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Batteries and storage: when will they take off?

November 2024

Agenda

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I. Policy and regulatory outlook

II. Markets available for storage assets

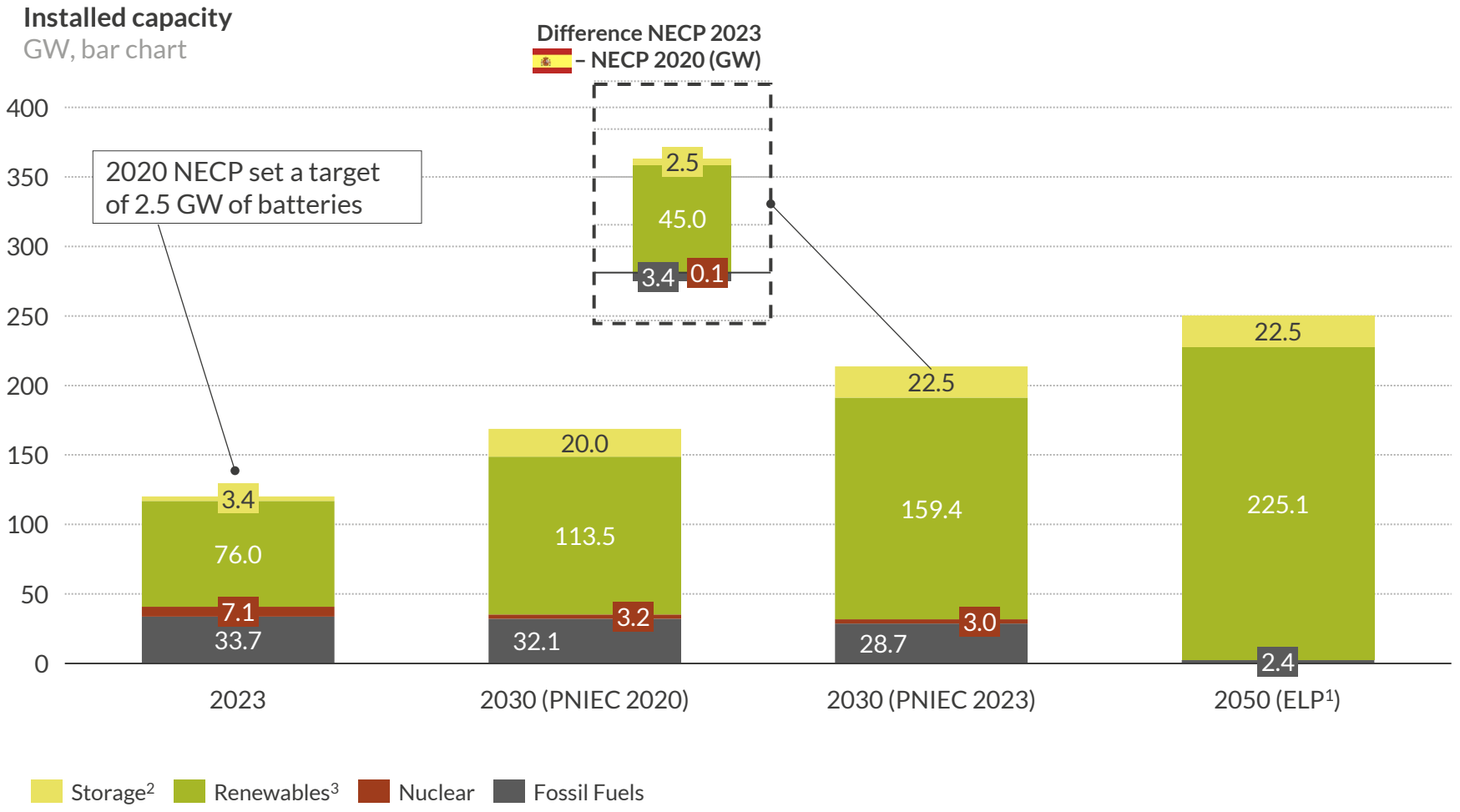
III. Battery cost perspectives

IV. Aurora's Central scenario: market evolution

V. Aurora's Central scenario: investment case for batteries

The Spanish and Portuguese decarbonisation roadmaps suggest a significant role for storage to support renewables integration

Evolution of the system composition in Spain according to the national 2030 and 2050 roadmaps



1) Estrategia de Descarbonización a Largo Plazo. 2) It includes batteries, pumped and thermal storage. 3) It includes solar CSP, solar BtM, hydro, biomass, waste and other renewables.

Sources: Aurora Energy Research, Estrategia de Descarbonización a Largo Plazo 2050, RNC 2050, 2020 and 2023 NECPs

Roadmap to 2050 in Iberia

- In 2020, the Spanish and Portuguese governments released economy-wide net-zero emissions roadmaps to 2050. These rely heavily renewables and storage-based system.
- Following the publication of the 2020 roadmap, the Spanish Government approved the Energy Storage Strategy, proposing a package of measures to increase the role of storage in ensuring system flexibility and security of supply.
- 2023 NECP increases renewables capacity targets by 36% and 62% respectively for Spain and Portugal since the 2020 NECP, and storage targets have increased 24% in Spain.
- Final updated NECPs were presented to the EU in June 2024.

The regulatory framework for storage has been amended in recent years, but there are still policy and regulation barriers to be addressed

Regulatory and policy updates for storage

2022	Jun	Consultation on grid capacity auction	Awards 5.8GW of grid access for RES and storage. Prioritises self-consumption, storage, hybridisation and repowering.
2022	Jul Sep	First voltage control sandbox	Regulatory sandbox for voltage control (pay-as-bid mechanism). Followed by regulatory changes allowing storage participation in system's essential services.
2022	Sep	CNMC allows storage in TR & VC[1] markets	Resolution by which storage is allowed to operate in TR and VC and excludes it from bearing costs on the demand side.
2023	Mar	CNMC approves testing procedures for storage	Testing operating procedures for storage approved, allowing the technology to enter ancillary services and operation in markets, and removing uncertainties in market participation.
2024	Mar	Changes to O.P.[2] in non-frequency services and TR	New classification for hybrid assets. It enables storage, demand and hybrid plants in TR, SRAP[3] and sets the validation tests to enable these to participate in AS[4]. Hybrid programming units become the first to be curtailed
2024	Apr	MITECO launches node capacity auctions	The five nodes fall under MITECO's Strategy for a Just Transition, seeking to replace thermal and nuclear retirements.
2024	Jul	CNMC proposes hourly patterns for flexible assets	Connection permits for batteries to the DN[5] will be awarded only if that they comply with an operating pattern, which limits charging and discharging across all markets.
2024	Oct	CNMC seeks to establish uniform conditions for demand facilities	Circular 1/2024 introduces flexible grid demand access permits, makes available capacity for demand publicly available, and recognises storage assets as demand applicants.

