Making BESS Happen

Turning Energy Storage Potential into Grid-Scale Reality

Contents

Introduction

The rapid expansion of renewable energy sources in Europe and globally is transforming power systems. The growing share of variable generation from wind and solar plants results in a more volatile and less predictable energy supply (see whitepaper: Battery Energy Storage Systems (BESS) by Commodity Technology Advisory & FORRS GmbH, 2024). Traditional power plants with dispatchable output are increasingly being replaced by resources that depend on weather conditions, which cannot be adjusted to meet demand. This shift drives a structural need for flexibility in energy systems.

In this context, flexibility means the ability of the power system to adapt to fluctuations in generation and demand on multiple time scales, from seconds to days. Without additional sources of flexibility, frequent imbalances between generation and demand will occur, resulting in excessive costs due to grid instability, more volatile electricity prices, and a less efficient use of renewable energy.

Our first whitepaper provided a broad overview of the available flexibility options. It highlighted the fact that, while several technologies contribute to this need, BESS currently offers the most immediate and scalable solution. Demand-side flexibility remains constrained by the complexity of market access and low participation rates. Hydrogen offers the prospect of long-term seasonal storage, but efficiency losses and high investment costs prevent its near-term deployment at scale. Electric vehicle batteries can provide distributed storage capacity, but the operational priorities of vehicle owners and warranty questions restrict their availability for grid services.

In contrast, BESS technology has developed rapidly and has reached a level of maturity that enables large-scale deployment. Falling costs, higher efficiency, and advances in battery management systems have improved its economic case. At the same time, regulatory barriers are gradually being reduced, particularly in European markets.

Battery energy storage systems are deployed in three main configurations:

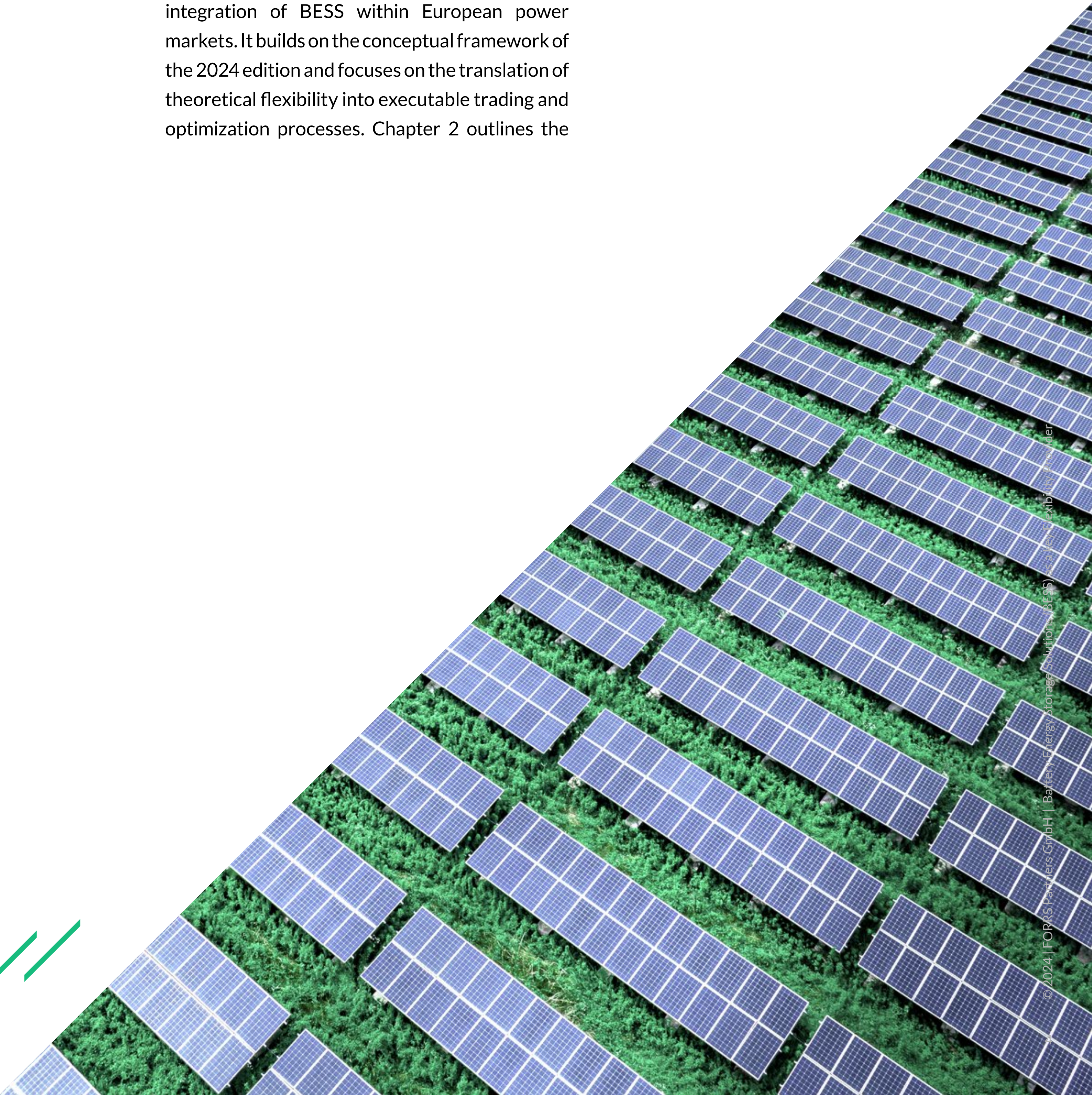
1. Standalone, in-front-of-the-meter installations stabilize the grid by participating in short-term trading and arbitrage.
2. Batteries, when co-located with renewable generation, help smooth the fluctuations of wind and solar output.
3. Behind-the-meter systems can be installed at customer sites, for example, to reduce peak demand. Further they can aggregated to provide flexibility to the market.

