Europe's energy storage transformation

Storage applications | Energy storage systems were historically used for grid balancing purposes within Europe, limiting their use to such applications or to be considered as "auxiliaries" to renewable generation assets. However, as market prices evolve and new revenue streams emerge, stakeholders must discover the diverse applications that such systems can tap into, writes Naim El Chami

Credit: Alfen

Opportunities for energy storage in Europe are gradually scaling up from early pilots and one-offs

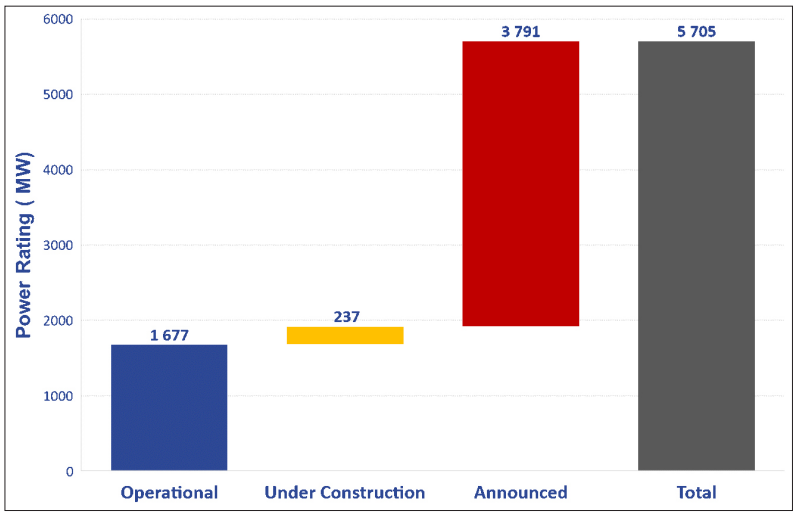

Figure 1. European large-scale energy storage projects by status as of August 2020

The European energy storage industry has witnessed remarkable growth over the last decade, going from 9MW of project announcements in 2010 up to a total of 5,700MW in 2020 (year to date). Out of these projects, around 1.7GW are operational while the remaining 4GW are either announced or under construction (Figure 1) [1].

Such uptake has been predominantly led by frequency control applications. However, things are changing as new revenue streams emerge and market prices tend to decrease.

The rise and fall of the frequency control bonanza

European frequency control markets played a major role in energy storage uptake thanks to lucrative revenues and accessibility to new technologies such as batteries. In fact, batteries are well suited for primary reserve provisioning thanks to their fast response and the assets get remunerated by the grid operator for each MW available (payments in €/MW/h) to ensure system resiliency.

In Western Europe, 3GW of frequency control reserves (denominated Frequency Containment Reserves, or FCR) are jointly procured by six countries on a common platform. The current FCR auction takes place daily and involves Germany (603MW), France (561MW), the Netherlands (74MW), Switzerland (68MW), Austria (62MW) and Belgium (47MW) with Denmark (DK1, 30MW) expected to join soon, as well as Spain (275MW) and Poland (168MW) in the years to come. Currently, 477MW of battery storage systems are already delivering this service (out of which 87% are located in Germany) with an additional 209MW on the way.

For each country, the frequency containment reserve requirement is based on the ratio of the yearly national production (in MWh) to the yearly total production over the synchronous

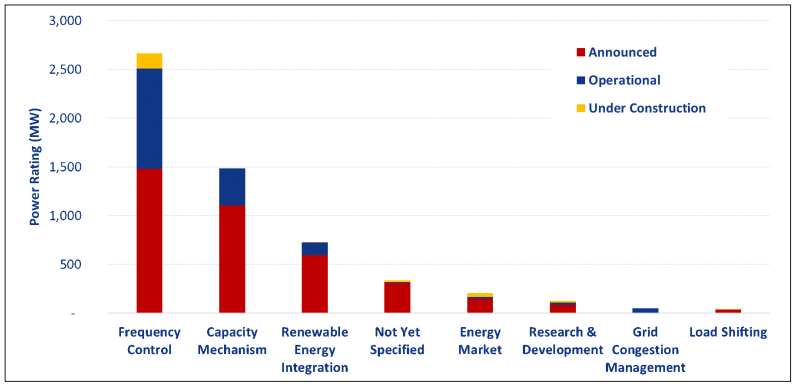

Figure 2. Most common applications for European large-scale energy storage systems

European area. Procurement targets slightly vary every week based on TSO (Transmission System Operator) requirements and past years' production. In fact, 30% of each country's reserve must be nationally sourced and the exports to other FCR Cooperation members are limited to the maximum between 100MW and 30% of each capacity block.

