BESS Revenue Optimisation Report

16/05/20256
final

REPORT

Standalone BESS Sizing Report

Sample report

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Document date:
16/03/2026

Version:
final

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Summary

This report presents the BESS sizing results of a planned standalone BESS. The aim of the study is to determine the most profitable BESS size.

Different simulations have been carried out considering the existing site constraints, the planned BESS size range as well as the forecasted electricity market prices in the coming years. The simulation considers a time horizon of 20 years starting in 2027. The BESS is expected to participate in the day ahead market and in ancillary services.

The summarised results are shown in Table 1, with different power and capacity BESS options. It can be seen that the most profitable option is the 30 MW / 60 MWh one. The scenarios show that profitability is very similar within BESS of the same duration, with 2-hour configurations being notably more profitable.

The price forecast indicates that time to market will be crucial for the viability, since the period from 2027 to 2033 is where most of the available revenues are, especially coming from the aFRR market. After that, the introduction of more BESS in the system is expected to make these prices steeply fall. From that point onwards, the main source of revenue is predicted to be the Day ahead market and wholesale arbitrage.

Table 1. IRR of the simulated BESS configurations

Power (MW)	Duration (h)	IRR (%)
10	2	11.41
	4	4.06
20	2	11.43
	4	4.12
30	2	11.52
	4	4.10

1. Scope

This report aims to help give the Client the optimal power and capacity of a standalone BESS system located in Spain to maximize its revenues.

This study first highlights the BESS market potential by detailing the potential revenue streams in chapter 2.1.1 and determines the project constraints that affect the BESS sizing. Secondly, the methodology to determine the optimal sizing is explained along with the inputs used in the study. Lastly, the results from the simulations are analysed and compared with alternative scenarios.

2. Study description

In this section an overview of the study will be given, considering the existing assets, the techno-economic and legal constraints and the methodology used in the optimisation.

2.1. Context

An overview of the different aspects affecting the study will be given.

2.1.1. Revenue streams

BESS can be operated in many ways, allowing them to participate in a range of markets beyond the wholesale market. This diversification of revenue streams is what is called revenue stacking, since the revenues come from different sources. In this section we will briefly explain the most suitable markets for BESS operation

Day-ahead and Intraday

The wholesale market (day-ahead and intraday) is profitable for BESS when doing energy arbitrage. The strategy is therefore to charge the BESS when prices are low and sell the energy when prices are higher (peak load hours). Days with high pricing volatility are ideal for this kind of operation.

Hybrid plants also benefit substantially from this strategy since the BESS can be charged with energy that would be sold at very low prices in the market.

The Day-Ahead market has a distinct pattern depending on the period of the year and hour of the day. The increasing penetration of renewables, especially PV, is pushing down prices in the central hours of the day. However, this also leads to steep price increases in the evening when all this solar generation is reduced as is shown in Figure 1.

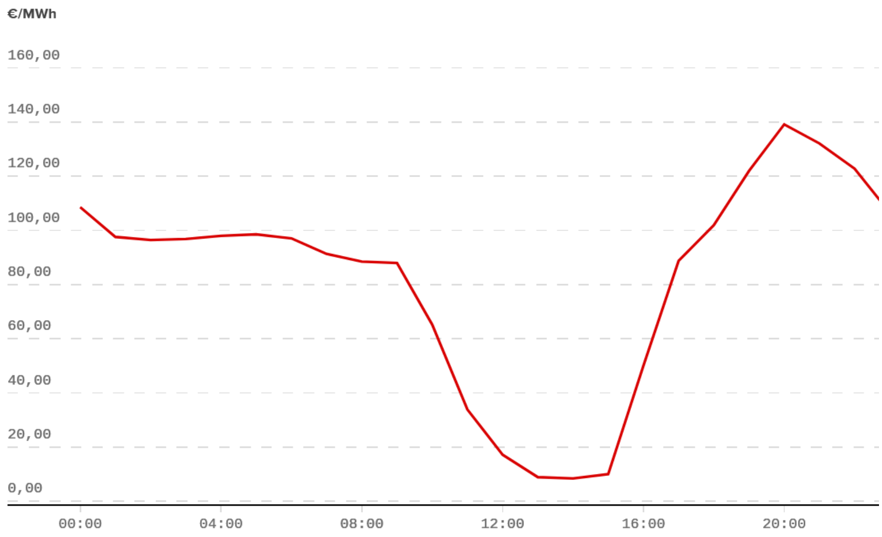

Figure 1. Day-Ahead hourly price from 21st April 2025

The price forecast for this study shows that the average price in the following years is expected to remain quite stable with some deviations. More interesting is the daily spread, which is also expected to offer good margins for BESS operations in the study period.

