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ENERGY RESEARCH

Capacity Mechanisms and Batteries in Europe

Study prepared for Fluence

27th August 2024

Project Context

Project description and context

- In light of the **increase in intermittent renewable energy generation, the phase-out of a considerable share of conventional generation assets**, and **increasing energy demand**, European energy systems are under pressure to **guarantee security of supply and facilitate flexibility.**
- In Europe, **capacity mechanisms are becoming a key instrument to incentivize the buildout of additional assets** solving this challenge. The **design of capacity mechanisms affects battery buildout and, vice versa**, battery capacity can change the set-up of capacity mechanisms.
- Fluence has commissioned Aurora Energy Research to prepare a **public study investigating capacity mechanisms in Europe and the role batteries play** in them**.** More precisely, Aurora conducted the following analyses:
  - Assessment of the **European regulatory framework for capacity mechanism** including an analysis of the existing capacity markets in Great Britian and Poland
  - Analysis of the **future capacity mechanism in Germany** including the role of battery de-rating factors
  - Investigation of the **proposed Spanish capacity mechanism** including the buildout of batteries incentivized by the instrument

The results presented in this report are based on **Aurora's most recent modelling of the covered power markets (in most cases the April 2024 Central Scenario),** additional research was conducted where required.

Sources: Aurora Energy Research

Capacity mechanisms have become an integral part of European market design and can solidify batteries' contribution to the energy transition

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Summary of findings

1 The **rise in intermittent generation by over 3.5 times between 2023–2050** in Aurora's Central scenario combined with emission reduction targets leads to a **need for low-carbon, flexible capacity**. The EU market reform anchored **capacity mechanisms as an integral part of market design to ensure security of supply**. Furthermore, the new regulation requires all European member states to **define energy storage targets.**

2 **Batteries will play a central role in achieving these energy storage targets:** By supporting the shift to low-cost zero-carbon power generation from renewables, they can **accelerate decarbonization** and **reduce dependence on fossil fuels**. On top of that, batteries can help **decrease costs of other system services**, for instance by avoiding unnecessary grid expansion and reducing curtailment losses.

3 **Technology-agnostic capacity mechanisms can de-risk battery investments** and thereby foster their buildout. As of today, **over 23 GW of batteries** have been successful in Capacity Market auctions across Europe.

4 **Batteries usually are price takers in capacity market auctions.** As batteries have existing business models covering the majority of their costs, they push more expensive assets to the end of the bid merit order, **fostering affordable and efficient security of supply.**

5 **De-rating factors are used to assess the role of batteries in stress-events,** using the methodology of an adequacy assessment. In defining capacity market parameters for energy storage, **Germany and Spain can learn and adopt rules and design elements from existing capacity markets** such as in Poland or Great Britain. This holds not only for de-rating factors, but also for other parameters like contract length.

Sources: Aurora Energy Research

Agenda

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I. Exploring Europe's capacity mechanisms

1. Flexibility in the future power system
2. European regulatory overview

II. Future trajectories for a German capacity mechanism

III. Introduction of a future capacity mechanism in Spain

IV. Appendix

1. Great Britain's mature capacity market
2. The evolving capacity market in Poland
3. List of Abbreviations

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Executive Summary

Europe

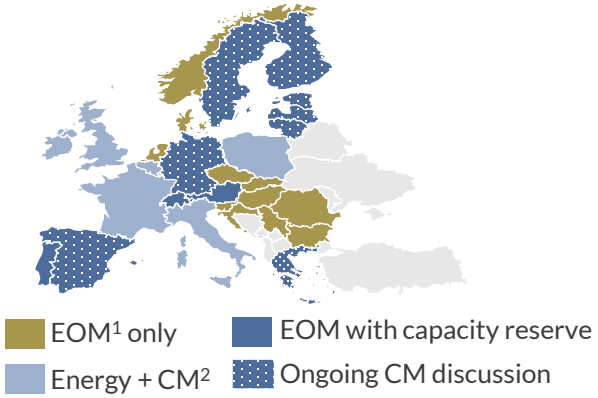
While Europe faces a rising need for flexibility, and energy storage in particular, it can also reap the benefits of a more flexible energy system.

- Europe's installed capacity of renewables is expected to grow by 3.5 times until 2050 according to Aurora Central, while decarbonization results in an increasing share of retiring conventional capacity and rising demand.
- These developments will lead to more variability in generation, creating the need for a more flexible energy system.
- Such a flexible system provides significant benefits in terms of cost savings and impact on social economic welfare, sustainability, and security of supply.

Across Europe, capacity mechanisms are becoming an integral part of the energy system to foster security of supply.

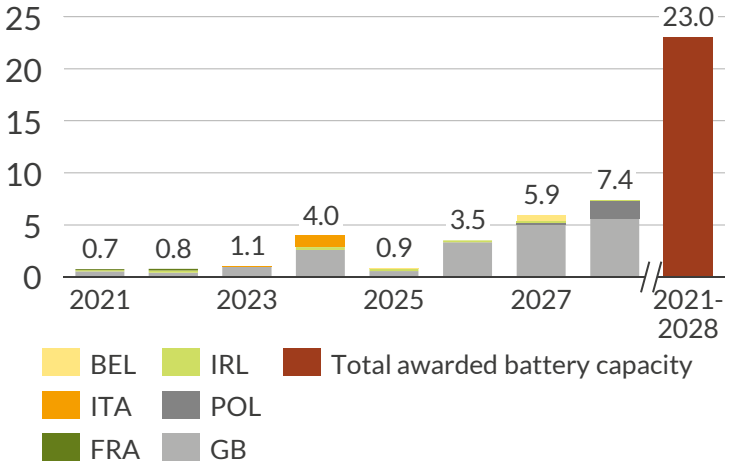
- The EU Electricity Regulation on capacity mechanisms enables flexibility and participation of low-carbon technologies including batteries.
- Batteries have secured contracts covering 23 GW of capacity in capacity mechanisms across Europe.
- Amid alleviating stress events, batteries can support the shift to low-cost generation from renewables, accelerate decarbonization, and help reduce costs of system services.

Energy market designs in Europe



Total battery capacity awarded by capacity mechanisms in the respective COD years

GW nameplate



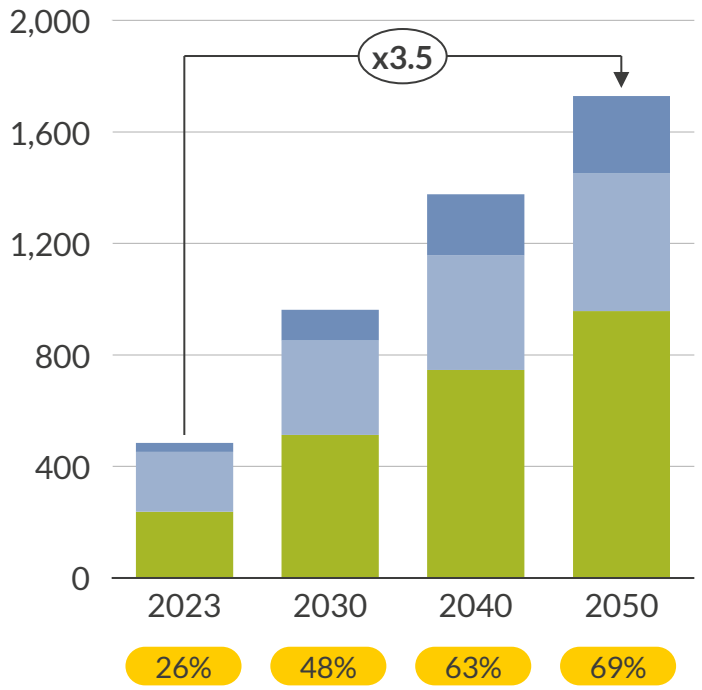
1) Energy-only market. 2) Capacity mechanism.

Sources: Aurora Energy Research, EU Electricity Regulation

Europe faces a rising need for flexibility, primarily due to the buildout of intermittent renewables and the phase-out of fossil assets

Installed variable renewable capacity in Europe[1], Aurora Central scenario

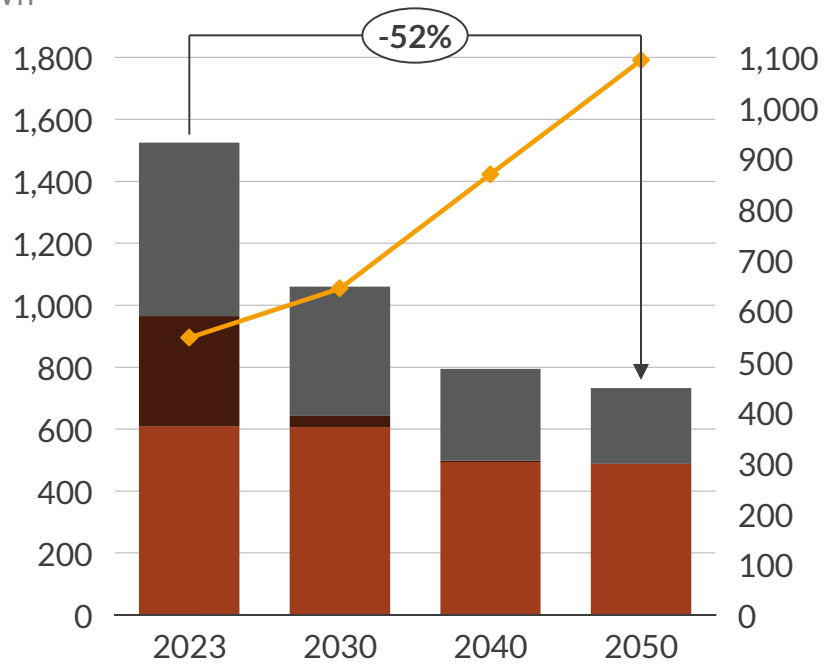
GW



Conventional generation in Europe, Aurora Central scenario

Peak demand GW

TWh



xx% Variable RES share of generation

Offshore Wind
Onshore Wind
Solar PV

Nuclear[2]
Coal[3]
CCGT[4]
Peak demand

1) EU27 plus Great Britain and Norway, minus Malta and Cyprus; 2) Generation from nuclear increases in the short-term from new capacity additions but decreases in the longer term as nuclear decommissions across Europe; 3) Includes Coal CHPs; 4) Includes CCGT CHPs, Gas CCS and Hydrogen CCGTs. Note that nuclear and abated thermal are still expected to play a long-term role for total generation in certain countries. Sources: Aurora Energy Research, Eurostat

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- Europe's installed capacity of solar, onshore and offshore wind grows over 3.5 times between 2023–2050 in Aurora's Central scenario (reflecting Aurora's best view on the evolution of the German power market until 2060 with full decarbonisation of the German economy by 2060).
- At the same time more and more conventional generation capacity retires, so that compared to today 52% less electricity will be generated by conventional assets in 2050.
- Concurrently, peak demand and overall demand are rising particularly due to the electrification of heat, transport and industry.
- These developments will lead to more variability in generation, creating a need for flexible supply and demand technologies to guarantee security of supply.

Besides being integral to security of supply, flexibility in the power sector can improve welfare, decarbonization and renewables integration

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Beneficial effects of a flexible energy system

Efficiency and Cost Savings

- Reduces electricity consumption when it is most expensive by shifting demand away from hours of peak residual demand
- Saves costs by avoiding overbuilding capacity, unnecessary grid expansion, and curtailment losses

Accelerate Renewables Integration

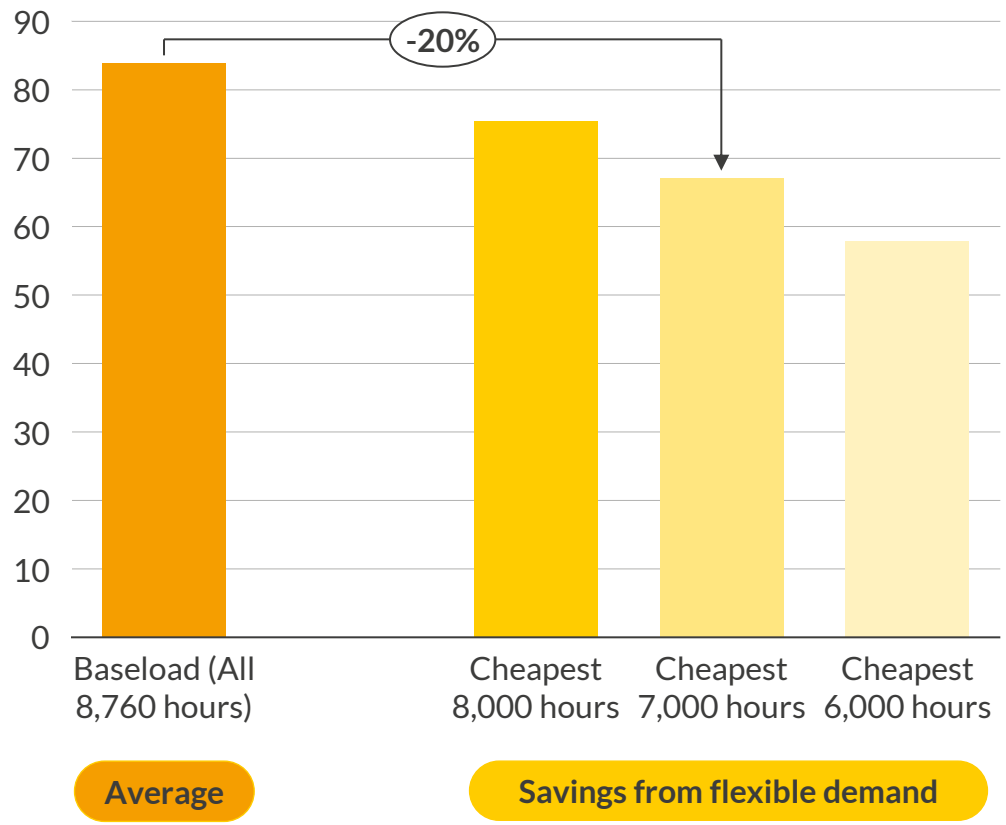
- Stabilizes prices for renewables, mitigating cannibalization and enabling further penetration of renewables
- Reduces electricity consumption when it is most carbon intense by shifting demand away from hours of peak residual demand, thereby replacing gas generators and saving emissions

Security of Supply

- Mitigates risks associated with supply disruptions
- Reduces reliance on imported fuels like gas or electricity

German electricity prices in 2030 and savings from flexible demand[1], Aurora Net Zero

Euro/MWh (real 2023)



1) Flexible demand includes, among others, demand side response and utility scale energy storage.

Source: Aurora Energy Research

Batteries can bring about significant costs savings and support an accelerated decarbonisation

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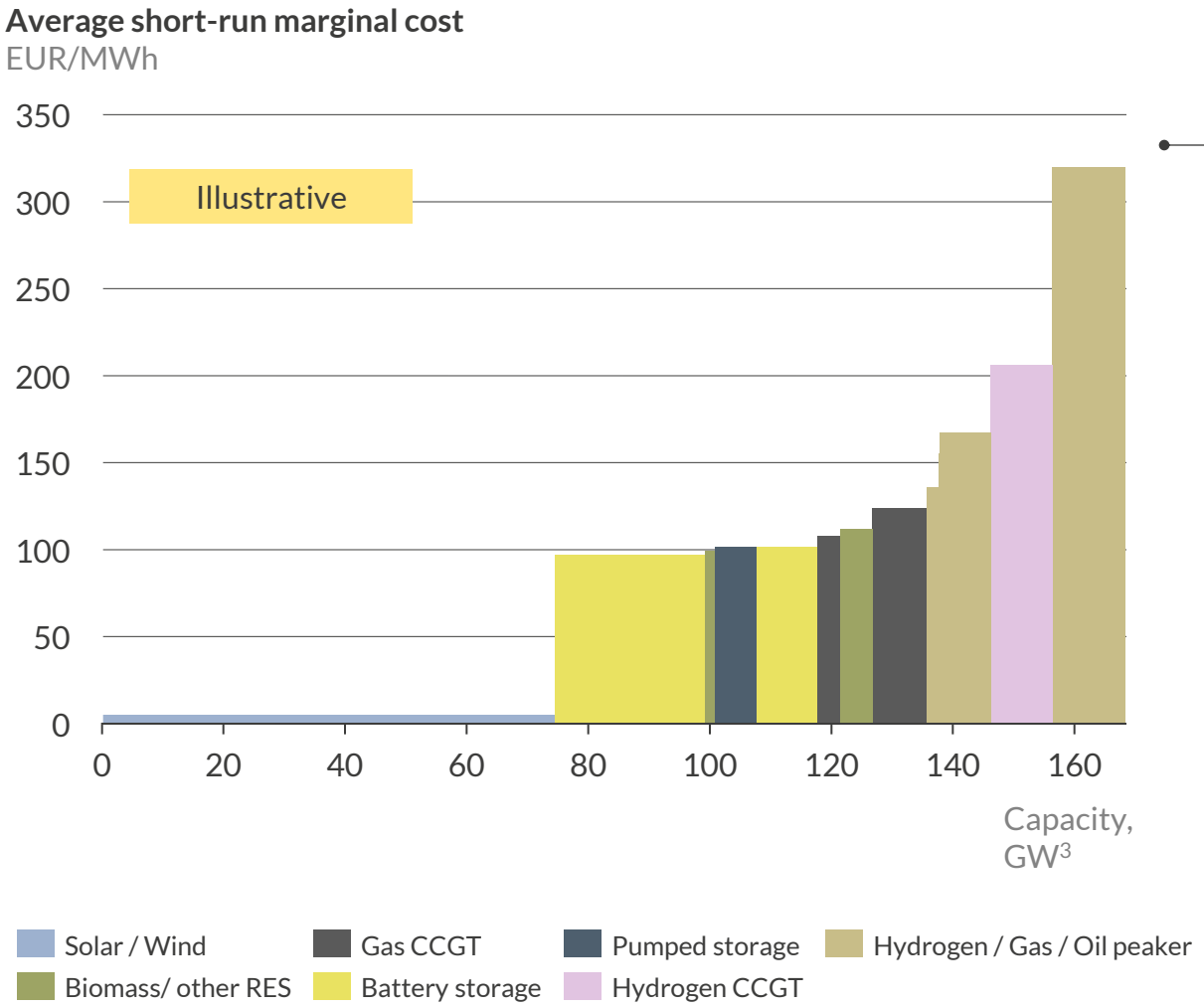
Illustrative German power market merit order in 2040[1,2]



Potential benefits of batteries in the capacity mechanism

- As shown in the merit order curve for 2040, batteries are likely to have relatively low marginal costs, i.e., they can cheaply buy power and then sell it at costs below the next significant baseload technology.
- They can effectively take advantage of price volatility in a system with high renewables generation through arbitrage on day-ahead and intraday markets, and offer additional grid services.
  - They thus require less additional payments from a capacity mechanism thereby putting downward pressure on clearing prices.
- More battery capacity can further bring about cost savings for instance by avoiding curtailment losses.
- On top of that, more batteries in the system can help increase average capture prices for renewables and thus mitigate the cannibalization effect of renewables and support their buildout.
- This, in turn, supports decarbonization targets on the energy system.

1) Individual plants are aggregated by technology. 2) Given their low capacity, DSR and LDES are not shown in this illustrative merit order. 3) For dispatchable plants, this refers to the availability multiplied by capacity. For load factor driven plants, this refers to the load factor multiplied by capacity.