1) TR refers to technical restrictions and VC refers to Voltage control. Spanish voltage control market opens in Q4 2023. 2) Operation Procedure. 3) Automatic Power Reduction System. 4) Ancillary Services. 5) Distribution networks.

Sources: Aurora Energy Research, MITECO, Boletín Oficial del Estado, CNMC

Storage assets need to obtain generation and demand grid permits, for which a new procedure has been developed

Procedure for grid access application as a generator

1. Access and connection permit requests

- Both may be processed simultaneously. Access permit is a condition for the connection request.
- The access and connection requests are analysed by the TSO and DSOs, and can take up to 5 and 3 months, respectively. Grid access for certain nodes might also be auctioned.

2. Environmental Impact Assessment (DIA)

- Projects of more than 50 MW or located in more than one AC are processed by the Central Administration (MITECO).
- Under RD 445/2023, stand-alone electrochemical batteries and hybridised storage are subject to a simplified DIA, without a public consultation, which expedites issuance of the DIA by a minimum of 4 months.

3. Approval of preliminary administrative authorisation (AAP)

- A Technical Access Contract (CTA) will be signed within a maximum period of one month from the issuance of the connection.

4. Administrative authorisation for construction (AAC)

- Subdirección General de Energía Eléctrica is responsible for authorising the construction within 3 months of its request.

5. Exploitation permit (AAE)

- A commissioning procedure is needed to physically connect to the network. All technical and operational requirements documentation should be sent at least 2 months before the scheduled date of commissioning.

New procedure for grid access application as a demand facility

Required if the BESS takes energy from the grid

- **Distinction between firm and flexible capacity –** Circular 1/2024 introduces the concept of *flexible access capacity*. This option will be available for the flexible demand installations that are expected to consume at least a certain percentage of hours in a year .
- **Alternative capacity proposal -** If the applicant's request can't be met, SOs[1] should develop a new proposal detailing alternative firm capacity and, when requested by the applicant, flexible capacity available.
- **Transparency –** Starting from November 2025, SOs will publish the available capacity of nodes on their website, distinguishing between firm and flexible capacity. Additionally, for substations greater than 66kV, they will specify the breakdown by connection point with their use. The expected resolution with key specifications will determine the deadline for publishing the capacity profile available to storage facilities.

1) System Operators

Sources: REE

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As assets can participate across all markets, optimal revenue stacking will be key for the profitability of batteries

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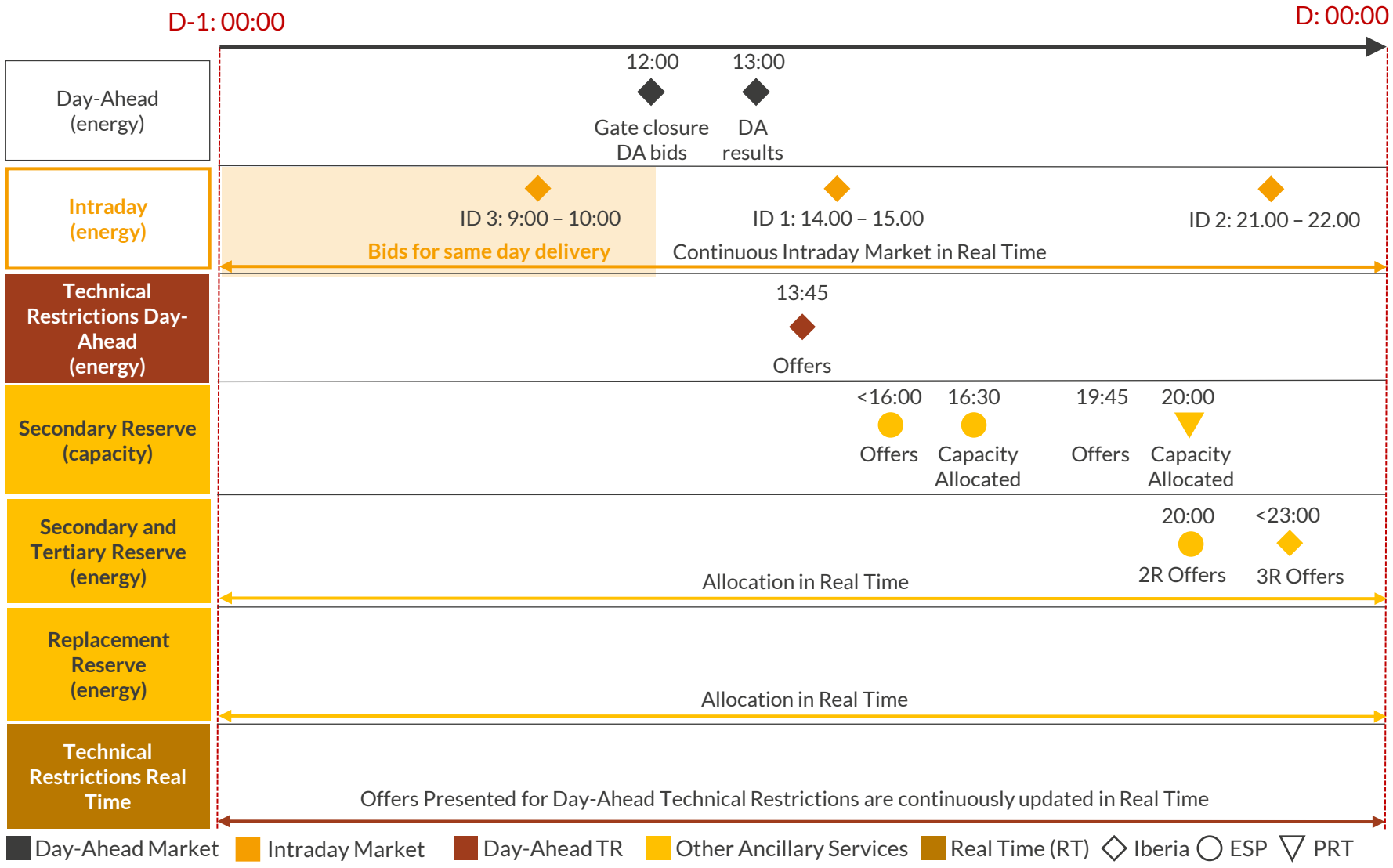

Sources: REE, Aurora Energy Research, OMIE, ERSE

Revenue stacking improves the profitability of batteries, however without a CM mechanism there is still a missing money problem

