italy or local pricing methods in the Netherlands undermine efficiency. Additional steps like shortening gate closure times, improving baselining methods, and reducing minimum bid sizes to 100 kW across all markets will boost participation from smaller, fast-acting assets like batteries and aggregated demand response.

A more open and competitive balancing market will maximise the value of battery storage, reduce system costs, and enhance overall energy security.

5 Enhance smart metering and data communication

Effective energy management depends on accurate data collection and seamless communication between energy storage systems and grid operators. Fragmented metering standards and inconsistent data-sharing frameworks limit the development of BESS across the EU, increasing costs for all affected parties. To facilitate the smart integration of batteries in the electricity system, the EU and Member States should take the steps below.

To reduce costs and fragmentation, **the EU should set minimal telemetry requirements for small loads and work toward a unified certification standard for dedicated measurement devices (DMDs)** while relying on existing metering standards in the meantime.

Communication protocols between BESS, energy management systems, and grid operators should be harmonised to enable real-time energy balancing and demand response. Standardised interfaces should be developed for cross-border scalability, allowing battery storage operators to participate in multiple energy markets seamlessly. This is further illustrated in Box 2.

The EU and its Member States must accelerate the rollout of smart meters, as their absence hampers demand response. Consumers should also have the right to use submeters (DMDs) like batteries, EV chargers, heat pumps, and inverters to contract flexibility services.

Box 2

Harmonisation of communication protocols for demand response

The EU should harmonise communication protocols for demand response to enhance the user experience, enabling consumers to easily switch between systems while ensuring interoperability at the lowest possible cost for demand response actors, such as BESS, across Europe. This will facilitate scaling across countries and drive the clean energy transition.

Communication protocols define the rules for data exchange between systems (e.g., syntax, structure, and procedures) involving market actors and smart energy devices like inverters. Currently, the lack of standardisation forces manufacturers to redevelop software interfaces for each market. For example, one major inverter company employs 200 developers just to integrate its systems with various assets, grid operators, and flexibility providers. This inefficiency increases development costs, slows cross-border scaling, and limits consumer choice. SolarPower Europe's vision for communication in the energy system, covering different data exchange layers (see Fig. 6), includes the following:

1. System-level data exchanges (light green arrows in the graph)
2. Service-level data exchanges (light blue arrows in the graph)
3. Device-level data exchanges (light pink arrows in the graph)

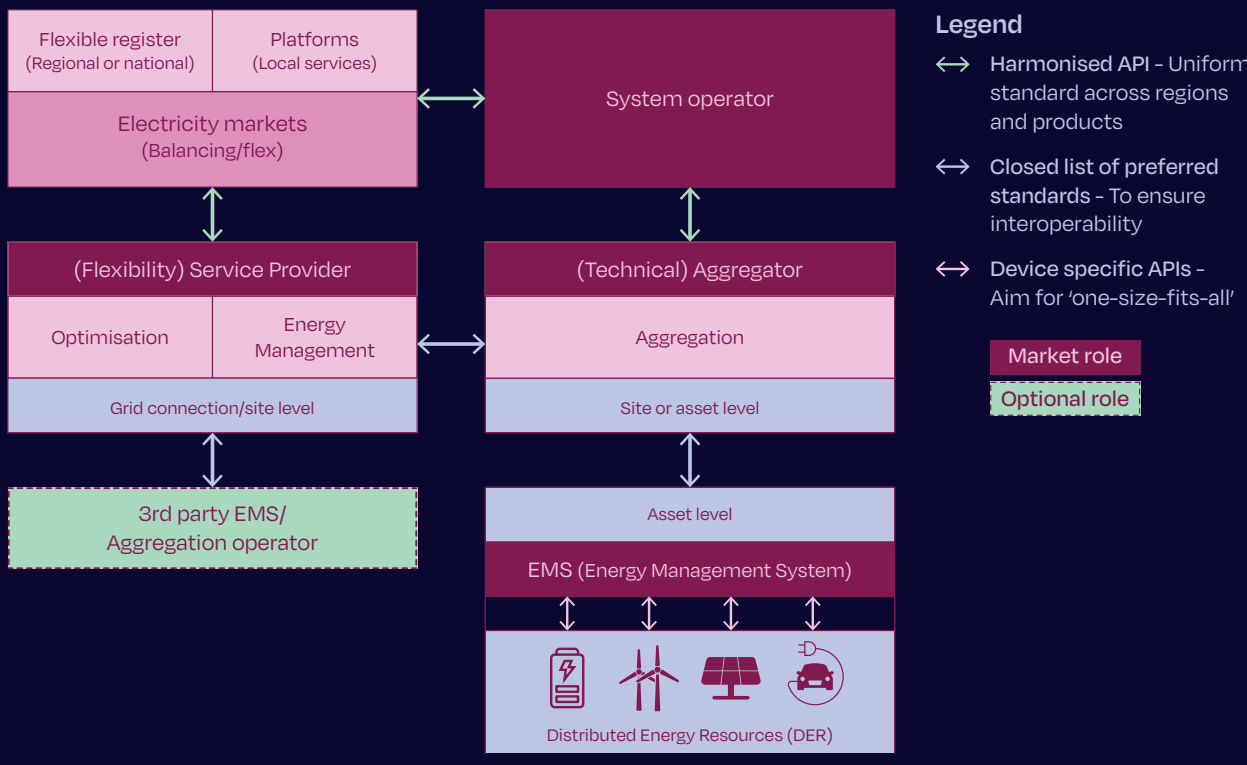
By establishing a unified framework, the EU can streamline operations, reduce costs, and accelerate clean energy adoption. The EU should implement a closed list of preferred communication protocols, ensuring standardisation while allowing room for innovation. Building on standards like ETSI-CEN-CENELEC and global experiences (e.g., IEEE 2030.5 in the US), this approach can foster harmonisation.

The European Commission should use the Demand Response Interoperability Regulation (DRIR) to implement this harmonisation, renaming it the 'Demand Response Interoperability Implementing Regulation'. The EU should also develop harmonised device-to-device communication, allowing smart devices to interact with energy management systems. Manufacturers should be free to innovate but align their products with consumer expectations for performance, comfort, and usability.

If devices cannot interoperate, manufacturers should communicate this to users, ensuring transparency and avoiding consumer complications.

Figure 6

SolarPower Europe vision for a plug-and-play energy system covering different data exchange systems



European battery storage markets 2024

Europe installed 21.9 GWh of battery storage in 2024, with the EU-27 contributing 85% of that. Residential battery deployment declined by 11% after years of rapid growth while large-scale grid batteries surged by 79%, marking 2024 as a turning point for utility-scale storage. C&I installations grew modestly (+17%) but remain below their potential. Europe's total running BESS fleet reached over 60 GWh, with 57% still in residential applications. Germany led annual installations but stagnated, and Italy closed in with a record large-scale buildout. The UK slipped to third due to project delays and investor uncertainty. Austria and Sweden entered the GWh-scale tier. Market concentration remained high – Germany, Italy, and the UK made up 70% of new installations.

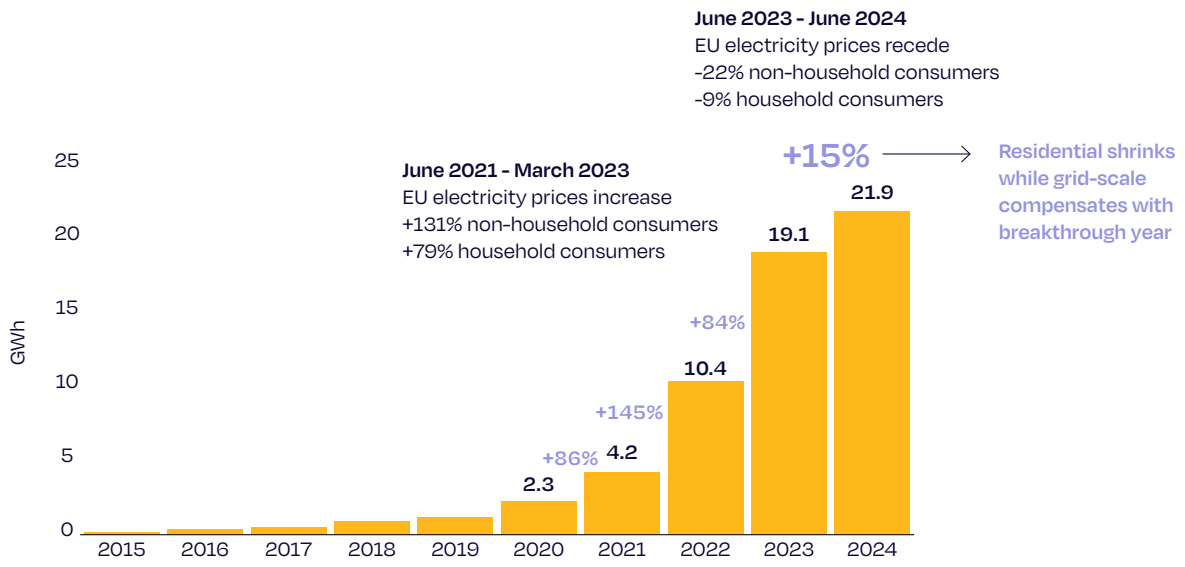
Europe reaches new heights in battery storage installation volumes in 2024, but leaves record-level growth rates behind as residential segment shrinks

In 2024, Europe installed 21.9 GWh of batteries, marking a decade of record-breaking yearly additions. Since 2020, battery deployment has almost doubled annually, reaching an average expansion rate of 145% in 2022. Last year, the annual growth rate declined considerably to 15%, marking the end of the great acceleration of the last 4 years. This deceleration was much anticipated, as the exceptional leap was largely driven by the residential segment, due to the unprecedented soaring in energy prices in the period of 2021-2023 (see Fig. 7). 2024 represents a turning point in Europe for batteries, as market and policy dynamics have changed dramatically in a very short period. Narrowing the scope to the EU-27, 18.5 GWh of BESS were installed across the bloc in 2024, equivalent to 85% of installations across the continent.

Figure 7

After four years of rapid growth, European battery deployment slows in 2024

Europe annual BESS capacity 2015-2024

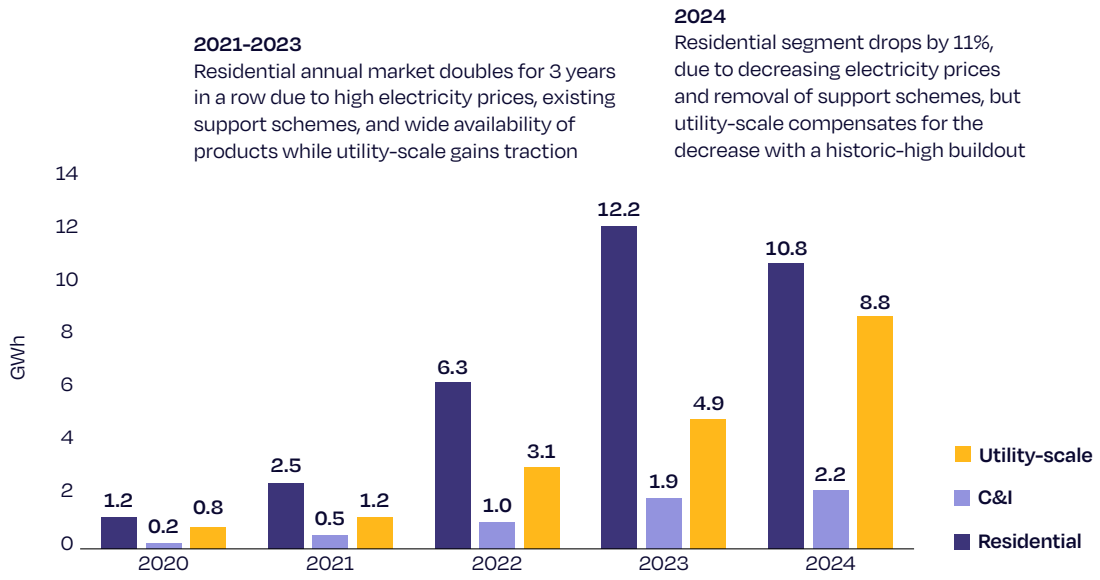


Along with the decrease in electricity prices after June 2023 for household consumers, the removal and reduction of important subsidies in key markets, and a parallel decline in residential PV deployment, the **home battery** segment witnessed an 11% drop in installations (see Fig. 8). Despite being minor, this decline has been widely felt across the industry, given the very high expectations for the segment's growth during the energy price shocks from 2021 to 2023. With painfully-high power prices during that period, families looked for ways to becoming less dependent from the grid, and found the perfect solution in solar and storage. Whether it was financially supported by governments like in Italy or Austria, or stimulated by a strong self-sufficiency drive as in Germany, home batteries were massively rolled out.

Figure 8

European home batteries decline in 2024, as utility-scale expansion continues

European BESS annual segmentation 2020-2024



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In just three years, more than 3 million residential batteries were connected to the grid in Europe, delivering on energy autonomy, security and emissions reduction. Families that had access to the technology could save up to 2,400 EUR per year on their energy bills and break even within the first 6 years, due to the very high power prices and existing support schemes.[3]

Europe didn't just experience strong demand – supply has been ample with widely available battery storage products, as of 2023. This came as a relief to the continent, following the temporary price spike of lithium in 2022 and general shortage of products, which caused battery prices to increase that year, given the tremendous demand.

Residential annual battery installations jumped to 6.3 GWh in 2022 (+153% relative to 2021), to then reach an all-time high for the segment in 2023. That year, almost 1.3 million solar powered batteries were installed in Europe, which translated into more than 12 GWh of battery storage capacity added in 2024.

3 BNEF (2024): Scaling up the residential segment

Nonetheless, despite last year's decline, the residential market still managed to remain the leading battery storage segment with almost 11 GWh, indicating that its momentum has not fully receded.

During that same period, a quiet revolution was unfolding at the **large-scale** level, led by the United Kingdom (UK), and driven by rapidly decreasing battery prices. Up until last year, the country added more than half of Europe's annual grid-scale deployments. However, the wider European market's annual growth rate was very much hindered by project setbacks due to grid connection delays, inadequate legislation, slow permitting procedures, and other major regulatory hurdles on the continent. The investment appetite was already sizable, but the framework conditions were not yet ready to accommodate further growth. In 2021, Europe reached the GWh annual mark in large-scale BESS (1.2 GWh), more than doubled its annual market in 2022 (3.1 GWh), and grew by 60% in 2023, reaching almost 5 GWh of yearly deployment.

Last year, the European large-scale segment finally made a breakthrough in deployment, grid-connecting almost 9 GWh (+79%). 2024 was the watershed moment for grid-scale battery buildout in Europe, proving that the technology can be mobilised at scale and become a critical element of the energy transition. Going forward, large-scale deployments will only go upwards, as the segment is expected to surpass the residential market already in 2025.

The **commercial and industrial** (C&I) BESS segment persevered on its growth trajectory in 2024, but remained below its true potential. After nearly doubling for two consecutive years in 2022 and 2023, deployment slowed in 2024 to a 17% growth rate (2.2 GWh). Due to the capping of retail electricity prices during the energy crisis, the absence of sufficient support schemes, and the limited availability of flexibility revenues, the C&I market continues to be relatively small.

Currently in Europe, companies generally invest on battery storage to maximise self-consumption of on-site PV generation, avoid peak demand charges and reduce reliance on backup diesel generators. Additionally, solar and storage allow businesses to meet corporate sustainability targets by reducing carbon footprint of operations. Lastly, the electrification of production processes, heating, and transport fleets is driving unique use cases and a need for storage. In the EU, the electrification rate, which has been stagnating at 22-23% over the past five years, is targeted to grow to 32% by 2030 under the Clean Industrial Deal.

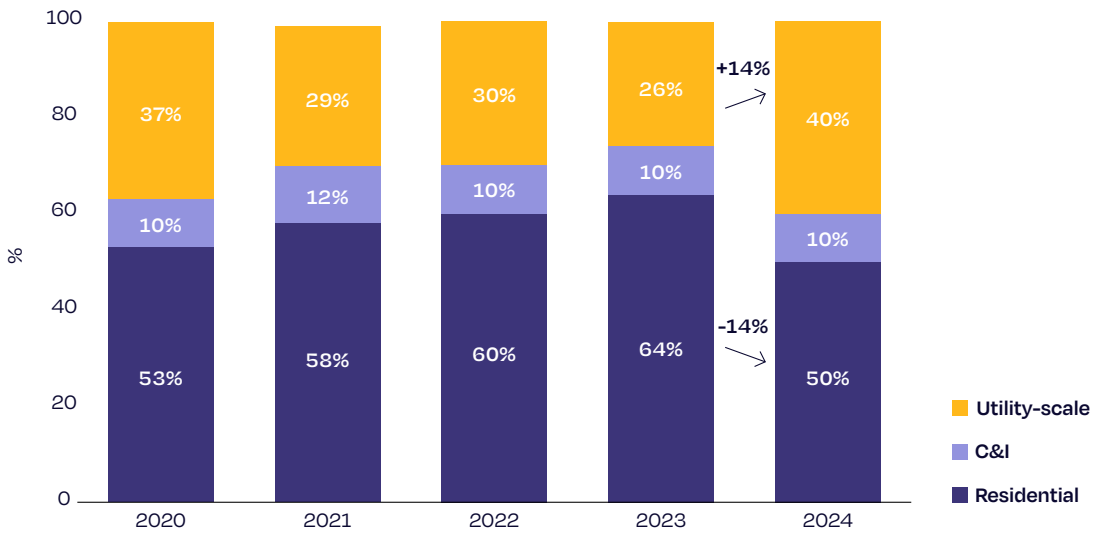
These critical use cases for companies and industrial sectors are already served with solar and storage, but are still unable to unlock full investment potential against the background of regulatory barriers. Far from a mature market, where grid services are remunerated and active trading is enabled, installations are still dependent on electricity prices and the existence of support schemes.

All in all, 2024 was the first year that saw the weight of residential deployment decline to 50%, losing 14 percentage points (see Fig. 9). In contrast, the utility-scale segment ramped up its contribution by the same percentage points to 40% of total annual additions in Europe. C&I batteries remained at the same level (10%), meaning that the drop in residential installations was proportionally offset by the utility-scale segment.

Figure 9

Home batteries' market share decreases for the first time in 2024, as utility-scale soars

Europe annual BESS segmentation shares 2020-2024



European battery storage fleet reaches 60 GWh in 2024, still 2/3 of it behind the meter

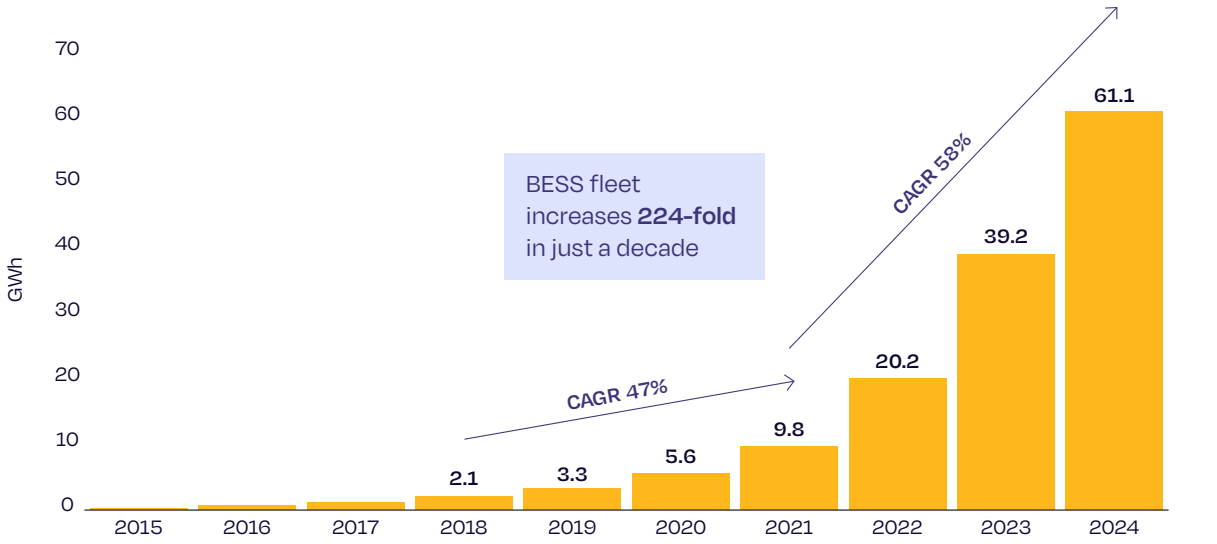
When looking at the operating BESS fleet in Europe, it remains evident that the cumulative capacity continues growing at an exponential pace. The battery storage base augmented by 56% in 2024, lifting the total installed capacity over the 60 GWh mark (see Fig. 10). Considering the EU-27 bloc alone, the operating battery storage capacity reached 49.1 GWh at the end of 2024.

Over the past 4 years, the enlargement of Europe's BESS fleet has intensified, achieving a CAGR of nearly 60%, whereas from 2018-2021, the average annual increase remained below 50%. Thanks to this upswing during the last 4 years, the battery storage capacity in Europe is over 200 times larger than in 2015, when merely 300 MWh had been installed.

Figure 10

European total battery fleet crosses 60 GWh mark in 2024

Europe cumulative BESS capacity 2015-2024



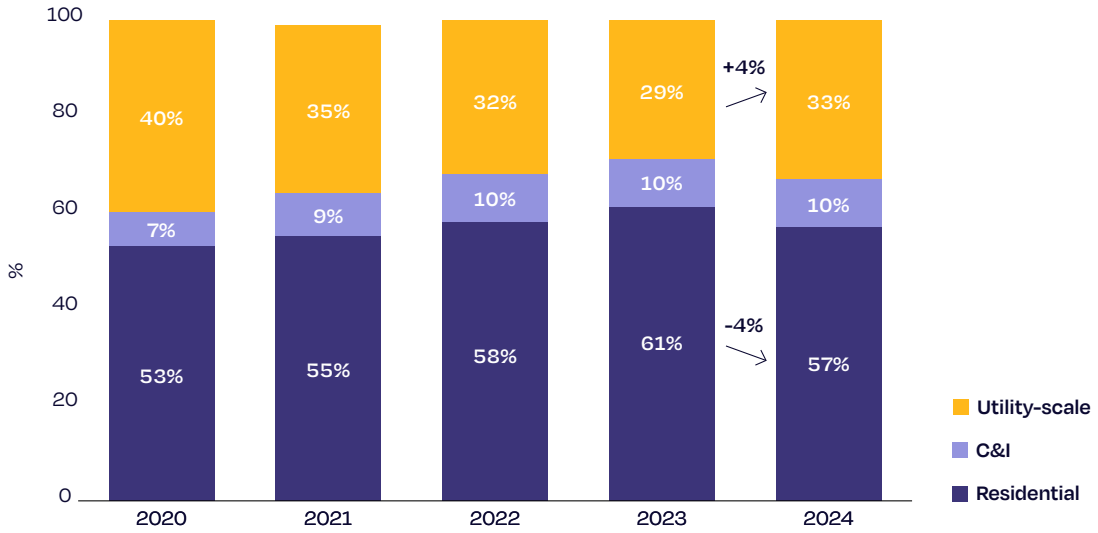
The bulk of the accumulated capacity is still found in the home solar and storage segment, which now accounts for 57% of the total installed capacity (see Fig. 11). Then again, the dominance of home batteries shrank by 4 percentage points in 2024, with the share captured by the large-scale segment, which now holds 33% of Europe's fleet. C&I preserved its 10% cumulative share, which has remained unchanged for the last 3 years.

Looking back at 2020, large-scale and C&I BESS constituted respectively 40% and 7% of the operating capacity, whereas the household segment already represented more than half of the fleet. For the next three years, the residential share only increased, reaching a peak of 61% of the cumulative base in 2023. Household pursuit of energy security outpaced all the other market and regulatory drivers in the C&I and utility-scale segment. But in 2024, the enormous pipeline of grid-scale BESS projects started to be cleared, which has prompted a tidal change, which will only exacerbate over the coming years.

Figure 11

Home batteries represent 60% of the European fleet, but 2024 marks inflection point for grid-scale batteries

Europe cumulative BESS segmentation 2020-2024



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17.2 MW PV coupled with 5 MW / 5 MWh BESS, Bontepolder, the Netherlands

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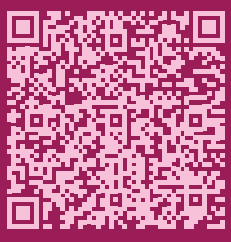

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Germany, Italy and the UK play in a different battery storage league, while new markets gain significance

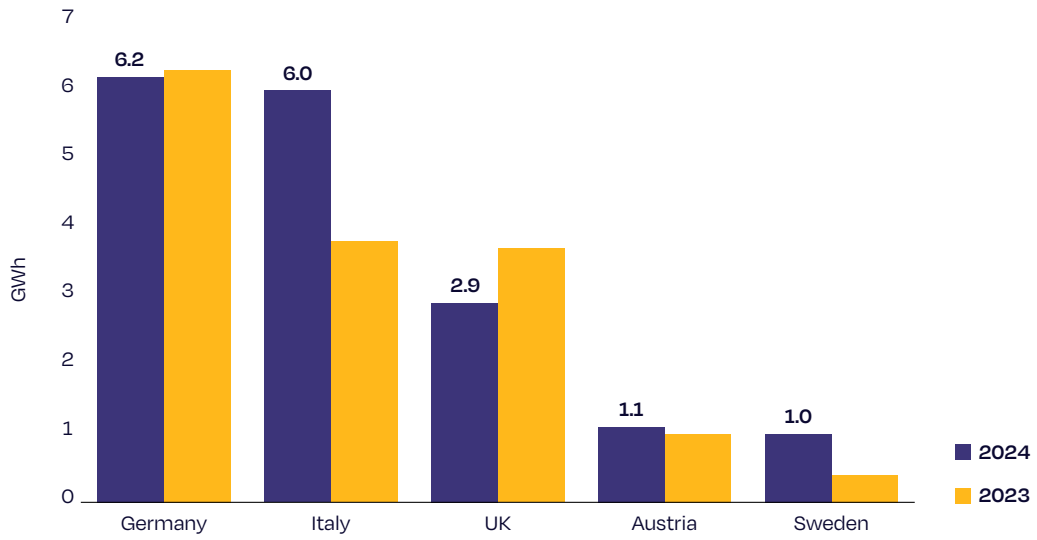
In 2024, Germany, Italy, the UK, and Austria, solidified their dominance as the largest markets for battery storage in Europe (see Fig. 12). These four countries have been able to keep up with rapidly changing dynamics and maintained in 2024, their previous positions from 2023. In particular, Germany, Italy, and the UK, have been market leaders over the last decade, with 10 consecutive years on the podium. The newcomer in this year's edition is Sweden, which, after a very strong performance in 2024, claims the 5th position in our ranking. The Czech Republic, despite installing almost 600 MWh in 2024 (fifth largest addition in Europe), falls now in the 10th position in our ranking of European BESS markets.