Source: Aurora Energy Research

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Capacity mechanisms ensure that security of supply standards are fulfilled by paying generators for capacity, rather than for energy alone

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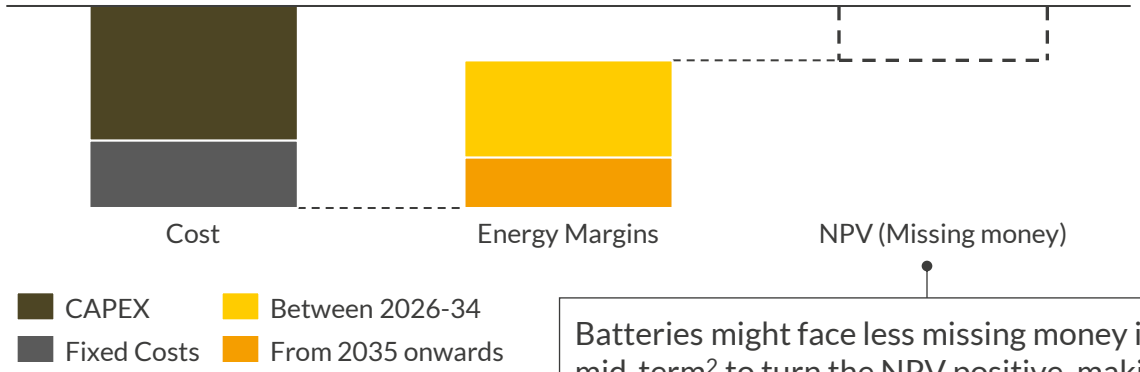
The rationale behind capacity mechanisms

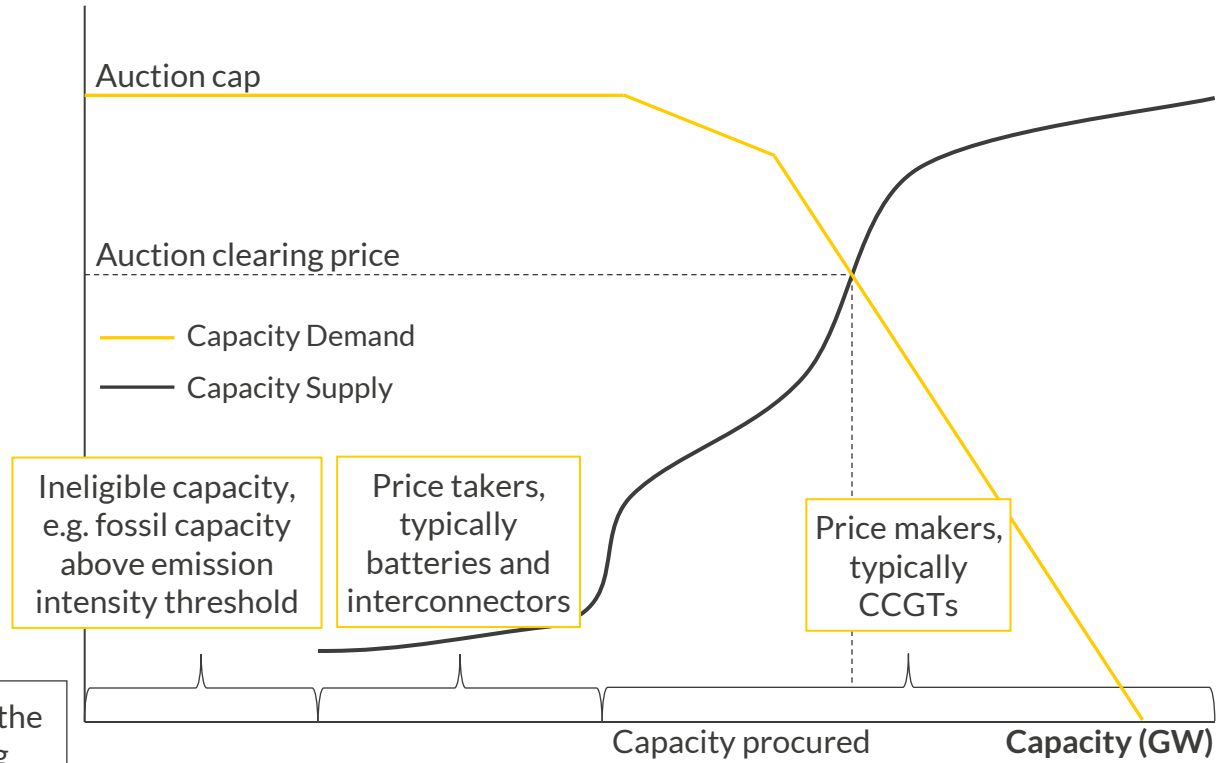
- Projected prices are insufficient to encourage building sufficient firm capacity like gas or hydrogen-fired CCGTs.
- Particularly with regards to the 2022 energy crisis, political actions and signals have undermined confidence in peak prices and the persistence of the energy-only market altogether.[1]
- This results in increasing shortfalls in generation over time.
- A capacity mechanism provides an additional revenue stream to encourage firm capacity to be built and thereby reduces hours of loss of load.

Illustrative present value for a new-build CCGT building in 2025/26 in Europe
€/kW



Batteries might face less missing money in the mid-term[2] to turn the NPV positive, making them price takers in the capacity mechanism and in turn lowering clearing prices.

Supply and demand prices in the capacity mechanism
€/kW



1) For instance, the German government intervened in the market and skimmed off surplus revenues ("*Überschusserlösabschöpfung*"). 2) See slides on the German and Spanish capacity mechanism below.

Source: Aurora Energy Research

In contrast to a capacity reserve, existing capacity mechanisms allow for plants to participate in wholesale markets

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Can plants participate simultaneously in the capacity mechanism and in the wholesale or other ancillary markets?

No → **Targeted capacity reserve**

Reserve / **Wholesale market**

- Usually used to extend lifetime of existing plants

Another concept currently discussed in Germany is the "Strommarkt Plus" concept, where suppliers have an insurance obligation.

Yes → **Capacity mechanism**

Who sets the capacity target?

Central authority[2] → **Central capacity mechanism**

- It is ensured that security margins are met for the region

Each supplier → **Decentral capacity mechanism**

- Power suppliers and large consumers must secure capacity certificates issued by generators and DSR.
- Capacity certificates are then traded on market or bilaterally.

Legend:

Reserve plant only receiving capacity payment

Plant only receiving wholesale market[1] revenue

Plant receiving wholesale[1] and capacity mechanism revenue

1) Another option Wholesale market mentioned as this is usually the biggest revenue stream. Other markets like ancillary services or balancing markets are also applicable. 2) In most cases, the TSO is the central authority.

Sources: Aurora Energy Research

Capacity mechanisms shall become a core part of EU power markets with the market reform facilitating their introduction

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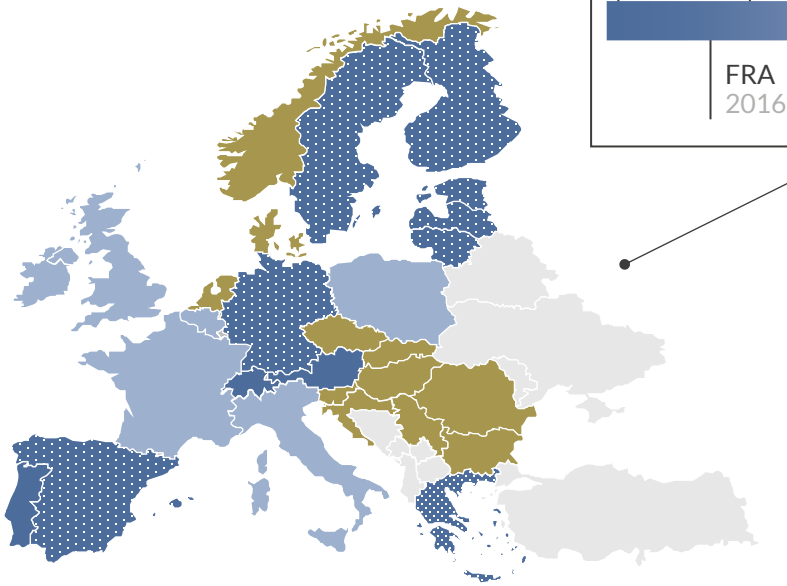
Energy market designs in Europe



Implementation timeline

GBR	IRL	ITA/BEL	DEU
2013	2017	2021	2028?
FRA	POL	ESP	
2016	2018	2025/6	

EOM[1] only
EOM with capacity reserve
Energy + CM[2]
Ongoing CM discussion[3]

Adopted changes under EU market design reform

In response to the energy crisis in 2022, the EU passed a power market design reform that eases the implementation of capacity mechanisms.

Main changes include:

- **Less strict implementation conditions:** Capacity mechanisms can now be considered a structural element of EU power market design instead of a measure of last resort. Member States will be allowed to continue operating capacity mechanisms – even if no new contracts are entered in 3 consecutive years.
- **Streamlined approval processes:** Approval will still be granted for up to 10 years only. Yet, application processes shall be facilitated based on an upcoming EU Commission proposal.

December 2023
Provisional political agreement on market design reform reached between EU Council and Parliament

March 2025 (expected)
EU Commission to make final proposal on streamlining approval procedures

2024 — 2025

May 2024
Formal adoption of the reform

December 2024 (expected)
EU Commission to publish report outlining simplification possibilities for consultation

1) Energy-only market. 2) Capacity mechanism. 3) In Greece, there are ongoing discussions to propose a capacity remuneration mechanism as part of the amendment of the NECP amendment. However, no final announcement or dates when such mechanism should be introduced have been made so far.
Source: Aurora Energy Research

The current regulatory framework for European capacity mechanisms incentivizes flexibility and participation of low-carbon technologies

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Current EU regulation on capacity mechanisms

The main features related to capacity mechanisms are contained in the EU Electricity Regulation[1], and include:

- **CO_2 emission limits:** Assets must fulfil the following CO_2 emissions standards to be able to participate in capacity mechanisms:

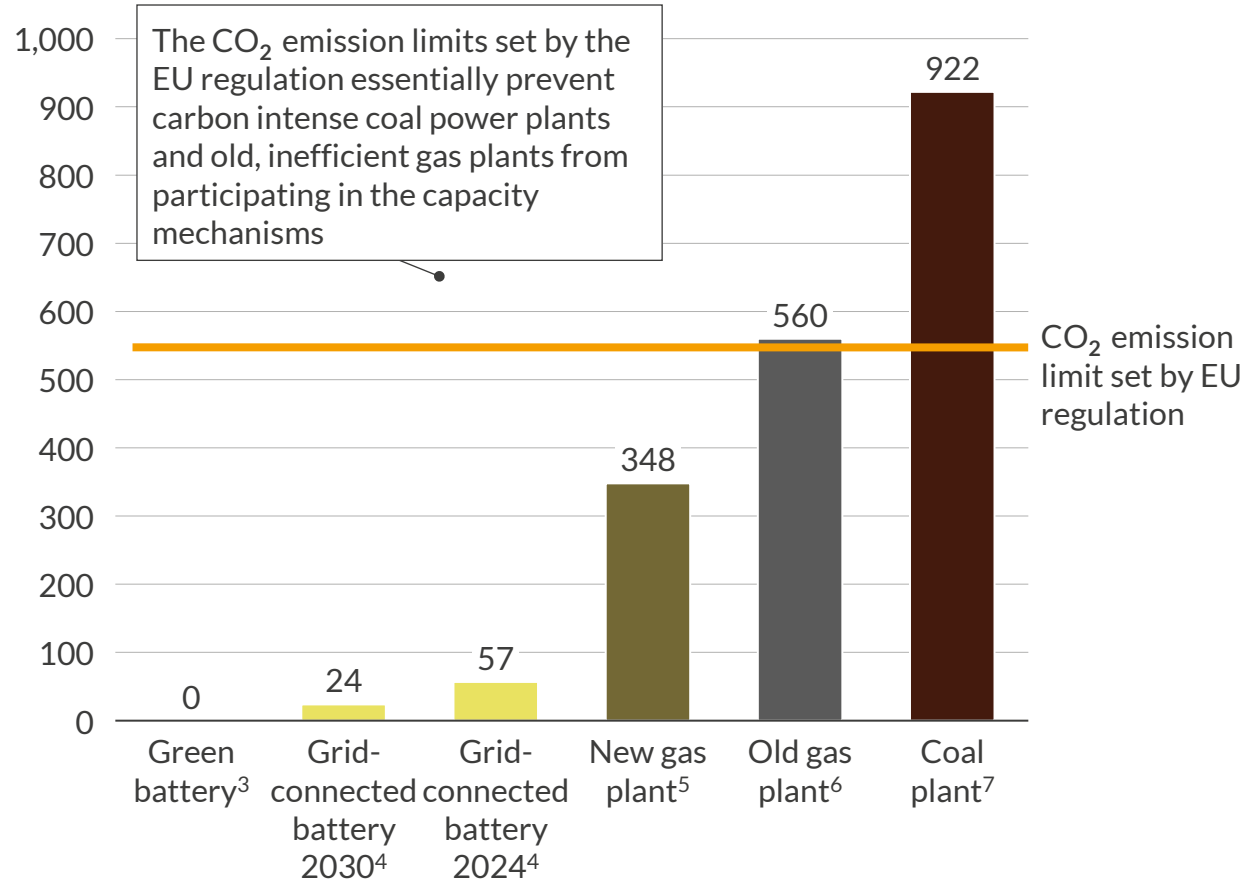
Currently applicable	For COD[2] from 4 July 2019: ≤550 gCO_2/kWh
Additionally, from July 2025	For COD[2] before 4 July 2019: ≤550 gCO_2/kWh **or** ≤350 $kgCO_2$/year/installed kW_{el}

- **Incentivizing flexibility:** Capacity mechanisms should incentivize the buildout of flexible assets including demand side response and energy storage
- **Non-discrimination and technology neutrality:** Capacity mechanisms should be open to new and existing capacities as well as different technologies and demand-side measure
- **Resource Adequacy Calculation:** To ensure security of supply across member states, each member state must assess its resource adequacy using a standardized methodology.

Within the boundaries set by EU regulation, member states have leeway in designing their respective capacity mechanism.

Exemplary emission intensities of conventional generation assets in Germany

gCO_2/kWh



1) EU Electricity Regulation 2019/943 Art. 19, 20, 21, 22, 64, 69. 2) Commercial operation date. 3) Charged with green electricity only. 4) Carbon intensity based on average German electricity mix in the respective year inclusive of battery's efficiency losses. 5) Exemplary gas plant with an efficiency of 52% and emission intensity of 180 gCO2/kWh . 6) Exemplary gas plant with an efficiency of 32% and emission intensity of 180 gCO2/kWh. 7) Exemplary gas plant with an efficiency of 37% and emission intensity of 340 gCO2/kWh. Source: Aurora Energy Research

EU Member States are recommended to support non-fossil flexibility via capacity mechanisms

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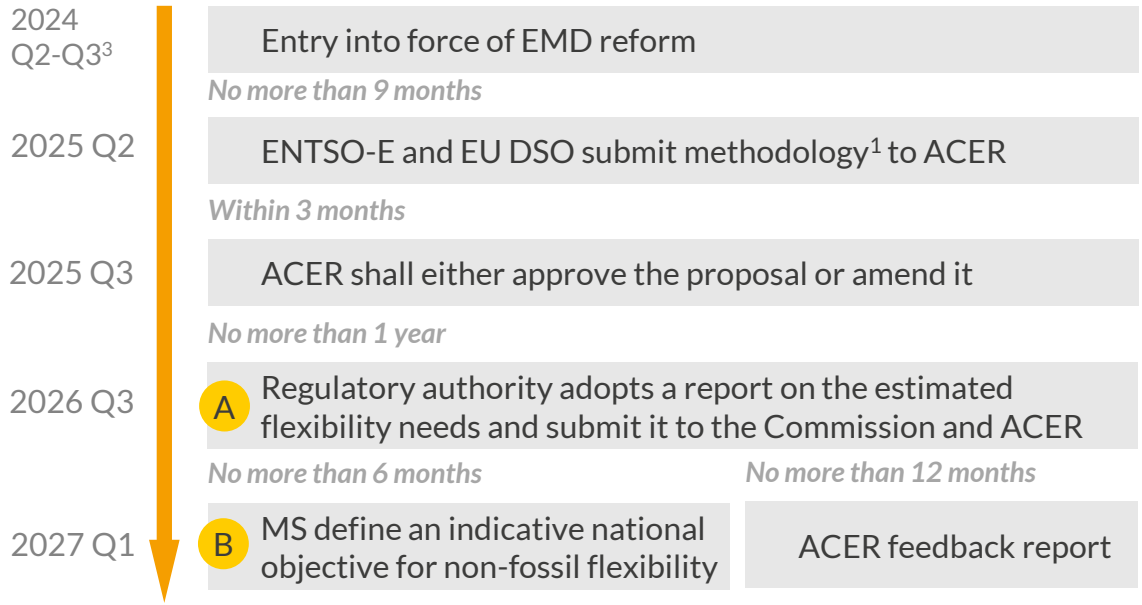
In April 2024, the Parliament of the European Union adopted the proposal to reform the electricity market design (EMD) regulation, that is now being implemented. The proposal aims to stabilise electricity prices and enhance consumer protection through regulatory measures. Detailed flexibility provisions are introduced.

Main flexibility provisions:

- Member States (MS) shall submit **flexibility needs assessment reports** A
  - It must be updated every two years to estimate the flexibility needs for the next 5 to 10 years at the national level.
  - ENTSO-E shall update the Union-wide network development plan to include the results of these reports.
- MS shall define **indicative national objectives for non-fossil flexibility** B
  - It must **include** the respective specific contributions of both **demand response and energy storage** to these objectives.
- Non-fossil flexibility support schemes
  - The reform recommends the use of capacity mechanisms as support scheme, involving payments for the available non-fossil flexibility[2] capacity.

EMD reform and follow-up actions are expected within the next 2-3 years

Estimated action time



Key takeaways:

- The reform emphasises the critical need for increased flexibility across all MS, primarily through energy storage and DSR.[4]
- By 2027, all MS are expected to have a flexibility needs assessment and set objectives for non-fossil flexibility, particularly energy storage and DSR. However, the impact can be limited for MS with established energy storage strategies or targets.
- Member States are encouraged to use capacity mechanisms as support scheme, reassuring their role in MS with an existing capacity mechanisms or in the process of implementation.

1) A proposal regarding the type of data and format to be submitted to a regulatory authority or another authority or entity designated by a Member State. 2) Assuming that investment in non-fossil flexibility is insufficient to meet the indicative national objective. 3) We estimate the Council will adopt the proposal at this time. 4) Demand Side Response.

Source: Aurora Energy Research, European Parliament

Most European capacity mechanisms have opted for pay-as-clear pricing with price caps between 77 and 164k €/MW

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Price formation

- Auctions can award capacity remuneration:
  - at the level of the individual bid ('pay-as-bid'), or
  - at the level of the highest accepted bid ('pay-as-clear').
- In theory, both methodologies should lead to similar auction results under the following conditions:

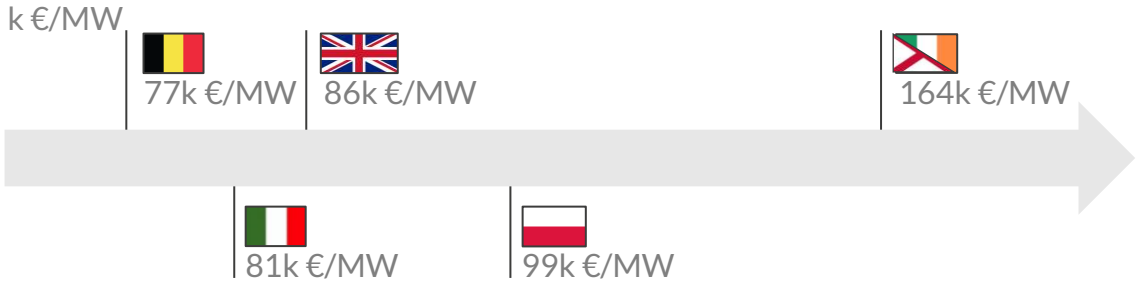
Condition	Status in European markets
Homogeneous product	✓ Capacity mechanisms procure capacity without distinction
Sufficient market competition	✓ Most power markets feature high levels of competition
Perfect information for all participants	✗ Lack of complete information on investment costs for new-build capacities

- Due to imperfect information, most capacity mechanisms[1] apply a pay-as-clear pricing mechanism. This also allows to reduce administrative complexity if coupled with descending clock auctions.

