

The French battery market

Prepared for CampusEnR – April 2025

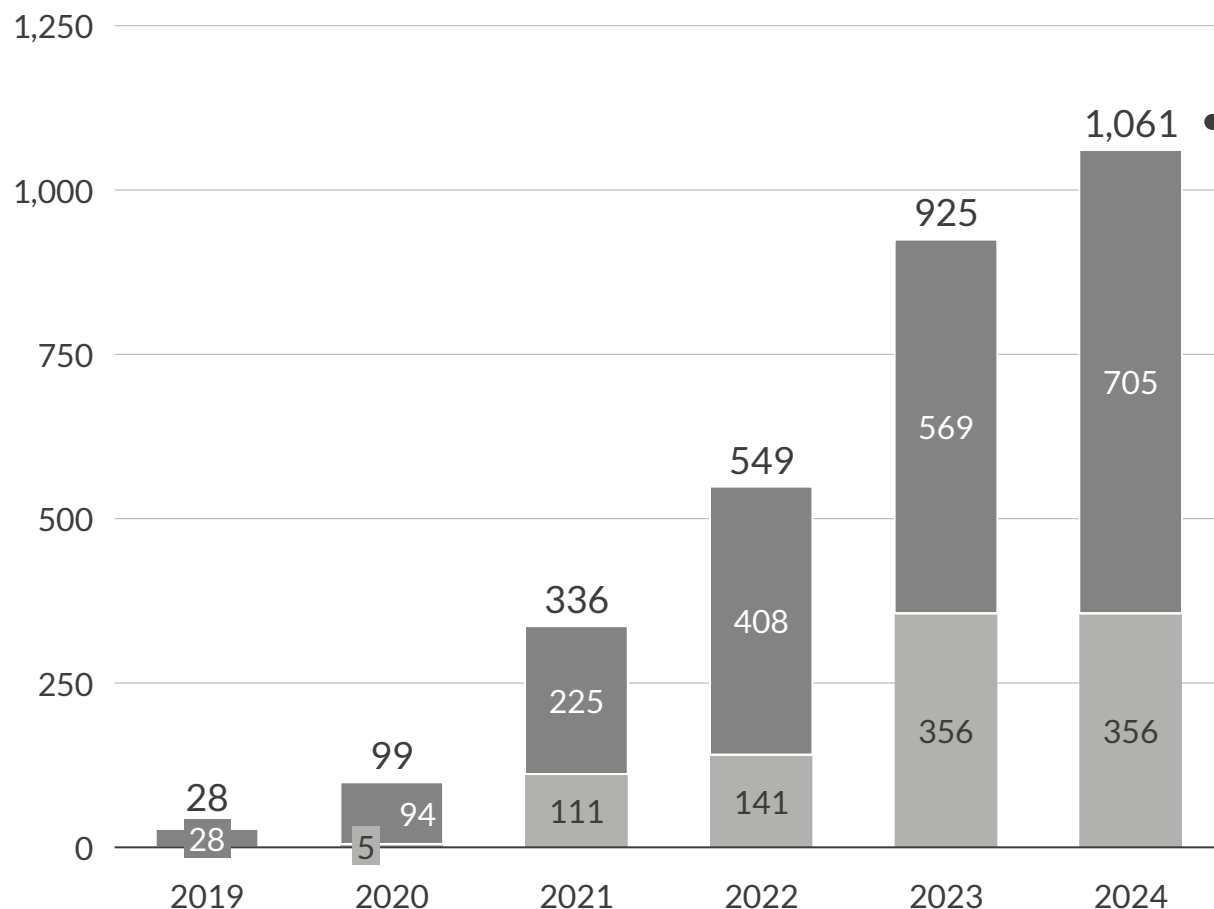


1. **State of the French market**
2. Ancillary services
3. Modelling battery revenues
4. Battery business models

Historical deployment of grid-scale battery storage in France is dominated by 1-hour batteries, reaching 1,061MW total installed capacity in July 2024

Total installed battery capacity¹

MW-nameplate



■ Haute Tension A (HTA) : 1kV<voltage ≤50kV ■ Haute Tension B (HTB) – 50kV<voltage ≤ 500kV

Updates

- As of July 2024, the total installed battery capacity reached 1,061MW, compared to only 28MW in 2019, with an average of more than 200MW per year.
- In the first half of 2024 at least 100MW of new battery capacity has been installed in France¹.
- The pipeline of connection requests for large-scale batteries is significant, with a total of 6,900MW² of battery projects currently on the waiting list for approval by the French grid operators.

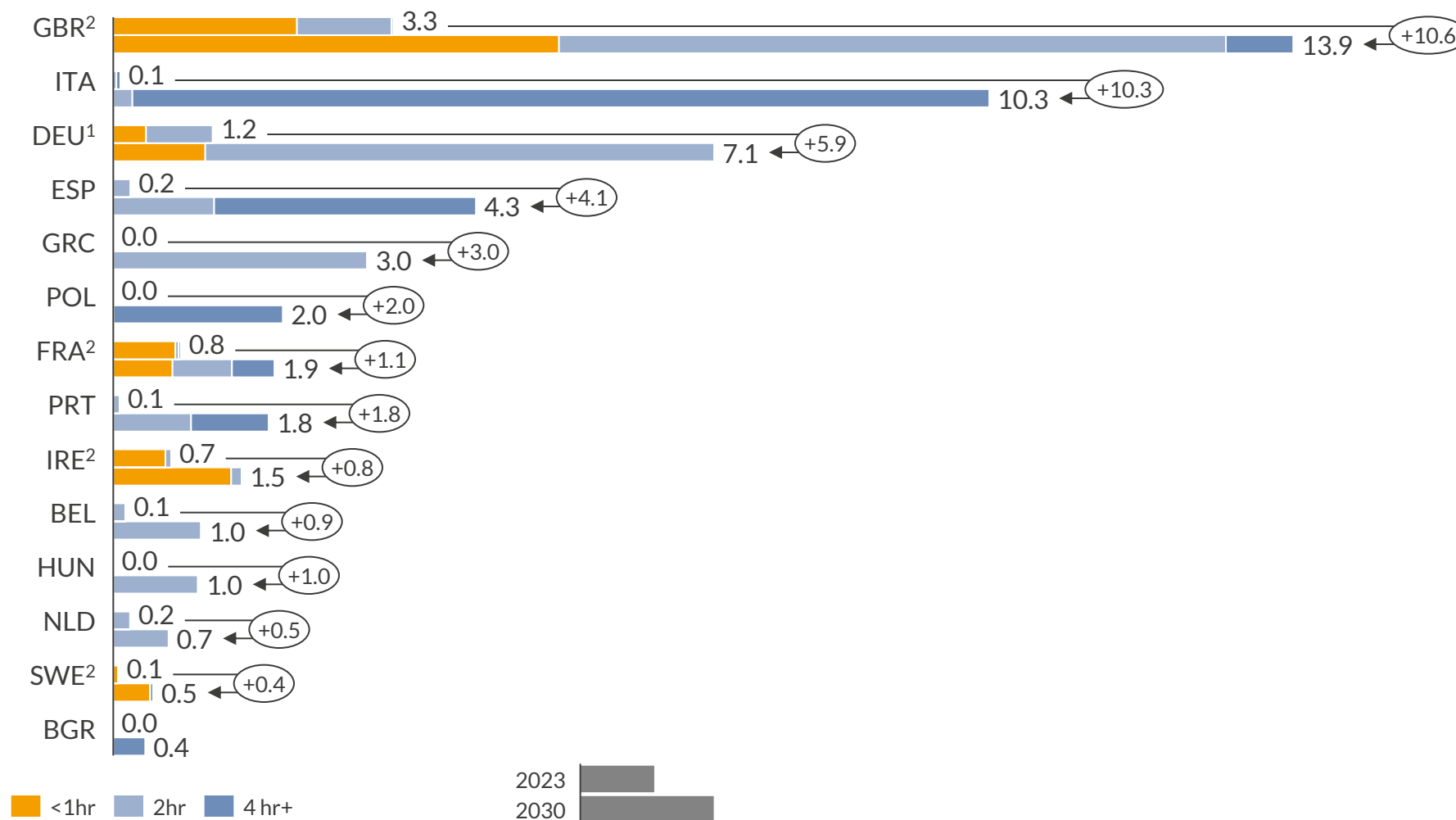
Trends

- Grid-scale battery development has **surged from 2020 onwards** in France. As ancillary markets such as FCR and aFRR become more liquid, batteries have access to these profitable markets.
- A large majority of grid-scale batteries today are **1-hour duration assets** connected to HTA³ grid level. With the FCR Market being saturated with batteries, deployment of longer-duration batteries connected to HTB³ grids is expected to increase in the future.
- 253MW were awarded a contract in the 7-year capacity market auctions** ("AOLT"⁴) for the 2021-2027 and 2022-2028 periods for 29k €/MW/y and 28k €/MW/y respectively. However, most of them are not yet operational.
- The load-shedding tender⁵ is being replaced by a new tender for decarbonised flexible assets⁶, opening a stream for supporting development of new storage assets of at least 4-hour capacity.

1) Open Data Réseaux Energies "Registre national des installations de production et de stockage d'électricité" website – situation on 30/06/24; 2) Figure from 15 October 2024; 3) HTA refers to electricity distributed at voltages between 1kV and 50kV while HTB refers to electricity transmitted at voltages above 50kV; 4) "Appel d'Offres Long-Terme"; 5) Tender for flexibility but focusing on DSR mainly; 6) Appel d'Offre Flexibilité Décarbonée ("AOFD").

Aurora's 2030 forecasted capacity denotes over 40GW of capacity additions from 2023, mainly deployed in GBR, Italy, and Germany

Installed battery capacity in 2023 and 2030 (Aurora Central scenario)
GW



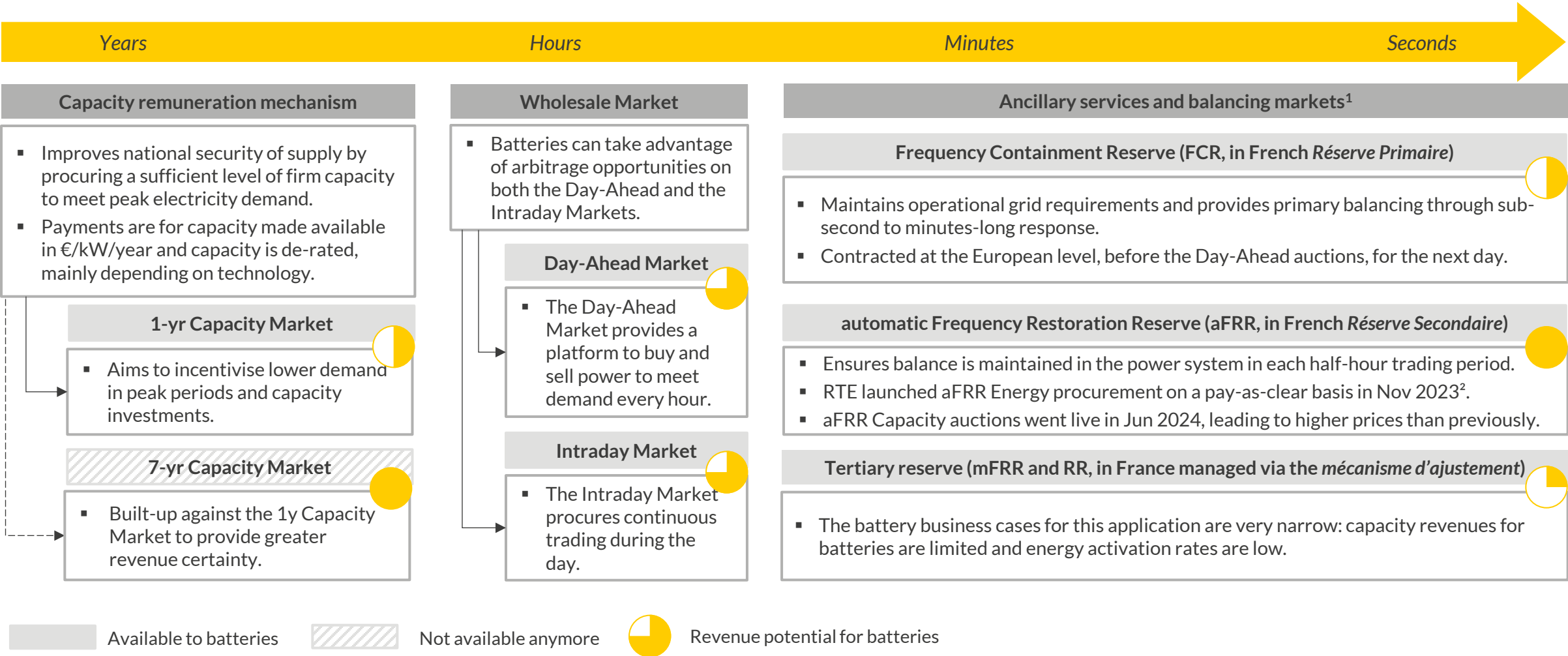
- Germany and Great Britain are market leaders by installed capacity today
- By 2030, Great Britain and Italy are expected to have the greatest installed capacity of batteries, together making up almost 50% of European capacity
- Great Britain, Italy and Germany see the largest capacity additions between 2023 and 2030
- German grid-scale figures¹ mask substantial existing and projected capacity in behind-the-meter storage, from 4GW today to 14GW in 2030
- Significant battery growth is expected in emerging markets, driven by deployment targets in Spain and Greece, along with capacity market support in Poland and France.
- Other European markets not shown see increases of 300MW or less over the coming 7 years

1) Additional capacity build-out by 2030 is assumed to be predominantly 2h duration in Germany, with 700MW of 1h duration grid boosters. 2) In some regions, ancillary markets remain profitable (eg, Ireland, and the Nordics) which allow 1h duration batteries to build out; capacity markets (eg, in France, Great Britain) also provide some upside for shorter duration batteries.

