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ENERGY RESEARCH

Equity and Debt Cases for Batteries in France

Public Report

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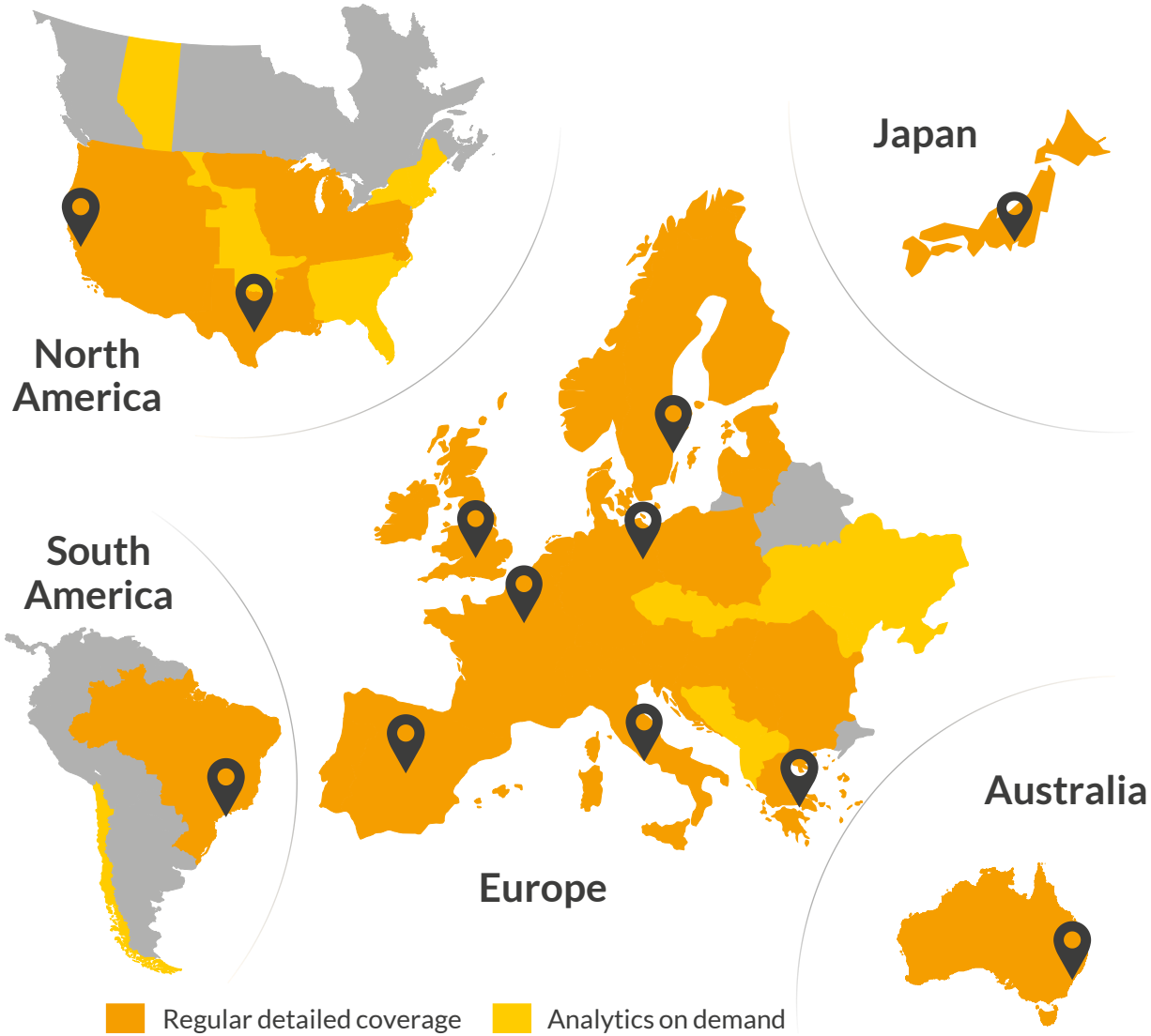

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transactions supported in 2022

Source: Aurora Energy Research

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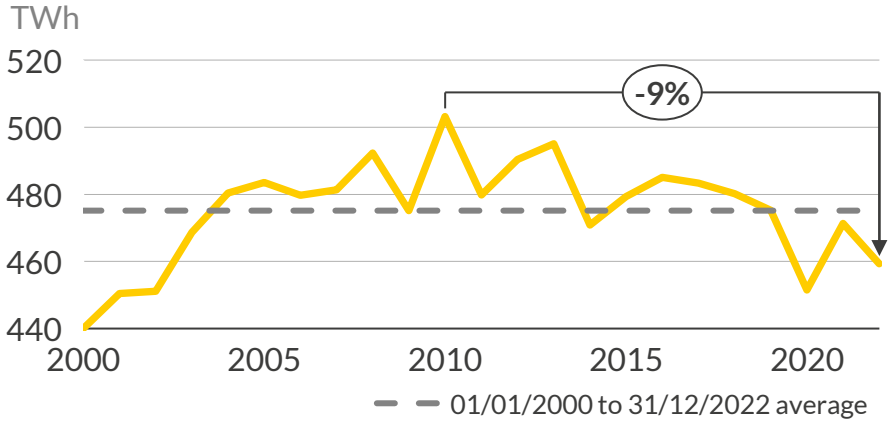
- How does the Aurora battery dispatch model work?
- How does the profitability of a 2-hour battery respond to the equity and the debt scenarios defined in the previous section?

Key takeaways

Recent shocks have impacted the very fundamentals of energy systems …

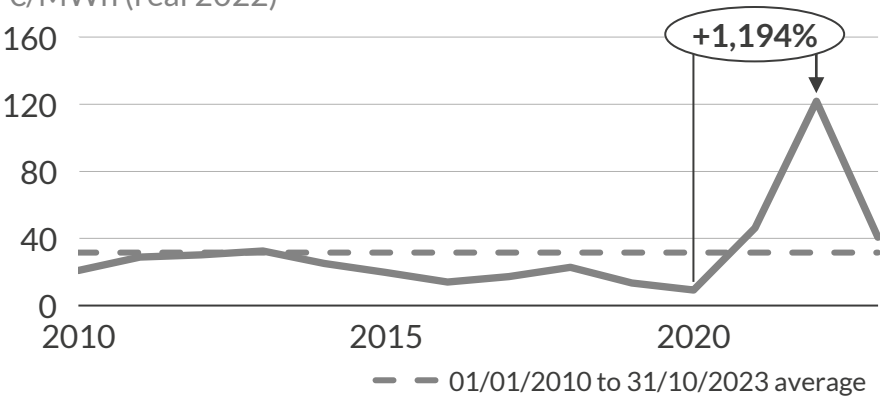
The outbreak of COVID-19 accelerated the general decline of French power demand …

