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SPRING FORUM

LONDON 2025

Evangelos Gazis

Head of Southeastern Europe, Aurora

AURORA KEYNOTE

BATTERY STORAGE ON THE PATH TO MATURITY: OVERCOMING FINANCIAL AND MARKET UNCERTAINTY

Grid scale battery storage could grow to 126 GW by 2050; additions represent a cumulative investment opportunity of almost 100bn €

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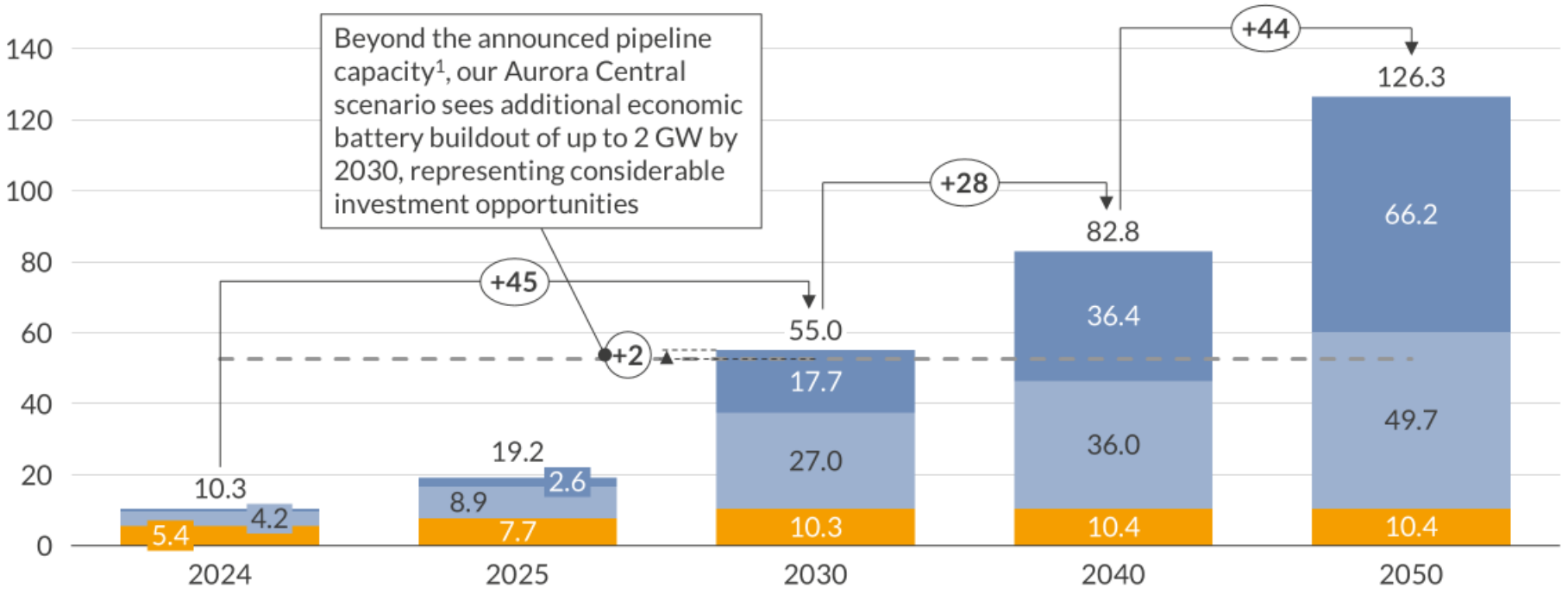
Installed grid-scale battery capacity in Europe (Aurora Central scenario)
GW

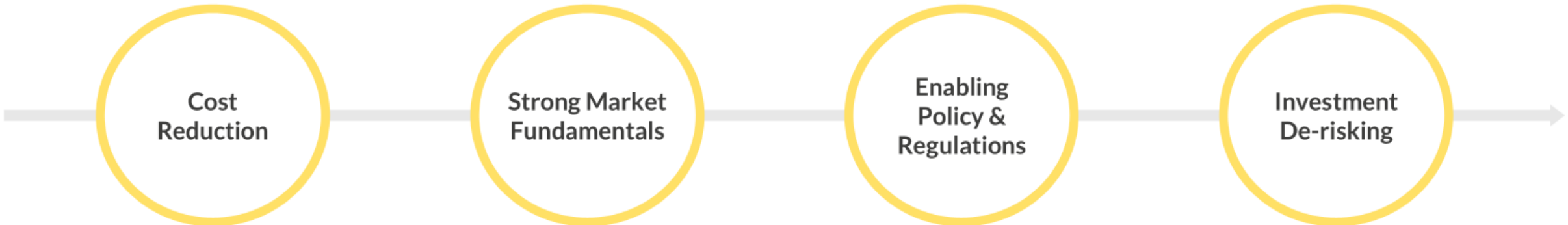


Total CAPEX spent on grid-scale batteries
bn € (real 2024)

- Total capacity is forecasted to grow 12x from 2024–2050 and is initially led by durations up to 2hr, making up 47% of total capacity in 2025.
- In the long term, 4hr+ batteries become more sizeable in share, making up 52% of total capacity in 2050.
- The shift to longer durations is driven by the capacity shift that requires longer durations of flexible capacity, as well as stronger CAPEX declines for longer durations due the greater relative impact of battery cell cost reductions.
- Italy, Spain, and Great Britain see the largest capacity additions in the short term while significant growth is also expected in Germany and Poland in the long term.
- Projected battery capacity additions represent a **cumulative investment opportunity of c. 100bn €** between 2025–2050.

1) Announced pipeline capacities are taken from confirmed capacities with capacity market contracts, confirmed pipeline capacities holding grid connection agreements from TSOs or DSOs, or auction procurement targets.
Sources: Aurora Energy Research, Eurostat

Advancing toward grid-scale BESS market maturity will require overcoming several key challenges



Focus points today:

- CAPEX and OPEX breakdown and evolution
- Long-term outlook of key cost drivers

- Current trends on market volatility
- Outlook for revenue stacking and the risk of market saturation

- European balancing markets integration
- Clean Industrial Deal to strengthen Europe's battery supply chain and flexibility

- Different routes to market and risk implications
- The value of revenue contracting

Source: Aurora Energy Research

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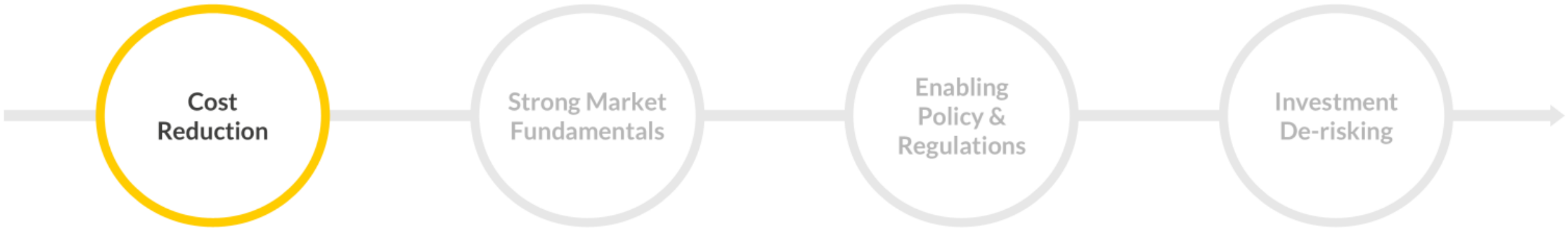