This year's 'top 5' is again strongly upstaged by the leading three markets, which continue to outshine the rest by a significant margin. Even so, both Austria and Sweden succeeded in delivering at least 1 GWh of new battery storage capacity. 2024 marks the first year that reaching the GWh scale is required to enter the top 5.

Figure 12

Germany dominates European annual battery market, while Italy is close behind and the UK temporarily slumps

Europe top 5 BESS markets 2023-2024



Germany maintains the top European spot in 2024, but its performance worsened compared to 2023. Last year, the market basically stagnated at 6.2 GWh, around 100 MWh less than in 2023, which almost caused Italy to take over the pole position.

The lacklustre year-on-year growth can be interpreted as a transitory deceleration in the expansion of the German BESS market, which has been growing consistently for the past 4 years, reaching its deployment record in 2023 with 6.3 GWh (+132% relative to 2022). Anyhow, this new addition takes the German BESS fleet to 19.5 GWh of installed BESS capacity, by far the biggest in Europe, capturing almost one third of the continent's fleet.

Out of the 6.2 GWh installed in 2024, 79% was connected at the **residential** level (4.9 GWh). The home battery storage segment registered a 12% market loss in 2024, significantly affected by a 14% decline in household PV installations. Falling energy prices, widespread regulatory uncertainty, and persistent high borrowing costs pushed installation levels down.

Even so, Germany continues to be the European #1 residential market, installing twice as much home battery capacity as Italy, which ranks second. It is worth highlighting that Germany's decline in residential buildout in 2024 was not more acute thanks to a number of supporting factors, such as the somewhat continued momentum from the energy price crisis, VAT exemptions for BESS and solar, and the strong drive to self-sufficiency of German households. Low PV injection tariffs also continue to incentivise the adoption of storage to optimise the use of PV systems. Home batteries make up now over 80% of the existing BESS fleet in Germany, totalling around 1.8 million home systems at the end of last year, according to BSW-Solar data.

At the **C&I level**, Germany reports a 26% increase year-on-year (530 MWh), which makes the country gain back first place, after arriving second in 2023. However, C&I batteries grew by almost 140% in 2023 compared to 2022, which reveals a clear deceleration. Due to decreased electricity prices, the absence of support schemes, and the economic challenges facing industry in Germany, C&I battery storage adoption continues to underperform. Participation in ancillary markets remains complex requiring aggregation or third-party platforms while regulatory uncertainty persists around revenue stacking. Combining peak shaving, trading and balancing operations remains a difficult feat for businesses. As a result, attachment rates remain below 20% and existing C&I solar PV systems are not yet being retrofitted at scale, a trend that would boost the market given the country's enormous C&I solar fleet, which stood at 61 GW at the end of 2024. Nonetheless, Germany operates the largest C&I battery storage fleet in Europe with 1.4 GWh at the end of last year, topping Italy by a very small margin.

18.2 MW PV coupled with 6.2 MW / 20.7 MWh BESS, Deisenhausen, Germany

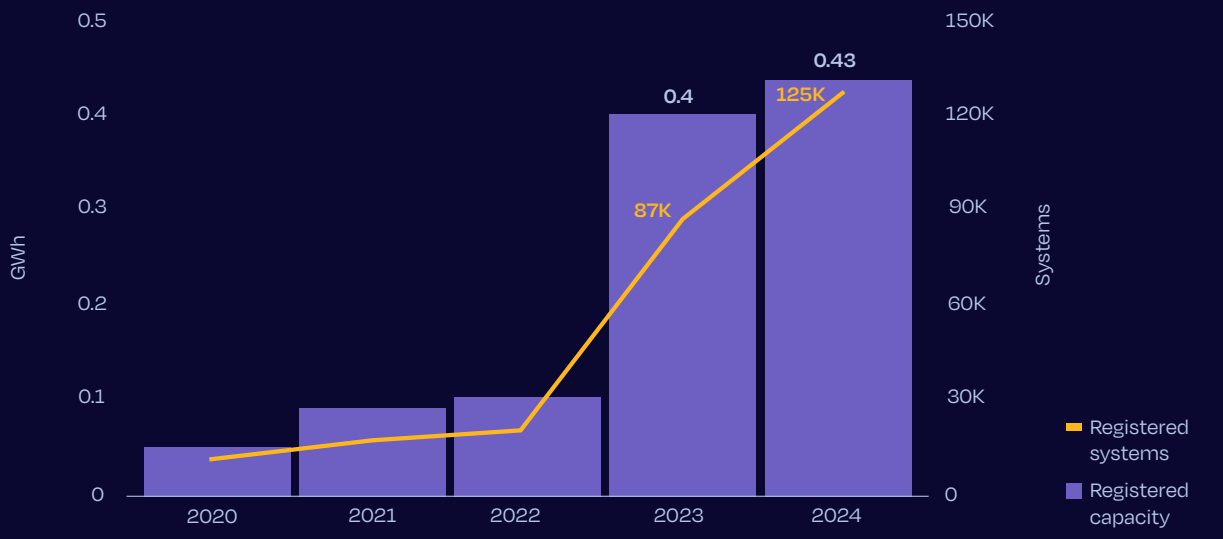
Box 3

Micro-storage and plug-in solar PV in Germany

One notable development in the German market is the growth of the small/micro-storage segment, for systems with a capacity of less than 5 kWh. Figure 13 shows the evolution of storage installations of less than 5 kWh in Germany in recent years. In capacity terms, this segment saw a 300% year-on-year market growth between 2022 and 2023, from 1 MWh annually installed capacity to 400 MWh. This trend continued in 2024, albeit at a slower rate, with 7.5% annual growth and 430 MWh of micro-storage installed. However, in terms of the number of systems, 2024 saw a 44% increase in the number of installed micro-storage systems, from 87,000 in 2023 to 125,000, or over a fifth of the total annual home storage market (580,000).[4] This increase also implies a skewed market towards increasingly smaller system sizes.

Figure 13

Small battery storage systems < 5 kWh installed in Germany, 2020-2024



Source: BSW Solar, SolarPower Europe
Note: BSW Solar's own calculations are based on MaStR as of January 23rd 2025, accounting for expected late registrations. Further revisions to be expected due to late registrations.

This impressive uptake of micro-storage in Germany can be largely correlated with the growing popularity of plug-in solar systems/devices/kits in the country.

Plug-in solar power plants, also known as balcony solar, micro-PV/micro-generators, or plug-and-play solar, are small-scale PV systems, of 1-5 modules,[5] which can be plugged directly into a grounded home power socket. Easily installed on balconies, terraces, gardens, walls or rooftops, these solar 'kits' are connected to the home's end circuit, and generated electricity is either consumed directly by appliances in the household, or, in some cases, fed back into the power grid as surplus generation via the electricity meter. At this scale, plug-in solar typically helps power a household's continuous baseload during the day (100-300 W), including refrigerators, Wi-Fi routers, and other standby appliances, and more during peak production hours.

4 BSW Solar, 2025: Statistical data on the German Solar Battery Storage and E-mobility Market.

In 2024, 435,000 plug-in PV devices were registered to the German network regulator's Core Energy Market Register (MaStR), out of a total 1 million new PV systems, amounting to a 426 MW annual market. This means that two in five PV systems installed in Germany in 2024 were plug-in solar PV. In 2023, this was the case for one in four PV systems.

Many plug-in PV providers/distributors now offer plug-in products with optional micro-storage with capacities in the 1-5 kWh range, in partnership with different inverter and battery companies. A growing number of battery and inverter providers now offer 1-5 kWh products designed for plug-in solar systems or other small household appliances.

Although such small-scale storage systems were not previously considered a financially beneficial investment for plug-in PV, given their high upfront costs, decreasing module and battery prices have contributed to an increase in demand for these systems.

Looking specifically at the under 2 kWh segment, which specifically targets storage solutions for small, 1-2 module kits, "*Steckersolargeräten*," this segment has also seen a significant increase. According to available data from the MaStR, this segment grew an astonishing 24-fold between 2023 and 2024, rising from just over 1,000 systems to more than 30,000. Out of 580,000 home storage systems installed in Germany in 2024, more than 5% of them fell within the < 2 kWh range, compared to less than 1% in 2023.

Demand for storage in this segment is such that the VDE, Germany's technical regulator, plans to develop a specific plug-in standard which includes rules for plug-in storage, since this segment is currently not currently clearly regulated. The VDE is expected to publish the first ever plug-in PV product standard towards the end of 2025, setting a precedent for the industry.

Outside of Germany, Belgium also legalised plug-in solar and plug-in storage in April 2025. This is in line with growing interest for plug-in solar technologies across Europe, notably in France, Spain, and the Netherlands, as detailed in SolarPower Europe's Plug-In Solar PV report (2025).

5 The average capacity of plug-in PV in 2024 is about 800-900 W.

Plug-In Solar PV

Solar for all - a deep dive on a fast emerging PV segment

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Grid-scale batteries erupted in 2024 as the fastest growing segment in Germany (+140% relative to 2023), almost stretching to 800 MWh deployed. Up until last year, the surge in large batteries had been erratic, as installations decreased by 33% in 2023. Delays in the commissioning of projects as a result of lengthy permitting and difficulties in getting grid connection points caused deployment to tumble in 2023, and deferred projects to 2024.

There is currently little practical experience and lack of personnel in local administrations to deal with the enormous investment interest on large battery projects. Permitting procedures generally last more than 8 months, increasing costs and creating an administrative bottleneck to all project developers. At the end of last year, nearly 230 GW of BESS projects had requested grid connection in Germany, illustrating the country's attractive revenue opportunities, but also its administrative bottlenecks.

Italy ranks #2 with 6 GWh of BESS capacity installed in 2024, shortening the distance to the market leader. Despite witnessing a substantial downturn in residential (-19%) and C&I installations (-70%), total installations rose by 58% thanks to a massive increase in the large-scale segment. That catapults Italy to 12.9 GWh of total operating capacity, second after Germany.

Grid-scale batteries delivered a whopping 3.4 GWh in Italy in 2024 and 57% of the total, an all-time high for the segment in Europe, surpassing the previous deployment record in the United Kingdom (2.9 GWh). From one year to the next, Italy was able to bring online 15 times more capacity than in 2023 (230 MWh). Much-awaited commissioning of battery projects contracted in previous Capacity Market and Fast Reserve Instrument rounds, and the possibility to trade on energy markets on a merchant basis, has allowed the country to become the #1 annual large-scale BESS market in Europe. The country stands as the clear example that grid-scale battery assets can be deployed with the magnitude required by the energy transition to renewables. Although deployment volumes of utility-scale batteries were impressive, significant commissioning delays limited the amount of grid-connected capacity in 2024. Our Medium Scenario was projecting a larger buildout of 5.2 GWh, which would have turned Italy as the #1 market in 2024.

The speed of deployment of large BESS must continue to accelerate to deliver the latest TSO Terna target of 58 GWh of new utility-scale energy storage sites by 2030. At the end of 2024, Italy had deployed a total of 3.8 GWh of grid batteries, ranking #2 behind the United Kingdom in the segment.

50 MWh, Pelham, UK

In turn, behind-the-meter applications experienced a substantial drop in installations. At the **residential level**, the phase-out of the Superbonus 110% tax incentive, in combination with lower power prices, resulted in 2.4 GWh added in 2024. That represents just 40% of the total annual additions, whereas in 2023 the household segment delivered 77% of the annual market. The introduction of the Eco-bonus (up to 50% tax credits) and other regional investment grants managed to sustain household interest in solar and storage, but it was not enough to prevent a decrease in installations.

C&I performance also nosedived in Italy, from almost 650 MWh in 2023 to 190 MWh in 2024, bringing to an end four consecutive years of annual doubling of the market. Skyrocketing retail electricity prices in 2021-2023, strong state support via the Transition 4.0 programme and stimulus investment measures after the COVID pandemic nudged companies to invest in solar and storage as a way to become less dependent on volatile market prices, optimise their consumption profiles, and decarbonise their operations. Still, the market's potential remained constrained as C&I batteries cannot access dispatchable markets, which would improve the business case and help mitigate grid congestion and instability. Also in 2024, the implementation of the new Transition 5.0 scheme achieved very limited success as the application procedure was too burdensome and difficult, while deadlines were too short. The scheme received little interest from companies as a result.

The **United Kingdom** kept the third standing despite annual deployment sinking to 2.9 GWh, 22% less than in 2023. At 10.8 GWh of BESS cumulative capacity, the country has now conceded the title of the second largest European battery fleet to Italy.

This substantial UK slump originates from the decline of **large-scale** deployment, where major project postponements hampered growth. A significant backlog in grid connection applications has led to extended waiting periods for new projects. Increased lead times and costs due to the enormous surge in global demand for electrical hardware components also appears to have hindered timely completion of BESS projects in the biggest grid-scale market in Europe. Local opposition to large-scale energy projects has also led to planning delays. Lastly, investors' confidence weakened in 2024 amid falling revenues driven by frequency market saturation, which caused slowing project rollout.

As a result, grid-scale battery buildout decreased to 2 GWh in 2024, down 31% from almost 3 GWh that were grid-connected in 2023. That takes the UK's large-scale fleet to 8.7 GWh at the end of 2024, still two times bigger than Italy's installed capacity.

Blackhillock, UK

Reaching the UK Clean Power 2030 target of 23-27 GW of battery storage capacity by the end of the decade will hinge on several factors, with investor and developer confidence in returns playing a key role. While further declining battery costs and prices will continue to strengthen the business case by reducing capital expenditure, investors and developers must remain mindful of the evolving market dynamics that shape BESS revenue streams.

Distinctively, unlike in Italy, the United Kingdom's BTM segment grew significantly by adding 840 MWh. The **residential** segment installed more than 730 MWh (+13% relative to 2022) thanks to a supportive regulatory framework with VAT exemptions for new and retrofitted home batteries and streamlined permitting procedures.

British households have also started to recognise solar and storage as an effective solution to persistently high electricity prices. PV exporting tariffs are also on average more than 40% lower than imports, which makes coupling storage with PV generation very attractive. **C&I** BESS also showed growth but at a somewhat higher rate of 18% and added more than 100 MWh, as the segment continues to expand allowing companies to shield against structurally high electricity prices. However, both segments need to ramp up their contributions if the Clean Power 2030 energy storage target is to be met.

Also preserving its previous position in the ranking, **Austria** registered another record year, with almost 1.1 GWh installed in 2024. It's the first year that the market surpasses the GWh mark, after coming very close in 2023, which allows the country to also retain the #4 position in terms of cumulative BESS capacity, with more than 2.8 GWh.

Like Germany, the Austrian BESS market continued to be strongly anchored to the residential segment, but unlike in Germany, this segment registered 13% more battery capacity in 2024. The home storage market took the lion's share with 83% of total installations (880 MWh) and constitutes more than 80% of the existing fleet. It's also worth emphasising that over 70% of the annual PV additions were also added in the residential segment.

At the beginning of 2024, Austria's new 'Stromspeicheranlagen' (Electricity Storage Systems) funding programme replaced the former ÖMAG and KLIEN schemes for residential and small commercial installations. The programme offers a flat-rate subsidy of 200 EUR/kWh of usable storage capacity for batteries ranging from 4 to 50 kWh. By May 2024, the program's 35 million EUR budget had already been fully allocated.

25 MW / 50 MWh BESS, Birmingham, UK

However, this programme was also phased out and replaced by a VAT exemption for PV systems up to 35 kW including BESS that had been introduced in January 2024. Various subsidy programmes continued to target the small BESS segment between 10-50 kWh but the available budgets were reduced significantly. Despite the market and policy uncertainty unleashed by the continued change in the support frameworks, household installations flew higher last year. Additionally, the absence of net metering and feed-in tariffs provides a strong incentive for homeowners to invest in energy storage systems. In 2025, the VAT exemption for small-scale PV and BESS has been phased-out by the new government, which will hamper the segment's growth.

In contrast, the **C&I** segment stagnated at 150 MWh despite the existence of support schemes for small and medium sized C&I batteries. The weak economic situation of the country seems to be playing a role, as general investments of companies decreased in 2024. The segment now counts with nearly 600 MWh of installed capacity, the third biggest C&I fleet in Europe, behind Germany and Italy.

At the **front-of-the-meter scale (FTM)**, the country deployed around 40 MWh, a very similar figure to 2023. The cumulative FTM capacity remains below 100 MWh as the country remains in the early stages, with developers beginning to seize opportunities created by high volatility and wide spreads in the wholesale power markets. The New Electricity Industry Act (EIWG) brought significant simplifications to the operation of large batteries, and the Renewables Expansion Acceleration Act (EABG) is accelerating investments in BESS. Additionally, the country introduced in 2024 a subsidy for large battery projects above 1 MWh, which significantly reduced upfront costs for developers.

Closing the top five ranking, after 3 years of remarkable growth, **Sweden** hits the GWh scale in 2024, jumping by 151% relative to 2023 (410 MWh). This enabled the country to enlarge its BESS fleet to nearly 1.7 GWh installed at the end of 2024. This expansion is driven by the country's ambitious energy transition goals, increasing renewable energy penetration, and the need for grid stability. Notably, in 2024 the country achieved a very balanced growth across the three segments, with all of them adding around 350 MWh.

Swedish **household** installations climbed by 33% to more than 330 MWh in 2024, despite regulatory challenges and a significant decrease on residential PV deployment. Back in January 2024, the Swedish Tax Agency made an incorrect interpretation of the eligibility criteria for the 'Grön Teknik' scheme – the existing and highly successful tax deduction programme allowing private individuals to subtract 50% of the battery installation and component costs from their income tax.

The change meant that household batteries used for selling energy to the grid, cutting power peaks, or supporting the electricity grid, were no longer eligible for the tax reduction. Only self-consumption was due to be allowed, tremendously limiting the optimisation of solar and storage systems. After several months, this decision was reversed following continued negative feedback from the industry, and extended battery use cases were allowed. This helped revitalise demand for household solar and battery systems.

Newly installed Swedish **C&I** batteries rose to 350 MWh in 2024, coming from 100 MWh in 2023. The upward trend has been remarkable over the past 3 years, and much of it is owed to the fact that C&I battery systems can bid in the balancing market, providing highly remunerated grid services. This has made the business case of solar and storage very attractive for companies, and has triggered a very notable expansion, proving that allowing commercial entities to trade in flexible markets creates a win-win situation for both companies and grid operators.

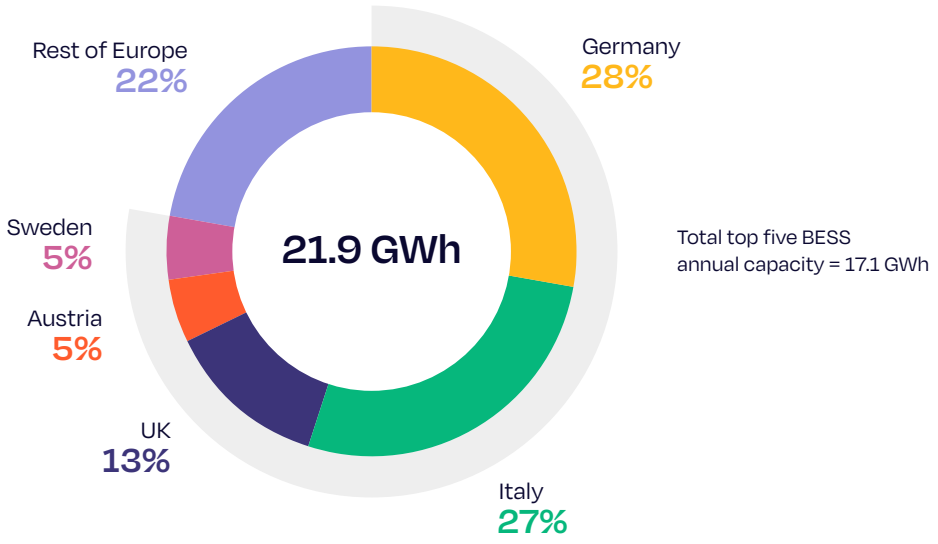
At the **large-scale** level, 350 MWh were also deployed in 2024, growing nearly sixfold from just 60 MWh in 2023. The revenues in the Frequency Containment Reserve for Disturbances (FCR-D) market and wide spreads in the wholesale market have been the major drivers of new standalone battery projects. Given the significant growth and rush to connect projects, already in 2024 prices in the FCR-D stream have decreased, which has sent operators exploring alternative transmission services such as Frequency Containment Reserve for Normal Operation (FCR-N) and manual Frequency Restoration Reserve (mFRR). Despite these advancements, regulatory uncertainties and interconnection limitations with neighbouring markets pose significant challenges.

Altogether, in 2024 the European top 5 BESS markets accounted for 78% (21.1 GWh) of new battery installations across the continent (see Fig. 14). The persistent concentration of deployment on the five biggest markets continues to determine overall installations in Europe. In 2023, the top 5 countries delivered at 81% only slightly more of the continent's annual capacity (15.1 GWh).

Figure 14

Germany and Italy bring online more than half of Europe's annual installations, as top 5 delivers almost 80% of yearly deployment

Europe top 5 BESS markets 2024



This market concentration is even more pronounced when the top 3 markets are added together (70%), with just a 2 percentage point difference to 2023 (72%), indicating that BESS deployment in Europe continues to be dominated by Germany, Italy, and the United Kingdom. Over the coming years, these three markets will remain the frontrunners but will lose relative weight on total installations as more countries join the battery revolution.

Looking beyond Europe's leading battery markets, many emerging countries have already garnered significant attention, like Ireland or France at the utility-scale level, or have continued to add sizable capacity behind the meter, like the Czech Republic.

Ireland is strongly focused on developing its **large-scale** battery storage base as the cornerstone of its strategy to reach 80% of renewable electricity by 2030. Last year, the country installed close to 700 MWh, with over 90% being connected in front of the meter, for a total of almost 1.7 GWh of cumulative BESS capacity. Given its already high penetration of wind generation, and the rapid deployment of more wind and solar, battery storage will be essential for maintaining grid stability and frequency response, time-shifting of renewable production, and reducing curtailment, particularly of wind assets. With its condition as an island system, obviously much less interconnected than mainland Europe, local balancing solutions like BESS are even more important to manage imbalances, peak demand events, and requirements of power reserve. The country plans to implement both short and long-duration storage solutions to enable a smooth integration of renewable into the power mix.

To ensure market attractiveness, the country offers a variety of revenue opportunities for BESS including the DS3 programme which provides payments for fast frequency and related grid services, a capacity remuneration mechanism (CRM) that ensures power availability at peak demand, and wide power spreads for energy arbitrage operations. As of 2024, most of the country's installed BESS capacity comes from grid-scale assets, whereas small-scale storage remains limited, primarily due to a lack of targeted funding mechanisms and consumer incentives.

France is accelerating towards the country's national energy strategy (Programmation Pluriannuelle de l'Énergie) aiming at 40% renewable electricity by 2030. To support the enlargement of the renewable fleet, batteries will be needed to balance variability, reduce curtailment, and enhance grid reliability. The country is modernising its legal and regulatory framework to better integrate BESS within the energy and capacity markets. Some key improvements include the recognition of storage as a dual asset, enabling multi-revenue stacking models and the participation of BESS in the capacity market. Batteries are now able to earn revenues from the wholesale market, frequency regulation and reserve services, and the French capacity mechanism.

Nevertheless, there are still significant challenges on improving the regulatory environment on grid fee structures or the rules for hybridising renewable plants. Revenue streams remain fragmented, highly volatile and long-term contracts are limited. At the end of last year, France had installed a total of 920 MWh of **utility-scale** BESS, and almost half of that capacity was brought online in 2024, illustrating the rapid growth of the segment. On the contrary, **behind-the-meter** storage remains underdeveloped, with 100 MWh installed last year at the residential level and just over 80 MWh in the C&I segment.

Notable for its outstanding growth of the small-scale segment, the **Czech Republic** continued supporting the rollout of solar and storage with the New Green Savings Programme, the Modernisation Fund, and the National Recovery Plan. Last year, the country installed slightly less than 600 MWh, primarily driven by the **residential segment**, which deployed more than 80% of the annual capacity. Despite continuing its growth trajectory, home batteries experienced an anticipated drop in installations, adding 36% less in 2024, after the record years in 2022 and 2023. It also registered the highest attachment rates in Europe with over 90% of new home PV systems being coupled with BESS, thanks to the effectiveness of its subsidy programme. The success of the support schemes was tremendous, and now the market is consolidating, both for PV and batteries.