French power demand



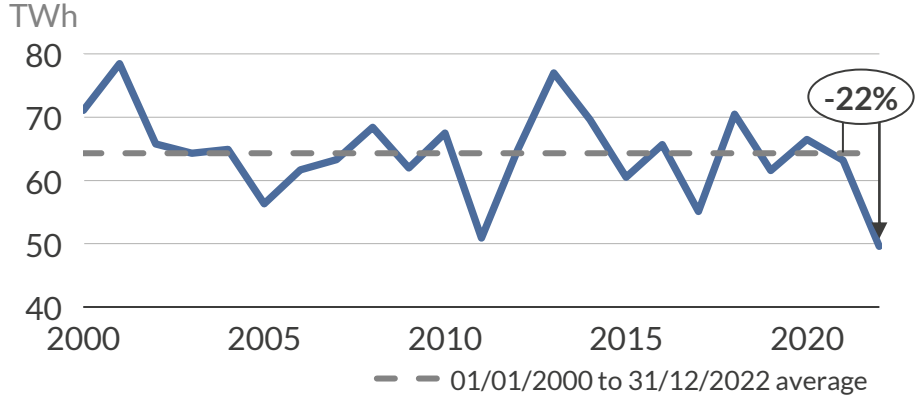
Gas prices spiked as a result of the Russian invasion of Ukraine…

Gas price (TTF)



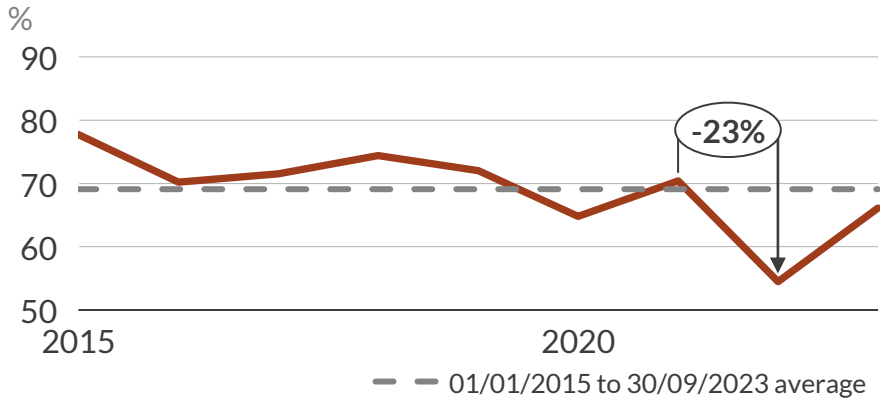
Climate change caused a severe drought in France, reducing the hydro production in 2022 …

Hydro production



Reactor shutdowns led to significant decreases in nuclear availability…

Nuclear fleet availability



Sources : Aurora Energy Research, RTE, IEA

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9% demand drop since 2010

Mainly due to long-term efficiency gains and de-industrialisation, and intensified by the outbreak of COVID-19.

Up to 238 €/MWh for gas price (average Aug. 2022)

Disruption and uncertainty in gas supply due to the Russia-Ukraine war.

24% hydro production loss (2022)

Drier rivers and low reservoir levels disrupting the operation of hydroelectric dams.

54% nuclear availability (2022)

Stress corrosion and other maintenance work postponed due to COVID-19 leading to a drop in nuclear availability (by 23% compared to 2021).

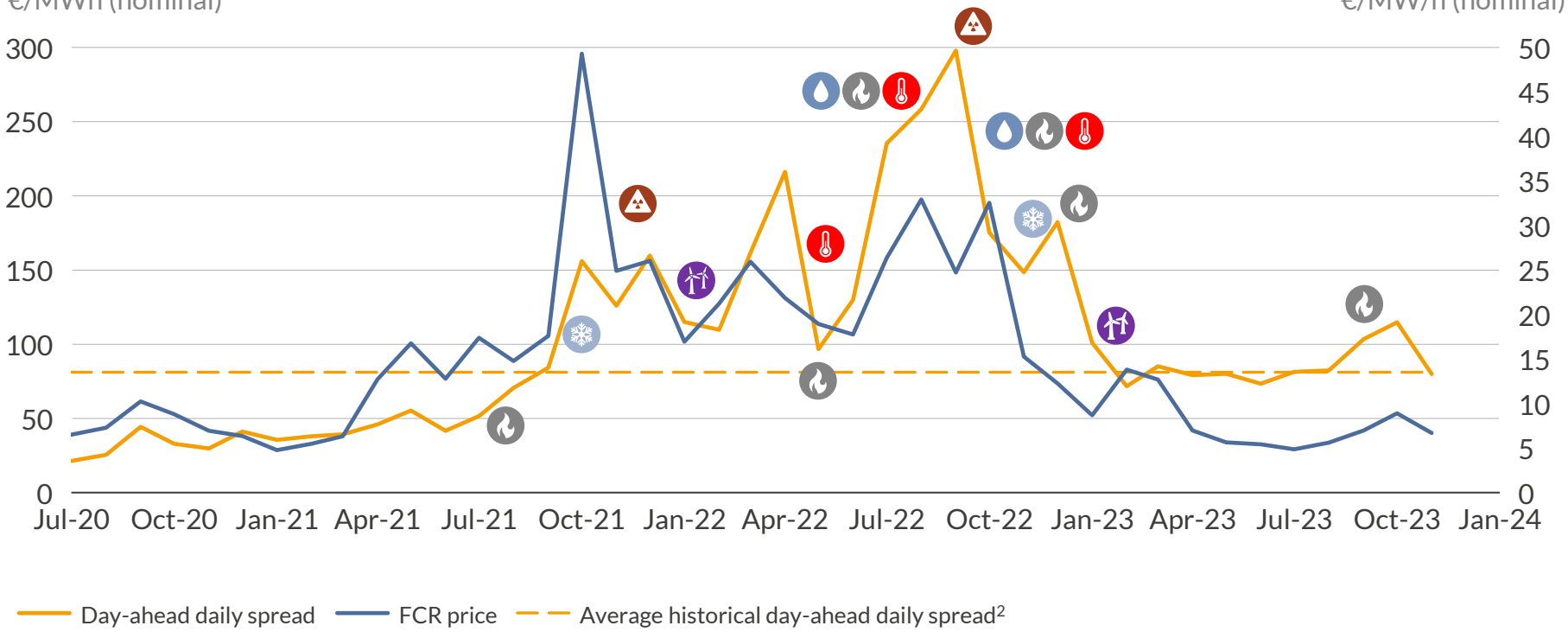
… leading to significant fluctuations in day-ahead and ancillary service prices

Main market uncertainties

- **Reduced nuclear availability** due to ageing fleet's increased technical risks
- **Rising demand** due to cooling temperatures in France
- **Renewables production uncertainty** due to weather dependence
- **Lower hydro production** due to dryness (climate change effect)
- **Supply issues** due to warming temperatures in France
- **Commodity price volatility** from geopolitics and global demand trends

Monthly average day-ahead daily spread[1]
€/MWh (nominal)

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



1) Based on data up to 15/11/2023; 2) From 01/01/2019 to 30/06/2020.