The business case for BESS depends on operating them within technical limits, such as cycle life and warranties, while managing the tradeoff between short-term revenue and battery longevity. Profitability may become limited due to cannibalization of profitability by reducing price volatility and the increasing participation of other storages and certain subsidies.

Market access differs significantly across Europe. Front-of-the-meter systems, whether standalone or co-located, participate in wholesale and ancillary service markets. Rules for behind-the-meter aggregation are less uniform: In France and the UK, aggregators can access several markets, while Germany applies stricter regulations.

The BESS value chain extends from component management and system optimization to participation in energy markets. Projects usually involve several companies, making software integration across systems essential. At present, specialized software vendors cover individual steps of the chain, while a single end-to-end solution does not exist.

This whitepaper aims to deepen the analytical perspective on the operational and market integration of BESS within European power markets. It builds on the conceptual framework of the 2024 edition and focuses on the translation of theoretical flexibility into executable trading and optimization processes. Chapter 2 outlines the required trading architecture for BESS. Chapter 3 examines the structure and dynamics of the German energy markets, focusing on wholesale and ancillary services relevant to BESS participation. Chapter 4 consolidates these aspects by introducing methodologies for multi-market optimization and revenue stacking, including the explicit treatment of degradation and forecast uncertainty within optimization models.



Trading Architecture for BESS

Bidding any asset in the short-term energy markets requires a surrounding trading architecture that must encompass comprehensive sets of capabilities, spanning across front, middle, and back-office operations. These include market access to various exchanges and platforms, trade execution mechanisms, portfolio and risk management tools, and systems for regulatory compliance and settlement.

Assets must be able to interact with auction-based and continuous trading environments, while maintaining accurate position tracking and dispatch capabilities. The architecture must support automated trading strategies, real-time data integration, and seamless communication with transmission system operators (TSOs) and other market participants.

At the center of the architecture lies the optimization engine, which synthesizes market signals, asset constraints, and operational forecasts to generate actionable trading decisions.

As the energy landscape evolves, the growth of BESS introduces additional complexity into this trading architecture. Unlike traditional generation or consumption assets, batteries are flexible, bi-directional, and rapid-response units capable of absorbing and injecting energy within very short timeframes. This increased capability means that several components in the trading stack must be enhanced. For example, the core optimization engine must incorporate battery-specific constraints, such as state of charge, round-trip efficiency, ramp rates, and degradation profiles.

An additional essential component in the trading architecture is the Energy Management System (EMS). The EMS provides real-time data on state-of-charge, temperature, and performance metrics, all of which are critical for accurate dispatch and optimization. Seamless integration between the EMS and the trading stack ensures that any resulting market decisions are grounded in the fundamental physical capabilities of the battery.

The optimization engine encounters maximum complexity when a battery participates concurrently in both ancillary services and wholesale markets. It must dynamically allocate capacity between different market segments while respecting technical constraints and regulatory requirements. This requires sophisticated algorithms that can balance profitability with grid-supportive behavior, often under tight operational timelines.

Participation in the auction markets requires technical interfaces to the exchanges, along with the ability to properly aggregate and disaggregate bids with the portfolios. While, for conventional assets, linear merit orders or block orders are the main product type, loop blocks (EPEX), or analogous products on other exchanges, are more suitable for capturing arbitrage opportunities and aligning with the physical constraints of storage systems. Unlike linear merit orders that assume a continuous price-volume relationship, loop blocks allow for structured bidding strategies that reflect the operational flexibility of batteries. Consequently, existing auction bidding tools may need to be amended to enable the trading of these new product types.