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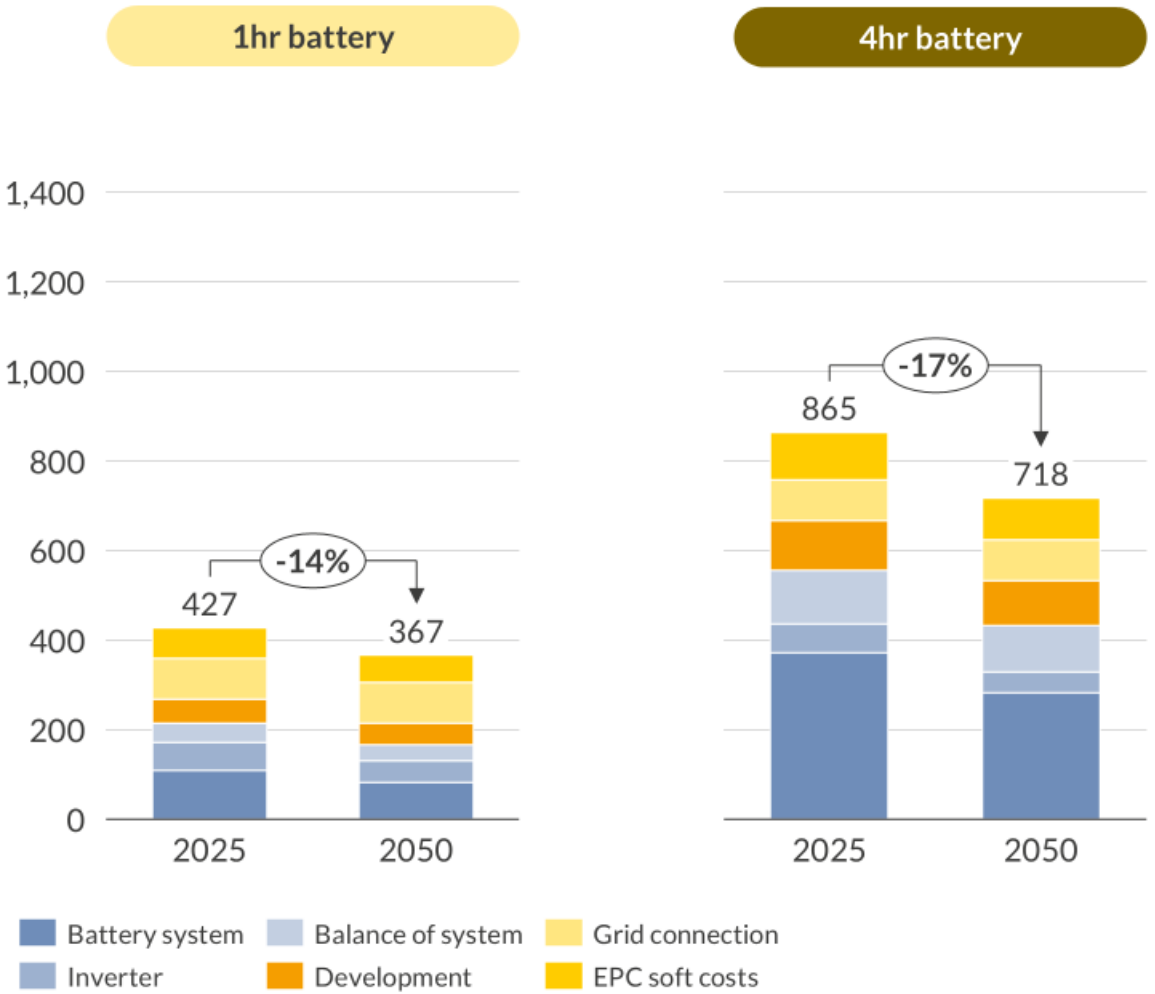
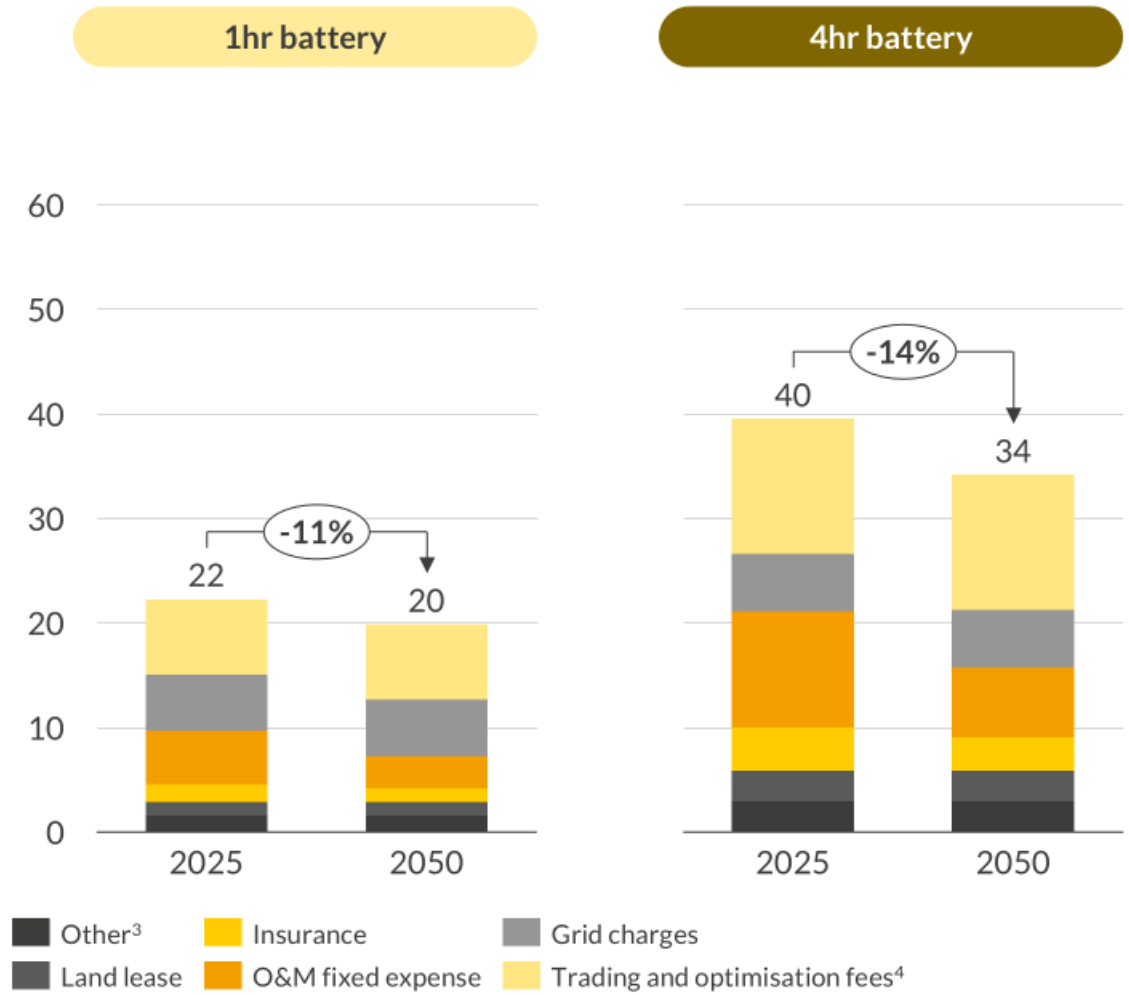
Source: Aurora Energy Research

CAPEX drops by 14–17% by 2050 due to technological progress and scale; efficiency gains and market competition drive OPEX declines of 11–14%

BESS CAPEX, by duration[1]
€/kW, real 2024



Fixed costs breakdown by duration[2]—Central assumption
€/kW/year, real 2024



1) Representative average grid-scale stationary battery cost for a 50MW size for Europe; 2) OPEX shown exclude property taxes. The reason is that we calculate pre-tax IRR for better comparability across markets; 3) Includes auxiliary loads, admin charges, communications and other small costs; 4) Trading and optimisation fees may have both fixed and variable elements but are represented here as a single fixed charge.

Source: Aurora Energy Research

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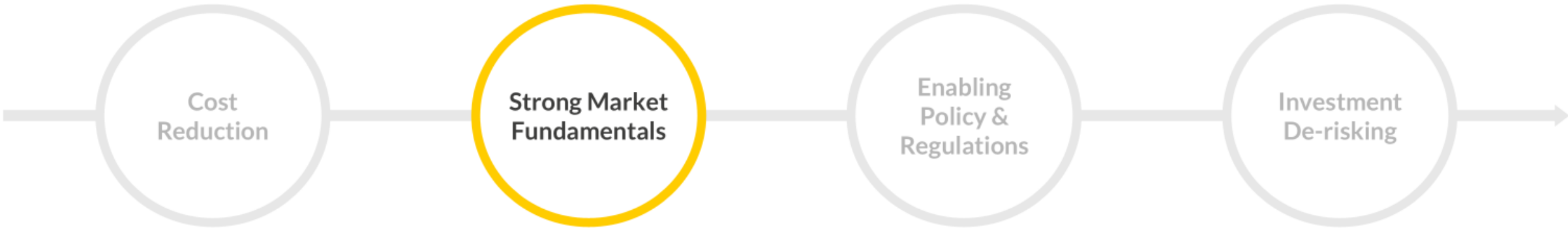

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Source: Aurora Energy Research

The shift in energy capacity mix and rising electricity demand drive the need for greater flexibility and battery storage across Europe

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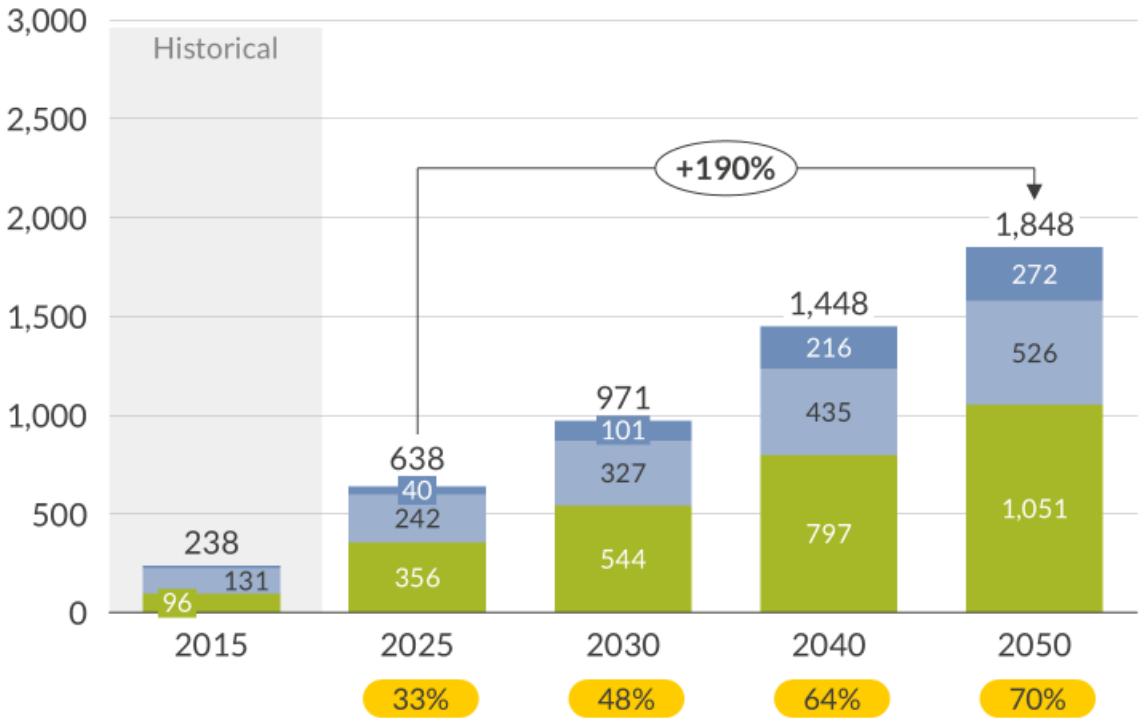
1 Installed variable renewable capacity in Europe[1] (Aurora Central)

