FORRS

Battery Energy Storage Systems (BESS) as a Key Flexibility Provider

BESS demand, market integration and software solutions

Commodity Technology Advisory

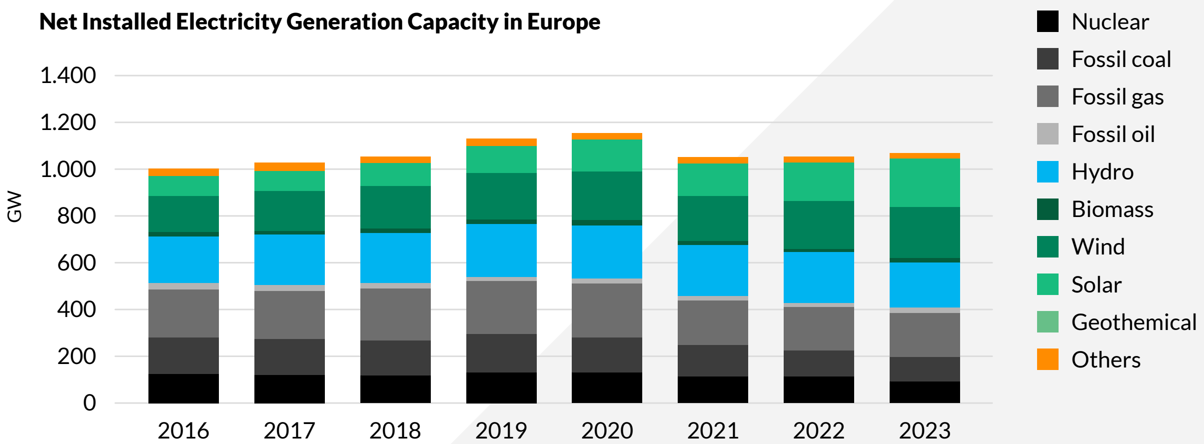
Introduction and Motivation

1.1 Rising Renewables

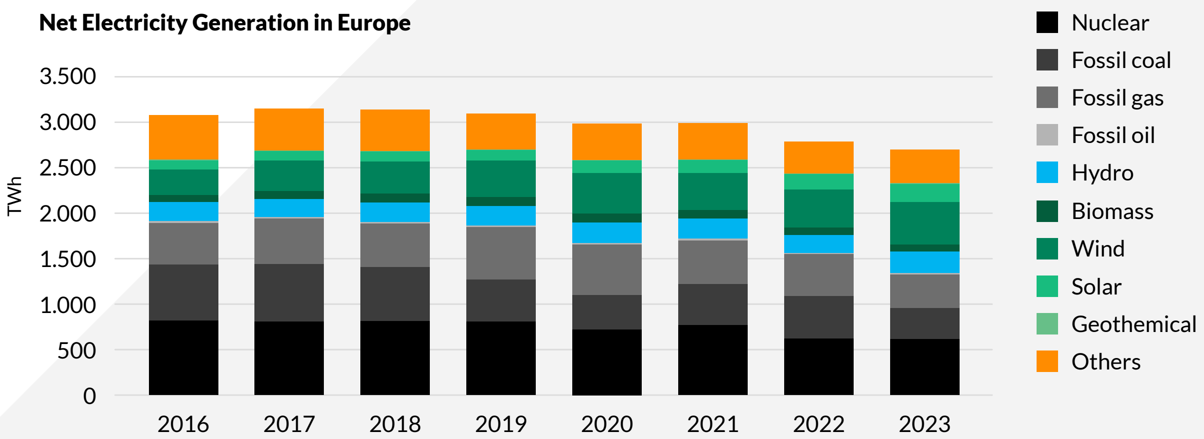
Switching to renewable energies is an important step in combating the impending climate crisis while simultaneously strengthening energy independence. The EU intensively promoted the expansion of renewable energy over the last two decades. In 2022, the share of renewables in EU energy consumption rose to a record high of 23 percent from a share of only about 10 percent in 2005. This progress is further driven by the European Commission's 2023 update to the Renewable Energy Directive with a target for renewable energy for 2030 of 42.5. percent It is in line with the European Commission's overarching climate target of reducing greenhouse gas emissions by 55% by 2030 and achieving climate neutrality by 2050. Power accounts for about 21% of the EU's final energy consumption. The remaining is used for other purposes such as heating, cooling, transportation, and direct industrial processes. For power production, the share of renewables is even higher, with about 37 percent of electricity coming from renewable sources.

Figure 1 Panel (a) shows the yearly net installed electricity generation capacity in Europe from 2016 to 2023. We see a substantial increase in renewables, with wind and solar capacity nearly doubling over this period. Panel (b) depicts the respective net electricity generation. Here, we have an increase in renewables as well, but not as pronounced as for the capacity.

Figure 1.
Panel (a):
Yearly net installed electricity generation capacity in Europe.[1]



Panel (b):
Yearly public net electricity generation in Europe.[2]