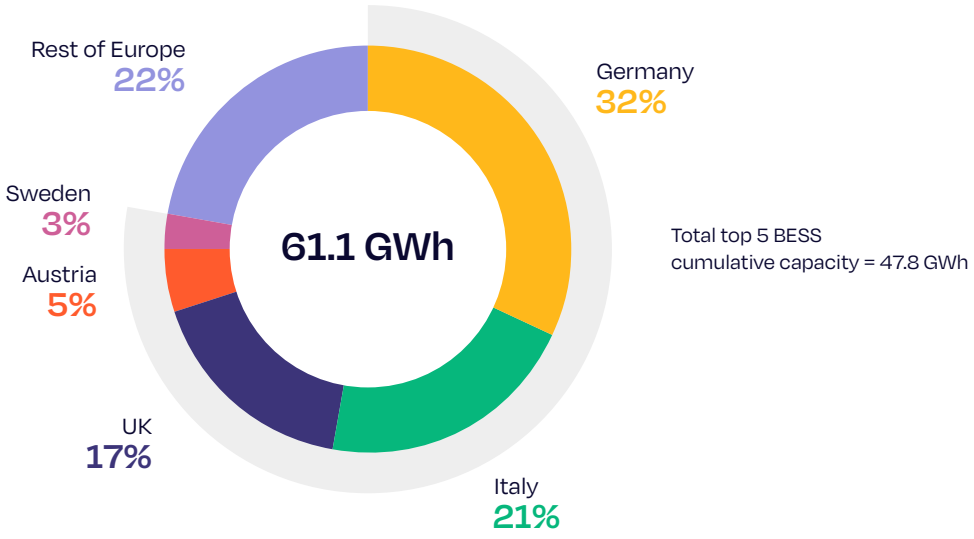
Some other countries that have grown substantially over the past year are **Switzerland** (510 MWh), the **Netherlands** (470 MWh) or **Romania** (330 MWh). Switzerland kept its upward trajectory thanks to the home storage segment, while the Netherlands and Romania reported significant increases in C&I and utility-scale battery deployment.

In 2024, the five largest European battery markets were also the countries with the most extensive total operating battery storage fleets (see Fig. 15). The ranking remains unchanged, with Germany leading the pack, accounting for 32% of total capacity, followed by Italy at 21% and the UK at 17%. Together, the top three capture over 70% of the current European battery fleet. Austria and Sweden represent 5% and 3% respectively and stay ahead of the rest of BESS markets in Europe. Altogether, these top five markets represented 78% of Europe's total battery storage capacity, while the remaining 22% is distributed across all other European countries.

Figure 15

Germany, Italy, and the UK host over 70% of the European battery fleet

Europe top 5 cumulative BESS capacity 2024



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Drivers for battery storage deployment

The energy crisis accelerated home solar & storage adoption to cut energy bills and enhance energy independence, while the uptake in the C&I segment was small in comparison. CAPEX subsidies and tax incentives continue to play a vital role, but schemes remain fragmented and insufficient. Uneven smart meter rollouts and limited access to dynamic tariffs still hinder broader flexible solutions. Battery prices have declined steeply, driven by global overcapacity, technological advancements, and lower lithium costs. Full revenue stacking opportunities exist in only a few EU countries, and energy storage targets are missing or remain largely insufficient. The rapid growth of solar and wind power will increase flexibility needs fivefold by 2030, requiring battery storage to scale up to 1.8 TWh by 2040. Despite their clear benefits, hybrid PV-plus-storage projects remain mostly underutilised across Europe.

High retail electricity prices, decreasing technology costs, and supportive regulatory frameworks remain key drivers for behind-the-meter storage

Retail electricity prices and attachment rates

In the aftermath of the major disruptions caused by the COVID-19 pandemic in 2020, which brought the global economy to a halt, energy consumption surged rapidly across the globe as economic activity quickly resumed. This sudden rebound in demand, coupled with constrained energy supply, triggered a temporary structural rise in electricity prices across European markets, which had already become apparent by the end of 2021.

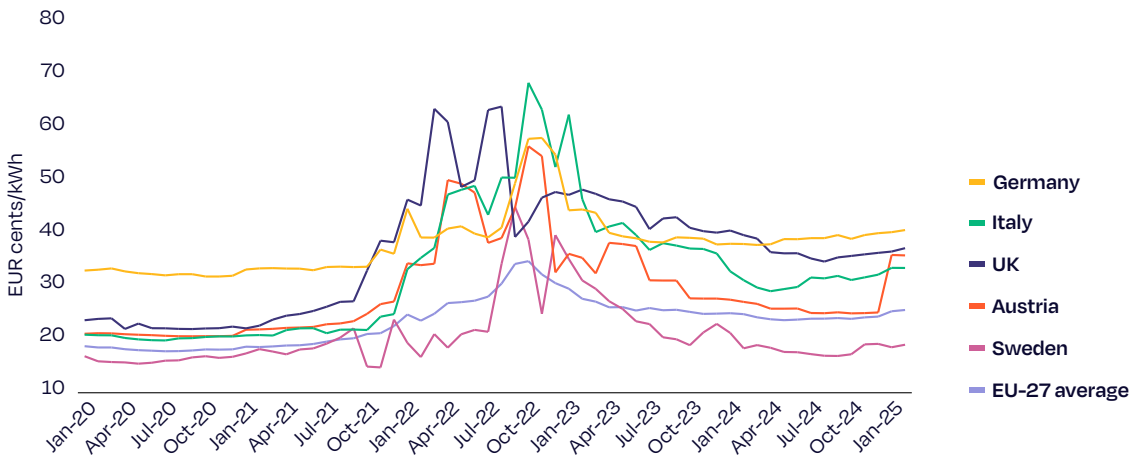
The surge in energy prices was significantly worsened by Russia's invasion of Ukraine in early 2022, which plunged global and European energy markets into chaos. Combined with soaring inflation, this situation caused widespread disruption to industrial production across Europe, as extreme price volatility and sharp spikes made operations unsustainable. Europe's heavy dependence on Russian natural gas exposed a critical strategic and economic vulnerability, severely limiting its capacity to respond effectively and absorb the shock to its energy supply.

Since natural gas typically determines the marginal cost of electricity in Europe, its price volatility was the primary factor behind the sharp rise in electricity prices during the peak of the energy crisis. This led to an immediate and widespread increase in residential electricity bills, especially in those countries that relied heavily on Russian gas like Germany, Italy, and the United Kingdom (see Fig. 16). For instance, household electricity consumers in Italy, where prices spiked most, were facing a 214% increase between 0.22 EUR/kWh in October 2021 and the peak of 0.69 EUR/kWh one year later.

Figure 16

European household electricity prices have declined substantially but remain above pre-energy crisis levels

Europe top 5 BESS markets and EU-27 average household electricity prices Jan 2020 - Mar 2025



Source: Household Energy Price Index (2025)
Data shows household electricity prices for each country's capital

Most European small and medium enterprises (SMEs), which procure their power mostly using retail electricity contracts, had to endure a very similar high energy price landscape to households.

In response to rising electricity costs and the need for greater energy resilience, a growing number of European households turned to solar PV and battery storage systems. This shift also aligned with efforts to lower carbon emissions. However, demand for residential solar and storage quickly outpaced supply, hampered by a widespread shortage of qualified installers – especially electricians – resulting in significant delays.

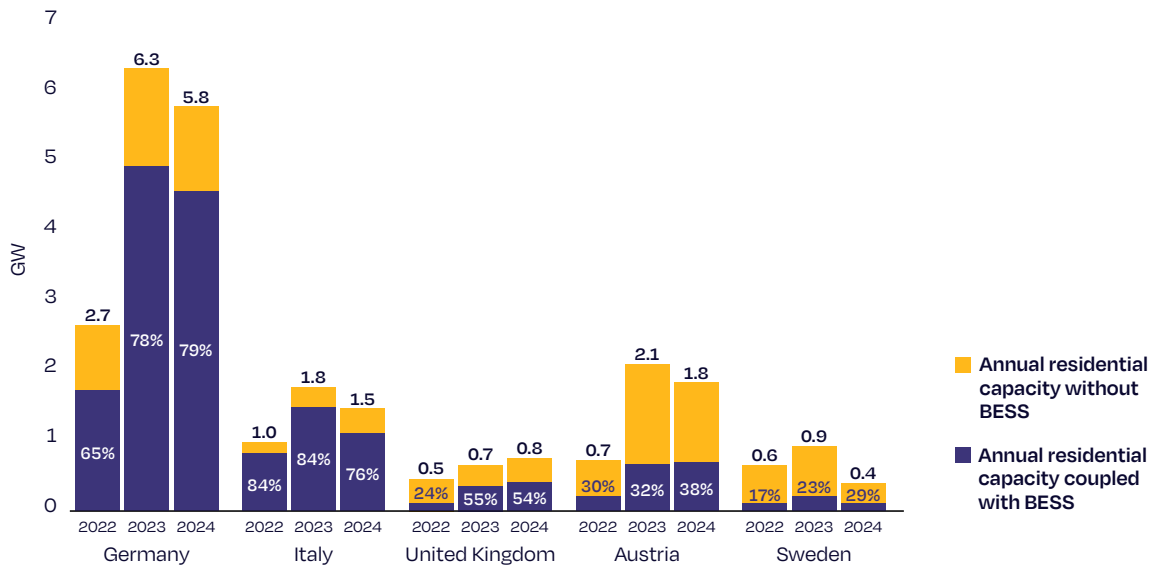
Despite these challenges, key European markets saw record-breaking installation levels as more households paired solar systems with batteries (see Fig. 17). This was reflected in rising battery attachment rates. In Germany, 78% of residential PV systems in 2023 included a battery – up 13 percentage points from 2022. Italy's rate remained very high at 84%, supported by the Superbonus scheme which was introduced already in 2020. The United Kingdom saw a 31-percentage point increase, while Austria's rate rose from 30% to 32% over the same period. In Austria, coupling rates were kept constant as the country was already supporting residential solar & storage.

The impact of the energy crisis also boosted home PV installations in 2023, which went from 2.7 GW to 6.3 GW in Germany (+133%), and from 1 GW to 1.8 GW in Italy (+80%). Installations also surged in the UK (+40%), in Austria (+200%) and in Sweden (+50%).

Figure 17

Germany and Italy present the highest battery attachment rates of the top 5 markets

New annual residential solar PV installations coupled with BESS 2022-2024



In 2024 and 2025, retail electricity prices have dropped significantly but remain higher than pre-pandemic levels. In all top four residential battery markets, household electricity prices continue to exceed the European average, with Germany reporting the highest power prices in 2025 (41 EUR cents/kWh). This sustained price signal keeps driving demand for residential solar PV and battery storage installations, though at lower levels.

The energy crisis has left lasting economic and psychological effects on European households, motivating many to adopt solar-plus-storage solutions as a practical and cost-effective way to protect against future energy disruptions. The value proposition for battery storage remains strong – particularly because it can raise household PV self-consumption rates to 70% or more. Well-designed support schemes for battery adoption have also proven effective in maintaining demand even if power prices ease, reinforcing household energy security in uncertain times.

This momentum from the energy crisis has therefore driven battery demand in 2024 and will continue doing so in 2025. Despite the notable decrease in household PV installations across the top five markets, attachment rates have been kept constant in 2024 in Germany (79%) and the United Kingdom (54%), as home solar & storage has become the standard with most installers offering both products in more competitive packages. In Austria (38%) and Sweden (29%), coupling rates have even increased in 2024 as more households make the investment decision to couple BESS with solar. Italy has been the only country that has experienced a decline in the BESS/PV attachment rate, down 8 percentage points to 76%, due to the cuts in the tax deduction programme, which have increased capital investment costs for households.

The astounding growth in solar & storage at the residential level during the energy price crisis was not mimicked by the C&I segment, which has expanded quite slowly in comparison. Facing very high retail and wholesale electricity prices, SMEs and large industrial players did choose solar PV to lower their electricity bills and decrease emissions but did not generally couple on-site generation with BESS.

From 2022 through 2024, the European C&I segment installed more than 65 GW of PV capacity, much more than the residential segment (47 GW). However, C&I attachment rates during this period did not reach 5% across Europe. Several factors hindered the expansion, including unclear regulatory frameworks with excessive grid tariffs or taxes, very limited financial support, permitting bottlenecks, general lack of awareness and expertise from businesses, system integrators and financiers, and insufficient revenue stacking opportunities. Out of the top 5, only Italy and Austria reported higher C&I coupling rates between 10-20% in 2022 and 2023. But in 2024, attachment rates in these two counties have fallen under 10%. In contrast, average household attachment rates of solar PV to batteries in Europe were around 20% between 2022 and 2024.

4.1 MW PV coupled with 3.5 MWh BESS, Bruchsal, Germany

Support schemes

Home batteries

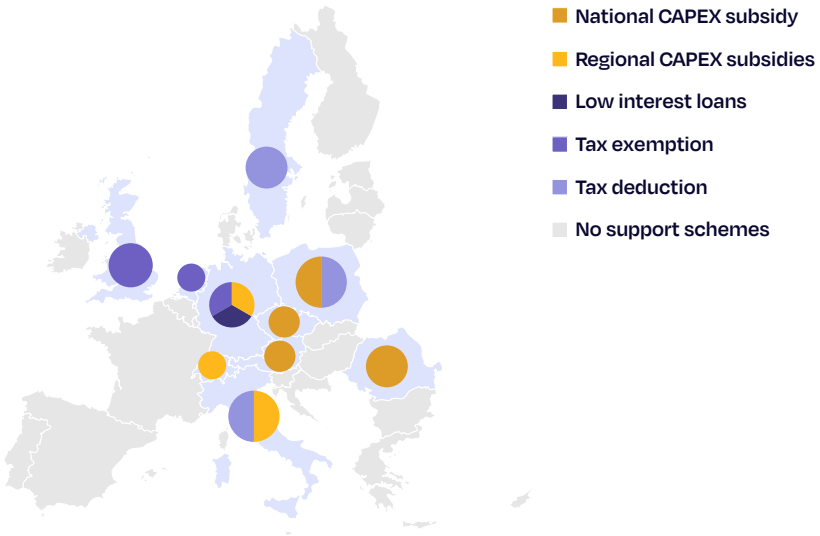
Government support schemes play a crucial role in promoting the adoption of residential batteries by helping households lower initial investment costs. In Europe, direct support for home batteries typically falls into two main categories: capital expenditure (CAPEX) subsidies and tax incentives.

CAPEX subsidies can be differentiated between national and regional programmes, depending on the application of the subsidy. At the national level, countries like **Austria,** the **Czech Republic, Lithuania, Malta, Poland,** and **Romania**, promote the uptake of batteries, whether retrofitted or in new PV installations, through CAPEX grant schemes (see Fig. 18). These subsidies can be temporary and subject to budget restrictions, leading to an immediate and sharp increase in applications, which continues until the funds are quickly exhausted. This was the case for example in Lithuania, where 15 million EUR were earmarked for the installation of home batteries up to 15 kWh, and the budget was quickly drained early in 2025. However, the government is planning to launch 3 more subsidy rounds in 2025 to meet the massive demand for residential storage.

Figure 18

Financial support for home batteries remains fragmented across Europe

Mapping of tax incentives and direct/indirect support schemes for residential batteries in Europe 2025



Romania also serves as a notable example of steering funds in the right direction, as the last iteration of the Casa Verde programme finally included 80 million EUR for home batteries. The size of the battery installation must be at least 5 kW, and applicants may receive back up to 90% of the initial investment. The scheme will fund at least 70,000 installations/prosumers and could lift attachment rates above 70%. In the country there are also other funding opportunities for residential solar and storage under the National Resilience and Recovery Plan, with similar conditions to the Casa Verde scheme.

The **Czech Republic** will continue in 2025 with the very successful New Green Savings programme which provides subsidies to households that install solar PV and battery storage systems. The funds have been lowered twice in 2024 and are expected to be decreased again in 2025. At the moment, successful applicants receive a maximum subsidy of 4,500-5,500 EUR depending on the installation.

In parallel with national capital support schemes, certain regional administrations may introduce short-term subsidies to bolster installations at the local level. This has been the case for **Germany**, **Italy**, and **Switzerland**, but these funds, despite their local impact, tend to have short-lived and minor effects on national installation levels.

Tax incentives include tax exemptions and deductions, such as VAT exemptions in **Germany** and the **United Kingdom**, as well as tax rebates like the Green Deduction programme in **Sweden** or the Eco-bonus in **Italy**. Such schemes provide a direct, effective, and transparent way to encourage the installation of residential batteries, along with solar PV.

The sales tax waivers in Germany and the United Kingdom have demonstrated to be very effective in boosting residential battery installations as both markets have registered impressive growth since the measure was implemented. VAT exemptions are generally more administratively efficient, reducing the need for extensive paperwork and approval processes that are normally associated with subsidies. The effect on demand is also immediate, as it directly enables individuals to reduce the costs of the best solutions available for their specific needs as soon as the exemption has been applied.

On the other hand, CAPEX subsidies can offer targeted support for certain groups or regions and generally provide higher financial support, covering a more substantial portion of the initial investment, which can be more effective in countries with lower purchasing power. CAPEX subsidies are usually tied to a rather small budget pot, which is often exhausted very quickly, resulting in unwanted stop-and-go market dynamics.

1.3 MW, Amsterdam, the Netherlands

Austria has changed the support framework for home batteries, as the government has recently eliminated the VAT exemption that sent installations to a new record in 2024. In 2025, there will only be one national CAPEX programme that provides funding of 200 EUR/kWh for residential batteries, but the budget has been cut very significantly.

Tax deduction programmes are also a common practice in Europe, particularly in Sweden and Italy. Sweden continues to offer a tax rebate scheme that allows private individuals to deduct 50% of the costs associated with battery installation and material costs from their income tax. The joint adoption of solar & storage also allows households to benefit from an extra 15% reduction on top of the 50%. The programme has been highly successful in Sweden as individual installations can also trade in the FCR market to optimise the use of their PV+battery system and provide critical services to the grid.

In **Italy**, after the Superbonus was finally terminated in 2024, the government has now shifted to the Eco-bonus programme. In 2025, the scheme provides a tax credit of 50%, which will be lowered to 36% in 2026, and further down in 2027. Less attractive than the Superbonus, the Eco-bonus is still driving home storage adoption, but at a reduced scale. Also, the government has introduced some constraints as the new tax credits are more difficult to obtain, whereas direct tax transfers are much preferred. Lastly, the tax credits can only be obtained in the first residence of the individual.

In addition to direct support schemes like CAPEX grants and tax benefits, governments can also offer indirect support through **zero- or low-interest loans** for green investments. These loans are especially beneficial for households that cannot afford significant upfront investment costs. For instance, **Germany** provides low-interest loans for the installation of renewable energy systems in residential properties.

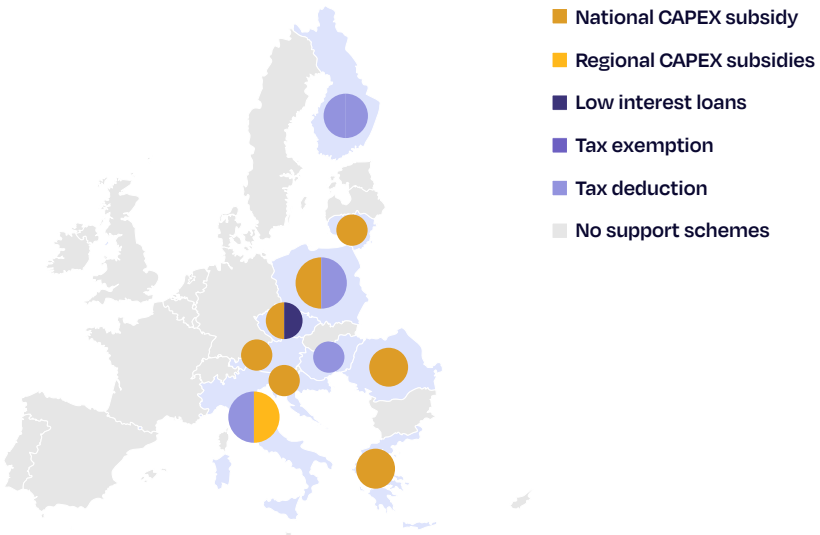
C&I batteries

At the C&I level, the same taxonomy can be utilised to map the existing support schemes in Europe. National C&I eligible **CAPEX subsidies** are running in 2025 in **Austria**, the **Czech Republic, Greece, Lithuania, Poland, Romania,** and **Slovenia** (see Fig. 19).

Figure 19

C&I batteries still get limited support across European markets

Mapping of tax incentives and direct/indirect support schemes for C&I batteries in Europe 2025



In **Austria**, existing funding has been significantly lowered or not renewed in parallel to the residential segment, which will have a detrimental effect on new C&I storage installations. The **Czech Republic** continues to support the segment through the Modernisation Fund by covering up to 35% of investment costs for commercial solar & storage projects, but up to 75% for energy communities. Additionally, the Czech Republic provides interest-free loans to promote solar and storage adoption among companies.

Greece has recently launched a 154 million EUR programme to fund new C&I storage systems which is open to any kind of business, regardless of their size and sector of economic activity. Small companies can get up to 50% CAPEX support, medium-sized companies may obtain no more than 40% refund, and large corporations get a discount of 30% of the total investment cost.

Lithuania has also implemented a new 18 million EUR CAPEX programme in 2025 that covers storage for companies and energy communities with a 30% subsidy rate. The programme is expected to deliver more than 110 MWh of new C&I storage projects by April 2026.

Poland and **Romania** also incentivise the adoption of small-commercial storage in their My Electricity and Casa Verde programmes as small companies and farmers can apply for the existing funds. **Slovenia** has set aside 16 million EUR to support solar energy communities, requiring projects to install at least 100 kW of PV capacity, with or without storage. The programme will run until 2027. Lastly, over the coming months, **Slovakia** will launch a subsidy programme to grant CAPEX subsidies for solar & storage installations for businesses with up to 5,000 EUR per installation.

When it comes to **tax incentives**, **Finland**, using the EU State Aid scheme, is promoting investments in local generation of solar electricity and storage for companies. Applicants may obtain tax credits and any sector except for credit or financial institutions are eligible.

Italy also changed the support framework from the programme Transition 4.0 to the 5.0 edition. However, the new programme structure has received wide criticism from the industry and attracted very little interest from companies. The ex-ante and ex-post energy savings calculations required to apply for the programme were very cumbersome and the timeline was too narrow, translating into a very small number of applications. Calls for going back to the 4.0 structure have been listened to, and now companies can apply with much simpler requirements, although it is unclear whether the funds will remain available or will be redirected in to other industry-supporting programmes. Some regional governments also provide CAPEX subsidies for SMEs that adopt solar and storage, but they remain scattered.

Overall, despite the inclusion of various support schemes and the significant drop in battery prices, installation levels in Europe indicate that more support is needed for companies to overcome the cost barriers of coupling storage with solar PV.

Box 4

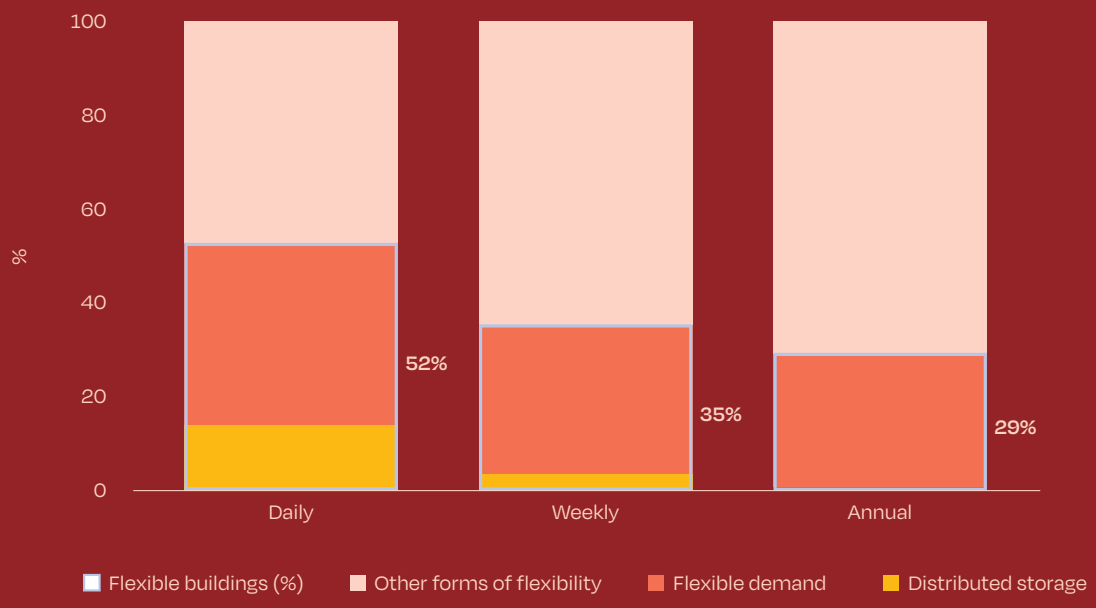
Leveraging flexibility from EU buildings

The European Union must urgently enhance the security and affordability of its energy system. To this end, buildings have a great potential that is still vastly untapped. Today, about two-thirds of solar capacity in the EU is installed on buildings, and despite a recent slowdown in the rooftop segment following the normalisation of power prices post energy crisis, PV on buildings still provided close to 60% of the EU's newly installed solar capacity in 2024.