Batteries can capture several revenue streams, with ancillary services, Wholesale and capacity markets being the most profitable

Delivery

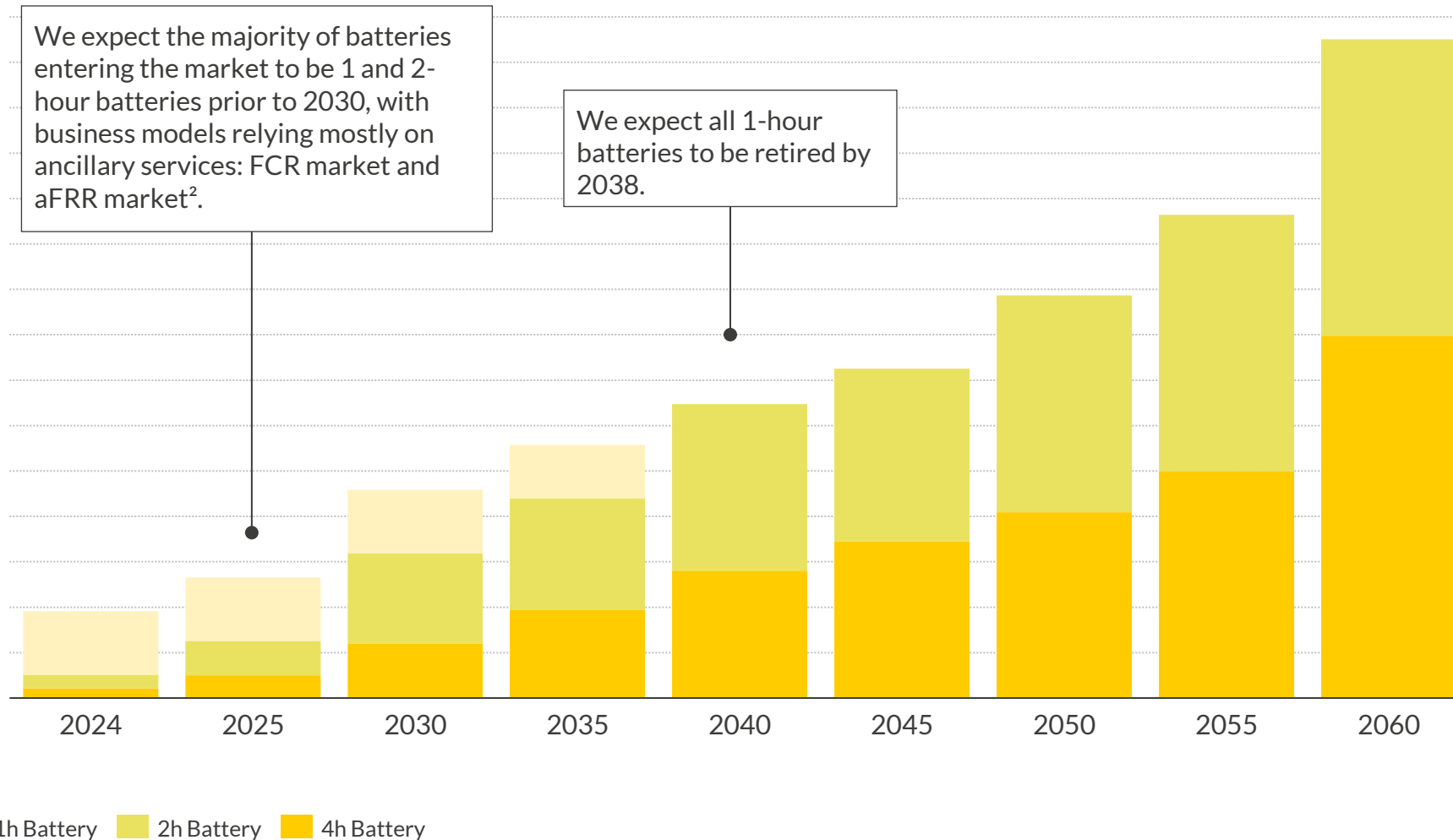
Delivery



1) Tertiary Reserves (mFRR and RR) are not relevant for batteries due to the required duration of these products: 120 minutes for the manual Frequency Restoration Reserve (mFRR) and 90 minutes for the Replacement Reserve (RR); 2) The aFRR Energy has opened on 21/11/2023.

In Aurora's Central scenario, battery capacity in France will be composed mostly of 2h then 4h batteries

Battery capacity in Aurora Central¹
GW



1) Aurora April 2024 Central Scenario; 2) The automatic frequency restoration reserve (aFRR) is activated based on the merit order since 21 November 2023.

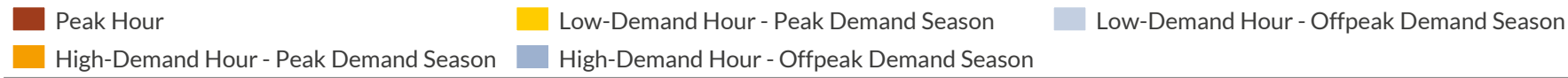
- Our exogenous battery deployment strategy across different durations is shaped by current capacities and the ancillary services accessible to batteries:
 - 1-hour batteries will keep their current capacity (~0.7GW) due to saturation in the FCR market¹. When they expire, 2-hour batteries will replace them in this market.
 - The aFRR² market (up to 1250MW of procurement) will be served mainly by 2+ hour duration batteries.
 - We expect 4-hour batteries to be mainly build for energy arbitrage purpose.
- On top of our exogenous forecast, our power model construct endogenous BESS capacity from 2047, reaching 430MW by 2050 and 2240MW by 2060.

The TURPE 6 mechanism has been designed to encourage consumers to adjust their consumption according to demand

TURPE tariff varies based on the grid level and time of the year

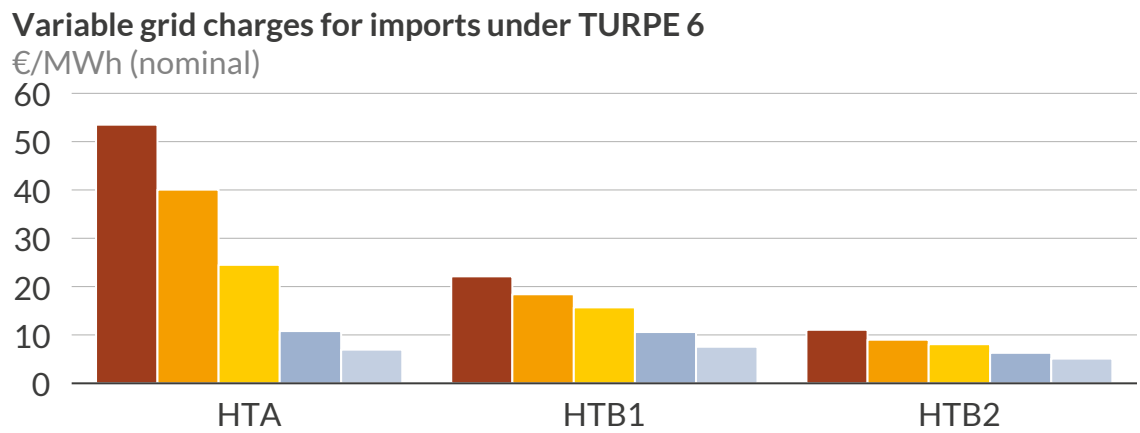
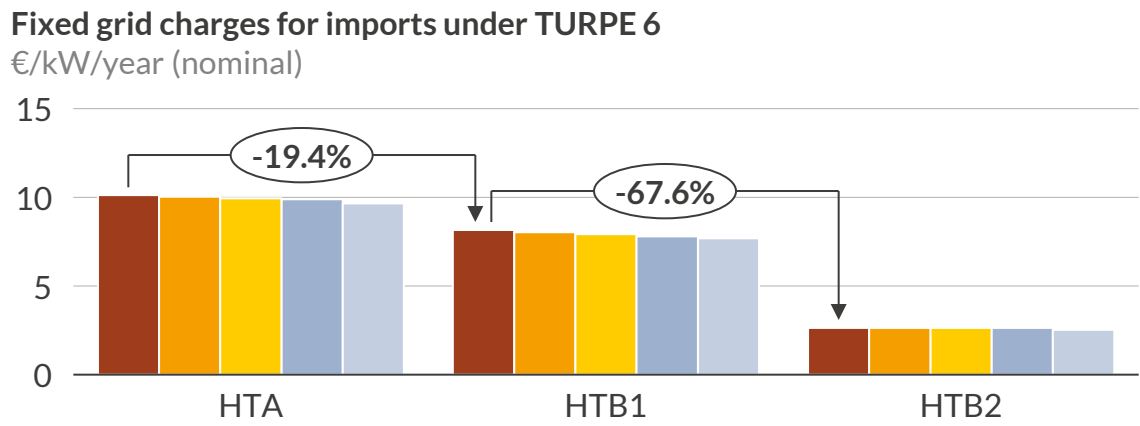
Grid level	Responsible	Voltage domain	Max. installed capacity
HTA	DSO ¹	1-50kV	12MW
HTB1	TSO ²	50-130kV	50MW
HTB2	TSO	130-350kV	250MW
HTB3	TSO	350-500kV	>250MW

Month	Hour type	Hours
Apr. – Oct.	Peak ³	9h-11h / 18h-20h
	High-Demand ³	7h-9h / 11h-18h / 20h-23h
	Low-Demand ⁴	23h-7h
Nov. – Mar.	High-Demand ³	7h-23h
	Low-Demand ⁴	23h-7h



1) Distribution System Operator; 2) Transmission System Operator; 3) Only on working days; 4) Every non-working day is considered as low-demand.

Both fixed and variable TURPE are higher for HTA than for HTB grid level



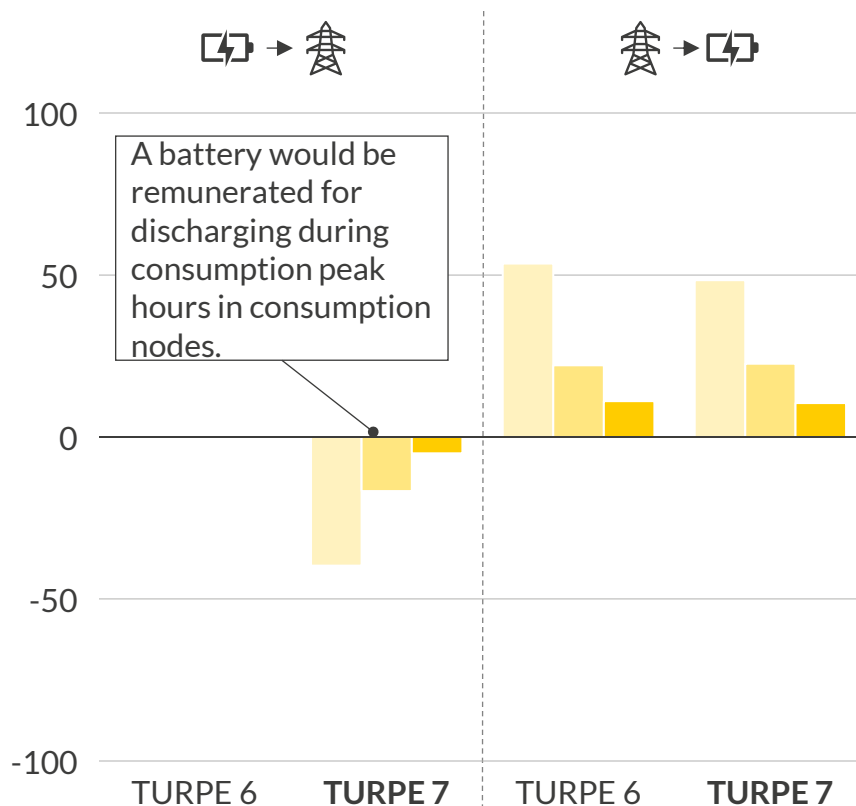
The upcoming TURPE 7 in 2025 will set bidirectional tariffs for batteries to incentivise them to act countercyclically during peak hours



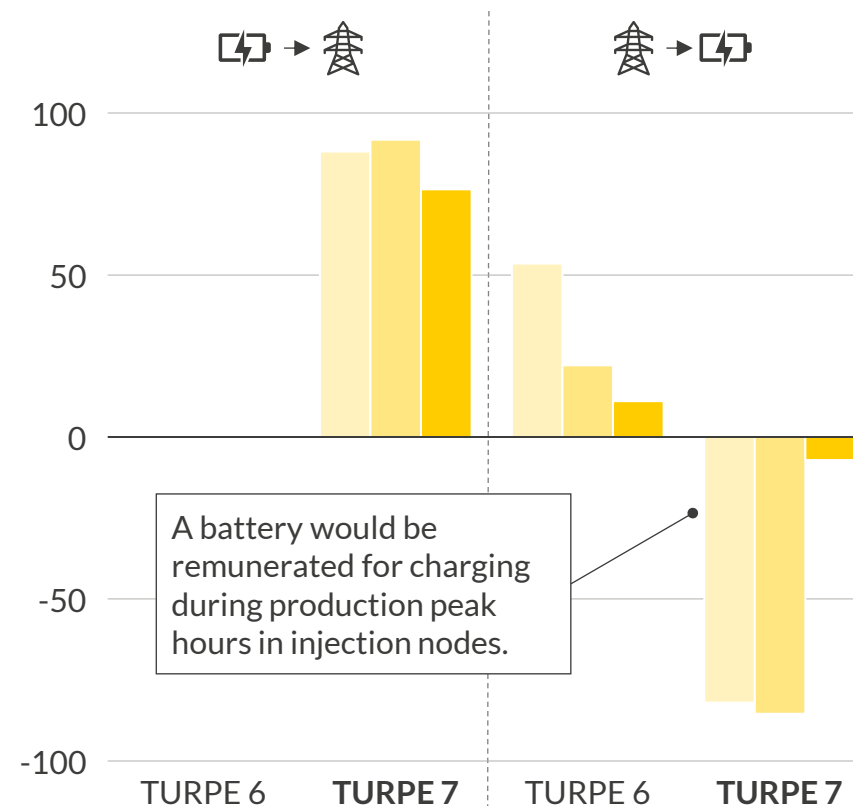
Consumption node^{1,2}

Network fees during peak hours

€/MWh (nominal)



Injection node^{1,3}



HTA HTB1 HTB2

1) A node ("poche de réseau") is defined as all the network structures in a voltage area connected downstream of a transformer station. It is considered as a consumption node if there is more consumption than generation on the node during peak periods; 2) Peak consumption hours are the same between TURPE 6 and 7; 3) Peak production hours under TURPE 7 are set by network operators, and may not necessarily match peak consumption hours.