GW

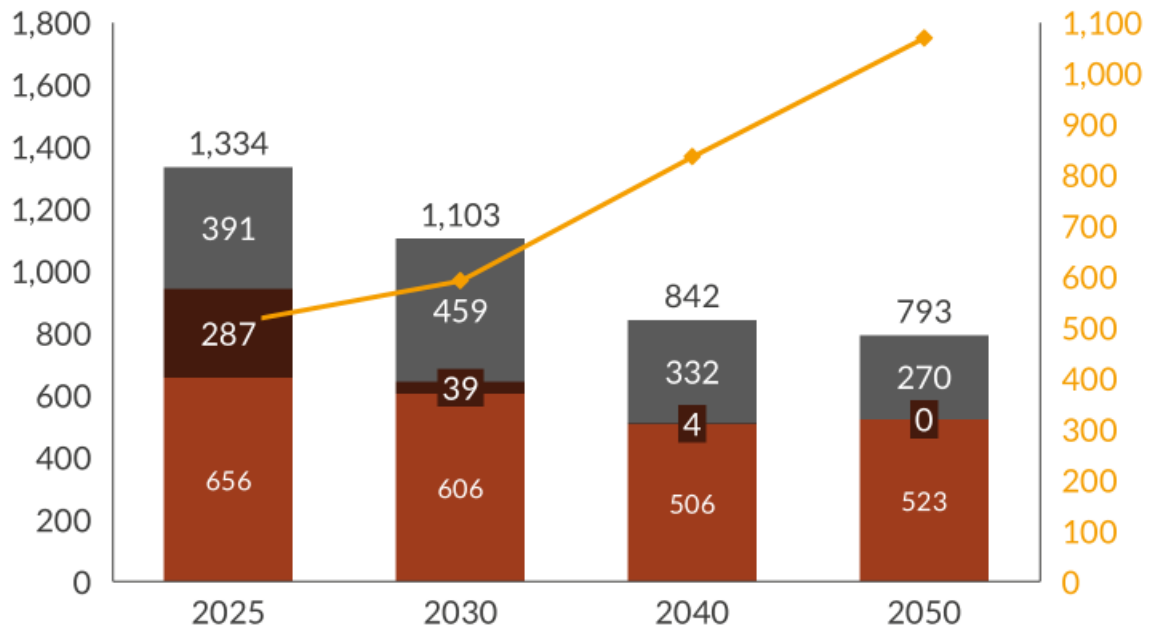


- Europe's installed capacity of solar, onshore, and offshore wind is forecast to almost triple by 2050, resulting in an increase in the share of generation from variable renewables to 70%.

2 Conventional generation in Europe[1] (Aurora Central)

TWh

Peak demand
GW



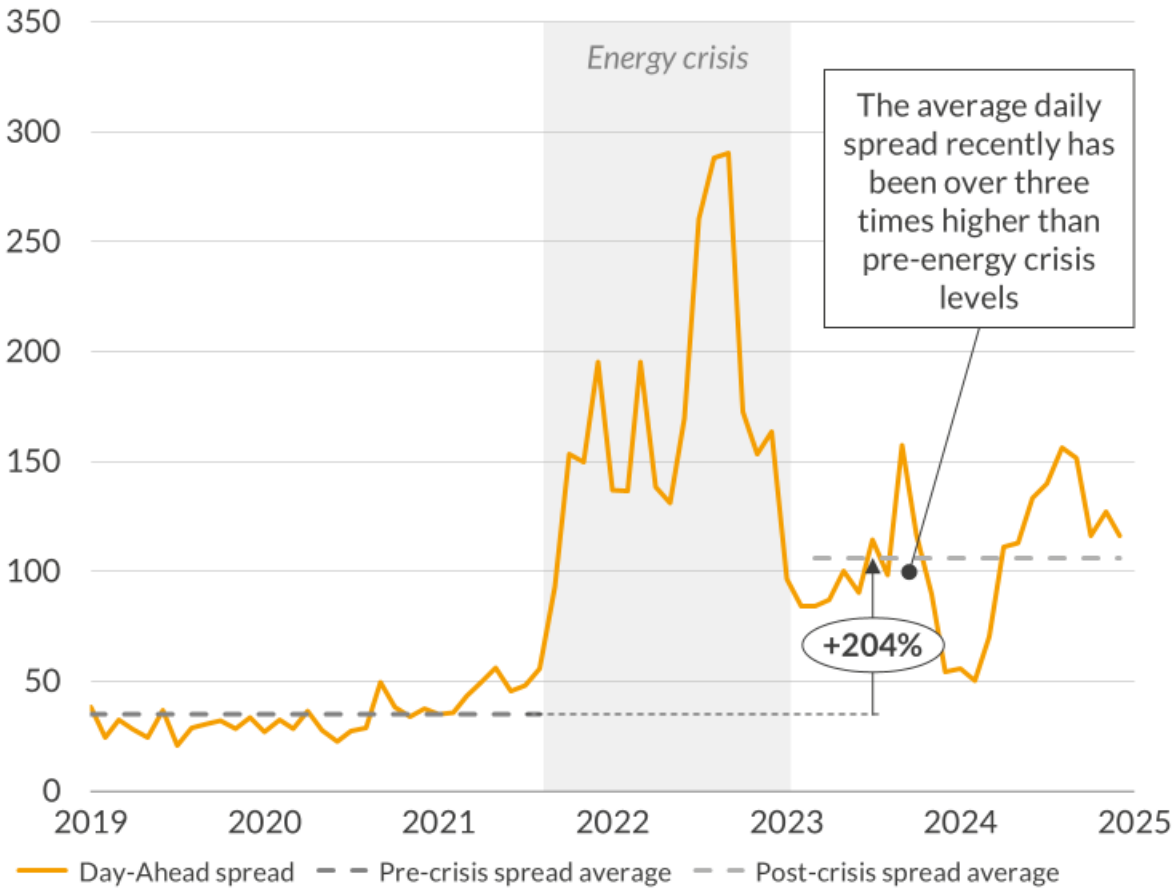
- The rising penetration of renewables contributes to the phase-out of conventional generation capacity and the loss of grid services (including inertia, frequency and voltage control, and black start), increasing the need for flexibility to maintain system security amid the rising peak demand from wider sector electrification.

Offshore Wind[2] | Onshore Wind | Solar PV | xx% Production share of variable renewables[3] | Nuclear[4] | Coal[5] | CCGT[6] | Peak demand

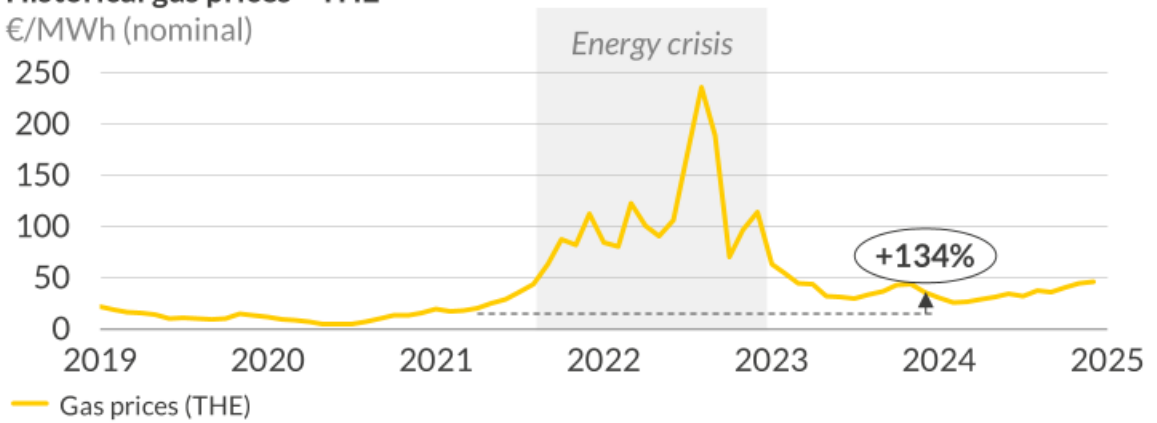
1) EU27 plus Great Britain and Norway, minus Malta and Cyprus; 2) Includes fixed bottom and floating offshore wind; 3) Considering all low carbon generation, we get to about 95% by 2050 (i.e. including hydro, nuclear, etc); 4) Generation from nuclear increases in the short-term from new capacity additions but decreases in the longer term as nuclear decommissions across Europe; 5) Includes Coal CHPs; 6) 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

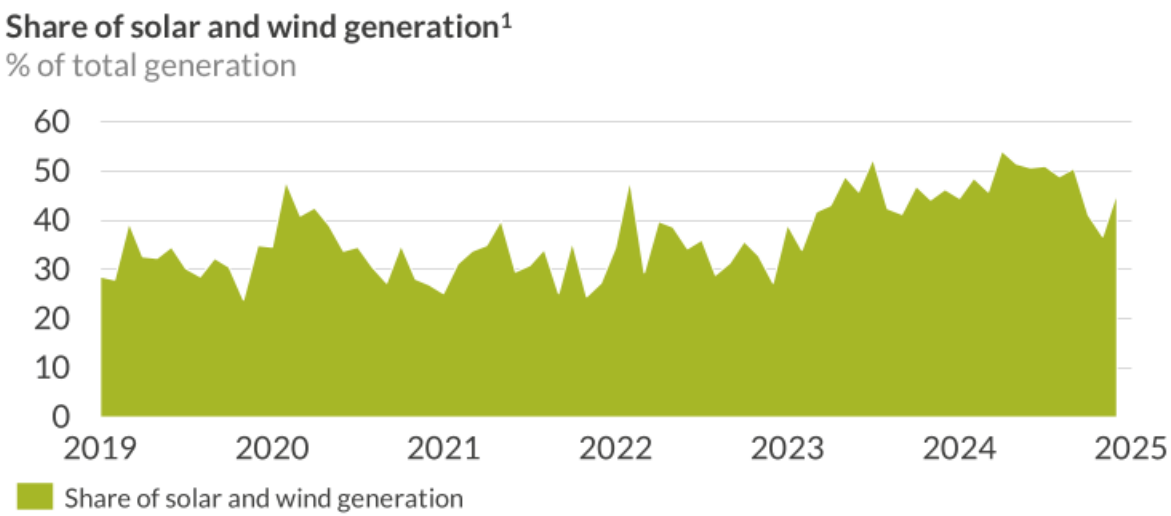
Early market growth is driven by high market volatility, which is now more than three times higher than before the energy crisis

