

Charging ahead: Navigating risks in French battery storage projects

April 2025



Introducing the speakers



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Aurora provides market leading forecasts & data-driven intelligence for the global energy transition

A U R  R A

Power markets



Renewables & PPAs



Storage



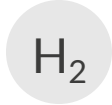
Grid & Congestion



Electric vehicles



Hydrogen



Carbon



Natural gas



 Regular detailed coverage  Analytics on demand



17 offices
+ Mexico coming soon



900+
market experts



850+
subscribing companies



150+
transactions supported in 2024

French Power and Renewables Markets Service:

Dive into key market analysis and forecasts for the French power and renewables market

Power and Renewables Service

Forecast Reports & Data



Quarterly market reports with forecast data

- **Detailed report** on regulatory and market developments (bi-annual)
- **Forecast data** of wholesale, capacity and capture prices to **2060** with annual, monthly and quarterly granularity
- **Data under 4 scenarios (Central, Low, High, and Net Zero)**
- National prices
 - 11 weather years
 - Curtailed and uncurtailed capture prices for RES assets
- **Capacity development**, generation mix, interconnector capacity, capacity buildout, exports
- **Number of negative prices**
- **Input assumptions:** demand, gas and CO2 prices, CAPEX and OPEX
- **Capacity market prices to 2050**
- **Guarantee of origins to 2060**

Strategic Insights



3 Strategic Insight Reports

Three in-depth thematic reports on topical issues



Policy Updates

Timely research notes on recent changes to policy and regulation, demonstrating the impacts and opportunities for market participants



3 Group Meetings

3 Group Meeting roundtable events in **Paris** with key market participants such as developers, investors, financiers, utilities, grid operators, and government officials



Analyst Support

Biannual workshops and support from our bank of analysts, including native speakers and on-the-ground experts



Access detailed power market analysis and investment case data for batteries with our French Flexible Energy Add-On

Flexible Energy Add-On

Forecast Reports & Data



Technology and Market Development Reports

- Overview of regulatory framework for batteries
- Revenue stacking models for batteries
- Projections for battery CAPEX and OPEX by delivery year
- Reports and datasets follow the same format with content tailored to specific markets



Forecast Data

- Central and [low \(June 2025\)](#) case forecast prices until 2060:
 - Hourly wholesale power prices
 - Yearly capacity market prices
 - 4-hourly FCR market prices
 - aFRR (15-min for energy, and hourly for capacity, upward, and downward) prices
 - Hourly Intraday Continuous Index Prices

Investment Cases



Standalone battery

- Multiple investment cases per country or zone including:
 - Arbitrage of wholesale market, FCR, and aFRR market
- Annual project margins to 2060; IRR and NPV for two entry years



Co-location

- At least 3 investment cases for batteries co-located with solar PV in three different battery durations (1-hour, 2-hour, 4-hour)
- Central and [low \(June 2025\)](#) hourly wholesale, hourly intraday continuous index, 4-hourly FCR and hourly aFRR (capacity and energy) prices

Workshops and Assistance

- 1h Workshop with our Market Experts
- Ongoing analyst support

Our advisory services can help provide bespoke battery valuations for debt and equity transactions, and optimal debt sizing analysis

Analyses

1



Technical sensitivities

- ✓ Degradation profiles, round trip efficiency, cycling rate
- ✓ Repowering, colocation
- ✓ TURPE level, derating and certification

2



Commercial sensitivities

- ✓ High/Low scenarios
- ✓ Extreme events
- ✓ Weather sensitivities and Monte Carlo distributions

3



Other bespoke sensitivities

- ✓ Curtailment analyses
- ✓ Co-located solar/BESS with CfD contract
- ✓ Tolling agreements

Use cases

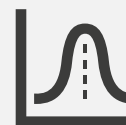


Lending market advisory



M&A (buy and sell side)

NEW!

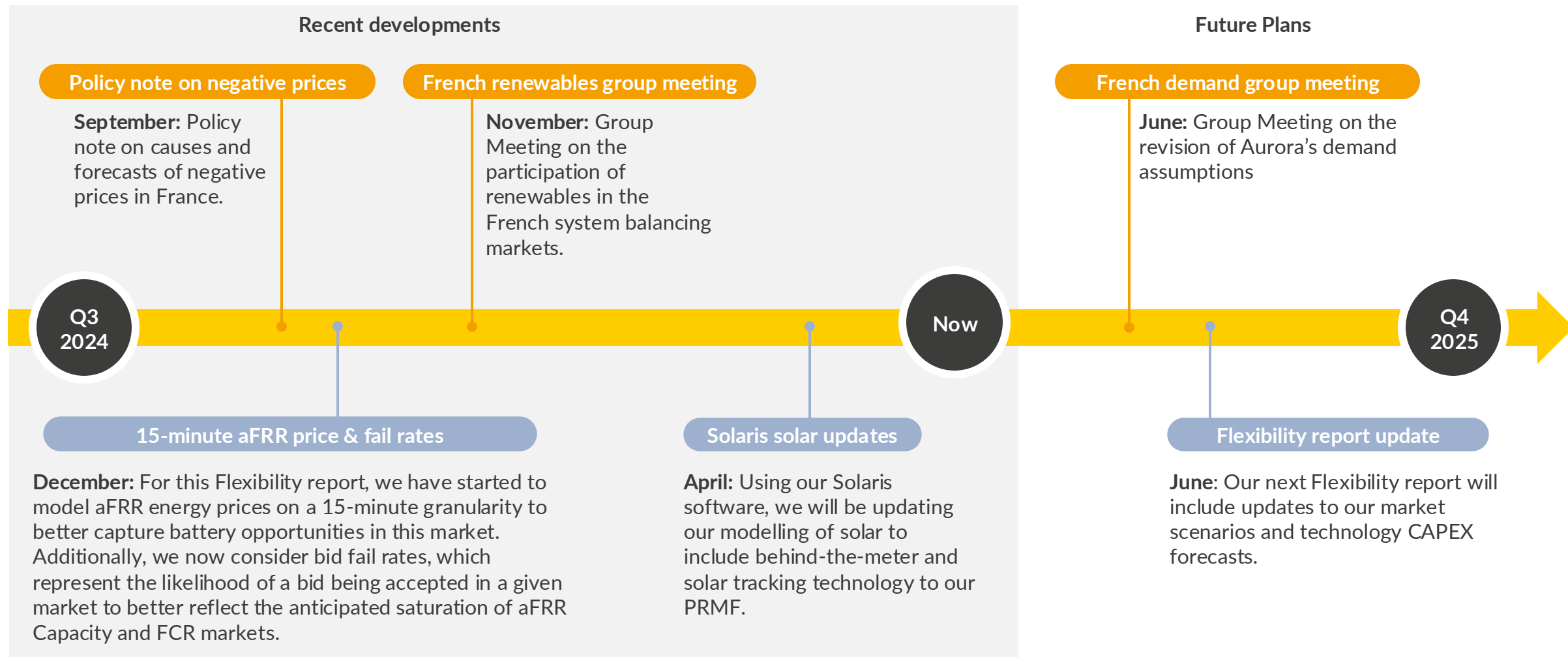


Asset Optimal Sizing
& Batch Sensitivities



Market exploration
& First of a Kind

Upcoming developments for Aurora's French services





- How has the French market for batteries evolved over the last years?
- Could the rapid expansion of battery projects create market saturation across Europe?
- To what extent will the French battery market be affected by potential saturation?



- What are the key risks that could impact battery business cases, and how might they materialise?
- What impact could a battery overbuild have on market prices?
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- To what extent does market saturation erode battery revenues?
- Which revenue streams are most and least affected by higher battery cannibalisation?
- Why does curtailment have a limited impact on battery profitability?