Grid-interactive buildings are increasingly crucial in the electricity sector. Rather than being passive consumers, buildings have the potential to actively contribute by exporting energy to the grid and providing essential flexibility services. These services enhance system efficiency and reduce operational costs for building owners and occupants. Flexible buildings can offer a range of revenue streams, including self-consumption optimisation, local energy sharing, and access to electricity markets such as balancing and capacity markets. A variety of business models can be devised, especially considering the diverse policy frameworks across Member States.

Figure 20

Buildings' contribution to EU flexibility needs 2030



Box 4 - continued

Leveraging flexibility from EU buildings

Integrating solar PV systems with battery storage, heat pumps, electric vehicles, and smart energy management systems, flexible buildings are key enablers of demand response. Smart solar buildings improve efficiency, reduce costs, and bolster grid stability, especially in mature solar markets. Against this background, SolarPower Europe's report Flexible Buildings, Resilient Grids examines the potential of flexible technologies at the distributed level and the interplay between solar PV, BESS and other demand-side flexibility technologies. These technological solutions are highly complementary and can be further encouraged by policies, such as the availability of dynamic time-of-use tariffs.

The report highlights that by 2030, flexibility from buildings could meet more than half of EU daily energy system flexibility needs, and about a third of its weekly and annual flexibility needs (see Fig. 20). Further, grid-friendly flexibility from the demand side can significantly reduce the need for investments in distribution grids, while also bringing direct economic benefits to consumers. All of that means a more cost-effective system, resilient to shocks and strengthening Europe's energy security.

Unlocking this potential requires coordinated action at both the EU and national levels. Policies must encourage flexibility through appropriate pricing mechanisms, wider deployment of smart meters and submeters, technology incentives that optimise flexibility, streamlined data exchange, and fair access to competitive energy markets.

Flexible buildings, resilient grids

How rooftop solar strengthens the electricity system

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SolarPower Europe

Key regulatory enablers and smart devices

Strengthening the business case for BTM battery storage goes beyond financial support mechanisms; it also requires a solid regulatory framework that removes technical obstacles, cuts down on excessive bureaucracy, and accelerates permitting processes.

In this regard, more decisive legislative steps are needed to smooth the integration of solar and accompanying technologies like batteries. A good example of sensible policymaking is the recent 'Solar Peak Act' (Solarspitzengesetz) in Germany, which introduced significant amendments to the Energy Law.[6] The goal of the legislative package is to maintain system balance amid rising peaks in photovoltaic generation, minimise periods of negative electricity prices, and stabilise the market value of solar energy. To achieve this, a range of measures has been introduced to encourage PV systems to operate in a manner that supports both the energy market and overall system stability.

A supportive regulatory environment includes creating better conditions for complementary technologies such as solar PV, electric vehicles, heat pumps, and other solutions that increase the flexibility of distributed assets, whereby battery storage plays a pivotal role (see Box 4 on flexible buildings).

Against this background, a key enabling technology to accompany BESS deployment are smart meters, which are essential for delivering accurate, real-time data on electricity consumption, empowering consumers to make better-informed decisions, and engage in demand response initiatives. Households can reduce or shift power consumption during peak periods in exchange for financial incentives. Smart meters also allow utilities to offer time-of-use tariffs or dynamic pricing, where electricity rates vary depending on demand or grid conditions, enabling home energy appliances like batteries or heat pumps to optimise costs and reduce strain on the grid. If scaled, smart meter data allows grid operators to manage distributed energy resources like rooftop solar and batteries more efficiently, contributing to a more resilient power system.

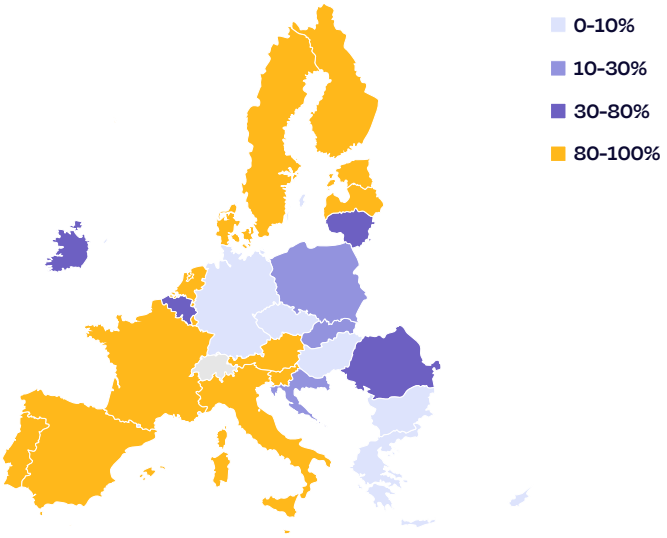
41.4 MWh, Sellingerbeetse, Netherlands

6 German Solar Industry Association (BSW-Solar): FAQ Solar Peak Act

Figure 21

Smart meter roll-out shows significant progress but EU countries still lag behind

Roll-out of smart meters among households across EU-27, 2023



Source: ACER (2025)

As of the end of 2023, the deployment of smart electricity meters among households showed significant progress in several countries (see Fig. 21). Fifteen countries – Denmark, Estonia, Spain, France, Italy, Latvia, Luxembourg, Malta, the Netherlands, Austria, Portugal, Slovenia, Finland, and Sweden – have achieved roll-out rates exceeding 80%. Belgium, Ireland, Lithuania, and the United Kingdom report roll-out rates ranging between 30% and 80%, while ten countries (Bulgaria, Czechia, Germany, Greece, Croatia, Cyprus, Hungary, Poland, Romania, and Slovakia) have seen very limited progress in rolling out smart meters to household consumers, with adoption rates below 30%. Among them, only Croatia, Poland, and Romania have achieved roll-out rates exceeding 10%.

Without access to smart meters, consumers in these markets face significant limitations in the range of offers available from energy suppliers and have few opportunities to participate in flexibility initiatives. Additionally, the slow adoption of smart meters restricts suppliers and third parties from providing flexibility services.

The absence of time-differentiated retail electricity contracts also limits the delivery of effective price signals to consumers, reducing their ability to adapt energy usage based on fluctuating production costs. According to the EU Agency for the Cooperation of Energy Regulators (ACER),[7] at the end of 2023, 73% of EU household consumers are on some form of fixed-price contract, meaning they cannot actively engage in demand response. When it comes to EU non-household consumers, out of a selected sample of EU countries, only 33% have access to dynamic contracts.

7 ACER (2025): Unlocking flexibility

Battery costs and prices

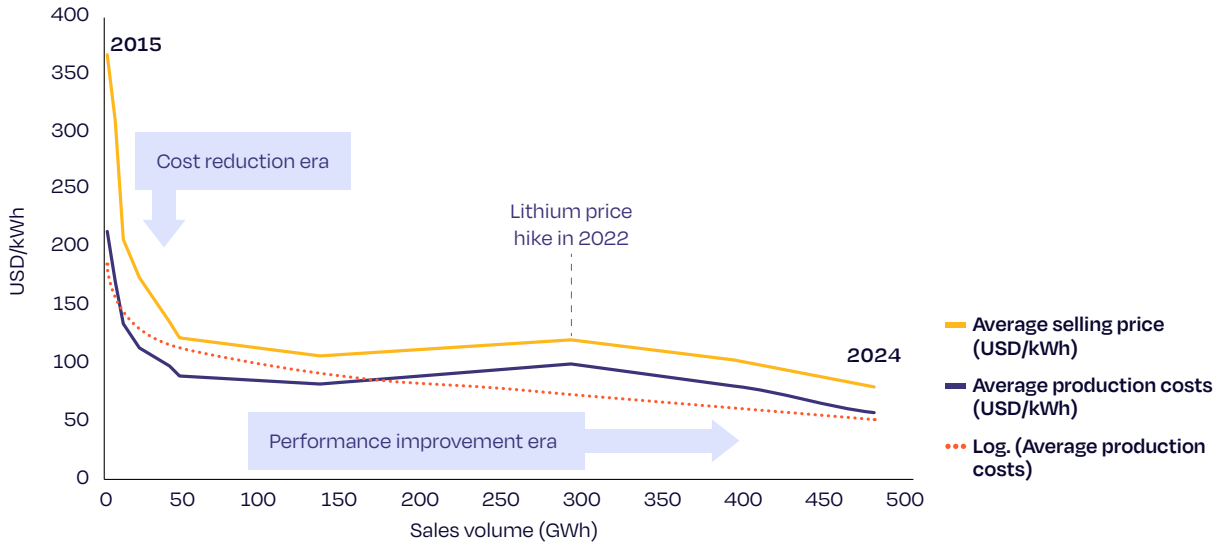
A key factor driving battery storage deployment, both for BTM and FTM applications, is the sharp decrease in the production cost of lithium-ion batteries (LIBs), which currently dominate the market. Differently from EV batteries, size and weight are not critical factors for stationary battery storage; the main priorities are low costs and high durability. In this respect, LIBs continue to hold a significant advantage over other technologies.

In batteries, similarly to solar PV, the industry has experienced two distinct transitions, namely the cost reduction era and the performance improvement era (see Fig. 22). Since their commercial inception in the 1990s, LIBs have undergone a steep reduction in their manufacturing costs and prices as industry manufacturing output has risen and enabled economies of scale. This included the scale-up of the upstream mining and material supply stages to support the growth of LIBs.

Figure 22

As battery costs and prices fall, sales volumes soar

Annual price and cost of lithium-ion battery production per year 2015-2024



Source: CRU Group
Analysis of financial filings of a large Chinese battery manufacturer. Includes LFP and NMC batteries

Between 2015 and 2020, with annual battery sales for this specific company rapidly ramping up to 50 GWh, production costs of mainstream batteries dropped by almost 60% from 210 to 90 USD/kWh (185 and 79 EUR/kWh). This remarkable decline in production costs allowed manufacturers to decrease their average selling price by nearly 70% over the same period.

After reaching the 50 GWh sales volume milestone, large manufacturers entered the next stage, where further reductions in cell and system prices were feasible, but would require performance improvements or increases in the amount of energy stored. From 2020 to the first half of 2024, cell and system production costs further decreased by 37% while prices fell by almost 40%. During this period, the annual sales volume increased ten-fold to about 500 GWh at the end of 2024.

Box 5

BESS manufacturing

In 2024, global battery cell production reached about 1.6 TWh, after exceeding the TWh mark just one year before (see Fig. 23). China dominates battery manufacturing with 77% of cell production located in the country. Europe ranks second with 145 GWh of battery production capacity, above North America (104 GWh) and the rest of the world (130 GWh).

Over 90% of the existing cell production capacity in Europe serves the EV market. Worldwide, around 80% of cell production is dedicated to EV batteries, but this is rapidly changing as the demand for stationary batteries gains traction. Also, nearly 60% of cell production was devoted to LFP (Lithium Iron Phosphate) batteries, a share that is expected to grow larger over the coming years given the cost competitiveness of LFP versus other chemistries like Li NMC (Lithium Nickel Manganese Cobalt) based batteries.

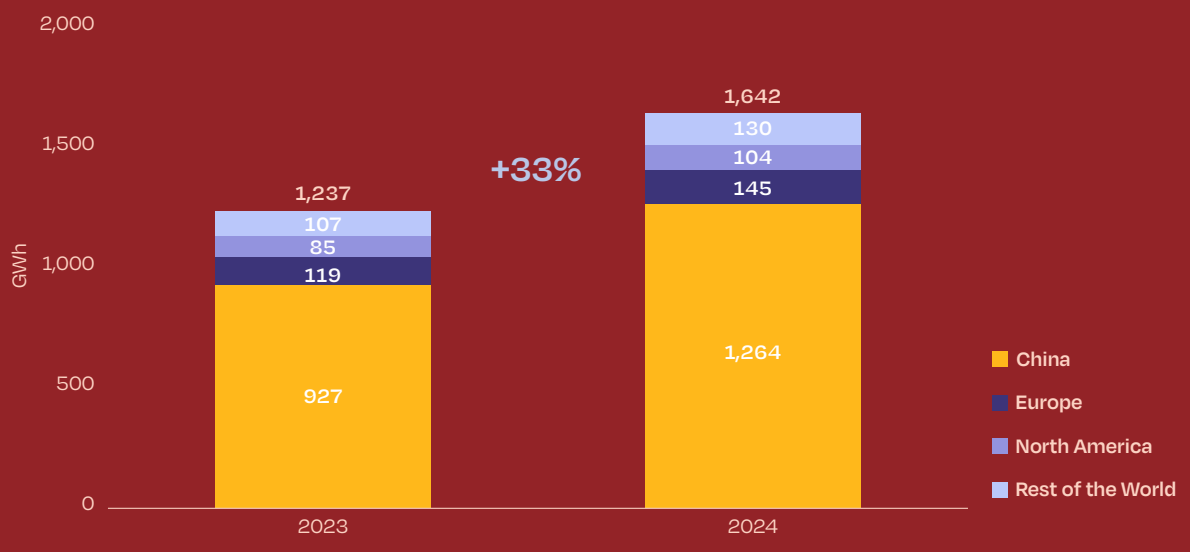
According to the Battery Atlas from 2024, current planned capacity in Europe has shrunk by 473 GWh in recent years. Several gigafactories have been halted due to weakened market demand, high energy costs, and logistical issues. Countries like Germany, Sweden, and Italy have been particularly affected by these negative developments.

However, this trend could be reversed with lower electricity prices for manufacturers, higher automation in factories, cell design optimisation, yield improvements, and easier access to lithium supply, which could lead to an optimised cost reduction in the production of battery cells to around 40 USD/kWh (35 EUR/kWh), a competitive cost range. Given the complexity of battery manufacturing, it is important to highlight that new manufacturers who started production on their own have rarely survived. Joint ventures with experienced producers have been the most successful strategy, and it is critical to rapidly scale up production. It also increases investors' confidence in the quality and reliability of supply.

Figure 23

Battery manufacturing grows further into the TWh era

Geographical breakdown of global lithium-ion battery cell production 2023-2024



Source: CRU Group

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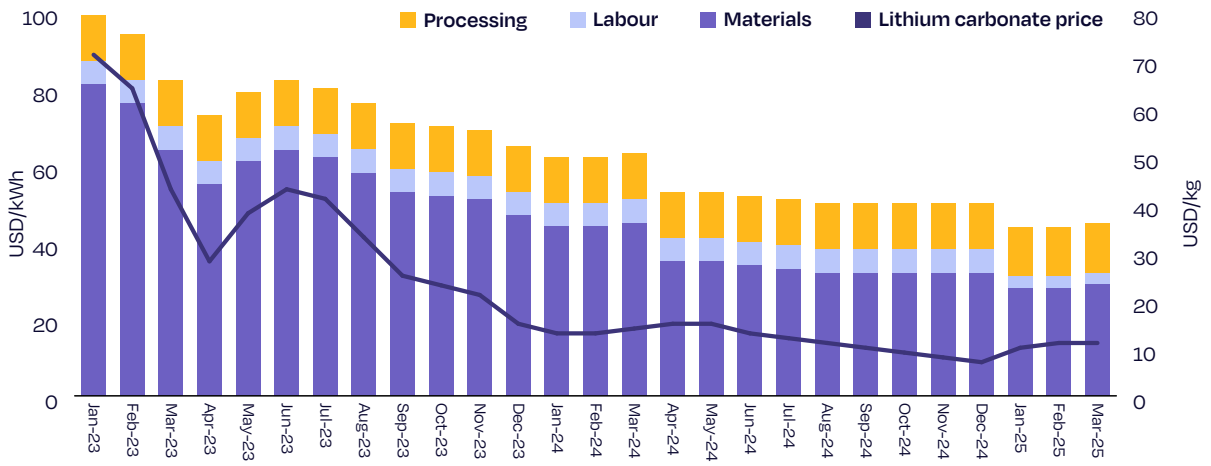
Due to the enormous advancements in research and development, economies of scale, and technological breakthroughs, the proportion of raw material costs within the overall battery cost increased. This means that battery prices were heavily influenced by the price of critical minerals, which can be volatile. That was the case in 2022 when a lithium price hike increased battery production costs by 22%. Production costs in cell manufacturing can be divided into materials, labour, and processing, with the first being the most impactful parameter. Lithium carbonate is the current frontier in cost reductions, as the overall cost of the cell closely follows the price of lithium. In 2024, LFP battery production costs in China dropped significantly due to lower lithium carbonate prices and decreased LFP manufacturing costs, reducing the overall cost of producing LIB cells. The decline in lithium prices throughout 2024 was reflected in BESS cell prices, which at the start of 2025 ranged between 45-50 USD/kWh (40-44 EUR/kWh) (see Fig. 24).

The driving factor behind this steep downward price trend is the large overcapacity that emerged in 2023 and continued in 2024. In China, the lithium-ion cell manufacturing overcapacity ratio rose above 600%. This led to manufacturers selling at or below production costs to maintain competitiveness and market share, pushing prices to new lows.

Figure 24

Material prices and cell capacities drive Chinese LFP costs

Average production cost of Chinese lithium iron phosphate (LFP) cells, vs lithium carbonate prices, nominal, Jan 2023 - Mar 2025



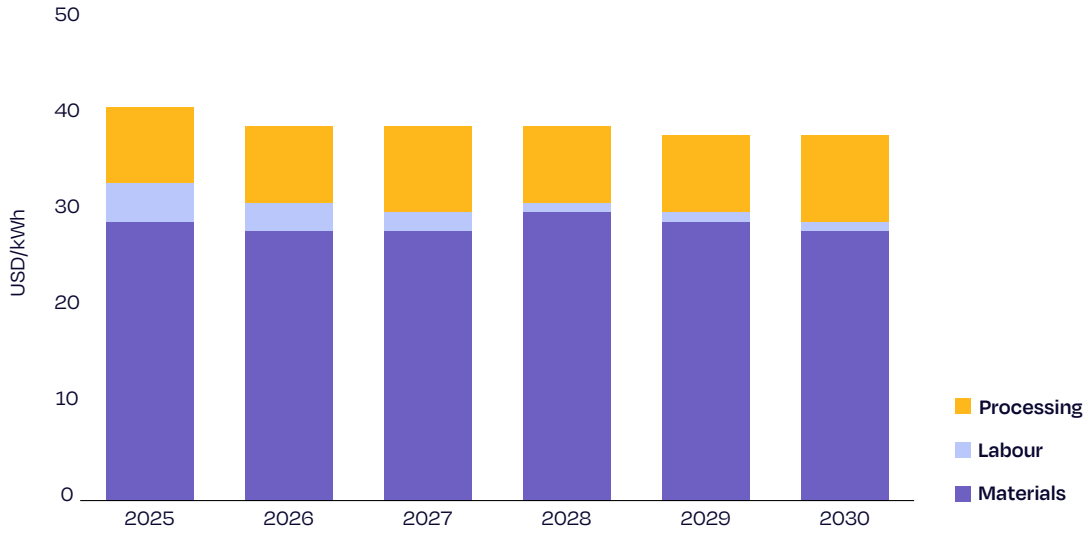
Source: CRU Group
CRU Battery Cost Model, 280 Ah LFP prismatic cell manufactured in China in 2023 shifted to 314 Ah in 2024 to match industry standard cell capacities

Considering the current trends and ongoing technological advancements, such as higher density and larger cell capacities, we can expect a further cost decline as cell-level energy density increases with more efficient material packing. Deeper automation of factories is also expected to push further down the production of LFP cells to less than 40 USD/kWh (35 EUR/kWh) (see Fig. 25).

Figure 25

Automation and larger cells will drive down the production cost of LFP in real terms

Average production cost of Chinese lithium iron phosphate (LFP) cells, 2025 real, 2025-2030



Source: CRU Group

200 MW BESS, Blackhillock, UK

Box 6

Research and Innovation in battery storage

The rapid expansion of battery applications across mobility and stationary storage is driving intensive research and innovation (R&I) efforts to improve energy density, safety, and sustainability. To meet growing demand while improving performance and resource efficiency, R&I focuses on advancing lithium-based chemistries and developing non-lithium alternatives.

A key objective is to increase material efficiency and reduce reliance on critical raw materials (CRMs). This involves both improving battery chemistry, through innovations that improve energy density and lifecycle, and advancing recycling technologies to recover valuable materials more effectively.

Focusing on both mobility and stationary applications, this section details improvements in lithium-based batteries and non-lithium chemistries, advantages, challenges, usages and relevant players and R&I projects for each technology. An overview of the different chemistries taken into account and their main features is provided in Table 1.

Trends in lithium-based solutions

As the battery industry evolves, research efforts are shifting from purely improving performance and safety toward developing a new generation of cost-effective and high-performance chemistries. Among Lithium-ion (Li-ion) chemistries, there has been a shift from Nickel Manganese Cobalt (NMC) to Lithium variants such as Lithium Iron Phosphate (LFP) and Lithium Iron Manganese Phosphate (LFMP) (Gen 3), driven by the e-mobility industry. Solid-state solutions (Gen 4) and new anode alternatives are also being investigated.

LFMP and LFP batteries

LFP and LFMP solutions reduce reliance on expensive CRMs such as nickel and cobalt, making batteries more cost-effective. They also offer excellent thermal stability, minimising the risk of thermal runaway and enhancing overall safety, as well as offering a long lifecycle. Their enhanced safety and longevity make them particularly well-suited for urban EVs.

LFMP batteries represent an advancement over LFP technology and could gain greater importance in the future, potentially surpassing LFP. With higher energy density and greater storage capacity, LFMP can deliver larger amounts of energy more quickly, making it advantageous for power-intensive applications. Due to reduced material costs, LFMP is considered more cost-effective than LFP.

Despite their advantages, LFP and LFMP have lower energy density compared to current chemistries. R&I efforts are needed for cathode, anode, and electrolyte materials to improve energy density, lifecycle and cost and lifetime to enable stationary applications.

LFP batteries are commercially available among the main players in China and Asia. The same companies are also advancing LFMP technology, reaching TRL 6-8. In Europe, R&I projects such as IntelLiGent and NEXTCELL are aiming to increase Li-Ion batteries performance.

Solid-State batteries

The shift toward solid-state energy storage is driven by two main factors: the recognition of limitations in traditional energy storage systems, particularly those using liquid electrolytes, such as Li-ion batteries, and significant advancements in materials science, introducing novel materials and fabrication techniques essential for solid-state battery (SSB) development. In terms of electrolyte technology, there is no consensus, both ceramic (Oxide and Sulphides) and polymer electrolytes are being developed.

One of the most critical advantages of SSBs is their enhanced safety, reducing the risk of fires, explosions, and battery leakage. Additionally, SSBs have the potential for higher energy densities compared to Li-ion, partly due to the ability to use Lithium-metal anodes. The stability of solid electrolytes also contributes to a longer battery lifespan.

Anode and cathode materials and chemistries compatibilities need to be further explored in R&I to meet performance and low-cost objectives and scale up production. Once this challenge has been overcome, SSBs could leverage existing Gen 3 manufacturing infrastructures, reducing the need for entirely new production lines.

Most SSB technologies are currently at TRL 6-7, with advancements driven by OEM with in-house research, or in partnerships with, or investments in, SSB companies. European R&I projects on SSBs include AM4BAT, SEATBELT, HELENA, ADVANGEN, and ARISE.

Lithium Silicon batteries

Lithium-Silicon (Li-Si) materials have great potential in battery applications due to their potential high energy density and long lifecycle compared to Li-ion. They also have great charge-discharge cycle efficiency, enabling fast charging.

However, this superior performance comes with a challenge: silicon expands significantly (up to 300%), leading to mechanical stress such as cracking, ultimately reducing battery lifespan. Manufacturing costs and complexity are other challenges of Li-Si batteries, as integrating silicon into existing battery manufacturing processes requires advanced techniques.

As an anode material silicon has only recently gained traction in the battery industry, especially with players focused on fast charging for EVs. Further R&I is ongoing in EU-funded projects, such as SiGNE and HighSpin. The ReSilex project is recycling silicon from end-of-life solar PV modules to produce Li-Si battery cells.

New and emerging technologies for non-lithium batteries

R&I efforts are increasingly focusing on non-Li-ion batteries to address several challenges associated with lithium-based technologies, including resource availability and sustainability, cost, safety and specific application requirements, especially for long-duration storage. Various technologies are considered below, ranging from technologies close to the market, such as Sodium-ion batteries, to novel materials with lower TRL, such as aqueous batteries.

Metal-ion batteries

Besides widely used Li-ion batteries, metal-ion batteries include other chemistries that use alternative metals such as sodium, aluminium, zinc, or magnesium. This section focuses on Sodium-ion batteries (SIBs) due to their market potential for stationary storage and their closeness to commercialisation.

Similarly to LFP and LFMP batteries, SIBs reduce reliance on expensive CRMs such as nickel and cobalt, making batteries more cost-effective regarding material availability. Their key technological advantages include high power capability, long lifecycle and safety, making them suitable for both mobility and stationary applications. SIBs can be manufactured using existing LIB production methods, enabling rapid scalability.

The main challenges they face are their current lower energy density than Li-ions and higher near-term costs of manufacturing. Advancements in cathode design could further enhance their competitiveness, making SIBs a viable option for sustainable energy storage and mobility applications.

While several companies are nearing mass production, research is still needed to optimise electrode materials and improve efficiency. European R&I projects such as NAIMA, SPRINT, EPISODE, and SOLSTICE are working on Metal-ion batteries.