Even after the energy crisis, the daily spread on the Day-Ahead market stayed on a level above 100 €/MWh



The higher volatility is mainly driven by increased gas prices and higher renewable generation





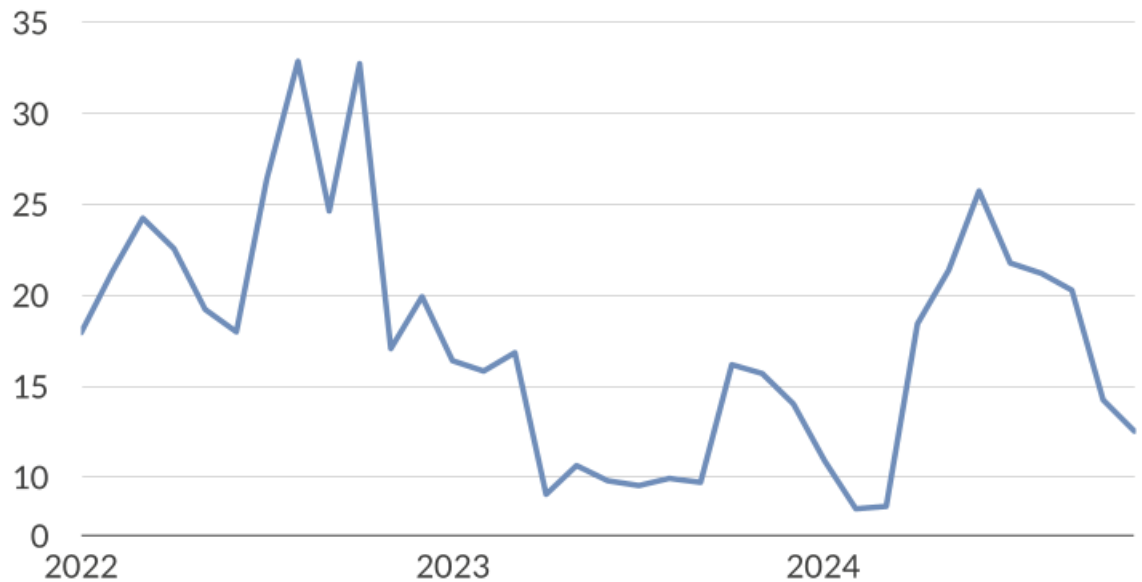
1) Share of renewable generation (including Solar PV, Onshore Wind, Offshore Wind) on total output.

Sources: Aurora Energy Research, EEX, EPEX Spot, ENTSO-E

After prices reduced following the energy crisis, a stronger seasonal pattern is visible with high prices and spreads in summer months

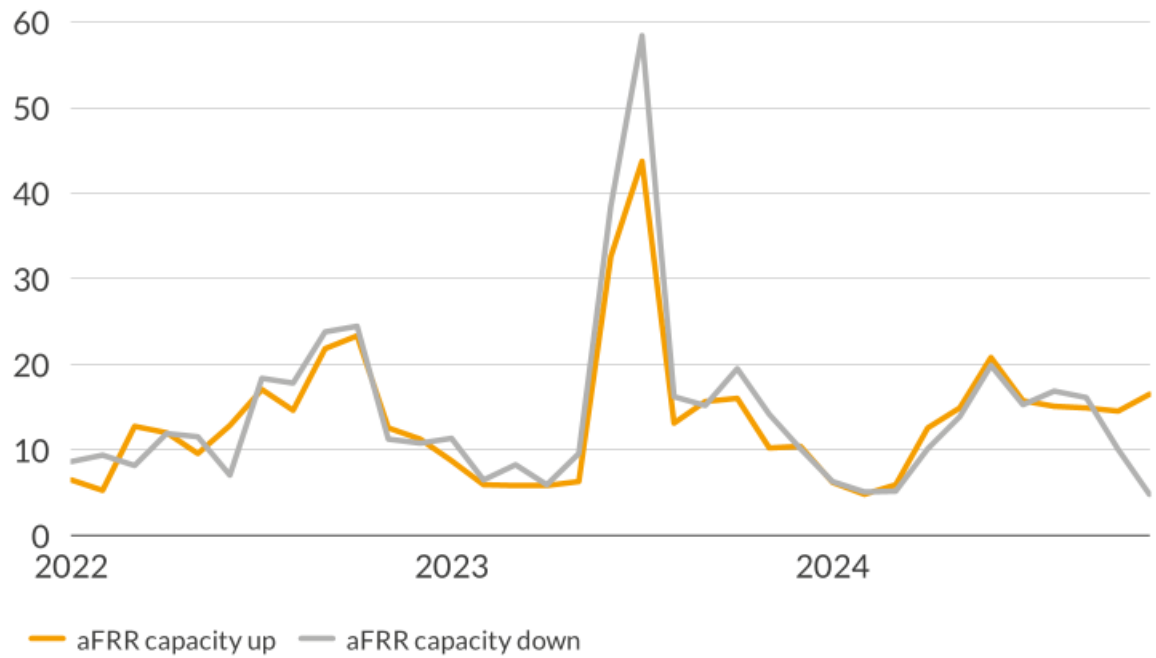
High solar generation in the summer months leads to higher daily spreads and higher FCR and aFRR prices than in the winter

Monthly average FCR prices[1]
€/MW/h, nominal



- In 2023, FCR prices were relatively low, staying under 17 €/MW/h. In 2024, prices increased strongly, peaking at a monthly average of 26 €/MW/h in June, before dropping back to 2023 levels in October and November.

Monthly average aFRR capacity prices[1]
€/MW/h, nominal



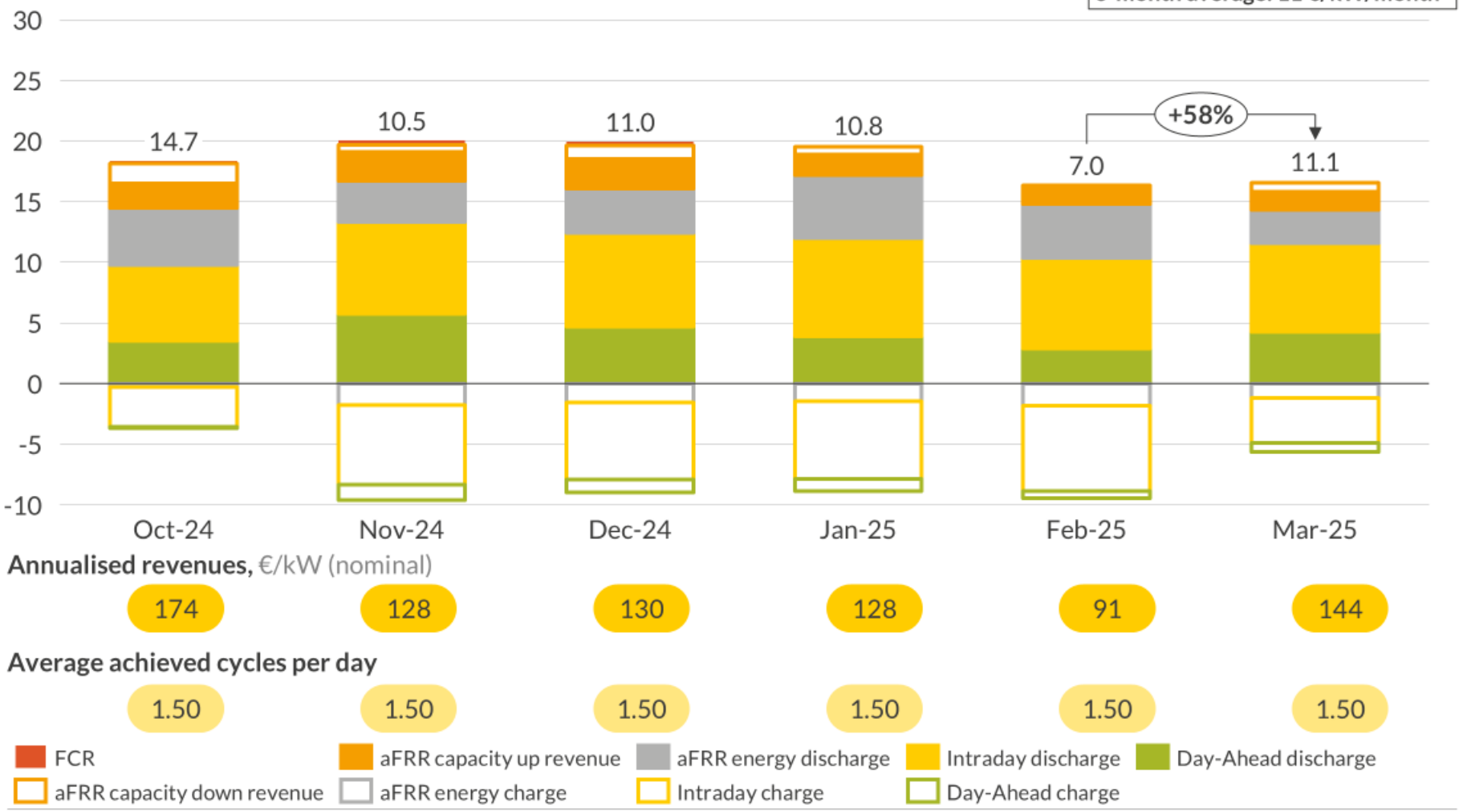
- Prices on the aFRR Capacity Market reached an unexpected high in the summer 2023 when strong renewable generation led to few thermal plants running. Prices peaked again this summer, albeit at lower levels of around 20 €/MW/h.