- What new route-to-market options are emerging for batteries?
- How can offtaker agreements help mitigate market risks for battery storage?
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Battery capacity in France reached 1GW in 2024 driven by the availability of new revenue streams and increasing renewables deployment

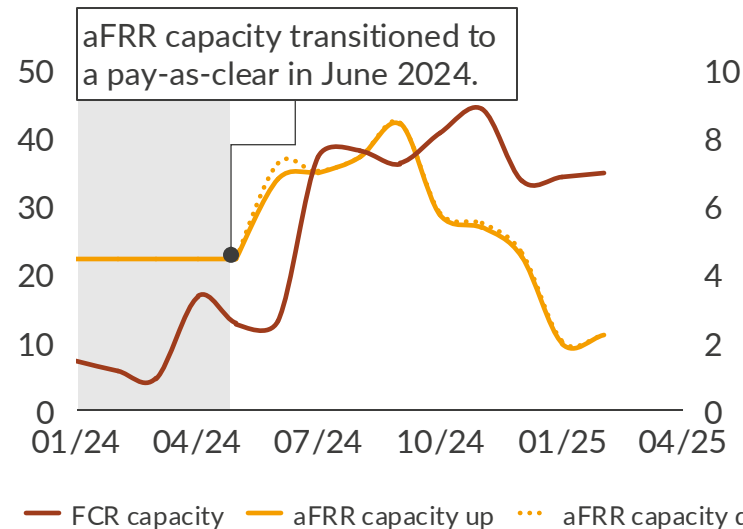
Ancillary services are key sources of revenues for batteries.



Ancillary services revenues

Currently nuclear, gas and hydro generation dominate FCR and aFRR Capacity markets; batteries will add more competition as they increase their participation in these markets.

Monthly FCR¹ and aFRR Capacity prices €/MW/h



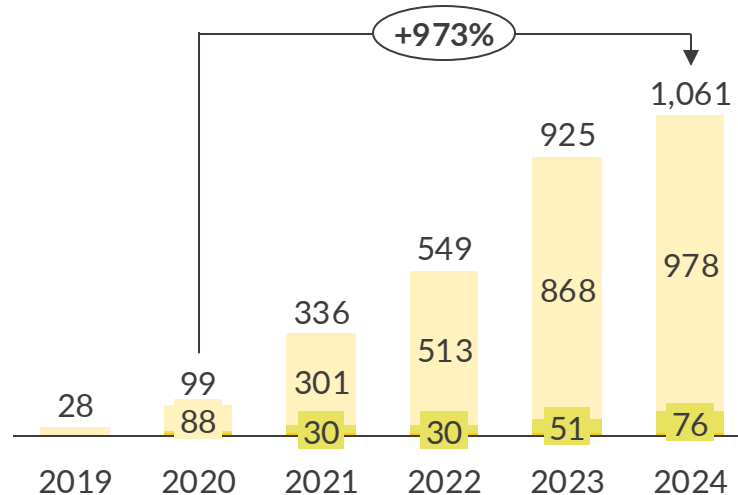
Alongside renewables, battery deployment has seen a strong acceleration in recent years.



Variable renewables (RES²) deployment

Intermittent renewable capacity increased by 70% between 2019 and 2024 in France, by 9.3GW (+98%) for solar PV and by 9.0GW (+55%) for wind.

Total installed battery capacity³ MW-nameplate



Yet, with rapid deployment, various risk factors for batteries start to materialise.



Regulatory uncertainty

Changes in subsidies and regulation for batteries, or other technologies might impact long-term profitability of battery projects.



Market saturation Focus of this session

Competition between batteries in ancillary and balancing markets can drive prices down and diminish revenue streams.



Low price volatility

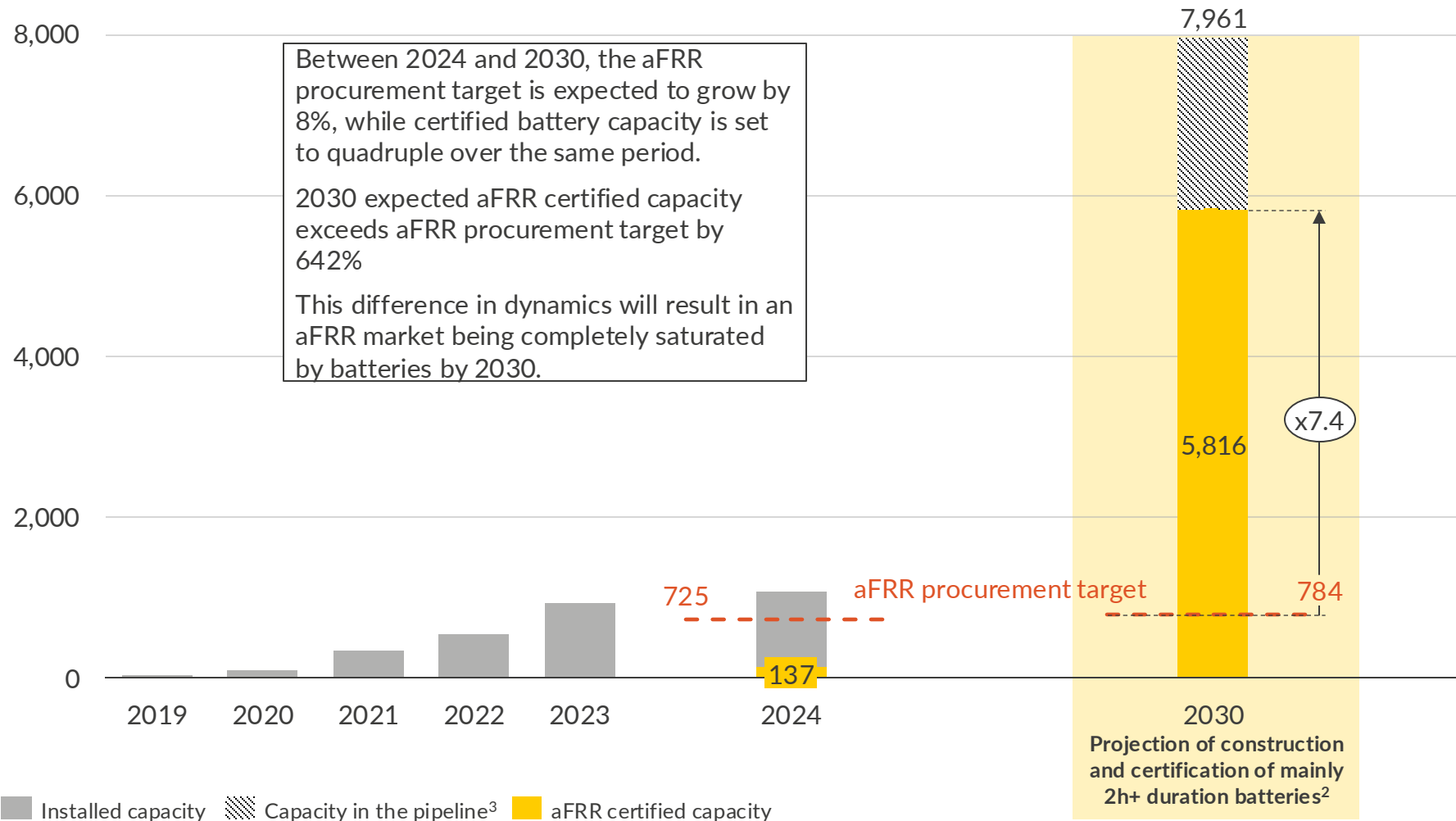
Low variation in prices throughout the day lowers revenue opportunities for batteries.

