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ENERGY RESEARCH

Winter is coming: French power prices and their implications for developers and consumers

October 2022

Today's presenters and other key information

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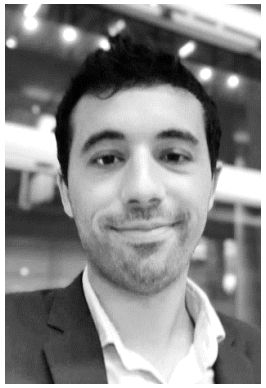

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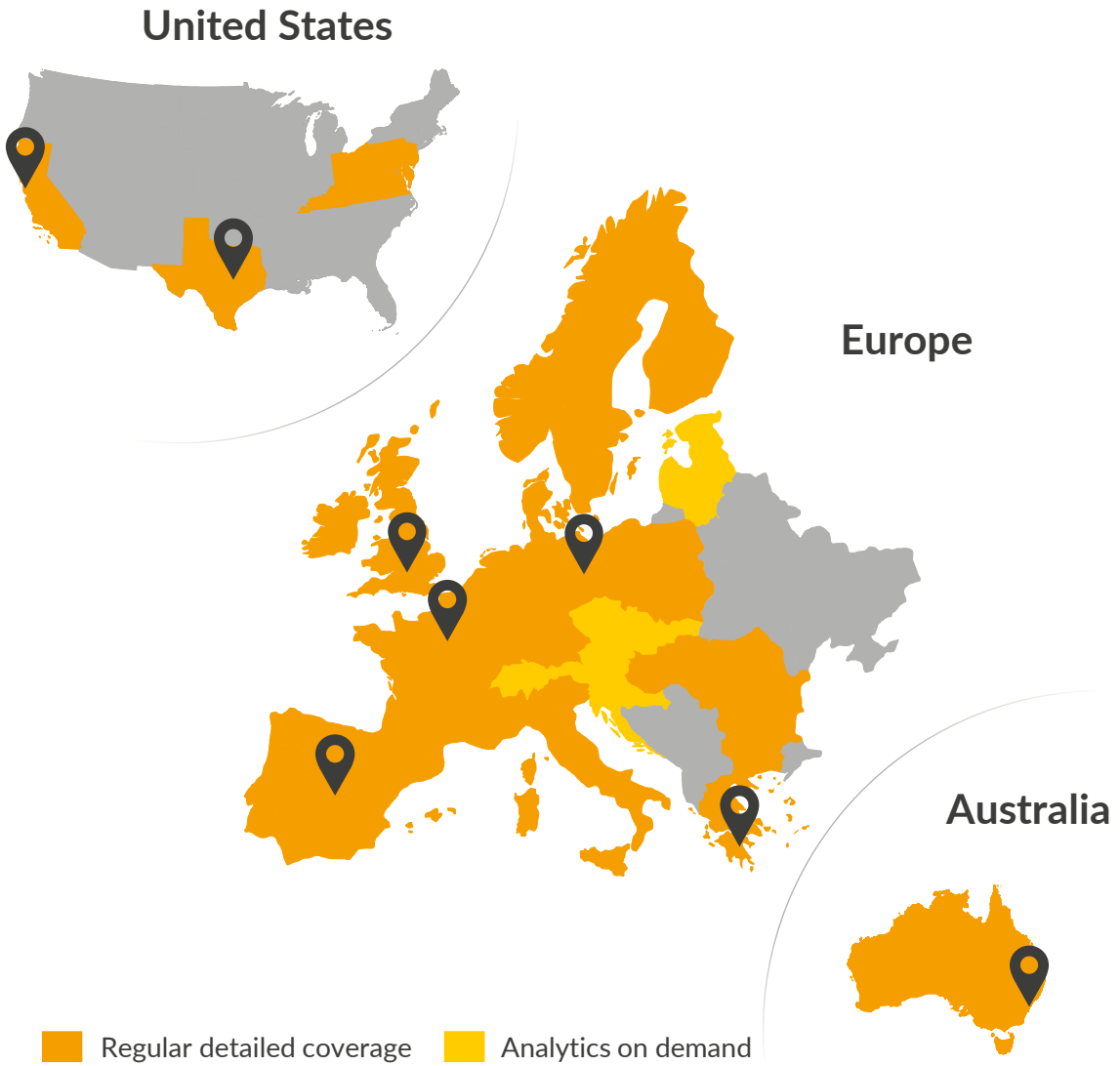