1) Data up to and including 30 November 2024.

Sources: Aurora Energy Research, Netztransparenz.de, ENTSO-E

A 2h battery trading on Day-Ahead, Intraday, aFRR energy, FCR, and aFRR Capacity Markets reached 11 €/kW margins in March

Revenues and costs—2h Battery Benchmark
€/kW per month (nominal)



Sources: Aurora Energy Research

Comments

- In March, a 2h battery would have achieved 11 €/kW margins, with 1% of the net earnings coming from the FCR market, 20% from the aFRR capacity market, and the remaining 79% from energy trading.
- Compared to February, margins increased by 58%, driven by higher ancillary prices and a strong rise in wholesale spreads, reaching the highest level since October 2024.
- This follows the typical seasonality, with the darkest month being over and solar generation leading to a better revenue potential again.

Statistical modelling can be suitable for short-term forecasts; however, long-term developments are captured better by fundamental models

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There are two approaches that are commonly used to forecast prices: fundamental and statistical modelling.

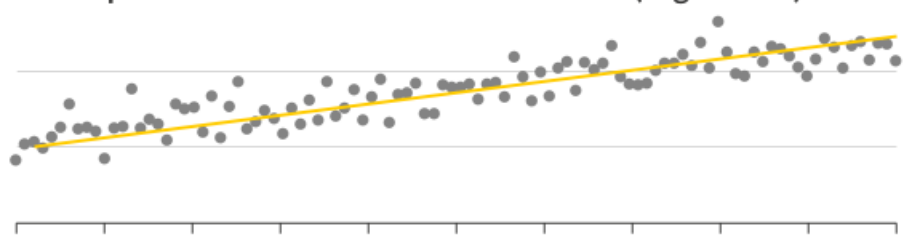
Statistical modelling

Statistical modelling aims to create mathematical representations of complex relationships and processes based on historical data, enabling estimation, inference, and prediction of outcomes.

Advantages: This approach is efficient and easy to scale and apply to large amounts of data which allows for fast decision making and makes it suitable for short term forecasts.

Disadvantages: As it heavily relies on the historical input data, it cannot capture fundamental market changes. Also, it depends on the quality of the historical data and is prone to overfitting.

Illustrative price formation in a statistical model (regression)



Source: Aurora Energy Research

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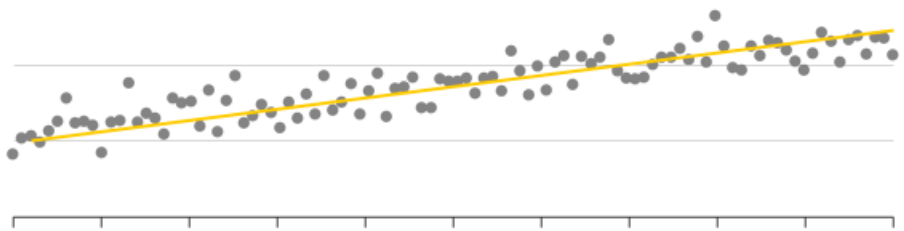


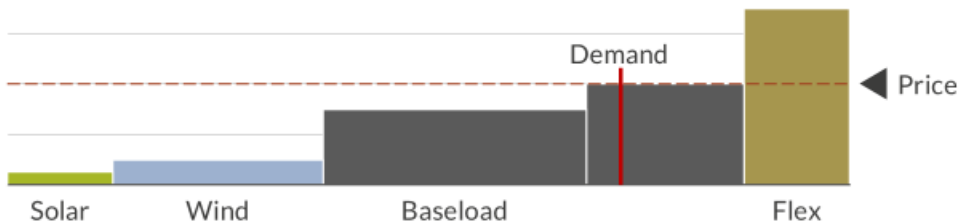
Fundamental modelling—Aurora's approach

Fundamental modelling aims to create simplified, abstract representations of real-world systems or processes to understand and predict their behaviour. Thus, it tries to capture fundamental relationships.

Advantages: As fundamental modelling is an abstract representation of reality, it can model system changes and provide insights about the underlying mechanisms that are driving system behaviour. Therefore, it is especially suitable for long-term projections.

Disadvantages: This approach is strongly driven by input assumptions and time-consuming to calibrate and maintain.

Illustrative price formation in a fundamental model (merit order)



While **statistical modelling** can be suitable for forecasting prices in the short-term or in systems with no major changes expected, **fundamental modelling** is the better option for modelling long-term developments in systems that change fundamentally, like the power markets. Therefore, Aurora has chosen the fundamental modelling approach for long-term price forecasts.

Source: Aurora Energy Research

Aurora's fundamental battery model anticipates market structural changes well; statistical forecasts less so

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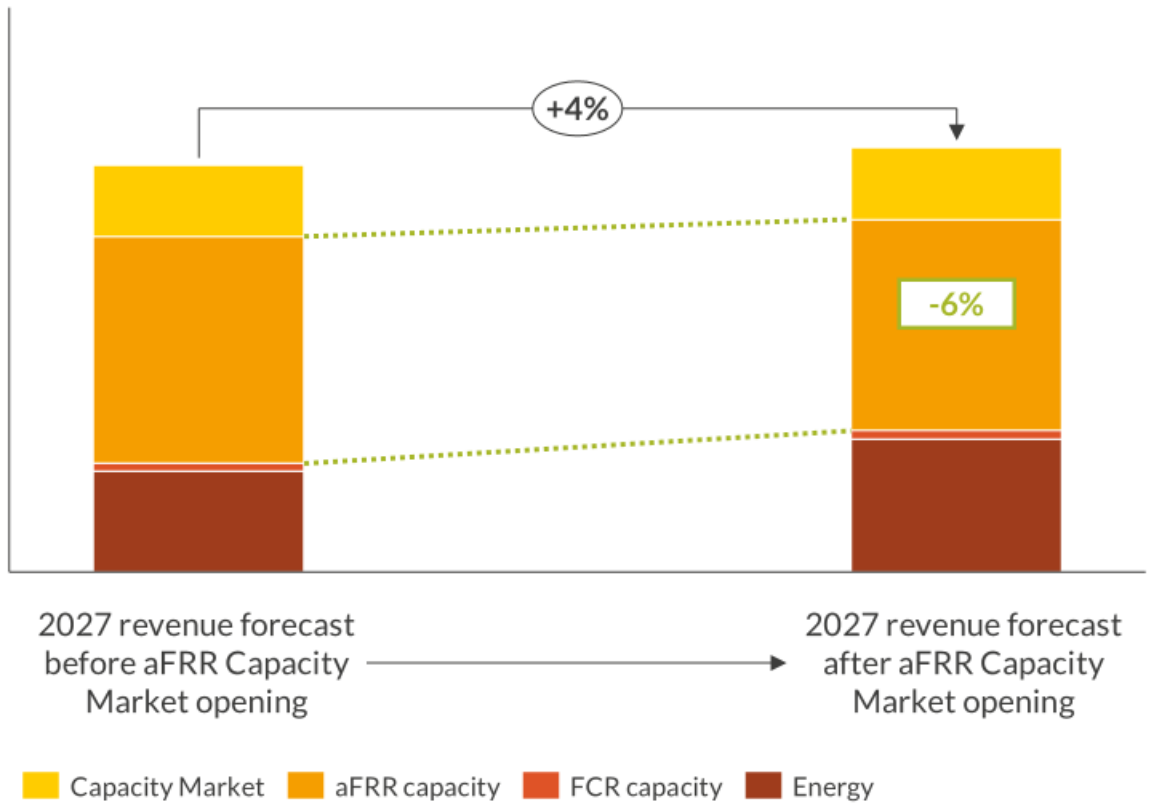
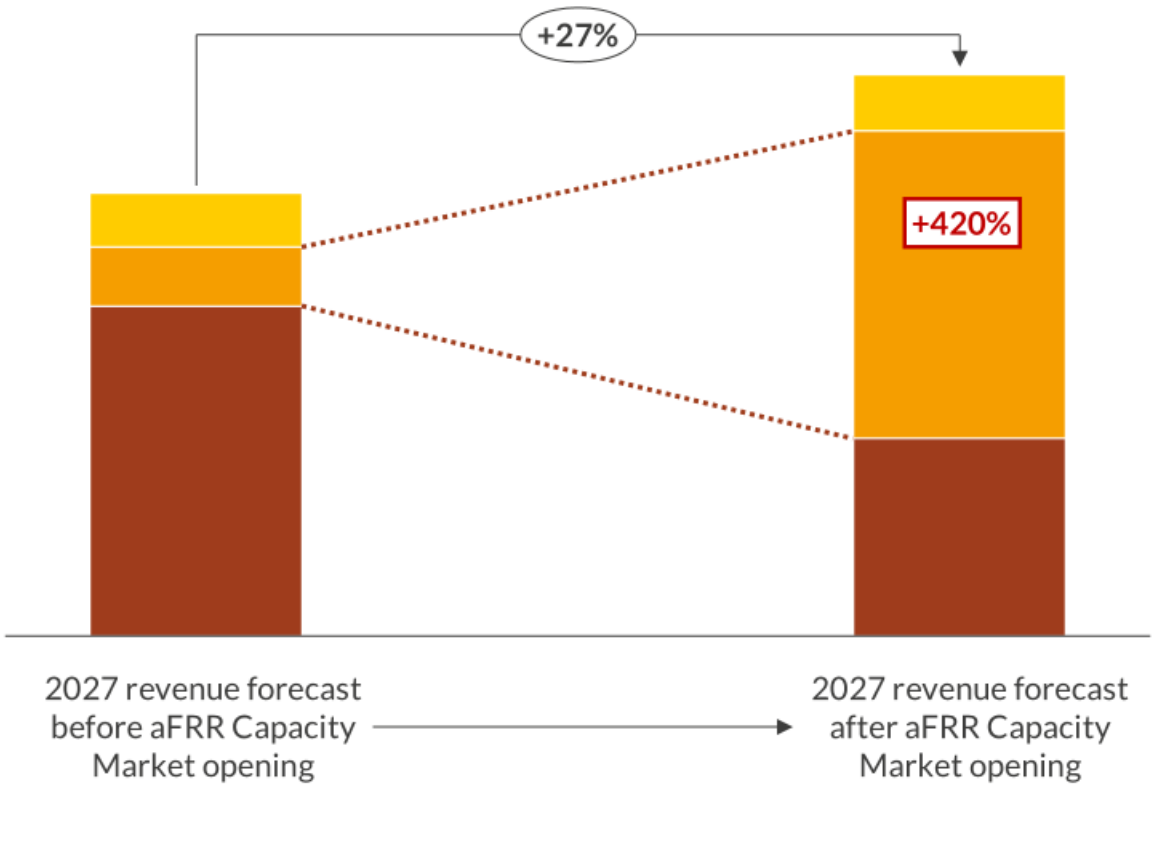
Aurora's fundamental model anticipated the role of aFRR capacity before the market opened and only slightly revised its forecast afterwards.