1) The FCR market is symmetrical, and the price shown here corresponds to the price in both directions; 2) Renewable energy systems; 3) Open Data Réseaux Energies website – November 2024.

As seen across Europe, France's limited aFRR market depth makes it particularly exposed to saturation by 2030

Total installed battery capacity, aFRR certified capacity, and aFRR procurement target¹

MW-nameplate

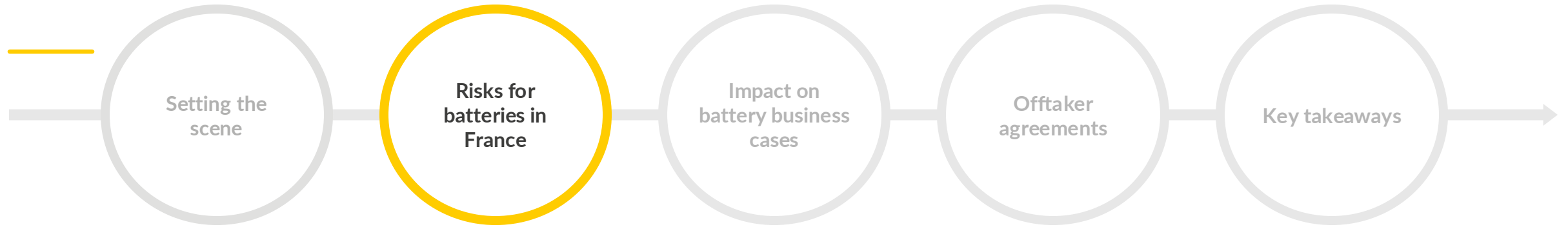


- Most batteries in the pipeline have 2-hour or 4-hour durations, ideal for the aFRR market. Their certification will speed up market saturation.
- In 2024, certified battery capacity in the **FCR market** already exceeds the procurement target, indicating that this market is already saturated with batteries.
- This trend is due to the fact that 1-hour batteries, which are better suited to FCR, currently make up the majority of the battery fleet.
- Batteries are not the exclusive providers of FCR at every hour of the year, as other technologies also participate.

■ Installed capacity ■ Capacity in the pipeline³ ■ aFRR certified capacity

1) Open Data Réseaux Énergies website - November 2024; 2) Certification rates based on the current and projected number of programming gates, battery duration, and the neutralisation period; 3) This is estimated from the battery capacity in the pipeline announced by the Minister of the ecological transition on 15/10/2024.

Sources: Aurora Energy Research, CRE, Ministry of Ecological Transition, ODRE, RTE



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Aurora identified two key battery specific risks relating to increased battery and renewables capacity in the system

1 Market saturation

- Rapid deployment of battery storage solutions exceeding demand in ancillary services
- Increased competition of batteries in addition to other technologies
- Lower price spreads due to increased battery capacity
- Slowdown of RES deployment, leading to lower price spreads



Battery overbuild scenario

- Design of a scenario with high battery buildout without any additional RES buildout.
- Markets that are central to battery business cases but have limited market depth are rapidly saturated:
 - 1 Reduction in Day-ahead & Intraday price spreads
 - 2 Reduction in Balancing market and Capacity mechanism prices
 - 3 Lower success rate on bids due to high competition

2 Grid constraints

- Challenging transformation of grid infrastructure needed for RES integration
- Risk of grid infrastructure updates not being rolled at same speed as RES capacity is installed



Grid curtailment scenario

- Battery operation might be restricted by the TSO due to grid constraints:
 - 1 Estimation of time steps at risk of grid curtailment
 - 2 Curtailment of discharge in profitable dispatch opportunities

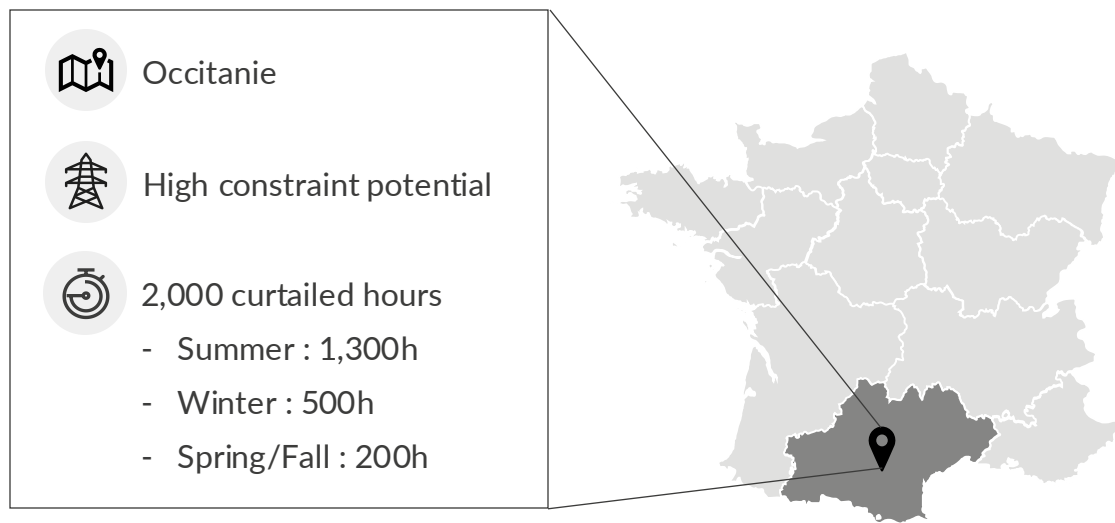
When modelling injection restrictions, we assume they happen during hours of highest RES production, partly correlating with lower prices



How do we select the hours to curtail ?

- The Technical and Financial Proposal (PTF) defines the number of hours per year during which the battery may be curtailed, and an indication of the distribution of those hours over seasons.
- For our analysis, we assume curtailment will occur during hours with the highest renewable generation.
- We consider a curtailment of 100% of the production on the selected hours.

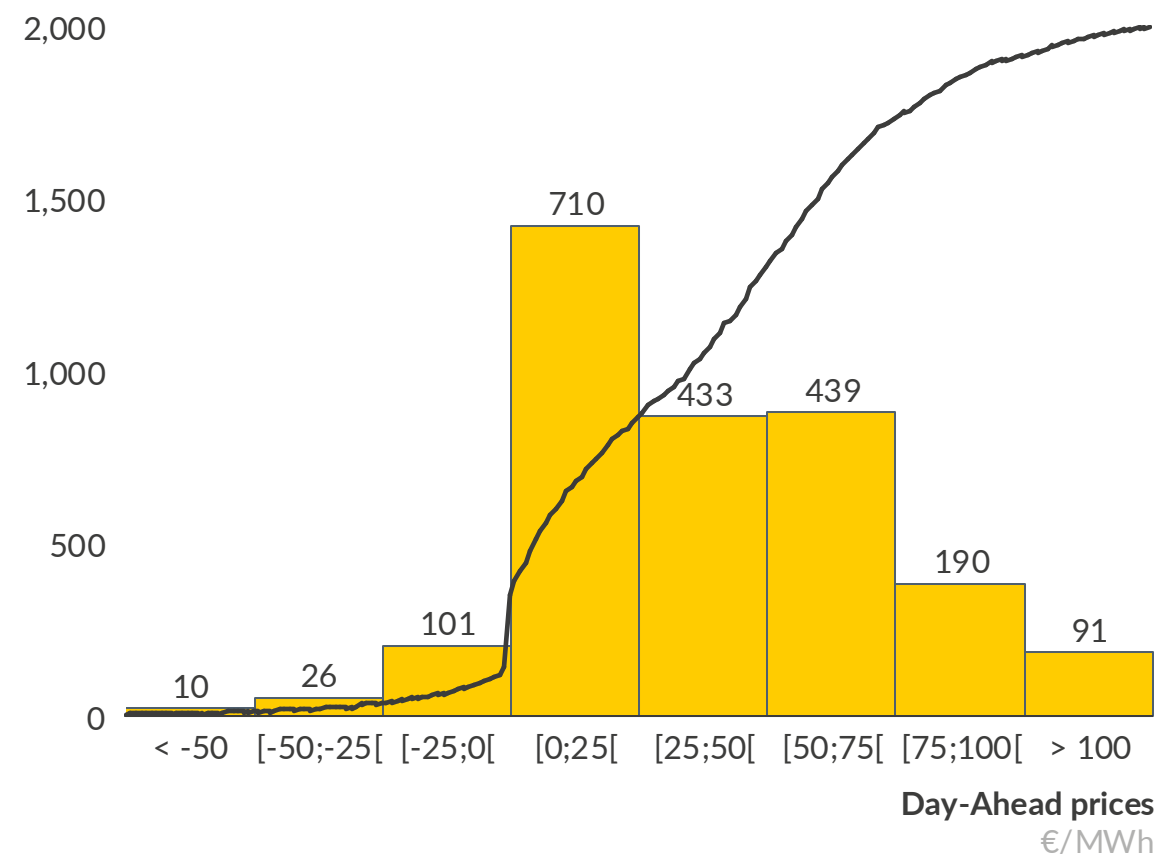
Case Study - Project location and constraints