Sources : Aurora Energy Research, RTE

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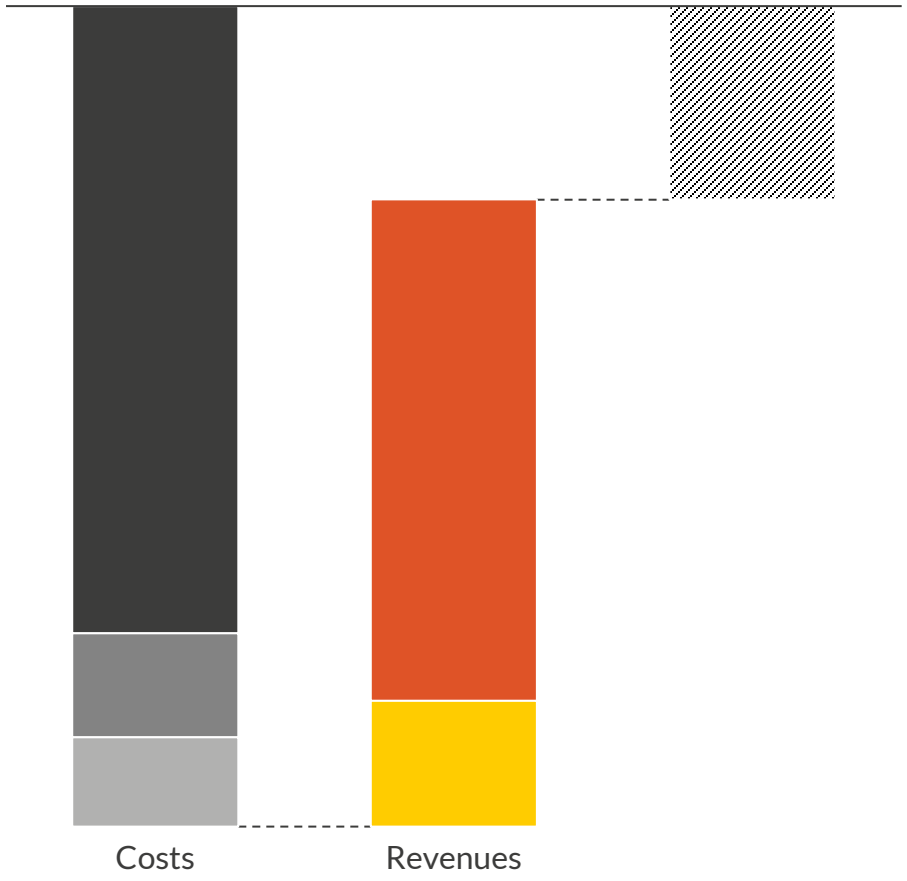
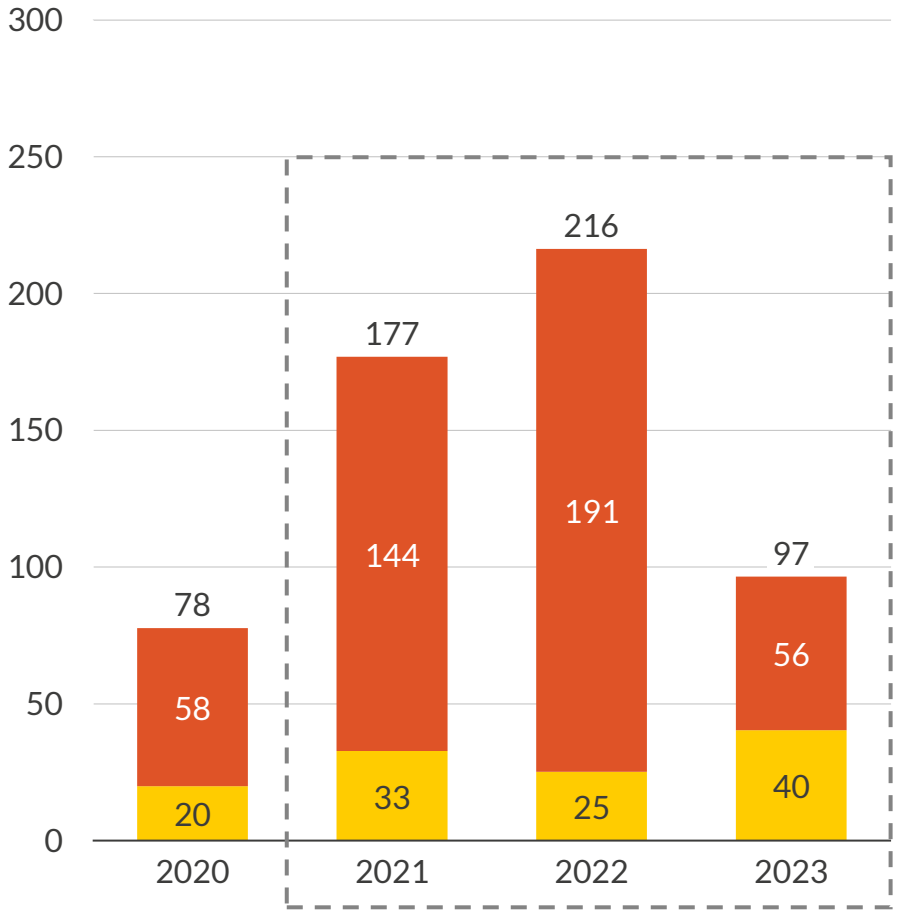
- The occurrences of hydro and nuclear events (such as variation in water availability due to dry weather or nuclear maintenance shutdowns etc.) are critical factors shaping electricity prices.
- During periods of high volatility, batteries can capitalise on price differentials by charging during low-price hours and discharging during high-price hours. This volatility-driven strategy enhances the revenue potential for battery operators.
- However, batteries have traditionally extracted most of their revenues from ancillary service provision (notably in the FCR market) through their ability to respond quickly.
- Importantly, FCR market prices are closely tied to the opportunity costs of assets in the day-ahead market.