2027 revenue stack forecast for a 2h battery (Aurora fundamental model)
EUR/kW



Forecasts rooted in historical statistics did not anticipate the role of aFRR capacity and changed drastically after the market opened in July 2024.

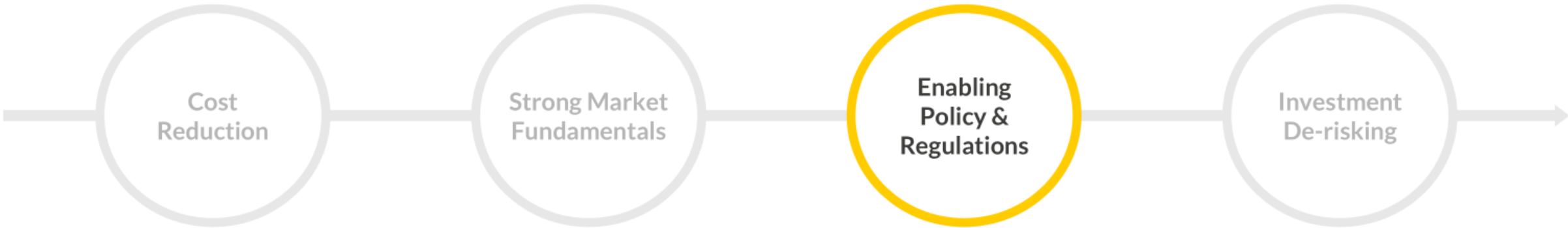
2027 revenue stack forecast for a 2h battery in France (Statistical model)
EUR/kW



Capacity Market | aFRR capacity | FCR capacity | Energy

Source: Aurora Energy Research

Advancing toward grid-scale BESS market maturity will require overcoming several key challenges



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Source: Aurora Energy Research

The European TSOs' initiative for aFRR energy exchange, PICASSO, now has 14 operational members with more to come in 2025

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Timeline for TSOs to enter PICASSO[3]

2020 Development of the functions of the aFRR-Platform

2021 Interoperability & Operational tests. TSOs connection to aFRR platform

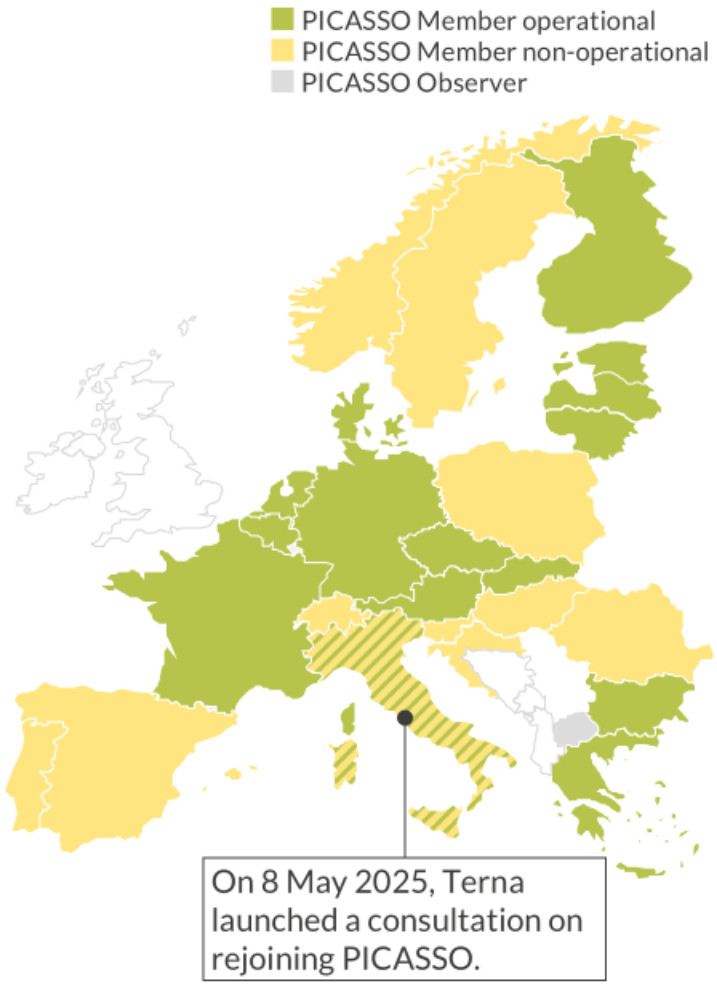
2022 PICASSO went live since June 2022

2023 (Temporarily suspended)

2024 (2024 Q4)

2025 (2025 Q1) (2025 Q2) (2025 Q2) (2025 Q3) (2025 Q4)

2026 (2026 or later[4])



Key takeaways:

- PICASSO aims to enhance electricity balancing through standardisation, cross-border cooperation, and efficient grid use.
- After initial delays caused by Italy's price spike issue[1] in 2024, ACER's recent amendments have prompted renewed confidence, with 14 countries now onboard and many more expected to join in 2025.
- Following PICASSO integration, newly joined countries did not experience significant issues like in Italy directly related to the platform, indicating the amendments may be fulfilling their intended purpose.
- However, balancing market volatility can still rise as countries with legacy market structures adjust their products and operations to the PICASSO framework—dependant on their existing regional setups, as seen in Denmark.

1) Unforeseen sharp spikes in Italian imbalance prices after joining PICASSO; 3) Based on V12 of Accession Roadmap of PICASSO; 4) The technical readiness of Swissgrid has been acknowledged, however, the go-live is postponed due to legal and political uncertainties of Switzerland not being part of EU.

Source: Aurora Energy Research, Elia, ENTSO-E, Regelleistung.net, TenneT

The Clean Industrial Deal strengthens Europe's battery supply chain and flexibility but stops short of resolving deployment and market design challenges

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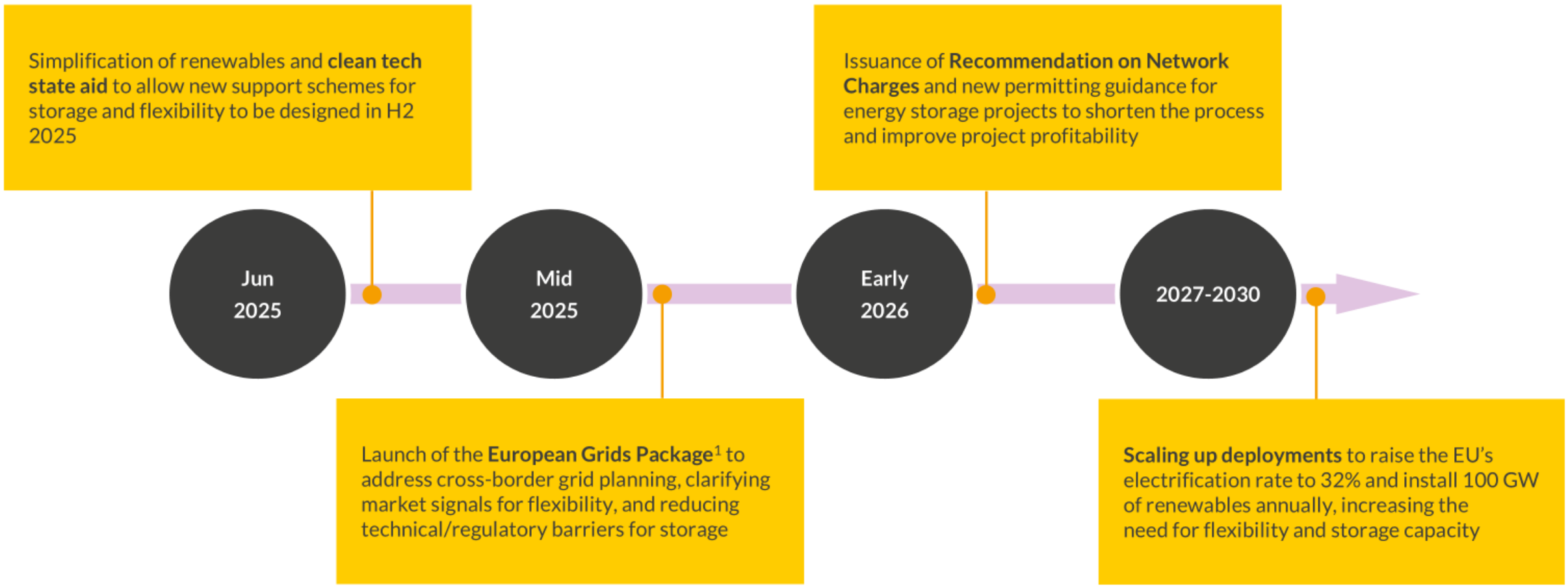
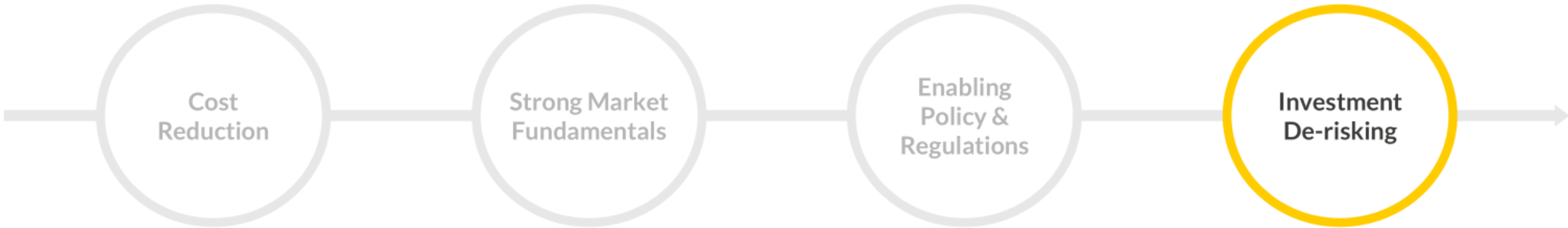
Unveiled in February 2025, the Clean Industrial Deal (CID) strengthens Europe's battery supply chain and unlocks flexibility potential by streamlining permits and mobilising long-term investment, but clearer storage-specific guidance to target existing deployment and market design challenges remains lacking.