2,000 hours with highest renewables generation in 2024

#, cumulative

#, by price buckets



— Cumulative 2,000 hours with highest RES generation

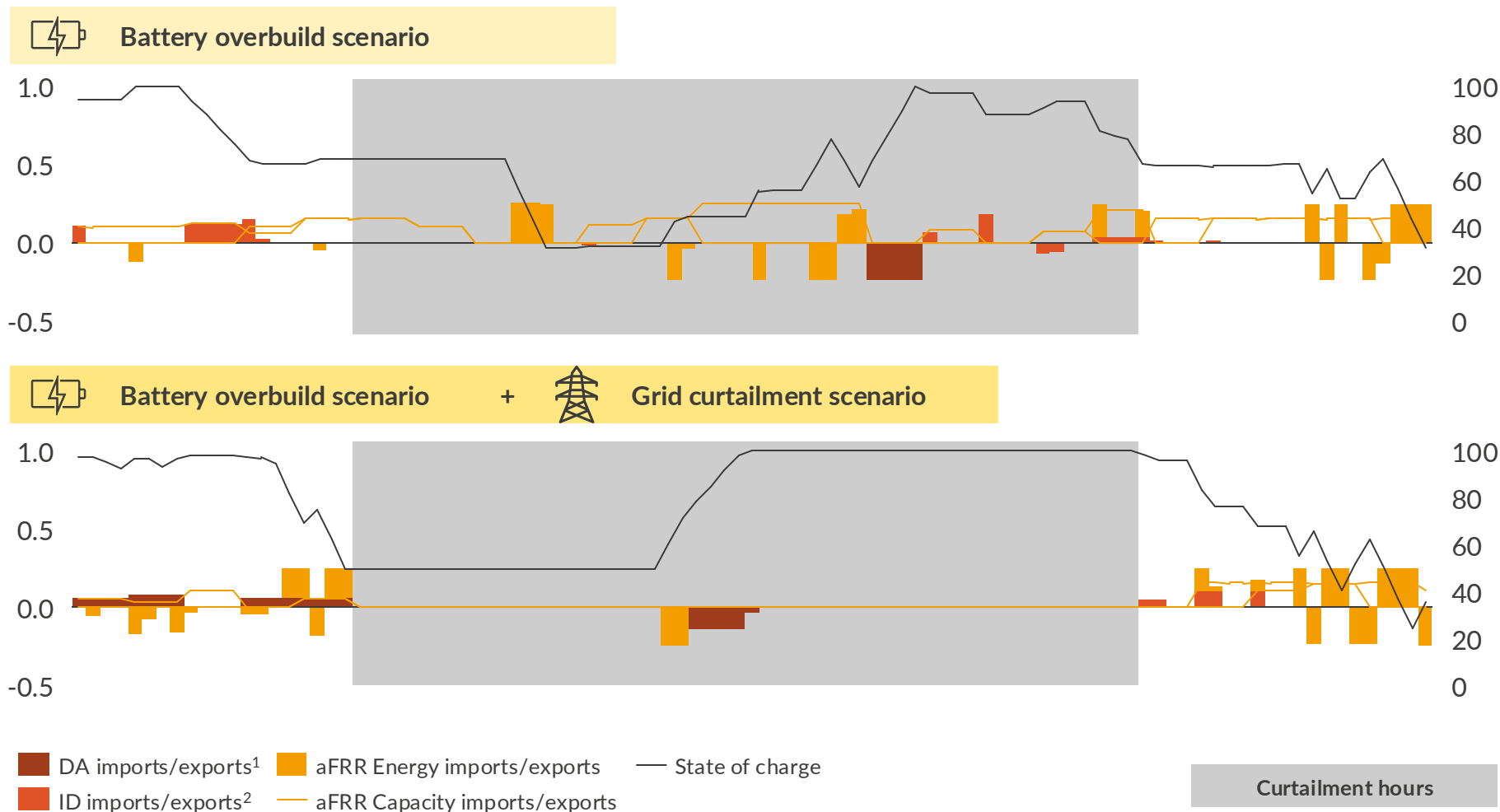
■ 2,000 hours with highest RES generation, by price bucket

1) In this analysis, we only look at curtailment on the production (discharging) and not on the consumption (charging).

Curtailment affects the battery's ability to optimise its position, leading to decreasing revenues

Quarter-hourly imports and exports per market, 31/07/2026
MWh/MW installed (FLH)

Battery state of charge
%



- Since batteries can often anticipate curtailment days using weather and demand forecasts, they can adjust their positions accordingly to avoid penalties.
- Although grid curtailment only impacts grid injection, batteries must still halt operations once fully charged and limit their commitments to downward balancing services.