However, this market's revenues fell from an average of €26/MW/h in 2015 and €18/MW/h in 2017 to as low as €5/MW/h in early 2020. Henceforth, this market could no longer justify project viability by itself, requiring new and additional revenue streams.

The fall in FCR prices and the impact of energy storage systems

Frequency Containment Reserve auctions take place over the Regelleistung platform. Until July 2019, these auctions used to occur on a weekly basis before shifting to a daily one as products were procured on a day-ahead term. The older auction model incentivised bidders to "guess" bidding prices, rendering them unrepresentative of the actual merit order of FCR resources.

Another change took place on 1 July 2020 as the FCR auction timeline was once again changed: instead of bidding for 24-hour products, market participants are now able to bid daily for six four-hour delivery periods. This evolution offers more flexibility to market participants, allowing them to participate in other markets and diversify revenue streams within the same day. Thus, a better market transparency is expected since FCR prices will probably reflect market conditions (higher prices in the day, lower in the night).

This evolution can be seen in Figure 4 that represents marginal FCR prices over the last three years. The most significant event is the sharp decrease of market revenues as prices fell from an average of €18/MW/h in 2017 to as low as €5/MW/h in early 2020. Such price fall renders the new market evolution even more crucial to ensure project viability through multiple revenue streams that will be discussed in the next part of this article.

One of the price fall causes is the high volume of battery storage uptake: there's about 477MW of storage providing FCR services, which lowers prices as batteries are inherently more competitive than any other participant in this

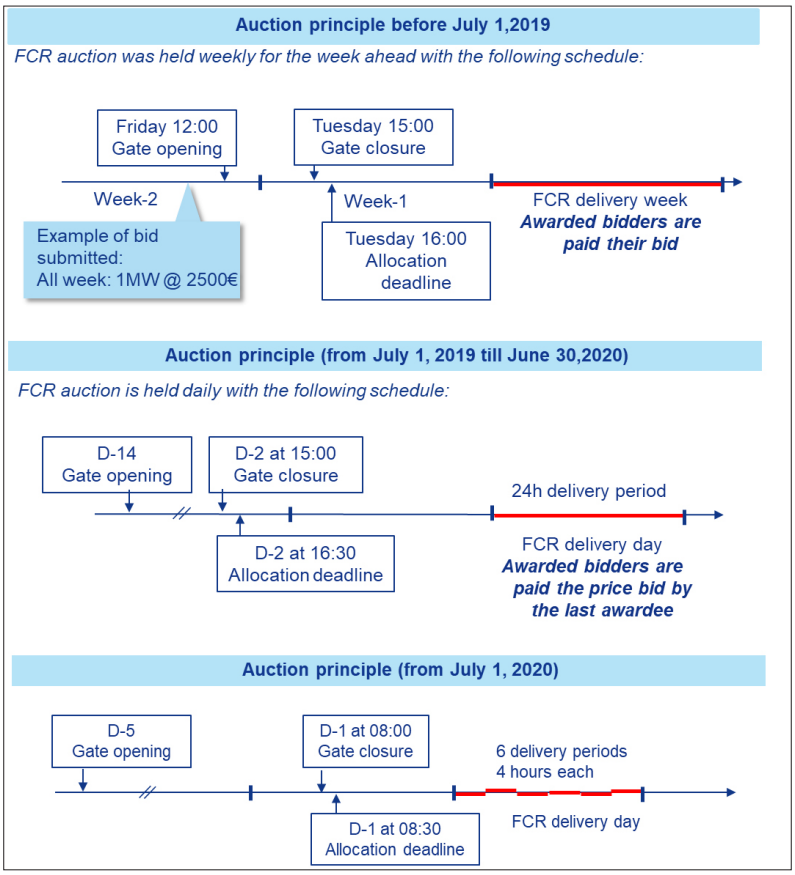

Figure 3. FCR auction timeline

market since the marginal price for FCR provisioning is lower. Such impact was witnessed in multiple cases such as the French one following the conclusion of its long-term capacity market auctions (*"Appel d'Offres Long Terme"* – AOLT) through which 253MW of battery storage systems were contracted out of a 377MW total of new capacity uptake (Figure 5).