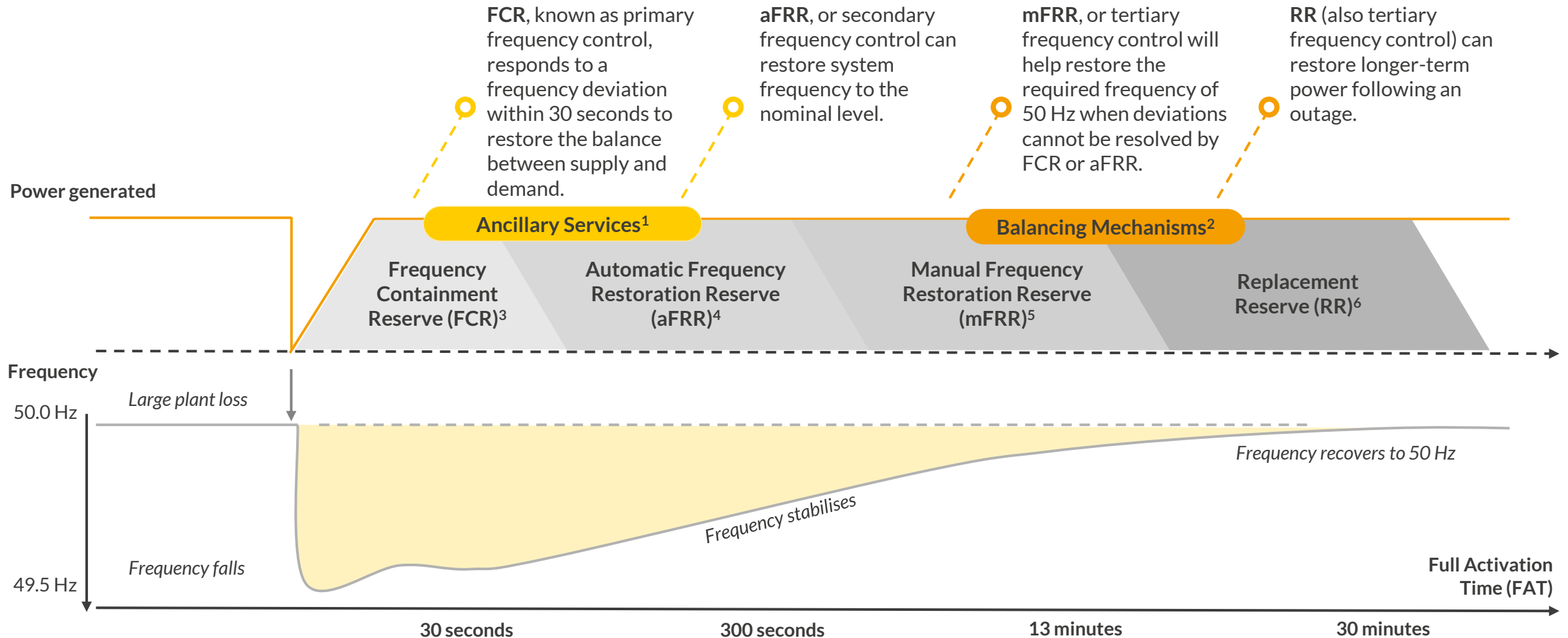
- CRE has launched rounds of consultation for the future grid tariff setup (TURPE 7) that would be implemented as of 1st August 2025 and valid until 2029.
- In this consultation, CRE proposes introducing new network fees to incentivise battery buildout in specific geographical locations of the grid. With this new format, batteries will also be subject to a tariff for injection.
- Consumption nodes represent 88% to 92% of the network. The split may evolve over time.
- Peak hours in injection nodes are set by network operators and there are 312 and 252 peak hours (4 hours a day during 78 and 63 days) in a year for the distribution and the transmission grids respectively.

Agenda

1. State of the French market
2. **Ancillary services**
 1. FCR market
 2. aFRR market
 3. Balancing market
3. Modelling battery revenues
4. Battery business models

Ancillary services and balancing mechanisms are used by RTE to respond to frequency deviations

When power plant outage happens in France...



1) "Services Système Fréquence"; 2) "Mécanisme d'ajustement"; 3) "Réserve primaire"; 4) "Réserve secondaire"; 5) "Réserve rapide"; 6) "Réserve complémentaire".

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FCR capacity is procured daily for the next day through a pay-as-clear auction mechanism



What is the Frequency Containment Reserve (FCR)?

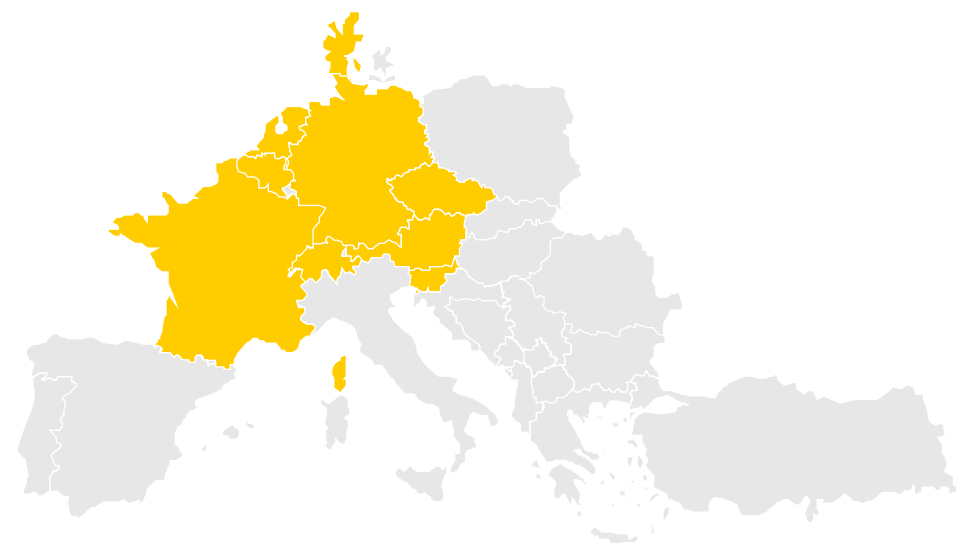
- The FCR, or the primary reserve, is designed to maintain the stability of the grid frequency. It involves the provision of immediate, automatic responses to counteract frequency deviations from the nominal value (50 Hz in Europe).
- Balance Responsible Parties can participate in the FCR market by offering their capacity to respond to frequency deviations.
- As part of the European electricity market, the FCR in France adheres to harmonised standards and regulations set by European bodies such as Electricity Balancing Guideline (EB GL).
- The remuneration streams are capacity payments per hour of availability, based on the clearing price of the FCR auction.
- The energy payments at the spot price are not a source of revenue for batteries as on average the energy used for charging/discharging nets out.

Key FCR market characteristics	
Product characteristic	Capacity
Procurement	Daily auction for next delivery day
Reserve size	+/- 500MW (FR), 3,000MW (EU)
Product direction	Symmetric (upward and downward FCR are procured together)
Duration of product	4 hours
Pricing principle	Pay-as-clear in €/MW
Delivery requirements	Participants are required to deliver full power within 30 seconds of activation and to cover a period of 15min (min. activation time ¹)
Min / Max bid size	1MW / 25MW (indivisible)
Gate opening/closure time	D-14 11:00 CET – D-1 8:00 CET

1) Continental Europe TSOs submitted a proposal to set minimum activation period for Limited Energy Reservoirs to 30 minutes to ensure system safety.

The FCR Cooperation provides half of the required capacity in Continental Europe to ensure stability of the power grid

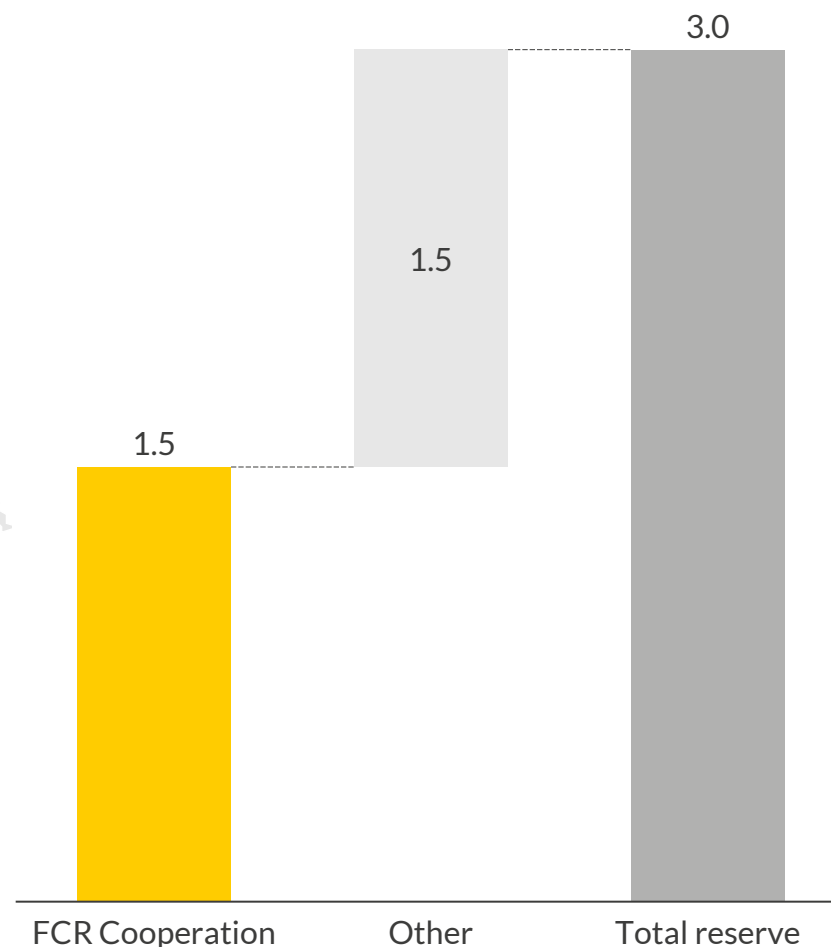
Members of the synchronous grid



Members of the FCR Cooperation: Austria, Belgium, Switzerland, Germany, Western Denmark, France, the Netherlands, Slovenia and Czech Republic

Members of the Continental Europe Synchronous Area (CESA) but procuring FCR individually

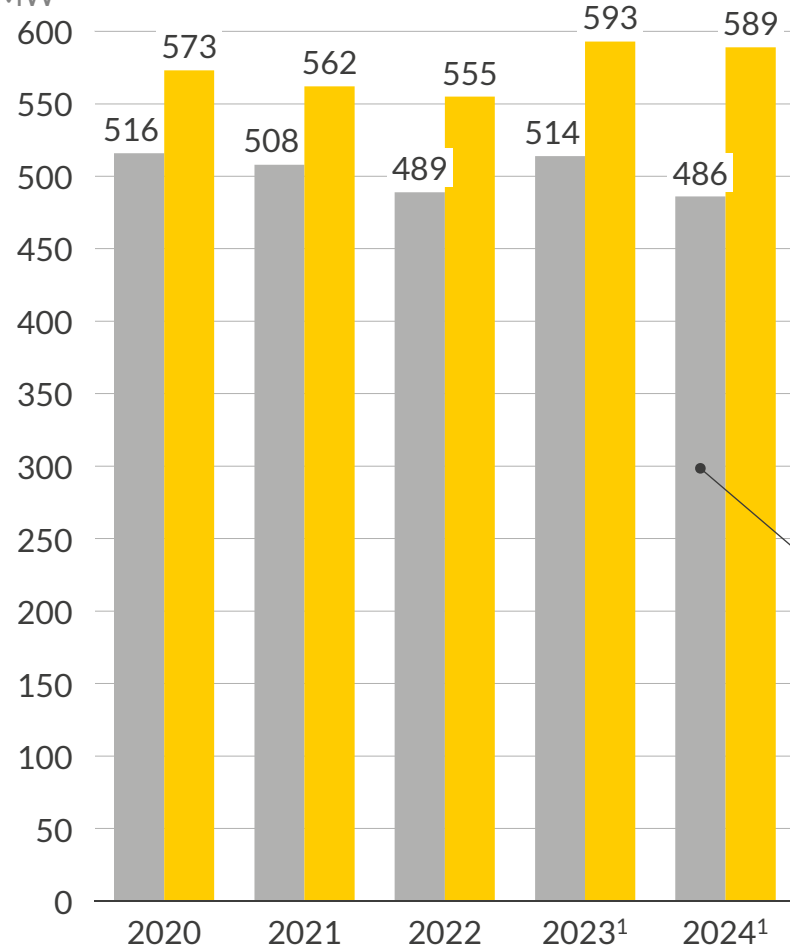
FCR in the synchronous grid of continental Europe GW



- The FCR serves to ensure grid frequency at 50Hz by intervening automatically within seconds in the entire synchronous grid to restore the balance between supply and demand.
- ENTSO-E defines the amount of FCR capacity that needs to be procured: 3GW for Continental Europe in order to withstand the maximum expected instantaneous power deviation between generation and demand in the synchronous area, equivalent to the losses of the largest power generation modules or loads, loss of a line sector or a bus bar, or loss of an HVDC interconnector.
- As of March 2023, Czechia is part of the FCR Cooperation, joining the eight historical countries (Austria, Belgium, Switzerland, Germany, Western Denmark, France, the Netherlands and Slovenia).