Metal-sulphur batteries

Metal-sulphur (Me-S) batteries use sulphur as a low-cost, abundant cathode material, combined with lithium, sodium, magnesium or other metals, reducing reliance on CRMs. They offer high energy potential but face challenges in stability and power performance. Among these, Sodium-sulphur (Na-S) batteries stand out for their promise in stationary energy storage, with both high temperature (HT) and room temperature (RT) variants under development.

Na-S HT batteries are a mature, commercially available technology, particularly in Japan and the United States. They offer long discharge durations (6-7 hours) and scalability to grid-scale storage. The production process is well-established, with automated manufacturing and easy recycling. However, their high operating temperatures require thermal management, affecting environmental impact. Currently, R&I efforts focuses on improving electrolyte performance, energy density, and overall efficiency to reduce operating costs and enhance safety.

Na-S RT batteries are still in early research stage (TRL 4) and seems promising for cost-effectiveness and sustainability, also solving the safety and volume expansion issues of Na-S HT. While not yet commercially available, they offer potential for stationary applications, with expected commercialisation after 2035. Future research is needed to enhance energy density, safety, and recyclability. R&I projects such as MXNA SB and SOLIDCON are working on Metal-sulphur batteries.

Flow batteries

Flow batteries differ from other battery technologies. They encompass various chemistries, including iron-, copper-, zinc- or vanadium-based. Vanadium Redox Flow Batteries (RFBs) are the most mature, with a TRL of 9 and commercial availability.

RFBs offer high cycle stability and long discharge duration (5-10 hours), making them suitable for stationary applications. Sustainability and recyclability are another advantage of this technology, except for vanadium RFBs.

Vanadium's high cost and limited supply drive research into alternative chemistries. Challenges for R&I and market uptake include a limited operating temperature range (5-40° C), lower round-trip efficiency and a lack of automated manufacturing. Further advances in alternative chemistries could enhance RFBs' cost-effectiveness, material availability and environmental impact. R&I projects working on different flow batteries technologies include ReZilient, HyFlow, and MeBattery.

Other chemistries: Metal-air and Aqueous batteries

Metal-air batteries generate energy through a reaction between metal and oxygen, offering high theoretical energy density, low costs due to inexpensive cathode materials and sustainability. However, challenges remain to be solved, notably their poor cycling capabilities, low energy efficiency and short lifetime. Their main market potential lies in stationary energy storage. Lithium-air and zinc-air batteries receive the most R&D focus, alongside other metals like sodium, aluminium, and magnesium. R&I projects such as HIPERZAB and HEMZAB are working on Metal-air batteries.

Aqueous batteries, including Zinc-ion and Sodium-ion variants, are gaining attention for their high safety, sustainability, and affordability. They use non-toxic, non-flammable electrolytes, offering high power and reversibility. However, they face challenges such as a limited voltage window and electrode material dissolution hinder commercialisation. Research is needed to improve stability and performance, making aqueous batteries a promising alternative for cost-effective and sustainable energy storage solutions. R&I projects such as WIZBAT aim to develop Aqueous batteries.

Conclusion

Research and innovation in battery technologies, particularly lithium-based chemistries, continue to be driven by the growing demands of the e-mobility sector. At the same time, the energy transition calls for advanced solutions in stationary storage, where promising non-lithium chemistries are gaining momentum alongside ongoing improvements in lithium technologies.

While major advancements are led by key industry players in Asia, Europe's battery R&I community is actively contributing to the development of a competitive and sustainable industrial value chain. Supported by EU initiatives and frameworks such as the BATT4EU Partnership, Europe is positioning itself to lead in battery innovation.

As battery technologies evolve rapidly, their strategic role in achieving the EU's Green Deal objectives becomes increasingly clear. Continued investment in R&I is essential to delivering safe, efficient and sustainable energy storage solutions for a decarbonised future.

Table 1

Battery chemistries and their main features

Battery type	Lithium based			
	LFP	LFMP	Solid-state	Lithium silicon
CRM dependence	+/-	+/-	+/-	+/-
Safety	+/-	+/-	+	+/-
Application	Mobility & Stationary	Mobility & Stationary	Mobility & Stationary	Primarily mobility
Gravimetric Energy Density	+/-	+	++	++
Volumetric Energy Density	-	+/-	++	+
Life cycle (cycles)	+	+	-	+/-
Lifespan (years)	+/-	+/-	varies	varies
Manufacturing cost	+/-	-	- -	- -
Recyclability/ sustainability	+	+	+/-	varies

Battery type	Non-lithium					
	Sodium-ion	Sodium Sulphur HT	Sodium Sulphur RT	Advanced Redox Flow	Metal air (Zn-air)	Aqueous (Zn-ion)
CRM dependence	++	+	+	+ (except Vanadium)	++	++
Safety	+	-	-	++	++	++
Application	Stationary, light weight mobility	Stationary	Stationary	Stationary	Stationary	Stationary
Gravimetric Energy Density	-	+	+	- -	+	-
Volumetric Energy Density	-	Unknown	Unknown	- -	+	- -
Life cycle (cycles)	++	+	+	++	-	+/-
Lifespan (years)	+	+	+	++	+	++
Manufacturing cost	+/-	-	+/-	-	+	+
Recyclability/ sustainability	- -	+	+	+	+	+

Legend	
++	Very good
+	Good
+/-	Average
-	Low
- -	Poor

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EUPD RESEARCH TOP BRAND PV WECHSELRICHTER DEUTSCHLAND 2024
TIER 1 Bloomberg NEW ENERGY FINANCE
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Grid-scale battery boom enabled by power price volatility, cost competitiveness, revenue stacking opportunities and growing flexibility needs

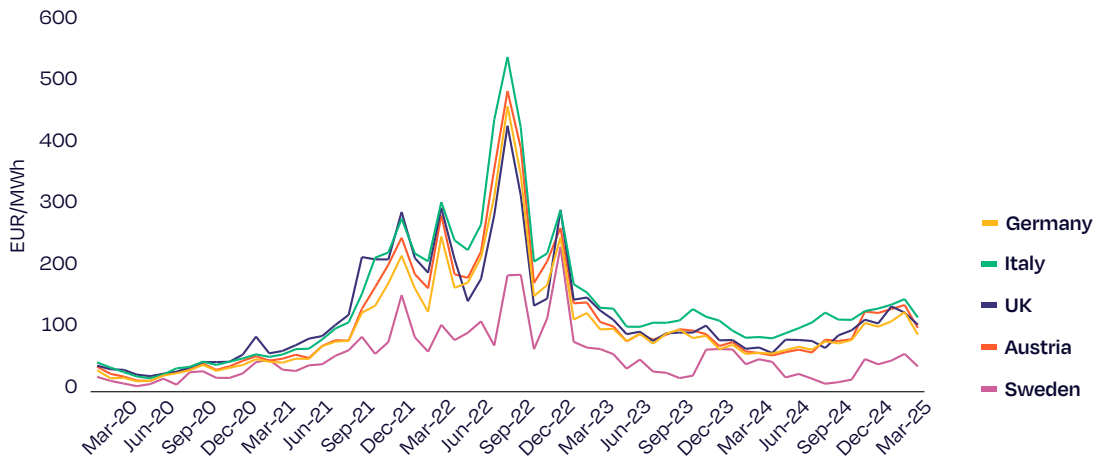
Wholesale electricity prices

Electricity prices in European wholesale markets follow similar trajectories to retail electricity prices for households and SMEs (see Fig. 26). In the second half of 2021, wholesale electricity prices rose sharply throughout 2022, peaking during the summer. Because natural gas frequently sets the electricity price under the marginal pricing system, the spike in gas prices also drove electricity costs higher. By 2024, average spot prices fell below the 100 EUR/MWh mark and remained well below the peaks of the past two years, but still above the pre-energy crisis levels, signalling a deeply rooted and structural increase in power prices. At the end of 2024, wholesale market prices hiked again to more than 100 EUR/MWh for the top 4 markets, due to rising supply uncertainties in natural gas markets, heavier reliance on fossil fuel generation during the winter months, higher carbon emission costs, and increased electricity demand.

Figure 26

European wholesale electricity prices retreated in 2023 and early 2024 but increased again after August 2024

Europe top 5 BESS markets wholesale electricity prices Jan 2020 - Mar 2025



Source: Ember (2025)

The current price conditions reiterate the need to further advance the energy transition to reduce dependence on fossil hydrocarbons, which create high price instability and are subject to geopolitical tensions, supply disruptions, and market speculation. At the same time, the current wholesale electricity price volatility provides a strong incentive to deploy battery storage for energy arbitrage and self-consumption optimisation.

Cost competitiveness

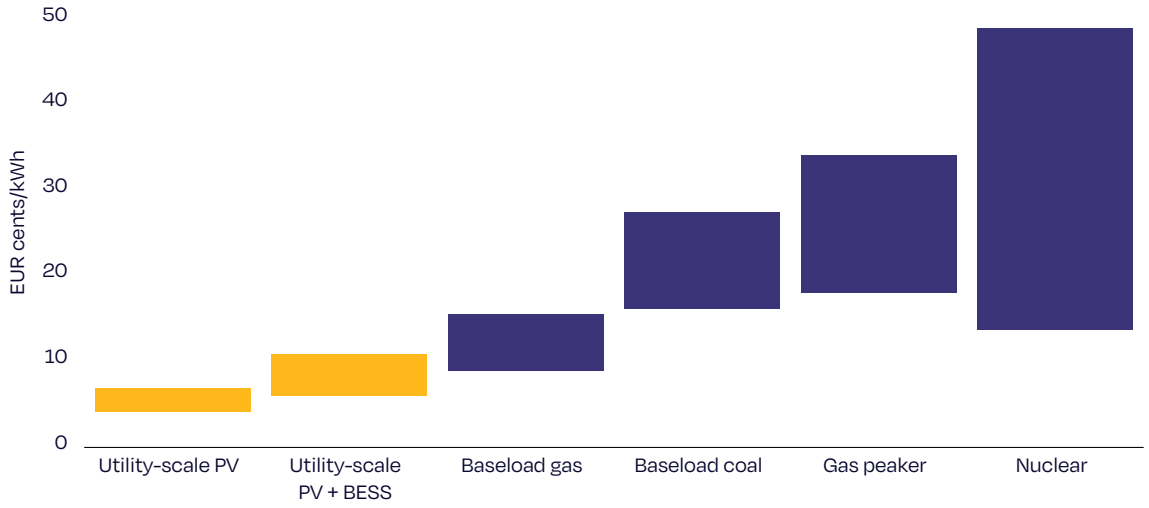
Solar PV and battery storage have become highly cost-competitive in Europe for both technological and economic reasons. Over the last decade, solar PV system costs have dropped by 85% due to the massive scale-up in manufacturing, technological improvements in PV module efficiency and durability, and decreased component costs (inverters, racking, and balance of systems).

According to the latest Fraunhofer ISE analysis on the levelised cost of electricity (LCOE) of renewable energy technologies in Germany, utility-scale solar PV is now delivering electricity at an average of 5.6 EUR cents/kWh (see Fig. 27).[8] Only a decade ago, the LCOE of utility-scale PV in Germany was 60% higher than in 2024. Compared to utility-scale solar, average baseload gas and coal generation costs are 120% and 292% higher respectively.

Figure 27

Utility-scale solar couples with batteries is already more cost-competitive than fossil baseload

LCOE of solar PV + BESS and selected technologies in Germany in 2024



Source: Fraunhofer ISE (2024)
Baseload gas plants refer to combined cycle gas turbines (CCGTs), while gas peaking plants include gas turbines running on methane (GT-CH4) and conventional oil/diesel power plants reconverted to burn natural gas or hydrogen blends (GT-conversion)

However, to deliver on the flexibility requirements of a renewable-based energy system, solar PV at the large-scale level needs to transition to a hybrid configuration with battery storage. Hybrid solar + storage projects strengthen energy security by delivering a more consistent and reliable supply of cheaper and cleaner electricity. Battery storage enables excess solar power to be stored and utilised during periods of high demand or lower solar generation, greatly reducing the reliance on fossil fuel-based backup plants.

In Germany, newly constructed large-scale solar + storage systems can now dispatch electricity at an average of 8.4 EUR cents/kWh at different times of the day, a level that is cost-competitive against all conventional power sources. The average LCOE for newly built baseload gas plants (CCGT) is 45% higher, at 12.3 EUR c/kWh, while new gas peakers generate electricity at an average LCOE of 26 EUR c/kWh, a cost that is 208% higher than average utility-scale PV + storage. Coal-based generation has a 159% higher LCOE (21.9 EUR c/kWh), while new nuclear plants generate electricity at a cost of 31.3 EUR c/kWh, which is 271% higher than utility-scale solar + storage.

8 Fraunhofer ISE (2024): Levelised cost of electricity of renewable energy technologies

Revenue streams and energy storage targets

The regulatory landscape shapes the financial attractiveness, technical integration, and operational viability of battery storage. Supportive policies, market mechanisms, and energy storage targets continue to drive large-scale BESS deployment in Europe.

As the transition to a decarbonised energy system progresses, the design of electricity markets must evolve to effectively integrate the flexibility required by renewable-based electrification.

Battery systems are flexible by definition and can provide a wide range of essential services to the grid, namely:

- frequency regulation;
- peak shaving;
- voltage support;
- spinning reserves;
- grid balancing and stability;
- black start capability;
- mitigation of costly grid upgrades at the transmission and distribution level.

All these fundamental capabilities must be remunerated fairly via the provision of markets for grid services, which can be auctioned with:

- capacity markets, to ensure a sufficient level of firm capacity to meet peak demand;
- balancing markets and slower frequency response revenues (such as mFRR, replacement reserves, and secondary/tertiary reserves);
- faster frequency responses, and maintaining operational grid requirement via fast-acting injections (e.g. FCR);
- additional ancillary markets to procure non-frequency services such as black start capabilities, inertia, and local congestion mitigation services.

15.8 MW / 35 MWh BESS, Tangermünde, Germany

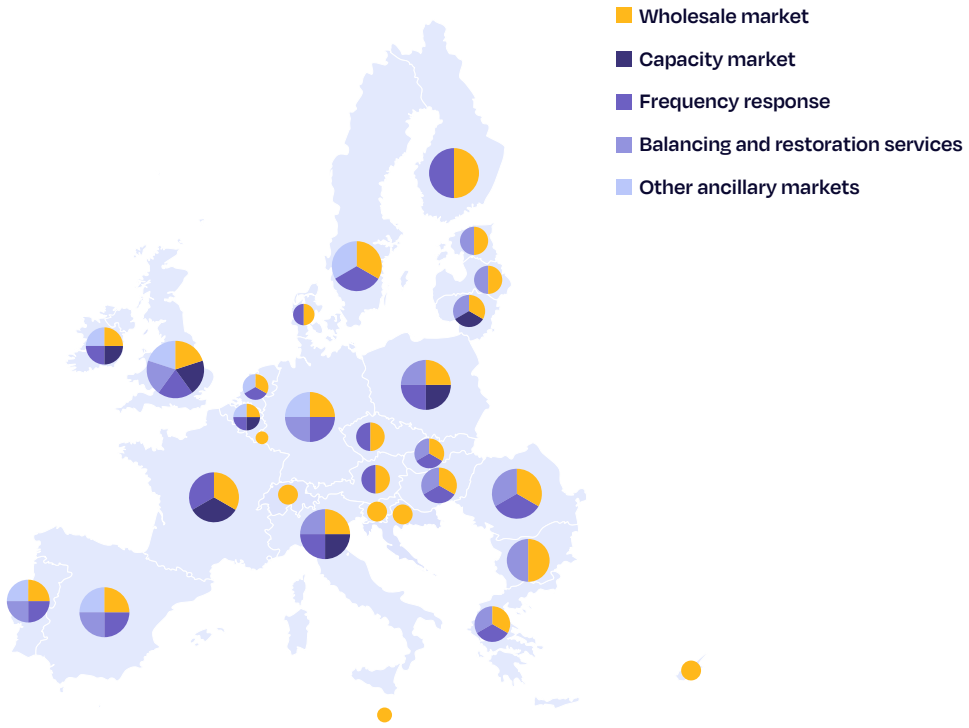
The existence of these different market streams determines the potential for revenue stackability, the economic viability of battery projects, and ultimately the provision of essential grid services that enhance stability, efficiency, and resilience.

Currently, 19 out of 29 countries included in the scope of the report have created some form of fast frequency regulation markets, 14 have opened balancing and restoration services, and just 8 have created other ancillary markets (see Fig. 28). To ensure adequate security of supply capacity, remuneration mechanisms can also be created; at the current stage, however, only in 7 countries batteries can access this type of remuneration. Overall, the three main revenue streams (frequency response, balancing and restoration, and other ancillary services) are available in only four countries – Germany, Portugal, Spain, and the United Kingdom – and only the United Kingdom combines them with a capacity market.

Figure 28

More battery revenue streams have opened across Europe, but most grids services are still not remunerated

Mapping of key revenue streams for grid-scale batteries in Europe 2025



Source: SolarPower Europe, Aurora Energy Research

Wholesale energy trading for BESS is allowed across all European markets because it is the primary process to help stabilise prices, reduce grid congestion, smooth renewable integration, and encourage market liberalisation and cross-border cooperation. This fundamental is reflected in the Clean Energy Package, where battery storage is recognised as a distinct asset class, separate from generation and consumption, and has market access rights and is expected to participate on a level playing field. However, the principle of exclusivity is applied in certain schemes, such as Germany's innovation tenders. Under the current rules, storage can only be charged from the PV system and not from the grid. This largely limits the potential of the co-located installation, and restricts the system services that the technology can provide.

Another crucial policy element for BESS deployment is the existence of energy storage targets. Clear, time-bound, targets provide investment certainty and drive innovation, while providing key input for grid expansion planning. Energy storage targets help improve energy security ensuring a reliable power supply, and foster collaboration between public and private entities.

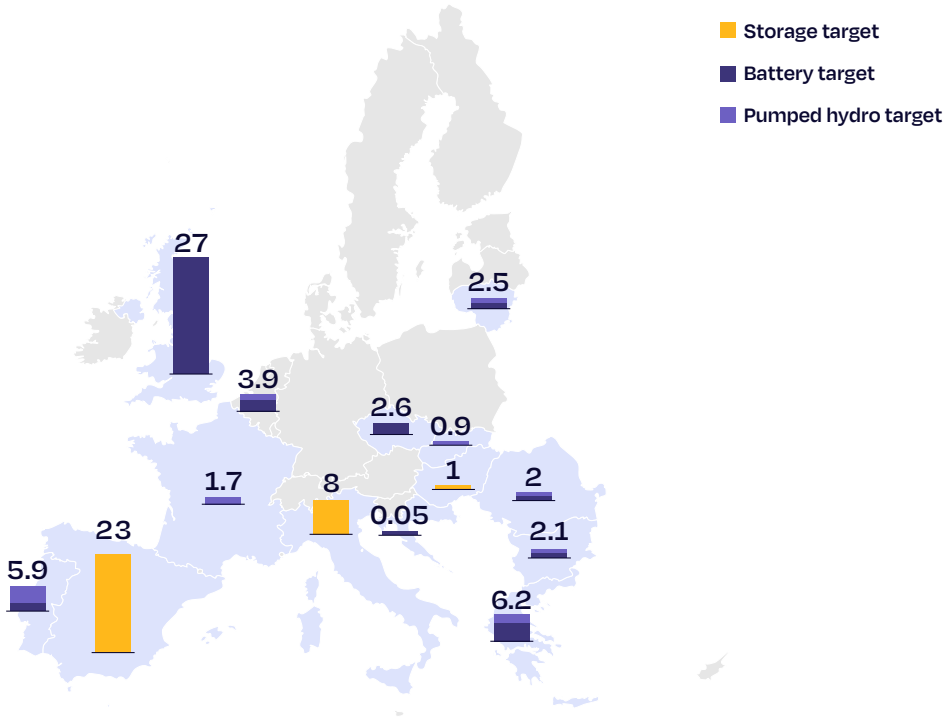
Most EU National Energy and Climate Plans (NECPs) do not adequately address the investments required for grid expansion, flexibility, and digitalisation. While most NECPs mention flexibility in some form, only 14 have set energy storage targets measured in MW/MWh or EUR (see Fig. 29). In the previous edition of this report, only 9 countries had established storage targets, indicating that more and more governments are recognising the critical role of energy storage. However, most of the existing targets remain rather unambitious and not adequate to the scale of renewable deployment. Only 9 countries have dedicated battery storage targets (Belgium, Bulgaria, Croatia the Czech Republic, Greece, Lithuania, Portugal, Romania, and the United Kingdom), most of which will be vastly surpassed under our Medium Scenario. By contrast, the UK and Spain serve as good examples of setting a high bar for energy storage.

As a general good practice, Member States should commit to setting energy storage targets in their NECPs to guarantee that storage is fully integrated into their national strategies for decarbonisation and energy security.

Figure 29

Most European countries do not have a national energy storage target

European map of energy storage targets in National Energy and Climate Plans (or equivalent)



Source: SolarPower Europe, Wood Mackenzie
The UK's Clean Power 2030 Action Plan includes specific targets for energy storage

Flexibility needs

The growth of renewables in Europe – particularly solar PV – has been remarkable over the past decade. At the end of 2024, solar PV capacity in the region reached 407 GW, a four-fold increase from 98 GW in 2015. In the EU, PV capacity reached 338 GW in 2024, enabling solar to generate 11% of the EU's electricity (304 TWh) and surpass coal (269 TWh) for the first time.[9] In 2024, solar and wind combined provided a record-breaking 30% of the EU's electricity consumption.

Over a third of Europe's solar PV capacity (124 GW) is utility-scale, with Spain (36 GW) and Germany (30 GW) leading the way, together accounting for over half of ground-mounted PV systems. However, most of this capacity has been deployed as standalone projects, without hybridisation with wind or battery storage.

Several Member States with high levels of solar PV penetration are already facing both technical challenges, such as grid connection and integration bottlenecks (increasing curtailment), and financial challenges, such as market structure, investment attractiveness, and remuneration for renewable producers. Countries like Spain, Germany, and the Netherlands show that increased energy system electrification and the deployment of appropriate flexibility sources like battery storage are needed to accompany the renewable energy transition.

Germany serves as a prime example, as the European market leader in both solar and battery storage, but also grappling with the challenges of variability, limited system flexibility, insufficient demand-side response, and a lack of adequate storage solutions.

17.2 MW PV coupled with 5 MW / 5 MWh BESS, Bontepolder, the Netherlands

9 Ember (2025): European Electricity Review

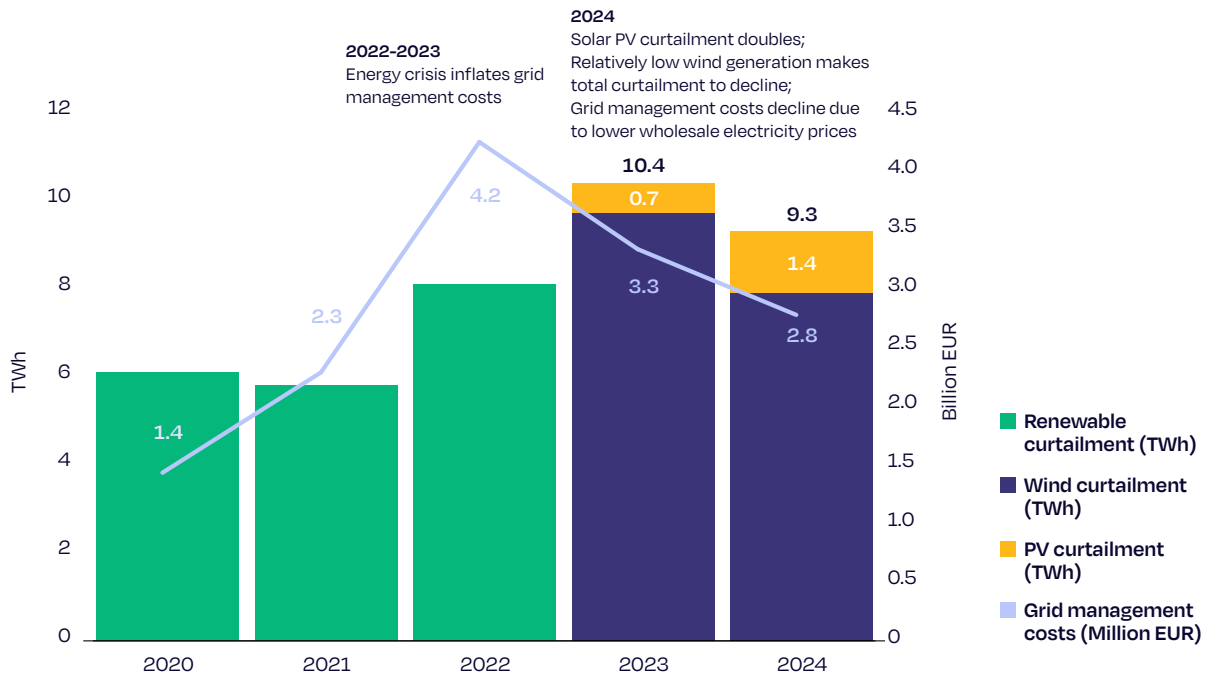
Two key indicators that highlight renewable integration challenges are the level of curtailment of renewable power generation and grid management costs. At present, in times of low demand, renewable energy producers are compensated for halting electricity production, while fossil fuel power plants are remunerated to ramp up generation during periods of low renewable output.