A Clean Horizon analysis shows that the deployment of 100MW of new battery storage capacity could lead to an 18% fall of FCR revenues, which is directly translated in Figure 6. The analysis replays the FCR auctions by integrating additional storage shares (i.e. by introducing additional "floor" bids in the bid ladder for each day of the auction).

So, as previously mentioned, the market had to cope with such price movements in order to offer additional flexibility to asset owners so that they can tap into new and additional revenue streams while ensuring project viability.

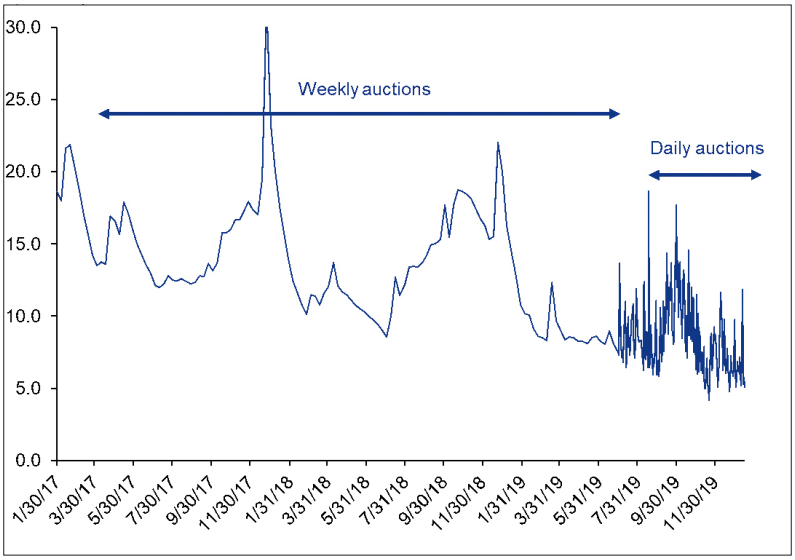

Figure 4. Evolution of the FCR marginal prices over the last three years (coupled market) (€/MW/h)

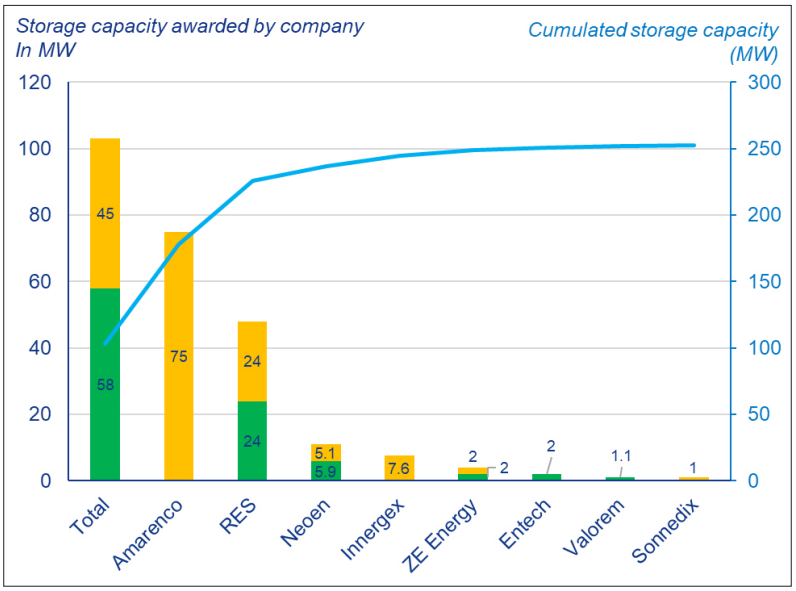

Figure 5. Volume awarded for each delivery period per company in French AOLT

New revenue streams emerge as stakeholders are progressively aware of energy storage potential