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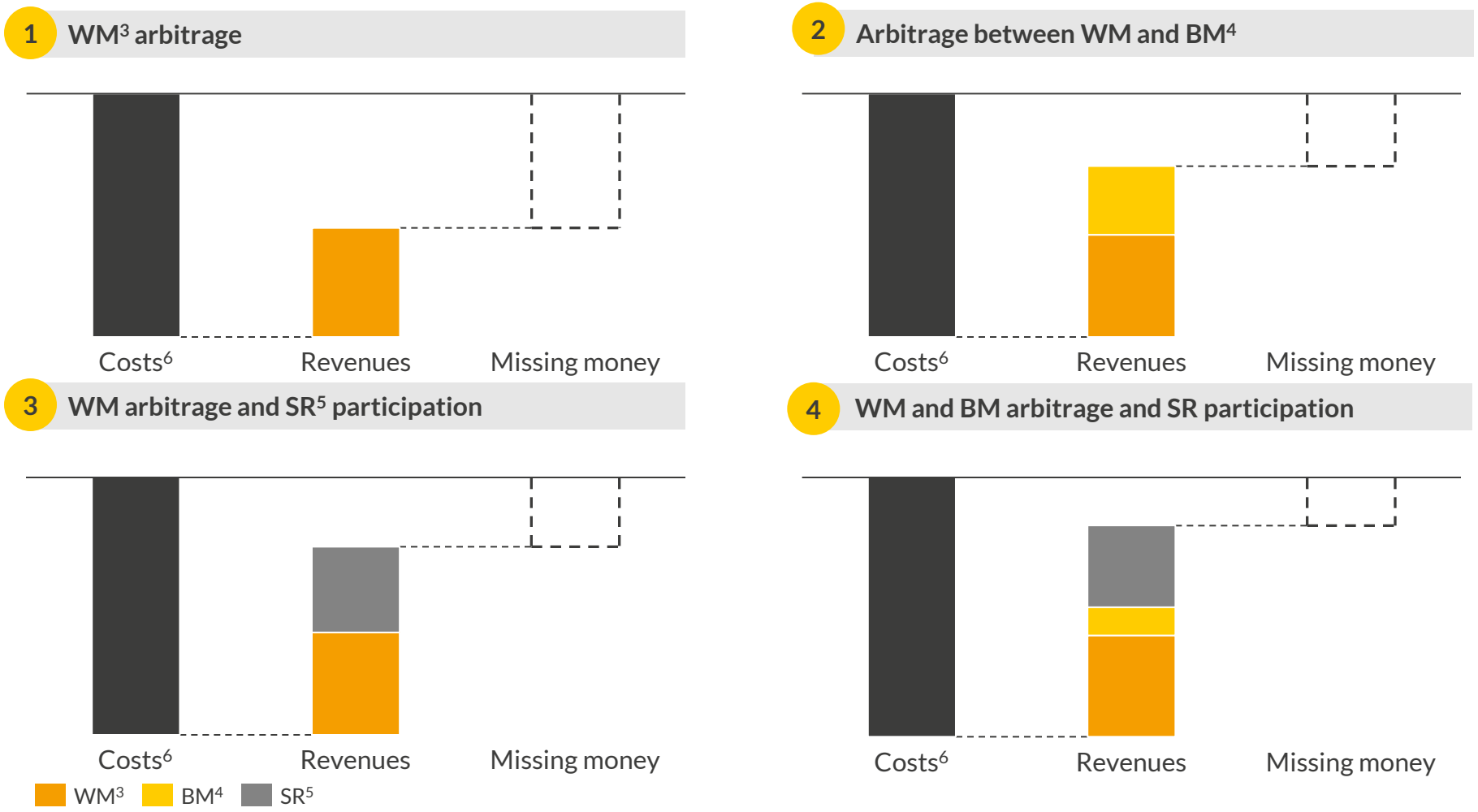
Example of present value of cashflows[1] for a 4-hour duration[2] stand-alone battery

€/kW



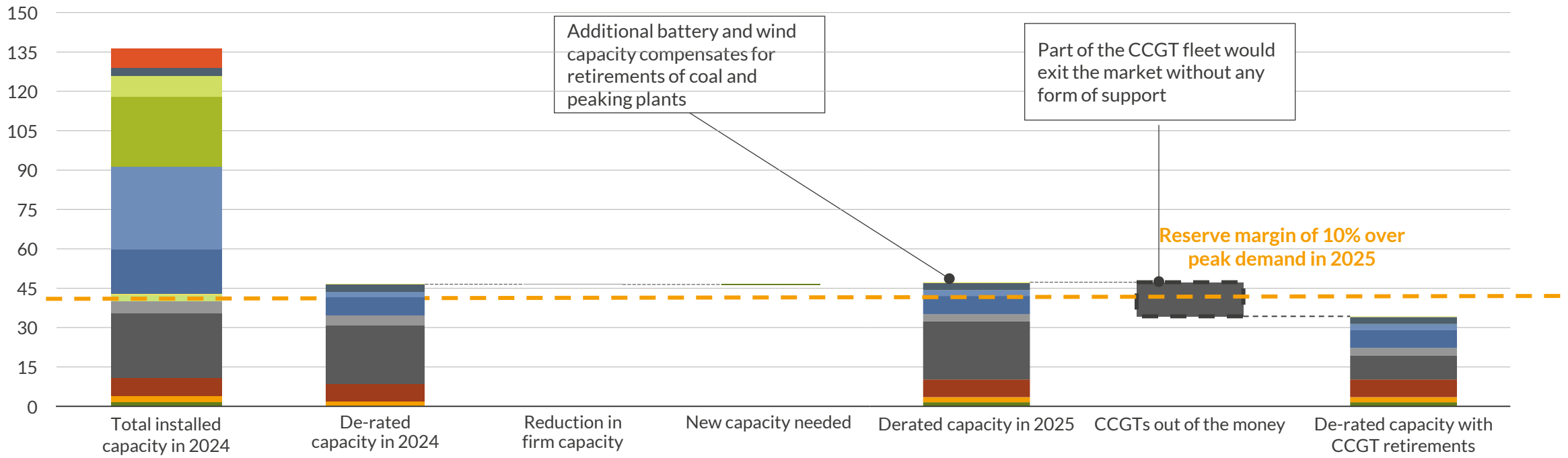
1) Cashflows discounted at 11%. 2) 86% round-trip efficiency entering in 2025, 1.2 target cycles per day with a 0.0048% degradation per cycle. 3) Wholesale market. 4) Balancing market. 5) Secondary reserve. 6) CAPEX of 1080 €/kW and FOM of 31.7 €/kW/year, for entry year in 2025.