Within the synchronous grid area, Germany - West Denmark and France have by far the largest shares of FCR demand

Yearly FCR demand from France and Germany
MW

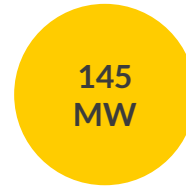


■ France ■ Germany

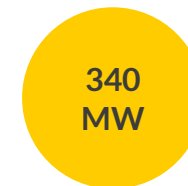
1) Since 2023, Germany and West Denmark form a single block; 2) Includes Austria, Belgium, Germany - West Denmark, France, the Netherlands, Slovenia, Switzerland and the Czech Republic; 3) Data until 31/05/2024.

Sources: Aurora Energy Research, ENTSO-E

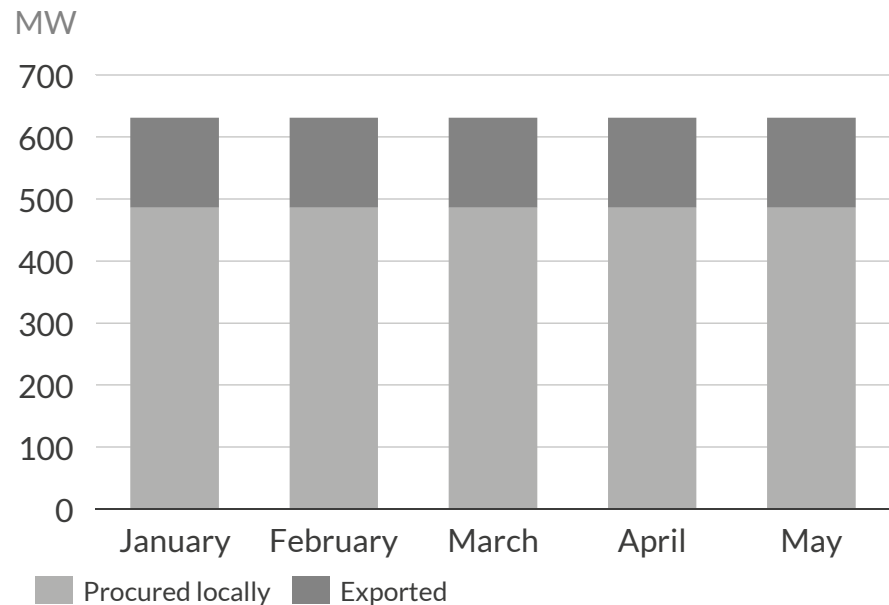
2024 export limit



2024 import limit



Monthly FCR demand and exports from France

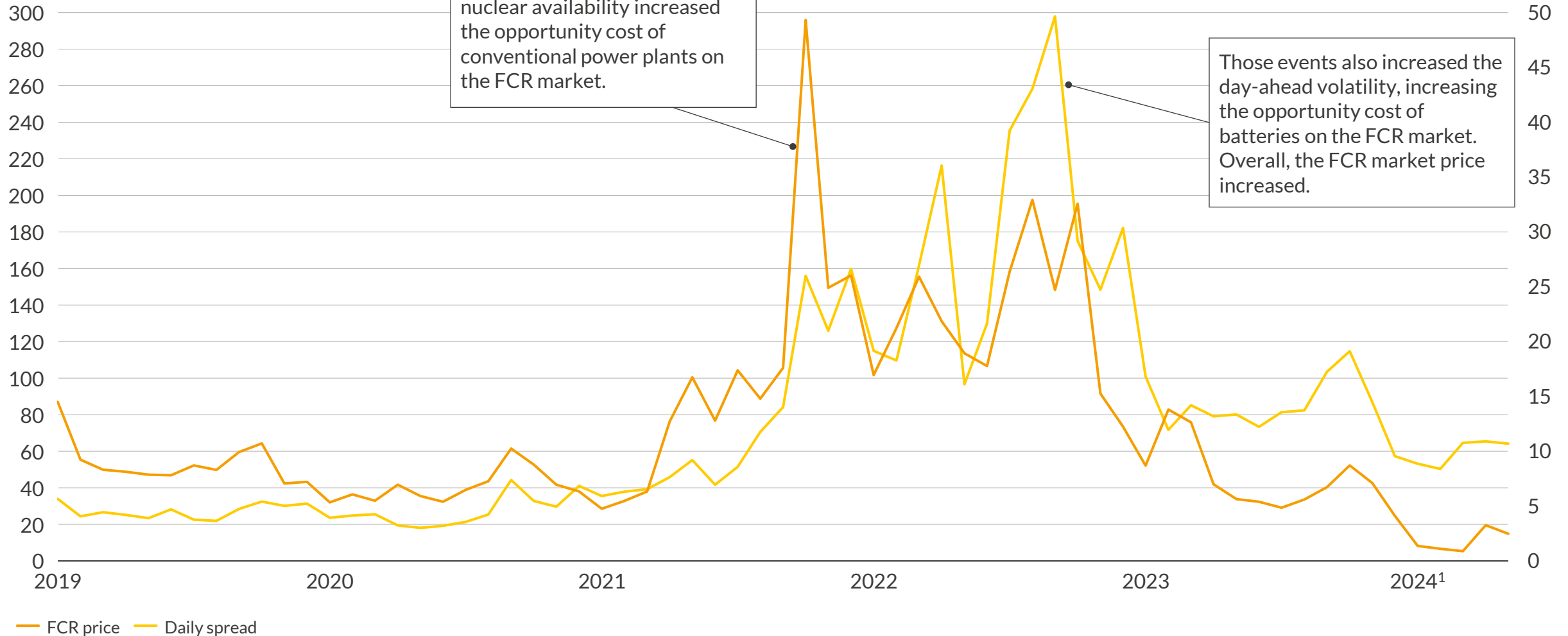


- The FCR demand for the Continental European synchronous area is equal to the reference incident of 3GW.
- It is computed annually in Q1 of each year by ENTSO-E and is based each country's share of generation and consumption in the previous year.
- The FCR demand is set at 1.5GW for the FCR Cooperation².
- 72% of FCR demand was procured by France and Germany in 2023.
- France is a net exporter with a monthly average of 145MW of exports so far in 2024³. In 2024, France has constantly been hitting its export limit.

FCR prices are driven by the opportunity cost of assets on the day-ahead market

Monthly averages of daily spread
€/MWh, nominal

Monthly averages of FCR capacity prices
€/MW/h, nominal



1) Data until 31/05/2024.

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The provision of aFRR services is currently undergoing structural changes and evolving from a regulated to a market-based system



What is the automatic Frequency Restoration Reserve (aFRR)?

- aFRR, or Secondary Reserve, is key to addressing longer-term imbalances following FCR activation. Unlike the FCR, the aFRR product is asymmetrical managing both upward and downward frequency adjustments independently.
- RTE activates aFRR energy from Balancing Responsible Parties (BRPs), with response times of up to 300 seconds allowed.

Example of the activation of upward aFRR energy

Activation of scheduled upward aFRR

Ni level¹ goes from 0 to $n \leq 1$

Deactivation of scheduled upward aFRR

Ni level goes from n to 0

Bid is selected based on the merit order

Start of activation

FAT² 300s

$x * 4s$

DAT³ 300s

Bid is no longer selected based on the merit order

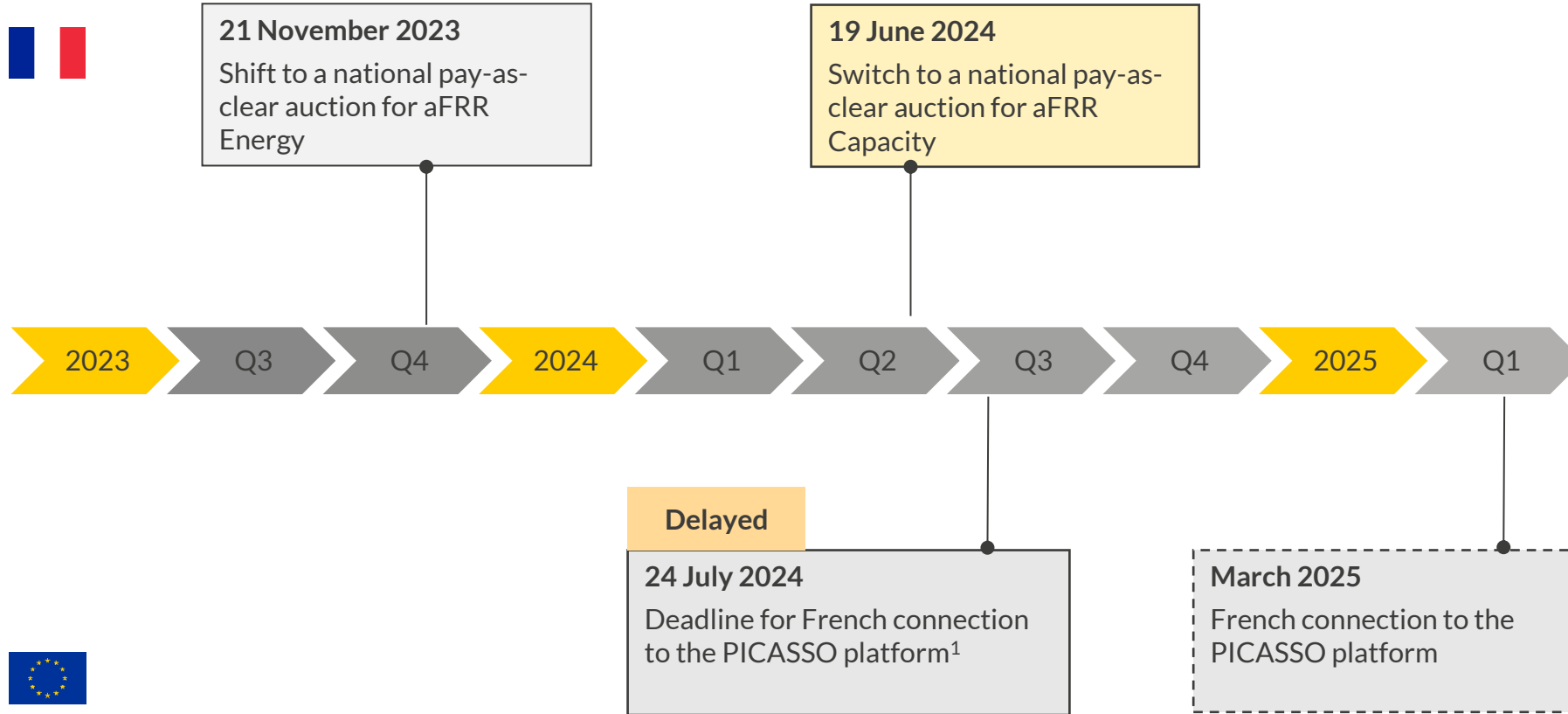
Start of deactivation

 Volume of energy settled

Key aFRR market characteristics	

1) Ni level is an indicator of the level of activation of the aFRR energy bid ranking between 0 and 1. For example bid = 10MW, if the Ni level is 0.1, the battery will be activated for 1MW; 2) FAT = Full activation time (300 seconds); 3) DAT = Deactivation time (300 seconds).

Currently settled via national auctions, the provision of energy aFRR services will soon move to the European-wide PICASSO platform



Capacity

- Due to structural dysfunctions and a lack of competition, the aFRR Capacity Market was opened in November 2021 but suspended 3 weeks later.
- In January 2024, CRE concluded that the necessary conditions to reopen the aFRR Capacity Market under an auction system had been satisfied.
- Since 19 June 2024, aFRR Capacity is tendered via pay-as-clear auctions on a daily basis.