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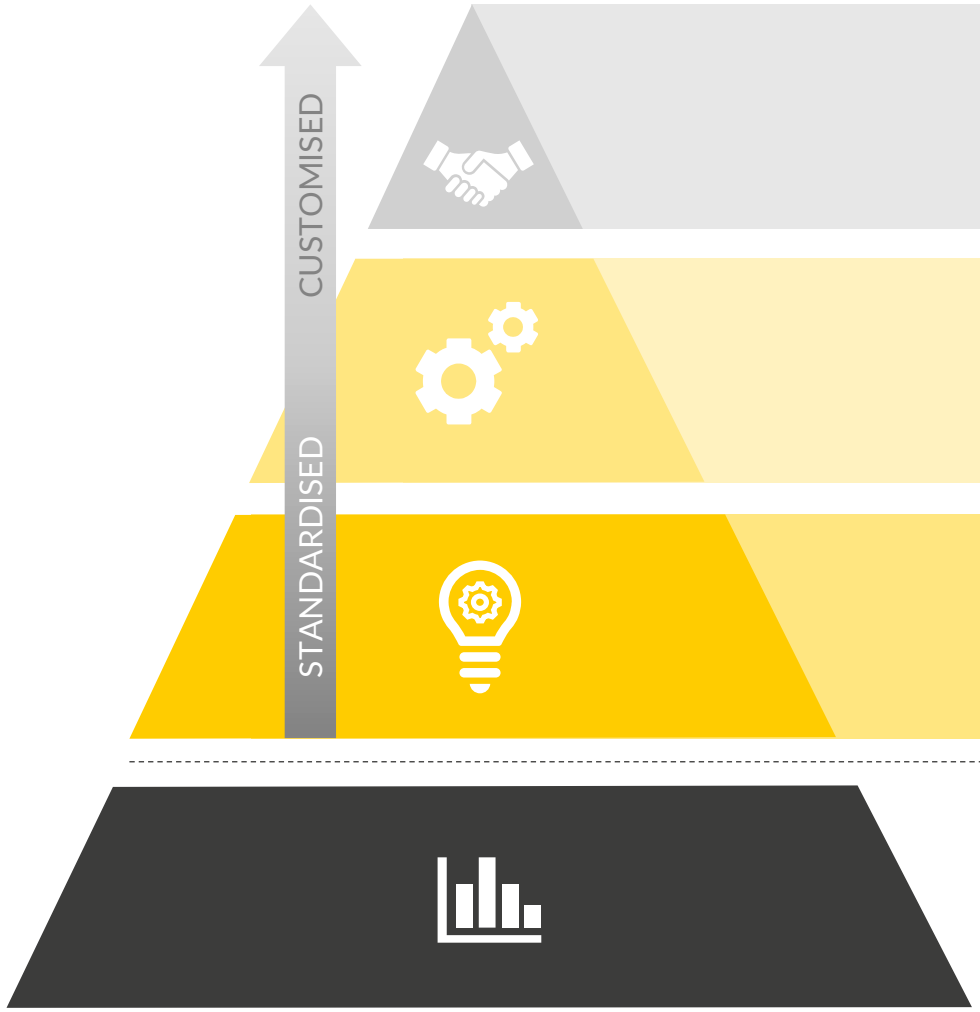
Source: Aurora Energy Research

Aurora brings a sophisticated approach to the provision of analysis and insight to the energy industry