Batteries which entered the market in 2021 recovered 100% of their CAPEX in less than three years

Economics of a 1-hour battery entering the market in 2021[1,2]
€/kW (nominal)



Yearly gross margins of a 1-hour battery
€/kW (nominal)



CAPEX OPEX TURPE[3] FCR Capacity Market NPV as of today

1) Economics of a battery until the 31/10/2023; 2) Battery availability set at 98%; 3) Variable grid charges. The fixed ones are included in the OPEX.

Source : Aurora Energy Research

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- Batteries have benefitted significantly from the 2022 energy crisis, capturing unusually high prices.
- Assuming participation only in the FCR and in the capacity market, batteries entering the market in 2021 have almost recovered 80% of its costs over the last three years.
- The capacity market also had higher prices than usual, as nuclear reactors had lower availability in 2023. Capacity market prices increased leading to an 86% increase in revenues compared to the average previous three years.
- The capacity market provided 24% of BESS revenues between 2021 and 2023.

Learn more about battery investment opportunities:

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Battery business cases

- How does the Aurora battery dispatch model work?
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Key takeaways

Battery revenues are dependent on a number of market and policy uncertainties, that can lead to significant upsides or downsides

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	Risk	Key drivers
Technology	**Renewables penetration**	Technology costs, policy support and renewables cannibalisation may challenge renewables revenue expectations and therefore renewable buildout levels.
	Batteries development	Technology costs and regulatory decisions may challenge BESS revenue expectations.
	Renewables uncertainties	Weather-related uncertainties impact intermittent generation.
	Nuclear availability	The ageing nuclear fleet may encounter more frequent technical constraints (e.g. stress corrosion).
Policies	**Delay in the aFRR opening**	The transition from a regulatory mechanism to a market-based one may be delayed as RTE has a derogation until June 2025 to switch.
	Interconnections	The planning of new build interconnectors may affect export/import levels.
Market	**CO_2 prices**	Market dynamics, governmental policies, and international agreements (e.g. carbon tax, ETS, etc.) drive CO_2 prices, impacting emission reduction incentives.
	Gas prices	Geopolitical uncertainties may impact gas prices upward.
Demand	**Base demand**	Decarbonisation policies may affect demand levels by electrification (transport, industry etc.).
	Flexible demand	A larger share of smarter, price-responsive devices would increase flexibility demand.

Source : Aurora Energy Research

In this report, we modelled new scenarios to reflect a broad range of possible outcomes for batteries

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	Equity		Debt			
Scenario name	**High** H	**Weather sensitivities**	**Low** L	**Battery overbuild**	**aFRR delay**[1]	**Wholesale only**
Key industry concern	**What would be the impact of a higher price world?**	**What would be the impact of non-Central weather conditions?**	**What would be the impact of a lower price world?**	**What would be the impact of battery overbuild?**	**What would be the impact of a delay in the opening of the aFRR capacity market?**	**What would be the profitability of a battery only participating in the day-ahead market?**
Why ?	It would increase prices in the day-ahead as well as on the ancillary services markets.	Weather risk would impact day-ahead prices, daily spreads and ancillary services prices.	It would decrease prices in the day-ahead as well as in the ancillary services markets.	It would increase the competition in the day-ahead as well as ion the ancillary services markets.	There is a regulatory risk on the opening of the aFRR capacity market.	It would be an extreme case where the FCR and the aFRR market are fully cannibalised.
Difference to Aurora Central	▪ Higher commodities prices ▪ Higher demand ▪ Higher RES CAPEX ▪ Lower nuclear ava. ▪ Higher aFRR procurement target	▪ Wind/solar/run-of-river profiles and generations ▪ Demand profile ▪ Total demand ▪ Hydro dams inflow pattern	▪ Lower commodities prices ▪ Lower demand ▪ Lower RES CAPEX ▪ Lower aFRR procurement target	▪ Increasing battery buildout	▪ The aFRR capacity market is only available from 2026.	▪ Battery does not participate in the FCR and the aFRR market.

Deep-dived in this presentation

1) Opening aFRR capacity postponed by 1 ½ year.

Source: Aurora Energy Research

Using Aurora's in-house power model, we modelled the Central case across several weather years

Weather conditions exert a considerable influence on electricity markets by impacting both supply and demand dynamics. On the one hand, they determine the generation from renewable sources and, on the other hand, they influence the demand for electricity, illustrated by factors such as the use of electric heating.

Weather conditions

- Temperature
- Wind speeds
- Solar irradiance
- Precipitation

- We use an extensive set of recent historical data covering 11 weather years (2006-2016), up to hourly granularity.

… impact market fundamentals

- Demand
- Renewable production
- % Renewables load factors
- Hydro levels

- Using Aurora's in-house power model, we model the Central case with the chosen representative weather year to forecast and analyse long-term market-level outcomes.
- Aurora Central uses 2013 patterns scaled to long-term weather averages, giving the most representative outcome across key metrics.

… and therefore power prices and asset margins.

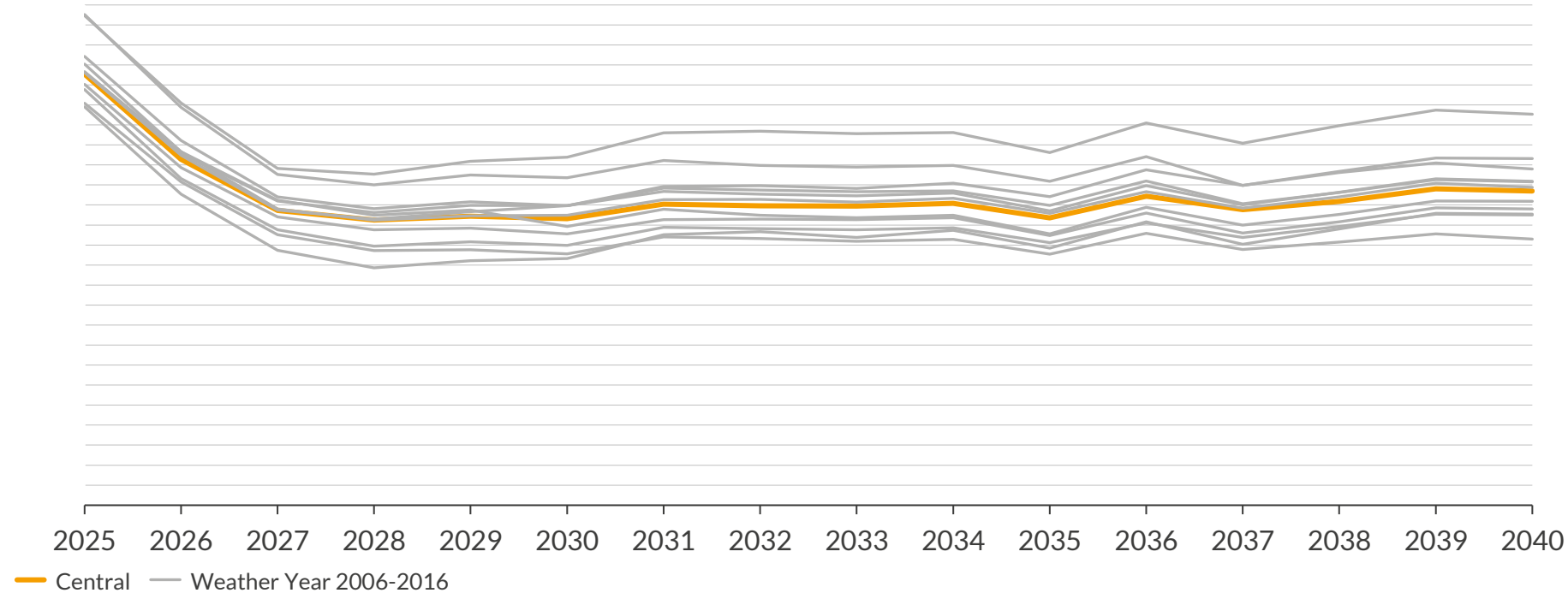
- Wholesale prices
- Asset capture prices
- Imbalance prices
- € Asset margins