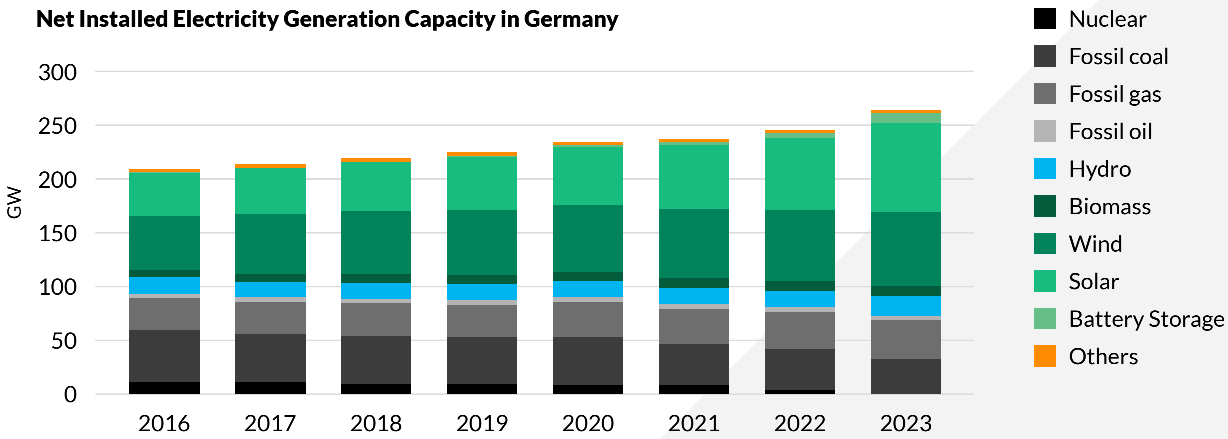


[1]Source: Fraunhofer Institute, Installed Power | Energy-Charts
[2]Source: Fraunhofer Institute, Column charts on electricity generation | Energy-Charts

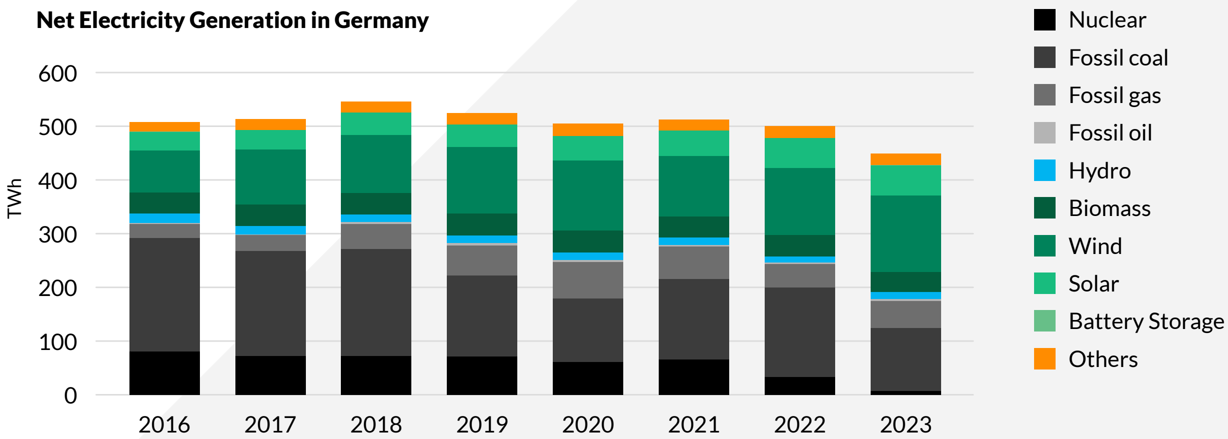
In Germany, the expansion of renewable energies and their role in power production ran almost parallel to the trend in the EU. Figure 2 Panel (a) depicts the yearly net installed electricity generation capacity, which describes the total amount of electrical power a plant can supply to the grid, and its composition in Germany from 2016 to 2023. The share of coal and nuclear power decreased substantially over the years, the latter as a result of the politically determined nuclear phase-out. In contrast, the share of renewable energies, particularly wind and solar energy, rose by more than 50 percent.

Figure 2 Panel (b) shows the net electricity generation in Germany over the same period. The share of renewables among generation is significantly smaller than the share among installed capacity. The main reason for this is that renewable generation depends on external circumstances, such as wind patterns, cloud coverage, and daily and yearly seasonality, so the necessary conditions for generating the theoretically possible quantities of power are not always present. Fossil power plants, on the other hand, can generally be controlled well and run up to maximum capacity if and as necessary.

Figure 2.
Panel (a): Yearly net installed electricity generation capacity in Germany.[3]



Panel (b): Yearly public net electricity generation in Germany.[4]

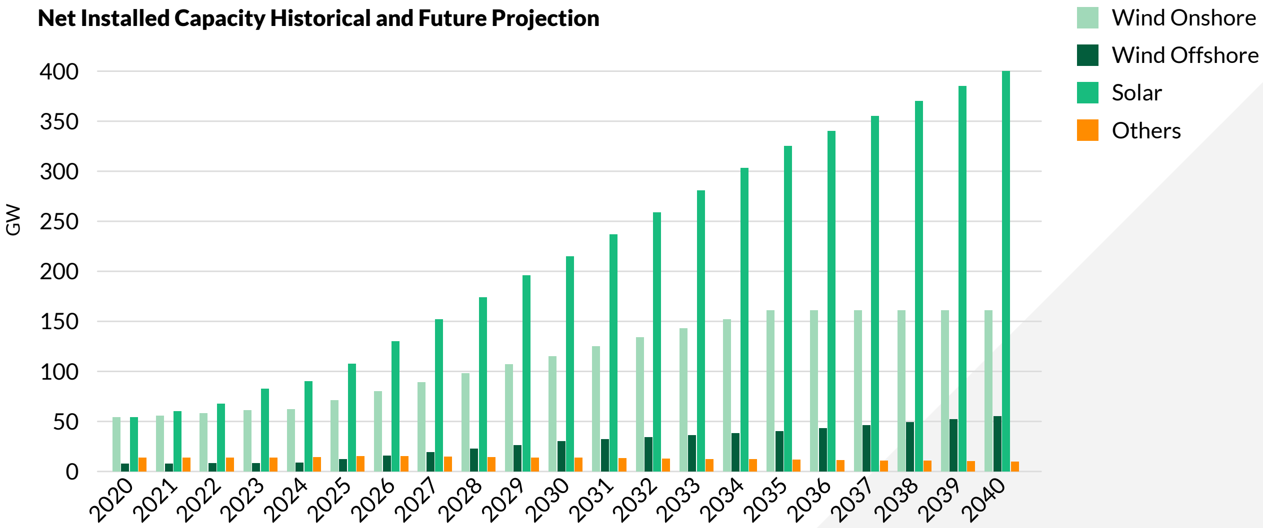


[3]Source: Fraunhofer Institute, Installed Power | Energy-Charts
[4]Source: Fraunhofer Institute, Column Charts on Electricity Generation | Energy-Charts

The trend towards having renewable energies provide more and more installed capacity is projected to continue. Figure 3 shows a forecast for net installed capacity in Germany for renewables up to 2040, mainly building on data from the German Federal Ministry for Economic Affairs and Climate Action (BMWK). It shows that the net installed capacity of wind is expected to approximately increase by a factor of three and solar by a factor of four till 2040.