In 2024, Germany curtailed 9.3 TWh of renewable generation and incurred 2.8 billion EUR in grid management costs, a decrease compared to the previous two years (see Fig. 30). After grid management costs peaked at 4.2 billion EUR during the energy price crisis in 2022, they have declined towards pre-crisis levels as wholesale electricity prices have receded. This decrease in costs should not be misinterpreted, because it is not directly related to successful grid buildout, which continues to progress very slowly in the country. In fact, grid management costs are expected to rise again to 3.5 billion EUR in 2025 and more than 4.4 billion EUR in 2027, according to German grid operators.[10]

Figure 30

German curtailment and grid costs temporarily decrease in 2024, despite solar curtailment surge

Evolution of renewables curtailment and grid management costs in Germany 2020-2024



Source: Bundesnetzagentur
Breakdown of curtailment of renewables for the period 2020-2022 not available

The 9.3 TWh of German renewable power generation curtailed in 2024 represents 3.5% of the total renewable power generation. Solar PV curtailment accounted for about 1.4 TWh and a 15% share of renewable curtailment, a doubling in absolute terms, and 8 percentage points higher compared to 2023. This increase was due to the steep growth of solar PV installed capacity and exceptionally high solar irradiation in the summer of 2024. Wind energy curtailment remains much higher than solar PV, and almost 8 TWh of onshore and offshore wind generation had to be curtailed. However, due to less windy conditions in 2024, wind curtailment was reduced by 19%.

10 Bundesnetzagentur (2024): Prognose des umfangs und der kosten der maßnahmen für engpassmanagement

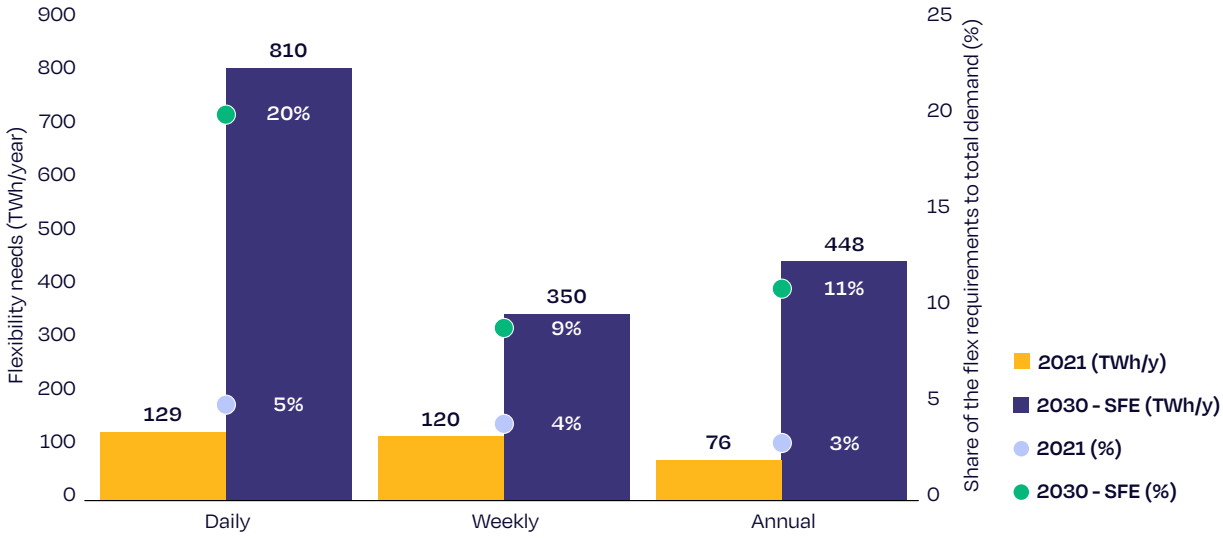
Regardless of this temporary decrease in grid congestion costs and curtailment, as renewable capacity continues to grow, and thermal power plants are gradually retired, supply-demand imbalances will occur more frequently in Europe. Without adequate clean flexibility solutions like battery storage, this will result in increased curtailment and rising grid management costs. A flexible, electrified and renewable-based energy system provides clear economic and climate benefits. According to SolarPower Europe's Mission Solar 2040 report, a more flexible and electrified energy system in 2030 saves the European Union 30 billion EUR in annual energy system costs, decreases wholesale electricity prices by 25% relative to 2023 levels, and avoids the emission of 151 million tonnes of CO_2 equivalents per year.[11]

Balancing supply and demand now requires increased flexibility across various timescales – daily, weekly, and seasonal. With a rapid growth of variable renewable generation across the EU, total flexibility needs are projected to increase five-fold from 325 TWh/year in 2021 to 1,608 TWh/year in 2030, according to SolarPower Europe's Mission Solar 2040 study (see Fig. 31). These needs are set to represent 40% of EU electricity demand by 2030.

Figure 31

Total EU flexibility needs will quintuple by 2030, half of requirements will be on a daily basis

EU flexibility requirements by 2030 under the most advanced flexibility scenario



SFE is the most advanced flexibility scenario in the study Mission Solar 2040.

11 SolarPower Europe (2024): Mission Solar 2040

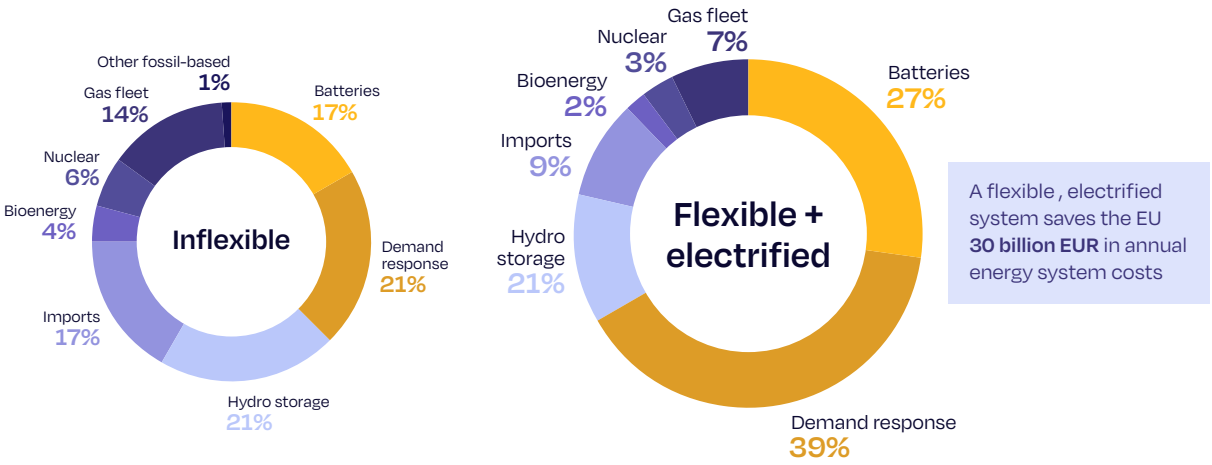
Notably, half of these flexibility requirements will arise on daily basis (810 TWh/year), providing an opportunity for battery storage to play a critical role by shifting excess daytime generation to meet evening demand peaks.

In a flexible and electrified energy system, batteries and demand-response step in as game-changers with the potential to meet two-thirds of EU daily system flexibility by 2030 (see Fig. 32). Other clean flexibility solutions can deliver more than 30% of these daily flexibility needs, while nuclear and natural gas are only required to provide 10%. To meet the EU's increased energy system flexibility needs, the Mission Solar 2040 report modelling shows that a massive scale up of battery storage capacity is required – with a 16-fold growth from 49.1 GWh installed in the EU-27 in 2024 to 780 GWh in 2030 and an almost 40-fold growth to 1.8 TWh in 2040.

Figure 32

Batteries and demand response can provide two-thirds of EU daily system flexibility by 2030

Breakdown of EU daily flexibility sources in a rigid vs electrified & flexible energy system in 2030

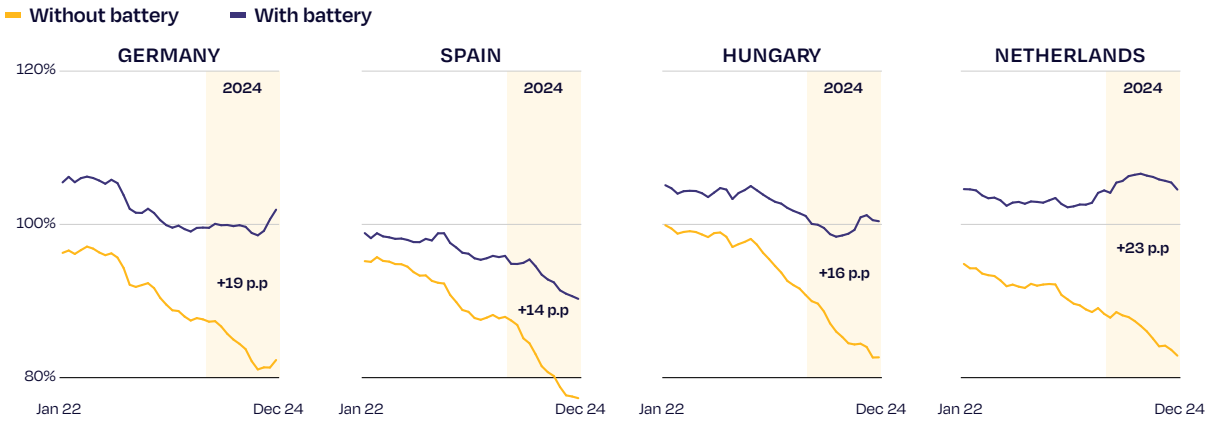


Under the right framework conditions, adding batteries to renewable plants increases investment attractiveness and ensures viable business models for developers. Hybridising solar PV with BESS increases solar capture rates – the market value of solar electricity relative to the average wholesale price – which are dropping as more solar capacity is added to a system without adequate flexibility resources. In front-running solar markets like Germany, Spain, Hungary, or the Netherlands, where the challenges associated with the smooth integration of renewables are already visible, coupling storage and solar generation brings a sharp improvement in solar capture rates. In 2024, batteries increased the market value of solar electricity in these four countries by 18 percentage points on average, reinforcing the business case for utility-scale solar (see Fig. 33).

Figure 33

In 2024, batteries improved the market value of solar electricity by 18 percentage points onverage in four major European solar markets

Price captured by a typical solar PV asset relative to the average price of electricity (%) in selected countries



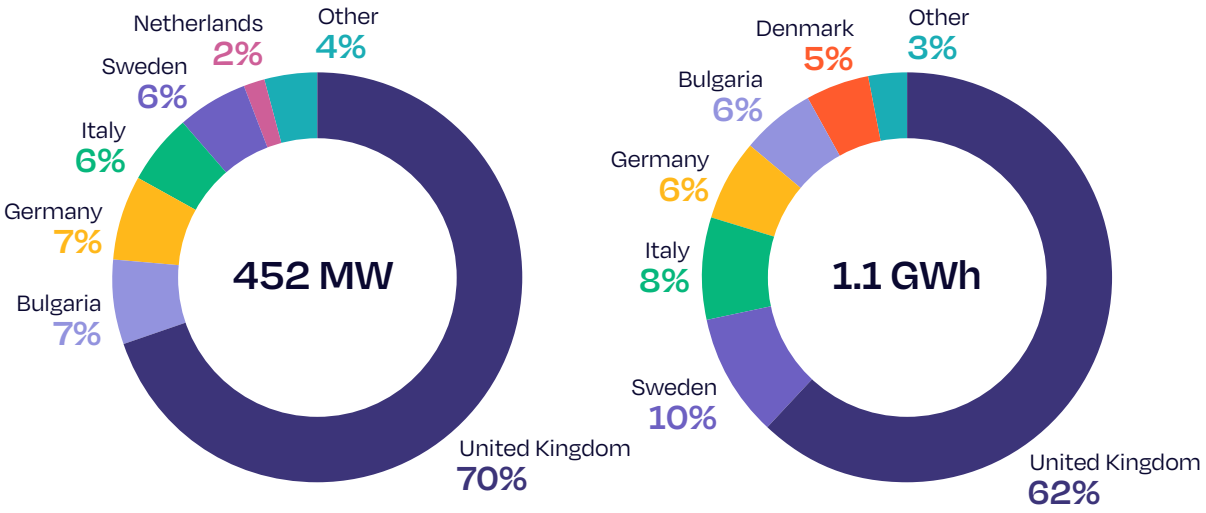
Source: Ember (2025), SolarPower Europe
The lines represent solar capture rates and reflect the market value of solar energy when sold on the day-ahead market, with and without a co-located battery. Battery model is for a 90 MW solar array with a 60 MW 2-hour battery. It is for a marginal unit and assumes that electricity prices are not affected by the existence of the battery. Average solar capture rate indicated in the title refers to the average of the countries shown in the chart for 2024. Percentage points are abbreviated to p.p.

Despite the tremendous benefits associated with the hybridisation of large-scale solar PV with batteries, the uptake has been rather slow until now. In the last 10 years, the standalone configuration has consistently added more than 90% of the annual utility-scale installations. In cumulative terms, standalone projects represented 92% of the 20.3 GWh of grid-connected large-scale BESS, while PV+BESS only constituted 5% of total capacity, slightly over 1 GWh. Despite rapid growth in recent years, the current installed battery storage capacity remains inadequate to address the variability of renewables, particularly for large-scale solar PV. By the end of 2024, the installed power of grid-scale BESS represented less than 10% of total installed solar PV capacity, and less than 1% of large-scale PV systems were paired with BESS.

Figure 34

The UK leads Europe on hybrid solar + storage projects

Geographic breakdown of Europe cumulative hybrid solar + storage in 2024 in power (MW) and storage capacity (GWh)



Source: Rystad Energy (2025)

The **United Kingdom** is the European leader in hybrid PV+BESS installations, accounting for 62% of total deployed capacity (see Fig. 34). This dominant position is driven by strong policy support, and favourable market conditions, which enabled the construction of Europe's largest hybrid parks. Long-term financial incentives through a well-structured capacity market, an inclusive CfD framework, streamlined permitting, and market reforms enabling BESS to provide grid services have made the UK the most attractive hybrid market in Europe. Outside the UK, key markets include **Sweden** (10% of the hybrid PV+BESS capacity), **Italy** (8%), **Germany** (6%), **Bulgaria** (6%), and **Denmark** (5%). The remaining EU-27 countries and Switzerland collectively represent only 3% of installed capacity, highlighting the high market concentration in hybrid solar and storage deployment.

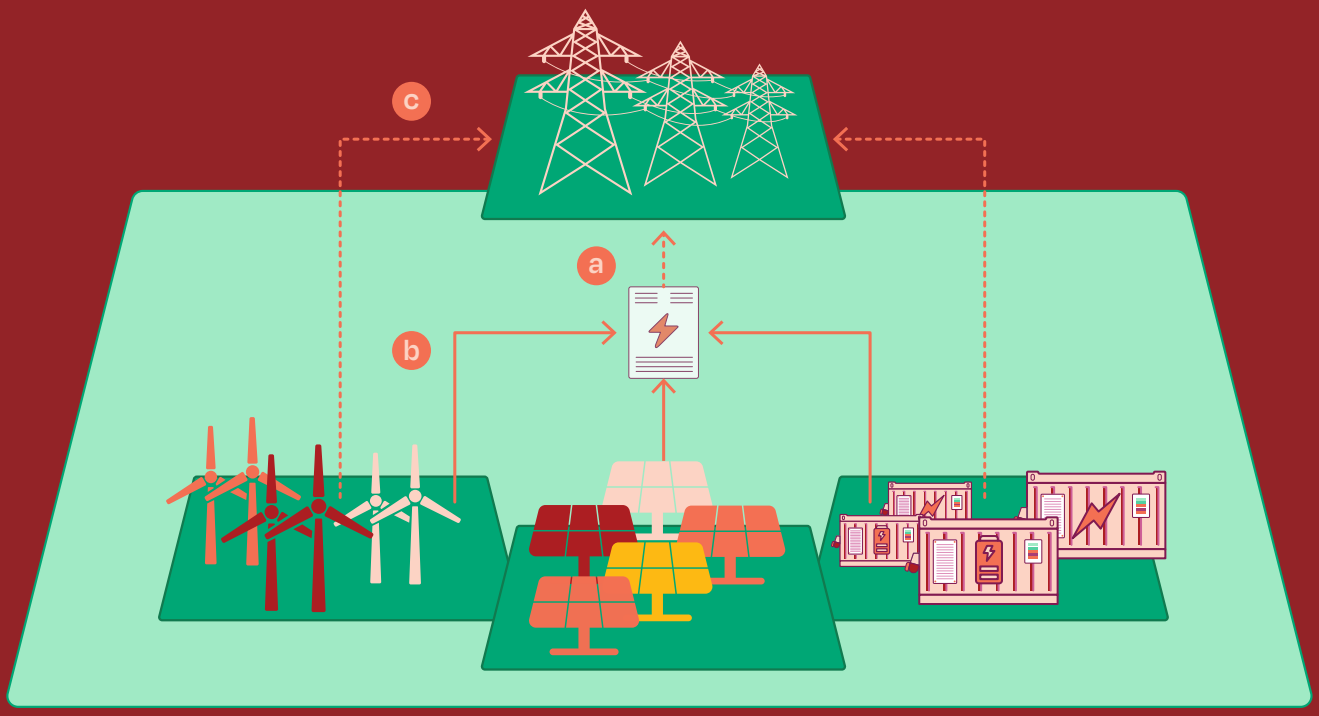
Box 7

Embracing the benefits of Hybrid PV and Storage systems for Europe's energy transition

Hybrid systems are the combination of technologies in the same facility and sharing a single grid connection access point (see Fig. 35). The most common combination of hybrid systems today is solar PV with BESS, or with wind turbines. Both project structures offer numerous benefits to the energy system, electricity consumers and developers of renewable projects.

Figure 35

Fully hybrid vs co-located projects



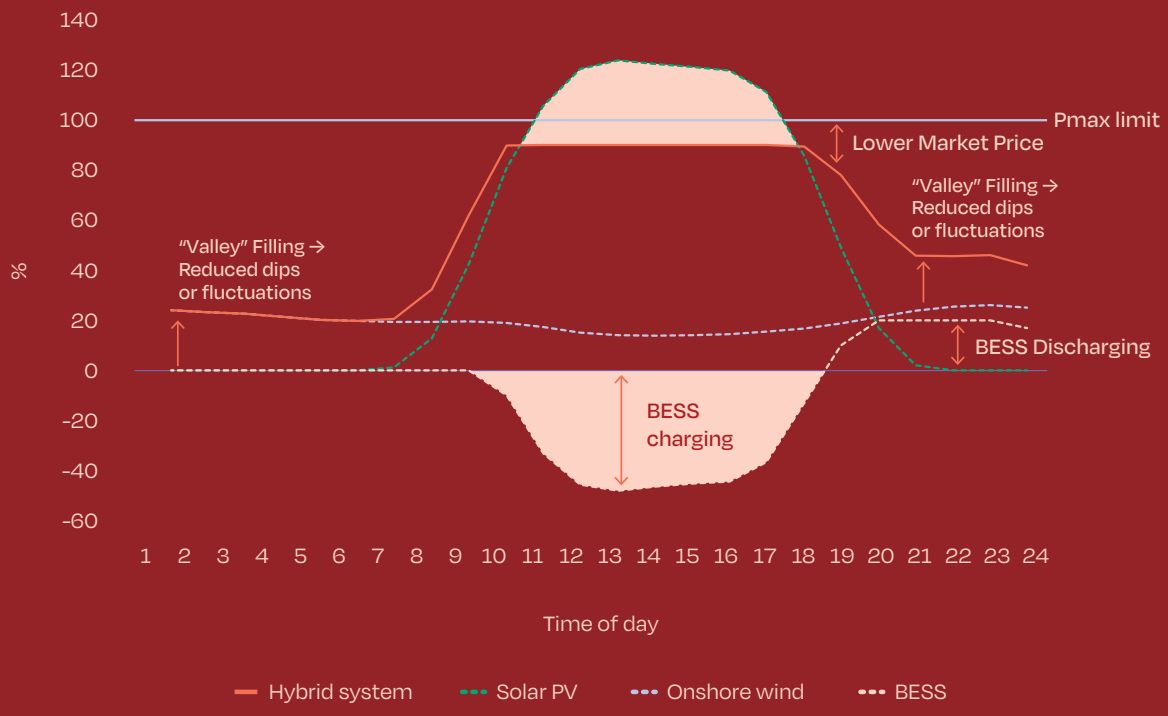
a Grid connection point
b Fully hybrid: Operating together
c Co-located: Operated separately

Source: AFRY, SolarPower Europe

Hybridisation enables resource-related synergies between generation technologies. For example, integrating different energy sources can optimise the use of grid infrastructure – such as grid connection point capacity, as illustrated in Fig. 36 – and minimise land usage. Coupling solar PV with BESS also enhances energy security by ensuring a more stable and reliable power supply. A battery will allow surplus solar energy to be stored and used when demand is high or sunlight is low, which ultimately reduces curtailment and increases the number of hours per year when renewables fulfil the EU's energy demand, substantially reducing the EU's reliance on fossil-based backup plants. An overview of the benefits of hybrid projects is provided in Fig. 37.

Figure 36

Illustrative grid connection point usage optimisation (%)

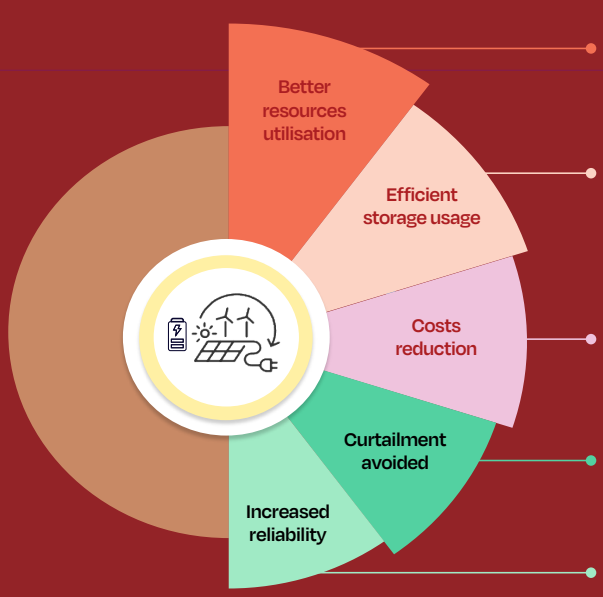


Source: AFRY and SolarPower Europe's analysis

Despite these benefits and significant growth in recent years, PV + BESS projects constituted only 7% of total BESS additions in continental Europe in 2024, with more than 60% of these projects being located in the UK. Europe is far from exploiting the full potential of hybrid PV systems.

Figure 37

Benefits of hybrid projects



Better resources utilisation. By combining different generation technologies, a more efficient usage of the existing resources can be achieved.

Efficient storage usage. Allowing hybrids to withdraw electricity from the grid enables an optimised operation of the system.

Costs reduction. Hybrid projects realise cost synergies by maximising existing infrastructure usage and reducing the financing costs for renewables.

Curtailment avoided. By hybridising renewables with storage, the surplus renewable output can be stored and be injected later into the grid during hours of peak demand.

Increased reliability. Combining different generation technologies and/or storage increases the reliability of the energy output.

Source: AFRY's analysis

15.9 MW PV coupled with 5.3 MW / 17.9 MWh BESS, Kreuth, Germany

Addressing existing bottlenecks today would significantly accelerate the development of PV + BESS projects. It starts with the development of clear strategies for storage and flexibility, enhance planning with grid hosting capacity maps, and ensure accessible EU funding and targeted state aid for hybrid projects. Permitting processes should be streamlined and fast-tracked for hybridising existing plants in congested grid areas, with standardised rules and alignment with grid expansion plans.

Furthermore, grid operators must modernise their systems by digitalising grid connection agreements, implementing fast-track connection processes for system hybridisation that do not need extra capacity and are located in congestion areas, and eliminating double charging for storage to create fairer tariffs.

On the economic front, more inclusive auction design, CAPEX support for storage, and enabling batteries to participate in multiple revenue streams, are essential steps to support the hybrid business case. Additionally, fair de-rating factors in capacity markets should be reflective of the role hybrids can take in enhancing energy security. Finally, Guarantees of Origin (GOs) should be issuable for stored renewable energy, ensuring tracking accuracy and opening new routes-to-market for batteries, such as Power Purchase Agreements (PPAs).

By tackling these challenges and adopting suitable measures, the EU can significantly speed up the rollout of hybrid solar projects, enhancing energy security, advancing decarbonisation, and improving grid resilience.

Embracing the benefits of hybrid PV systems

for Europe's energy transition

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SolarPower Europe

European battery storage market scenarios 2025-2029

European battery storage markets are projected to experience significant growth over the coming five years, with annual installations reaching about 120 GWh and total capacity hitting 400 GWh by 2029. Utility-scale batteries will drive this expansion, more than compensating the decrease in household installations. Germany, Italy, the UK, the Netherlands, and Spain are expected to lead the market. Large-scale batteries will dominate, with hybrid projects becoming the norm, and regulatory support and increased storage duration will enhance system flexibility. Our High Scenario predicts an even steeper upward trajectory, potentially reaching 600 GWh installed by 2029 – which however falls below the trajectory needed to accompany variable renewable deployment across the continent.