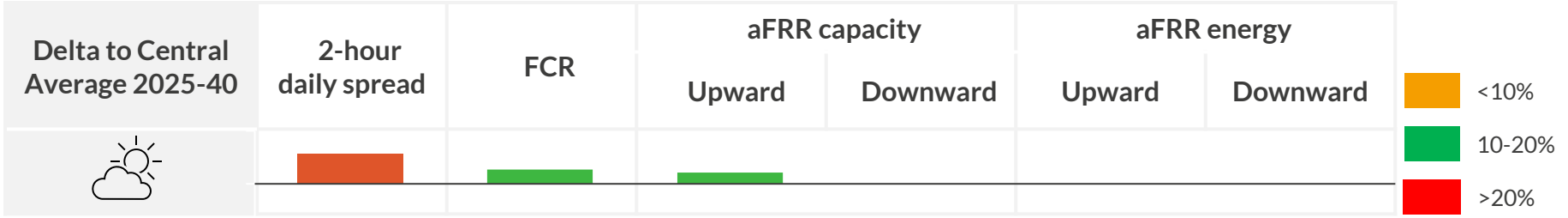
- Weather Year runs are based on the capacity mix outlined in the Central scenario.
- By using Central scenario as a reference point, the Weather Year runs aim to provide insights into how different weather conditions can interact within the established capacity mix.

Source: Aurora Energy Research

On average, weather sensitivities increase the daily spread and therefore the prices of the FCR and the aFRR capacity upward

Wholesale prices
€/MWh (real 2022)





- While the capacity mix of the Weather Years scenarios is based on Aurora Central, the deviation from our Central weather forecast increases the market volatility on average, increasing the opportunity cost of batteries and pump storages on the ancillary service markets.
- The baseload price and the day-ahead market dispatch (i.e., by including or not a starting cost) impact the opportunity cost of conventional power plants on the FCR and the aFRR capacity markets.
- Overall, the FCR and the aFRR capacity prices are on average higher compared to our Central scenario.
- The aFRR energy prices are on average similar to our Central forecast as those prices are highly correlated with the baseload price.

Source: Aurora Energy Research

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Key takeaways

Aurora analysed the economics of batteries through a dispatch model that optimises between the wholesale and ancillary service markets

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1

Inputs

1.A - Energy markets

	Modelling	Granularity	Foresight
Wholesale markets			
▪ Day-Ahead (DA)	Iterative modelling with dispatch and capacity investment decisions	Hourly	Perfect[5]
▪ Intraday (ID index)	Stat. modelling of VWAP[1] of trades in the last 3 hours before delivery	Hourly	Imperfect
Ancillary services			
▪ FCR[2]	Minimum constraints of FCR capacity in any given settlement period	4-hour	Perfect[5]
▪ aFRR[3] capacity	Capacity prices in each direction	Hourly	Perfect[5]
▪ aFRR energy	Single price in direction of net imbalance. Imbalance volumes determined stochastically, driven by demand & RES generation	Hourly	Imperfect
Capacity market (CM)	CM does not affect the dispatch optimisation[4]	Yearly	N/A

1. B - Battery parameters

- Degradation
- Lifetime (15 years)
- Target cycle rate (2 daily cycles)
- Duration (2h)
- Round-trip efficiency (86%)
- Battery capacity (1MW)
- Grid level (HTA)
- Availability (98%)

2 Aurora's dispatch model optimises the battery revenues across multiple markets

- Using DA, FCR, and aFRR capacity prices with perfect foresight, the battery makes daily capacity and dispatch decisions across markets simultaneously.
- As the battery has a limited view of aFRR energy prices, its dispatching depends on:
  - aFRR programming constraints
  - aFRR prices attractiveness compared to other markets
  - its state of charge to meet its prior commitments and avoid paying penalties.