Arbitrage on the balancing markets

July 2020's change in the FCR auction timeline will allow storage to diversify its activity within the same day. In France, at least two other ancillary services are evolving towards a storage-friendly configuration in the next two years: the Balancing Market should open to standalone storage systems by the end of 2020 following the recommendation of the French Energy Regulation Commission (CRE); and the French secondary reserve (aFRR) is expected to open itself to new participants by mid-2021, therefore allowing the current dedicated generators to move on to different activities while creating a new potential source of revenue for storage systems.

Regarding arbitrage on the balancing market, the imbalance management structure is quite similar among multiple European countries such as France and Germany. The TSO can adjust system imbalances through two mechanisms: the balancing market (ex-ante) and imbalance settlement (ex-post).

An asset that offers imbalance management services can either be remunerated by providing tertiary reserves (balancing market) or by contributing positively to system balance in order to benefit from the Settlement Price afterwards. In both cases, the remuneration depends on forecast abilities and market flexibility.

On D-1 (the day before delivery day, D), an asset owner can bid on the balancing market through 30-minute blocks (in the French case, 15-minute blocks in Germany) by precising available capacity (in MW) as well as an energy activation price (in €/MWh) for a given direction (upward or downward).

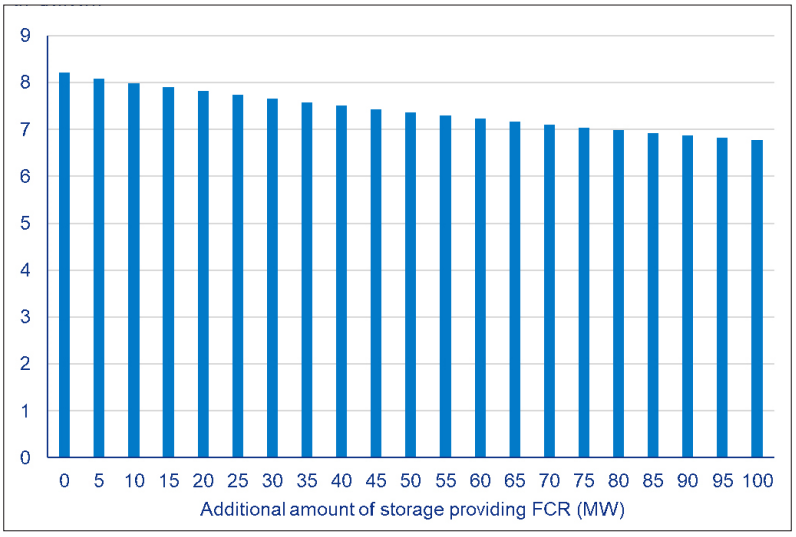

Figure 6. Evolution of the average FCR clearing price in France as a function of the amount of storage deployed (in addition to the already deployed storage). In €/MW/h

On D day, unexpected fluctuations in generation or demand or forecast errors lead to energy imbalances, which requires balancing assets to ensure system stability. Henceforth, reserves get activated with respect to the merit order of their energy activation prices.

On the Billing Day, the TSO compensates for the additional reserve activation costs by penalising or remunerating market participants depending on their contribution to the imbalance event. The energy is remunerated through the Settlement Price.

Similarly to the FCR concept, national balancing markets (RR or Replacement Reserves) have been moving towards a European standardisation of the product since 2019 with the MARI (for manual Frequency Restoration Reserves or mFRR) and TERRE (for Replacement Reserves) projects. The main goals are to establish a common platform as well as 15-minutre auction blocks, which will be favourable to storage.

Grid investment deferral

During peak demand periods, the power that flows through the transmission and distribution networks might exceed the load-carrying capacity of such networks and lead to congestion issues. This issue has been addressed by system operators via traditional practices such as investing in new transmission and distribution assets to increase the initial carrying capacity.

However, when such events happen occasionally and for limited periods, the investment in reinforcing the entire network does not seem to be the optimal solution.