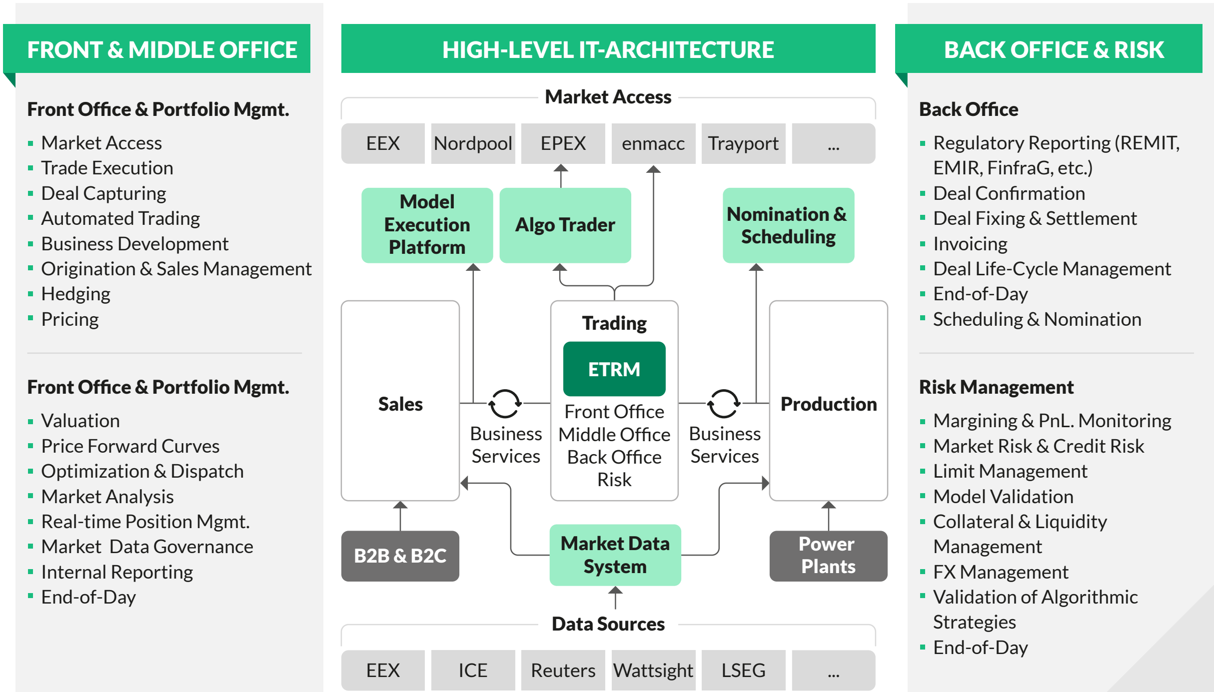


Figure 1: High-level IT Architecture Aligned with Organizational Structure

2.1 Alignment with Organizational Structure

All capabilities must align with the organizational structure of a trading house or department, as illustrated on high-level in Figure 1. In the front office, market access is facilitated through platforms such as Trayport, ENMACC, and EPEX, enabling participation in various market segments, including day-ahead, intraday, and balancing services.

The middle office functions include compliance with regulatory frameworks such as REMIT and EMIR. These systems ensure that all trades are properly reported and confirmed, and that settlement and invoicing processes are accurate and timely. Risk management systems monitor market, credit, and operational risks, providing information on margin requirements, collateral needs, and potential exposures. Together, these components form a robust infrastructure that supports the entire lifecycle of energy trading.

2.2 The Role of ETRM Systems

Trade capture systems must be capable of handling diverse product types across day-ahead, intraday, and ancillary service markets. The energy trading and risk management (ETRM) system plays a pivotal role in recording trades, managing exposures, and ensuring that all transactions are accurately reflected in the portfolio. Moreover, these systems can handle the lifecycle of trades, including confirmation, settlement, invoicing, and compliance reporting under frameworks such as REMIT and EMIR. ETRM systems must be adapted to capture charge and discharge cycles as tradable entities, as well as to support structured products such as loop blocks that align with battery operations.

Post-trade processes include settlement, confirmation, and accounting, supported by systems that manage asset master data, market data, and time series data. Reporting tools provide

Short Term Functional Architecture Design

Tailored Custumized ST Achitecture

A set up with a central ETRM is evaluated in comparison with other set ups on the ST Business

Regulatory & TSO Requirements

The right 3rd party vendor can manage different asset types and their reporting In the different market Areas required

ALGO Trader

The use of an algo trader and the impact of BESS optimization must be considered in the design of the ST archi-tecture

Modern Short-Term Trading = Real Time Data

- Market Access on different market-places and order execution have a central role for modern short-term BESS trading
- Trade management and subsequent position update and asset optimi-zation happens with high-frequency

Dimension and Coverage

- BESS integration with a variety of assets type (Wind, Hydro, Solar, BESS...) require customized deal management
- BESS in in different market areas challenges the industry software coverage

BESS Optimization Increases Perfor-mance Demands

- BESS optimization strategy can run with frequency less than every 5 minutes and imposes an additional performance challenge

Challenges

Figure 2: Functional Architecture Suitable for BESS Trading

transparency for short-term positions and profit-and-loss performance, enabling traders and analysts to evaluate the effectiveness of their strategies.