Sources: Aurora Energy Research

We do not expect the Spanish system to require new capacity by 2025 but the CM is critical to ensure that existing CCGTs remain operational

Total installed capacity and de-rated capacity in Aurora Central[1,2]

GW



Until the design of the market is defined, we assume a yearly contract for existing assets and a 5-year contract for new build assets, technology-neutral capacity payment to compensate for missing money

Interconnectors · Solar BTM · Onshore wind · Battery · Peaking[3] · CCGT · Nuclear · Other RES
Pumped storage · Solar PV · Hydro · Solar CSP · CHP · Coal · DSR

1) De-rating factors used are aligned with those used by CNMC in the past and other European countries where a Capacity Market is implemented. 2) The market scenario considered is April 2024 Aurora Central. 3) Includes OCGTs, small gas peakers and existing oil peakers.

Sources: Aurora Energy Research

The proposed Capacity Market mechanism would be pay-as-bid and would significantly limit the participation of CO_2-emitting capacity

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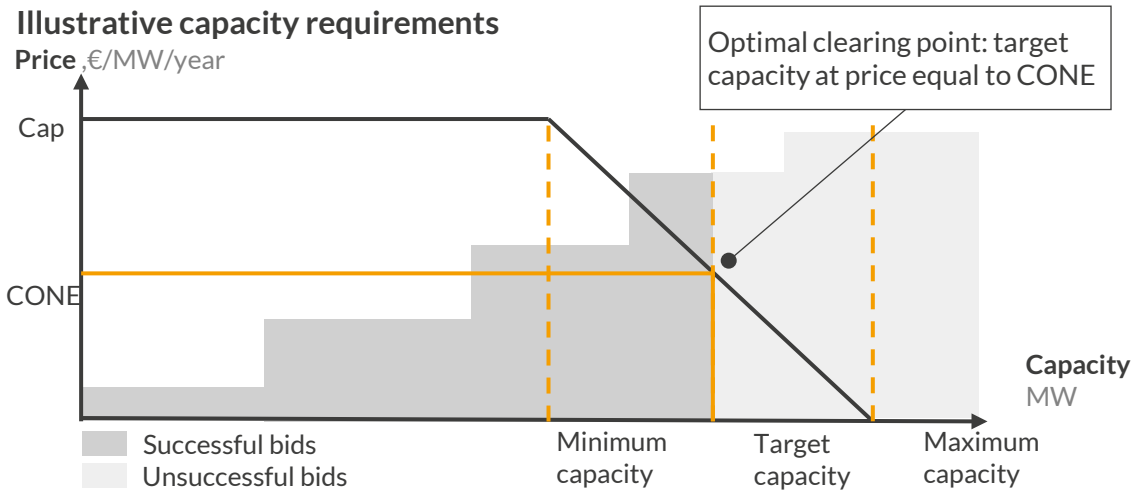
Main features of the Capacity Market

Auction design	▪ Pay-as-bid auction ▪ **Product:** Firm capacity in MW ▪ **Offer unit:** Price per unit of firm capacity in €/MW-year
Settlement	▪ Fixed monthly payment (1/12 of yearly contract) without inflation adjustment
Contract period	▪ Existing capacity: 12 months ▪ New capacity: five years
Eligible technologies	▪ Generation technologies, including renewables ▪ Storage technologies ▪ Demand-side response
Participation constraints	▪ Maximum emission rate of 550g CO_2/kWh for existing assets ▪ New generators must accredit Net Zero CO_2 emissions ▪ Participating demand (DSR) must not have associated generation under Specific Remuneration Regime
Expected de-rating factors	▪ 2-h batteries: 40% ▪ 4-h batteries: 60% ▪ Pumped hydro: 80% ▪ CCGTs (under emission cap): 90%

- If new capacity is needed, as the CM is carbon neutral, we expect a combination of battery storage, brownfield pumped hydro and DSR to compete for new build firm capacity requirements.
- Intermittent renewables are unlikely to receive substantial support due to their limitations in providing firm capacity, leading to low derating factors.
- Further clarity around key parameters like the **target auction capacity,** as well as the technology **de-rating factors**, will be required to understand the competitiveness of different technologies in this market.



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Battery system CAPEX reduces in the short-term due to cheaper costs of raw materials