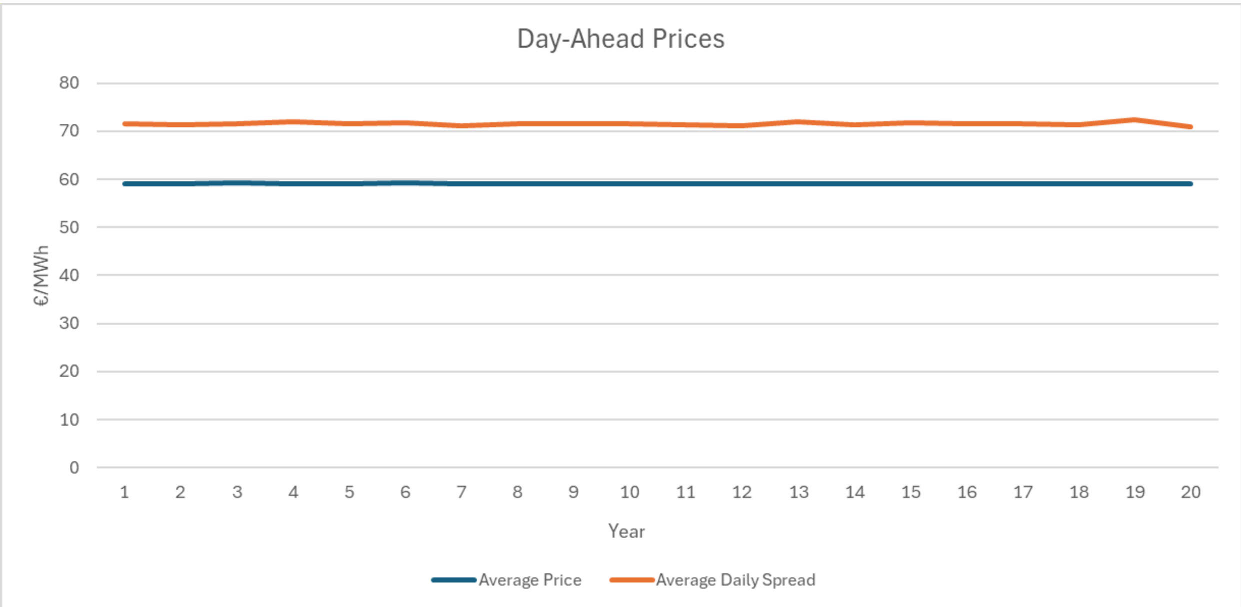

Figure 2. Forecast of Day-ahead prices

aFRR

Automatic Frequency Restoration Reserve or secondary reserve is activated to offset larger frequency deviations if primary reserve has been unable to counter them.

This product is somewhat like FCR but does not require such a fast response. However, the energy activations in aFRR are substantially higher than in FCR so the SoC management strategy plays an even more important role.

Remuneration from aFRR is obtained in two different ways: capacity reservation and energy delivery. Every participating asset is remunerated to have the designated power available. Then, if the asset is eventually ordered by the TSO to deliver or withdraw energy, it is remunerated accordingly. Therefore, the energy remuneration is only obtained if the asset is activated.

aFRR is the main source of revenue for BESS nowadays. This is expected to remain the same for just a few years. However, with the addition of more BESS the prices are expected to quickly fall as the increased competition pushes them. This phenomenon of ancillary services saturation has already been seen in more BESS mature markets such as in Great Britain. The price forecast used in this study clearly reflects this trend, as shown in Figure 3 where prices are very high in the first years of operation. However, they quickly drop in 7 years when they remain stable until the end of the study period.