BESS trading adds stress factors to both the trading architecture and the ETRM system. Short-term markets are evolving and require the management of larger data volumes at higher frequencies, as illustrated by the shift of EPEX to a 15-minute day-ahead interval. Trading companies with multiple assets face increasing performance constraints, as they must adapt multiple processes across the trade lifecycle, including day-ahead asset optimization and bid generation for batteries. Additionally, companies active in different markets must comply with varying market access and regulatory requirements, which are only partially harmonized across European exchanges and TSOs, creating a technical burden on the trading architecture. These aspects are central to defining the role of the ETRM in the trading functional architecture.

A centralized ETRM configuration is recommended for companies that can base their ETRM choice on this key KPI parameter, or that still manage relatively small and limited activities in the short-term market. Conversely, some ETRM systems cannot keep pace with the high data volumes that must be processed, frequently updated, and exchanged with other applications in the trading landscape. In such cases, a hybrid approach is preferred, where a short-term trading tool is directly connected to the marketplace for bidding management. In this setup, nomination and dispatching are also managed through the short-term trading tool, while the relevant trading information is passed asynchronously to the ETRM system (for example, at the end of the business day or according to a scheduled process).

Figure 2 summarizes challenges associated with the market integration of BESS and how these can be addressed by a short-term functional architecture design.

2.3 Co-located BESS and Grid Connection Capacity

For co-located assets, such as photovoltaic systems paired with batteries, the architecture must integrate generation forecasts and manage shared grid connection capacity. Trading strategies must be adapted to reflect hybrid asset behavior, combining generation and storage capabilities. This adds complexity to the optimization and dispatch processes, requiring advanced forecasting and decision-making tools.

3 Energy Markets Focusing on Germany

The German power market relies on a layered structure of short-term trading venues that ensure efficient price formation and system operation. For BESS, these venues are not just abstract constructs, but platforms where flexibility, arbitrage, and ancillary services can be monetized.

At the core are wholesale markets, including the day-ahead auction market, the intraday auction market, and the intraday continuous market operated by EPEX SPOT. Ancillary service markets complement the trading of power and are run by the TSOs. Together, they allow BESS operators to optimize revenues while contributing to grid stability. Figure 4 shows an overview of the markets suitable for BESS.

3.1 Wholesale Markets

Wholesale markets can be split into day-ahead and intraday markets. The day-ahead market is run as a blind auction once per day, covering all 96 quarters of the next day. Market participants submit their bids and offers before the order book closes at 12:00 (D-1). After closure, the exchange's algorithm matches supply and demand across Europe deriving a market clearing price that applies to all accepted buy and sell orders. This mechanism ensures that total buy and sell volumes match each quarter-hour, creating legally binding contracts for delivery. The day-ahead auction concentrates liquidity, yields transparent prices and volumes, and serves as the main reference point for subsequent intraday and balancing markets.

Once the day-ahead schedules are fixed, the intraday market provides flexibility that is closer to real time. Continuous trading in Germany opens at 15:00 (D-1) and runs up until five minutes before delivery. This allows participants to react to updated forecasts of load, renewable generation, or unexpected outages. Products traded on the continuous market are hourly, half-hourly, and quarter-hourly products. To supplement continuous trading, intraday auctions are held at 15:00 (D-1), 22:00 (D-1), and 10:00 (D), providing additional liquidity and transparent price signals.

There are various product types tradable on auction markets, such as the SDAC by EPEX Spot. While the most popular ones are the linear merit order and the block order, the relatively new loop blocks are most suited for battery trading.

Linear merit orders allow the participant to submit multiple pairs of offered price-quantity pairs for each hour of the delivery day. Block orders constitute blocks of variable power across a particular, participant-defined time span, which are defined either for buying or selling only. The participant may submit multiple block orders, which may span across any combination of hours of the delivery day.

Loop blocks allow for both buy and sell block orders, while only being accepted (or rejected) as a whole. Given price uncertainty (regardless of how well the forecasting approaches perform), it provides the safety net for not ending up with certain obligations which lead to mandatory trading activities in the continuous markets[1].

BESS operators optimize charge and discharge schedules by bidding into auction markets to capture price spreads, while the intraday continuous market allows them to react to forecast errors, capture short-lived price spikes, and adjust to imbalances in near real

[1] It can be shown that the expected revenue is higher when using loop blocks under price uncertainty compared to separate buy and sell blocks and hourly price-volume pairs (Karasavvidis et al., 2023).