Price cap

- Defined by the procuring entity, price caps set the maximum possible bid for each auction[2].
- In competitive auctions, the price cap indirectly impacts the participation of different technologies through its relation to their missing money[3].
- Price caps differ between European capacity mechanisms:
  - Belgium has the lowest price cap of 77k €/MW as the extension of the nuclear exit reduces capacity requirements.
  - The price cap in the Ireland I-SEM CRM[4] has been steadily increased from 138 to 164k €/MW since 2019 to incentivise required thermal capacity buildout in light of a high-cost environment and supply chain issues.

Capacity market price caps in Europe[5]



1) Belgium is the only country that opted for a pay-as-bid methodology. 2) The price above which no more remuneration is awarded. 3) Along with the contract length. 4) Capacity Remuneration Mechanism. 5) Referring to the latest main auction for new builds. In GB, £75k/MW.

Sources: Aurora Energy Research, BDEW, Elia, SEM-O

Capacity mechanisms support over 23 GW of batteries across Europe, although revenues vary due to de-rating factors and clearing prices

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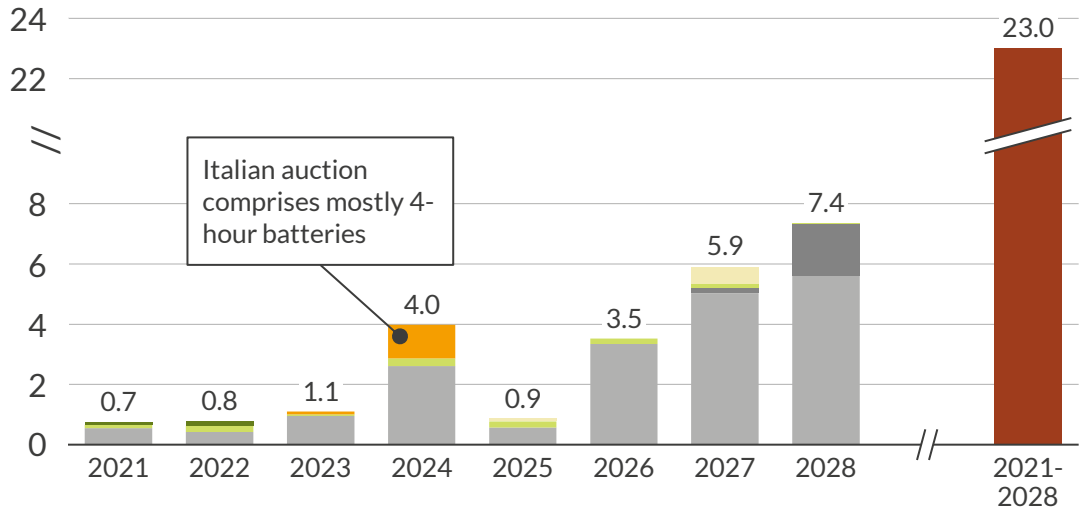
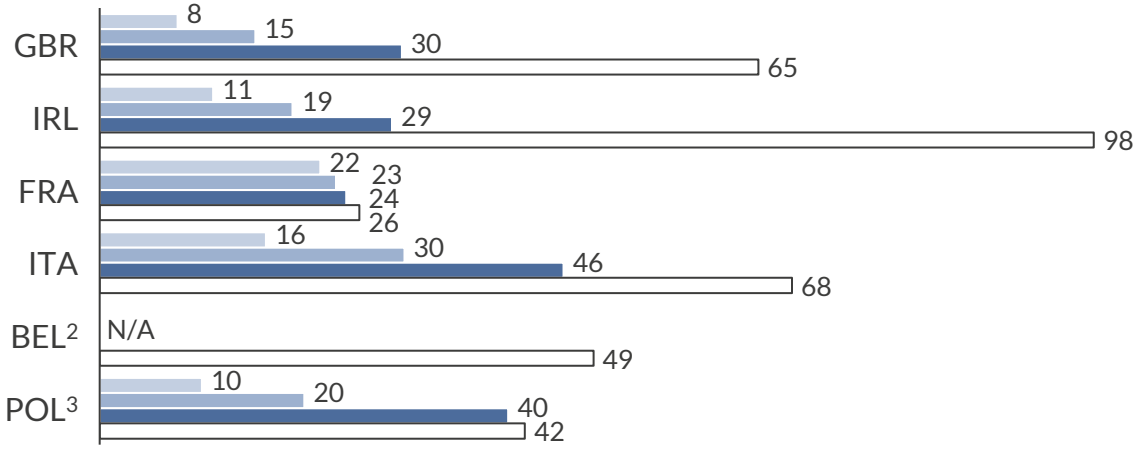
Total battery capacity awarded by capacity mechanisms in respective COD years
GW nameplate



Cleared and de-rated[1] capacity mechanism prices in latest auction
€/kW (real 2023)



- Over 23 GW of batteries have secured contracts in capacity mechanisms in six countries, of which 19 GW are located in Great Britain.
- Auctions are generally held annually, with delivery for new-build assets typically 4 years after the conclusion of the auction.
- The delivery year defines the year when batteries start delivering their contracted services.
- From delivery year on batteries support security of supply for up to 17 years.

BEL FRA POL Total awarded battery capacity
ITA IRL GB

- The methodology to determine battery de-rating factors considers simulated stress event distributions and likelihood that storage assets will cover them.
- De-rating factors decrease the remuneration accessible to batteries in alignment with their role in ensuring security of supply, thereby restricting their earnings.
- While revenues from other markets for batteries provide higher total revenues over lifetime, capacity mechanism revenues can be important contributions to the business case and secure financing by providing a baseload revenue steady in time.

1 hr 2 hrs 4 hrs Cleared price

1) Considers de-rating factors in latest auctions. 2) Average bid price for new capacity for the T-4 2023 auction. The highest awarded price bid in the 2023 Y-4 CRM auction was 69900 EUR/MW. Due to its pay-as-bid system, capacity mechanism prices awarded to batteries in Belgium are not known. 3) Poland's capacity market requires 4 hours of continuous generation, so batteries with duration under 4 hours must compete with reduced capacity (half capacity for 2-hour batteries and quarter capacity for 1-hour batteries). Source: Aurora Energy Research

To guarantee security of supply, adoption of binding de-rating factors reflecting availability of technologies in tight periods is common practice

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% De-rating factors

Purpose

- De-rating factors in a capacity market are adjustments applied to the nominal capacity of various types of power generation resources to reflect their expected availability and reliability during peak demand periods.
- They thus reflect the contribution that a specific technology can make to security of supply in case of a scarcity event: The higher the de-rating factor the higher a technology's contribution to a scarcity event.

Impact of de-rating factors on capacity payments

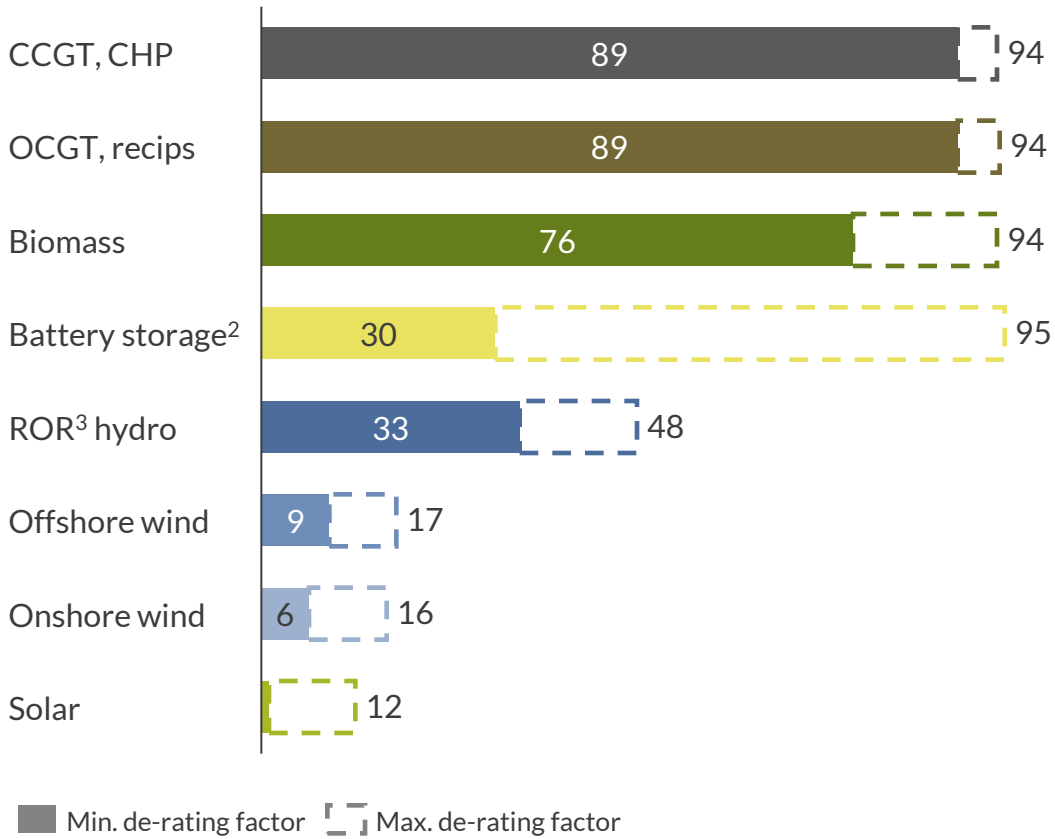
- Clearing prices in the capacity mechanism are multiplied by derating factors.
- Consequently, technologies with lower de-rating factors receive lower capacity payments because they are deemed to provide less reliable capacity, and conversely, resources with higher derating factors receive higher payments, reflecting their greater reliability.

International trends

- De-rating factors are based on market-specific historical availabilities. Key trends across markets include:
  - Thermal assets feature the highest reliability with de-rating factors between 89-94%.
  - Renewables are heavily de-rated due to the variability of weather.
  - Battery de-rating factors exhibit large variations across and within countries, with a range of 65% (see next slide).

Minimum/Maximum de-rating factors for latest EU T-4 auctions[1]

%



1) GBR, IRL I-SEM: 2027/28 T-4 auction; ITA: 2024 T-4 auction; BEL: 2024 Y-4 auction; POL: 2028 T-5 auction. 2) De-rating factors for 4h batteries with the lowest ones currently in Ireland. 3) Run-of-river.

Sources: Aurora Energy Research, PSE, Ministry of Climate and Environment, Elia, Terna, ARERA, EirGrid, SONI, National Grid, Consentec, BDEW

Battery de-rating factors depend on battery duration and overall battery capacity in the system

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Battery de-rating factors

- De-rating factors for batteries depend on two main aspects:

Duration

- Battery contribution to security of supply is limited by their ability to respond to stress events as defined in the Resource Adequacy Methodology.
- The shorter the duration, the lower the de-rating factor.

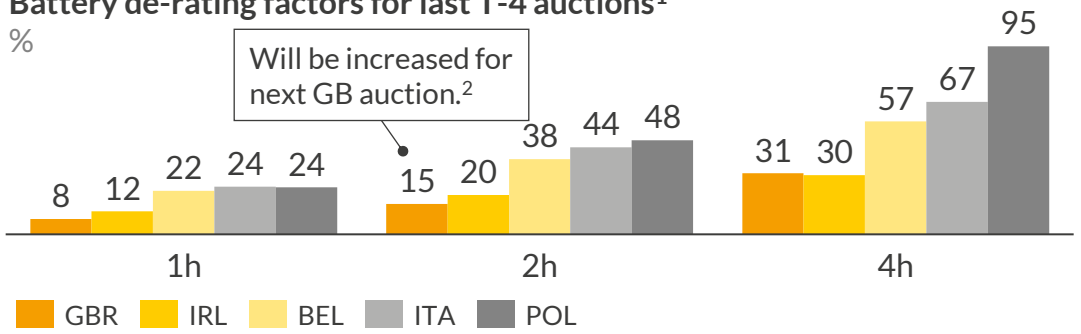
Capacity

- The incremental value of having additional batteries in the system decreases.
- The more batteries are active in the power market, the lower their de-rating factor.

- A recent paper suggests that the value of energy storage in a stress events could be higher, if energy storage did not self-dispatch at the beginning of the stress event, but if the assets in a capacity mechanism stress event would be dispatched centrally by the system operator.
  - This way energy storage would then be dispatched with full power, when it is actually needed the most in the system.

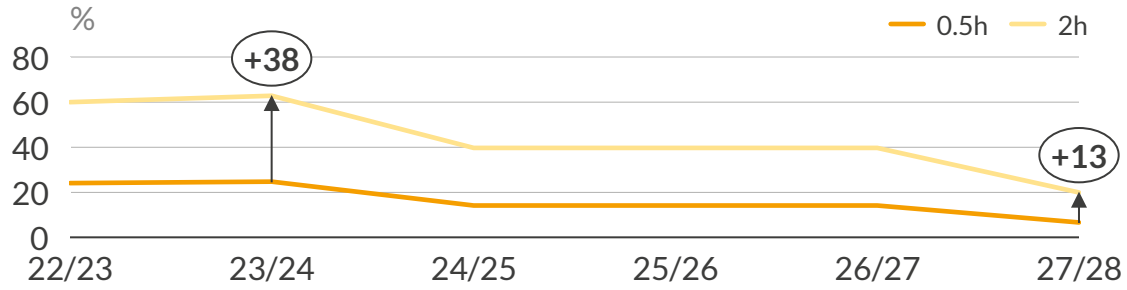
- Typically we observe lower battery de-rating factors in countries with relatively high market penetration of batteries, e.g. Great Britain and Ireland:

Battery de-rating factors for last T-4 auctions[1]



- The case of the Ireland I-SEM Capacity Market highlights the growing importance of capacity in determining de-rating factors, with de-rating factors for 2h batteries converging with shorter-duration batteries as buildout increase:

Ireland I-SEM battery de-rating factors by T-4 auction



1) GBR, IRL I-SEM: 2027/28 T-4 auction; BEL: 2024 Y-4 auction; ITA: 2024 T-4 auction; POL: 2028 T-5 auction. 2) 10% for 1h batteries, 21% for 2h batteries, 42% for 4h batteries,

Sources: Aurora Energy Research, PSE, Ministry of Climate and Environment, Elia, Terna, ARERA, EirGrid, SONI, National Grid

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AURORA

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Germany (1/2)

To meet future peak demand, Germany announced to implement a capacity mechanism, aiming to benefit security of supply while safeguarding decarbonization objectives and social welfare.

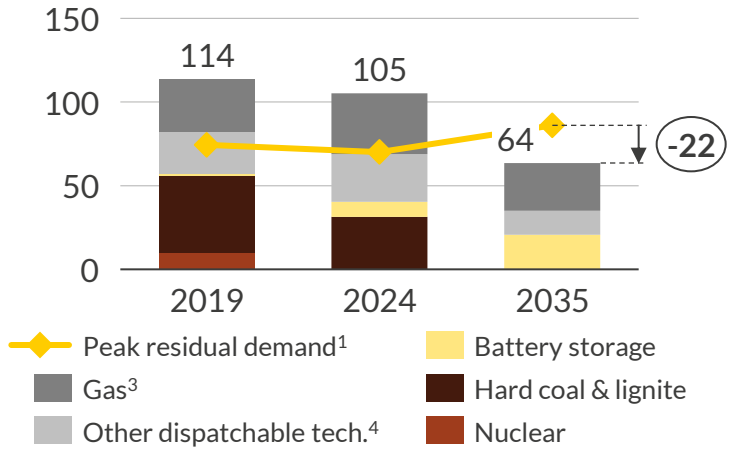
- The capacity mechanism is suggested to be effective by 2028 and to be market-based and technology agnostic.
- Given existing business models, and in line with outcomes across Europe, batteries are expected to bid into the capacity mechanism as price takers, pushing more expensive assets to the end of the merit order. They thus help realize security of supply in an affordable way.
- Stronger integration of batteries will also support accelerated decarbonization of the German power market, driving wider system benefits.

Batteries are expected to participate in the capacity mechanism with de-rating factors in line with EU examples.

- De-rating factors should be based on technical availability and battery contributions during system stress events as defined under the EU methodology.
- These factors vary across European CMs, averaging 58% for 4-hour assets. Given Germany's current battery market penetration, it is expected to adopt these European averages.
- Regular updates to de-rating factors are recommended to reflect changes in their role during scarcity events as the system evolves.

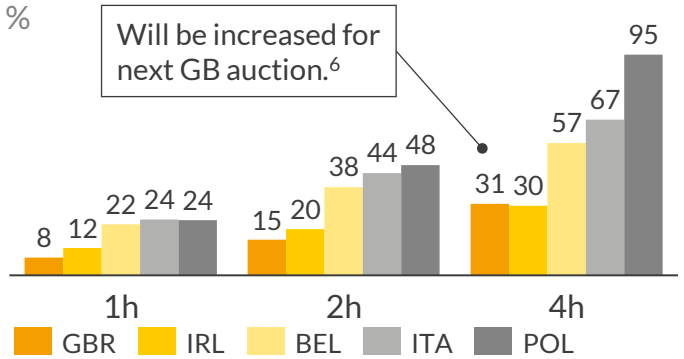
Peak residual demand[1] and dispatchable capacity without new builds[2]

GW



Battery de-rating factors for last T-4 auctions[5]

%



1) Peak residual demand refers to total net demand minus wind and solar generation. 2) Based on the Aurora Central scenario, but no buildout of non-CHP power plants is assumed. 3) Includes gas CCGTs and peakers. 4) Includes hydro, biomass, pumped storage, battery, and other thermal (i.e., waste plants and on-site industrial thermal power plants). 5) GBR, IRL I-SEM: 2027/28 T-4 auction; BEL: 2024 Y-4 auction; ITA: 2024 T-4 auction; POL: 2028 T-5 auction. 6) 10% for 1h batteries, 21% for 2h batteries, 42% for 4h batteries. Sources: Aurora Energy Research

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Executive Summary

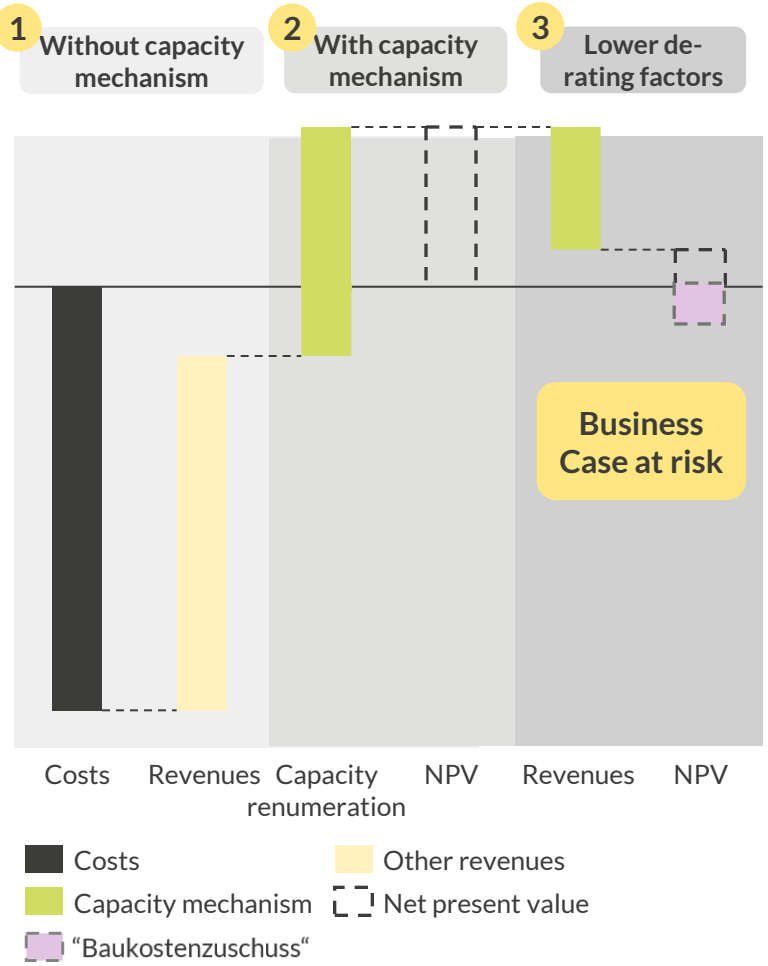
Germany (2/2)

A capacity mechanism provides an additional revenue stream, that can be secured for the long-term and reduce investor risk.