3 Dispatch model outputs

Revenues per market

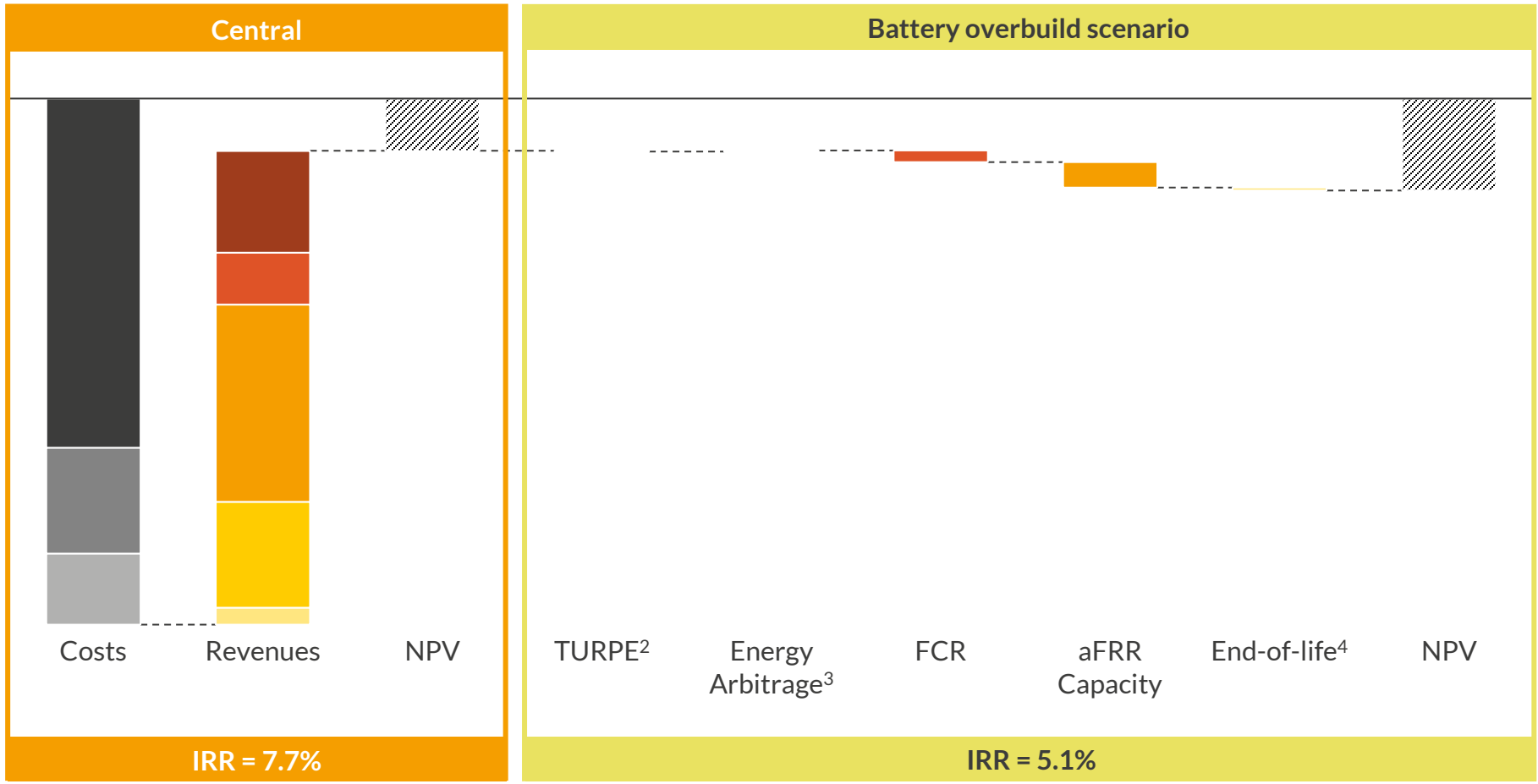
NPV and IRR

1) Volume-Weighted Average Price; 2) Frequency Containment Reserve; 3) automatic Frequency Restoration Reserve ; 4) Capacity market should be seen here as an extra cashflow, it is not part of the optimisation dispatch; 5) Perfect foresight the day before delivery.

Source: Aurora Energy Research

A higher battery build-out decreases IRRs by 2.6pp%

System NPV[1]
€/kW (real 2022)



1) Discount rate of 11%; 2) Variable grid charges. The fixed ones are included in the OPEX; 3) Energy arbitrage includes day-ahead, intraday and aFRR energy gross margins; 4) Capacity Market revenues are the same in the 3 scenarios; 5) The end-of-life value is calculated based on the additional discounted gross margins the battery could generate assuming a longer lifetime (+11 years).
Source: Aurora Energy Research

- In a scenario where battery capacity grows at a faster pace, the day-ahead market volatility decreases.
- As a result of a larger battery cannibalisation, the FCR and the aFRR capacity market prices decrease, reducing the gross margin of batteries on those markets.
- The end-of-life value of the battery decreases as the potential gross margins generated after the battery decommissioning are lower than in the Central scenario.
- Overall, this would push the battery IRR down from 7.7% to 5.1%.

Margins vary across weather years – averaging margins under a range of weather scenarios lead to an increased 11.0% IRR