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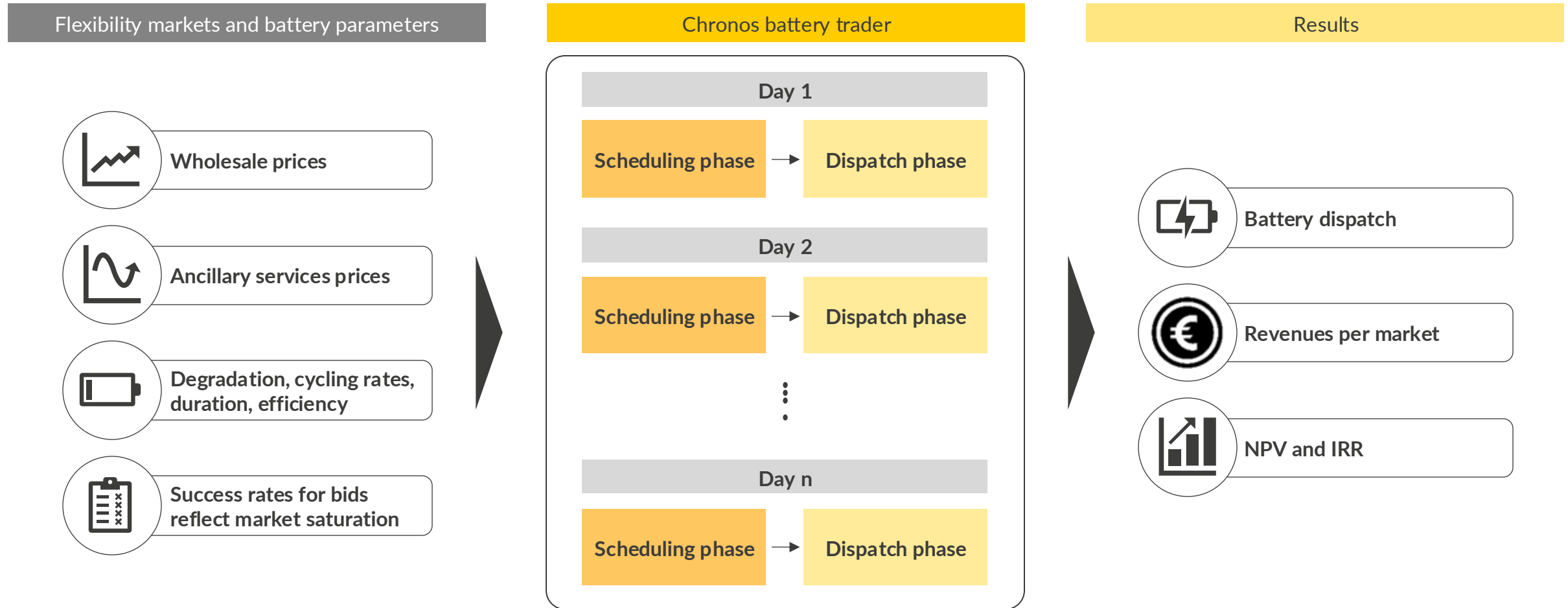
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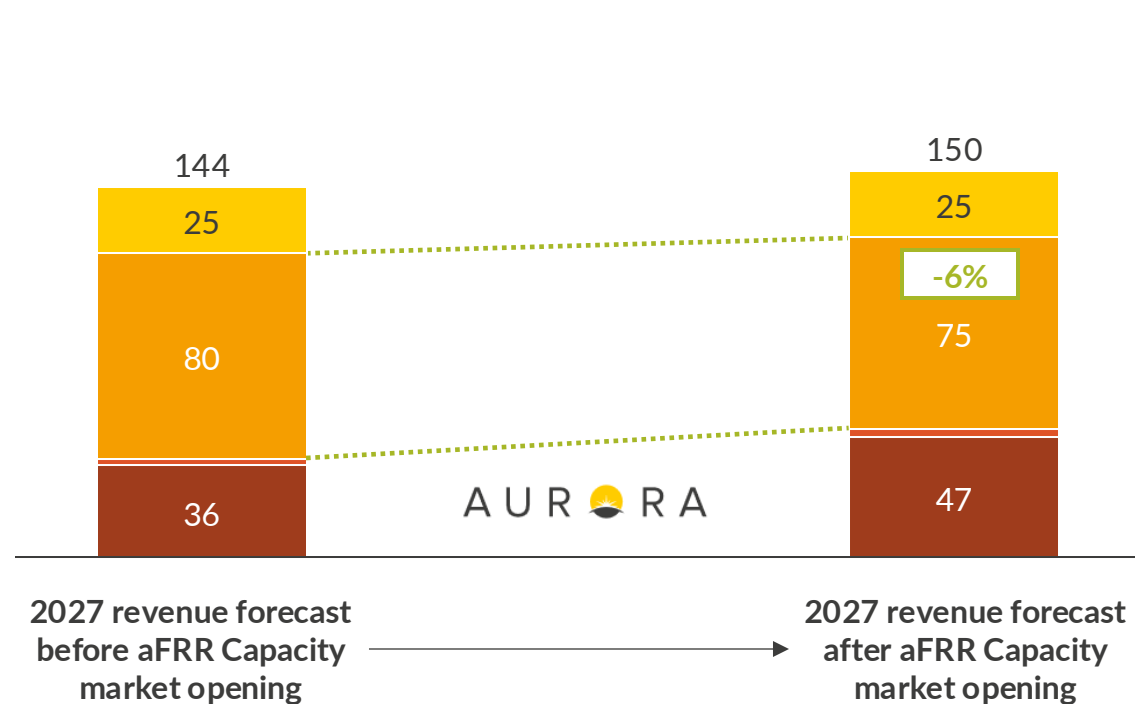
Aurora models battery business cases in two stages based on Origin, our in-house market-level model, and Chronos, our battery dispatch software



Fundamental market models like Aurora's are best at simulating changes in market dynamics as opposed to machine learning based models

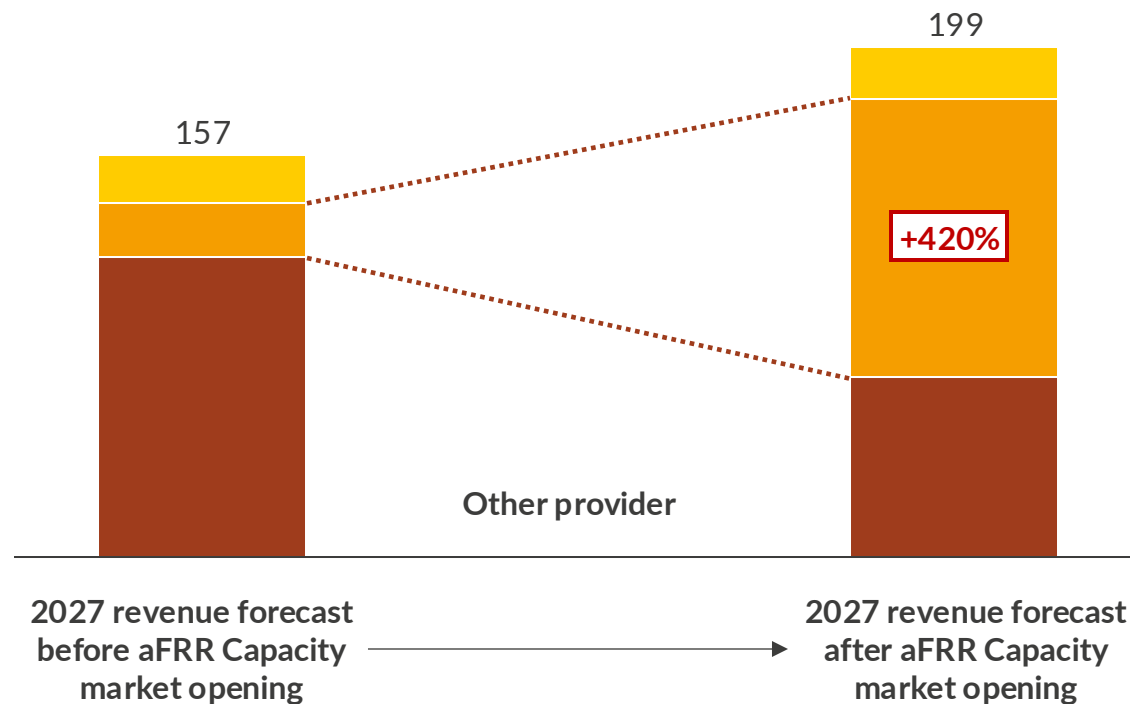
Aurora's fundamental model anticipated the role of aFRR capacity before the market opened and only slightly revised its forecast afterwards.