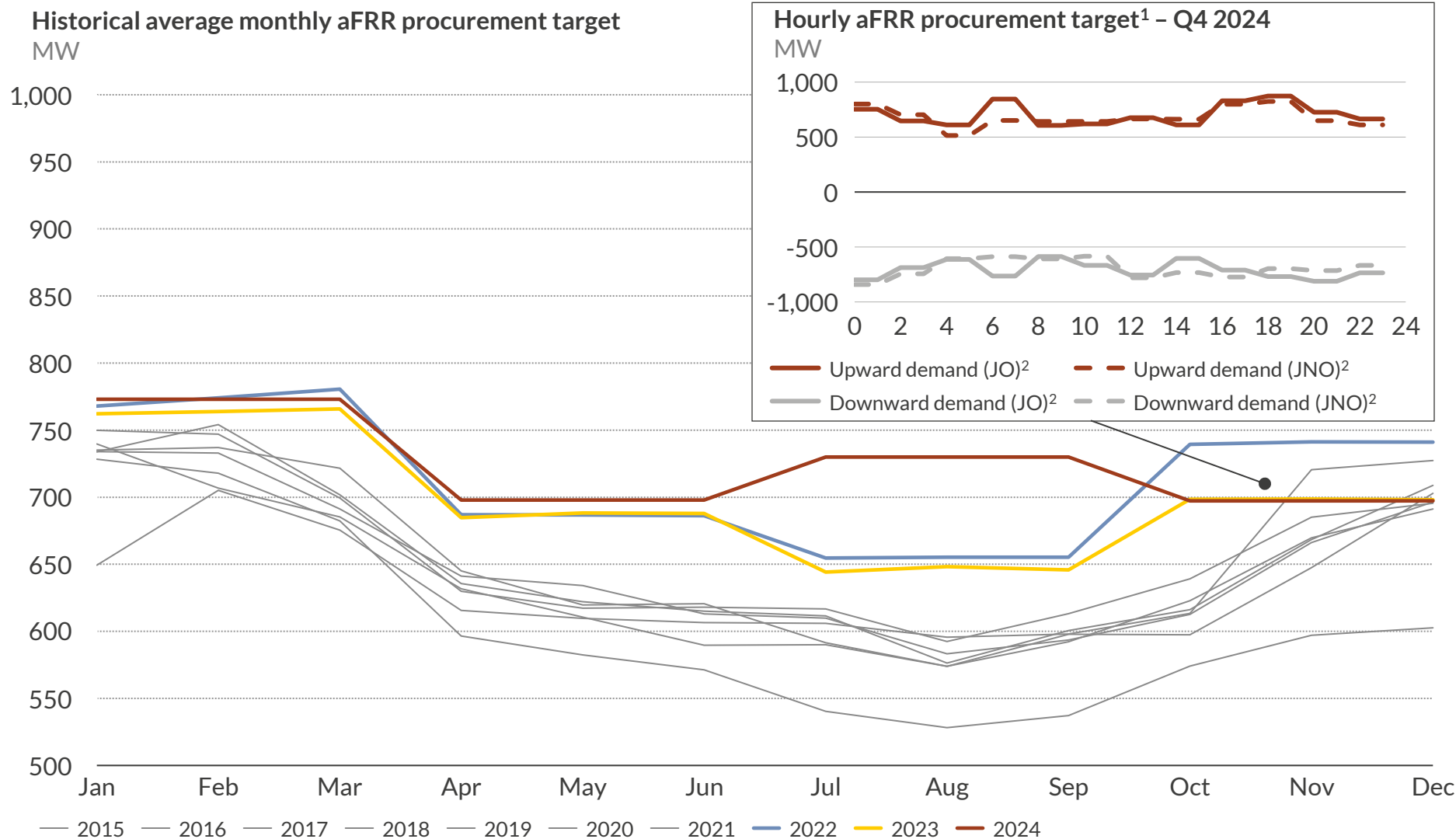
Energy

- The merit-order-based aFRR Energy Market has been active since 21 November 2023.
- RTE plans to connect to the PICASSO platform in Mar 2025.
- RTE is waiting for the implementation of the “elastic demand” feature, which allows for the adjustment of the demand for balancing energy based on real-time system conditions and prices³.

1) CRE decided to give RTE a 2-year derogation to connect to the PICASSO platform (before July 2024) on the 21st of July; 3) See the subsection about PICASSO in the section II. Market, Policy and Regulatory Overview - Policy and Regulatory Overview of this report.

Demand for aFRR increases in 2024 compared to 2023, with a notable 13% growth in Q3

aFRR Capacity



- Higher volumes from 2022 are explained by the change in calculation methodology for the procurement targets introduced in November 2021.
- aFRR requirements are calculated using historical data from the same quarter of the previous year, for 2-hour blocks of workdays and weekends.
- With the opening of the aFRR Capacity Market on 19 June 2024, RTE now procures aFRR for upwards and downwards directions separately.

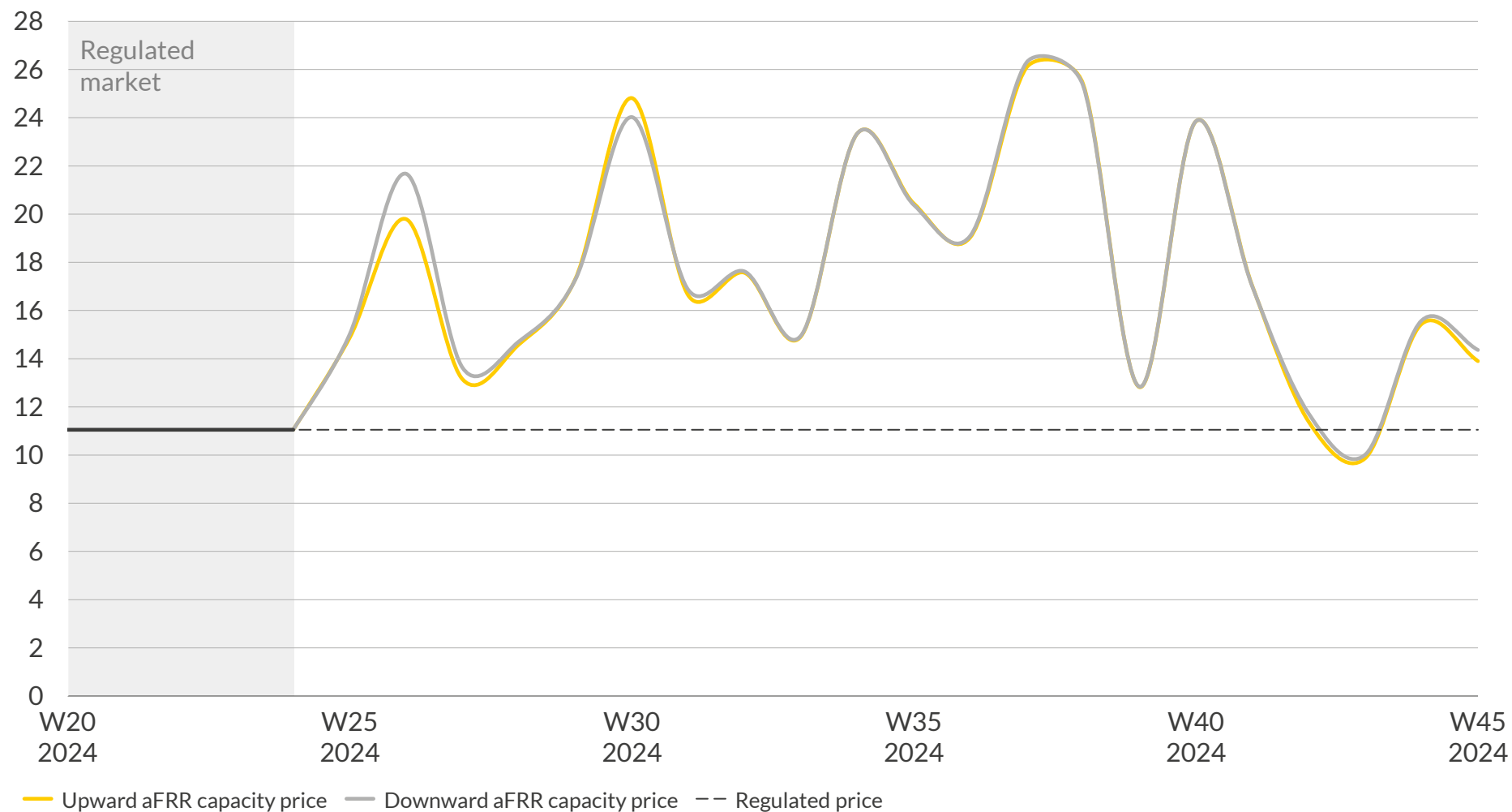
1) RTE publishes the procurement target for working and non-working days; 2) "JO" stands for "Jour Ouvré" which means working day and "JNO" stands for "Jour Non Ouvré" which means non-working day.

aFRR Capacity is procured based on competitive pay-as-clear auctions since June 2024 for France

aFRR Capacity

Weekly aFRR Capacity weighted average prices

€/MW/30min

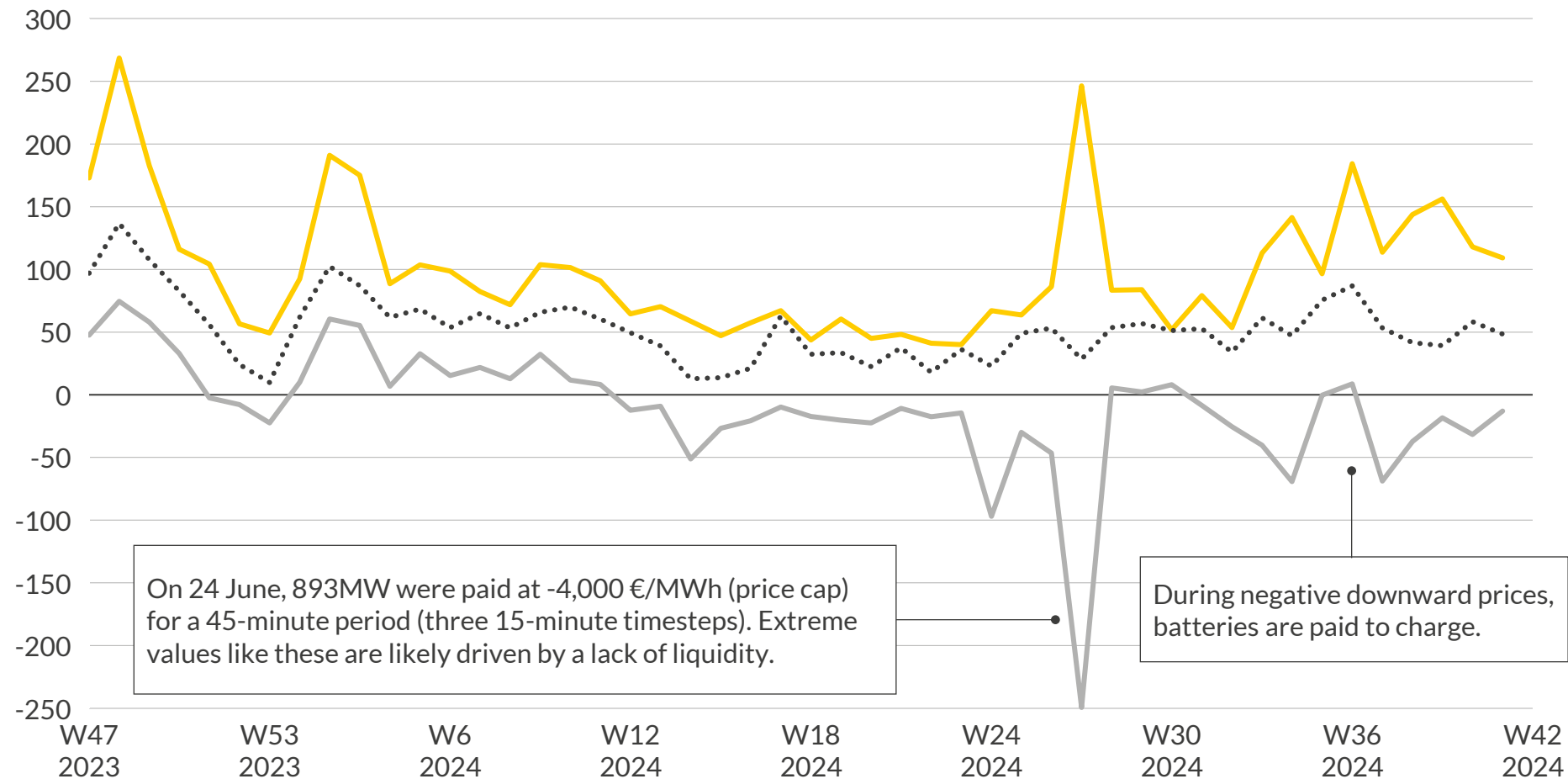


- For the first time since November 2021, aFRR capacity was procured based on a merit order logic in France. Assets bidded aFRR reserve capacity for the next day.
- The opening of the market unlocked an additional source of revenues for batteries in France which could not participate in the aFRR market before.
- Since the market opening, the market price has been on average 60% above the former regulated price. However, prices have diminished in recent months.
- As aFRR and FCR are covered by largely the same assets, the introduction of aFRR Capacity tenders may drive FCR prices upwards.