Energy storage systems that are located on congestion points can act as 'virtual power lines' (also called non-wires alternatives) to enhance the power system's performance without a need to overbuild transmission and distribution assets. These 'virtual lines' act as an extra lane that appears whenever it is needed to provide the additional capacity required to ensure system reliability and redundancy for a smaller footprint. So, instead of, for example, upgrading a substation capacity from 15MW to an oversized 20MW to address an occasional event,

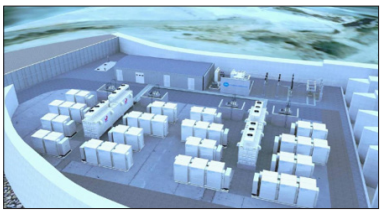

Figure 7. The 10MW/30.2MWh battery at Ventavon, one of the three energy storage systems RTE's RINGO project

system operators can procure the exact storage capacity to meet their demand forecasts. Moreover, as interconnectors could take up to seven (or more) years to get approved and constructed, large-scale battery storage can be operational within two years. Hence, storage systems do not face the same harsh permitting processes as new power transmission lines and poles do.

European countries are showing remarkable interest in storage as non-wire alternatives through multiple proactive approaches.

In France, both the Transmission System Operator (RTE) and the Distribution System Operator (Enedis) started experimenting with non-wires alternatives such as batteries for grid congestion management.

In 2017, RTE initiated the RINGO project, which involves deploying three battery systems totalling 32MW/98MWh to experiment with grid congestion management once they go online in 2021. However, as per the European regulation, system operators are not allowed to partake in energy markets. So, RTE proposed to implement a particular operational protocol: at any time, the net energy balance of the three systems has to be null – when one battery discharges, others charge at the same time.

RTE plans on selling those "virtual line" assets once the experiment is over, and contract third parties to provide the needed flexibility services starting from 2024.

The emergence of new fast reserve products, coupled to lucrative capacity market mechanisms: the Italian case

Italy's National Energy and Climate Plan (NECP) is claiming an ambitious transition to renewables and storage with a total coal phase-out by 2025 and the addition of 18GW of wind capacity and 25GW of solar. Thus, national TSO Terna estimated a need for 3GW of storage to ensure system adequacy and the ability to cope with the evolution of the power mix.

The Italian Capacity Market

In order to ensure security of supply and maintain sufficient generation capacity, Italy launched its capacity market in mid-2019. Similar to the Irish scheme in design thanks to its strike price mechanism, the Italian capacity market is distinguished by the extensive support of new-build, decarbonised assets as they benefit from 15-year contracts (in contrast with existing ones that get one-year contracts).

Storage can participate in capacity auctions and is considered as active if providing balancing services or partaking in the energy market, thus encouraged to stack revenues. It has an advantage over conventional generation thanks to CO2 emission limits (which prevent coal power plants from partaking in the capacity market).

"Given the growing market interest for Spain from developers, as well as the skyrocketing number of grid-connection queries, new business opportunities should emerge for utility-scale battery storage by the end of 2021"

The two first auctions were held on 06 November 2019 and 28 November 2019 for respective delivery in 2022 and 2023. These two capacity market auctions have awarded:

- One-year contracts to existing capacity (respectively 34.8GW and 35GW), with a remuneration of €33,000/MW/year (common to both auctions)
- 15-year contracts to new capacity (respectively 1.8GW and 4GW) with a remuneration of €75,000/MW/year (common to both auctions)

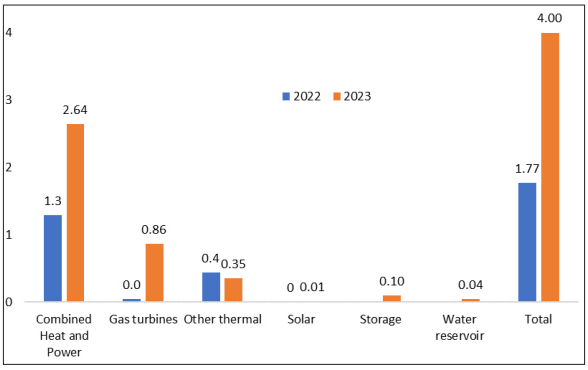

Figure 8. New capacity awarded under 2019's Italian capacity market auctions (by technology). In GW

The 2023 auction saw 90MW of new storage systems being awarded 15-year contracts, which is a very positive sign for the energy storage industry. Applied de-rating factors remain unknown for energy storage systems but would likely depend on storage duration.