However, the expansion of renewable energies poses challenges for our electricity grid. With more renewables in the system, when there is lots of wind and sun, we can potentially produce more power than the load. On the other hand, renewables cannot contribute to power generation without wind and sun.

Figure 3. Forecast for yearly net installed capacity for renewables in Germany.[5]



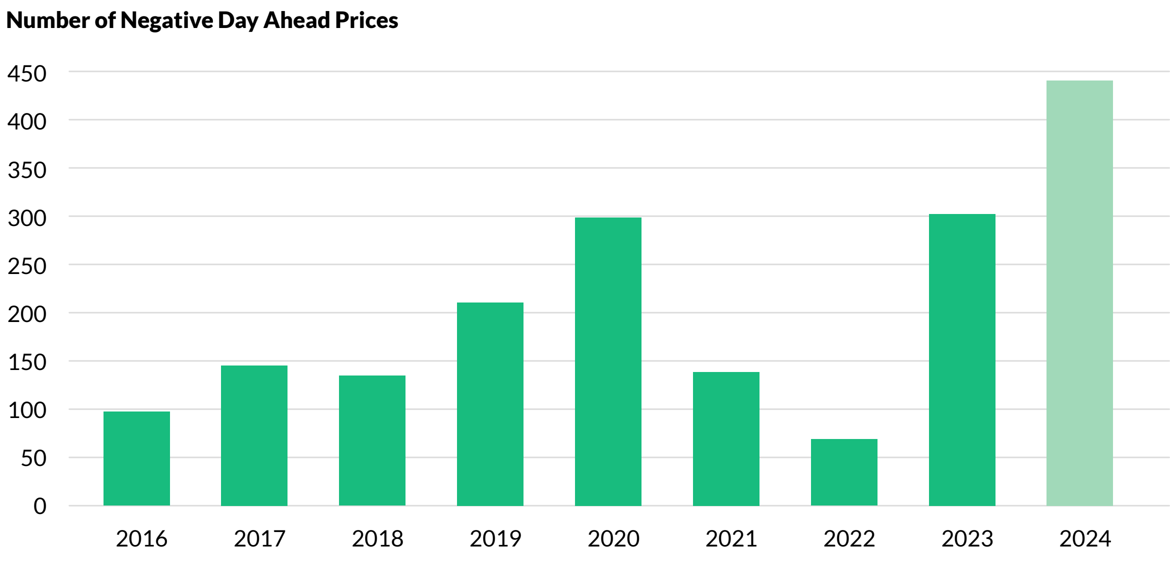
1.2 Increasing Flexibility Requirement

With a higher share of renewables, the fluctuation of the potential generation increases. This can lead to problems because the electricity grid is only stable if feed-in and withdrawal are balanced. On the one hand, there may be bottlenecks in the energy supply at times when consumption exceeds generation. Then, more expensive energy sources, such as gas, are currently being ramped up to compensate. On the other hand, at some periods, there may be a theoretical oversupply of energy, where less energy is consumed than potentially produced, requiring curtailment of power plants. Due to the expansion of renewables, these incidents have become more frequent and are expected to increase further in the near future. At these times, electricity prices can even become negative.

Negative prices have been observable in short-term electricity exchanges (day-ahead and intraday market) since 2008. They are particularly common during midday hours with high renewable power supply and during public holidays like Christmas. Figure 4 shows the yearly occurrences of negative day-ahead prices in Germany from 2016 to now. Due to the increased use of inflexible renewable energy sources, the general trend was that hours with negative electricity prices

[5]Source: Historical Installed Capacity – Fraunhofer Institute, Installed Power | Energy-Charts;
Projected Installed Capacity up to 2035 – BMWK, Overview of the Eastern Package | BMWK; Projected Installed Capacity beyond 2035 – BMWK and Netzentwicklungsplan Strom, Scenario Framework for NDP 2037/2045 | Netzentwicklungsplan Strom

Figure 4. Number of hours with negative day-ahead prices per year in Germany. The 2024 data is up to 22.10.2024, 11pm.[6]



increased over the last decade and are expected to rise even further in the future. However, shocks on the consumer can lead to a temporary decrease in the occurrences of negative prices, such as the pandemic in 2020 and the energy crisis resulting from the Russian invasion of Ukraine in 2022.

Contrary to popular expectation, negative electricity prices do not generally not result in lower prices for end consumers but actually increase them on average. In Germany, about 37 percent of renewable plants[7] receive a levy under the Renewable Energy Sources Act (EEG) in the amount of the difference between the market value of electricity and the legally guaranteed fixed EEG remuneration. This market premium results in particularly high subsidy costs in times of negative electricity prices.