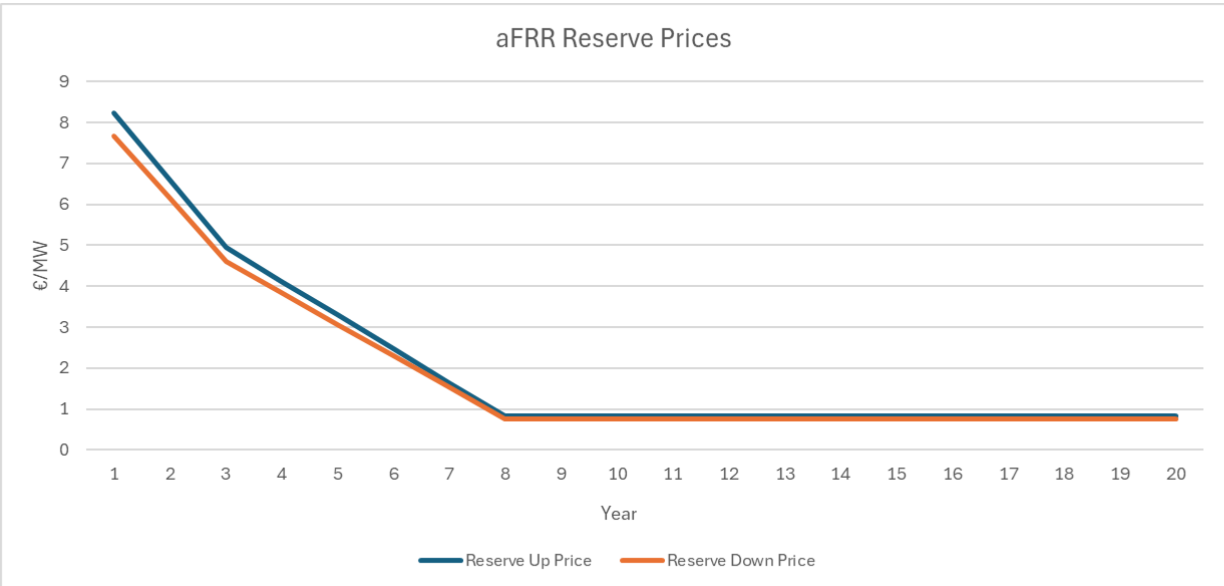

Figure 3. aFRR reserve prices forecast

mFRR

Manual Frequency Restoration Reserve or tertiary reserve is used to restore the previous reserves in the event of major and prolonged imbalances. This product is slower in response than the others and is manually activated. However, due to its low activation rate and long energy delivery requirements, it is not a suitable market for current BESS.

2.1.2. Project constraints

The current project has a maximum available power in the point of interconnection (POI) of 30 MW.

Knowing the POI limits, the BESS sizing power limits are defined not to exceed the injection limit.

2.2. Methodology

2.2.1. Model description

The optimum BESS size is found using 3E's in-house tool. It will formulate and solve a dispatch optimisation problem that considers all costs and benefits, including capital costs, operational costs, and service participation for a system. Furthermore, the optimisation problem is constrained by the technical capabilities and limitations of the different components (e.g., grid injection limit). Two size parameters are optimized, being power capacity and energy capacity. The optimisation aims to maximize the project profitability. Both costs and benefits increase with size, but there should be a point at some size where the benefits are largest with respect to costs, which is considered the optimal size.

Energy storage systems have a state of energy [kWh], also expressed as state of charge [%] that couples every time step in an optimisation window. Operating a storage system in time step t impacts the ability to operate the storage system at time t+1 and vice versa. When a storage system participates in a service, it could be precluding itself from participating in the future based on its limited energy capacity. As such, knowledge of future conditions (market prices, RES generation, etc.) is required for realizing the full value of a storage system. The 3E model uses a perfect foresight assumption. This implies that the optimisation solver has access to errorless information about the whole optimisation window when it decides on the optimal dispatch. Thus, it does not incorporate sources of error that might occur in the real world, such as production forecasting errors or controller performance. It is often useful to ignore this inefficiency in the planning phase of a project to understand the upper limit on the value a BESS could achieve. This allows to better compare scenarios as no knowledge is known yet about the quality of controller or forecasts during the operational phase.