The French aFRR Energy Market opened in November 2023 unlocking an additional source of revenue for batteries in France

Weekly aFRR activation weighted average price¹

€/MWh



— Upward aFRR energy price — Downward aFRR energy price ··· Day-ahead price

1) Data until 31/10/2024.

Sources: Aurora Energy Research, RTE

- RTE started to activate the aFRR Energy Market through a national merit order from the 21 November 2023.
- The aFRR activation prices are computed as the weighted average prices (WAP) of the clearing prices (every 4 seconds) over a day.
- Over the entire historical period, aFRR Energy prices were on average 99.7 €/MWh upward and -10.3 €/MWh downward.
- The daily spread (difference between the maximum upward and the minimum downward weighted average prices over 15 min periods) reached a maximum of 3,050 €/MWh on 2 July 2024.

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There are two types of contracted tertiary reserves: the rapid and the complementary reserves



What are the tertiary reserves ?

- Tertiary reserves are composed of the mFRR (rapid reserve) and the RR (complementary reserve).
- Tertiary reserves are used to restore the balance between supply and demand after primary and secondary reserves have been deployed. This helps in freeing up primary and secondary reserves for potential future imbalances.
- “Mécanisme d’ajustement” market bids may also be used for network congestion or to rebuild either the ancillary services or the margins as well as for balancing reasons.
- While mFRR and RR products are considered as ‘standard’ products, mFRR and RR activation from the “mécanisme d’ajustement” offers are considered as ‘specific’ products. ‘Standard’ products are confined to the rules of the mFRR and the RR in terms of their parameters (e.g. activation time), and offers on these platforms are identical. However, offers on the ‘mécanisme d’ajustement’ have parameters specific to the Balancing Responsible Party, and are not interchangeable with other offers.

Capacity remuneration		Yearly tender for both mFRR and RR Procured capacity: maximum 1000MW / pay-as-clear
		Daily tender for both mFRR and RR Procured capacity: minimum 500MW / pay-as-clear
Energy remuneration		Balancing market (“mécanisme d’ajustement”) Full activation time: variable / pay-as-bid
		mFRR European platform (MARI) Full activation time: 12.5 minutes / pay-as-clear
		RR European platform (TERRE) Full activation time: 30 minutes / pay-as-clear

 Not yet available in France.

1) Known as the ‘Réserve Rapide’ (RR); 2) Known as the ‘Réserve Complémentaire’ (RC);

French market participants (including batteries) can be remunerated for tertiary reserve capacity reservation

Capacity product definition

Product	mFRR ¹	RR ²
Full activation time (FAT)	12 minutes	30 minutes
Maximum Activation Duration	2 hours ³	1 ½ hour ⁴
Maximum activation number	Four times a day	Four times a day
Capacity procured	1,000MW	500MW

Batteries requirement for participation

- Batteries can participate to the mFRR tender if they have 3 hours of storage, and in the RR tender if they have 4 hours of storage.

Capacity tenders

Daily tender (minimum 500MW)

- Since the 1st of June 2021, RTE procures at least 500MW of its need for tertiary reserves through a daily auction, which is in addition to the yearly auctions.
- Daily auction takes place at 10 AM on D-1, and the publication of results takes place at 10:30 AM at the latest.

Required volume

2023 2024

750MW 750MW

Yearly tender (maximum 1000MW)

- Yearly pay-as-clear auctions for the rapid (mFRR) and the complementary (RR) reserve. There are 2 auctions for each week of the year: 1 for business days, one for weekends.
- It is open to both producers and DSR connected to the transmission or distribution network.
- Contract holders benefit from a capacity payment in €/MW/year.

750MW 750MW

1) Also known as the 'Réserve Rapide' (RR); 2) Also known as the 'Réserve Complémentaire' (RC); 3) Maximum of 4 hours total activation per day; 4) Maximum of 3 hours of total activation per day.

The French (energy) balancing market is a pay-as-bid market in which participants submit offers to RTE to increase or decrease their output

Energy activation on the “mécanisme d’ajustement” goes beyond balancing purposes

Activation reason	<u>Balancing (mFRR + RR) activation</u> Generation = consumption	<u>Non balancing activation</u> Network congestion	<u>Non balancing activation</u> Rebuild system margin	<u>Non balancing activation</u> Rebuild ancillary services
Definition	RTE activates balancing bids in order to sustainably replenish missing or excessive energy, after the activation of the FCR and the aFRR	RTE activates balancing bids in order to resolve grid congestion on a specific network line	RTE activates balancing bids in order to make sure that it secures its operational margins for proactive balancing management	RTE activates downward balancing bids to rebuild ancillary services that may have been lost
Activation period	During the operational window	Any time	Any time	Any time

- The French “mécanisme d’ajustement” is a pay-as-bid market where participants submit their offers (both financial and technical) to increase or decrease their output to RTE. Based on these, RTE modifies their generation/consumption output to physically balance the system.
- Both contracted reserves and voluntary bids are in direct competition with each other when clearing the market. After having established a merit order of the bids/offers according to their prices and technical characteristics, RTE activates the most economically efficient offers.
- Along with the activated aFRR (including the mutual emergency volumes - MEAS), it creates a reference price to settle the imbalances of the Balancing Responsible Parties (BRPs).

There are 3 types of bids on the “mécanisme d’ajustement”

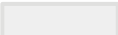
1. Offers contracted beforehand (mFRR-RR tenders) due to their specific technical characteristics.
2. Mandatory participation for generators connected to the RTE grid.
3. Voluntary participation for generators connected to the distribution grid, foreign capacities and DSR connected to both the transmission and distribution grid.

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Batteries can stack various type of revenues as long as they respect the markets' requirements for participation

Bid type	Market	Product duration	Year ahead	D-1	D	After delivery
Capacity	Capacity market	1 year	From Y-3			
	FCR ¹	4 hour		8:00 Gate closure time		
	aFRR	1 hour		9:00 Gate closure time		
	RR-RC tender	1 year or 1 day	Y-1 (yearly tender)	10:00 (daily tender) Gate closure time		
Energy	Day-Ahead	1 hour		12:00 Gate closure time		
	Intraday	1 hour or 30 min		15:00 Market opening for day D	H - 5 min Gate closure time	
	aFRR	15 min			H - 25 min Gate closure time	
	French balancing market	NA			H-1 Gate closure time for explicit bids	
	RR - TERRE platform	1 hour			H - 35 min Gate closure time	

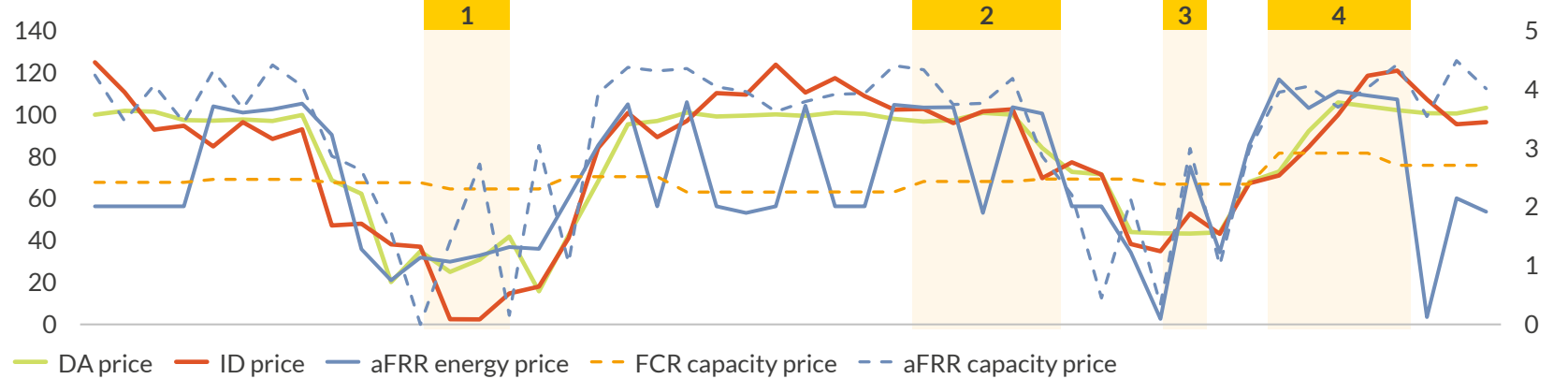
 Not modelled

1) "Recharge aux écarts" (possibility of changing the state of charge of a battery without programming it) is only permitted when the battery is only participating in the FCR Market. For aFRR participation, programming can be done every hour up to 1 hour before delivery.

Example of modelled battery: asset is optimising to price movements, but misses out on some opportunities due to imperfect foresight

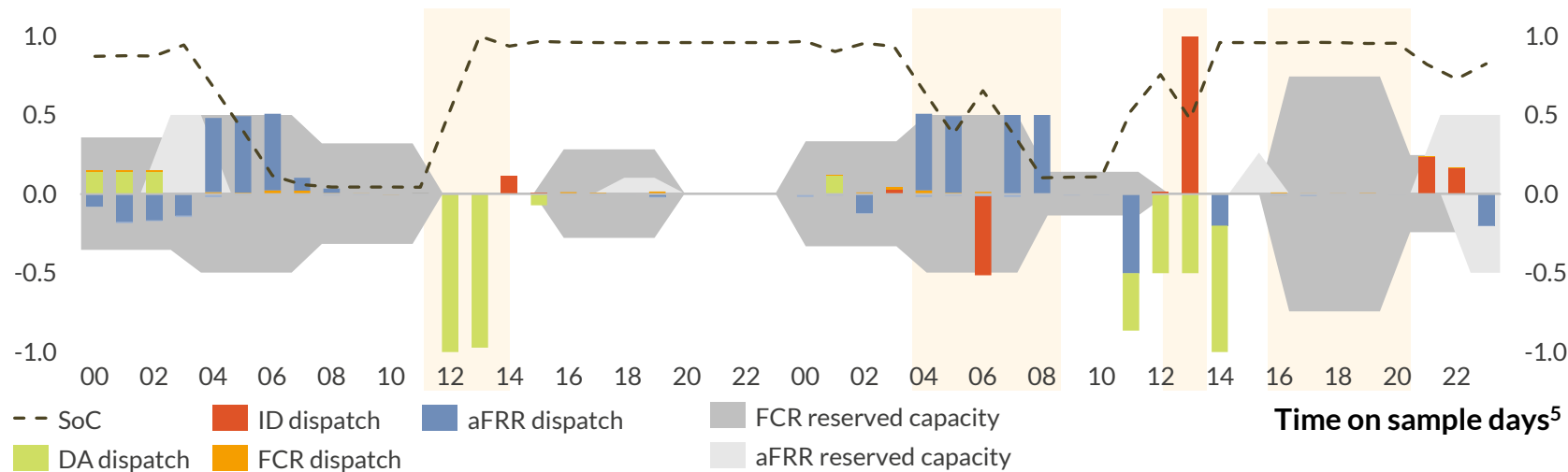
Power price

€/MWh, (DA¹, ID², aFRR energy), solid line



Battery dispatch³ and SoC⁴ for a 1MW, 2h battery

MWh, bar chart; SoC, dash line



1) Day-Ahead; 2) Intraday; 3) Discharging/export actions are shown as positive, while charging/import actions are shown as negative; 4) State of Charge; 5) Sample days of 10.07.2030 and 11.07.2030.

Trading strategies

1 Fulfilment of DA dispatch

- Despite lower ID prices, the battery was committed to import from the DA market, which closes a day before delivery, limiting foresight on prices.

2 Trading on intraday and balancing markets

- The battery can decide to trade on ID or aFRR energy markets depending on price when it is not constrained by DA or FCR/aFRR commitments.

3 Buying back in the ID market

- To fulfil a DA commitment, the battery can buy back electricity on the ID market if more attractive than injecting electricity itself.

4 Capacity reservation constraints

- Despite energy trading opportunities, the battery was committed to reserve capacity to the FCR capacity markets

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

	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.

Deep-dived in the section

1) Smart EVs and/or heat pump consumption.

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

	+ Equity		- Debt			
Scenario name	High 	Weather sensitivities 	Low 	Battery overbuild 	Wholesale only 	aFRR delay ² 
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 profitability of a battery only participating in the day-ahead market?	What would be the impact of a delay in the opening of the aFRR capacity 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 in the ancillary services markets.	It would be an extreme case where the FCR and the aFRR market are fully cannibalised.	There is a regulatory risk on the opening of the aFRR capacity market.
Difference to Aurora Central	- Higher commodities prices - Higher demand - Higher RES CAPEX - Lower nuclear ava. - Higher aFRR procurement target (+5%¹)	- 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 (-4%¹)	Increasing battery buildout	Battery does not participate in the FCR and the aFRR market.	The aFRR capacity market is only available from 2026.

 Deep-dived in this section

1) Average of the yearly procurement target changes for the underlying scenarios compared to Central due to change in the forecasted net imbalance volume ; 2) Opening aFRR capacity postponed by one year.