2027 revenue stack forecast for a 2h battery in France
€/kW (real 2023)



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

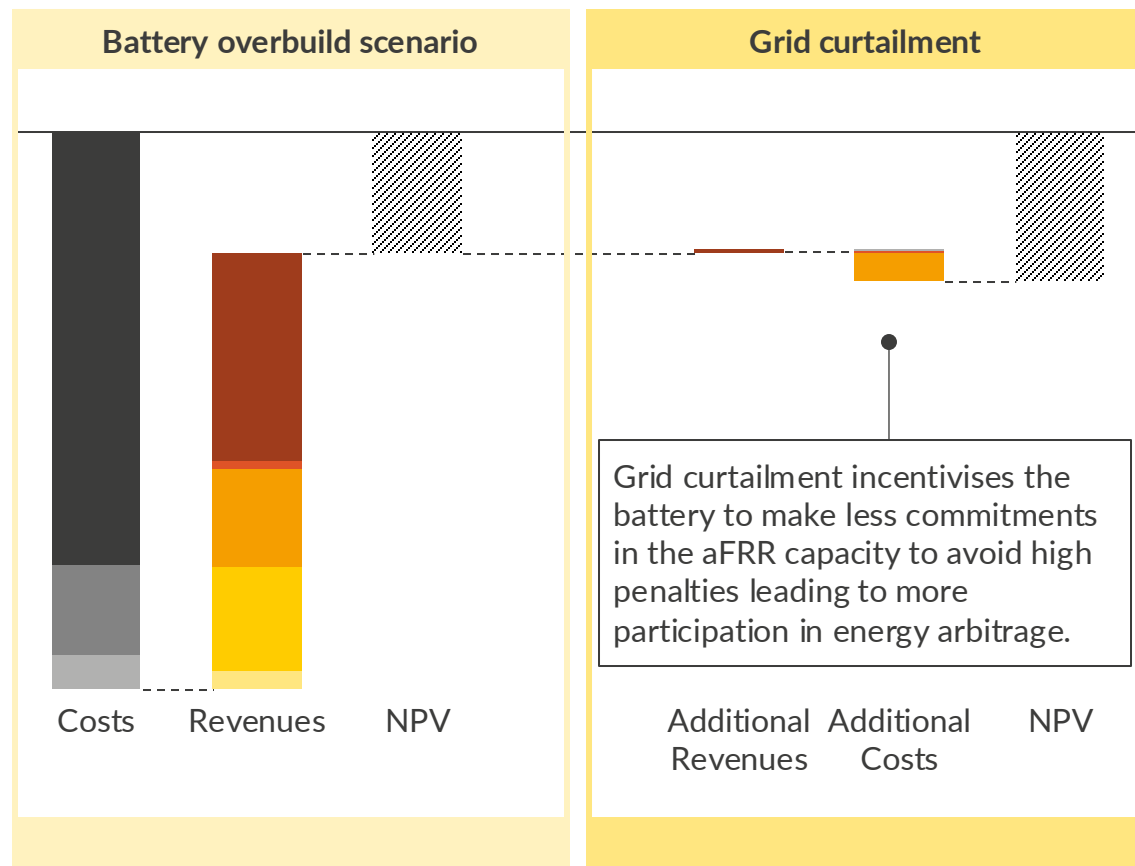
2027 revenue stack forecast for a 2h battery in France
€/kW (real 2023)



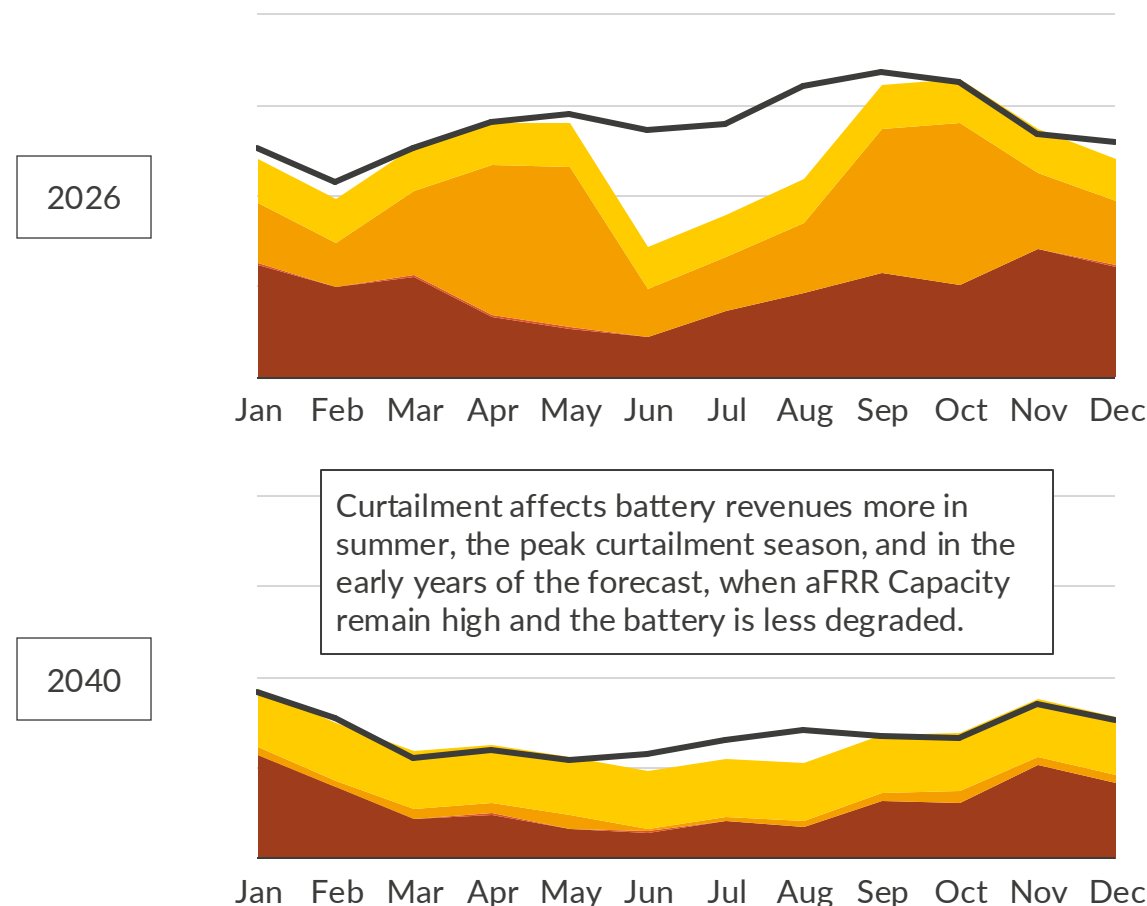
Capacity Market aFRR Capacity FCR Energy arbitrage

Battery overbuild leads to a lower IRR (-4.8p.p) compared to our Central scenario; grid curtailment further reduces the IRR by 1.2p.p

Net Present Value of battery in different scenarios¹
€/kW of grid capacity (real 2023)



Monthly battery gross margins in 2026 vs 2040
€/kW (real 2023)



■ CAPEX ■ OPEX ■ TURPE³ ■ End-of-life ■ Capacity Market ■ aFRR capacity ■ FCR ■ Energy arbitrage⁴ ■ NPV — Battery overbuild scenario gross margins

1) Net Present Value calculated assuming a discount rate of 11%; 2) Leveraged equity Internal Rate of Return (IRR) assuming 1.7 DSCR, 40% leverage, 10-year tenor; 3) Here, TURPE only corresponds to variable grid charges, the fixed ones are included in the OPEX; 4) Energy arbitrage gross margins include Day-Ahead, Intraday, aFRR Energy and chum gross margins.