To relieve the strain on the grid and counteract fluctuating electricity prices due to the increasing expansion of renewable energies, the electricity grid must become more flexible. The report "Flexibility requirements and the role of storage in future European power systems", published by the Joint Research Centre (JRC) of the European Commission in 2023, forecasts flexibility requirements and solutions in the EU power system. In this report, flexibility requirements are measured based on deviations from the average residual load and are calculated for different timescales. For short-term or daily flexibility, shortage and surplus of energy are calculated on an hourly basis as the difference between the residual load at the respective hour and the daily average. The sum of the hourly shortages and surpluses represents the total amount of energy that is needed to meet all hourly flexibility requirements in the year under consideration. Table 1 reports the short-term requirements in TWh per year for 2021 and the forecasts for 2030 and 2050 for the EU and Germany.

Table 1. Short-term flexibility requirements for the EU and Germany.[8]

Region	2021	2030	2050
EU	100 TWh/y	300 TWh/y	900 TWh/y
Germany	30 TWh/y	50 TWh/y	125 TWh/y

[6]Source: Fraunhofer Institute, Electricity Production | Energy-Charts
[7]Source: BMWK, Opportunities for Decarbonising SMEs | BMWK
[8]Source: BMWK, JRC, Flexibility Requirements and the Role of Storage in Future European Power Systems | JRC Publications Repository

1.3 Qualitative Assessment of Flexibility Solutions

The varying energy generation of renewables requires the addition of more flexibility to the electricity grid on both the supply and demand side as we transition our energy supply to greener technology. Until now, most of the flexibility in Germany's power system is provided by gas plants, whose power generation can be flexibly raised and lowered at short notice. In the following, we will elaborate qualitatively on some alternative options to increase flexibility by assessing whether these are viable solutions until 2030. The most prominent solutions, which can be categorized into demand response and energy storage, are:

- **Demand Side Flexibility (DSF)**
- **Energy Storage**
  - Hydropower
  - Hydrogen
  - Electric vehicle (EV) batteries
  - Battery Energy Storage Systems (BESS)

Additional supporting measures are a smart composition of energy sources using the complementary nature of wind and solar energy and strengthening the coupling of the electricity grid across borders.

Demand response describes when electricity consumers, which can be households, the private or the public sector (industry), adjust their power usage from standard consumption patterns in response to market signals. However, currently, demand response is not a large-scale solution that offers sufficient flexibility. The main reason for this on the household side is that most of the households in Germany get fixed prices from their electricity supplier, giving them no incentive to adjust their consumption patterns. Recently, the European Commission and the European Union Agency for the Cooperation of Energy Regulators proposed changes to the electricity market design to remove technical barriers for households to participate in the power markets. Even without these barriers, most households might lack the required knowledge and willingness to do so. While there are less technical barriers for the industrial sector, industrials often do not know that there is flexibility and a significant profit potential or cost reduction opportunity within their business. Usually, utilities or aggregators help C&I companies to understand their flexibility and utilize it on the market. Some utilities offer lower tariffs to their customers in response to the customer's flexibility. In this case, a utility plays the role of an aggregator of the flexibility of multiple customers into a Virtual Power Plant (VPP) and trade this flexibility along with own assets. In other cases, independent aggregators provide these services to C&I companies and possibly to households. However, different countries have different rules and entry barriers for market participation for independent aggregators. In Germany these entry barriers are particularly high, see chapter 2.4 below.

Energy storage refers to converting electricity to other types of energy, storing it, and releasing it when needed. There are several technology options available nowadays, such as those relying on mechanical, electrochemical, or thermal energy, as well as fuels (mostly hydrogen). The most common mechanical solution is pumped **hydropower**. However, certain geographical conditions are particularly suitable for hydropower, such as the presence of many rivers and latitude differences, e.g., in Switzerland, which does not make hydropower a well-suited solution for all areas.

Another very frequently discussed technology is using **hydrogen** for energy storage. However, within the next few years, this is unlikely to provide a viable solution for two main reasons. First, it is technically challenging and costly to convert the existing gas network so that it can be used for hydrogen. Second, the costs for power from hydrogen (and the preceding value chain) are currently too high to be competitive in the market. Only with large-scale electrolyzers, which first need to be built and require significant investment amounts, might hydrogen pose a profitable power storage. Yet, beyond 2030 hydrogen might be a viable solution to meet the flexibility demand due to technological improvements and large-scale investments.

In terms of electrochemical energy, electricity is stored as batteries. A frequently discussed solution to meet flexibility needs on this behalf are **EV batteries**. But certain difficulties arise with this solution. First, with a share of 3 percent of the total number of cars, there are currently only a small number of EVs in Germany while new registrations are declining. Second, EV battery quality deteriorates with the number of charging cycles. Using EV batteries for flexibility requires charging patterns that increase the charging cycles and thus decreases battery quality faster, which is indirectly paid for by the car owners or manufacturers due to warranty regulations. Third, to ensure the best possible flexibility solution, the cars must be connected to the grid during peak times, whereas most cars are on the roads at this time.

An alternative solution relying on batteries is given by BESS, which currently are the best option available to cover a significant part of the flexibility needs in the near future. As outlined in Section 1.2, the flexibility requirement analysis of the JRC predicts the short-term flexibility requirement for 2030 to rise to about 300 TWh/y in the EU and 50 TWh/y in Germany. The same report expects that BESS cover a share of 10% and 15%, respectively.

BESS and Market Integration

2.1 BESS

BESS are rechargeable batteries designed to store energy from various sources. The system then releases the stored electricity back into the grid when it is economically advantageous, such as during peak hours or in response to specific balancing orders from the Distribution System Operators (DSOs) and Transmission System Operators (TSOs).

BESS usually consists of some core elements. The fundamental element is a system of batteries. It contains individual low-voltage battery cells arranged in racks within a module or container enclosure. These battery cells convert chemical energy into electrical energy. While there are numerous battery chemistry solutions available, lithium-ion batteries are currently preferred for their efficiency and cost-effectiveness. Table 2 presents a comparative overview, mostly in a qualitative fashion, of the most important and widely used battery solutions. It is based on an analysis of the European Association for Storage of Energy (EASE) that builds on a comprehensive review of technological descriptions published between 2016 and 2018. There are other sources that compare battery solutions for similar characteristics. Note, however, that the findings sometimes differ substantially between different data sources.