According to Aurora's modelling, revenues from a capacity mechanism could strongly support future battery business cases.

1. If no capacity mechanism exists, revenues for a new-build battery entering operation in 2032 result in a negative net present value (NPV) so that new storage additions would diminish.
   - Hence, a negative NPV would risk having sufficient flexibility in the system, which would result in even higher curtailment costs and endanger achieving Germany's renewables expansion targets.
2. If batteries participate in a technology-agnostic and well-designed capacity mechanism, this could turn the NPV of such a battery positive.
   - In turn, this would positively affect battery buildout and contribute to having sufficient flexibility in the system.
3. If, however, de-rating factors of batteries are too low, such as in recent auctions in Ireland, this could significantly reduce the role of batteries in a capacity mechanism and hamper battery buildout.

Example new-build battery entering 2032[1]
Net present value, €/kW (real 2023)

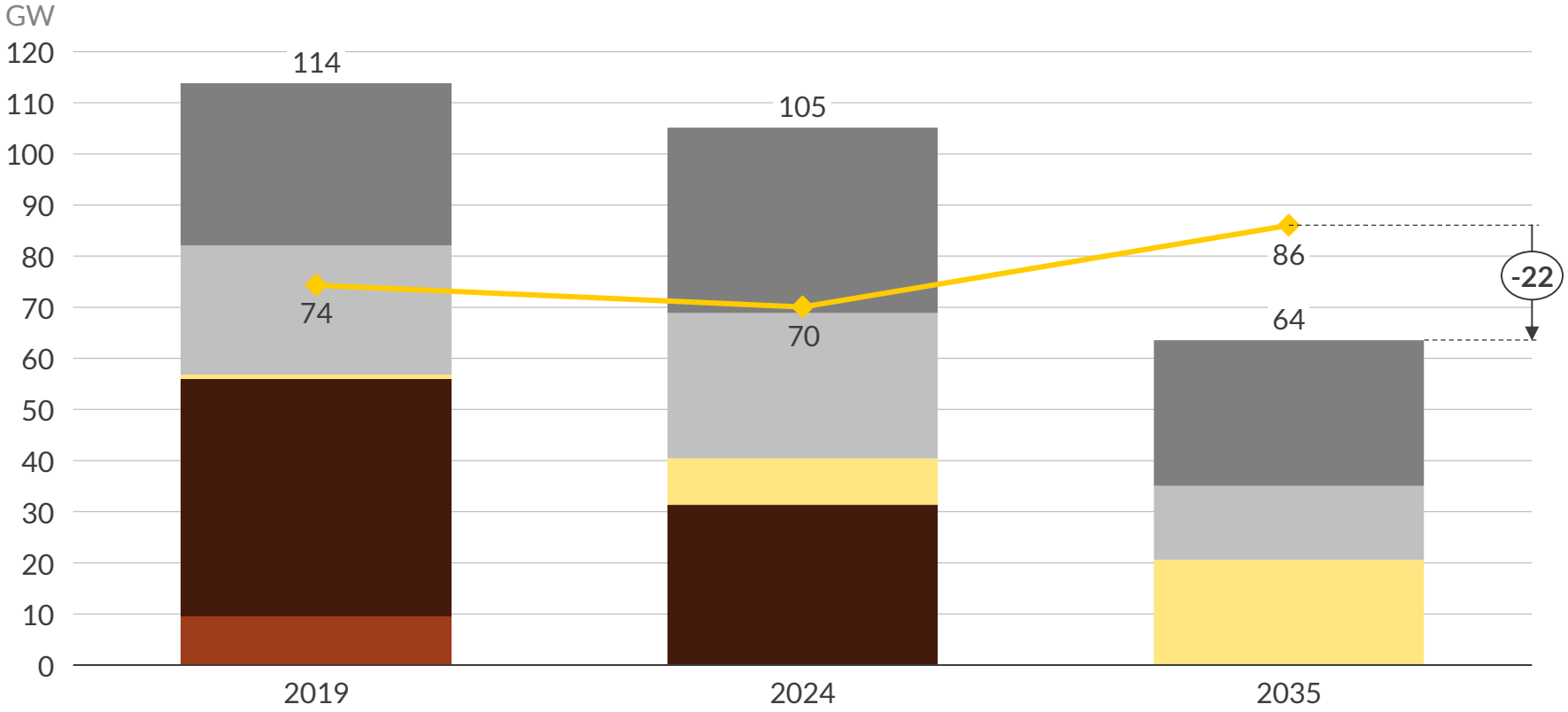


1) 4h duration, 1 cycle/day, 20 years lifetime 2) CAPEX, OPEX and considers end of life value.

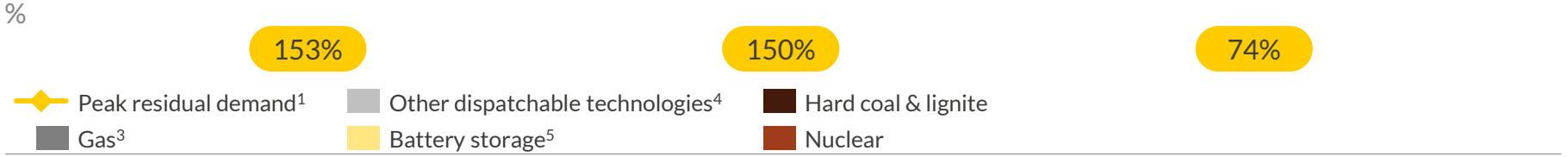
Sources: Aurora Energy Research

Without new builds, the coal exit and rising demand lead to a 22 GW gap between peak residual demand and dispatchable capacity by 2035

Peak residual demand[1] and dispatchable capacity without new builds[2]



Share of peak residual demand[1] covered by dispatchable capacity



1) Peak residual demand refers to total net demand minus wind and solar generation. 2) Based on Aurora Central, but no buildout of non-CHP power plants is assumed. 3) Includes gas CCGTs and peakers. 4) Includes hydro, biomass, pumped storage, and other thermal (i.e., waste plants and on-site industrial thermal power plants). 5) Home storage, industry and utility scale batteries.
Sources: Aurora Energy Research, BNetzA

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- In the past, the German power system was characterised by overcapacity, with dispatchable capacity significantly exceeding peak residual demand.
- Due to the coal exit, 40% of the currently installed dispatchable capacity (i.e. 31 GW of hard coal and lignite) is expected to leave the system by the early 2030s.
- Simultaneously, increasing electrification of industry, transport, and heat as well as the domestic production of green H_2 drive up peak residual demand by 23% (16 GW) between now and 2035.
- Significant buildout of new dispatchable capacity is needed to reduce this gap and ensure security of supply. At the same time, these new assets need to be able to decarbonise swiftly to not jeopardise climate targets.

To ensure buildout of dispatchable capacity, the government committed to introduce a capacity mechanism by 2028 as a complement to the new KWS[1]

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Auctions for 10GW of new H_2-ready gas plants and 2GW of plant retrofits form the core of the Power Plant strategy (KWS)

7 GW to be funded via the decarbonization objective of state aid, 5 GW as a security of supply measure.[2]

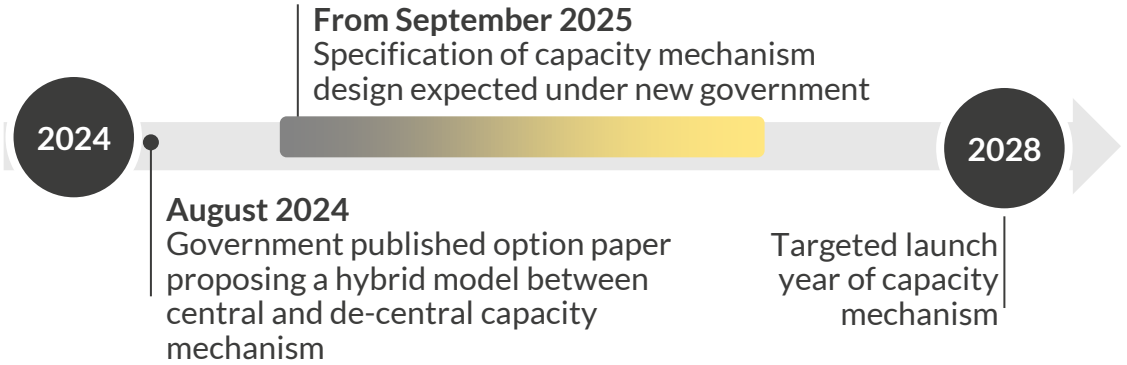
- Plants awarded in the auctions under the decarbonization objective need to convert to H_2 (green or blue) 8 years after COD.
  - Plants receive a fuel subsidy capped at 800 full load hours per year, duration of the fuel subsidy still unclear.[3]
- No fuel switch requirement announced for plants awarded in auctions under the security of supply objective.
- Geographic distribution: Plants shall be predominantly built in the South. Mechanism used to steer the location of the buildout still unknown.

+ 0.5 GW of H_2 sprinter plants and LDES each[4]

- 500 MW of gas-fired power plants that need to be operated with hydrogen from the start (H2 sprinter plants).
- 500 MW long duration energy storage (LDES) technologies.

Announcement of a **capacity mechanism**

- The government has committed to developing concepts for a **market-based capacity mechanism** to be **launched by 2028**.
- In August 2024, the ministry initiated a consultation on its design proposing a **hybrid model** between a central and de-central CM.
- Focus for this mechanism is on **technology neutrality**, i.e., allowing different generation technologies, storage, and demand-side response options to participate.
- New gas-fired power plants incentivised via the **Power Plant Strategy** are meant to be **"fully integrated" into the capacity mechanism**.



⚠ Introduction of both the Power Plant Strategy and capacity mechanism hinges upon **approval under EU state aid law.**

1) *Kraftwerksstrategie* (Power Plant Strategy). 2) Auctions may take place by end of 2024/early 2025 with no precise auction schedule published yet. 2) Subsidies require approval under the EU guidelines on state aid for climate, environmental protection and energy (CEEAG). 3) Support design for both technologies still unclear. 4) Available until 2040 for max. 800 full load hours per year. Subsidy level will not be determined ex-ante, but is suggested to depend on variable spread between fuel costs of gas and H2.
Source: Aurora Energy Research, BMWK

The recently published option paper by the German ministry favours a hybrid capacity market to ensure sufficient future dispatchable capacities

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The Ministry for Economic Affairs and Climate Action (BMWK) published an option paper addressing the need to redesign the future electricity market

- The paper is rooted in discussions by the Platform Climate-Neutral Power System (PKNS) and outlines different options along four fields of action; renewables deployment, local signals, flexibility and dispatchable capacity.
- Regarding dispatchable capacities, the ministry favors a hybrid approach (Deep dive on the right side of this slide).
- Stakeholders are invited to provide feedback on the proposed options for dispatchable capacities by September 2024.

Key takeaways of the option paper for batteries regarding the design of a future capacity mechanism

1. Re-enforces that a **capacity mechanism** with substantial effects on the German electricity system will be introduced by 2028.
2. Explicitly **acknowledges the relevance of battery storage** in such a future capacity mechanism.
3. Underlines the **need to correctly determine de-rating factors for storage**. The paper explicitly mentions that a central capacity mechanism has the tendency to view the contribution of flexible demand and storage in a risk-averse manner which could hamper their business model.

The favored hybrid capacity market combines both central and decentral elements of capacity mechanisms

Central capacity market component

Mechanism: Central capacity auctions with tenders held by central authority for the construction of new dispatchable capacities, with successful bidders receiving payments for capacity provision.

Participants: New dispatchable assets.

Financing: Levy on end-consumers.

Decentral capacity market component

Mechanism: Balancing responsible parties required to meet their peak residual demand through own flexibility and capacity certificates.

Participants: New and existing assets.

Financing: Costs borne by balancing responsible parties and passed on to end-consumers.

Sources: Aurora Energy Research, BMWK

Capacity mechanism targets will be challenging to define given uncertainty in demand levels and flexibility in Germany

Procurement target

Capacity mechanism target

- The capacity mechanism procurement target is set to guarantee sufficient capacity will be available to meet future power demand.
- According to EU methodology it is calculated in a way that the expected period of loss of load[1] falls below a certain threshold.

Key policies influencing the capacity mechanism target

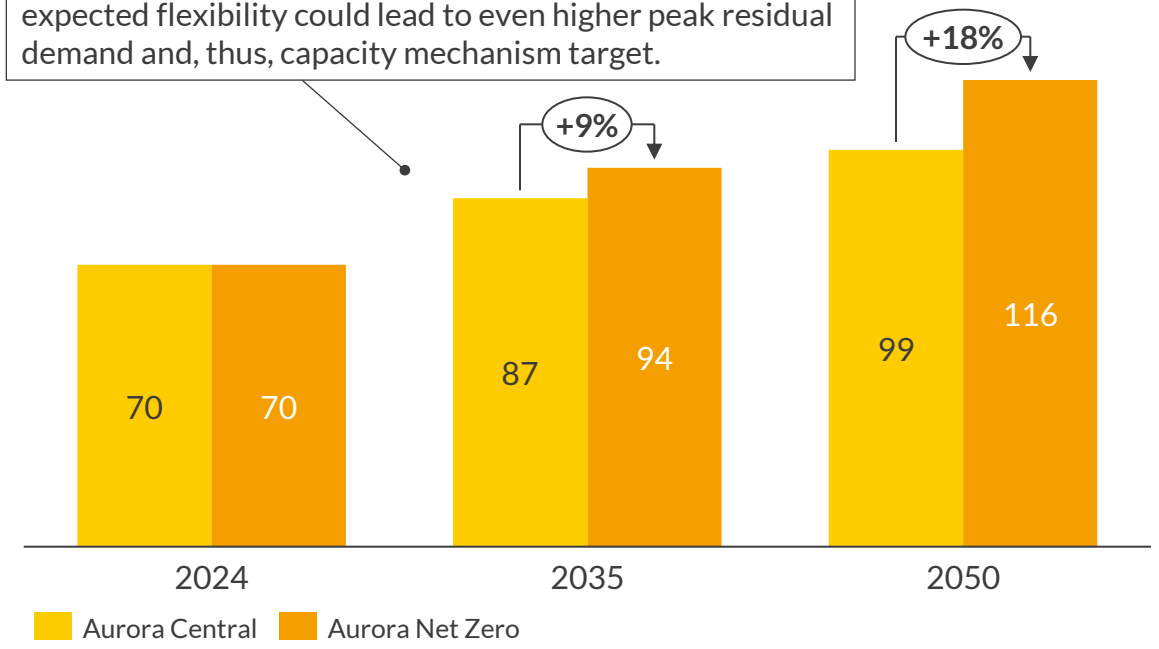
- While policy targets are defined for all major power demand segments in order to promote decarbonisation, their achievement remains uncertain:

Demand segment	Aurora Central	Government target
H_2 production	4.3 GW_{H2} electrolysers by 2030	10 GW_{H2} electrolysers by 2030
Electric vehicles	12mn by 2030	15mn by 2030
Heat pumps	4mn by 2030	About 6mn by 2030[2]
Total demand	638TWh by 2030	750TWh by 2030

Peak residual power demand in Germany

TWh

Projections reflect a significant flexibilisation of power demand – e.g. through sector-coupling, DSR, or batteries – driven by policy and market developments. Lower than expected flexibility could lead to even higher peak residual demand and, thus, capacity mechanism target.



Key takeaway for Germany

Uncertainty in future demand levels and demand flexibility in Germany poses a challenge for estimating the capacity mechanism target, potentially leading to overestimation which could result in over-procurement of new-build assets.

1) Loss of load refers to times when power demand is higher than available generation. 2) Derived from a government concept paper.

Sources: Aurora Energy Research, B MWK, Consentec, Netzentwicklungsplan Strom

For the German capacity mechanism, a pay-as-clear auction scheme and binding derating factors are advisable

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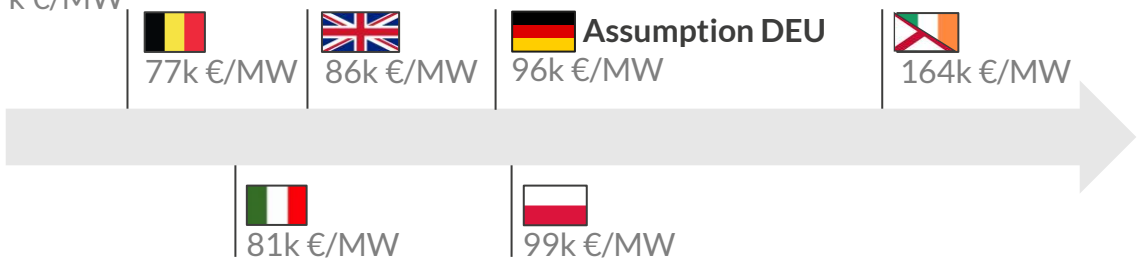
Price formation and price cap

- Due to imperfect information, pay-as-clear is the preferred pricing scheme for the German capacity market as it allows for more efficient auction results.
- Price caps should be sufficiently high to allow for thermal capacity buildout, accounting for their missing money.[1]
- To reflect cost changes and capacity needs, price caps should be adjusted on an ongoing basis.
- OPEX subsidies, such as potential subsidies for H2-ready plants participating in the Power Plant Strategy, should be accounted for in the price caps to not introduce a bias of double subsidies for thermal plants via fuel subsidies.

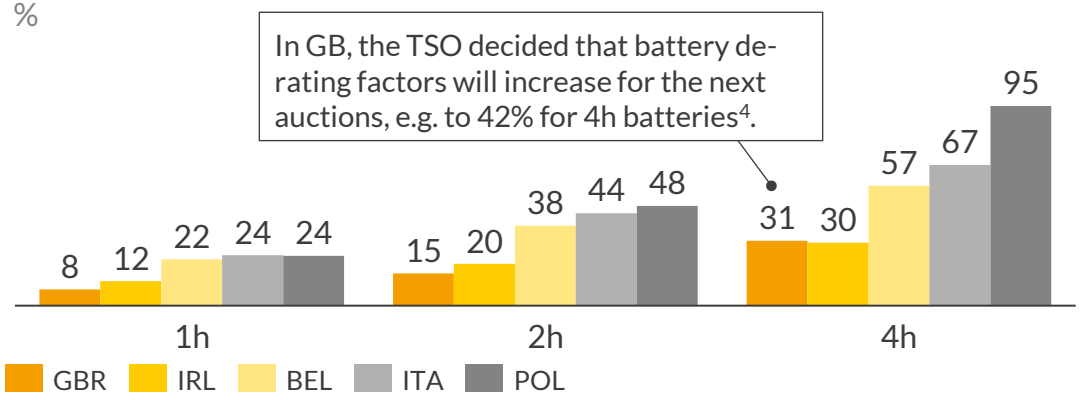
Capacity market price caps in Europe[2]



De-rating factors

- Generally, de-rating factors should be based on technical availability and the contribution of batteries during system stress events as defined under the EU methodology.
- Binding de-rating factors, recalibrated regularly to reflect changing availabilities and capacities, are recommended for the Germany capacity mechanism to ensure security of supply.
- We expect German battery de-rating factors to be situated close to European average levels of de-rating factors given its current battery market penetration.