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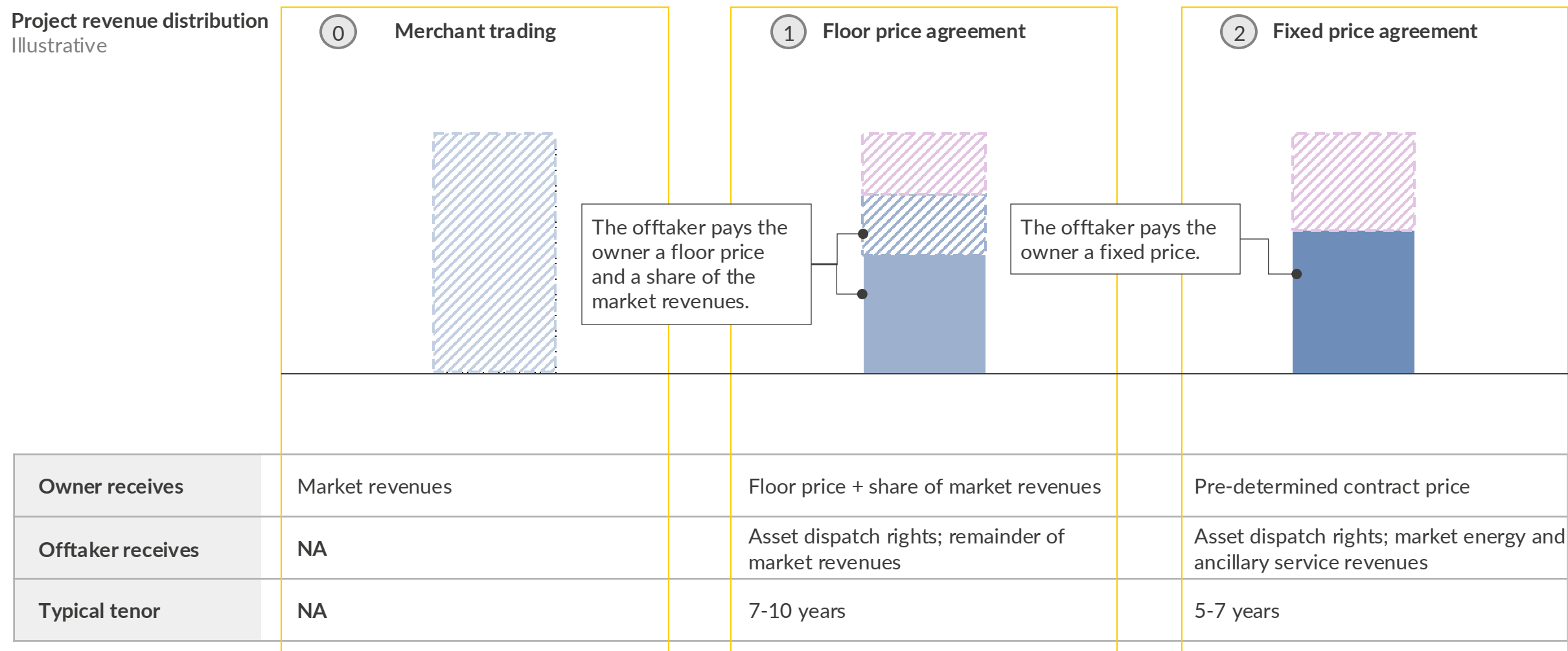


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A fixed price agreement provides full revenue certainty to the owner but limits upside opportunities compared to a floor

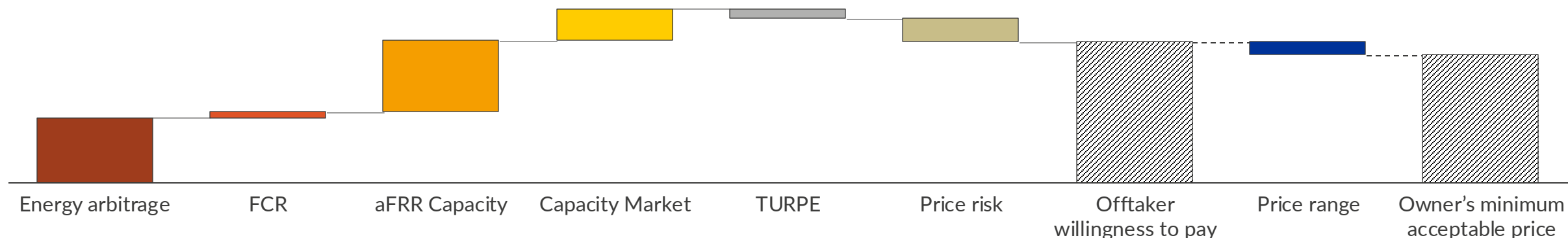
Project revenue distribution
Illustrative



 Received by off-taker
  Received by owner
  Market revenues
  Fixed revenues


Fixed price agreements de-risk battery revenues over the tenor of the contract, with a fair value falling between 103 and 94 €/kW/year


Fixed price agreement price calculation for a 2h standalone battery, COD 2026, HTB2, TURPE 6
€/kW/year (real 2023)



Offtaker's maximum willingness to pay


- The offtaker aims to maximise the value they can extract from the fixed price agreement while minimising their exposure to risk.
- To determine the maximum price they are willing to pay, they consider:


 The NPV of the expected revenues from Wholesale Market, the ancillary services and the Capacity Market as well as the grid charges.

 A price risk discount, reflecting uncertainty in future market prices due to a potential battery overbuild scenario or limitations on battery exports.

Owner's minimum acceptable price

- The owner aims for a fixed price that allows them to reach a target equity IRR of at least 8%.
- Such contracts facilitate project financing:

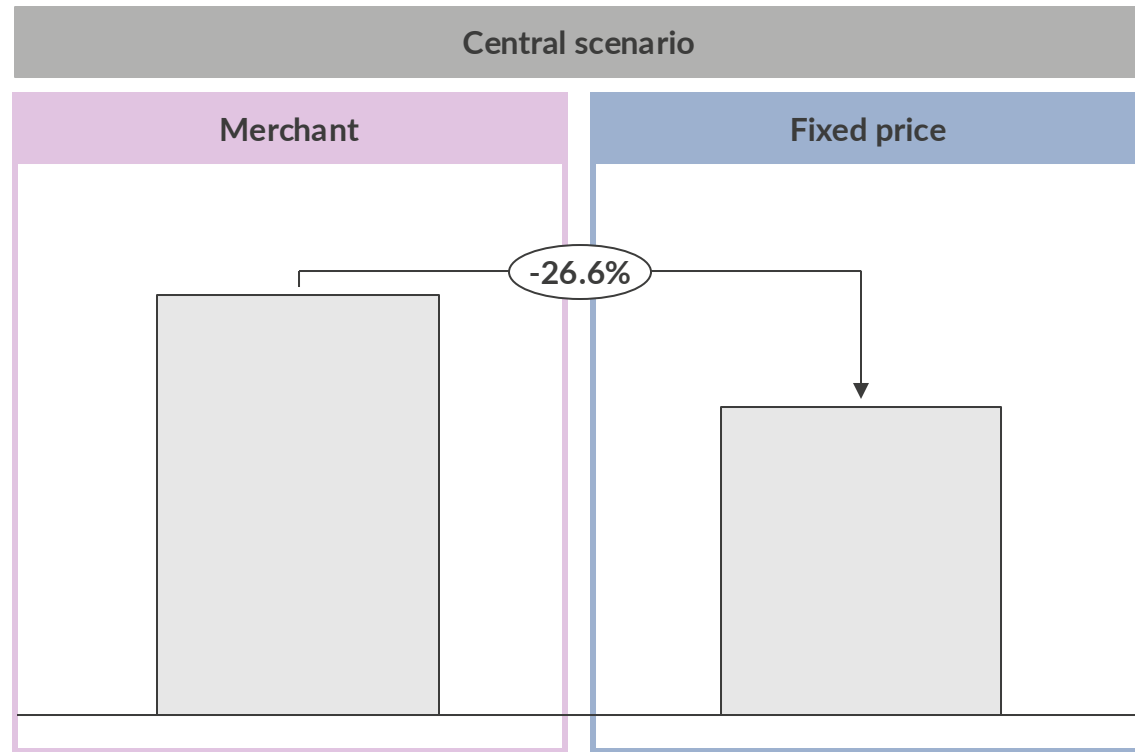
 By fixing a share of the revenues, risk and thus WACC is reduced and bankability improved.