1) The legislative proposal and Grid Package target accelerated permitting for grid, storage, and renewables by Q1 2026; 2) The Commission will propose a €100 billion Industrial Decarbonisation Bank funded by the Innovation Fund, ETS revenues, and InvestEU revisions; 3) European Investment Bank's PPA guarantee pilot encourages renewable roll-out by reducing risk in long-term renewable contracts through offering partial guarantees, strengthening BESS value chain; 4) In March 2025 a list of strategic projects surrounding the extraction, process and recycling of key battery materials were approved. Sources: European Commission, Aurora Energy Research

Advancing toward grid-scale BESS market maturity will require overcoming several key challenges



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Source: Aurora Energy Research

Several battery offtake structures exist in the market that allow the developer to pass part or all the revenue risk to an offtaker

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Project revenue
Illustrative

Owner receives	Market revenues
Offtaker receives	NA
Typical tenor	NA

Risk associated with:	**Owner**	**Optimiser**
Technical availability	⚠	
Market prices	⚠	
Dispatch optimisation	⚠	

Received by offtaker | Received by owner | Market revenues | Fixed revenues

Source: Aurora Energy Research

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Project revenue
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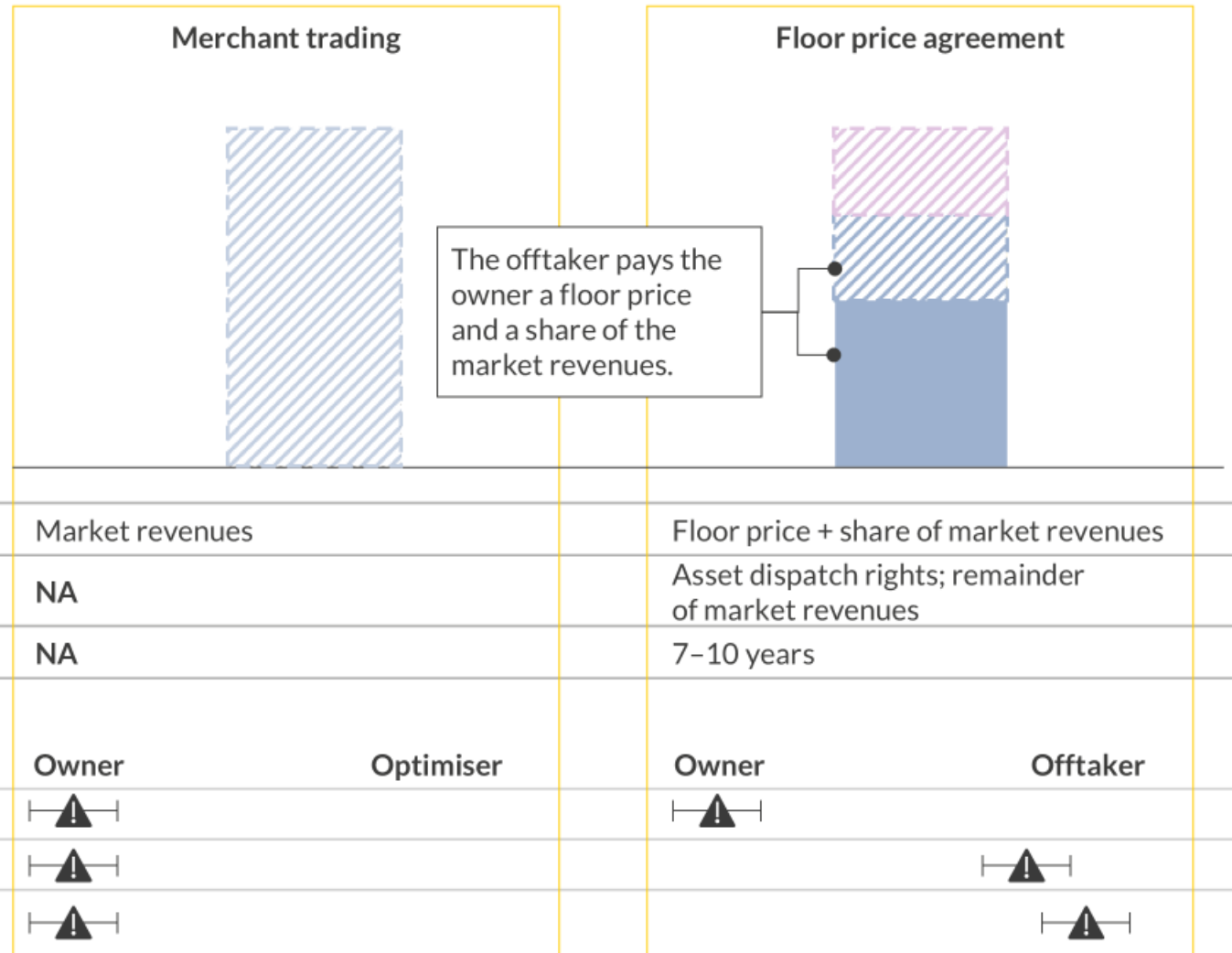

Owner receives	Market revenues	Floor price + share of market revenues
Offtaker receives	NA	Asset dispatch rights; remainder of market revenues
Typical tenor	NA	7–10 years

Risk associated with:	**Owner**	**Optimiser**	**Owner**	**Offtaker**
Technical availability	⚠		⚠	
Market prices	⚠			⚠
Dispatch optimisation	⚠			⚠

Received by offtaker | Received by owner | Market revenues | Fixed revenues

Source: Aurora Energy Research

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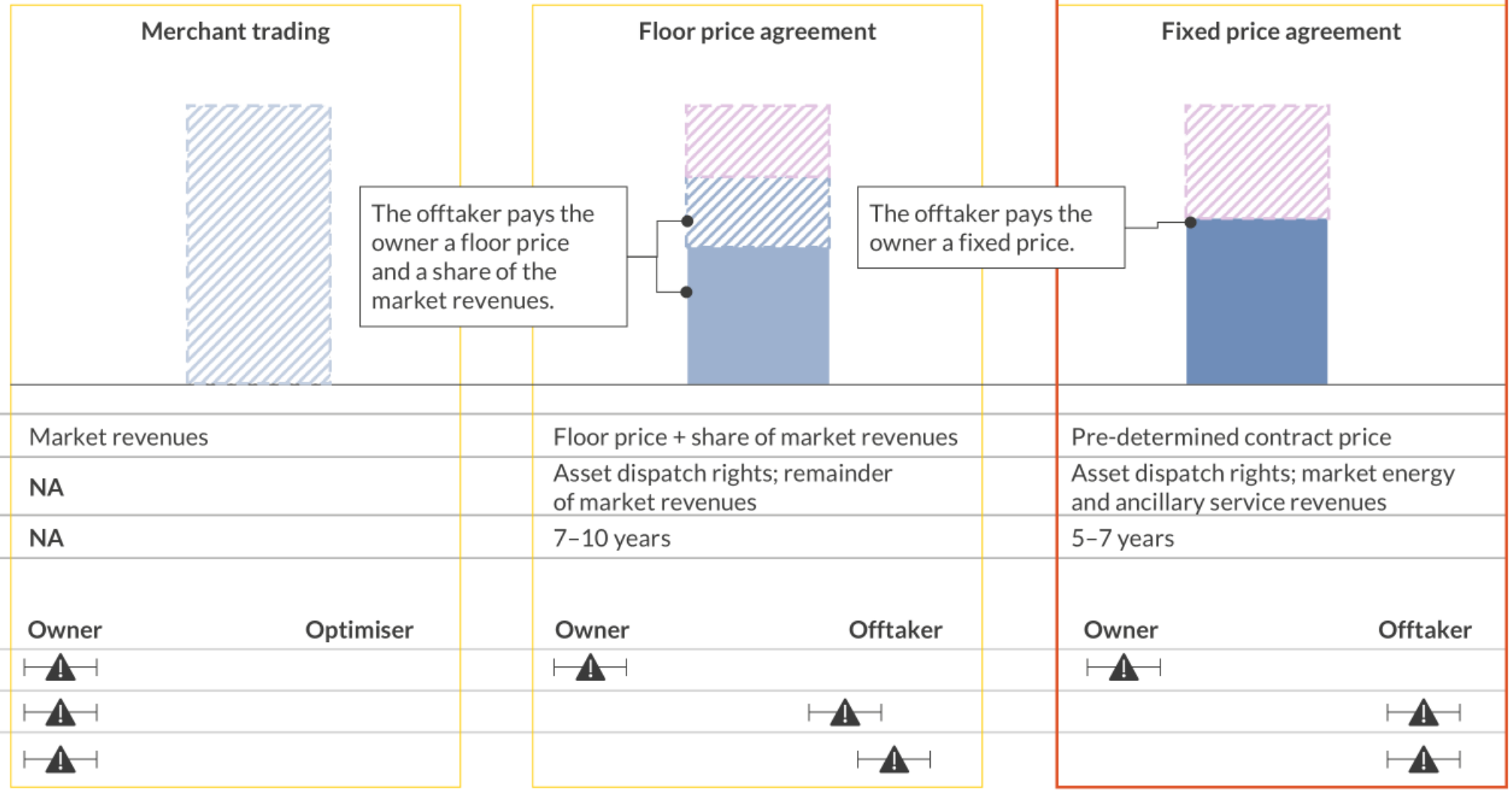
Deep dive on next slide