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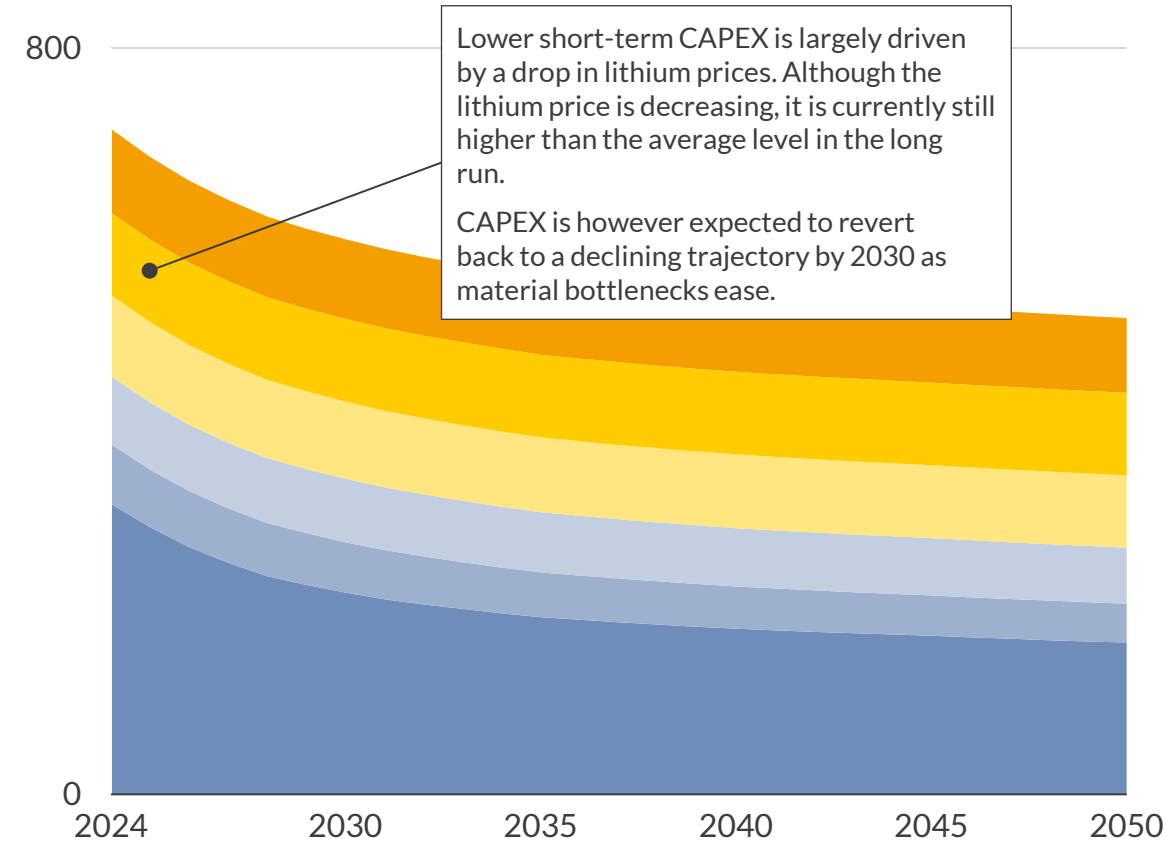
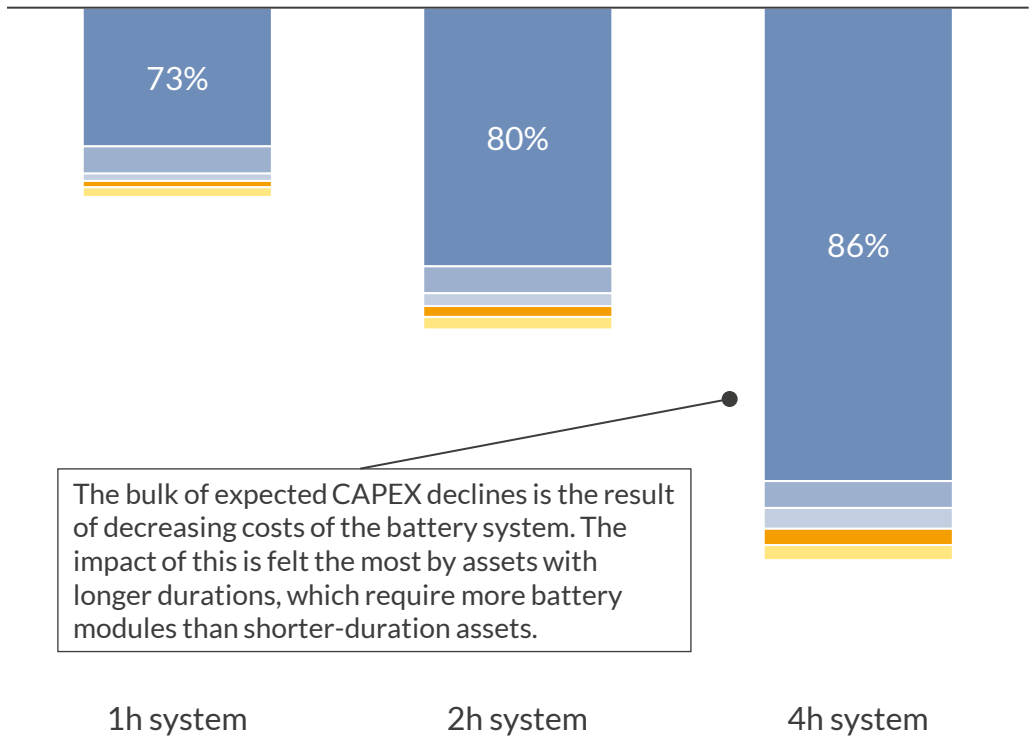
Li-ion battery total system costs – 2h asset
€/kW, real 2023



CAPEX changes from 2024 to 2030 by component
€/kW, real 2023



Development Connection EPC Balance of system Inverter Battery system

Source: Aurora Energy Research

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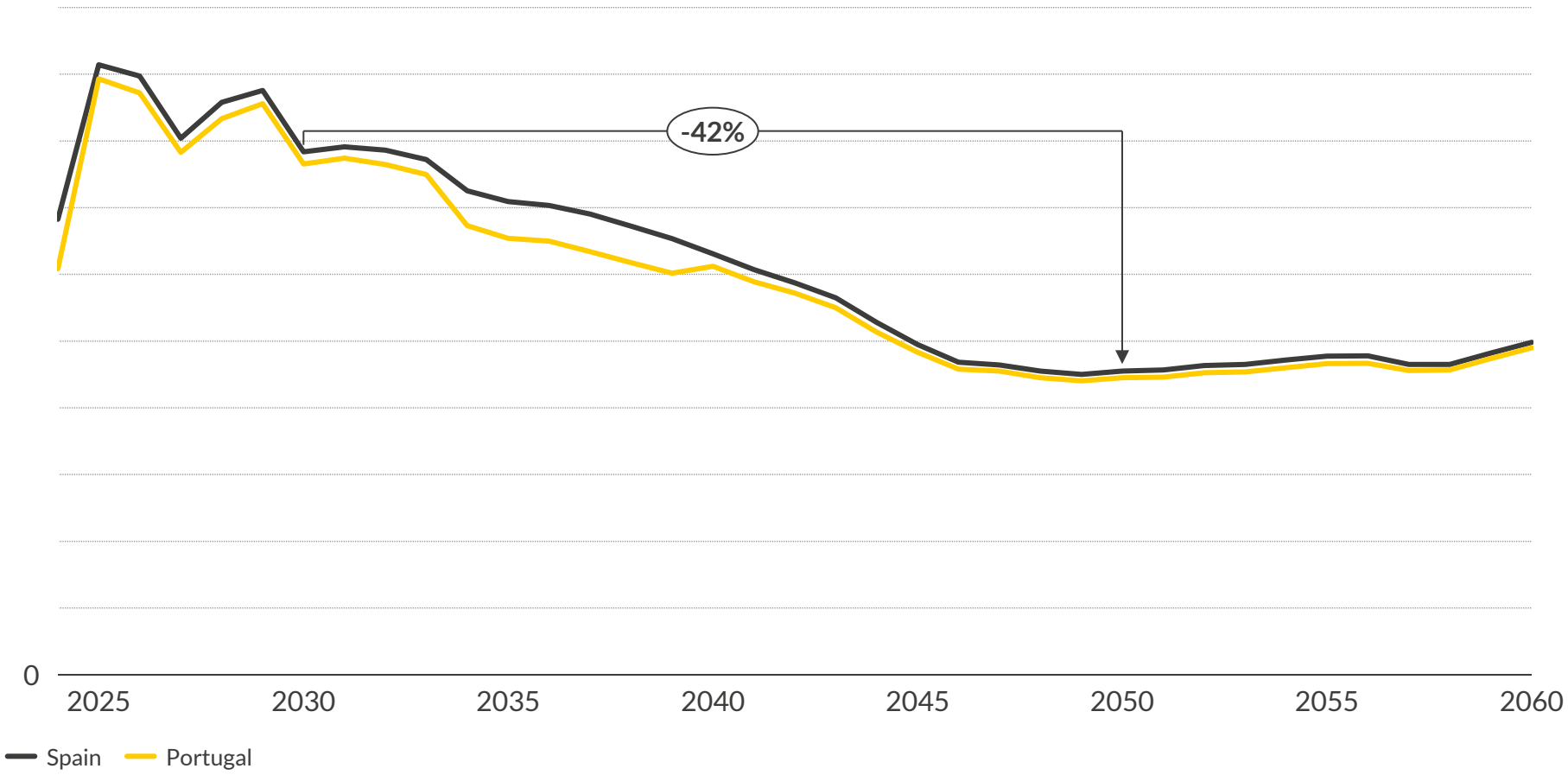
Price spreads increase driven by higher inflexible demand, delayed flexibility devices and increased renewable capacity

Average daily price spread[1]
€/MWh (real 2023)



1) Average spread between the lowest and highest price during a day.