 This improves project financing conditions and thus allows to accept a fixed price below what a fully merchant strategy would require.

→ The final fixed price agreement price falls between these two bounds and is driven by market supply-demand dynamics as well as the offtaker's risk appetite.

Tolling agreements at their minimum acceptable price reduce equity IRR but provide protection against downside risks

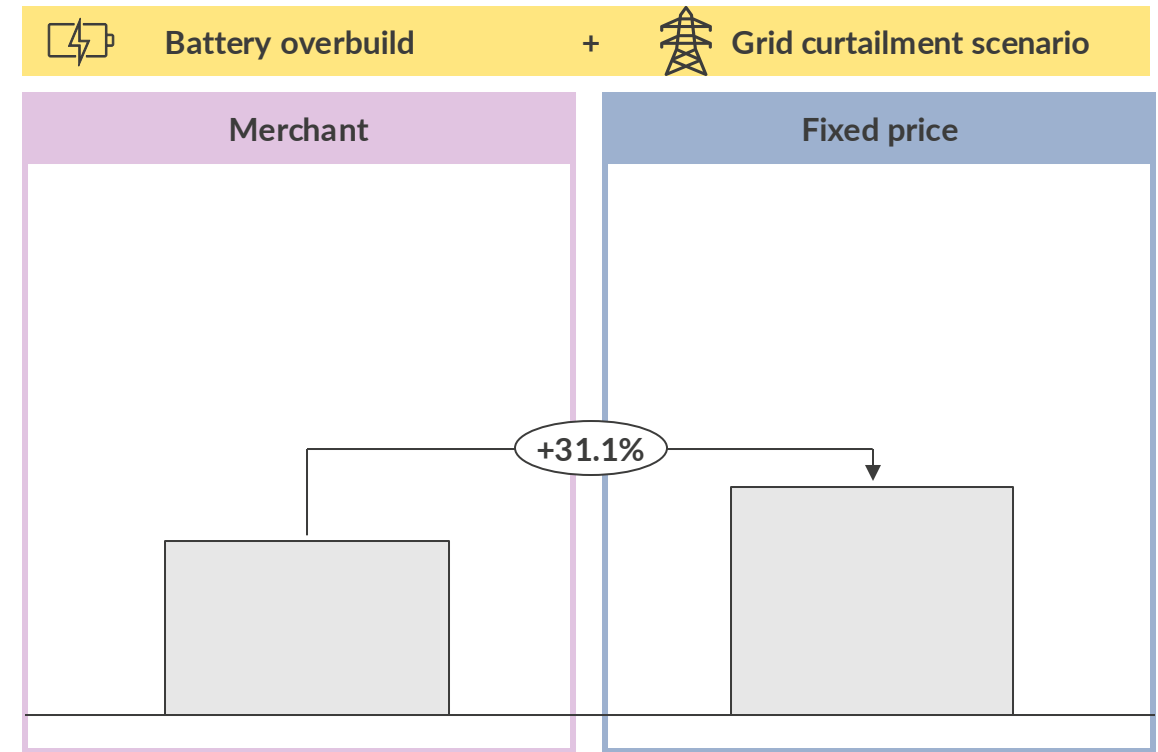
Levered equity IRR¹ of 2h standalone battery in different scenarios, COD 2026²
%



Assumptions on debt financing:



Debt Service Coverage Ratio (DSCR)

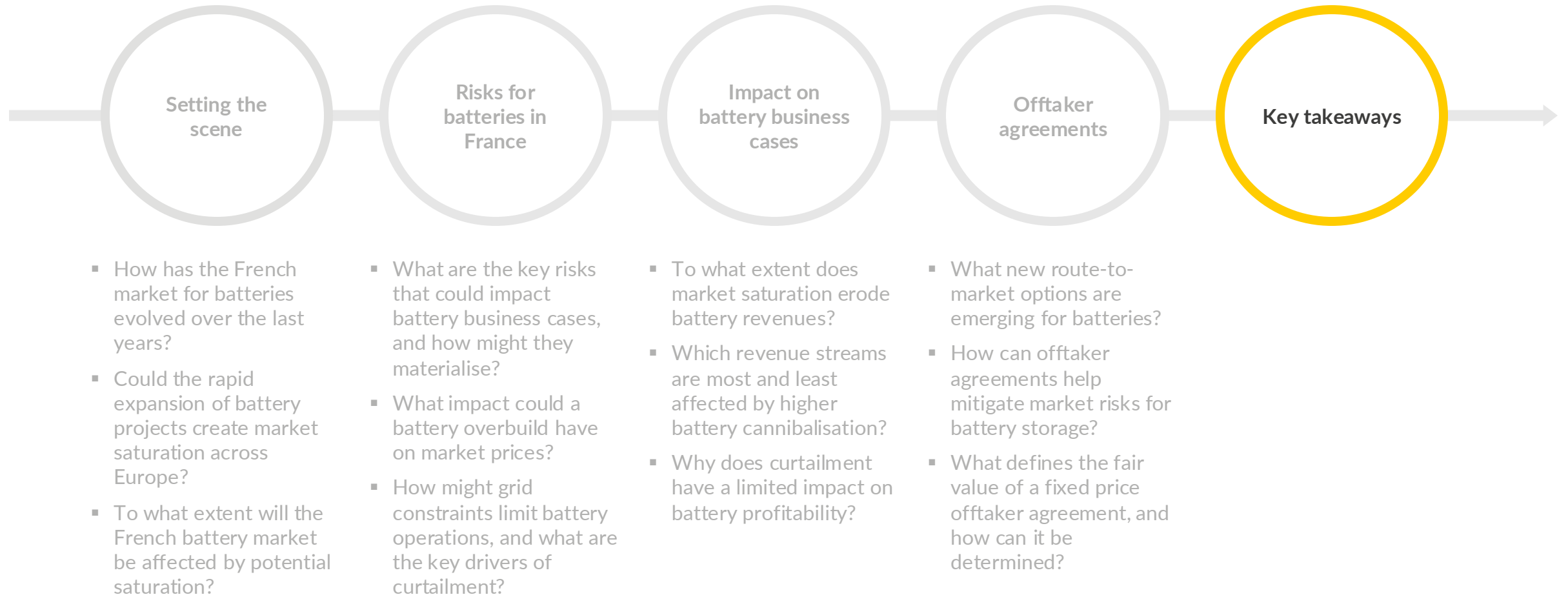


Debt maturity



Leverage

1) Internal Rate of Return; 2) HTB2, TURPE 6.



Key takeaways

- 1 With BESS deployment having strongly accelerated in France and across Europe over the recent years, attention is now turning to market saturation in ancillary services and other risks to income streams for batteries.
- 2 If battery deployment outpaces renewable growth, not only will ancillary services saturate more quickly, but wholesale price volatility will also decline, reducing opportunities for energy arbitrage. In this context, all revenue streams for batteries would be negatively impacted.
- 3 Grid curtailment, imposed by constraints in grid infrastructure, another risk to battery revenue streams, has a limited financial impact on batteries, even in the unlikely case that all curtailment hours manifest, as curtailment hours mostly coincide with low-price periods.
- 4 To secure financing, owners could consider offtaker agreements, which mitigate market risks and ensure stable revenues throughout the contract duration.
- 5 Such a fixed price agreement decreases the levered equity IRR by between in a Central scenario but increases in a downside scenario, as the project owner is less exposed to risk and can lever the project with more debt.



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Details and disclaimer

Publication

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23rd April 2025

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