Another element that needs to be factored in is battery degradation. This is very relevant since the time horizon of the study is usually over 15 years, which leads to a substantial battery capacity reduction. 3E's model uses an algorithm that has been tuned with SynaptiQ's data, 3E's SaaS solution that is used to monitor existing battery assets and analyse their performance. The elements that are considered for the degradation include the number of effective cycles, calendar aging, time spent at different SoC, depth of discharge and C-rate of the battery. These detailed modelling based on real data allows the model to forecast a realistic degradation over such a large time span.

2.2.2. Simulation inputs

The following tables detail all the inputs and assumptions used to carry out the simulations.

Table 2. Technical inputs and assumptions

Parameter	Value
General	
POI Voltage Level (kV)	220
POI Sell Power Limit (MW)	10 to 30
POI Buy Power Limit (MW)	10 to 30
BESS	
Rated DC power (MW)	10 to 30
Battery AC capacity (MWh)	20 to 120
Round-trip efficiency (%)	90
Maximum SoC (%)	95
Minimum SoC (%)	5
Maximum daily cycles	1.5
aFRR participation	Yes

Table 3. Financial inputs and assumptions

General	
Business case duration (years)	20
Inflation (%)	0
Actualization rate (%)	10

BESS	
CAPEX per kWh (€/kWh)	230
Decommissioning cost (% of CAPEX)	2,5
OPEX (% of CAPEX/year)	2,5
Land lease cost (€/year)	2044
Aggregator margin (% of revenues)	1
Grid connection cost (€/kW)	3
Auxiliaries' consumption (MWh/MWh capacity·year)	25

3. Results

Using the inputs from chapter 2.2.2 the different scenarios are computed to find the optimal one. The table below shows the IRR values for each BESS size.

Table 4. IRR for the different BESS sizes

Power (MW)	Duration (h)	IRR (%)
10	2	8.23
	4	2.56
20	2	9.86
	4	3.68
30	2	11.52
	4	4.10

Depending on the configuration IRR's vary for 2-hour and 4-hour battery systems. As it will be shown in the following graphs, the 4-hour BESS cannot offset the CAPEX increase with a corresponding revenue increase, leading to a less profitable configuration.

For the 30 MW / 60 MWh case, the revenues and costs are distributed in the following way.

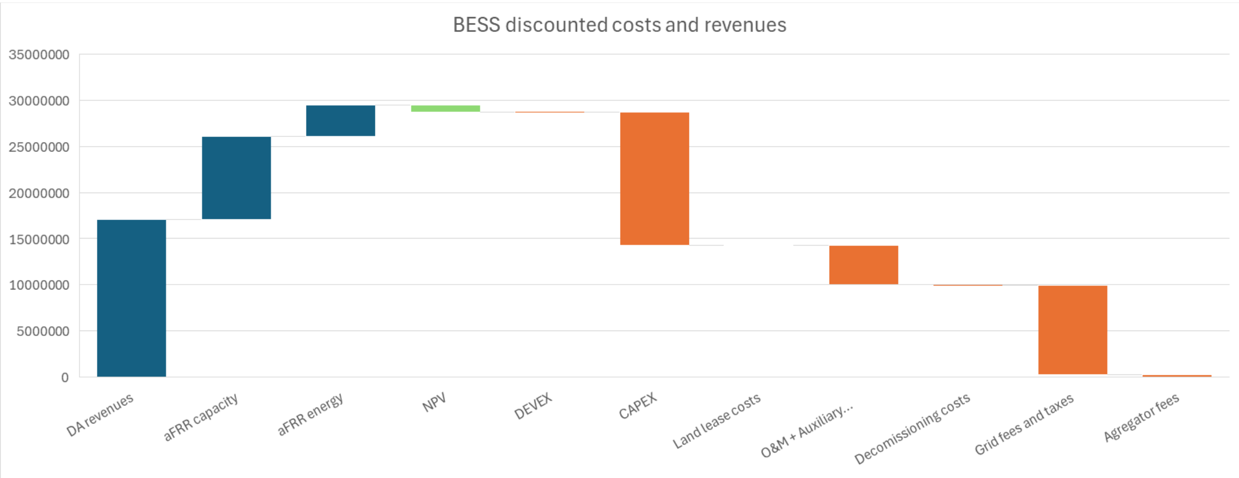

Figure 4. BESS total discounted costs and revenues

The CAPEX is the most significant cost representing 50% of the total expenditure. After that, the energy bought from the grid and their associated taxes take up 33% of the cost, followed by the OPEX with about 17% of the total. The other costs such as decommissioning and the aggregator margin represent a very small fraction comparatively.