Battery de-rating factors for last T-4 auctions[3]

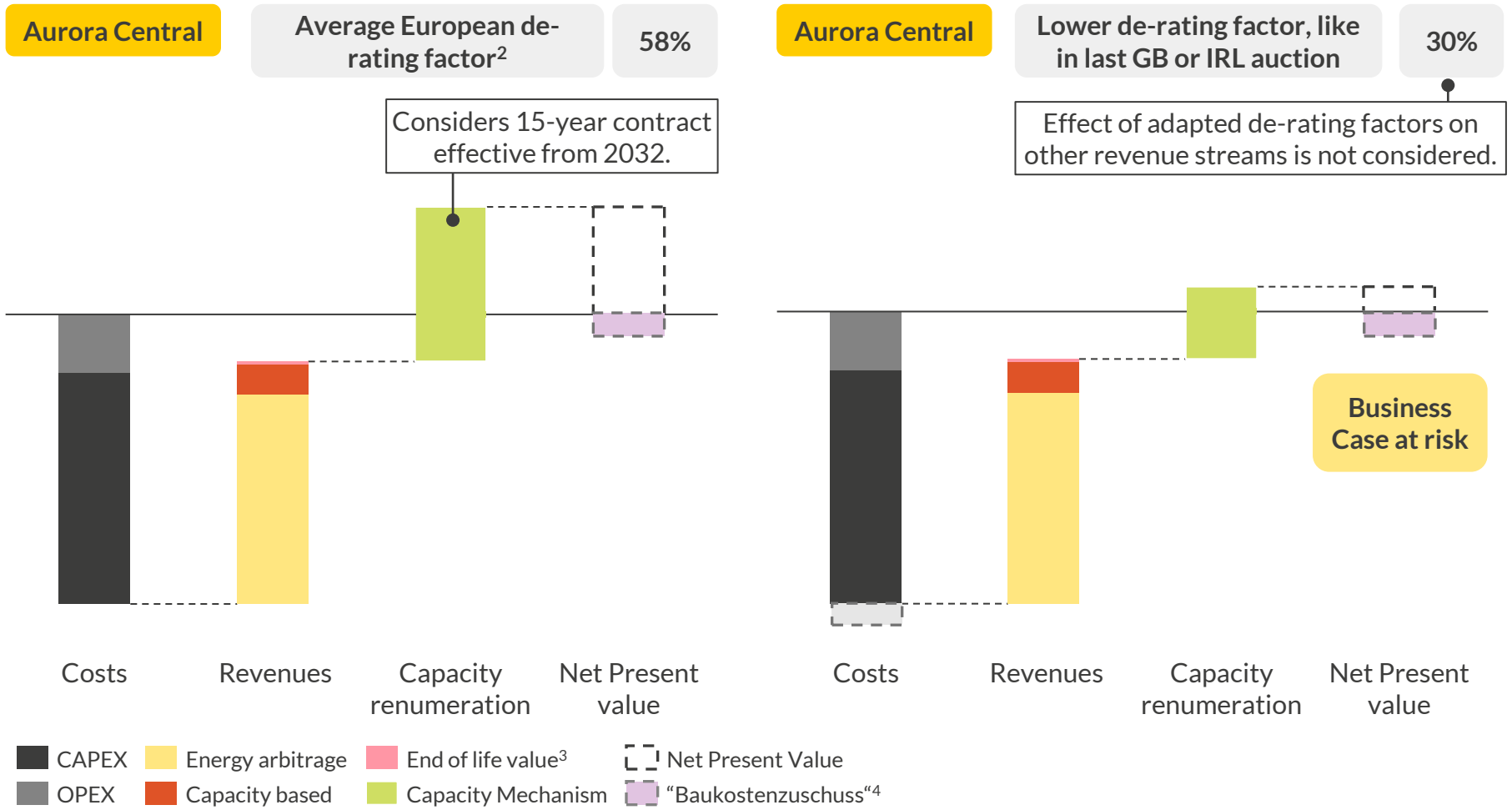


1) No final details are published yet on how H2-plants, that are incentivised by the KWS and might benefit from the OPEX subsidy, will bid into the capacity market. 2) Reflecting European average. 3) GBR, IRL I-SEM: 2027/28 T-4 auction; BEL: 2024 Y-4 auction; ITA: 2024 T-4 auction; POL: 2028 T-5 auction. 4) 10% for 1h batteries, 21% for 2h batteries.

Sources: Aurora Energy Research, BDEW, Elia, SEM-O

Additional revenue streams from a capacity mechanism can be secured for the long-term, thereby reducing investor risk

Economics for an example new-build battery entering 2032 (4h duration, 1 cycle/day, 20 years lifetime)[1]
Net present value, €/kW (real 2023)



11) NPV discount rates of 11.5% and 6.5% (real, pre-tax) for merchant and CM revenues, respectively. 2) Already reflects higher GB de-rating factors announced by TSO for next auction. 3) Depends on the year the battery is decommissioned, which depends on the total depth remaining. 4) The "Baukostenzuschuss" can strongly vary by region and is not modelled.
Source: Aurora Energy Research

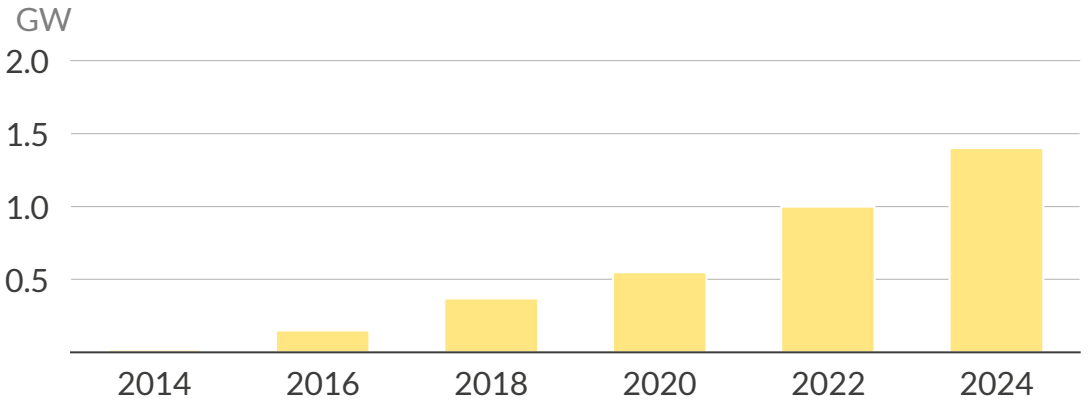
- Revenues from a CM could be key for 4h duration batteries, that start operating in 2032.
- Given the expected saturation of capacity-based ancillary services, arbitrage provides the main revenue source; yet, it is not sufficient to achieve a positive NPV.
- We assumed a new-build 4-hour duration battery to participate in a T-4 auction in 2028 (COD 2032) with a clearing price of 76€/kW.
  - Based on the average derating factor of 58% in recent and upcoming[2] European auctions, CM payments are crucial to turn the NPV positive.
  - However, lower de-rating factors of 30% could pose a risk to business cases, where already the "Baukostenzuschuss" could tip the NPV to be negative, which would likely halt storage additions.

To leverage the benefits of battery storage, also other regulations in Germany matter

Regulatory changes relevant for batteries		
Capacity mechanism	▪ Depending on its final design the German capacity mechanism could be a very important additional revenue stream for batteries.	
Baukosten-zuschuss	▪ The Higher Regional Court declared the calculation of the BKZ inadmissible.	
Storage strategy	▪ The Federal Ministry of Economic Affairs published a storage strategy, that aims to set a regulatory frame-work for a fast ramp-up of storage technologies.	
Solar package	▪ The solar package introduces that renewable electricity stored in a battery does no longer lose its green electricity character.	
Reactive power	▪ In the high and extra-high voltage grid, reactive power will be procured by auctions.	
Inertia	▪ Inertia will be procured by a premium model, in which batteries could participate and get renumerated.	
Blackstart capability	▪ Large batteries with capacities above 150 MW are eligible for providing blackstart capability.	

Estimated impact on battery projects

Commissioned utility-scale battery capacity[1]



- The installed capacity of utility-scale batteries has seen nearly a threefold increase over the past four years, signaling significant progress in the energy storage sector.
- This expansion is bolstered by a series of regulatory advancements designed to further accelerate the deployment of battery projects.
- Among these regulatory initiatives, the capacity mechanism plays a very important role due to its potentially significant impact on the feasibility and success of battery projects.
  - The effectiveness of this mechanism hinges on its specific design elements, especially the de-rating factors, which determine the extent of financial support available.
  - At the same time, capacity payments reduce risks compared to the merchant case.

1) Cumulative values at the end of the year. 2024 capacity includes data until end of May.

Source: Aurora Energy Research

Agenda

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I. **Exploring Europe's capacity mechanisms**
   1. Flexibility in the future power system
   2. European regulatory overview

II. **Future trajectories for a German capacity mechanism**

III. **Introduction of a future capacity mechanism in Spain**

IV. **Appendix**
   1. Great Britain's mature capacity market
   2. The evolving capacity market in Poland
   3. List of Abbreviations

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Executive Summary

Spain (1/2)

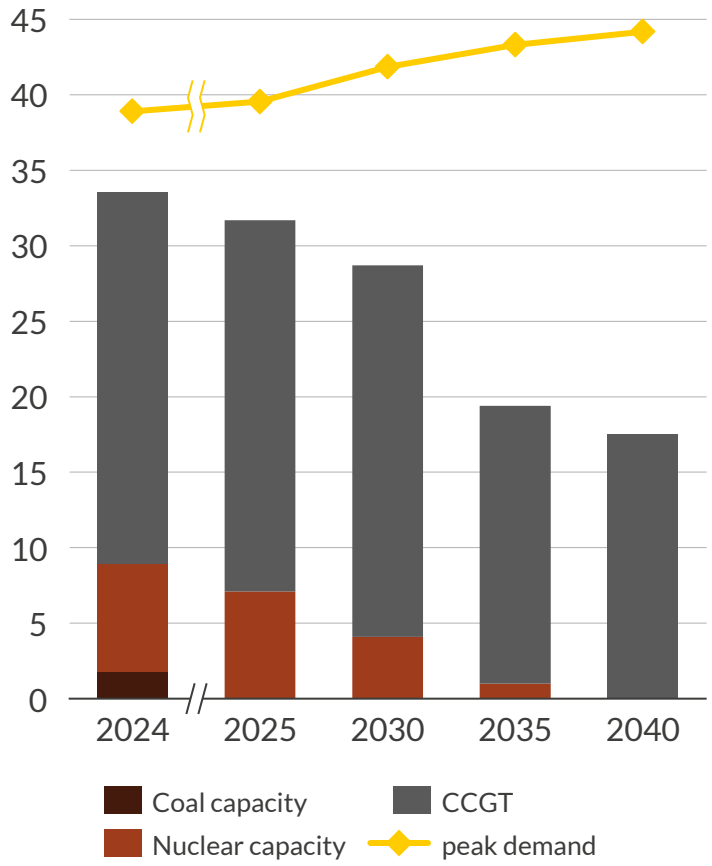
Spain will require a capacity mechanism to improve security of supply, decarbonization, and social welfare.

- Spain's governmental targets aim at retiring 7.5 GW of nuclear and coal capacity by 2030, while peak demand rises.
- A capacity mechanism is key to the buildout of additional capacity to guarantee security of supply.
- On top of that, it can support the buildout of low-carbon technologies, e.g., batteries, and enable decarbonization.
- By contracting flexible assets, the capacity mechanism can save costs, e.g., by avoiding unnecessary grid expansion.

The capacity mechanism proposal is a pay-as-bid auction; several parameters central to batteries remain undefined.

- The 2021 capacity mechanism proposal is now undergoing public consultation as part of the EU-level approval process.
- Contract durations of 12 months for existing capacity and at least five years for new capacity are currently proposed.
- Parameters that are yet to be defined include the methodology to define de-rating factors and final contract durations.
- The target capacity for the auction as well as penalties and testing regimes need to be clarified.

Installed baseload capacity in Aurora Central
GW



1) Assumes no new build firm capacity (CCGT, coal and nuclear).

Sources: Aurora Energy Research , MITECO

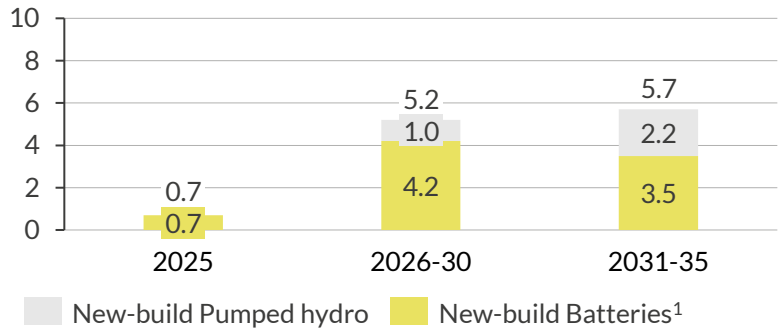
Executive Summary

Spain (2/2)

According to Aurora's modelling, the proposed capacity mechanism can support Spain to achieve its 22 GW storage capacity target for 2030.

- The proposed capacity mechanism can facilitate 4.2 GW of battery buildout, according to Aurora's modelling.
- Spain's 2023 draft of the National Energy Climate Plan sets a storage target of 22 GW by 2030, with no differentiation between batteries, pumped and thermal storage.
- Several opportunities within the capacity mechanism exist to incentivize additional battery buildout:

New builds as part of the proposed capacity mechanism
GW



	Options to incentivize additional battery buildout via the proposed capacity mechanism
General capacity mechanism considerations	▪ Add benefits for assets with low CO2 emissions like contract duration extensions[2] ▪ Implement T-3 auctions[3] that are tailored to development time required for battery projects
Considerations specific to batteries	▪ Increase battery derating factors, whereby batteries receive higher capacity remuneration[4] ▪ Lengthen the duration of contracts for batteries to provide a more secure financing floor — Current proposal states 5 years for new assets whereas contracts in GB and Poland can last up to 15-17 years for new-build battery capacity[2] ▪ Account for the degradation of batteries in testing regimes ▪ Consider including co-located assets in capacity mechanism (as is done in Italy)

1) Includes batteries participating in the ancillary markets. 2) In Poland, plants with emissivity below 450g CO2/kWh can qualify for a 2-year extension on their main capacity market contract. 3) In a T-3 auction, auctions take place three years before the delivery year. 4) Adjustment should reflect the degree to which batteries contribute to stress events.
Sources: Aurora Energy Research, Draft PNIEC 2023

The implementation of a capacity mechanism in Spain can foster security of supply, decarbonisation, and welfare benefits

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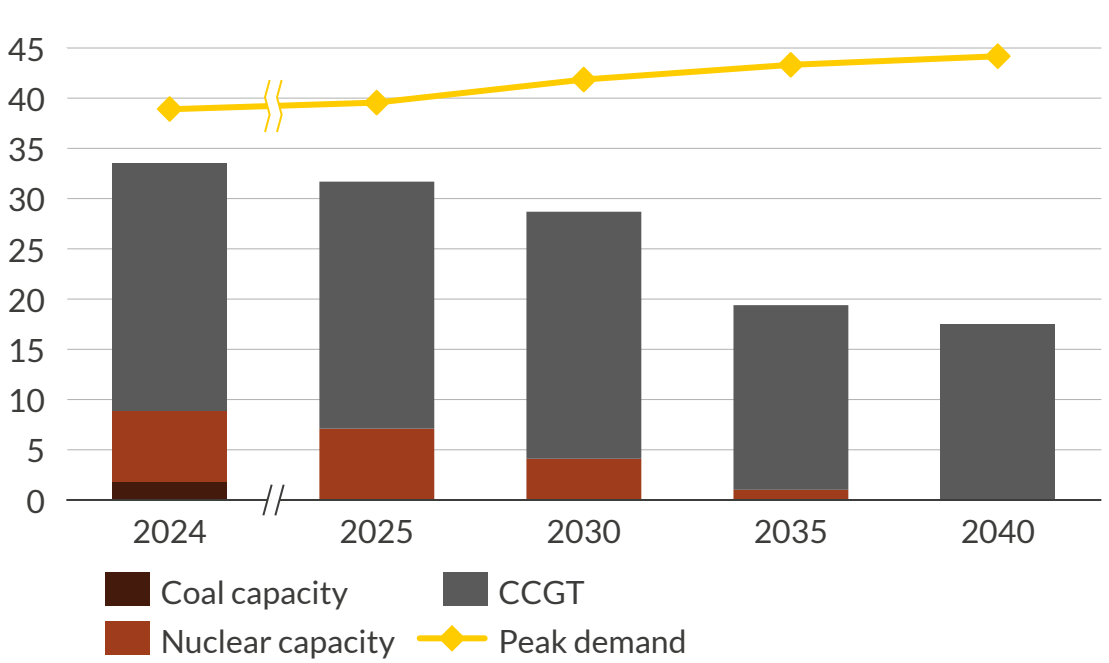
Installed baseload capacity in Aurora Central



- There are no planned retirements for CCGT capacity in Spain; these installations will be an important element in providing future security of supply.
- Government targets for Spain indicate retirements of 7.5 GW of nuclear and coal capacity by 2030.
- At the same time, the government targets 11 GW of electrolyzers for green hydrogen production by 2030.

Benefits of introducing a capacity mechanism to the Spanish energy system

Security of supply

- Given a significant number of baseload capacity will retire and peak demand rises, additional flexible capacity can reduce supply disruption risks.
- Further, adding capacity to the system can decrease dependency on imported fuels such as gas or electricity.

Decarbonisation

- A capacity mechanism that encourages the buildout of low-emission technologies in Spain can support the decarbonization of the energy system.
- The buildout of flexible assets can enable further penetration of renewable assets.

Welfare

- If the capacity mechanism contracts flexible assets cost savings can arise from avoiding overbuilding capacity, unnecessary grid expansion, and curtailment losses.
- Cost savings in a more flexible system can also result from reducing electricity consumption when it is most expensive by shifting demand away from hours of peak residual demand.

1) Assumes no new build firm capacity (CCGT, coal and nuclear).

Sources: Aurora Energy Research, PNIEC 2023

After the publication of the draft capacity mechanism proposal in 2021, the government recently launched a public consultation

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Key milestones

1 Proposal on auction rules and operating procedures

- ✓ Spanish Ministry of Environment (MITECO) to request a study by REE[1] on national coverage.
- ✓ MITECO determined CoNE, VoLL, RS[2] parameters and launched and closed a public consultation.
- ▪ MITECO will define de-rating factors, designing the auctions and sending the proposal to the EC.