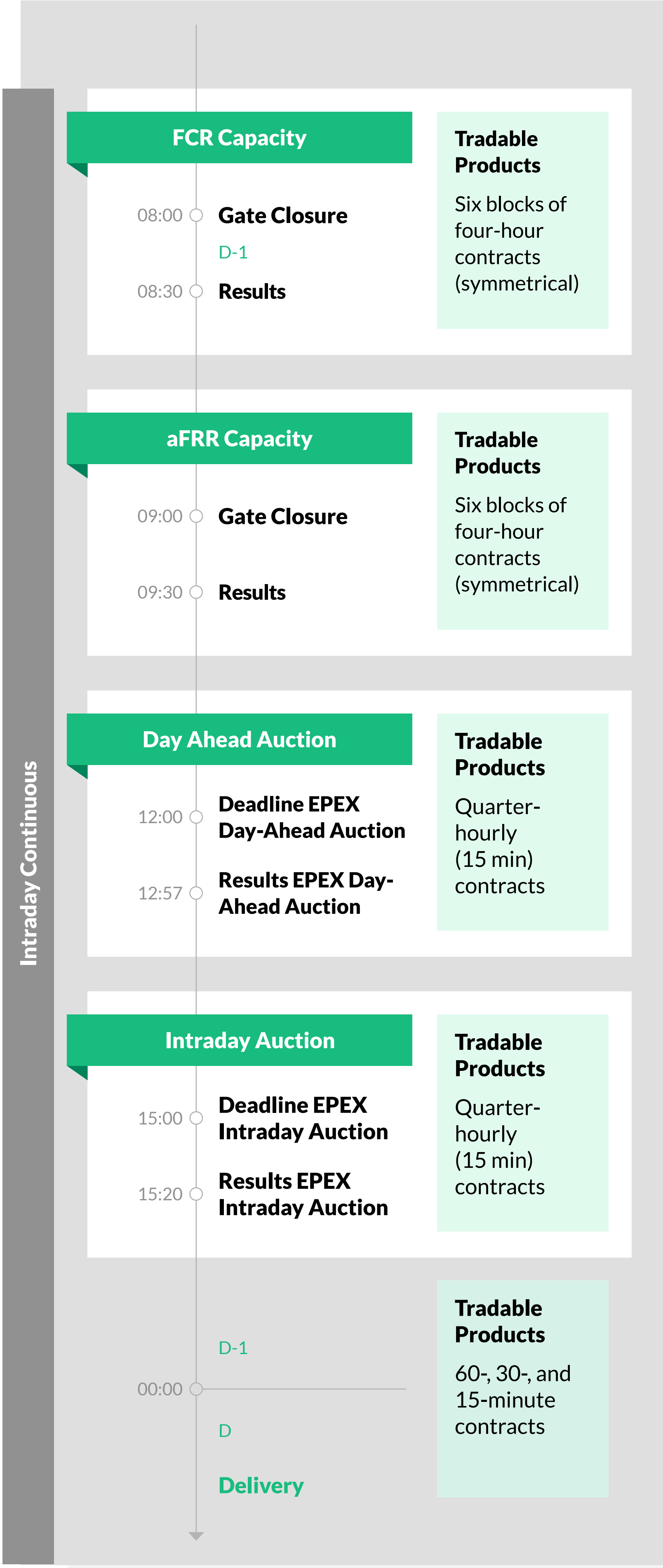


Figure 3:
Markets Suitable for Marketing BESS

time. Covering 96 quarters of the day-ahead/intraday auctions and the hourly, half-hourly, and quarter-hourly products in intraday trading, these markets align well with the flexibility of battery storage.

3.2 Ancillary Markets

Beyond wholesale, Germany operates balancing (ancillary) markets to safeguard grid stability. Markets include frequency containment reserve (FCR), automatic frequency restoration reserve (aFRR), and manual frequency restoration reserve (mFRR).

Due to their short-duration responses, FCR and aFRR are preferred markets for BESS. The potentially long activation duration leads of mFRR markets make these markets less suitable for generating revenue with BESS. Additionally, long activations can deplete the battery. Beyond wholesale arbitrage, BESS can participate in ancillary service markets by offering fast ramping and response times unmatched by conventional assets. It can monetize availability payments even when not dispatched, and stack revenues by combining balancing services with day-ahead/intraday trading when capacity is available.

FCR is the grid's first automatic response to frequency deviations, with full activation within ~30 s. Providers must be able to sustain the contracted power for a maximum of 15 minutes per incident, which is why FCR is well-suited to fast batteries.

In contrast to the pricing conditions of the aFRR and mFRR, where compensation is divided into a capacity price and an energy price, only the capacity price rewards the providers of FCR products, and the market mechanism is pay-as-clear, so all participants receive the market-clearing price. Recent data published by the German grid operators 50Hertz, Amprion, Tennet, and Transnet BW shows that prequalified FCR capacity in 2024 dropped by 35% to 4.5GW, while prequalified aFRR capacity remained steady compared to the previous year.