When it comes to revenues by source, it can be seen in Figure 5 how they are very large in the first years of operation but then quickly shrink in the following years. This is mainly due to a steep reduction in aFRR capacity prices, which is shown in Figure 3. Therefore, the main source of revenues also exhibits this behaviour. While in the first years aFRR capacity is the main one, trading in the Day-ahead becomes the most relevant one in the later years.

This evolution highlights the importance of a fast entry into the market, since the early adopters will benefit from these high prices. It is also important to remark that revenues along the years would still drop even if prices remained the same, since the SoH of the battery degrades over this period.

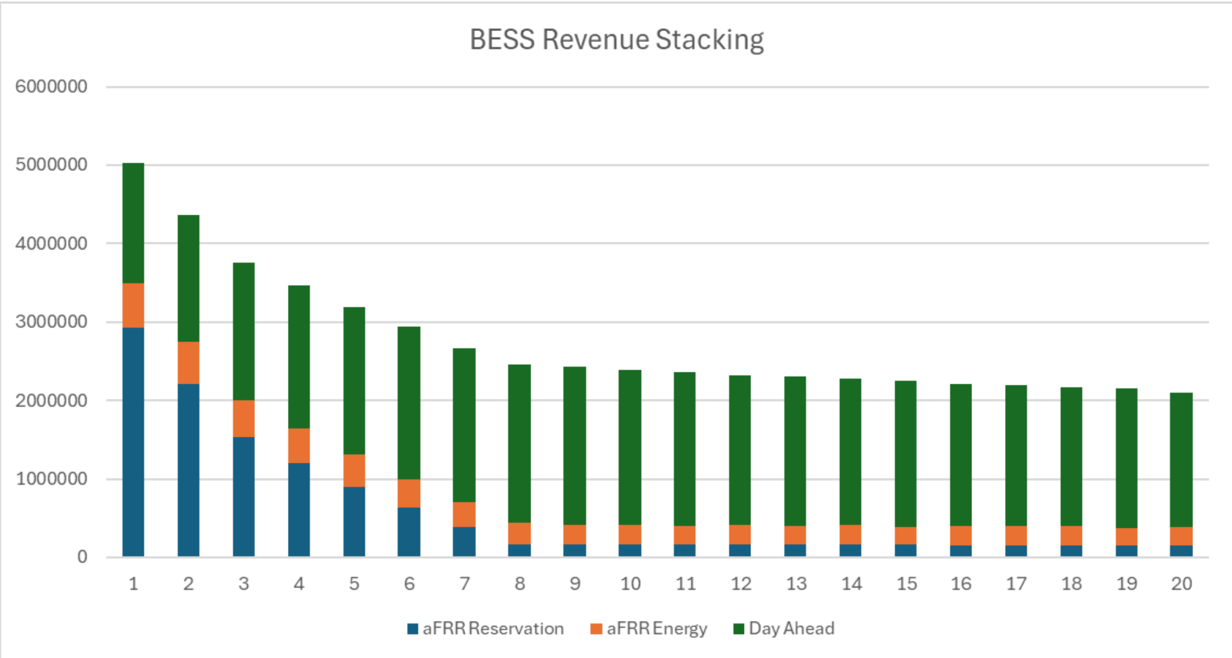

Figure 5. Revenue stacking throughout the period of simulation

The battery SoH at the end of each year is shown in Figure 6, where the SoH at the end of operation is slightly under 70%. The fastest degradation occurs in the first years of operation and slows down very slightly in the following ones.