2 European Commission (EC) issues opinion on CM mechanism

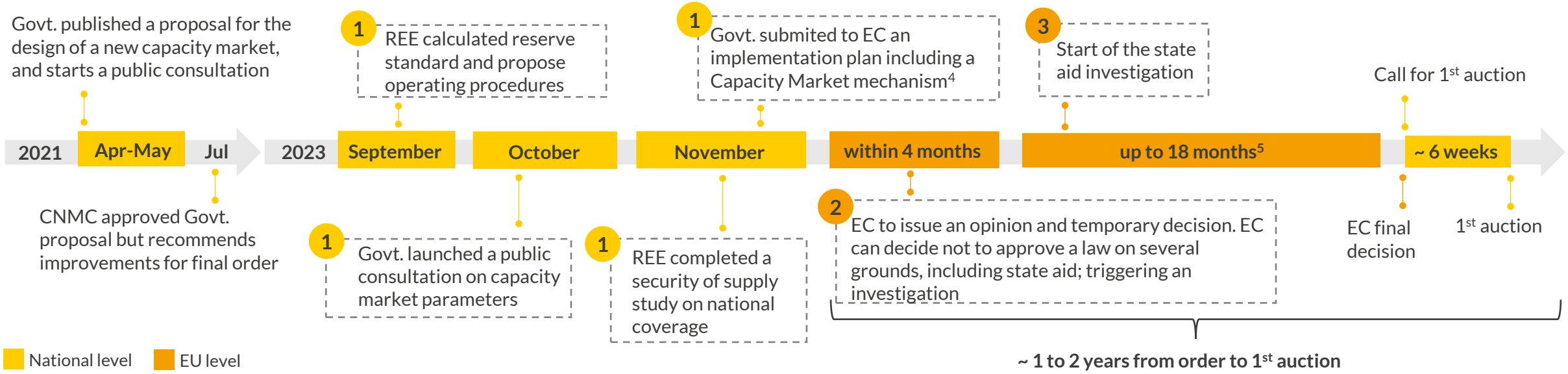
- ✓ EU Commission opened a consultation for one month; it assesses if mechanism is fit for purpose and can propose amendments.[4]
- ▪ Discussions (and additional consultations) might happen between TSO and regulator on modifications deemed necessary.

3 EC decides whether to start a state aid investigation

- ▪ Decision to initiate the procedure will be published in the *Official Journal of the EU*.
- ▪ Within two months, Govt. will need to comment on "*the Opening Decision*"; other interested parties might also defer observations which will be forwarded to the Govt. to react.

Implementation timeline for the proposed capacity mechanism[3]

✓ Milestone achieved ■ Pending



1) REE: System operator, set by the Government as capacity mechanism administrative entity. 2) Cost of New Entry (CONE), Reliability Standard (RS), Value of Lost Load (VoLL). 3) Based on Road Map elaborated by ENTRA (Entra Agregación y Flexibilidad). 4) This implies an assessment of the whole proposal including CoNE, VOLL and RS parameters. 5) European Commission in-depth investigation can take up to 18 months (e.g., process for Belgium took 1 year).

Sources: Aurora Energy Research, MITECO

The capacity mechanism is proposed to be pay-as-bid and to significantly limit the participation of CO_2-emitting capacity; final decision is pending

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Main features of the proposed capacity mechanism

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[1]	▪ Existing capacity: 12 months[1] ▪ New capacity: five years[1]
Eligible technologies	▪ Generation technologies, including renewables with special consideration to their availability ▪ Storage technologies ▪ Demand-side response
Participation constraints	▪ Maximum emission rate of 550g CO_2/kWh for existing or new-build assets[2] ▪ Participating demand (DSR) must not have associated generation under Specific Remuneration Regime

- If new capacity is needed, as the capacity mechanism 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.

Undefined parameters

- Definition of a "stress event" and its length[3]
- Methodology to define de-rating factors for eligible technologies, including renewables, storage and demand-side response
- Capacity requirements for the peninsula, accounting for uncertainty in:
  - Peak demand
  - Renewable generation contribution to security of supply
  - Availability of the thermal fleet
  - Interconnection participation and derating factors
- Contract obligations for capacity contract holders
- Penalties and testing regime
- Bid guarantees and development milestones

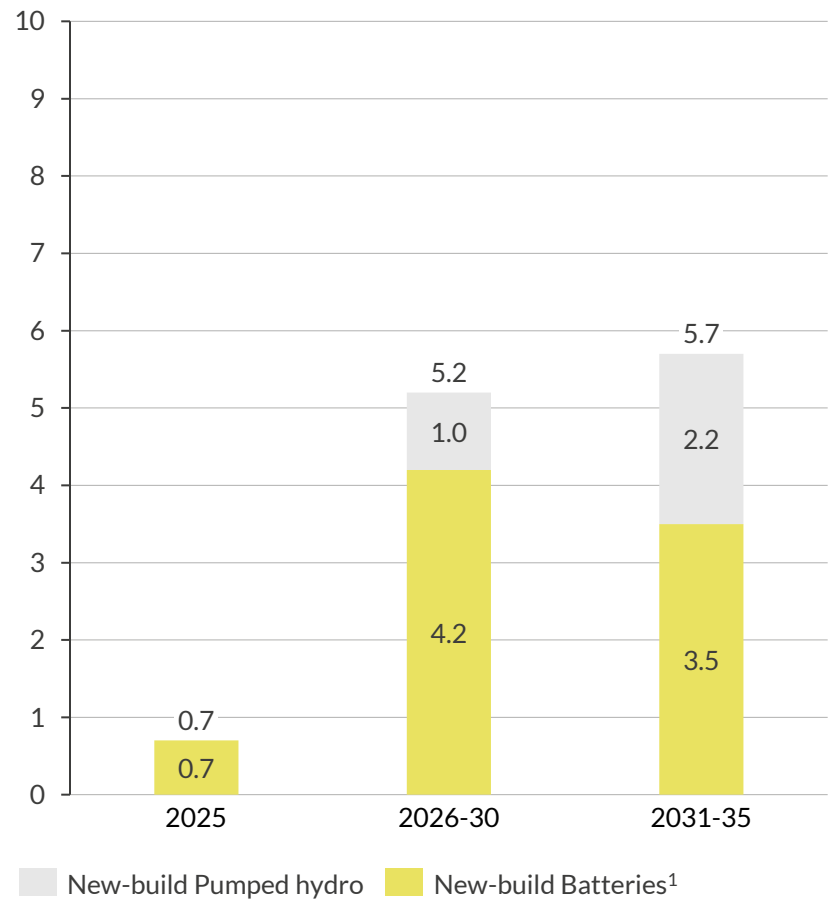
- REE will have a critical role establishing operating procedures and capacity requirements.
- Further clarity around key parameters like the **target capacity for the auction,** as well as the **de-rating factors** applicable to different technologies, will dictate how important this market is for new storage projects.

1) For the main auction; there will also be adjustment and extraordinary auctions both for 12 months contracts. Contract periods are still in discussion and not decided yet. 2) Emission limits depend on asset date of constitution (see slide 13). 3)This might affect batteries, since degradation has effects on the delivery of their full capacity over lifetime. Therefore, larger and prolonged stress events can pose a risk especially for battery storage.

Sources: Aurora Energy Research, MITECO.

According to Aurora's modelling, the currently proposed capacity mechanism fosters strong battery buildout

New builds as part of the proposed capacity mechanism
GW



Model assumptions

- Aurora's forecast is based on a "missing money" calculation assuming a 10% reserve margin, and shows the value of an expected capacity payment for a given entry year
- Based on the assumption that a capacity mechanism in Spain will be implemented at the earliest by beginning of 2025, for a first payment in 2026, we have included capacity mechanism revenues as a potential upside for our analysis of business cases[2]
- Given the uncertainty for the proposed capacity mechanism, we assume a 1-year rolling contract.
- De-rating factors are based on CNMC's assumptions and precedents in other countries in Europe with a capacity mechanism:

Scenario	De-rating factor
1h	20%
2h	40%
4h	60%

NECP storage target

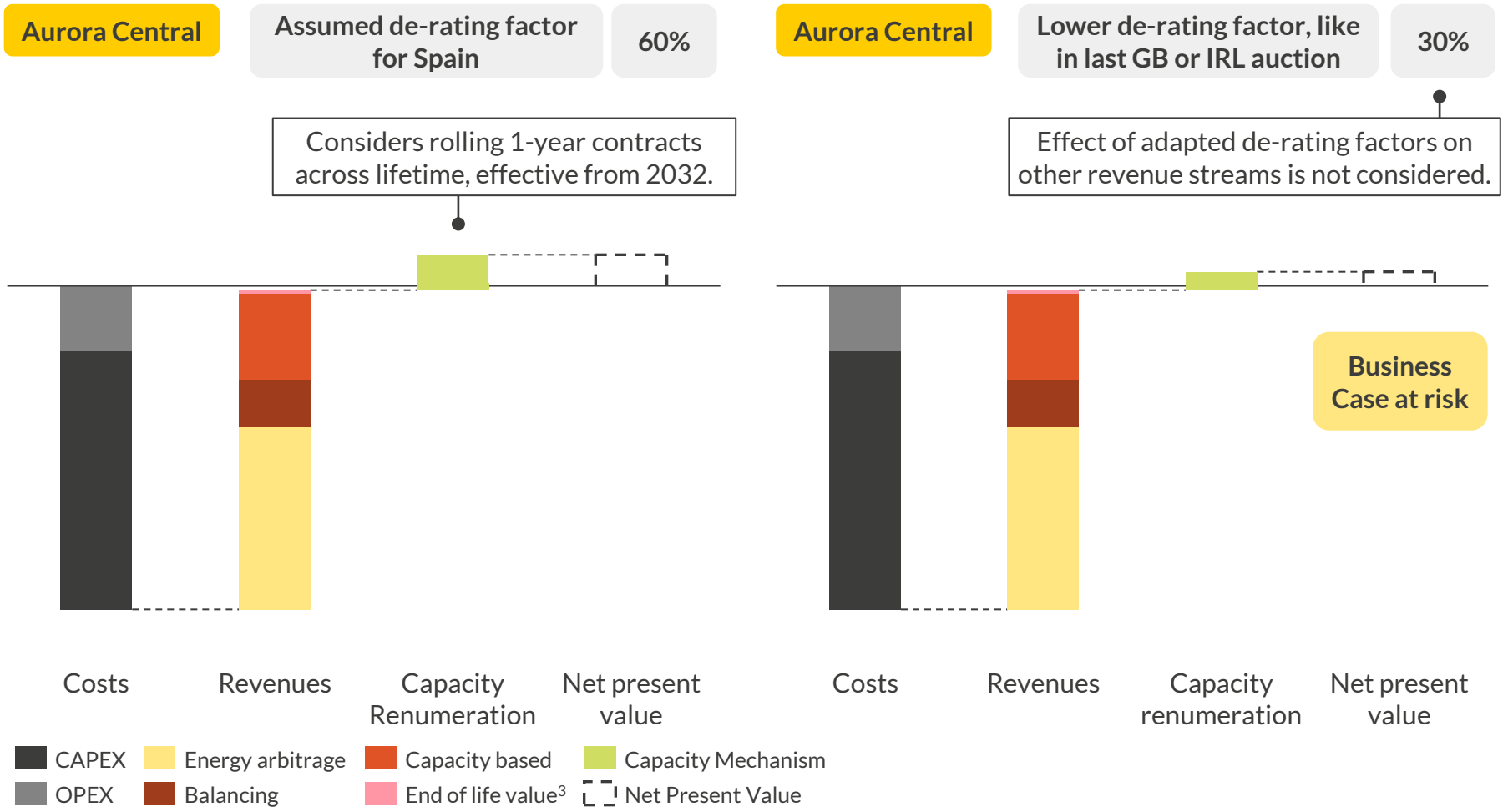
- The 2023 draft of Spain's National Energy Climate Plan (NECP) sets a storage target of 22 GW by 2030.
- This presents a steep increase compared to the 2020 NECP with a storage target of 17 GW in 2030.
- In these (draft) NECPs, capacities for batteries, pumped and thermal storage are aggregated.
- The final updated NECPs is yet to be presented to the EU.
- In Aurora's forecast, battery capacity reaches 5.5 GW, 4.2 GW of which are contracted in the capacity mechanism.

1) Includes batteries participating in the ancillary markets. 2) Our modelling implies the same assumptions for a capacity mechanism beginning in 2024 or 2025.

Sources: Aurora Energy Research, Draft PNIEC 2023

Capacity remuneration could be essential to turn the present value positive for new-build 4-hour batteries, that enter operation in 2032

Economics for an example new-build battery entering 2032 (4h duration, 1.2 cycles/day, 20 years lifetime)[1]
Net present value, €/kW (real 2023)



1) NPV discount rates of 11.5% and 6.5% (real, pre-tax) for merchant and CM revenues, respectively. 2) Depends on the year the battery is decommissioned, which depends on the total depth remaining.
Source: Aurora Energy Research

- Revenues from a Capacity Mechanism (CM) could be key for 4h duration batteries, that start operating in 2032.
- Given the expected saturation of the secondary reserve, arbitrage provides the main revenue source; yet, it is not sufficient for a positive NPV.
- We assumed a new-build 4-hour duration battery with a COD of 2032 to receive rolling 1-year contracts across lifetime.
  - Based on an assumed de-rating factor of 60%, CM payments are crucial to turn the present value positive.
  - Lower de-rating factors of 30%, such as in Ireland, would, however, barely turn the NPV positive.

By adjusting capacity market parameters that are either generic or specific to batteries, Spain can incentivize battery buildout

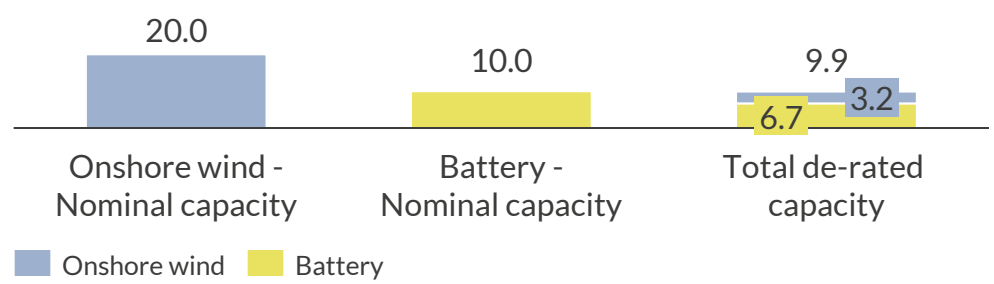
Several options exist to facilitate additional buildout of batteries via the capacity mechanism.

	Option to incentivize battery buildout via capacity mechanism:
General capacity mechanism considerations	▪ Add benefits for assets with low CO2 emissions, such as contract duration extensions like in Poland ▪ Implement T-3 auctions[1] that are tailored to the development time required for battery projects (as in Belgium)
Considerations specific to batteries	▪ Increase derating factors of batteries, whereby batteries will receive higher capacity renumeration ▪ Lengthen the duration of contracts for batteries to provide a more secure financing floor – Current proposal states 5 years for new assets whereas contracts in GB and Poland can last up to 15 years for new-build battery capacity ▪ Account for the degradation of batteries in testing regimes[2]: – Due to degradation batteries' available capacity decreases over their lifetime – Testing regimes should acknowledge this and test according to this degradation profile ▪ Consider including co-located assets in capacity mechanism (as is done in Italy)

Deep Dive: Co-located plants in the Italian Capacity Market

- Batteries that are co-located with another plant can participate in the Italian Capacity Market.
- De-rated capacity of a co-located system is calculated as the sum of the de-rated capacity of the battery and the de-rated capacity of the generating unit, each calculated according to the technology-specific de-rating factors.
- The battery does not alter the categorisation of the plant, which depends solely on the generating technology.

Illustrative de-rated capacity calculation for 4h battery co-located with an onshore wind plant



De-rating factors applied to nominal capacities are 16% for onshore wind and 67% for 4h battery.

1) In a T-3 auction, auctions take place three years before the delivery year. 2) Testing regimes test whether an asset is able to reach its maximum certified output level.

Agenda

AURORA

I. **Exploring Europe's capacity mechanisms**
   1. Flexibility in the future power system
   2. European regulatory overview

II. **Future trajectories for a German capacity mechanism**

III. **Introduction of a future capacity mechanism in Spain**

IV. **Appendix**
   1. Great Britain's mature capacity market
   2. The evolving capacity market in Poland
   3. List of Abbreviations

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Executive Summary

GB and Poland

Energy storage was awarded a major share of new build assets in CM auctions in Poland and GB.

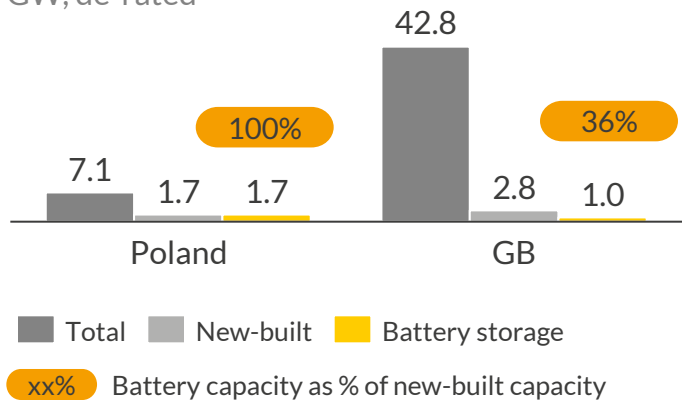
- GB procured 42.8 GW of de-rated capacity in the latest T-4 2027/2028[1] auction; clearing at £65.0/kW (74.7€/kW). New-build battery capacity continued to grow and was awarded 1 GW of de-rated capacity (5.6 GW nameplate capacity).
- Poland procured 20.9 GW of de-rated capacity in the latest T-5 2028 auction clearing at 244.90zł/kW (53.9€/kW). Batteries were awarded almost all of the new-build 1.7 GW de-rated capacity[2], growing tenfold compared to previous year's auction.

De-rating factors for batteries applied in European capacity markets vary across countries and time.

- In GB, de-rating factors for batteries have decreased significantly in the past. While long duration batteries (9h+) still had high de-rating factors of 95%, 4h duration batteries had a de-rating factor of 31% in the last T-4 auction.[3]
- In contrast, Poland had one of the highest de-rating factors in Europe with a factor of 95% for 4h duration batteries.[4]
- However, this difference may decrease in the future: Poland has proposed to decrease its de-rating factor for batteries for the next auctions and the UK has already updated de-rating factors to higher values for the next auctions.

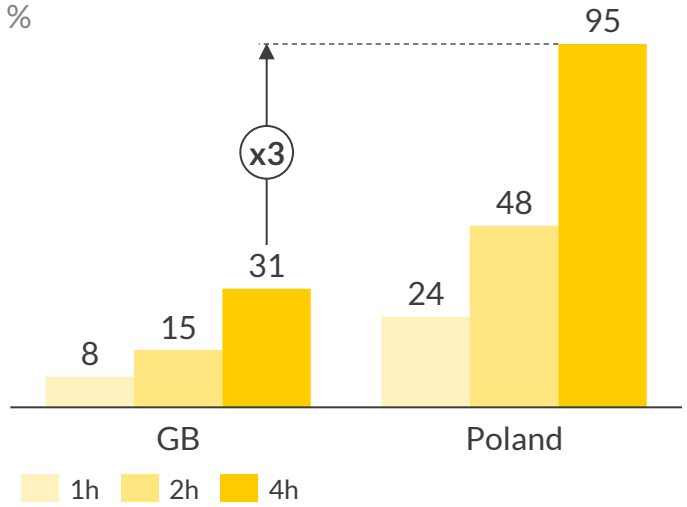
Procured capacity (last T-4/T-5 auctions)[3,4]

GW, de-rated



Battery de-rating factors (last T-4/T-5 auctions)[3,4]

%



1) T-4 auctions take place four years ahead of the delivery date. 2) Despite ongoing projects, next to no new gas units participated for new-build capacity, allowing batteries to claim most of awarded capacity. Several new gas projects were delayed due to increased cost estimates. 3) Based on latest T4 2028/2029 auction. 4) Based on latest T.4/T-5 2028 auctions.