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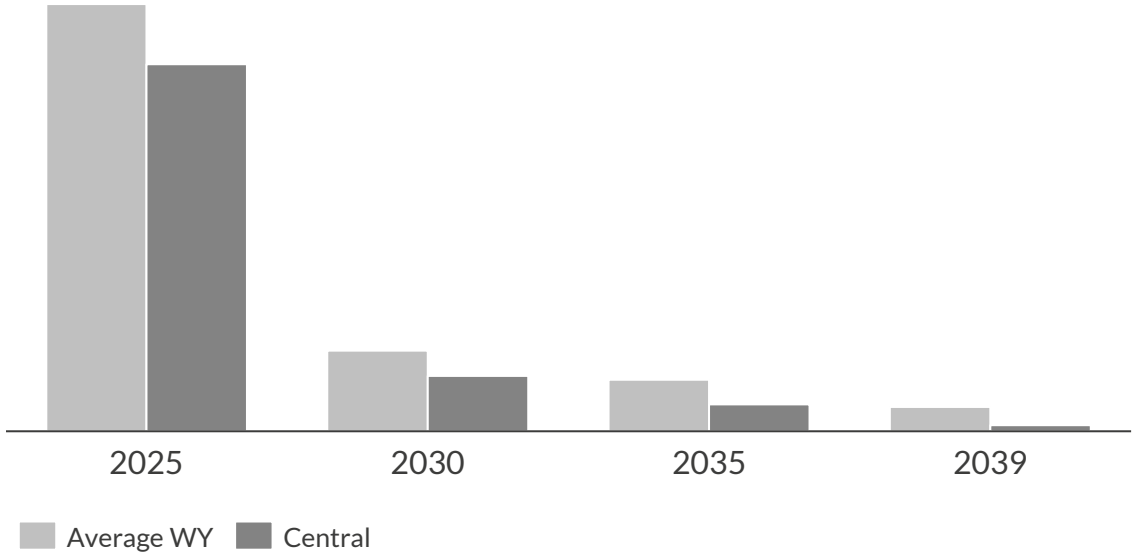
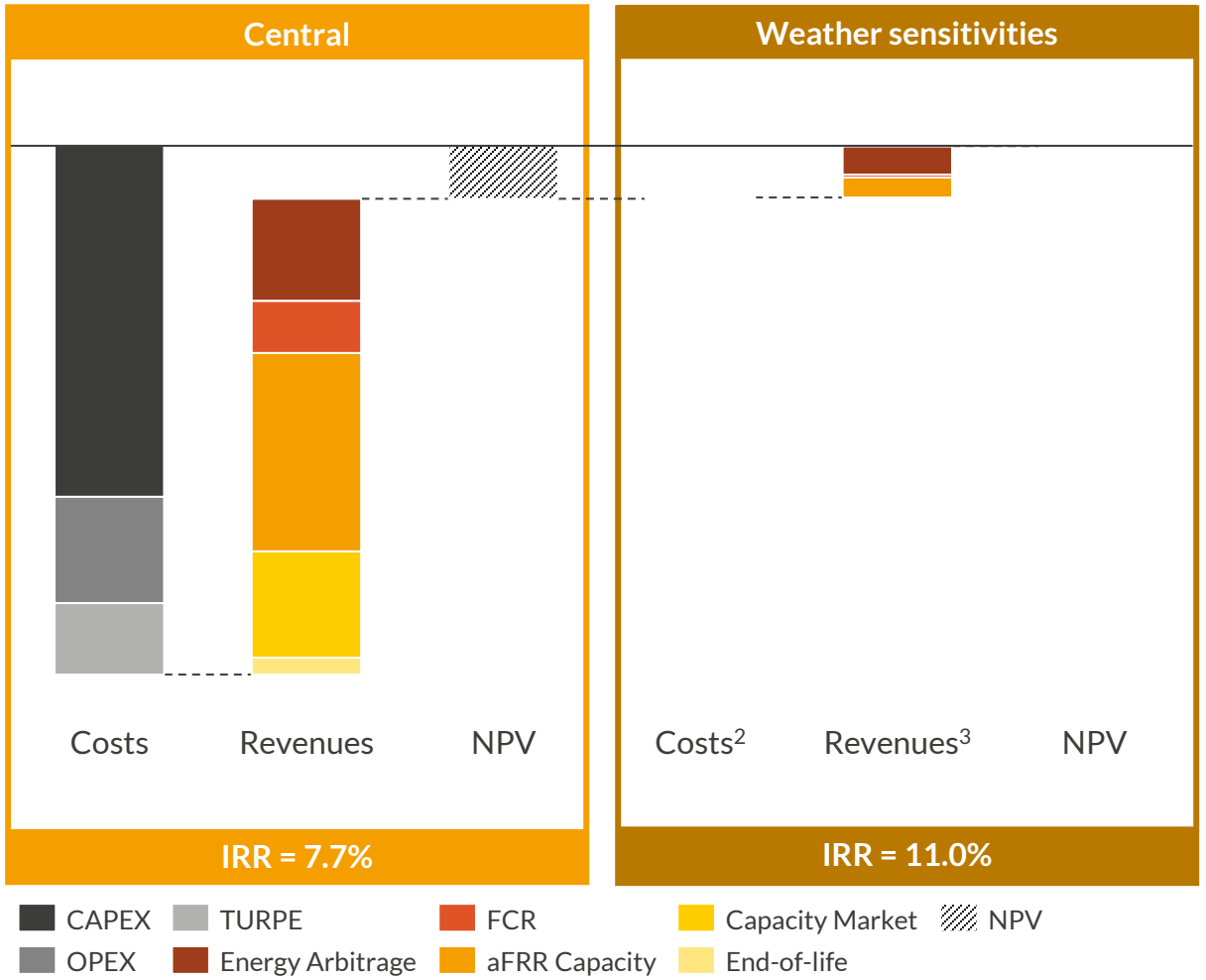
Battery gross margin
€/kW (real 2022)



- We computed the average gross margin that a battery can get in a year where weather conditions are unlike those of Central.
- On average, a battery captures higher gross margin compared to Aurora Central scenario across its whole lifetime leading to a 3.3pp% higher IRR.
- The increase in revenues is due to the increase of FCR and aFRR capacity prices as well as a higher market volatility – increasing the arbitrage revenues of the batteries on the wholesale market.

NPV calculations of a stand-alone battery with COD 2025[1]
€/kW of grid capacity (real 2022)



Source: Aurora Energy Research

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Key takeaways

1. The events of the last few years showed that market conditions are not as smooth as in a central case. Various economic factors, supply and demand dynamics and regulatory policies significantly influence the day-ahead electricity market, with substantial effects on ancillary services as well.

2. A range of uncertainties, resulting in variations in market prices, can lead to upsides (such as higher fundamentals or alternative weather conditions) and downsides (such as a delayed opening of the aFRR capacity or a higher penetration of batteries) on battery business cases.

3. In the Central scenario, a standalone 2-hour battery coming online in France in 2025 sees a 7.7% IRR if it participates in all markets (wholesale markets, aFRR, FCR and capacity market).

4. A larger penetration of batteries would lower the IRR to 5.1%, more than 2pp% below our Central case due to lower prices on the ancillary services markets where the batteries make most of their profit.

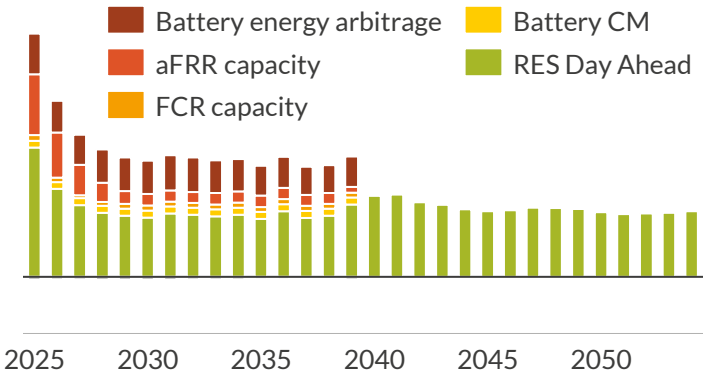
5. Alternative to Central weather conditions can increase the profitability of a battery by increasing market volatility. On average, a battery captures higher gross margin compared to Aurora Central scenario across its whole lifetime leading to a 3.3pp% higher IRR.