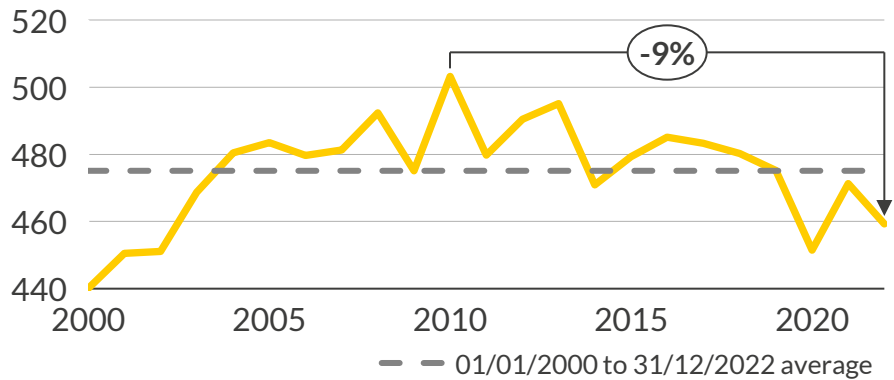
Recent shocks have impacted the very fundamentals of energy systems ...



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

French power demand

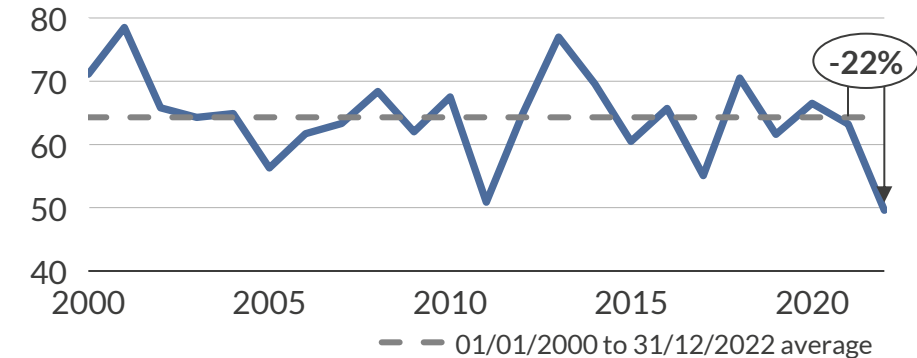
TWh



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

Hydro production

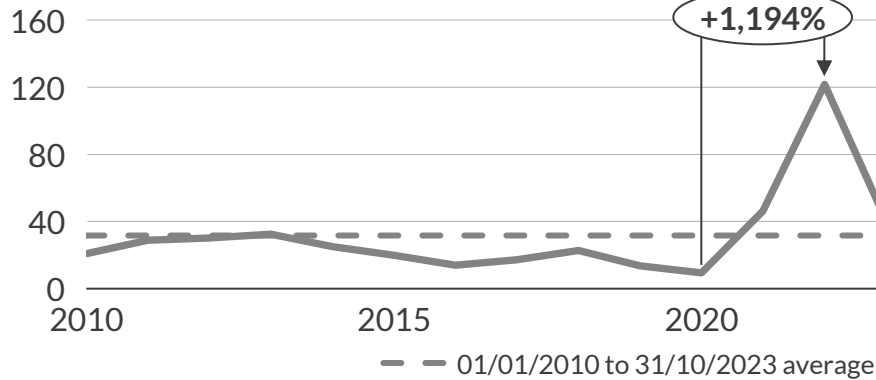
TWh



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

Gas price (TTF)

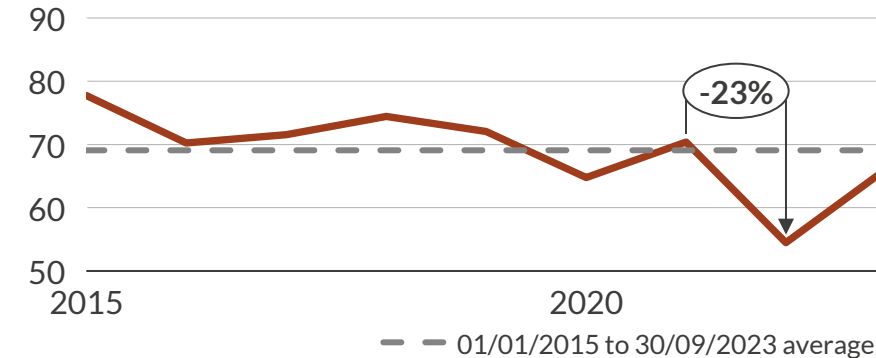
€/MWh (real 2022)



Reactor shutdowns led to significant decreases in nuclear availability...

Nuclear fleet availability

%



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).

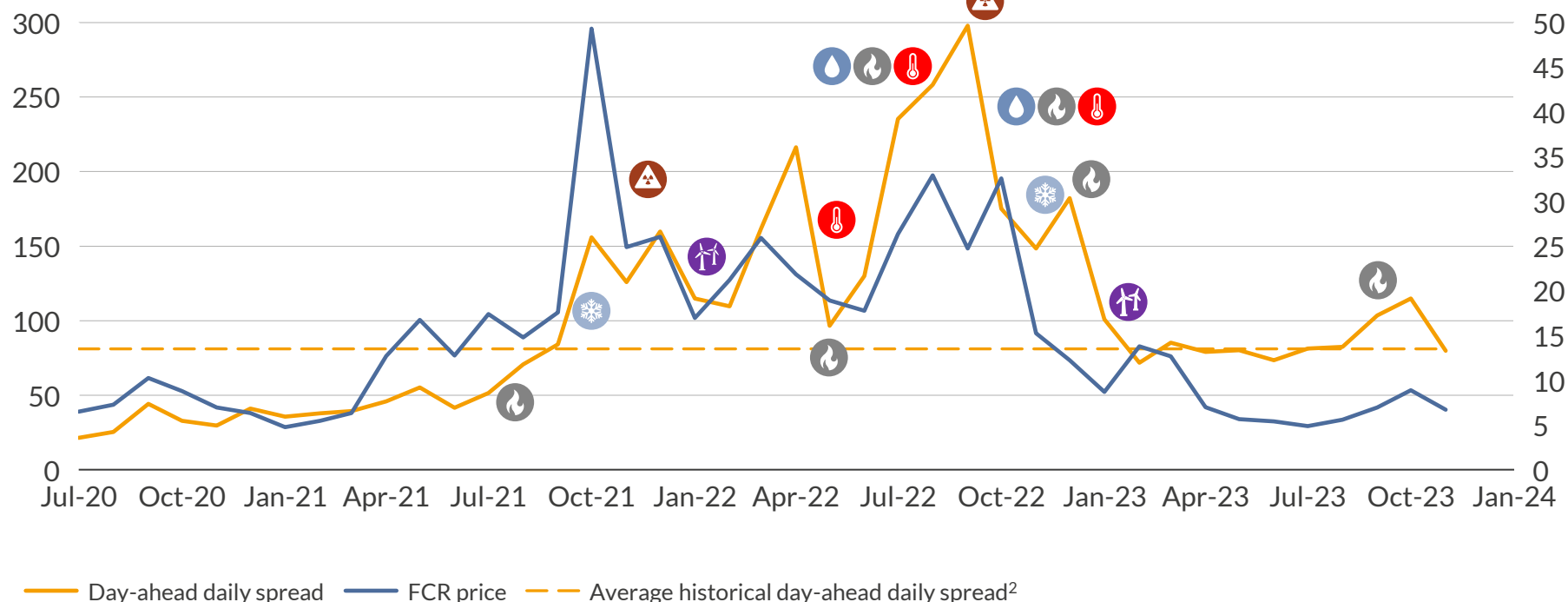
... leading to significant fluctuations in day-ahead and ancillary service prices

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 spread¹
€/MWh (nominal)

Monthly average FCR prices¹
€/MWh/h (nominal)

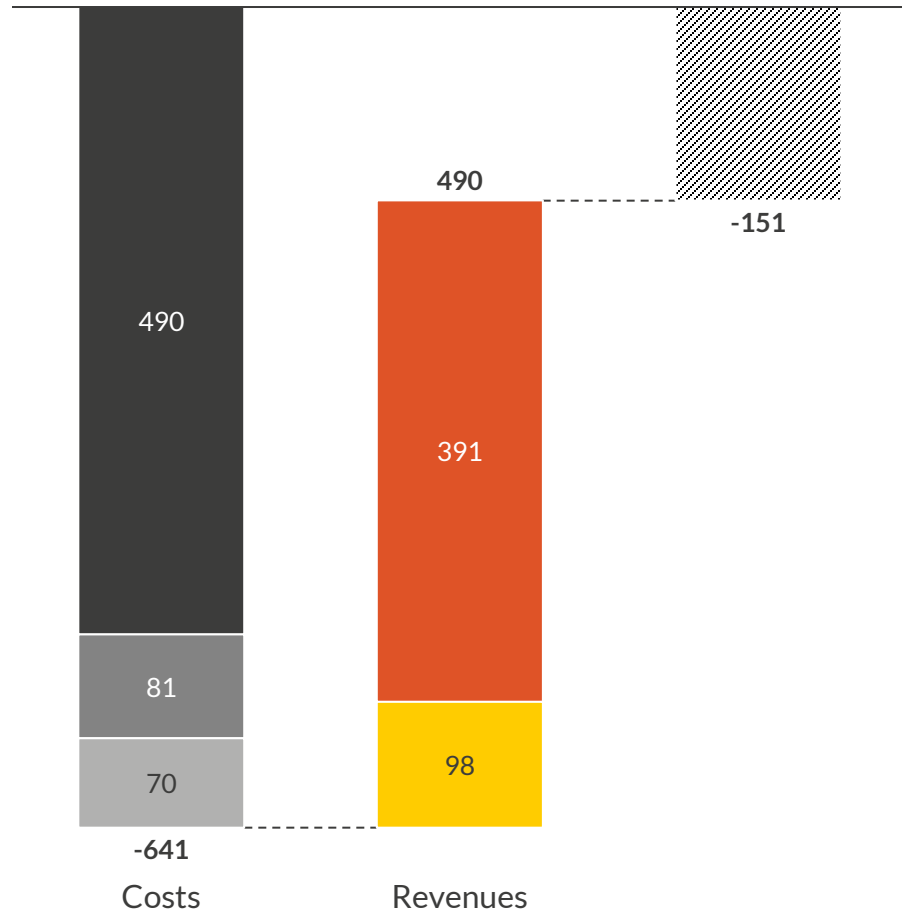


- The occurrences of hydro and nuclear events (such as variation in water availability due to dry weather or nuclear maintenance shutdowns etc.) are critical factors shaping electricity prices.
- During periods of high volatility, batteries can capitalise on price differentials by charging during low-price 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.

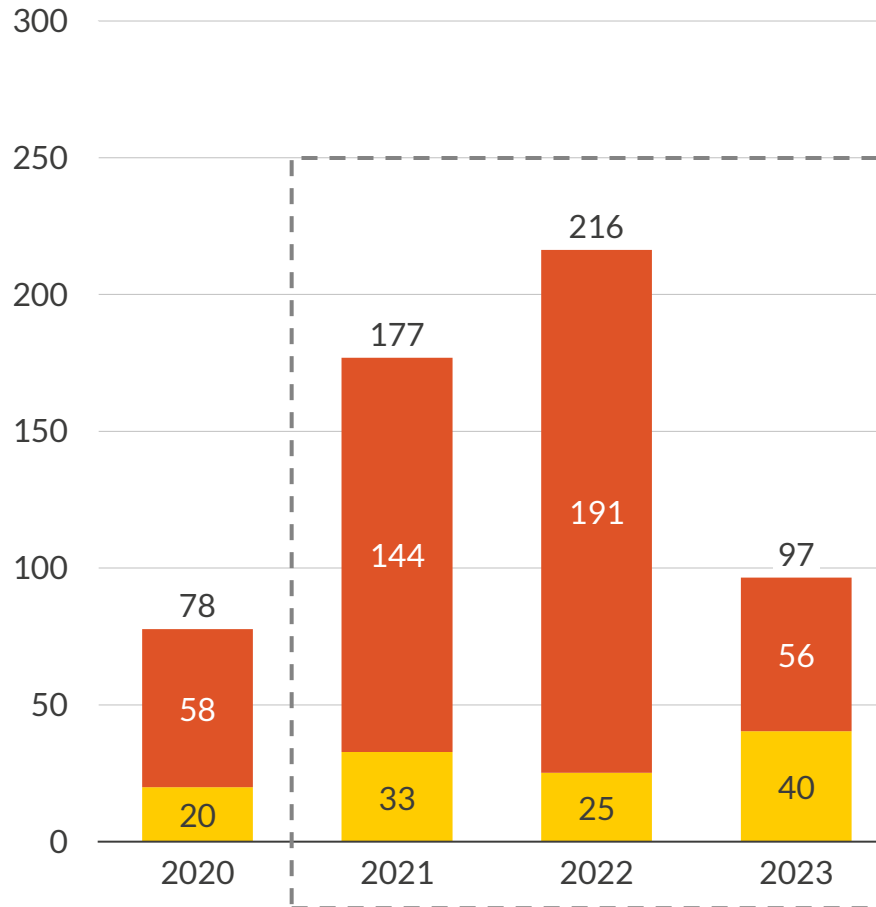
1) Based on data up to 15/11/2023; 2) From 01/01/2019 to 30/06/2020.

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)



- 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 received a total gross margin of 490 €/kW 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 24.0% of BESS revenues between 2021 and 2023.