Terna to procure 230 MW of fast reserves

Terna has recently announced that the Italian electricity system will face new constraints in the coming decade due to changes expected in the generation fleet such as reduction of system inertia (due to coal phase-out and increase in renewable capacity), increasing steepness of the evening load ramp, and increasing curtailment of renewables due to congestion issues and stability requirements

Fast reserves are seen by the TSO as a solution to compensate for the loss of inertia due to increasing renewable energy penetration and the continuous decommissioning of conventional thermal capacity. The proposed "Fast Reserve" service will not replace FCR but rather be coordinated with it to contribute to dynamic system stability.

Studies led by Terna show that no fast reserves are needed to guarantee system stability as long as the share of conventional generation remains above 35%. With the assumed addition of 13GW of renewables by 2025 (+7GW PV, +6GW wind in the 2017-2025 period) and coal being phased out, there would be more than 1,000 hours during which renewables would have to be curtailed, resulting in the curtailment of approximately 210GWh/year.

This service shall be cumulated with other applications as only 1,000 hours of availability are required. The remaining 88% of the time, the energy storage system will have to operate on other markets such as the ancillary service or wholesale electricity markets. As energy markets are regional, this will result in an interesting locational value for energy storage systems.

This fast reserve service is very similar to the British Enhanced Frequency

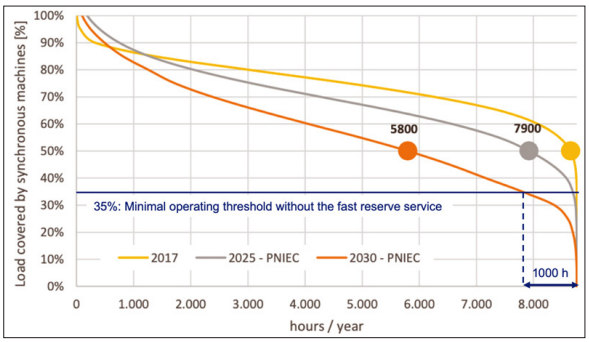

Figure 9. Current and future load coverage by synchronous machines in Italy. Source: Terna

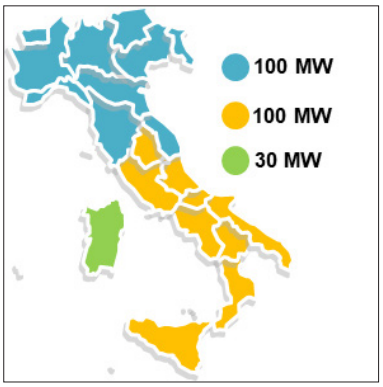

Figure 10. Terna's Fast reserve procurements in Italy

Response service and is perfectly fit for battery storage systems as it:

- Is symmetric (upward and downward);
- Is open to units ranging from 5 to 25 MW (to ensure the resource is spread across the territory and a various fleet of units);
- Will pay for availability with 5-year contracts (commissioning expected by January 1st, 2023);
- Requires 15 minutes of availability in both directions for limited energy reservoirs (i.e. at least 30-min discharge duration batteries);
- Requires full activation in one second.

To prevent further stability issues, Terna will hold an auction to purchase 230MW of fast reserves on 10 December 2020:

- 200MW of fast reserves in continental Italy (100MW in North and Centre North and 100MW in Sicily and the rest of the country)
- 30MW of fast reserves in Sardinia

The price cap for the auction is set at €80,000/MW/year under a pay-as-bid scheme for both areas.

Rise of the Iberian energy storage market: Portugal leads the way and Spain slogs along

In the middle of a global sanitary crisis, Portugal confirmed the next 700MW national solar auction that includes a storage option while Spain opened a consultation on the role of energy storage in the national energy strategy, which includes 2.5GW of battery storage to be installed by 2030.