Sources: Aurora Energy Research

- In the short-term, lower wind buildout leads to higher expensive CCGT generation during peak demand hours, leading to higher spreads.
- The forecast shows higher spreads in the late 2020s and early 2030s, primarily due to a combination of lower flexible demand and higher inflexible demand, leading to greater spreads within the day.
- Comparing the late 2020s to late 2040s, price spreads decrease by approximately 42%. This decrease is attributed to the growing participation of flexible capacity, particularly from battery storage.
- From the 2050s onwards, spreads stabilise as additional renewable buildout is offset with flexible demand.

The future of the Balancing Markets will be heavily influenced by the following factors

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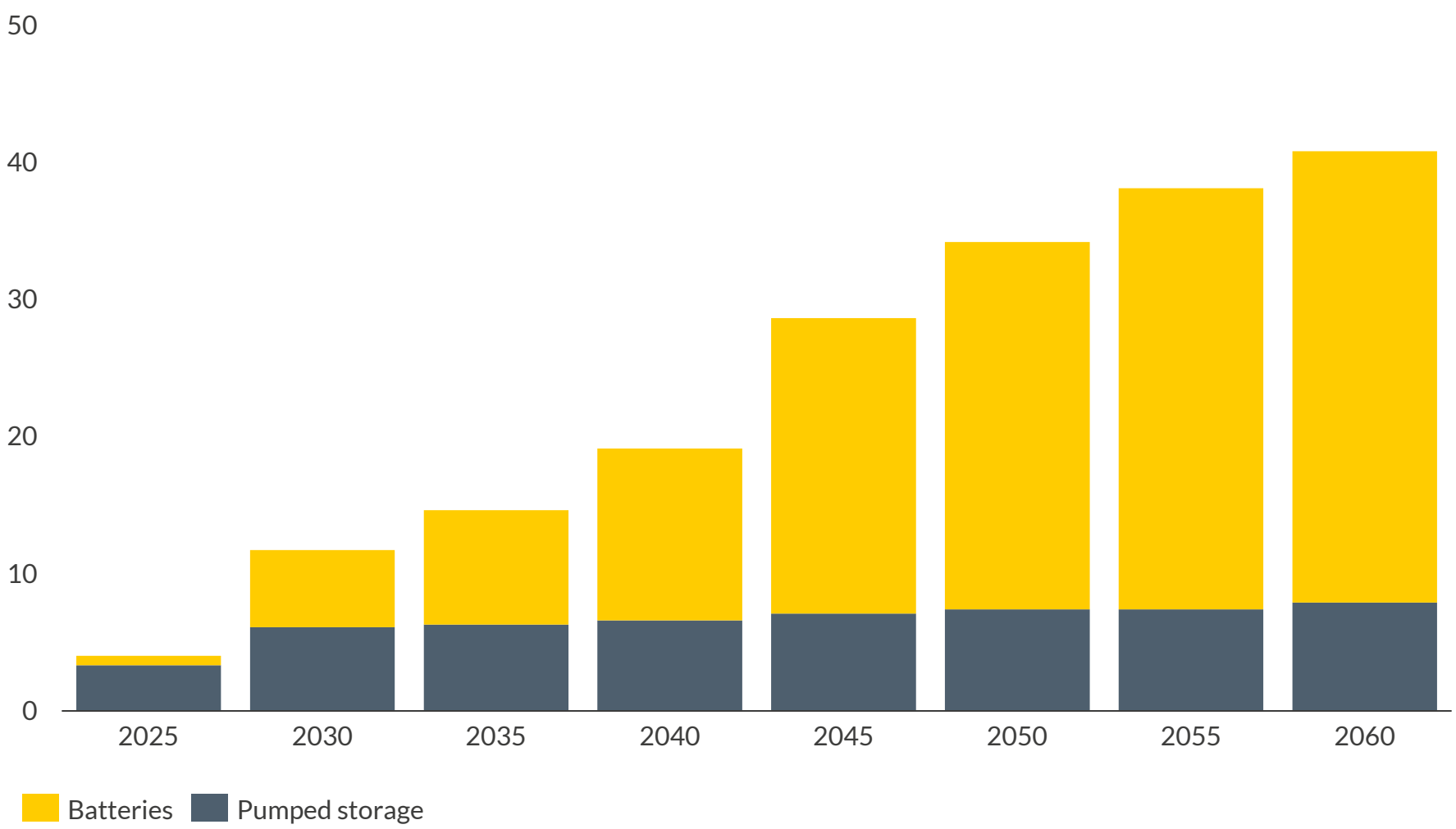
Key Drivers	Impact on market participation	Impact on volumes	Impact on prices
Increasing penetration of variable renewables	Not the most suitable market for renewables as response time must be quick, but can be feasible through power electronics	Due to the variable nature of the resource, and the difficulty to predict it, the growth of renewables is expected to increase secondary reserve requirements ↑	Unclear as it leads to more imbalances but also more participants in the provision of secondary reserve service, especially in the downwards direction; volatility is expected to increase and downward prices to decrease
Increasing participation of flex technologies	The NECP encourages the installation of flexible technologies by removing regulatory barriers to accommodate the increased RES capacity	Smart technologies like batteries or DSR can offset the potential increase in intermittency from RES ↓	Higher participation of Flex technologies reduces the probability of imbalances, which will bring the 2R prices down ↓
Regulation band dual pricing (PICASSO)	Regulation band procurement will be separate for downward and upward capacity	As procurement will differ depending on the direction, volumes could change asymmetrically to fit system needs ↑	The upward prices will likely be unchanged while downward prices might decrease due to higher competition ↓
Decreasing thermal baseload	CCGTs running hours in the WM are expected to decrease, limiting their participation in rapid response markets. However, we expect some peakers to substitute retiring coal and CCGT	Lower baseload generation in the Wholesale Market will increase the need for balancing services which will come from flex technologies such as pumped hydro, and batteries ↑	Higher prices are expected as a result of higher ramping costs for CCGTs, or the entry of less efficient gas peaking assets ↑

Sources: Aurora Energy Research

Battery capacity will account for over 5 GW in 2030 and reach over 30 GW by 2060, while ~4 GW of pumped storage will be built

Storage capacity under Aurora Central



- We expect the capacity for the majority of batteries entering the market to be of 4-hour duration due to its compatibility with solar profiles.
- By 2030, the storage buildout falls short of the government's targets.[1] By 2060, it is expected that battery storage systems installed in Spain reach more than 30 GW
- Aurora Central assumes the buildout of 2.8 GW of hydro capacity by 2030.