Sources: Aurora Energy Research, National Grid ESO

GB's capacity market is the most mature in Europe and has played an important role in battery buildout so far

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Battery storage in the GB capacity market and future trends

- GB has the most mature capacity market in Europe and plays a significant role for battery buildout. A record of 5.6 GW of new-build battery nameplate capacity (1 GW de-rated) was procured in latest 2026/27 T-4 CM auction and over 10 GW of total capacity are prequalifying[1] for 2027/28 T-4 CM auction.
- Several developments affect the potential of batteries in future auctions:
  - In the past, significantly decreasing de-rating factors for batteries and increasing buildout made CM contracts less lucrative for battery storage.
  - However, retirements of ageing CCGTs and nuclear capacities, which necessitate the entry of new-build firm capacities, might lead to an increase in CM prices in the 2030s, being beneficial for battery storage.
  - Also, an increase of de-rating factors for batteries for next auctions was suggested in August 2024 and could boost future battery participation.

Fact	Description
Introduction date	2013
Auction mechanism	Descending clock 'pay as clear' auction
Auction frequency	2 auctions annually (T-1, T-4)
Contract length	Contracts are awarded in durations between 1-15 years with a tenor of 15 years for new-build capacity[2]

Main criteria for storage to participate in the capacity market

Emission criteria

- Two carbon emission limits are applied: 550 gCO2/kWh and a yearly average of 350 kgCO2/kW_{el} of installed capacity.
  - Batteries' emissions are below both of them.

Participation criteria

- **SPD[3] testing:** Battery storage units must demonstrate that they meet their de-rated capacity obligation three times in winter of each delivery year.
  - This should be feasible for most batteries.
- **EPD[4] testing**: Unlike other capacity market units, batteries must proof extended performance capability. In the first delivery year and every three years thereafter, they must show that they can continuously deliver at least 95% of their connection capacity for their full duration.[5]
  - Battery degradation over time is a key issue in this test, particularly in relation to 15-year contracts.
  - To avoid charges, batteries may be 'overbuilt' (i.e. have a higher capacity than what is procured) or be on rolling 1-year contracts.

1) Includes conditionally prequalified capacity. 2) Mostly batteries, interconnectors, and gas recips. 3) Satisfactory Performance Day 4) Extended Performance Day 5) For instance, 2 MW battery with 2hr duration would need to discharge for 2 MW*95% = 1.9MW for two consecutive hours.
Sources: National Grid, Cornwall Insight, Aurora Energy Research

Strong previous battery buildout reduced their de-rating factors, but these are going to be increased in the next auctions

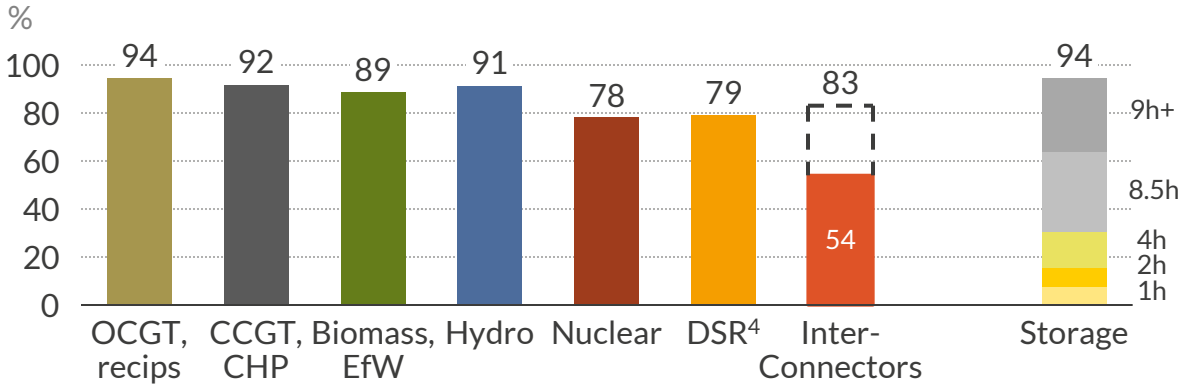
Structure of calculation of de-rating factors for storage

- The methodology to determine battery de-rating factors considers simulated stress event distributions and the likelihood that storage assets will cover them. Strong buildout of shorter-duration batteries has therefore reduced their marginal benefit to security of supply, decreasing their de-rating factors.[1]
- Storage de-rating factors increase linearly for batteries from 0.5h duration until 8.5h duration, ranging from 3.87% to 63.86%, while batteries of duration 9h and above have a de-rating factor of 94.37%.
- Longer duration batteries, currently with at least 9h duration, are classified as non-duration limited, meaning their storage is treated as firm capacity. The threshold duration for these assets has increased over the years.[2]

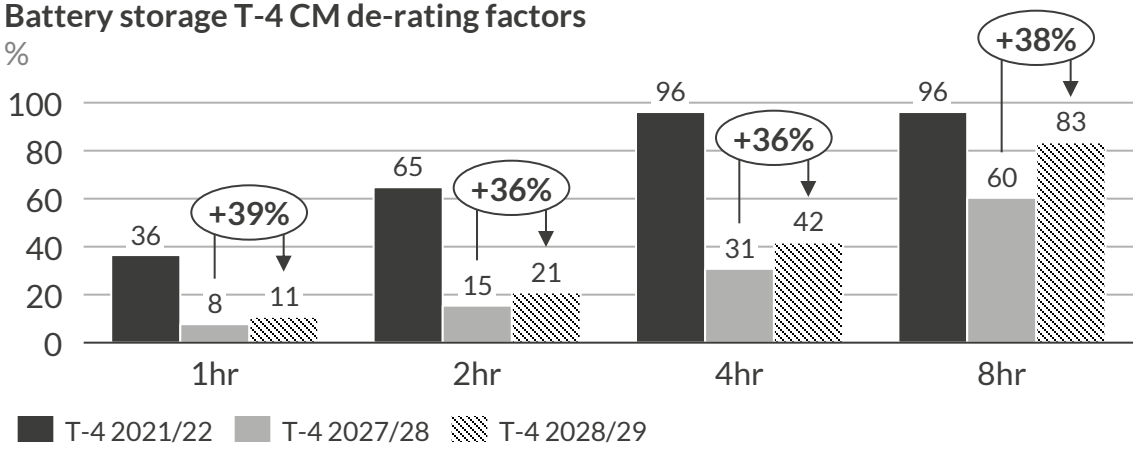
Reform on de-rating factors for storage

- In April, ESO opened a consultation on reforms to the storage de-rating factor methodology.
  - Back then, the incremental last-in equivalent firm capacity (EFC) calculation yielded storage fleet de-rated capacities that did not align with the total storage fleet EFC contribution
- In July, a reform was implemented and will apply for the next auctions, namely 2025/26 T-1 and 2028/29 T-4.
  - The scaled EFC method, which replaces the previous EFC method, adjusts EFCs to align with the fleet's total capacity.
  - This adjustment results in higher EFCs across most durations.

CM de-rating factors for 2027/28 T-4 auction[3]



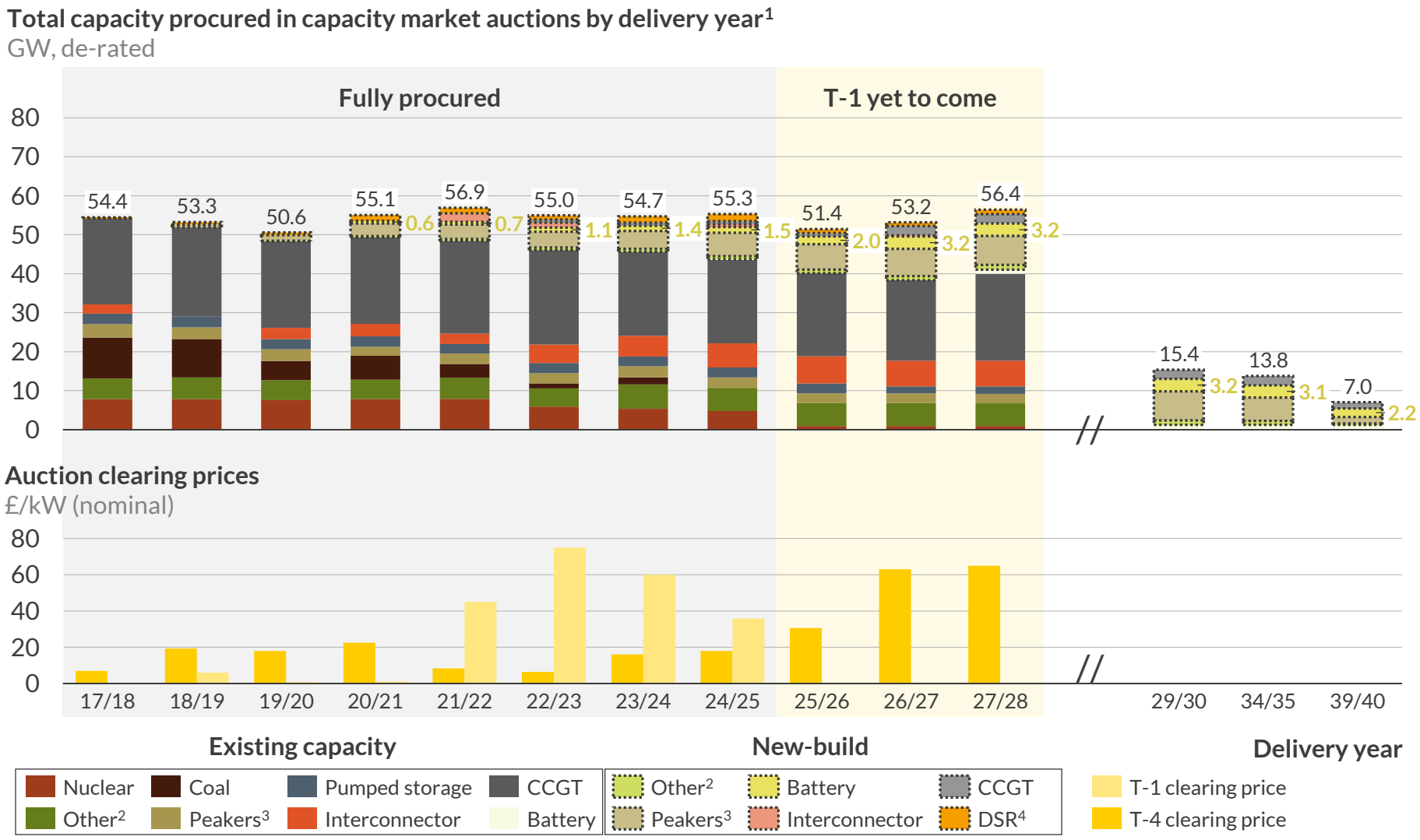
Battery storage T-4 CM de-rating factors



1) Between 2021 & 2024 T-4 CM auctions, de-rating factors for battery storage have decreased strongly durations shorter than 6.5hrs 2) The T-4 2021/22 auction considered assets of 5.5h duration & above to be non-Duration Limited, while the T-4 2027/28 considered only assets of 9h+ duration 3) De-rating factors vary with each auction. 4) DSR refers to commercial or industrial business that can reduce non-essential energy use.

Sources: Aurora Energy Research, EMR delivery body, ESO National Grid

The capacity market fully procured both new-build and existing battery capacity



1) Early documentation of the CM auctions is limited so we have opted to display the results of T-1 and T-4 auctions together. 2) EfW, onshore wind, solar PV, hydro, and CHP. 3) OCGTs, gas and diesel recips. 4) Proven + unproven DSR. 5) Based on the EMR Delivery Body Final results published on 8th March 2024. 6) Based on the EMR Delivery Body Preliminary results published on 20 February 2024

Sources: Aurora Energy Research, National Grid, DESNZ

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Latest auction outcomes

Latest T-4 auction (2027/28)[5]

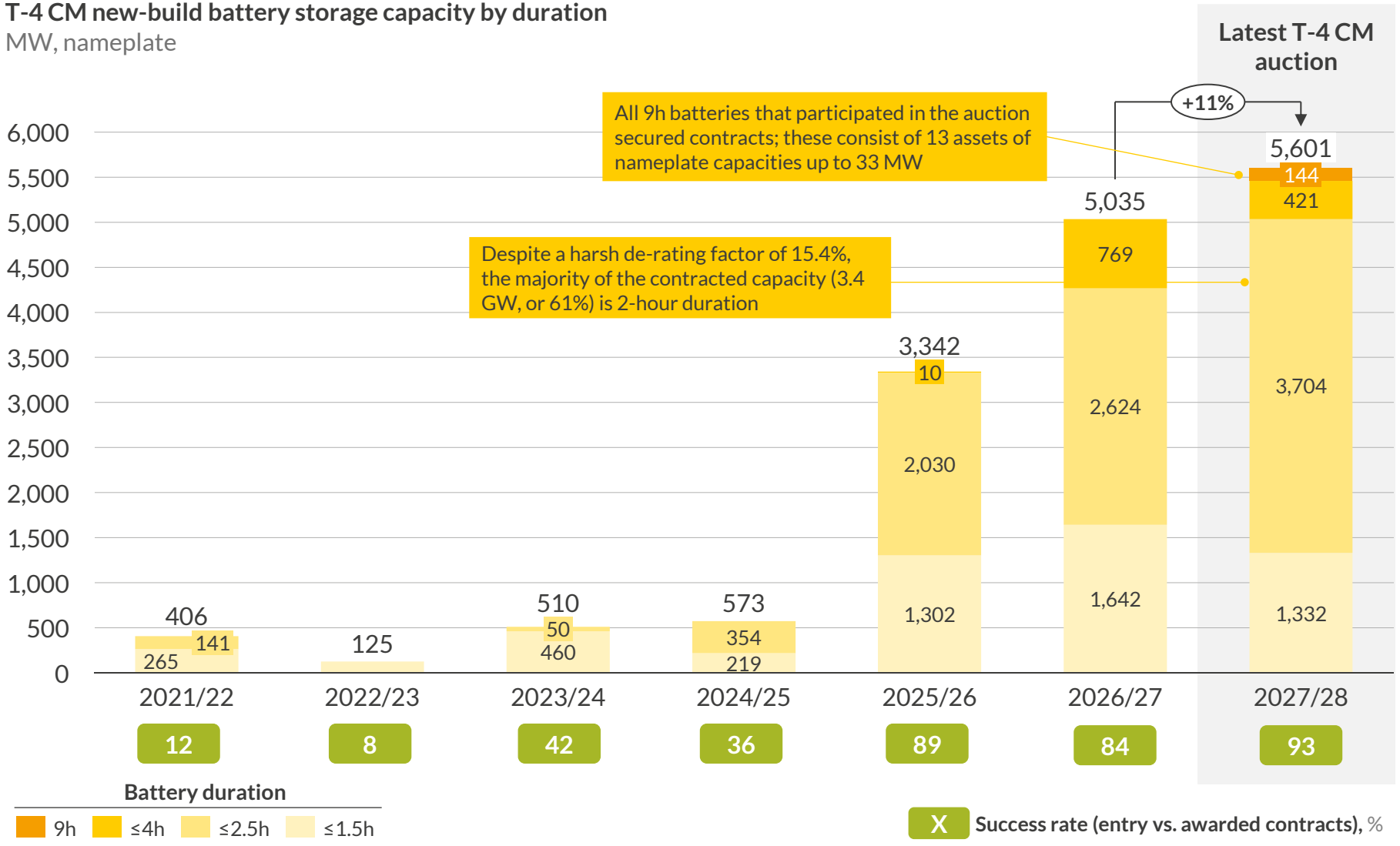
- Procured 42.8 GW of de-rated capacity clearing at £65.0/kW (74.7€/kW); thereby continuing high price trend observed in past auctions.
- Battery participation has continued to increase despite decreasing de-rating factors since clearing prices have increased making contract more lucrative. This auction procured a total of 995 MW de-rated new-build batteries with 15-year contracts (5.6 GW nameplate).

Latest T-1 auction (2024/25)[6]

- Procured 7.6 GW of de-rated capacity clearing at £35.79/kW.
- 488 MW of 1.2 GW new-build de-rated capacity was awarded to battery capacity.

Despite decreasing de-rating factors, a record 5.6 GW nameplate of new-build battery storage capacity secured contracts

T-4 CM new-build battery storage capacity by duration
MW, nameplate



1) GBP indexed to the average CPI from Oct 2022 to Apr 2023

Sources: Aurora Energy Research, EMR Delivery Body

- New-build battery capacity continues to grow, with 5.6 GW of nameplate capacity (998 MW de-rated) successfully securing a contract in the 2027/28 T-4 auction
- The auction witnessed a record-high success rate, with 93% of new-build projects securing contracts, continuing the trend of the past three years' high success rates
- Battery de-rating factors have notably decreased, impacting the payments these assets can receive from contracts. This year, the clearing price of £65/kW translates into a contract value of £10/kW-nameplate[1] for a 2h battery
- For the first time, 9-hour duration batteries participated in the auction as assets seek to attain non "duration-limited" de-rating factors of 94.4%

High confidence mature markets and subsequent revenues for battery storage in GB may reduce their bids in the capacity market

Response time

Years → Hours → Minutes → Seconds

CM Capacity Market

- Ensures national security of supply by procuring a sufficient level of firm capacity to meet peak electricity demand
- Contracts are awarded either one or four years in advance for lengths of 1-15 years
- Payments are made on a capacity basis in £/kW/year and de-rated based on contribution to security of supply

WM Wholesale Market

- Provides platform to buy and sell power to meet demand every half-hour
- Contracted from years ahead to T-1 hour trading

BM Balancing Mechanism

- Ensures balance is maintained in the power system in each daily half-hour trading period as well as other system operational needs e.g., thermal and voltage constraints
- Contracted over a variety of timescales, including within delivery periods

AS Ancillary services

- Maintains operational grid requirements and provides secondary balancing through sub-second to minutes long response
- Contracted in advance on monthly-yearly basis

LFM Local Flexibility Markets

- Flexibility services procured by DNOs[1] to manage constraints on distribution network. Contracted in advance on monthly-yearly basis

Revenue potential for batteries | Confidence in future revenues

Source: Aurora Energy Research

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Revenue streams for batteries

- Great Britain's robust installed battery capacity today and outlook make it the leading market by size, but with significant saturation risk for its revenue streams.
- Although saturation of markets decreases revenue potential, it indicates their maturity and subsequently underlines higher confidence in stable prices and future revenues

Effect on capacity market bids

- Batteries will likely bid with their marginal costs in pay as clear auctions as they can count on decreasing, but relatively stable future revenues from various markets.
- Given the relatively high confidence in revenues from other markets, financing batteries might decreasingly depend on capacity market renumeration in the future, putting downward pressure on their bids.