Table 2. Characteristics of battery chemistry solutions.[9]

Chemistry Type	Lithium-Ion	Lead-Acid	Sodium-Sulphur	Flow batteries	Nickel-Cadmium
Power range	Low-**High**	Low	Low-**High**	Low	Low
Energy range	Low	Low	Low-**High**	Low	Low
Discharge time	Short	Short-**Long**	Short	Short	Short
Cycle life	Low-**High**	Low	**Medium-High**	**High**	Low-**Medium**
Life duration	**Long**	Short-**Medium**	**Long**	**Medium-Long**	**Medium-Long**
Reaction time	**Fast**	**Fast**	**Fast**	**Fast**	**Fast**
Efficiency	**High**	**Medium**	Low-**Medium**	Low-**Medium**	Low
Energy [power] density	**Medium-High**	Low	**High**	Low	Low
CAPEX: energy [in €/kWh]	**700-1.300**	**100-200**	**300-450**	**100-400**	**400-700**
CAPEX: power [in €/kW]	**150-1.000**	**100-500**	**2.000-3.000**	**500-1.300**	**500-1.500**

[9]Source: EASE, Technologies | EASE

The battery management system (BMS) monitors the battery cell's working conditions and keeps track of the charging and discharging parameters. The power conversion system converts the power between the battery cells and the grid, and vice versa. The energy management system (EMS) coordinates the BMS, inverters, and other components and a safety system monitors the operating conditions such as the temperature and smoke development.

The recent rise in interest in BESS is driven by technological and political changes. On the technical side, increased battery efficiency with improved storage duration and decreased installation costs made the system more economical. On the political side, environmental initiatives pushing the shift to renewables increase the need for flexibility and indirectly provide financial incentives through taxes or subsidies.

2.2 BESS Value Chain

When discussing BESS technologies and market access, we need to distinguish several use cases:

1. **Standalone Industrial Size Batteries with Direct Access to the Network (In-Front-of-the-Meter):** The primary objective of such BESS projects is to contribute to network stability by providing ancillary services. Additionally, these batteries participate in short-term power trading and leverage arbitrage opportunities between different markets.

2. **Battery Co-Located with a Renewable Production Site:** These installations aim to smooth the production volatility of PV (photovoltaic) installations. While also in-front-of-the-meter, the primary objective differs from the first use case. In this scenario, we refer to production-oriented VPP.

3. **Battery as a Source of Flexibility on the Prosumer Site:** This is a behind-the-meter installation and forms part of the aggregated DSF. Typically, each DSF resource is part of a consumption-oriented VPP, which can participate in ancillary service provision or even in the wholesale market in some countries.

The graph below shows the general value chain, valid for the case of VPP, but also stand-alone BESS. In the case of standalone BESS, the aggregation and redistribution steps are not relevant.

Figure 5.
BESS value chain.

Any BESS or VPP project requires technical monitoring, fault detection, meter data management, and aggregation/redistribution when multiple distributed assets are involved.

The subsequent steps in the value chain involve pre-trade analytics, which include forecasting renewable production and optimizing flexibility. Optimization aims to maximize profit from using BESS while considering technical constraints and available markets for realizing this flexibility. Depending on asset qualifications and market regulations, these markets can include various ancillary services such as different type of reserves, frequency regulations, capacity markets, and wholesale markets including day-ahead, intraday auctions, and continuous markets. Renewable production typically participates in the wholesale market rather than qualifying for ancillary services, though some assets are eligible for both. BESS and DSF projects are primarily used for network stabilization and thus participate in ancillary service markets, though some also access wholesale markets.

For projects with arbitrage possibilities across different markets, trading is a crucial task. Intraday continuous trading is particularly important for BESS due to the additional price volatility, which can be leveraged to maximize profits.

The next steps in the value chain involve market interfaces for communication with system operators and regulatory reporting. Position and risk management could also be considered separate workflow steps, but since the markets in question are short-term markets, many companies consider risk management as a part of trading rather than a separate activity in these markets.

Not every BESS or VPP operator is involved in all steps of the value chain. Often, some steps are outsourced to other companies. However, for a BESS to participate in the energy market as part of a VPP or standalone, all these steps must be performed by some entities. So, who are these companies and how do they cooperate along the BESS/VPP value chain?

2.3 Market Segmentation

The market changes related to the energy transition are significant and impact all businesses across the industry. New actors are entering the market, and existing actors are taking on new roles and responsibilities.

Project Developers (PDs) play a crucial role as new market entrants, primarily investing in industry-scale batteries or other power storage technologies. They may also invest in demand response-based flexibility. Most PDs are not energy market specialists and usually rely on third-party services for trading their energy. Most PDs invest in in-front-of-the-meter facilities, with some, especially those investing in co-located batteries, being spinoffs of large utilities.

PDs can be categorized into three groups based on their activities. PDs covering **Basic Operations** with their assets focus on monitoring devices, managing meter data, and optimizing batteries for safe operation and longevity. They often use AI and ML for analytics and rely on trading companies for market access. Most PDs fall into this category.

PDs with **Advanced Operations** provide ancillary services and require solutions for commercial optimization of BESS and TSO/DSO interfaces. They focus on profitability, battery lifetime, and safe operations, using multiple data sources for prices, meter and weather data.

PDs supporting **Full-Scale Operations** usually have their own market access and traders, covering the entire value chain from monitoring to trading. They focus on short-term and algorithmic trading, and their software needs include EMS, pre-trade analytics, data management, and trading systems.