■ CAPEX ■ OPEX ■ TURPE³ ■ 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.

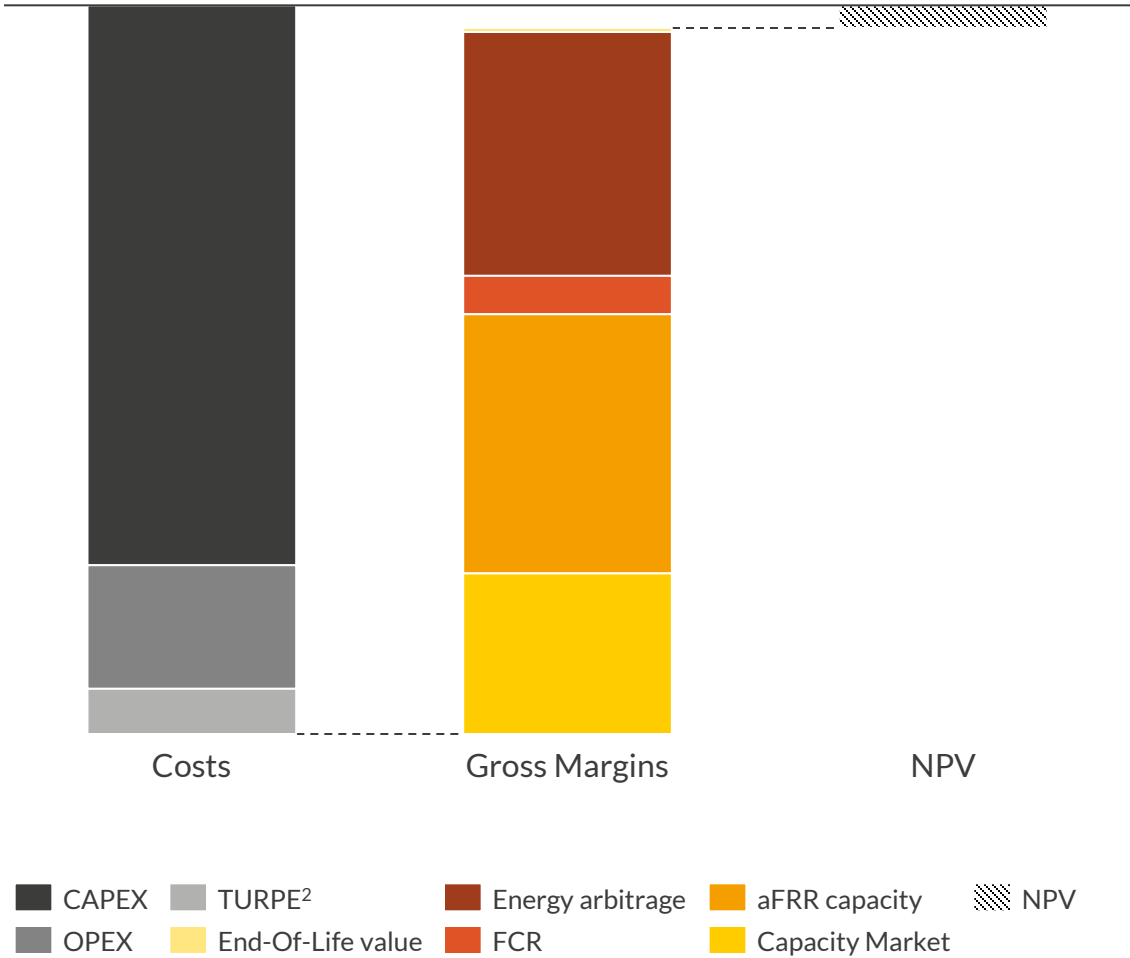
Agenda

1. State of the French market
2. Ancillary services
3. Modelling battery revenues
4. **Battery business models**

A standalone 2-hour battery coming online in France in 2025 would see an IRR of --% by stacking revenues from various markets

Case 0

Economics for a battery entering 2025 (2-hour, HTB2, with repowering)¹
€/kW (real 2023)



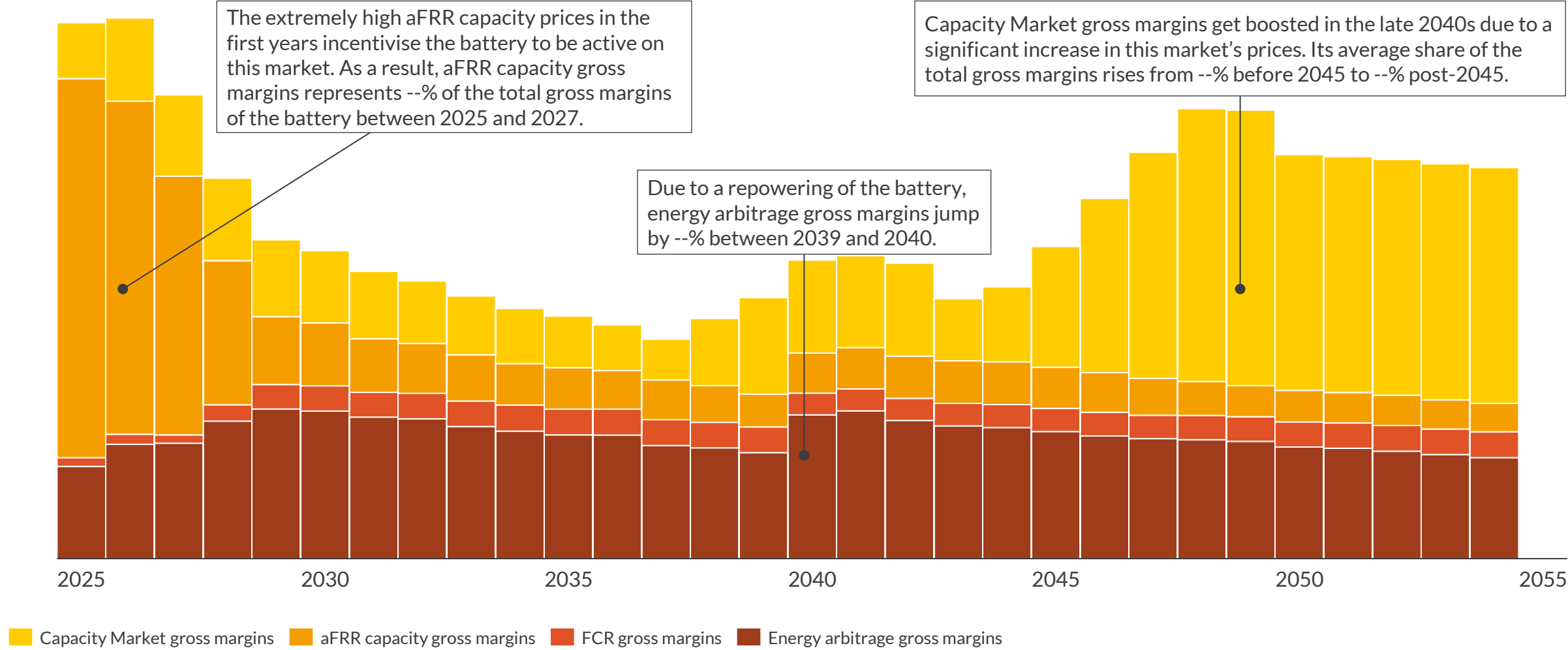
Battery NPV ¹	Battery IRR
----- €/kW (real 2023)	--%

- Assuming a battery coming online in France in 2025, we see an IRR of --% if the battery gets repowered at a SoH³ of 63%.
- The CAPEX estimate for a 2-hour battery has been revised upwards, in comparison to our previous publication.
 - This is because we now consider a battery connected to the transmission level (HTB2) which implies higher grid connection costs and lower grid charges.
 - We now allow the battery to repower which was not the case previously. In this scenario, repowering occurs in 2040 and the battery gets decommissioned in 2054, after a total of 30 years of operations.
- Over the forecast, aFRR markets dominate revenues due to high-capacity prices, particularly in the short-term and significant spreads on the aFRR energy market which leads to a high energy arbitrage revenue.
- Compared to our previous forecast, FCR revenues for our base case have fallen by 44%. This can be explained by the recent drop in FCR prices, pushing our short-term forecast for FCR revenue down.

1) Discount rate of 11%; 2) Variable grid charges. The fixed ones are included in the OPEX; 3) State of Health.

In the early years, capacity markets represent the main source of revenue whilst energy arbitrage trading picks up steadily over the years

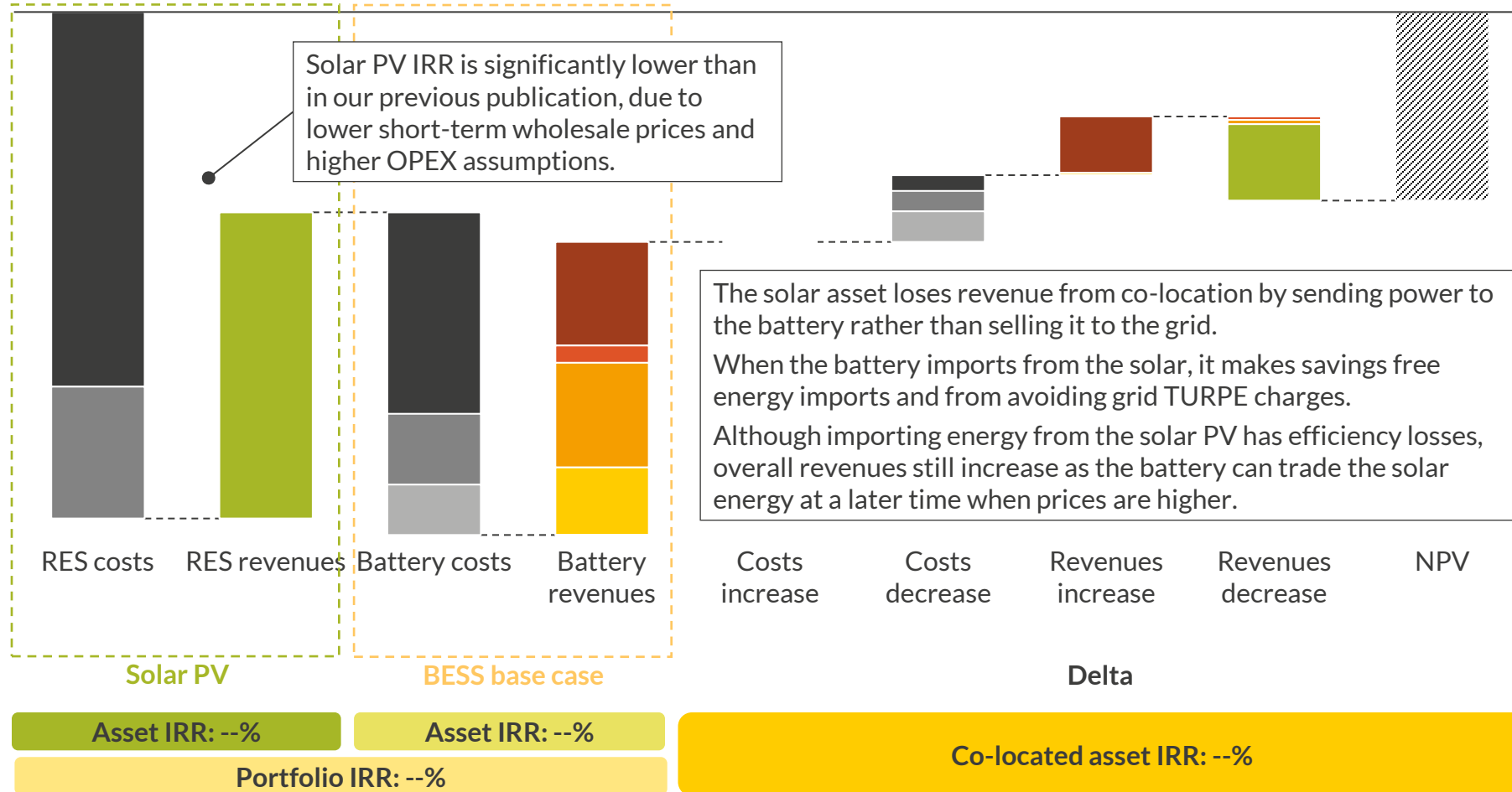
Battery gross margins
€/kW (real 2023)



With an entry year in 2025, the co-location of a 2-hour battery and a RES asset leads to a higher IRR than a portfolio of both assets

NPV calculations of a new-build co-location project with COD 2025¹

€/kW of grid capacity (real 2023)



- The battery can charge from both the renewable asset and the grid. The co-located asset is optimised to dispatch renewable generation to the grid or to the battery to be sold at a later point in time.
- Co-locating a battery with a PV asset results in a reduction in both CAPEX and OPEX costs due to shared infrastructure⁵.
- With the same solar PV asset backed by a 20-years CfD scheme with a strike price at 81.9 €/MWh⁶, the co-located system's IRR would jump to --%. In this scenario, the model assumes for the solar PV asset to be remunerated at the strike price when dispatching to the grid.

1) Discount rate of 11%; 2) Variable grid charges. The fixed ones are included in the OPEX; 3) Capacity Market; 4) End-Of-Life value; 5) Through co-location, savings can be made on the project CAPEX as both assets share a single grid connection. In addition, balance of system, installation, and developments costs are partially shared; 6) Based on the 5th CRE tender from March 2024.

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