Agenda

AURORA

I. Exploring Europe's capacity mechanisms

1. Flexibility in the future power system
2. European regulatory overview

II. Future trajectories for a German capacity mechanism

III. Introduction of a future capacity mechanism in Spain

IV. Appendix

1. Great Britain's mature capacity market
2. The evolving capacity market in Poland
3. List of Abbreviations

Poland's evolving capacity market offers favorable conditions for battery storage with contracts of up to 17 years

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Battery storage in the Polish capacity market and future trends

- Poland has a technology-agnostic, evolving capacity market, where battery storage has just begun to kick-off in the last two main auctions. In the latest 2028 T5 CM auction, batteries were awarded almost all of the new-build capacity with 1.7 GW de-rated capacity (out of 7.1 GW total capacity).
- Reasons for the success of batteries and its potential in future auctions are:
  - High de-rating factors with 95% for 4h batteries
  - Current issues to stimulate investments in new-build gas projects, which compete with batteries
  - Coal exiting the capacity market, which causes further demand for other technologies like battery storage

Fact	Description
Introduction date	2018
Auction mechanism	Descending clock 'pay as clear' auction[1]
Auction frequency	2 auctions annually (supplementary: T-1, main: T-5)
Contract length	Contracts for the main auction are awarded between 1-17 years with 15-17 years for new-build capacity.[2]

Main criteria for storage to participate in the capacity market

Emission criteria

- Assets must have an emissivity below 550g CO2/kWh for main CM auctions (T-5). Plants with emissivity below 450g CO2/kWh can qualify for a 2-year extension on their Main CM Auction contract.
  - Most batteries' emissions are below both limits.[3]

Participation criteria

- Storage units need to be able to operate 4 consecutive hours throughout contract lifetime.
  - Awarded capacity can be reduced to allow batteries to operate 4 hours; degradation needs to be considered.
- Contract types depend on Capex intensity, plant type and emissions.
  - Most batteries are able to qualify for all contract types as they are new-build, highly efficient, and Capex intensive.
- General and auction-specific certification need to be completed.
- Fulfilling testing and stress event obligations pose a limited risk for batteries as these so far did not occur for longer consecutive periods.

1) New entries to market (price makers) can drop out at any price under the auction cap, while existing units (price takers) can only drop out of auction at a price below a specified threshold. 2) For the supplementary one, durations of 1-4 quarters for next year are awarded. 3) For standalone batteries, the CO2 emission factor is a function of the emission factor for electricity of final consumers and the battery's efficiency; for the 2027 auction batteries needed an efficiency of 60.8% to qualify plus a 2-year extension.

Sources: Aurora Energy Research, PSE

While Poland has one of the highest de-rating factors for batteries in Europe, they might be downgraded to 57.6% for the next T-5 auction

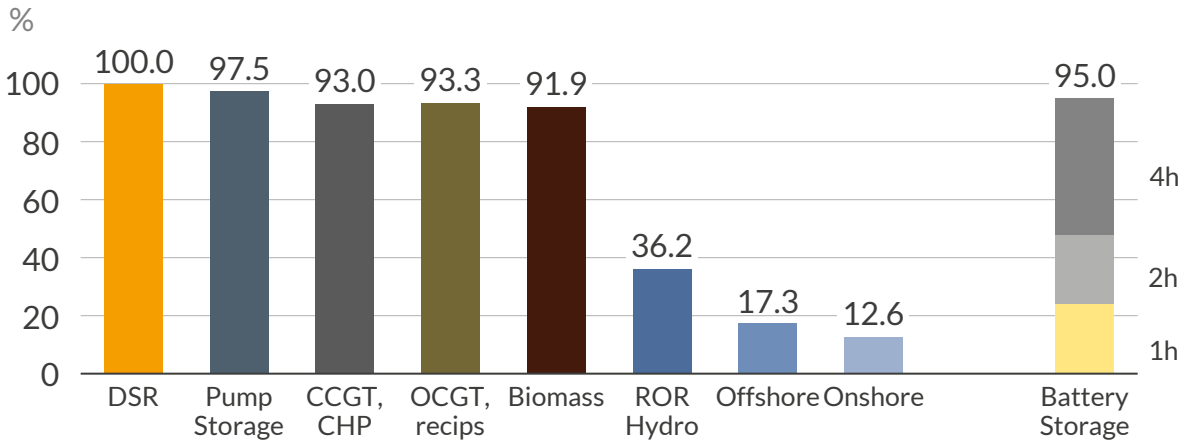
Structure of calculation of de-rating factors for storage

- Derating factors for batteries in Poland are determined based on historical data on power delivery as well as failure rate and loss of net achievable power.
- Currently, Poland exhibits one of the highest derating factors for 4h batteries in Europe with a factor of 95% for batteries.
- Batteries with a duration of less than 4h can compete in the Capacity Market if they have a reduced capacity. For instance, a 2h battery can enter the CM with only 50% of its maximum capacity, allowing it to operate for 4h hours.
- Degradation needs to be considered ensuring the awarded battery capacity can deliver for no less than 4 hours over contract lifetime.

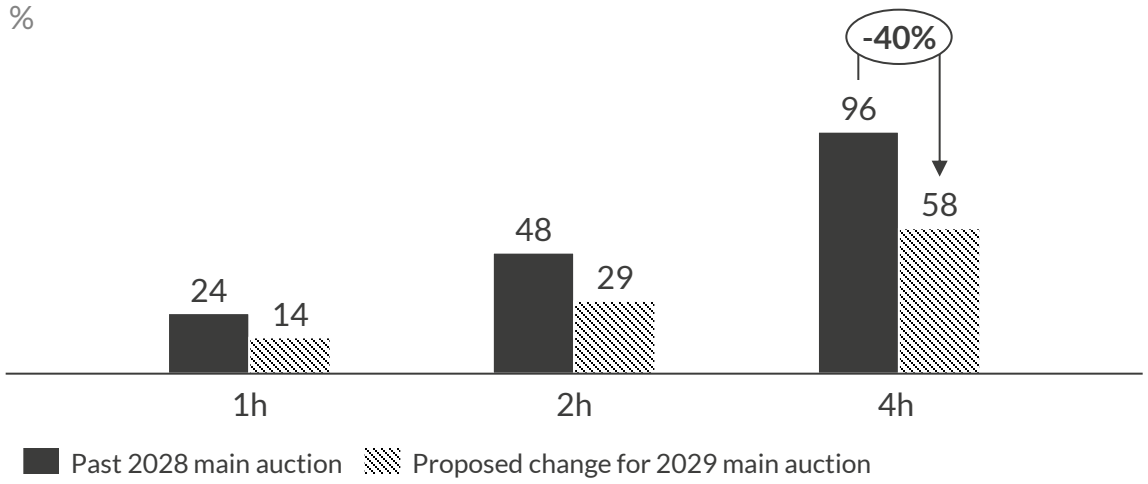
Future outlook on de-rating factors for storage

- An update of de-rating factors for battery storage have recently been proposed by the Ministry of Climate and Environment.
  - Accordingly, it was suggested to downgrade de-rating factors from 95% to 57.6 % for the upcoming main auction in 2029. The project is still subject to consultations and not decided yet.
  - The ministry's reasoning for the lower de-rating factors for batteries is that their availability during recurring demand periods is now taken into consideration.

De-rating factors for 2028 auction[1]



Proposed battery derating factors for last and upcoming main auction

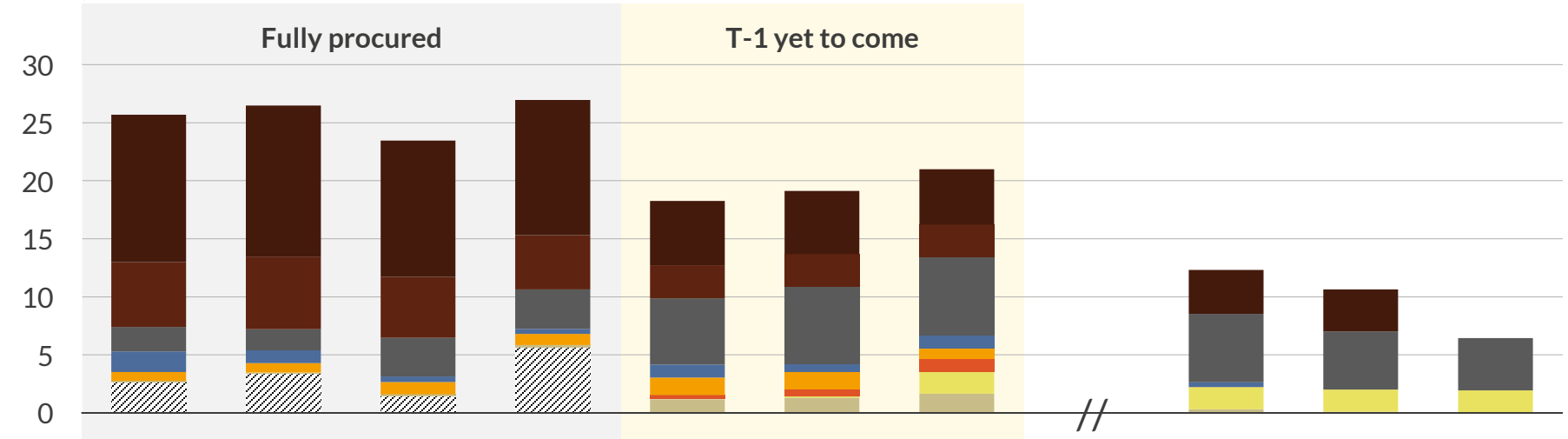


1) De-rating factors vary with each auction . 2) This is based on including 50% of a 2h battery's capacity under the Capacity Market at the 95% derating factor. 3) This factor is still subject to consultations.

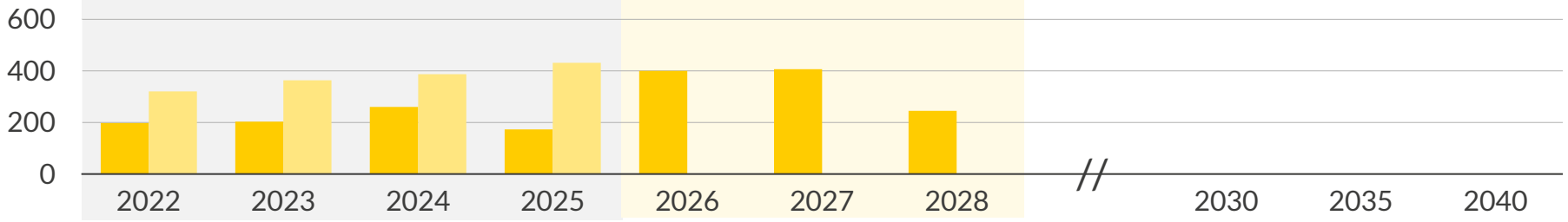
Source: Aurora Energy Research, PSE, Ministry of Climate and Environment

Contracted main T-5 auction capacities reached 20.9 GW for 2028, following two years of under-delivery as coal was excluded

Total capacity procured in capacity market by delivery year[1]
GW, de-rated[2]



Auction clearing prices by main auctions and supplementary auctions
zł/kW/year (nominal)



Hard coal · CCGT · DSR · Batteries · Supplementary auction (T-1) · T-5 clearing price
Lignite · Hydro · Interconnectors · Other · T-1 clearing price

1) Due to lack of transparency, for the main auction (T-5) fuel division has been based on internal units mapping and should be taken with caution. For the supplementary auction (T-1) no details are provided 2) Plant capacity given after taking into account derating factor and equal to final CM obligation.
Sources: Aurora Energy Research, PSE

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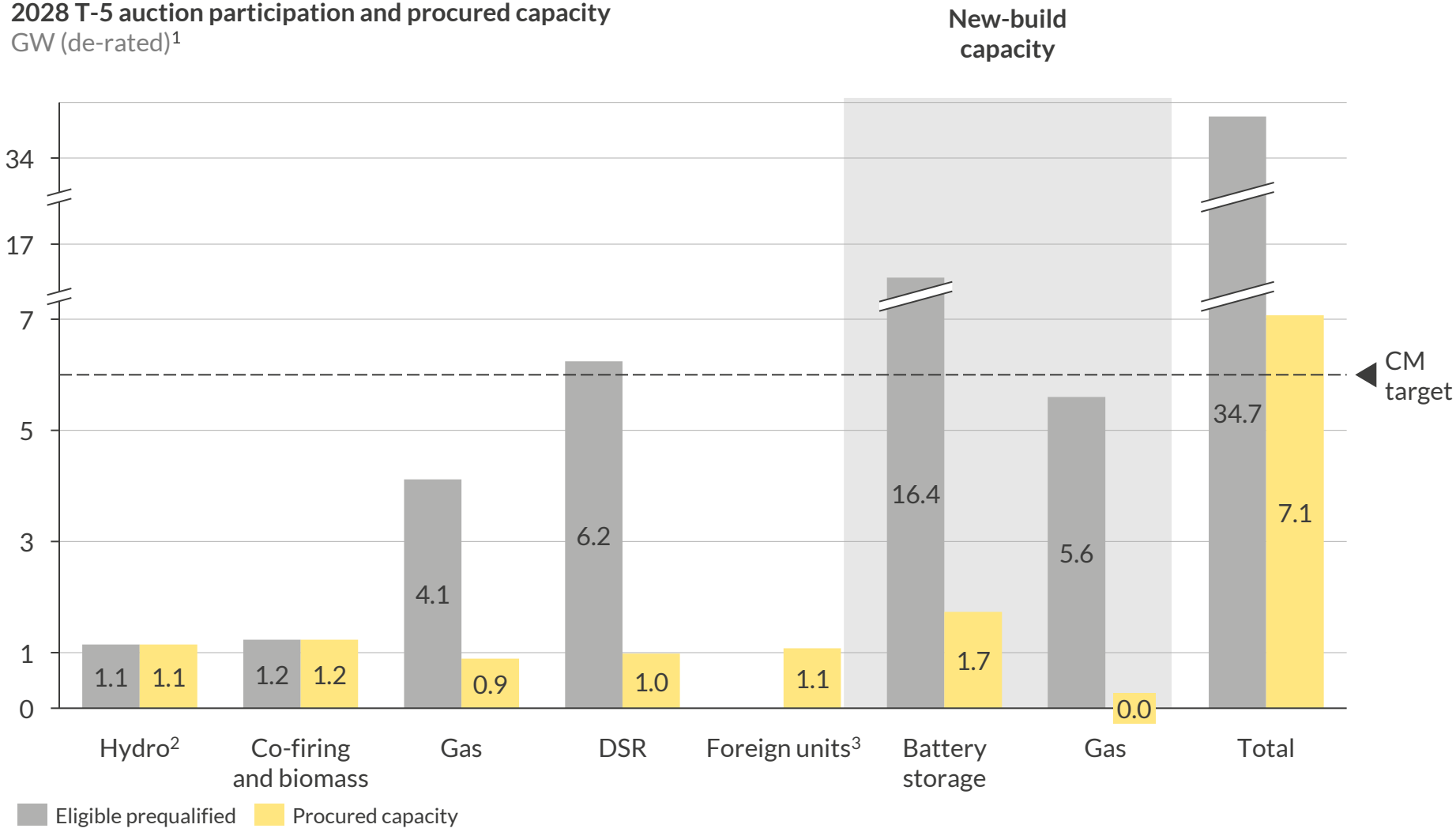
Latest auction outcomes

Latest T-5 auction (2028)

- The 2028 capacity market auction was oversubscribed with 7.1 GW of de-rated capacity procured.
- It cleared at a price of 244.90 zł/kW (53.9€/kw), significantly below that of previous years despite a higher auction price cap.
- Battery participation has strongly increased compared to the previous auction. This auction procured a total of 1.7 GW de-rated new-build battery capacity, which was almost all the new-build capacity awarded in this round.

Battery storage was awarded 1.7 GW de-rated new capacity in the last T-5 auction, a more than tenfold increase year on year

2028 T-5 auction participation and procured capacity
GW (de-rated)[1]



1) Due to lack of transparency fuel division has been based on internal units mapping. 2) Higher estimate used for prequalified, all capacity awarded had to be prequalified, URE states 1148 MW awarded, while PSE states only 608 MW of hydro prequalified. 3) Foreign units are not required to participate in prequalification.
Source: Aurora Energy Research, PSE

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- The 2028 T-5 Capacity Market auction was oversubscribed, with capacity mix significantly different compared to previous years.
- Battery storage constitutes almost all of the new-build capacity. It is the second time battery storage has taken part in the main auction and its share grew tenfold year on year, despite some projects withdrawing due to low prices.
- 1.2 GW of the new-build de-rated battery storage capacity was awarded to one developer for six projects ranging between 85 MW to the largest at 510 MW.
- Despite ongoing projects, next to no new gas units participated. Several new projects such as Gdansk and Kozienice were delayed due to increased cost estimates and failed tenders.

Upcoming markets for batteries in Poland offer great, but uncertain revenue potential, which may increase their capacity market bids

Response time

Years → Hours → Minutes → Seconds

CM Capacity Market

- Ensures national security of supply by procuring a sufficient level of firm capacity to meet peak electricity demand
- Payments are made on a capacity basis in zł/kW/year and de-rated based on contribution to security of supply

WM Wholesale Market

- The day-ahead market provides a platform to buy and sell power to meet demand every hour
- The intraday market procures continuous trading during the day
- Batteries can take advantage of arbitrage opportunities on both the day-ahead and the intraday markets

Ancillary and balancing mechanisms[1]

FCR Frequency Containment Reserve[2]

- Maintains operational grid requirements and provides primary balancing through sub-second to minutes-long response
- Contracted the day before the service can be procured

aFRR capacity Freq. Restoration Reserve capacity[3]

- Provides secondary balancing through minutes-long response
- Contracted the day before the service can be procured

aFRR energy Frequency Restoration Reserve energy ("Rynek Bilansujący")

- Ensures balance is maintained in the power system in each daily hour trading period as well as other system operational needs e.g., thermal and voltage constraints
- Contracted in real time between day ahead gate closure and 15 min prior to delivery window

Available to batteries | Not yet available | Revenue potential for batteries | Confidence in future revenues

1) While ancillary services already exist in Poland based on bi-lateral contracts, they are not yet market based. However, the Polish system is undergoing market reform, to establish market based procurement of ancillary services. This reform is planned to occur by the end of 2023 and are planned to be introduced in mid-June 2024. 2) "Regulacja pierwotna" 3) "Regulacja wtórna"

Source: Aurora Energy Research

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Revenue streams for batteries

- Aside from the capacity market, batteries generate revenues at the wholesale market, the frequency restoration reserve energy as well as the ancillary and balancing mechanisms, which are not yet market based.
- Ancillary services markets, such as FCR and aFRR will open as a part of ongoing balancing market reform in Poland and replace the current state-based mechanism.

Effect on capacity market bids

- Current and especially future revenue streams offer great potential for batteries, although confidence in proposed markets (FCR & aFRR) might be limited.
- In this context, capacity market renumeration plays an important role for providing a safe financing floor for battery storage, putting upward pressure on their bids.

Agenda

AURORA

I. **Exploring Europe's capacity mechanisms**
   1. Flexibility in the future power system
   2. European regulatory overview

II. **Future trajectories for a German capacity mechanism**

III. **Introduction of a future capacity mechanism in Spain**

IV. **Appendix**
   1. Great Britain's mature capacity market
   2. The evolving capacity market in Poland
   3. List of Abbreviations

List of abbreviations

Abbreviation	Full term
CAPEX	Capital expenditure
CCGT	Combined Cycle Gas Turbine
CHP	Combined Heat and Power
CM	Capacity Mechanism
COD	Commercial Operation Date
DSO	Distribution System Operator
DSR	Demand Side Response
EFC	Equivalent Firm Capacity
ETS	European Emission Trading Scheme
EU	European Union
EOM	Energy Only Market
EMD	Energy Market Directive
GoO	Guarantee of Origin
GW	Gigawatt

Abbreviation	Full term
GWh	Gigawatt-hour
H_2	Hydrogen
LNG	Liquefied natural gas
LDES	Long Duration Energy Storage
mn	Million
MW	Megawatt
MWh	Megawatt-hour
N/A	Not applicable
OCGT	Open Cycle Gas Turbine
OPEX	Operational expenditure
PV	Photovoltaic
RES	Renewable Energy Source
TSO	Transmission system operator
TWh	Terawatt-hour

Sources: Aurora Energy Research

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