Aggregators manage VPPs by consolidating multiple distributed resources to trade on specific markets. Co-located batteries as well as batteries used as source of prosumer' flexibility are an important part of these resources. Aggregators fall into the same three categories as PDs, but most are in the **advanced or full-scale operations** categories due to their primary goal of bringing flexibility to the market. Aggregators often serve multiple PDs as their market interface.

Many large **Commercial and Industrial (C&I)** companies have wholesale market access and some trading experience but face challenges in intraday markets and asset management. Their activities are similar to advanced PDs, with limited energy market experience. Small and medium C&I companies are willing to reduce energy bills and may install batteries to reduce peak demand, but usually do not take part in market activities, though they may take part in the consumption-oriented VPP offered by aggregators.

In most European countries, **Utilities** are the primary investors in renewable energy, focusing on production and sometimes co-located batteries, with their VPPs being production oriented. Due to market rules limiting arbitrage and BESS profitability, BESS investments by utilities are less common. However, with plans to increase battery capacity by 2030 and regulatory improvements, BESS investments are expected to grow. Utilities are prepared to support the entire BESS value chain, from pre-trade analytics to risk management, but may face new challenges. A major challenge is data management, as utilities operate in various markets and must handle vast amounts of data. Traders need a single, cloud-based repository for real-time data access. Ensuring data reliability, cybersecurity, integration, and performance is critical. Utilities are also interested in analytical solutions like battery optimization algorithms. While they have strong risk management systems, the shift to real-time trading requires near real-time valuations, which legacy ETRMs may not support.

Trading-as-a-service (TraaS) is a rapidly growing business model aimed primarily at serving IPPs and PDs that lack trading expertise or avoid trading due to high market access costs. However, as market rules evolve to make access easier and cheaper, more PDs and IPPs are expected to start their own trading, potentially impacting the future growth of the TraaS business.

TraaS providers typically cover steps of the value chain from pre-trade analytics to trading but usually do not handle aggregation or earlier steps. Their competitive advantage lies in their trading and optimization algorithms. Proper data management remains a significant challenge for them.

From a software solution standpoint, TraaS providers as well as utilities tend to use an ecosystem of solutions, combining standard commercial tools for tasks like nominations or regulatory reporting with proprietary software for trading algorithms and AI. Also outsourcing of non–core functions such as scheduling and nominations or regulatory reporting is very common.

2.4 BESS Market Access

Market access rules and available markets vary significantly across European countries, especially in the ancillary services market. The most efficient way to trade BESS and production-oriented VPPs (with co-located batteries) involves participating in both ancillary services and wholesale markets, with the potential for arbitrage between the two.

Access to markets for in-front-of-the-meter VPPs and BESS is generally less problematic compared to behind-the-meter projects. For these projects, market access is still in its early stages in many European countries. While market participants understand the needs, regulatory authorities are still implementing the necessary regulations. Furthermore, provision of services to DSOs by behind-the-meter projects require much stronger digitalization of DSOs which is still a challenge in most European countries.

Only a few European countries have trading platforms where companies including Demand Side Flexibility aggregators can submit bids for ancillary services, with multiple DSOs competing for those services. The most advanced marketplaces include PICLO Flex in the UK, eSIOS in Spain, and NODES in Norway. In the UK, six DSOs and the TSO use the PICLO platform to procure services. Similarly, Norwegian DSOs can be serviced via the NODES-NorFlex trading platform. Other markets, such as eSIOS in Spain, provide marketplace functions only for the TSO, not for DSOs. In markets like Spain and Portugal, C&I companies in sectors such as chemistry and agriculture actively trade ancillary services on flexibility platforms like PICLO or eSIOS. In France there is well developed capacity market with easy access for aggregators working with DSF. France has highest number of independent aggregators comparing with other European countries.

In Germany, no platform exists for behind-the-meter projects to bid their flexibility, requiring PDs and aggregators for DSF to navigate complex procedures for network access. Consequently, few companies meet market participation requirements, but successful ones like Sonnen gain a significant market share.

Standalone in-front-of-the-meter BESS participate in short-term trading and ancillary services, especially for primary reserves due to fast reaction times. However, large BESS projects face high costs and ROI concerns, with early-stage development slowed by market rules and specific challenges.

Firstly, BESS project financing is more expensive compared to renewable energy projects because credit organizations consider them riskier. BESS projects cannot rely on EEG provisions since batteries charge from the network and not from renewable plants.

Secondly, while using the price difference between the cheapest and the most expensive hours to generate profits, BESS are reducing this price difference, thereby cannibalizing their profit source. This cannibalization effect is expected to intensify as more projects enter the market, increasing project risk from a credit organization's standpoint.

Thirdly, the profitability of standalone BESS depends heavily on the trader's flexibility in arbitraging between different markets. This includes the timing of bids for different reserves compared to the intraday continuous market. Currently traders must decide in advance whether to use BESS for primary reserves or continuous trading. The shorter the time interval in which the trader can still decide between these two options the higher profitability can be expected.

BESS Software Solutions

Software vendors supporting the value chain can be divided into groups depending on the origin of their business and steps on the value chain they are covering. The figure below indicates the segmentation of these solutions.

Hardware, BMS and EMS providers – companies manufacturing hardware and providing associated software. EMS systems include managing technical and meter data, dispatch and some analytics. This software is designed to read data from local devices, accumulate this data on cloud platforms, and use it for monitoring, dispatch, and defect detection purposes or other analytics. These solutions usually include BESS optimization, but in many cases, it is not commercial but technical optimization focusing primarily on prevention of early aging and ensuring safe operations.

There are software vendors supporting **aggregation** and operations of in-front-of-the-meter or co-located batteries without hardware being hardware providers. They cover the BESS value chain from EMS, data management to aggregation and dispatch, interfacing with local monitoring software on the hardware side and trading/scheduling software on the other side. They support data management and forecasting for renewable production and develop their solution toward more optimization and other analytics.