We offer tailored battery support for strategy, development and transactions

Services		Deliverable
1	**Battery revenue assessment**	▪ Bespoke site-specific forecast of key revenue streams for batteries (2025-2050) based on battery (duration, efficiency, cycling target, AC vs. DC) and solar technology (profile)
2	**Battery optimal sizing**	▪ IRR sensitivities based on size, duration and target cycling rates
3	**Colocation benefits assessment**	▪ Market report covering the upsides resulting from co-location of a battery asset with a wind or solar asset (baseload PPA, imbalance costs, portfolio effect, risk hedging)
4	**Buy-side support for battery acquisition**	▪ VDR review, market analysis, long-term volume forecast, probability of success, transfer sheet, regulatory overview
5	**Market entry strategy**	▪ Off-the-shelf European-wide report covering the attractiveness of battery investments, including CAPEX/OPEX, routes-to-market and long-term IRR expectations for standard business models
6	**Ancillary service scenario analysis**	▪ Central forecasts (2025-2050), including aFRR capacity, aFRR energy (up and down), FCR capacity revenues, based on client or Aurora visions
7	**Battery auctions bidding support**	▪ Battery auction price forecast in countries with standalone battery subsidies

Illustrations

1 **Battery revenues**
EUR/MW



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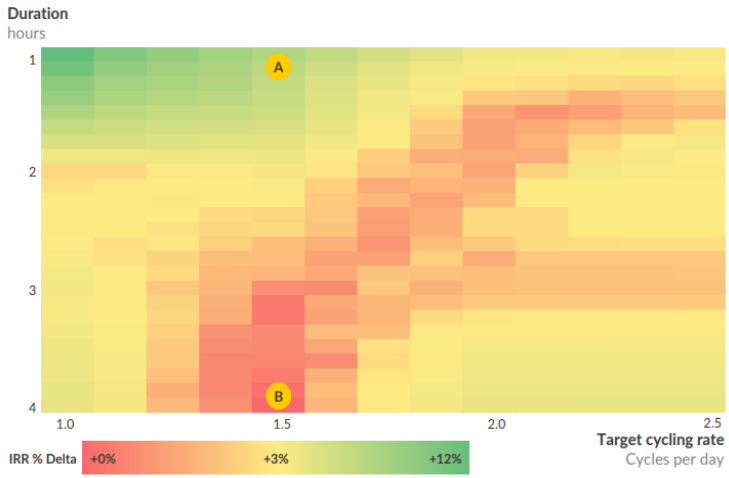

Source: Aurora Energy Research

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

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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 case forecast prices until 2050:
  - Hourly wholesale power prices
  - Yearly capacity market prices
  - 4-hourly FCR market prices
  - Hourly aFRR (energy and capacity, upward, and downward) 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 2050; IRR and NPV for two entry years

For more information on the French battery landscape please contact:

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Chronos delivers Aurora's state-of-the art battery investment case analysis with unmatched ease of use and speed

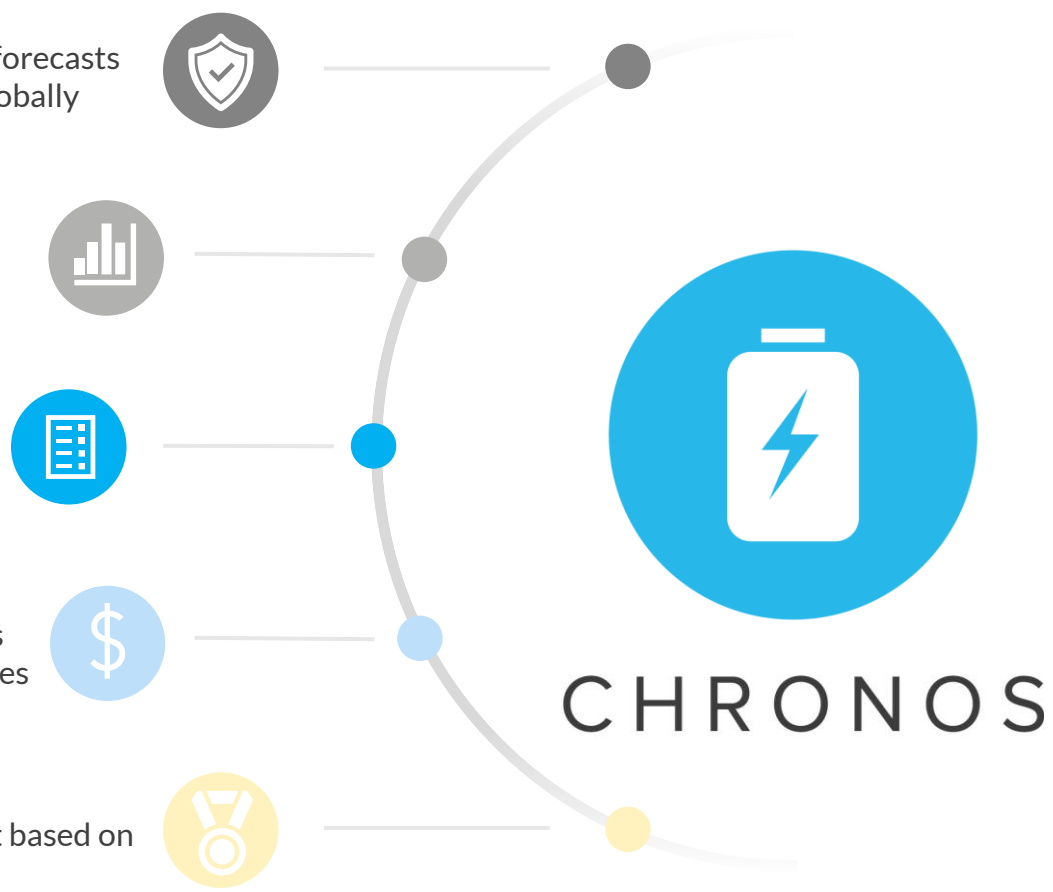
Aurora's trusted data
Underpinned by Aurora's bankable market forecasts used by and relied on by 350+ companies globally

Simple, intuitive, user-centric
User-friendly, and simple, requiring minimal training and no sophisticated in-house modelling capabilities

Exact same state-of-the-art model we use ourselves
Asset dispatch model integrated with our fundamental market forecast which structurally accounts for imperfect foresight

Cost-effective
Our simplicity and unique cloud-based SaaS architecture means large cost savings on set up, maintenance and licenses themselves

Always up-to-date
Easily update your portfolio's value forecast based on Aurora's latest market forecast



Chronos is the most advanced, feature-rich solution on the market

1 Input your site settings

Up-to-date locational benefits & charges: Chronos allows you to access a comprehensive database of the latest applicable network charges

Co-location support (upcoming): Chronos supports the co-location of solar & wind asset with your battery with different coupling schemes

Locational system balancing: Aurora's fundamental model allows Chronos to capture location-specific value from system redispatch actions

2 Input your technology settings

Customisable degradation: Capture battery degradation as it is defined exactly in your supplier's performance warranty

User-centric work flow: Chronos allows user to save, manage, and easily reuse different type of input data

Fundamental-driven forecast: Chronos is directly integrated with Aurora's long price forecast underpinned by market fundamentals

3 Select your market scenario

Realistic foresight: Chronos dispatch capture the imperfect foresight that battery operators have over future prices

Origin integration (upcoming): Value assets against your own market scenario by exporting scenarios created in Origin to Chronos

4 Analyse results

Bankable valuation on-demand: We can provide reliance on analysis run using Chronos

API: Integrate Chronos directly with your software or automated workflow for large scale computations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