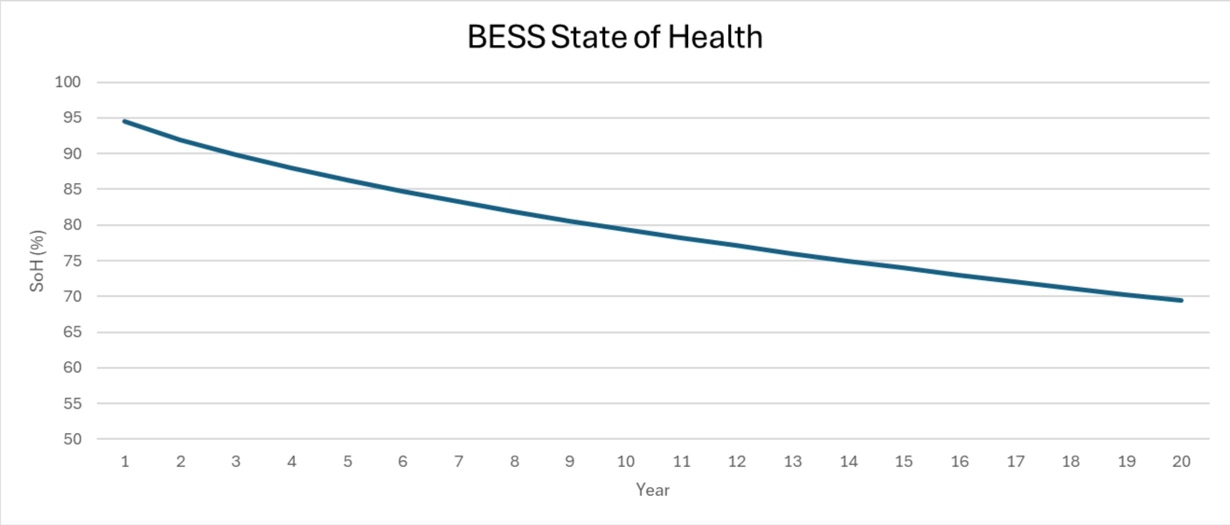

Figure 6. BESS SoH Evolution

A typical daily BESS operation is shown in Figure 7. BESS charges when DA prices are low throughout the day to be able to provide aFRR energy regulation. It gets activated in both aFRR up and down throughout the day until evening. Then, when the DA prices are at their peak, the BESS sells its energy on the DA market.