Aggregators solutions which include support behind-the-meter batteries fall into the same three groups as business aggregators and PDs (Basic, Advance and Full Scale), as they cover the needs of different aggregator groups. Most of the aggregators consider software development to be the core business and usually use in-house solutions. This makes it sometimes difficult to classify a company as either an aggregator or a software vendor for aggregation. However, when considering business expansion some companies find it easier to enter new markets as software vendors rather than aggregators. Some of them consider exiting or a significant reduction of their aggregation activities in favor of software development, while others separate their software and aggregation businesses into different units. Usually, aggregator's solutions consist of 3 parts: on-device software for reading

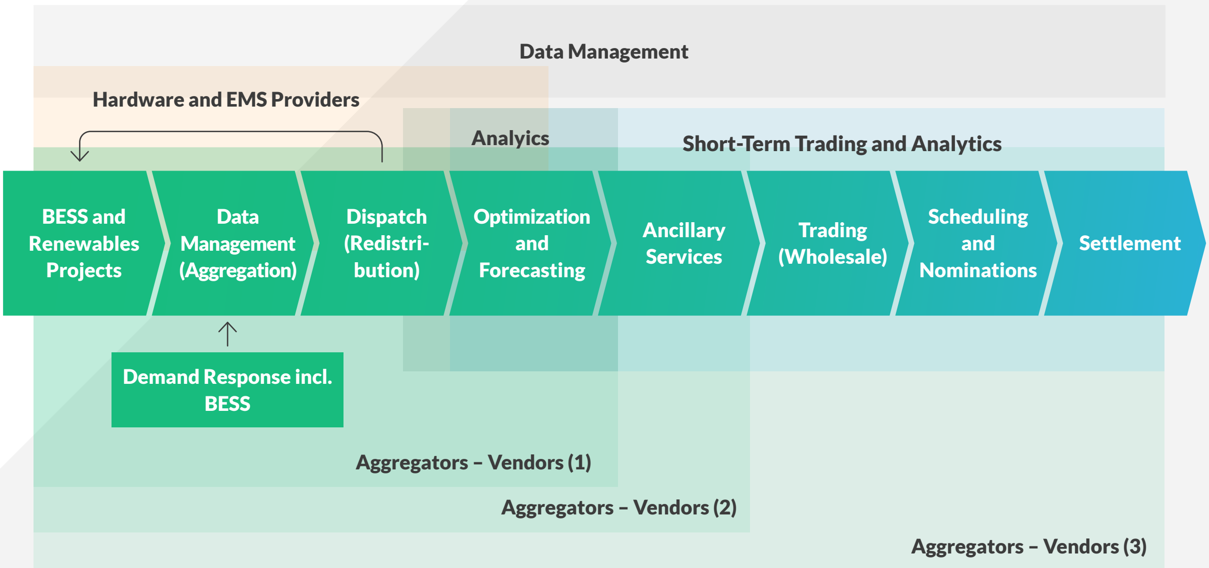


Figure 6. Software solutions along the BESS value chain.

the local data, cloud platform for the aggregation and analytics and customer dashboard to view positions, revenues, etc. The functionality of the platform includes data management for technical and commercial data, battery optimization tools, forecasting (e.g. demand). Sometimes optimization includes cross market trading optimization which results in some trading proposals, but usually does not include any trading support functions.

Trading and analytics solutions have some overlapping functions with ETRMs but are dedicated first of all to short-term and real time trading, including algo and automated trading. Analytics included in these types of solutions are supporting trading functionality. Battery optimization in commercial and cross market terms is usually a part of the supported functionality, but also an ability to seamless integrate optimization tools provided by EMS is important. Sometimes vendors developing this type of solution also offer trading services. The vendors concentrating specifically on the short terms trading usually are not supporting settlement or TSO/DSO interfacing. They prefer to partner with other companies for these areas or integrate with other solutions in projects.

Analytics solutions include more advanced analytics related to pre-trade processes, such as optimization of flexibilities, asset valuations including batteries and PPAs and various AI applications. There are two basic approaches to optimization in general and battery optimization in particular. One is based on classical optimization methodologies, such as linear or dynamic programming, combined with some method of considering the stochastic nature of market prices. The other approach uses AI, leveraging massive historical data on battery status, market prices, and trading decisions. The complexity of the BESS optimization lies in the need to consider the cost of earlier aging and warranty conditions along with prices and volatilities of the market involved. Sophisticated analytic solutions target utilities and traders which can employ large eco-system of solutions in their businesses.

Data Management solutions are dedicated to managing all types of data from meter data to prices and volume data as well as fundamental data and flexible interfacing with surrounding systems. Various machine learning (ML) and artificial intelligence (AI) applications for BESS optimization make data management especially crucial because unreliable data can undermine the entire effort behind these technologies (garbage in, garbage out). Extensive usage of the data makes cyber security of the data Management system a primary concern. For all these reasons, data management has become a new and increasingly important software solution category.

Scheduling and nomination solutions. Companies offering these solutions generally fall into two categories: those that provide software and those that offer services for scheduling and communication with TSOs/DSOs. While the core functionality needed for scheduling and market communication remains relatively unchanged despite the energy transition, the growing number of new market participants is driving rapid demand for this type of software.

In summary we see that there is no solution covering the entire BESS value chain, but groups of solutions that reflect segmentation of the energy companies involved in managing BESS from project development to operations, trading and settlement. The most advanced market participants which operate and trade batteries along with other assets in their portfolio are using eco-systems of solutions with different best – of – breed tools covering different aspects of their business.

Summary and Outlook

This white paper examines the increasing need for flexibility in energy systems driven by the rising share of renewable energy sources. It also explores the technologies available in 2024 and beyond that can meet this demand for adaptability. The flexibility requirements are projected to increase significantly.