The only technology with an increase in FCR capacity is battery storage, which grew by 180 MW in 2024 and covers more than the total demand. This means that batteries will have to move to other markets to counteract the cannibalization effect in FCR markets.

In contrast to FCR, aFRR is procured both in a Balance Capacity and Energy Market (BCM and BEM, respectively). On the BCM, there is a daily pay-as-bid capacity auction and on the BEM, there is a consequent pay-as-clear energy auction.

For the capacity market, BSPs submit bids for positive (POS, up-regulation) and negative (NEG, down-regulation) products in 4-hour blocks. The TSO awards the least-cost portfolio that meets demand and system constraints. All winning BSPs are paid their own bid for the reserved MWs (even if not activated). Awarded providers must also place energy bids in the BEM for real-time activation; the energy price can be specified with the capacity bid or updated up to 15-minute gate closure, and if no separate energy bid is submitted, the BCM energy price carries over to the BEM.

Overall, the prequalified capacity for aFRR in 2024 does not exhibit major divergencies from previous years. What has changed are the capacity sources. Prequalified battery capacity rose from 60 MW to 360 MW—an even higher increase than FCR.

Multi-Market Trading and Revenue Stacking with BESS

While BESS projects are often exclusively used in ancillary service markets, the number of projects with arbitrage possibilities across different markets has gained momentum. As explained in Section 2.2, BESS Value Chain, in the previous whitepaper (FORRS & ComTech Advisory, 2025), the value chain contains optimization and forecasting, ancillary services, and wholesale trading. These parts are intertwined and form the basis for multi-market trading and revenue stacking.

Revenue stacking refers to the strategic approach of maximizing financial returns by participating in multiple energy markets and services simultaneously. Instead of relying on a single revenue stream, energy assets can be utilized across various market segments, including wholesale energy markets, ancillary services, and capacity markets, to generate diversified income. This concept is particularly relevant in deregulated and liberalized energy markets where flexibility and responsiveness are rewarded. Revenue stacking enables asset owners to optimize their operations by leveraging price differentials, market volatility, and service requirements across different timeframes and geographies.

A key component of revenue stacking is arbitrage, which can be categorized into inter-market and temporal arbitrage. Inter-market arbitrage involves exploiting price differences between different markets; for example, buying energy in a low-priced wholesale market and selling it in a higher-priced ancillary service market. Temporal arbitrage focuses on time-based price fluctuations within the same market. This includes purchasing electricity during off-peak hours when prices are low and selling during peak demand periods when prices surge. Both forms of arbitrage require precise forecasting, real-time market access, and a robust IT infrastructure to execute trades efficiently and profitably.

BESS are uniquely positioned to capitalize on multi-market trading opportunities, due to their inherent flexibility and rapid response capabilities. Unlike traditional generation assets, such as gas turbines, batteries can switch between charging and discharging modes instantly, allowing them to respond to market signals in real time. This agility makes them ideal for participating in fast-acting ancillary services such as frequency regulation and reserve markets, as well as for executing arbitrage strategies in wholesale markets.

Batteries also offer technical advantages that enhance their suitability for revenue stacking. Their modular design allows for scalable deployment, and advanced control systems enable precise energy management. Moreover, batteries can operate independently of fuel supply chains, reducing operational risks and dependencies. Their ability to store and release energy on demand makes them valuable assets in balancing supply and demand, integrating renewable energy sources, and enhancing grid stability.

One important consideration in battery-based trading strategies is degradation. Unlike gas turbines or other mechanical assets, batteries experience wear and tear based on usage cycles, depth of discharge, and environmental conditions. Degradation affects the performance and lifespan of each battery, which, in turn, influences the economic viability of certain market activities. However, modern battery management systems and predictive analytics can mitigate

	FCR	aFRR Capacity	Day-Ahead uction	Intraday Auction & Continuous
Call for Tenders	Daily	Daily	Daily at 12:00	Daily at 15:00 + continuous trading
Gate Open	D-7	D-7	D-1, 12:00	D-1, 15:00 (IDA1); Continuous from D-1, 15:00
Gate Closure	D-1, 08:00	D-1, 09:00	D-1, 12:00	T-60 to T-15 min (auction); T-5 min (cont)
Awarding Period & Publication	D-1, 08:30	D-1, 09:30	Publication after 12:45, typically by 13:00	Publication ~15–30 min after closure
Products	4 hours, symmetrical	4 hours, positive + negative	60 min, 30 min, 15 min	15 min, 60 min, continuous trades
Minimum Offer Size	1 MW	1 MW	0.1 MW (typical)	0.1 MW (typical)
Offer Increment	1 MW	1 MW	Flexible	Flexible
Divisibility of Bids	Only divisible bids	Only divisible bids	Divisible	Divisible
Remuneration	Pay as Cleared	Pay as Bid	Pay as Cleared	Pay as Cleared (auction) Pay as Bid (continuous)

Table 1: Market Characteristics

these effects by optimizing usage patterns and scheduling maintenance. While degradation is a unique challenge for batteries, it is increasingly being addressed through technological advancements and financial modelling.