The Spanish market awaits an imminent regulatory change to initiate the deployment of commercial utility-scale storage

The Spanish electricity mix features a high penetration of wind and hydro power while coal assets are being phased out, compensated by gas-based generation. However, the strong penetration of hydro power renders the grid vulnerable to important seasonal generation intermittence as the Spanish territory is subject to droughts.

While the presence of utility-scale stationary storage remains marginal in Spain today, a goal of 2.5GW has been set up for 2030 under the National Energy and Climate Plan (NECP). Regarding electrochemical energy storage, only 26MW of utility-scale systems are currently operational, including the 20MW Endesa system commissioned in 2017.

Most of these systems are demonstration projects, illustrating a certain interest in storage from major stakeholders such as Iberdrola, Endesa or the TSO Red Electrica (REE). However, the small amount of MW deployed reveals some of the main the obstacles faced by developers, including the regulatory vagueness regarding electrochemical storage installations and the limited revenue streams that can be accessed by energy storage systems.

While the primary reserve was the core business driver of many storage projects in Western Europe, this mechanism is not remunerated in Spain. Three alternative revenue streams could become interesting for storage: secondary reserve, tertiary reserve, and deviation management.

Among them, only the secondary reserve service features an interesting level of revenue, cumulating a capacity remuneration close to €140,000/MW/year with around €25,000/MW/year for activated energy (best case scenario). However, this application explicitly states that pumped-hydro storage can participate, there are no rules regarding the participation of other technologies such as batteries.

One or several storage-favourable regulatory changes should arise within the next year

Despite the ambitious battery storage target set up last year by the Spanish NECP, there is currently no business opportunity justifying the deployment of 2.5GW of electrochemical storage by 2030. Given the growing market interest for Spain observed nationwide from developers, as well as the skyrocketing number of grid-connection queries received by REE in the last months, it is Clean Horizon's opinion that new business opportunities should emerge for utility-scale battery storage by the end of 2021.

This opportunity is likely to materialise if one or several of the following elements happens:

- Significant grid fee exemptions for battery storage;
- Creation of a long-term capacity auction remunerating renewable assets including storage like in France;
- Creation of a new fast frequency

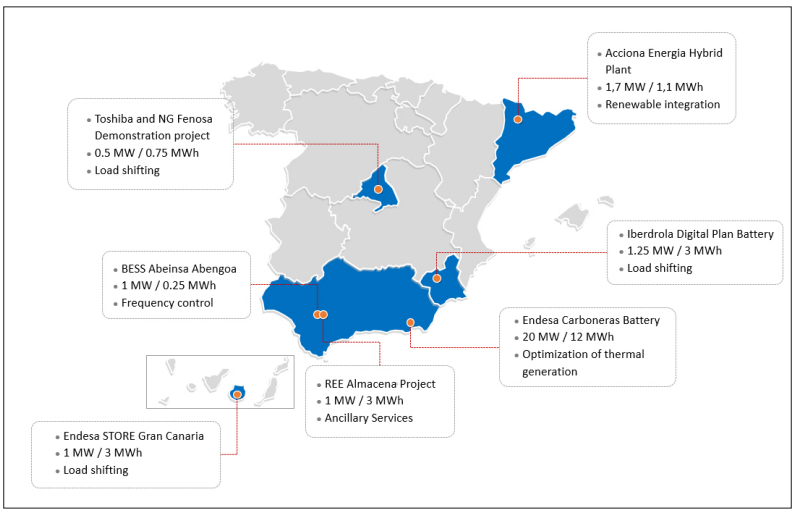

Figure 11. Operational utility-scale battery storage systems in Spain [1]

response service remunerating batteries for available capacity like the Italian approach;
- Opening of the primary reserve through a market mechanism that would enable electrochemical storage participation or adaptation of the secondary reserve rules.

Portugal gives its green light to storage developers with a stepping stone in the next long-term solar auction

The Portuguese electricity sector shares common features with its Spanish neighbour. Indeed, it is characterised by a strong penetration of renewables, mainly wind and hydro. Like Spain, Portugal experienced an historic drop in its coal-based generation in 2019, translating the efforts of the Portuguese government to let go this industry.