Sustained growth to bring European batteries to 120 GWh annual installations and 400 GWh total capacity by 2029

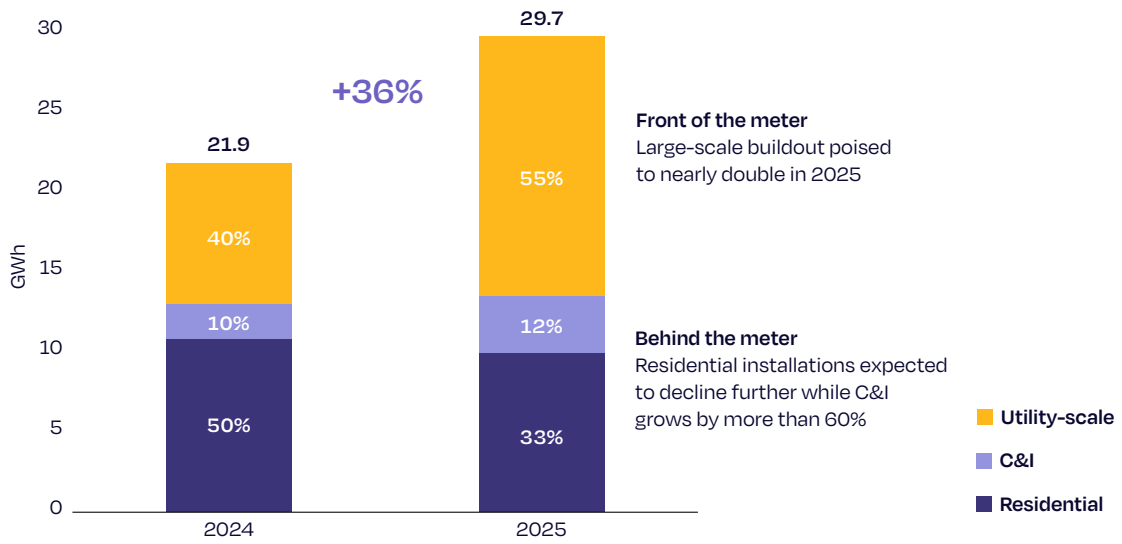
Following a decade of record annual growth, with an acceleration over the 2021-2023 period and a partial slowdown in 2024, battery storage deployment in Europe is expected to rise again with renewed strength from 2025. As from 2021, the energy crunch in Europe kick-started the battery revolution at the household level, with citizens driving the energy transition in times of crisis. As electricity prices started to recede in 2023, and demand for residential BESS cooled down, the large-scale segment reached sizeable volumes after years of continued growth, taking the European BESS market to new heights.

Last year, batteries registered a 15% increase in deployment, a clear deceleration from the 84% growth rate achieved in 2023. The 11% drop to 10.8 GWh in home battery installations significantly eroded European market growth in 2024, as the segment still provided half of total annual installations. However, grid-scale batteries surged 79% to 8.8 GWh, and delivered 40% of total yearly additions. In combination with a mild expansion in the C&I segment (+17%), 21.9 GWh of total BESS capacity were added in 2024. Last year was therefore a turning point for the market, when changed segment dynamics started becoming visible on total installations. But the new dawn of large-scale batteries in Europe is fully materialising in 2025, when the segment will become the market's trailblazer, speeding up total installations back again (see Fig. 38).

Figure 38

European annual battery market expansion set to speed up again in 2025, driven by utility-scale

Europe annual BESS installed capacity 2024-2025



With 16.2 GWh, the utility-scale battery market is projected to nearly double in 2025 with an 84% growth rate, compensating an overall stagnating behind-the-meter segment, where household batteries are expected to decline a further 9% to 9.9 GWh and C&I BESS are continuing their upward trajectory (+64%) reaching 3.6 GWh.

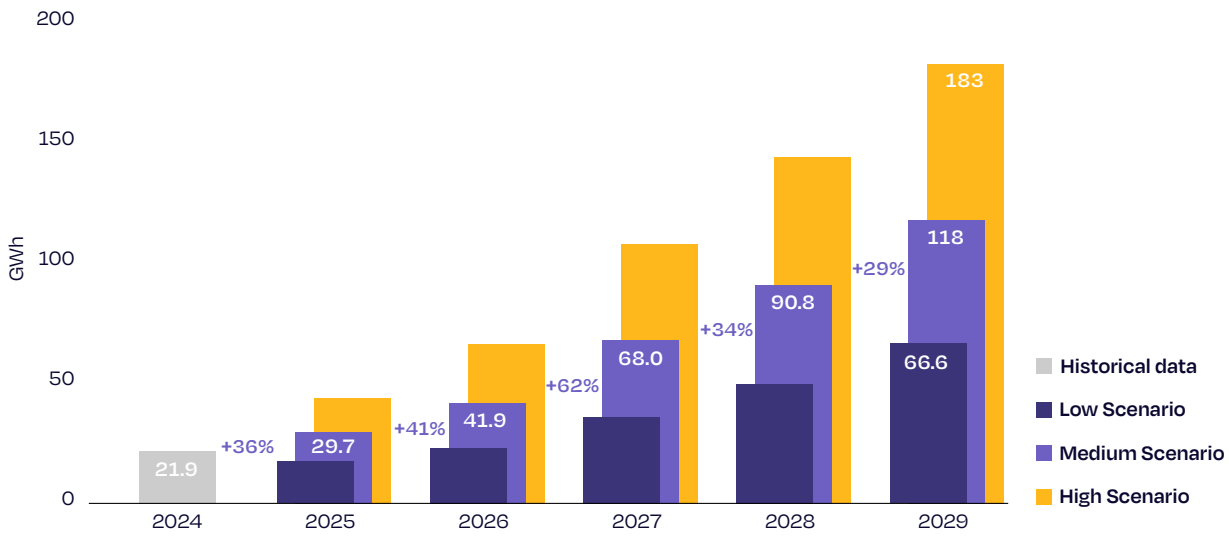
Under our most-likely Medium Scenario, the European battery market altogether will grow to 29.7 GWh this year, a 36% increase from 2024. That means that around half of the total battery storage capacity operating in Europe in 2024 will be deployed in just one year. Despite global geopolitical turmoil, volatile energy markets, continued reliance on fossil fuel imports, economic headwinds and competitiveness concerns, our Medium Scenario anticipates that battery deployment will accelerate in 2025. The energy security imperative, the integration of more renewables, strong climate commitments, favourable economics of BESS against conventional power generators, and new aid schemes and revenue streams, are all factors pointing to an unstoppable wave of battery deployment in Europe.

Beyond 2025, in line with current market and regulatory conditions, our Medium Scenario points to a steep upward trajectory, with almost 41.9 GWh (+41%) and 68 GWh (+62%) to be added in 2026 and 2027 (see Fig. 39). Towards the end of the decade, annual growth rates will somewhat slow down, as the market enters a maturity phase. Still, we expect a 34% increase to 90.8 GWh in 2028 and an additional 29% growth to 118 GWh in 2029, bringing the annual market to a level over five times larger than in 2024.

Figure 39

European battery growth to intensify reaching almost 120 GWh by 2029

Europe annual BESS market scenarios 2025-2029



Given the critical role of supportive regulatory frameworks in shaping market development across European countries, the divergence between the Low and High Scenarios becomes increasingly pronounced. Permitting and grid bottlenecks for renewables and batteries, commissioning delays in solar & storage auctions or aid schemes, limited progress in electrifying heating and transport, a further contraction of the residential PV market, continued limited attractiveness at the C&I level, and participation of reserve fossil-fuel based power plants in flexibility markets, constitute very concrete risks to speedy battery deployment.

The Low Scenario, taking into account these and other limiting factors, projects a 20% market contraction to 17.4 GWh in 2025 and slower growth to 66.6 GWh added in 2029. While this deployment volume is 43% lower than the Medium Scenario, it still constitutes a three-fold increase compared to 2024 levels.

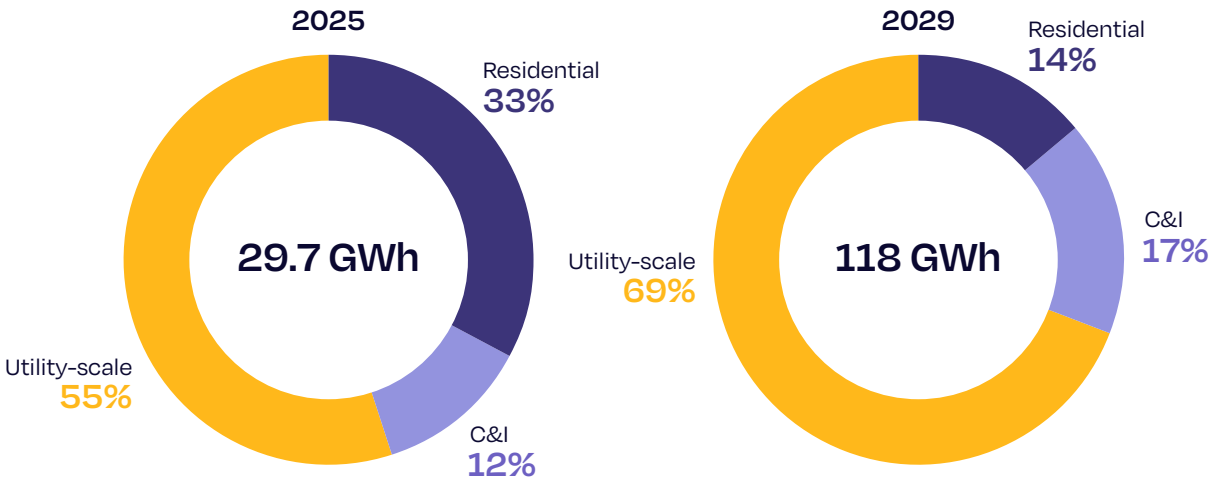
By contrast, boosted by an improvement in the above-mentioned policy and market conditions, which accelerate decarbonisation efforts in Europe, , our High Scenario anticipates a strong uptick in annual installations, projected to cross the 100 GWh threshold already in 2027 and reaching 183 GWh by 2029 – that's 56% higher than the Medium Scenario and an eight-fold increase from 2024.

Looking at the breakdown of installations under our Medium Scenario in 2025 and 2029, it becomes clear that the dominance of large-scale batteries will only exacerbate over the next five years (see Fig. 40). From a 55% contribution on yearly additions in 2025, grid-scale batteries are projected to deploy two-thirds of the annual market in 2029. By that year, the segment will deliver over 80 GWh, 5 times more than in 2025.

Figure 40

Grid batteries supply majority of European deployment in 2025, and capture more than two-thirds of annual market in 2029

Europe annual BESS segmentation 2025-2029



The growing dominance of large-scale battery installations reflects a fundamental shift in the energy transition: traditional standalone renewable power plants are evolving into integrated renewable-plus-storage projects. Hybridising battery systems with solar PV or wind farms, as well as retrofitting existing renewable assets with storage, is poised to become the industry norm.

Large-scale batteries are perfectly suited to complement the variable nature of renewable electricity generation, enhancing the value of renewable energy while providing crucial energy balancing and grid services. This transition will be especially apparent in European countries with high solar PV penetration, where effective integration of variable renewables increasingly depends on storage solutions to align supply with demand and support system flexibility.

Box 5

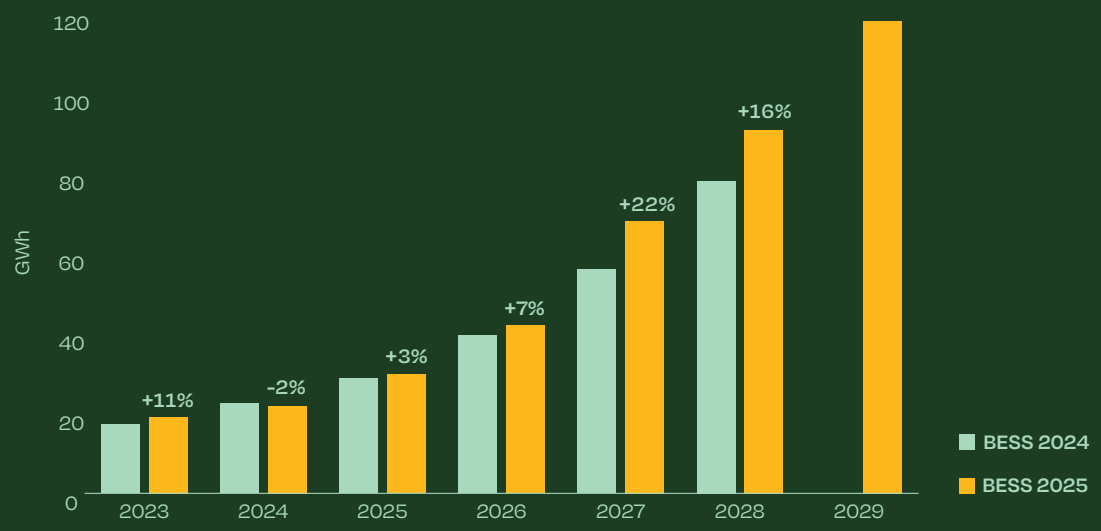
Looking back and forth

With the 2024 edition of this report, we extended the scope of our analysis to all battery segments across Europe for the first time. The scope enlargement came with a number of challenges, including on the estimation of the existing battery fleet, due to the widespread lack of data collection and reporting on battery storage across European countries. After updating historical data in this new edition, it appears that our previous estimates were slightly below actual deployment levels. In this year's report, we have revised upwards annual installations in 2023 by 11% (see Fig. 41). The major reason was a lack of visibility on the large-scale segment, which meant that we were unable to capture 3 GWh of utility-scale solar that had been installed in Europe up until 2023.

Figure 41

European annual battery market expectations are increased compared to previous outlook

Comparison Medium Scenario BESS 2025 vs Medium Scenario BESS 2024



BESS refers to the European Market Outlook for Battery Storage

In last year's 'European Market Outlook for Battery Storage 2024-2028' (BESS 2024) report, our Medium Scenario anticipated 22.4 GWh of battery capacity deployed in 2024. The current revision of the actual installation data lands very close to that level, as the market was just 2% lower than we thought, at 21.9 GWh.

Compared to BESS 2024, we have revised upwards our forecast numbers for all the years under analysis, especially towards the end of the decade. For 2025, we have raised our expectations by 3%, while in 2026 we expect 7% more battery capacity to be brought online. In this year's BESS 2025, the outlook for 2027 and 2028 is strongly increased – by 22% and 16% respectively – compared to our previous analysis. Given the tremendous boost to the large-scale segment in 2025, with enormous pipelines in major markets, sharp declines in battery prices, new support schemes across European markets, and improvements in regulatory frameworks, we are now more optimistic about future battery deployment across the board.

The need to balance energy supply and demand has also catalysed numerous CAPEX support schemes launched by EU Member States over the past months, which bring more visibility over future deployment. Countries like Spain, Bulgaria, Romania, Greece, Poland, Lithuania and Hungary have channelled EU funds to provide direct grants and loans to standalone or hybrid projects, with clear deployment targets and delivery milestones.

Additionally, grid batteries are set to increase their average storage duration as revenue stacking opportunities evolve and grid service demands grow. As the need for system flexibility and energy shifting intensifies, large batteries are expected to increase from today's average discharge duration of around 2 hours toward durations of 4 to 8 hours, whereas the first of several 8-hour projects is currently being developed by a European company in Australia. As storage durations lengthen, large-scale batteries will play an increasingly significant role in Europe's overall storage capacity mix.

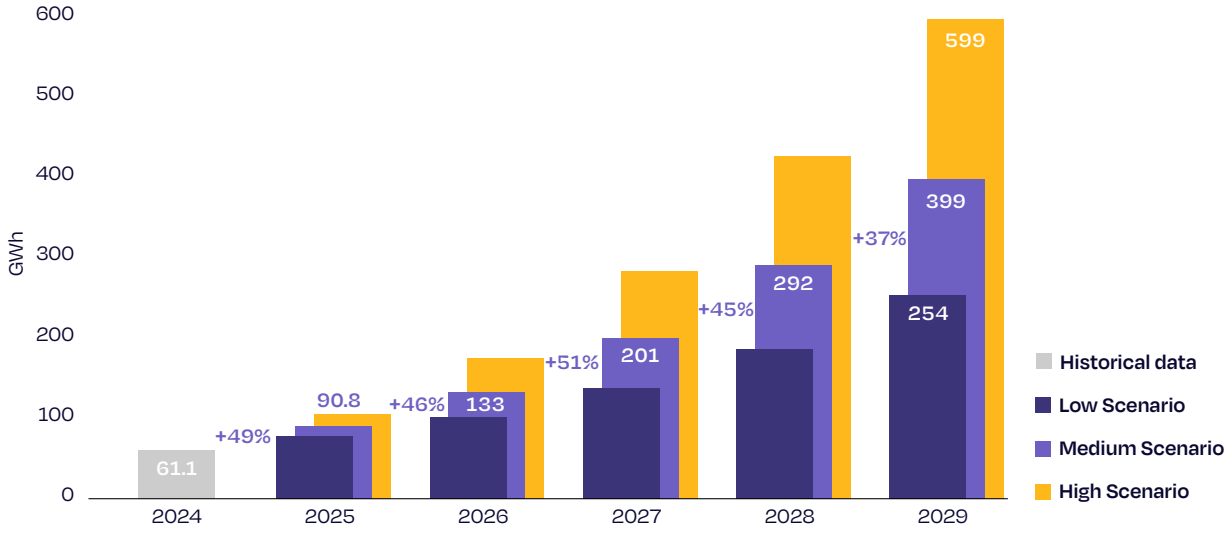
This intensification in the deployment of grid-scale batteries is not expected to be matched with a parallel uptick of BTM applications. Under the current conditions of relatively low electricity prices, fragmented and insufficient support, and high borrowing costs, the weight of BTM installations is expected to decline from 45% in 2025 to 31% in 2029 in our Medium Scenario. However, looking at the absolute installation volumes, both segments are poised to grow substantially. Under the Medium Scenario, the residential market will reach 16.8 GWh in 2029, which is 38% higher than the record 12.2 GWh added during the energy crisis in 2023, whereas the C&I segment continues its steady growth and becomes the second largest segment with 20.2 GWh in 2029.

Looking at the resulting evolution of the BESS fleet in Europe, our Medium Scenario anticipates strong expansion rates until 2029. In 2025, the cumulative BESS capacity in Europe is expected to grow by 49% and surpass the 90 GWh milestone (see Fig. 42). Going forward, current dynamics suggest a 45% CAGR in operating battery capacity reaching the 400 GWh scale by the end of 2029. Under the Medium Scenario projections, the total BESS running fleet in Europe multiplies its size by more than 6 times in just 5 years.

Figure 42

European battery fleet on track to reach 400 GWh by 2029 but High Scenario lies 200 GWh above

Europe cumulative BESS market scenarios 2025-2029



The High Scenario assumes much higher battery additions in 2025, which take the cumulative capacity over the 100 GWh mark. Over the next four years, this scenario presents a higher CAGR of 55% that brings the total operating fleet to about 600 GWh by 2029, which is exactly 200 GWh higher than the Medium Scenario. On the opposite end of the spectrum, the Low Scenario displays a more sombre deployment that results in less 80 GWh installed by 2025 and barely crosses the 250 GWh mark by the end of 2029, with a 34% CAGR.

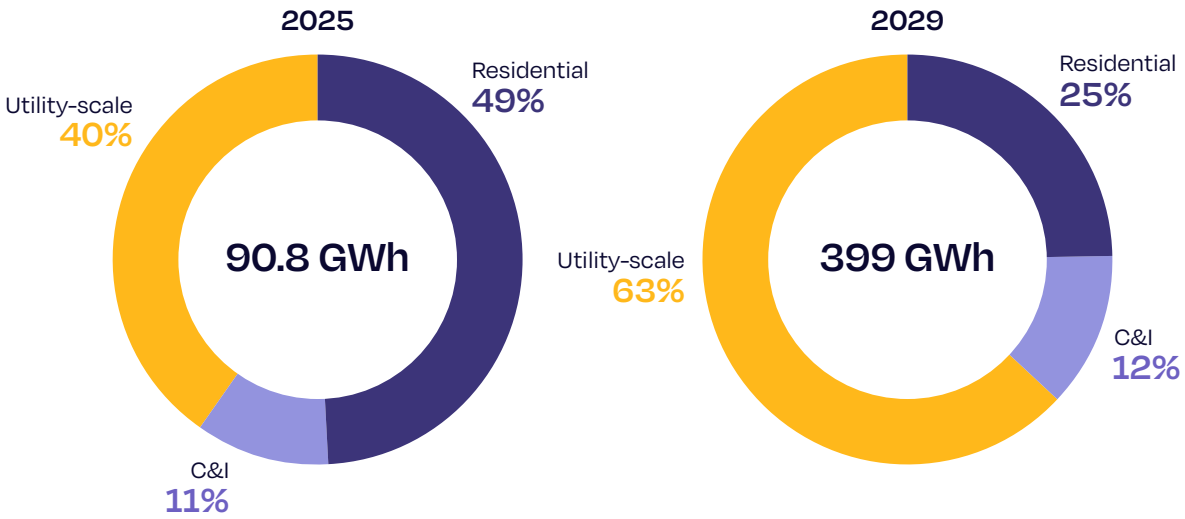
Looking at the EU-27, under the Medium Scenario total deployed BESS capacity is forecast to reach 334 GWh in 2029. While this is an impressive growth from the 49.1 GWh operating in 2024, it remains significantly below the levels needed to meet increased flexibility needs in a renewable-dominated and electrified energy system. To adequately accompany this transition, BESS capacity in the EU-27 should grow to 780 GWh by 2030 and 1.8 TWh by 2040, according to SolarPower Europe's Mission Solar 2040 study.[12] Even in the High Scenario, the EU-27 appears to be falling short of the trajectory towards the achievement of these volumes, reaching slightly over 500 GWh by 2029, just one year before the end of the decade.

The distribution of operational BESS capacity in 2025 and 2029 as per the Medium Scenario closely mirrors the pattern of annual battery additions (see Fig. 43). With 44.7 GWh, the residential segment is expected to represent about half of the running capacity in 2025; however, it will lose 24 percentage points by 2029, bringing its total capacity to 98.8 GWh and a 25% share. C&I batteries are poised to grow their base from 9.7 GWh in 2025 to 48.6 GWh in 2029, increasing marginally their share to 12% of the total. The lion's share is taken by utility-scale battery capacity, which is projected to surge from 36.5 GWh and a 40% share in 2025 to 251 GWh installed by the end of 2029, contributing 63% of the total BESS fleet.

Figure 43

Large-scale batteries set to be the backbone of Europe's fleet, small-scale batteries comprise 40%

Europe cumulative BESS segmentation 2025-2029



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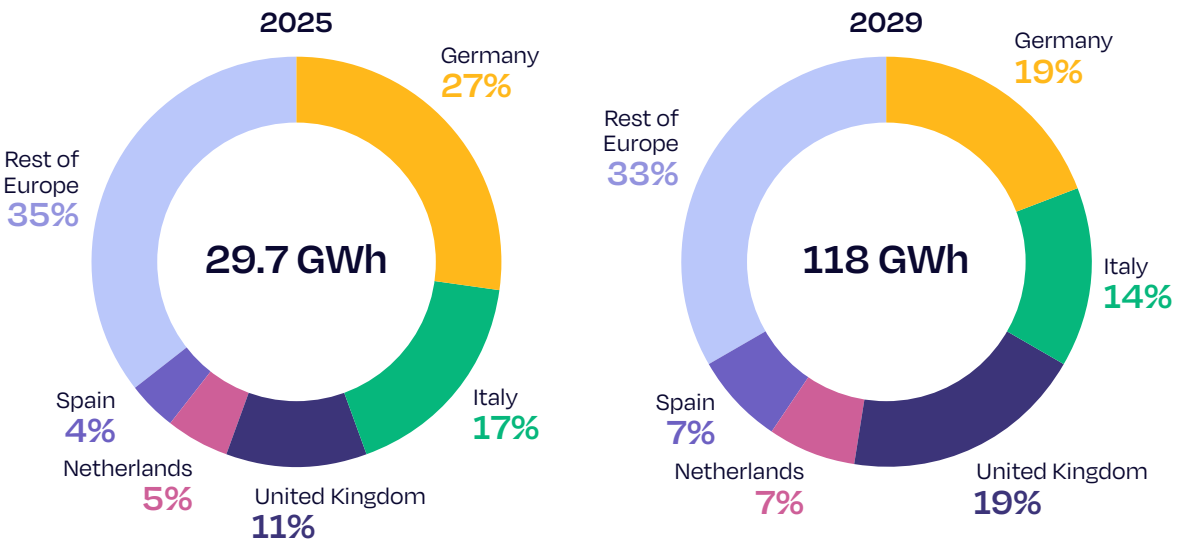
Leading battery storage markets keep booming, while growth diversifies and spreads across smaller markets in Europe

A focus on the growth prospects of the leading battery markets across the continent reveals some changes in the composition of the top 5 markets in 2025 and 2029 (see Fig. 44). While our Medium Scenario displays a further consolidation of the unquestioned top 3 markets – Germany, Italy, and the United Kingdom –, it also introduces two newcomers into the top 5 markets in 2025 – the Netherlands and Spain –, that are projected to take over from the Czech Republic and Austria.