1) The 2023 National Energy and Climate Plan aims at 22 GW of storage yet it does not break down storage targets by technology.

Sources: Aurora Energy Research, NECP

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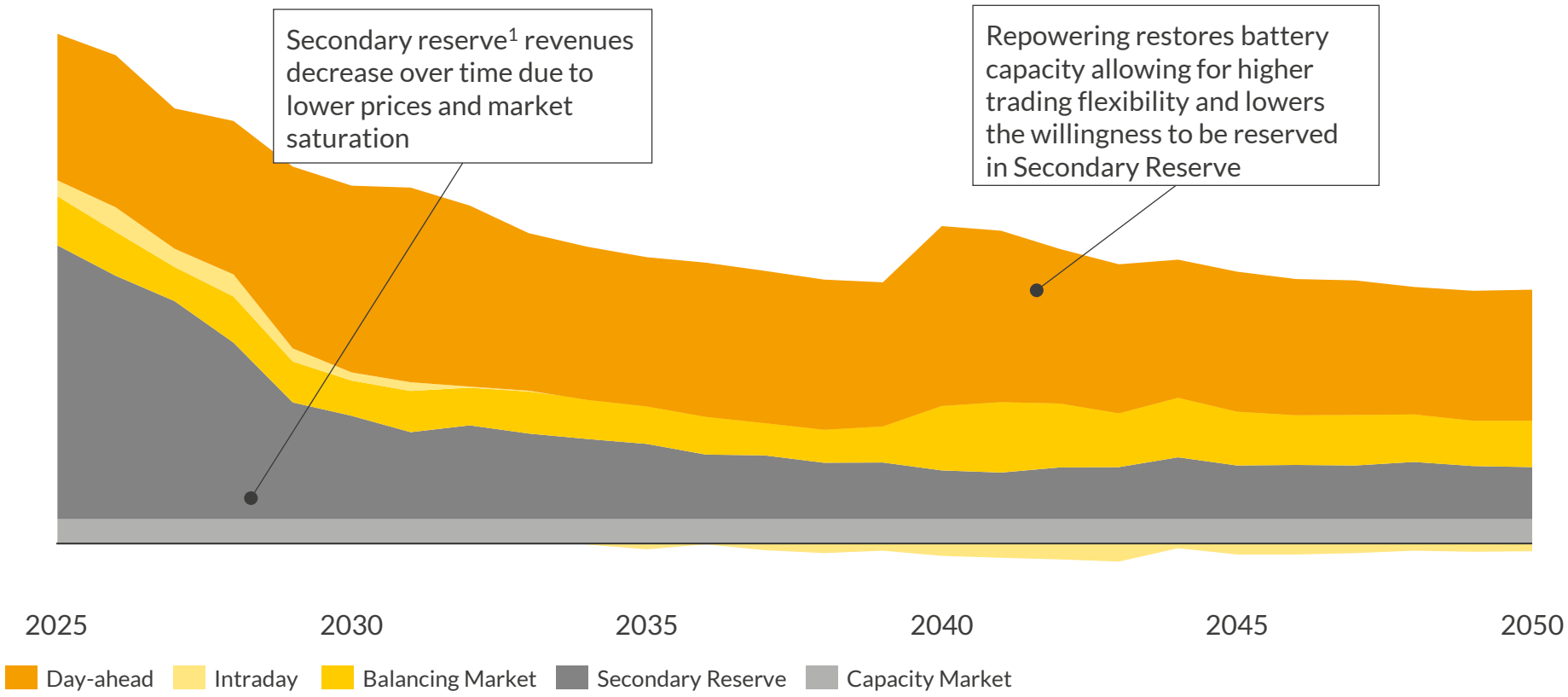
Aurora provides the revenues breakdown considering market prices, battery duration and the repowering strategy

Powered by CHRONOS

Example of a stand-alone battery in Spain (4h, 1.2 cycles per day)

Gross margins by market
€/kW/year (real 2023)



1) Includes both capacity and energy revenues. 2) State of charge.

Source: Aurora Energy Research

Comments

- As secondary reserve prices remain relatively high during the 2020s in both the upwards and downwards directions, batteries prefer to capture those revenues rather than doing energy arbitrage.
- The Intraday Market is mostly used for SoC[2] management. Therefore, the battery mainly operates in this market to avoid penalties for missed actions in Ancillary Services.
- Following a decrease in Day-ahead spreads due to increasing system flexibility in the 2030s, the Balancing Market becomes more profitable as volatility remains high in this market.

Co-location simplifies permitting procedures and optimises connection capacity as assets share the same grid connection point

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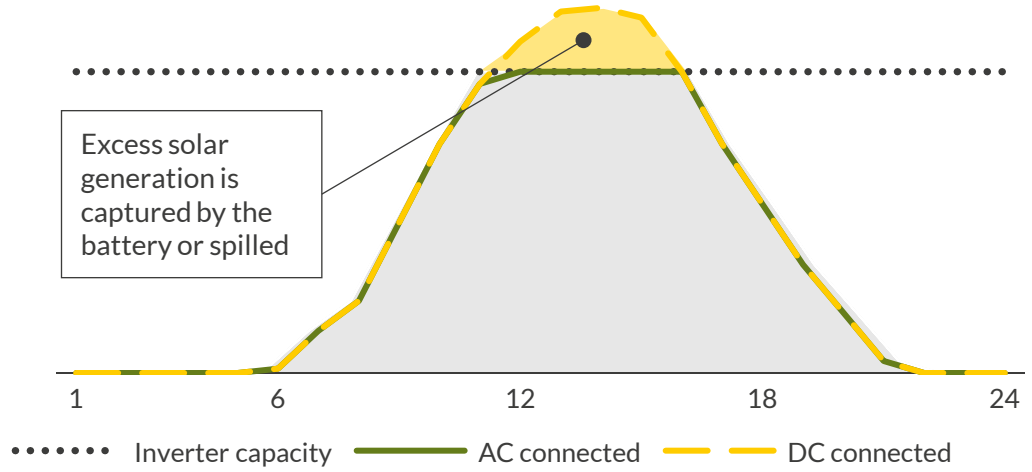
Under the current Spanish regulation, hybridisation can provide time and cost savings due to a streamlined permitting process

- ✓ Existing facilities hybridising with storage are authorised to use the same grid connection without the need to request new access permits.
- ✓ Economic guarantees required for grid connection are reduced by 50% for the additional asset.
- ✓ Abbreviated procedure for hybridisation for access and connection permits.
- ✓ Storage assets allowed to operate independently from RES assets in all markets.