Comparable to Spain's, the Portuguese ancillary service opportunities for storage are limited to a lucrative but currently inaccessible secondary reserve:

Primary reserve services are mandatory for large generators and are not remunerated.

Secondary reserve services are remunerated through an attractive payment for available capacity (€/MW) and an additional payment for activated energy (€/MWh). A battery could potentially pull out as much as €190,000/MW/year but the bidding process is limited to day-ahead auctions without intra-day bid modifications, which is not flexible enough for storage.

Tertiary reserves feature limited revenues through activated energy payments, which do not justify a business case.

Portugal opens its national auction to solar-plus-storage systems

The ongoing 700MW solar auction will enable storage to participate in competition with traditional PV systems. The 700MW of new capacity will be awarded to the most economical solutions, regardless of the option model used.

Looking more closely at storage participation, the remuneration model is similar to Italy's new capacity mechanism. Indeed, the solar-plus-storage plant receives a fixed yearly capacity payment in exchange for availability on peak times, defined as periods when market prices go beyond a threshold called "strike price".

> "Portugal's 700MW solar auction will enable storage to participate in competition with traditional PV systems. The new capacity will be awarded to the most economical solutions, regardless of the option model used"

The strike price is defined as a quarterly variable based on the average marginal costs of Combined Cycle Gas Turbines (CCGT).

The contract between the TSO and the awarded bidder is the following:
- In a normal period, the solar-plus-storage plant is allowed to operate at its convenience, for example by selling energy on the wholesale market;
- When the day-ahead market price goes beyond the strike price threshold, the solar-plus-storage plant must pay the difference between its selling price and the strike price to the system operator;
- In compensation, the plant receives a fixed annual payment in €/MW equivalent to a percentage of a reference maximal price.

This type of agreement benefits both the power producer and the system operator. The power producer can count on a fixed yearly payment for 15 years, mitigating the market risk of its project while the system operator ensures having reliable assets while avoiding price spikes on the wholesale market.

In conclusion, to promote energy storage uptake, two paths are open for Portuguese market operators:

The creation of artificial forecast parameters for the auction inputs, considering a strong increase of market prices in the years to come, thus driving up the potential capacity payments for Option #3 in Figure 12.

The redesign of ancillary market participation rules, especially for the secondary reserve, enabling storage systems to cope with their limited energy capacity without jeopardising accessible revenues on these markets. It can however be noted that the secondary reserve market can already provide significant revenues for storage. A favourable change in the regulation would therefore be a significant upside to a developer basing its bids on a combination of capacity payments and secondary reserve revenues. ■

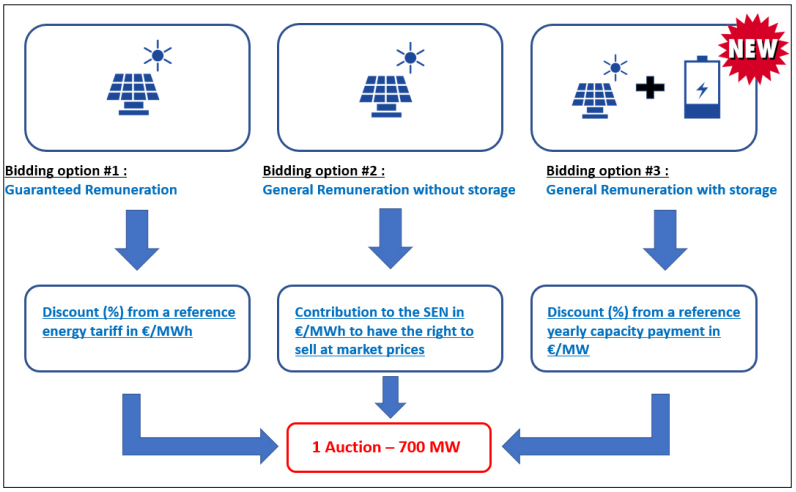

Figure 12 Bidding options for Portugal's 2020 solar auction

References

[1] Data sourced from the Clean Horizon Energy Storage Source – CHESS, Clean Horizon's own database of international large-scale energy storage projects (excluding pumped hydro installations, public projects only)

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