In summary, multi-market trading and revenue stacking present significant opportunities for maximizing the value of energy assets. With their rapid response, flexibility, and advanced control capabilities, BESS are particularly well-suited for these strategies. Despite challenges such as degradation, batteries continue to play a pivotal role in modern energy markets, enabling efficient arbitrage and contributing to grid reliability and sustainability.

4.1 Optimization

Both standalone and co-located batteries (including the local renewable energy source) can be marketed on all or a subset of the markets described in Chapter 3. Participation in the ancillary markets requires them to undergo the so-called pre-qualification process.

To achieve optimum revenues, the trading strategy is usually derived from a multi-market optimization approach, with the objective of maximizing revenues. From a mathematical perspective, this can be formulated as a Mixed-Integer (Non-) Linear Programming (MI(N)LP) problem, where the constraints represent both physical and market limitations. Growing integration of batteries into the grid will eventually lead to a growing impact of grid constraints on trading strategies.

As pointed out in Chapter 3, the price formation, both regarding timing and type of price, is heterogeneous. As a result, aspects of price and information availability must be considered while formulating the objective function from a mathematical perspective. Approaches that look at each market individually, optimizing each market in isolation and ignoring the existence of future markets along the timeline, are commonly referred to as myopic models. On the other hand, approaches that consider all markets simultaneously are called coordinated models.

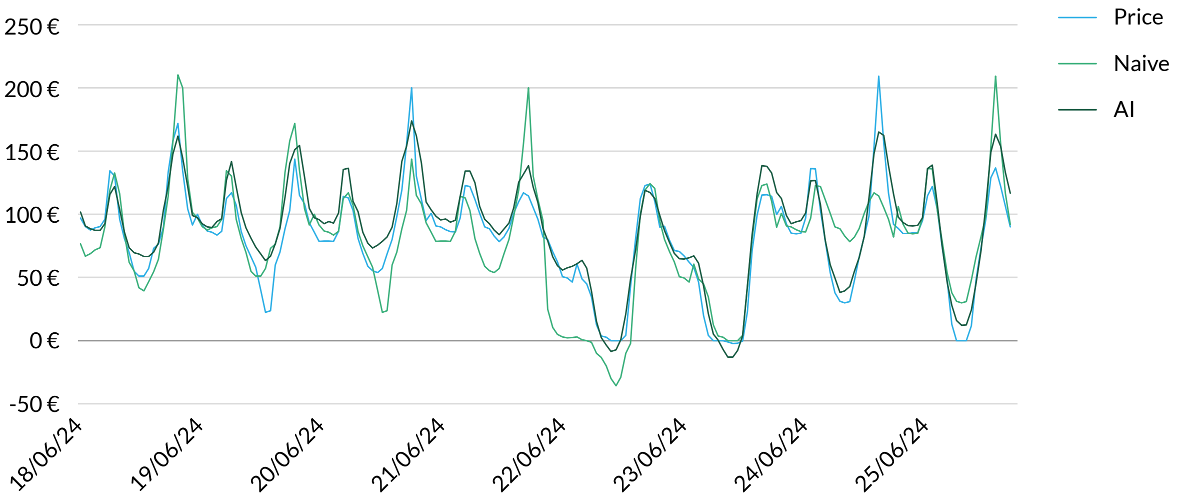


Figure 4: Comparison of Forecasting Methods[2]

For the continuous market with changing prices of each tradeable product, models can also be myopic, due to the fact that optimization is performed once on a snapshot of the order book. This approach is called an intrinsic model. Building on that, the rolling intrinsic policy repeatedly resolves the intrinsic problem on a receding horizon as prices in the order-book update.

4.2 Constraints and the Interplay with the Real-Life Battery

Exact solution approaches are optimization problems given constraints. Broadly speaking, one can distinguish between market-implied and battery-specific constraints. Market-implied constraints, such as the maximum number of products allowed or defined offer increments (see also Table 1) remain fixed. Battery-specific constraints, such as the minimum and maximum state-of-charge, the c-rate, maximum capacity, and more, must be updated regularly, as battery degradation has an impact on efficiency rate, maximum capacity, and other characteristics.

4.3 Degradation Approaches

All rechargeable batteries degrade due to a combination of chemical, mechanical, and thermal factors that affect their internal components. During each charge and discharge cycle, chemical reactions gradually alter the structure and composition of the electrodes and electrolyte, reducing the battery's ability to store and deliver energy efficiently[2].