Co-location of storage and renewable assets lead to economic advantages

- ✓ Optimal renewable asset dispatch against power prices means that economic curtailment can be avoided, and imbalance costs reduced.
- ✓ If the renewable asset is oversized in relation to the grid, the battery can capture spilled energy.
- × Battery operations might be suboptimal as the upside of solar spill may not offset the downside of grid constraints. Additionally, if more profitable actions are available, the battery will choose not to charge from the solar, and the energy would be lost.
- × Co-located renewables assets in Spain may be more likely to be technically curtailed than stand-alone renewables following the update of O.P. 3.2.

Illustrative example of a daily production profile for solar oversizing

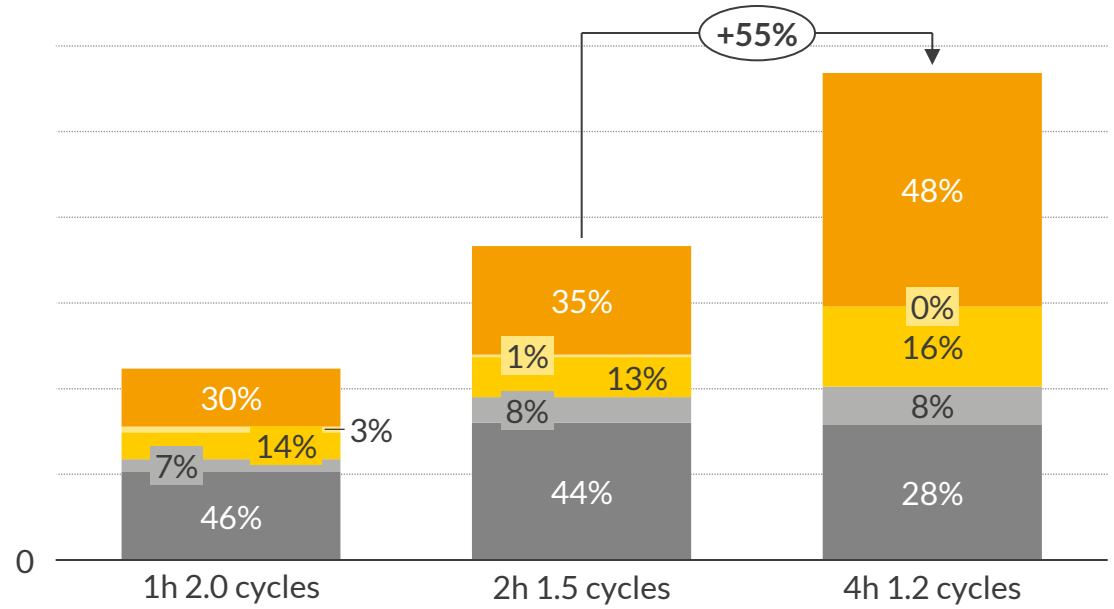


Stand-alone batteries can achieve reasonable returns as long as Capacity Market payments are available

Powered by CHRONOS

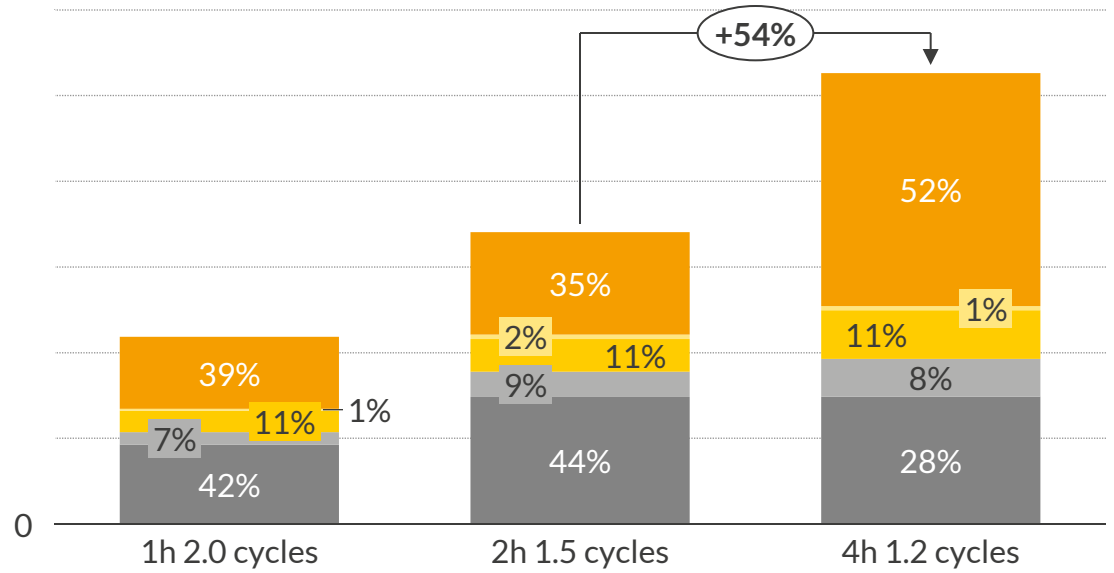
Entry year: 2025

Average total gross margins with Capacity Market Payments[1] (2025 – 2054)
€/kW/year, real 2023



Stand-alone

Average total gross margins with Capacity Market Payments [1] (2025 – 2054)
€/kW/year, real 2023



Co-located Solar and Battery, AC configuration

Day-ahead Intraday Balancing Market Capacity Market Secondary Reserve [2]

1) Revenues account for penalties. Assuming a CM from 2025 onwards. 2) Includes both capacity and energy revenues.

Sources: Aurora Energy Research

Key takeaways

1. The Spanish regulation is providing more clarity to storage assets; however, there are still regulatory barriers to be addressed such as fixed charging patterns for distribution-connected assets and higher curtailments for hybrid assets.

2. The revenue stack for storage comprises arbitrage in the Wholesale Market, and participation in Ancillary Services, which is encouraged by increased solar cannibalisation. Other revenue streams like intraday trading and the Capacity Market are opening up.

3. We foresee storage taking off and achieving ~12GW by 2030 and ~40GW by 2060, with predominance of 4-h stand-alone and co-located batteries. About half of the revenues over battery lifetime will be provided by arbitrage, while the Capacity Market can solve the missing money problem.

Sources: Aurora Energy Research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