Project revenue
Illustrative



	Merchant trading	Floor price agreement	Fixed price agreement
Owner receives	Market revenues	Floor price + share of market revenues	Pre-determined contract price
Offtaker receives	NA	Asset dispatch rights; remainder of market revenues	Asset dispatch rights; market energy and ancillary service revenues
Typical tenor	NA	7–10 years	5–7 years

Risk associated with:	Merchant trading: Owner	Merchant trading: Optimiser	Floor price agreement: Owner	Floor price agreement: Offtaker	Fixed price agreement: Owner	Fixed price agreement: Offtaker
Technical availability	⚠		⚠		⚠	
Market prices	⚠			⚠		⚠
Dispatch optimisation	⚠			⚠		⚠

Received by offtaker | Received by owner | Market revenues | Fixed revenues

Source: Aurora Energy Research

Fixed price agreements de-risk battery revenues over the tenor of the contract, with a fair value up to 106.5 €/kW/year

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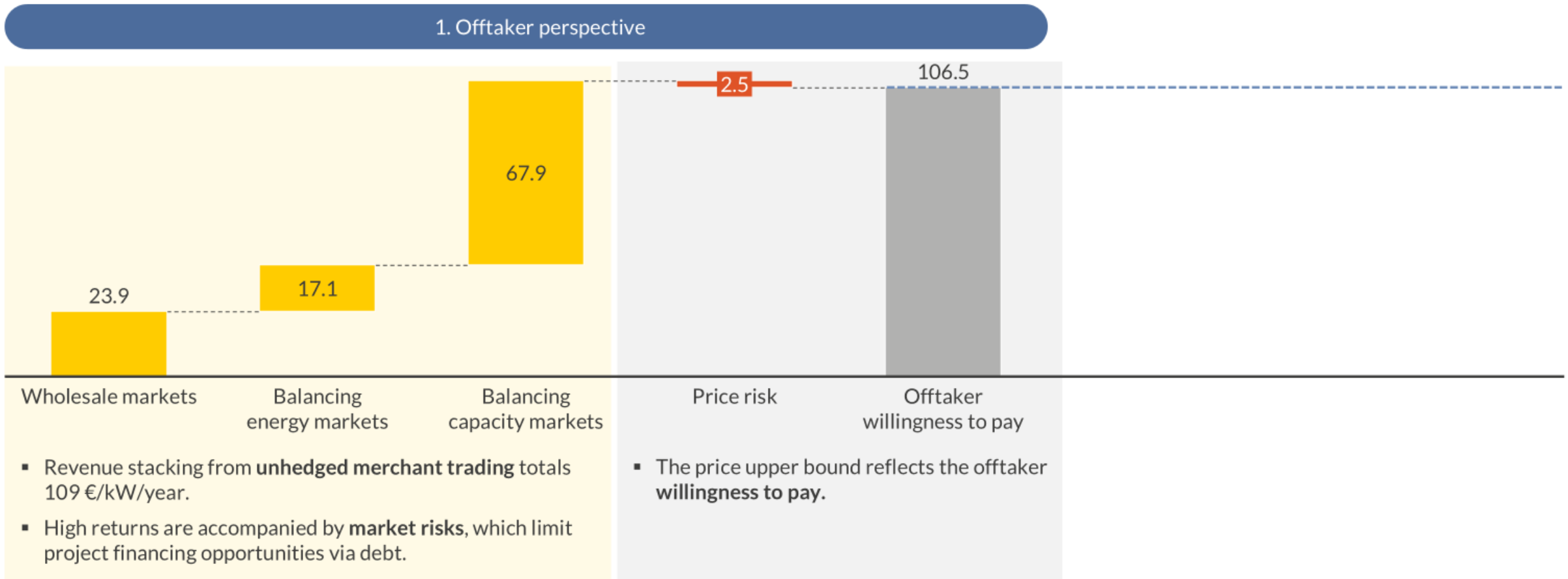
Exemple: 2h standalone BESS | COD[1]: 2026 | 7-year tolling agreement tenor

Tolling agreement fair value
€/kW/year (real 2024)



- Revenue stacking from **unhedged merchant trading** totals 109 €/kW/year.
- High returns are accompanied by **market risks**, which limit project financing opportunities via debt.

- The price upper bound reflects the offtaker **willingness to pay.**

Source: Aurora Energy Research

Fixed price agreements de-risk battery revenues over the tenor of the contract, with a fair value falling between 97.8 and 106.5 €/kW/year

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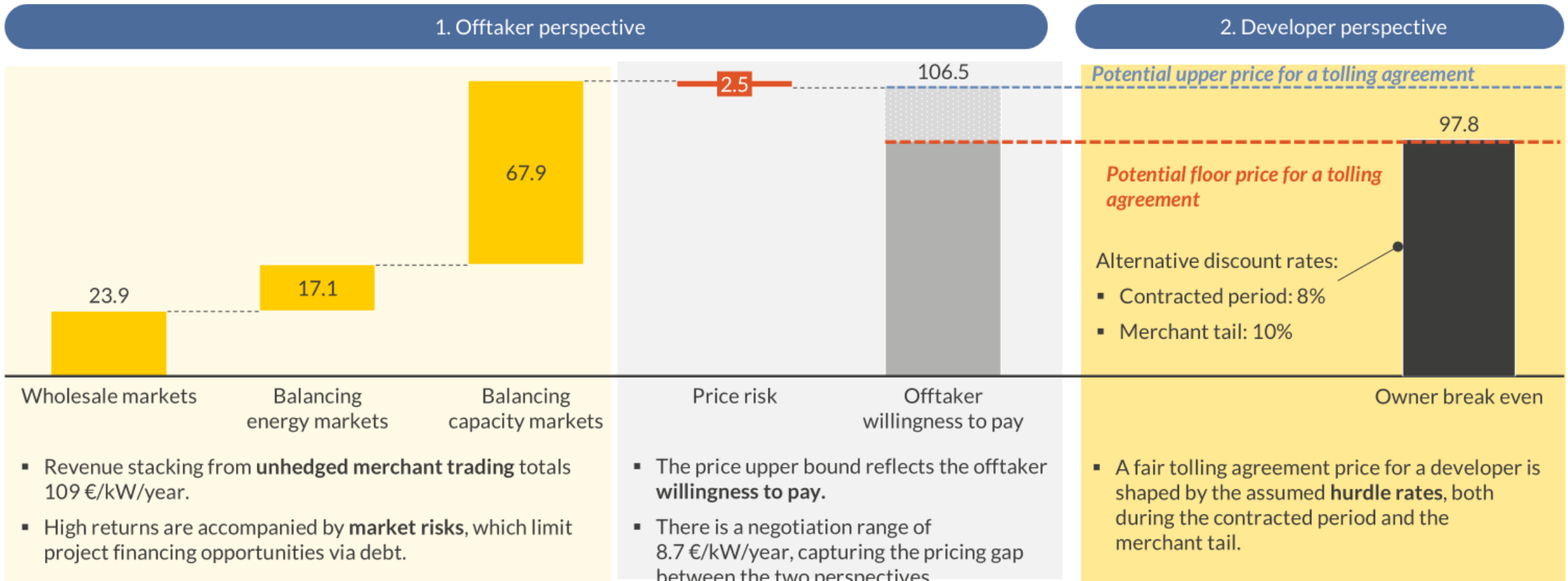
Exemple: 2h standalone BESS | COD[1]: 2026 | 7-year tolling agreement tenor

Tolling agreement fair value
€/kW/year (real 2024)



- Revenue stacking from **unhedged merchant trading** totals 109 €/kW/year.
- High returns are accompanied by **market risks**, which limit project financing opportunities via debt.

- The price upper bound reflects the offtaker **willingness to pay.**
- There is a negotiation range of 8.7 €/kW/year, capturing the pricing gap between the two perspectives.

- A fair tolling agreement price for a developer is shaped by the assumed **hurdle rates**, both during the contracted period and the merchant tail.

Source: Aurora Energy Research

Key takeaways

1. Driven by increased deployment of renewables, declining thermal capacity, and growing electricity demand, investment in battery storage will be significant. Aurora anticipates **a cumulative investment opportunity of c. 100bn € between 2025–2050.**

2. Significant cost reductions, strong market fundamentals, and the development of an enabling policy landscape will drive the deployment of BESS, but **future market saturation** poses material risks to investors.

3. Statistical modelling can be suitable for short-term forecasts; however, **fundamental models are needed** to capture long-term market evolution and structural changes.

4. **Contracting of revenues and tolling agreements** specifically can reduce revenue volatility risk for developers, thereby enhancing debt sizing and decreasing cost of capital. The fair value of such contracts will depend on market fundamentals but crucially also by the demand and supply dynamics in the market.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