Battery degradation is influenced by the stress factors of calendar aging and cyclical effects (Collath et al., 2022). Calendar aging is primarily driven by time and temperature. In contrast, cyclical effects are associated with the number of full equivalent cycles and the depth of cycle, which represents the variation in state-of-charge levels that a cell experiences during use.

Degradation modeling methods are classified into three main categories: empirical, semi-empirical, and physicochemical approaches (Collath et al., 2022). Empirical models are based solely on cell aging data and do not explicitly represent the

[2]There is notable progress toward developing ultra-long-life batteries, including self-healing materials, stable organic chemistries, and designs that block degradation mechanisms like hydrogen migration or water-induced reactions. These innovations, ranging from salt-stabilized aqueous batteries to nuclear microbatteries, show early promise in dramatically extending battery lifespan across various applications

physical processes behind degradation. Semi-empirical models, however, combine experimental aging data with mathematical functions that approximate the underlying degradation mechanisms. These models often rely on data collected from a limited number of cells subjected to accelerated aging tests, with stress factors calibrated using empirical observations to reflect technical and physicochemical behavior. Physicochemical models go a step further by directly simulating the internal mechanisms responsible for cell degradation.

During the development phase or for simulation purposes, one can rely on digital twins. This monitoring and gradual updating of the constraints requires a reliable EMS providing the optimizer with real-life battery data.

4.4 Combining Revenue Maximization with Degradation Costs

Aging-aware models consider degradation to be part of the optimization problem. Degradation has a direct impact on the trading strategy; as with receding state of health of the battery, less energy (MWh) can be traded. Efficiency only suffers from calendar and cyclic aging. Degradation can be considered as an adjustment to the objective function, where the linkage between maximizing revenues and degradation is represented by further constraints. Additionally, degradation is part of the objective function, as it allows the derivation of optimal aging costs, to maximize the revenues of the lifetime of the battery.

4.5 Forecasts

Any optimization approach, however, requires accurate price predictions, as the markets are traded at various times throughout the day, as depicted in Table 1. Decisions made on the auction market, for example, have a direct impact on the potential trading options in the continuous market, due to physical constraints of the battery, such as the maximum state-of-charge (for example, 2 MWh for a 1 MW, 2-hour battery).

Power price forecasting, both in the short term and the long term, is challenging, particularly in recent years, due to increased market volatility driven by the growing integration of renewable energy sources. While some prices are formed individually for each hour, auction markets determine 24 hourly prices and 96 fifteen-minute prices simultaneously. From a technical perspective, machine learning and AI models are superior to naïve approaches. Figure 4 shows an exemplary plot of prices on the German Day Ahead auction at EPEX in June 2024, compared with forecasts from an AI model and predictions from a naïve approach[3].

Accuracy is often measured as the Mean Absolute Error (MAE), although the best results also require an accurate shape of the prices, as the spreads indicate arbitrage opportunities.

4.6 Grid-Serving Usage

Another aspect of growing interest from a grid operator perspective is the "grid-serving usage" ("Netzdienliche Nutzung") of BESS, which

[3] Naive:
- Differentiates two categories: weekdays and weekends/holidays.
- The forecast for a given day is a repetition of the previous day that belongs to the same category.
AI:
- An optimized multi-layer neural network model.
- The model learns complex, non-linear relationships from historical values of the target variable together with exogenous inputs in order to generate forecasts.

may create alternative revenue opportunities. Currently, there is no market standard definition of what aspects are encompassed by the term "grid-serving usage" of a battery. One definition, which helps quantification of a battery's contribution (or damage) regarding the grid, is that a participant is acting in a (positive) grid-serving manner if it reduces the grid costs (re-dispatching costs).

A large-scale BESS can increase, reduce, or be neutral regarding the grid costs. The economic value added by a battery consists of market value added and grid value added. Market value added is the sum of the welfare effects in the wholesale and balancing power markets. The value created through battery operation, or by marketing the battery in these electricity markets (see also revenue stacking), accrues to the battery operator as revenue. However, the grid value added, defined as cost savings from redispatch activities, cannot currently be monetized by the battery.

Numerous studies have examined how to quantify grid value added, and explored potential instruments to increase the value that batteries provide to the grid (Lohr et al., 2025). These studies show that batteries are slightly beneficial to the grid overall, but this effect is purely coincidental and not systematic, due to a lack of incentives.

Introducing a redispatch price signal that specifically promotes grid-friendly behavior could significantly increase grid value added compared to today, without negatively impacting batteries or discouraging investment. In fact, from a BESS perspective, the total value added could rise by a double-digit percentage. However, this instrument creates a conflict of interest between batteries and grid operators, as the economic benefits accrue solely to batteries. As a result, it does not provide an additional revenue source for the continued expansion of the grid, which remains necessary.

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