Figure 44

Top 3 countries to install half of Europe's batteries in 2029, but their market share is diluted by more countries

Europe top 5 BESS markets 2025-2029



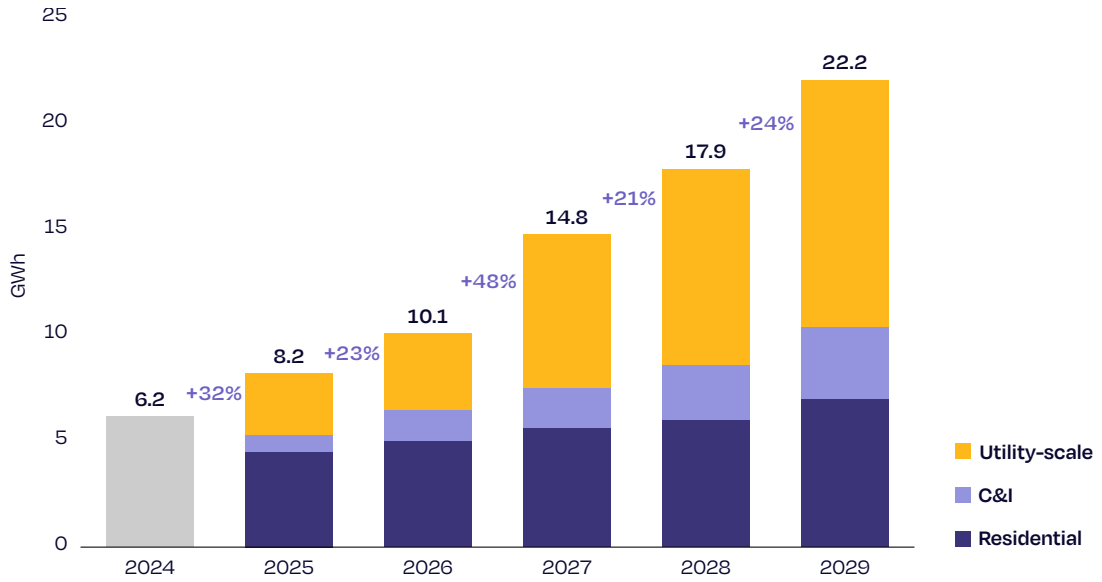
In 2025, the top 5 markets are foreseen to absorb about two-thirds of total installations, with the top 3 adding more than half of the new capacity (16.7 GWh). Compared to 2024, the top 5 share indicates stronger diversification across Europe, as the Rest of Europe's contribution will climb 10 percentage points from 22% to 35% this year. According to our Medium Scenario, countries like Sweden or Greece are expected to add more than 1 GWh in 2025, while Romania and France will deploy more than 900 MWh and other countries such as Portugal, Lithuania and Poland will ramp up their contributions. However, reaching the GWh scale will be not enough anymore to join the top 5 club in 2025, as the new entry level is now set at 1.3 GWh.

Over the next four years, the contribution of the countries outside the top 3 and top 5 will grow more or less proportionally to the overall European market expansion. Stronger deployment in the Netherlands (+2 percentage points) and Spain (+3 percentage points) will result in a reduction by 4 percentage points in the top 3's contribution and a 2 percentage points decline in the weight of Rest of Europe's additions. In total, European markets outside the top 5 are anticipated to connect 39 GWh in 2029, about four times as much as in 2025. In the meantime, the share of the top 3 markets is expected to become more balanced in 2029, each providing between 14 and 19% of total installations.

Germany is expected to consolidate its leading position in 2025 deploying 8.2 GWh and contributing 27% of total additions in Europe, increasing its annual market by 32% (see Fig. 45). Following a minor contraction in 2024, when decline in the home storage segment thwarted total installations, the German BESS market is anticipated to restart and maintain a steady growth rate. By 2029, the BESS market will reach 22.2 GWh and a cumulative capacity of 90.9 GWh.

Figure 45

Germany annual BESS installed capacity Medium Scenario 2025-2029



The main driving factor is the much-awaited expansion of the **large-scale battery fleet**, which is assumed to reach 2.9 GWh of new additions in 2025, as the enormous pipeline of projects starts to be grid-connected at scale. Still, the market is only at the beginning of an enormous growth cycle.

The surge in grid connection requests and the growing need for flexibility in an increasingly volatile energy system clearly demonstrate this trend. The intraday market has attracted enormous interest over the past two years, driven by exceptionally high arbitrage opportunities, and at certain times, extreme price spreads. The market currently offers a very attractive revenue stack model with frequency response revenues, balancing and restoration services, and other ancillary markets that are available. Additionally, the increasingly unfavourable economic conditions that solar developers are facing, such as the increasing number of hours with negative electricity prices, is leading to a major paradigm shift as the majority of new solar parks are now planned in combination with BESS.

However, the new government's stance towards energy markets and its impact on battery storage remains to be fully understood. Key topics like the country's flexibility strategy with potential activation of old fossil plants and the financial support to new gas capacity, the creation of the capacity market, and the progress on streamlining permitting procedures will all have a strong effect on future deployment. Going forward, the large-scale segment is expected to grow very rapidly and is anticipated to surpass the residential segment already in 2027. Under the Medium Scenario, by 2029, large-scale battery additions total 11.7 GWh, reaching 37.1 GWh of cumulative capacity.

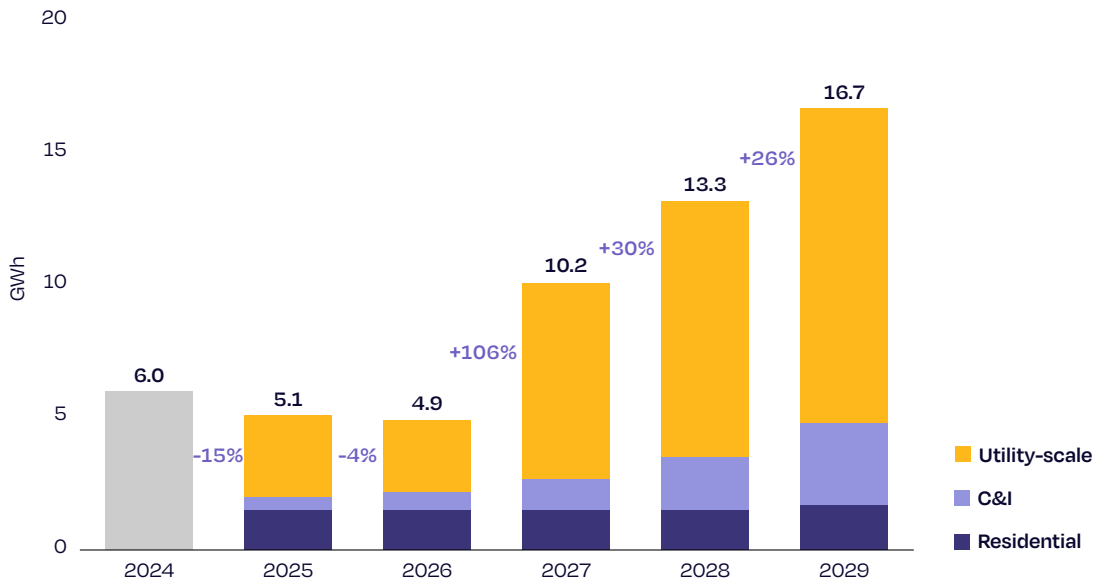
Residential installations are expected to drop again in 2025 to 4.5 GWh, but will maintain their dominant position, adding more than half of total deployment. In 2025, framework conditions on electricity prices, funding schemes and borrowing costs have not significantly changed from 2024. Therefore, residential PV will register a decline, while the attachment rate slightly decreases, but at the same time retrofitting rates continue to grow. Over the coming years, we expect the Solar Peak Act to catalyse a recovery in the BESS segment, as households are financially incentivised to couple existing or new solar generation systems with storage. The new regulation bring key changes, including: no feed-in compensations during hours of negative power prices, with the possibility to recover the lost revenues after the 20-year compensation period; mandatory smart metering and injection control devices; simplified registration access to direct marketing and the possibility to charge from the grid to store excess midday solar generation and receive compensation in the evening. By 2029, the annual market climbs to 7 GWh, much higher than the level attained during the energy crisis.

The **C&I segment** in contrast will continue to increase in 2025 (+800 MWh) as more companies embrace the need for flexible on-site generation to decarbonise their operations and increase their resilience to power price spikes. However, more use cases need to be permitted for C&I installations – arbitrage revenues, grid services, and demand response – to improve project bankability, along with new financing products available for businesses. Over the coming years, the market will expand by 15% to reach 3.4 GWh installed in 2029.

The second largest market in Europe will be **Italy** again, despite registering a 15% dip in installations to 5.1 GWh caused by a decline in both the household and the large-scale market (see Fig. 46).

Figure 46

Italy annual BESS installed capacity Medium Scenario 2025-2029



At the **residential level**, deployment is expected to fall again as conditions remain similar to last year, but this time without any positive impacts protracting from 2023. The reduction in the Eco-bonus, accompanied by lower electricity prices and persistently high borrowing costs, will push the market further down. The growth in the segment is expected to remain limited after 2025, as the market is affected by the continued drop in home PV installations. However, key factors like the gradual phase-out of net metering, the expansion of energy communities, and the simplification of permitting for systems below 11 kWh could lift installations more towards the High Scenario.

Large-scale batteries will also experience a drop in grid-connections in 2025 as the project pipeline from past auctions was already partially cleared last year. In 2025 and 2026, the rest of the projects will be brought online, in combination with newly contracted sites in the capacity market. Until 2027, most of the newly added capacity will be delivered through the capacity market. However, the investors are waiting until the MACSE scheme, Italy's large-scale electricity storage procurement mechanism, will be officially launched in September 2025. Awarding winners of competitive auctions with 15-year contracts, the MACSE scheme targets 50 GWh of new large-scale energy storage capacity by 2030. The capacity market auctions are expected to provide 8 GWh by 2030.

The overall strategy of the country points to the combination of these two mechanisms, with most capacity market projects to be located in the North to provide adequacy, and the majority of the MACSE plants to be commissioned in the South to tackle excess renewable generation. The latest utility-scale energy storage target from Italian TSO Terna has been revised downwards from 95 to 58 GWh, as the grid operator foresees less flexibility needs and network losses due to a partial shifting of renewable generation to the North. The impact of the capacity market and MACSE volumes is expected to have a major impact on prices and revenues, leaving very little room for fully merchant projects, with the exception of some areas where batteries can provide additional ancillary services. Additionally, the split of the bidding zones at the beginning of 2025 is not expected to have a substantial impact on power prices as the MACSE scheme will be primary determinant of local power prices.

For large-scale BESS, several challenges persist regarding the definition of network codes for hybrid projects, lack of a proper definition around grid forming, administrative overloads that could delay grid-scale project connection, continuous changes on safety requirements, and a lack of transparency with the status of projects contracted in the various auctions. Our Medium Scenario anticipates very strong growth in Italy as of 2027 and thereafter, reaching 11.9 GWh deployed in 2029. This will take the cumulative large-scale fleet to 38.7 GWh at the end of 2029, close to the 2030 target.

Niestetal, Germany

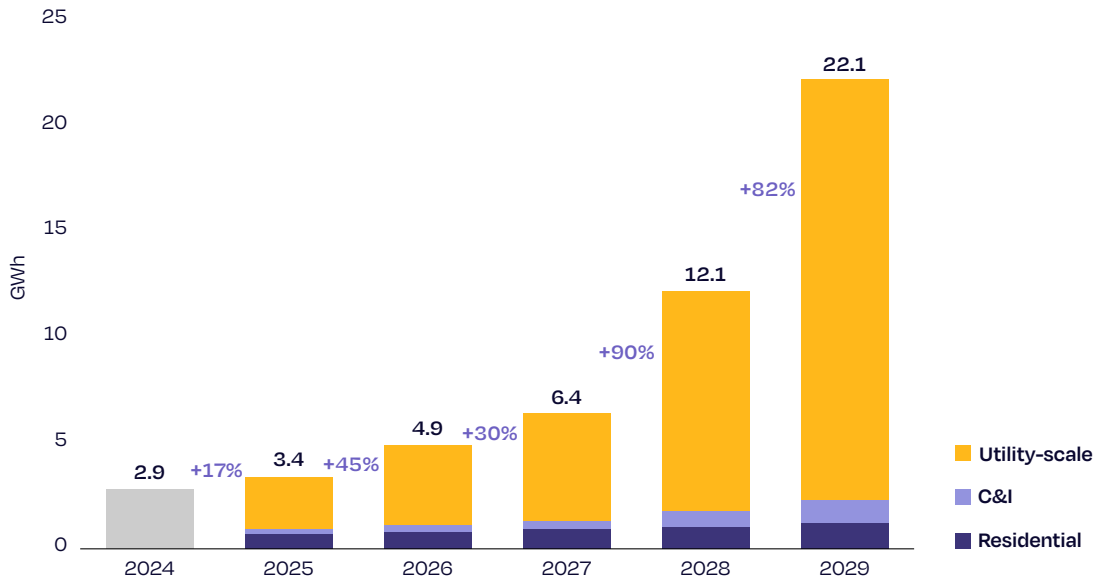
C&I installations will recuperate their growth trajectory in Italy in 2025 with around 500 MWh to be added, and crossing the 3 GWh level by 2029. Currently, the main use case is self-consumption, peak shaving and avoidance of grid outages, but this could change as soon as C&I storage is allowed to participate in dispatchable markets. The support schemes remain somewhat limited and sub-optimal (namely Transition 5.0 and PNRR) due to complicated application procedures and the possibility that existing funds will be redirected elsewhere.

All in all, following a temporary decline in 2025 and 2026, under the Medium Scenario the market rebounds in 2027 with 10.2 GWh of additions, reaching 16.7 GWh in 2029. At the end of our outlook period, the Medium Scenario expects the Italian BESS fleet to cross the 60 GWh mark.

Maintaining its third position, the **United Kingdom** will install 3.4 GWh of battery storage in 2025, making a come-back from the slump in 2024 (see Fig. 47). With this 17% annual growth, installations will remain below the 3.7 GWh record volume achieved in 2023.

Figure 47

United Kingdom annual BESS installed capacity Medium Scenario 2025-2029



The main rebound factor for UK storage installations in 2025 will be the **large-scale segment**, which will provide 73% of total installations. With the largest grid connection queue of the continent, the UK continues to expand its grid-battery fleet, which will remain the biggest in Europe in 2025 with 11.1 GWh. The availability of multiple revenue streams and the strong support from both the government and grid operators make the country a global leader in the deployment of large-scale BESS.

Meeting the national target of 27 GW of battery storage capacity by 2030 included in the Clean Power 2030 Action Plan will hinge on several factors, with investor and developer confidence playing a central role. If confidence declines, project deployment could slow down. This was the case in 2024, when revenue streams weakened due to frequency market cannibalisation. While falling battery prices are expected to strengthen the business case through a further CAPEX reduction, traded volumes in frequency markets are expected to grow only marginally compared to overall BESS capacity. The high earnings previously seen from frequency services are unlikely to make a comeback as this market has reached maturity. As a result, investors must strategically adjust their business models, focusing on merchant opportunities and/or contracted revenue sources to align with the evolving market landscape.

The UK BTM market is expected to contribute with about 900 MWh to 27% of all installations in 2025, as the segment stabilises after two record years. Most of this capacity will be installed at the **residential level** (700 MWh) while the **C&I** segment will add around 200 MWh. However, the weight of BTM applications will further decrease over time due to the enormous large-scale fleet that is expected to be installed until 2029.

The UK residential market will nonetheless continue growing thanks to improved framework conditions – VAT relief for both new and retrofitted BESS, support schemes for low-income households, low PV exporting tariffs, and a substantial reduction in permitting procedures. In addition, retail electricity prices remain quite high despite the retreat in 2023. The residential BESS market is expected to grow slowly but steadily rising to 1.2 GWh in 2029.

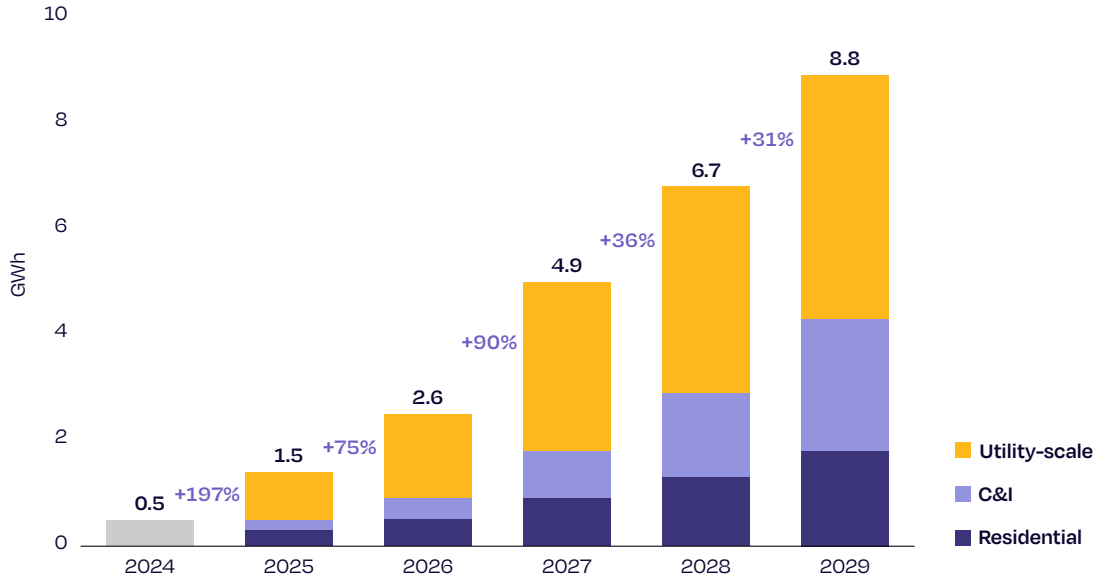
Simultaneously, the C&I segment offers significant growth potential, supported by a much-improved regulatory framework. Substantial opportunities exist, particularly for peak shaving and energy arbitrage. The segment will reach the GWh scale by 2029, one year after the residential market.

Across all battery segments, under our Medium Scenario the UK market reaches 22.1 GWh in 2029, with 90% coming from the grid-scale segment. Total capacities will reach the 60 GWh scale by 2029, putting the country closer to the 2030 target.

200 MW BESS, Blackhillock, UK

Figure 48

The Netherlands annual BESS installed capacity Medium Scenario 2025-2029



Despite still being at the early stages of its BESS development, the **Netherlands** ranks fourth in 2025 due to a very strong performance of the large-scale segment (900 MWh) while BTM batteries will provide around 500 MWh (see Fig. 48). This marks an annual doubling of the market, from less than 500 MWh in 2024 to almost 1.5 GWh this year.

The country has been navigating a complex political landscape over the last years, while electricity grid networks have become increasingly stressed as their inadequacy to enable pronounced renewable penetration becomes more acute. Higher levels of grid congestion have also augmented risks associated with blackouts, and the construction of new small-scale rooftop PV systems have also been constrained. Connecting more battery capacity to distribution and transmission lines can tackle some of the country's near-term energy challenges, as the Netherlands aims to have 39% of its energy mix from renewable sources by 2030.

Large-scale battery deployment has gained significant traction in recent times, reaching a 1.4 GWh fleet at the end of 2024. Key drivers have been the removal of double taxation for large-scale batteries, and the recognition from the government and grid operators of the centrality of energy storage. Dutch TSO TenneT set a target of 9 GW of grid batteries by 2030, providing a roadmap for investors on the type of services, markets and locations that developers could tap into. However, the country still needs much improvement on the grid tariff structure, permitting, strengthening the electrical workforce, and earmarking land and grid connection points. Even so, our Medium Scenario expects very rapid growth in the coming years, with 4.6 GWh of utility-scale batteries annually installed in 2029 and bringing total grid-scale capacity to 14.7 GWh by the same year.

In 2024, the Dutch net-metering scheme experienced major policy shifts. A proposed phase-out bill passed Parliament in late 2023 but was rejected by the Senate in early 2024. This led to a temporary market boost, with around 100,000 residential solar installations between March and May 2024. In May, the new coalition government unexpectedly announced a full termination of the scheme by 1 January 2027, without a gradual phase-out. By November 2024, the new bill was approved by Parliament, with Senate support also confirmed.

The **residential market** has come to terms with receiving less political support and stimuli in the next years, and the focus is on guaranteeing interoperability and developing flexibility assets on low-voltage levels to keep energy costs low. With the adoption of dynamic tariffs, strong smart meter penetration, and VAT exemptions for home solar & storage systems, the Dutch household segment will likely grow rapidly, even before 2027. The retrofitting of one of the largest European residential PV fleets will also play a major role in the expansion of the segment. A prime concern is the existence of double taxation for household and non-household consumers which currently does not apply due to the existence of the net-metering scheme. Clarity is needed on the decision to what will happen after January 2027. All in all, by 2029, our Medium Scenario points to 1.8 GWh of residential BESS additions, delivering 20% of total yearly installations.

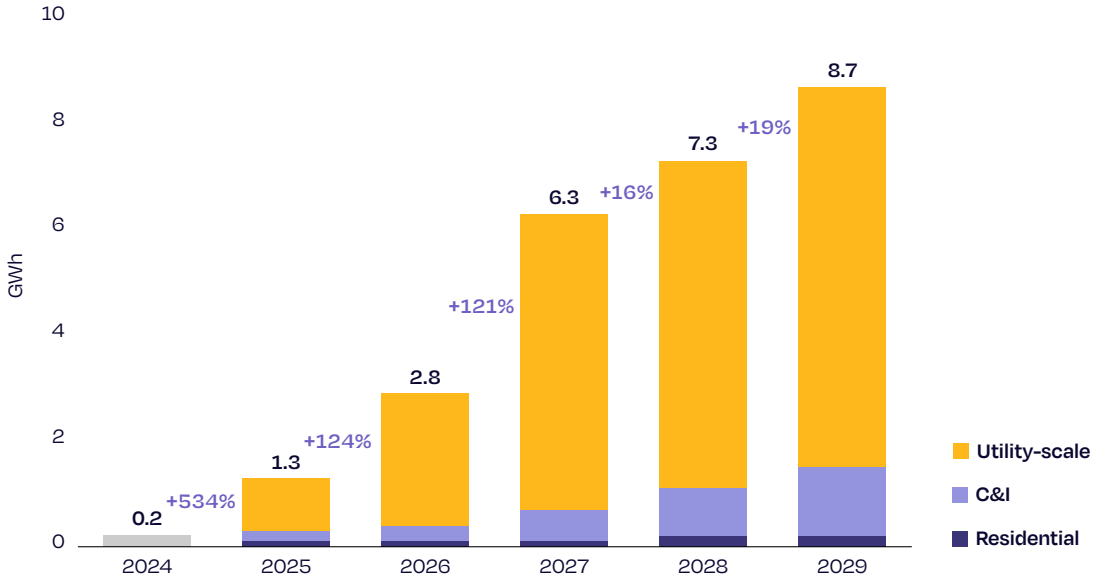
At the **C&I** level, the Dutch battery market has been driven by specific use cases for electrification of commercial operations, increasing self-consumption, reducing peak charges, and adding backup power and resilience. The potential of the segment remains largely untapped, but we expect the market will grow 80-90% on a yearly basis until 2028 and will reach 2.5 GWh of installations in 2029.

All combined, the Dutch battery market is projected to install 8.8 GWh by 2029, with grid batteries adding more than half of the capacity. That leads to 24.3 GWh of installed capacity at the end of 2029.

Closing the 2025 ranking, **Spain** makes a comeback to the main stage after two years of continued decline. In 2025, our Medium Scenario anticipates 1.3 GWh annually deployed, mostly thanks to the grid-scale segment, which will deliver 81% of the capacity (see Fig. 49).

Figure 49

Spain annual BESS installed capacity Medium Scenario 2025-2029



After a strong increase in residential deployment in the aftermath of the COVID pandemic, boosted by the Next Generation funds and the energy crisis, the Spanish **household segment** is expected to decline for the third year in a row, reaching the bottom in 2025. The lack of support schemes, low electricity prices, and high financing costs have driven down installations as households postponed their solar + storage investment decisions. Under current conditions, over the coming years the segment is expected to stabilise and remain marginal, without reaching again the heights of 2022.

At the **C&I** level, the picture is quite similar; however, companies and industries face a stronger need for coupling onsite generation with storage. There is a growing interest in achieving greater stability in electricity prices and to increase their power availability, given the limited grid capacity. The electrification of demand and the growing need for fast-charging points for electric vehicles have led many companies to adopt storage solutions at their facilities. Additionally, distributed solar + storage installations will be allowed to participate in the upcoming capacity mechanism if they aggregate to more than 1 MW of installed power. Thus, and despite remaining a niche market, our Medium Scenario anticipates that C&I batteries in Spain will reach the GWh scale in 2029, resulting into a fleet of 2.9 GWh at the end of that year.

However, the true driver in our Medium Scenario is the **grid-scale** segment, driven by ambitious national targets, conspicuous public funding and further increasing renewable integration challenges. Spain has set the target to reach 22.5 GW of energy storage capacity by 2030, with batteries constituting 40% of that volume. In total, standalone and hybrid batteries would represent 7.3 GW while BTM storage would provide 1.6 GW. To support this target, the Spanish government has launched three different aid schemes over the past two years, for innovative energy storage (50 million EUR), hybrid BESS (150 million EUR) and standalone storage (150 million EUR). In May, an additional 700 million EUR were earmarked to fund up to 5 GW of new energy storage capacity.

Moreover, the capacity market is under public consultation and is likely to be launched by the end of 2025. Additionally, the absence of grid tariffs for batteries has also improved the bankability of projects in the country. At the same time, the current lack of revenue stacking opportunities, paired with the administrative barriers for standalone and hybrid projects, still hinder deployment. There is also some political opposition against large-scale battery projects at the regional level: in Asturias, the local government is threatening the timely commission of many projects that were contracted through the aid schemes. In 2025, the utility-scale BESS market in Spain is expected to reach the GWh scale, with the annual market rapidly increasing to 7.2 GWh by 2029.

Overall, the Spanish BESS market is anticipated to reach 8.7 GWh in 2029 and 27.5 GWh of cumulative capacity by the same year. However, our High Scenario points to 43.3 GWh installed by the end of 2029, which seems more aligned with the direction the country is heading, given the growing queue of pipeline grid-scale battery projects requesting grid connection and initiating the permitting stages.

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