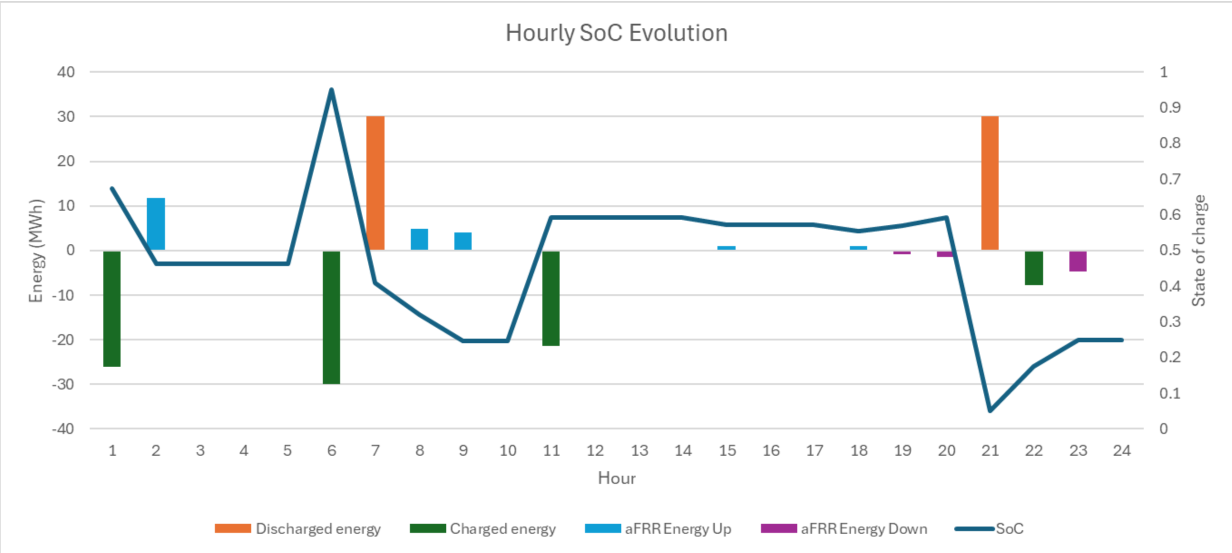

Figure 7. Hourly BESS operation

The aFRR participation is better appreciated in Figure 8, where the capacity reservation is shown alongside the energy delivery. There it can be observed that when the SoC seems to remain stable is due to the BESS participating in aFRR but not getting activated or minimally doing so. aFRR participation is quite symmetric throughout the day. The only exceptions are hours when SoC is high or low and therefore participation in the down and up directions respectively is limited. Also, the BESS doesn't participate in aFRR when it participates in DA, either buying or selling.

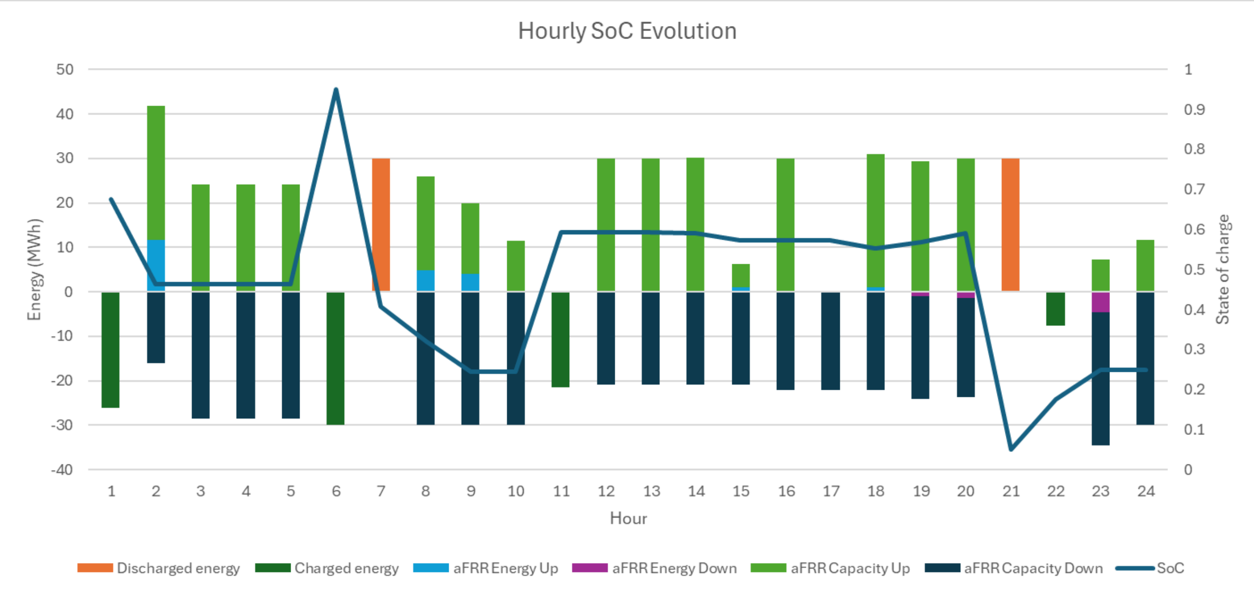

Figure 8. Hourly BESS operation with aFRR capacity reservation

Abbreviations

AC	Altern Current
aFRR	Automatic Frequency Restoration Reserve.
BESS	Battery Energy Storage System
CAPEX	Capital Expenditure
DC	Direct Current
FCR	Frequency Containment Reserve
IRR	Internal Return Rate
mFRR	Manual Frequency Restoration Reserve.
NPV	Net Present Value
O&M	Operation and Maintenance
OPEX	Operational Expenditure
POI	Point of Interconnection
RTE	Round-Trip Efficiency
SoC	State of Charge
SoH	State of Health

Quality information and document history

N°	Date	Author	Summary of changes/event
1	16/03/2026	Biel Roig	Author
1	16/03/2026	Joan Vinaixia	Review
1	16/03/2026	Bianca Ciarloni	Marketing review

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