Various technologies are under consideration to provide this flexibility, including demand side management, Battery Energy Storage Systems (BESS), EV batteries, and hydrogen. Demand side management faces challenges, including the need for aggregation, complex market access rules, and insufficient consumer engagement due to missing incentives and lacking expertise. Although hydrogen is promising, it offers limited efficiency and is costly for building electrolysers and converting the existing gas network. For EV batteries to play a crucial role, conflicting objectives with grid needs must be addressed first, such as restricted availability due to vehicle operation, limited capacity, and the necessity to maintain a minimum charge level for vehicle use.

In contrast, BESS currently represent the best option to provide badly needed flexibility from all options discussed in this article. This is due to cost efficiency, fast technological improvements for BESS, and regulatory changes. Greater battery efficiency with improved storage duration and lower investment costs have made BESS a profitable business case without governmental subsidiaries. Regarding the regulatory framework, it's expected that European countries will further ease the development and connection of BESS to the power grid.

Major use cases for BESS in the energy market include:

- **Stand-alone, front-of-the-meter BESS:** These storage capabilities ensure grid stability by engaging in short-term power trading and arbitrage across different energy markets, with the potential to generate significant profits.
- **Co-located BESS with renewable energy:** This involves smoothing renewable energy production volatility; for example, compensating for production fluctuations from wind or solar plants.
- **Behind-the-meter BESS:** These batteries are usually installed at prosumer sites for purposes such as peak shaving, or as part of aggregated flexibility brought to the market.

When optimizing BESS profitability, it's essential to consider technical factors, such as cycle limits, warranties, and battery lifespan. There's an important trade-off between maximizing profits and ensuring battery longevity. Another obstacle for BESS optimization is the cannibalization of profitability due to reduction of price volatility. If there is a high degree of participation of other storages and specific subsidies and fees, such as EEG in Germany, BESS as an investment case can become less attractive due to increasing BESS competition.

European markets vary in terms of market access rules. For front-of-the-meter installations, whether stand-alone or co-located with renewable energy, participation in wholesale and ancillary services markets is possible. However, demand-side flexibility and behind-the-meter aggregation vary significantly across countries. For example, in France and the UK, demand-side flexibility aggregators can participate in multiple markets, while in Germany, the situation is more complex.

The BESS value chain is comprehensive and spans from technical BESS component management and BESS optimization to market participation. Typically, multiple companies are involved in a single battery project; from investment to operations and market access. These players all require software solutions and a robust architecture to manage their parts of the process. The integration of those software components is challenging on a technical basis, requiring a holistic architecture design across systems and interfaces.

A wide variety of software vendors exist along the battery value chain. Currently, no single solution covers all stages. Instead, there are specialized vendors offering solutions for different steps in the process.

Commodity
Technology
Advisory

About ComTech Advisory

Commodity Technology Advisory (ComTech Advisory) is the leading analyst organization covering the Energy and Commodity Trading and Risk Management (E/CTRM) and Energy Transition technology markets. Led by Dr. Gary M. Vasey, along with affiliate analysts Dr. Irina Reitgruber and Kevin Mossop, ComTech Advisory provides invaluable insights, backed by primary research and decades of experience, into the issues and trends affecting both the users and providers of the applications and services that are crucial for success in markets constantly roiled by globalization, regulation and innovation. ComTech Advisory helps software vendors to gain more visibility on the market and helps energy and commodity companies to overview various vendors solutions in their sphere of interests.

One of the recent research projects performed by ComTech Advisory around broader flexibility trading and renewables is the ComTech Advisory market study on VPP (Virtual Power Plant) technology and market sizing for aggregation solutions. The research covers the key European markets, highlighting their strengths and identifying areas that still need development. It provides information about the advantages and challenges each of these market presents, helping to understand which business segments are driving VPP technology in different countries and who are typical buyers of VPP-related software in each of these key countries. Furthermore, the study takes a close look at the software solutions that are critical to supporting the VPP value chain from energy data management to aggregation, flexibility trading and post-trading activities and provides a SWOT analysis for each solution segment. Finally, the report provides estimates of the current market size for the aggregation related solutions and its growth rate up to 2030. The free download of the report is available here: VPP Market Study - ETT Center | ETT Center.

Further plans include a study dedicated to AI applications and data management solutions in energy and commodity businesses.

Commodity Technochlogy Advisory
Vyhlidalova 823/19
625 00 Brno | Czechia

Phone: +420 775 718 112
Email: info@comtechadvisory.com
ComTechAdvisory.com

ETT Center

News and views about commodity / energy markets and technology at www.ctrmcenter.com

About FORRS

FORRS is a leading strategy and management consultancy with a strong focus on the entire Trading Value Chain. We support clients with complex, business-critical processes in the Energy and Financial sectors.

At FORRS, we carry out projects in electricity, gas, certificates, and commodities trading. We focus on solving problems along the entire value chain in the trading sector; from front to middle to back office. Our extensive consulting services focus on areas such as portfolio management and ETRM systems, market data, risk management, automated trading, and the design of entire architectures.

In addition, we offer services that go beyond consulting, as we developed GRYT, a software platform specifically for customers in the Energy sector. Its intelligent, cloud-based framework provides an integrated market data management system, as well as a platform to develop, standardize, and execute individual models and processes. GRYT acts as a central platform between generation units, sales platforms, trading systems, and markets to benefit data-sensitive businesses and leverage and grow trading businesses.

Problem-Focused, Solution-Driven. This is the difference maker. This is FORRS.

FORRS GmbH
Dachauer Straße 63
80335 München | Germany

FORRS Office Frankfurt
Große Gallusstraße 16-18
60312 Frankfurt am Main

Phone: +49 89 38 16 45 59
Email: mailbox@forrs.de

www.linkedin.com/company/forrs

www.instagram.com/forrs_gmbh

www.forrs.de