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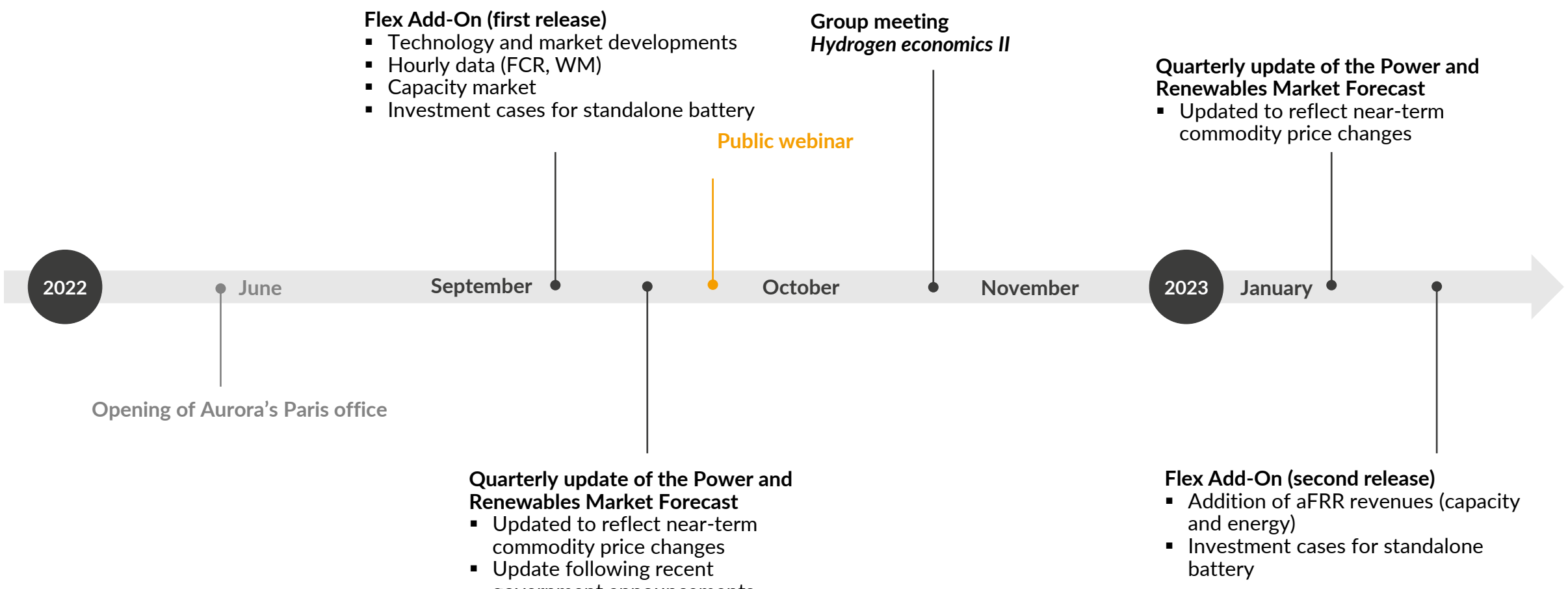
Developed over 10 years, 40+ dedicated modellers

Source: Aurora Energy Research

Recent developments for Aurora's French services



Sources: Aurora Energy Research

Agenda

France's high prices

- **Why have French power futures been so high?**
- **Do French futures reflect market conditions?**

Can renewables capture those prices this winter?

- Can solar and onshore wind assets capture those prices?
- What discount to baseload should RES developers expect in the winter?

The implications of France's energy sobriety plan

- What measures are planned to reduce power demand?
- What impact will they have on power market prices and loss of load expectations?

Source: Aurora Energy Research

A number of weather-related and exogenous factors have contributed to exceptionally high power prices in 2022

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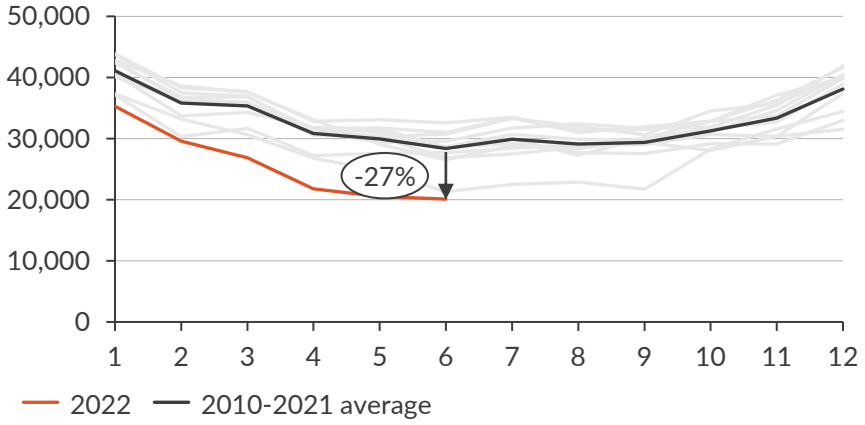
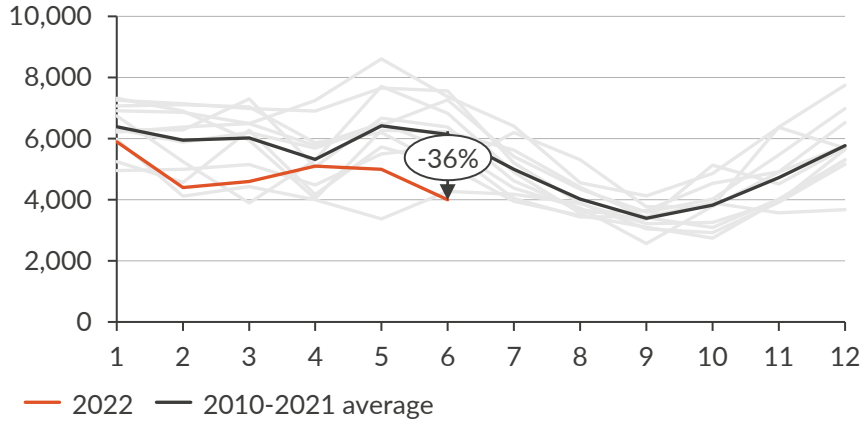
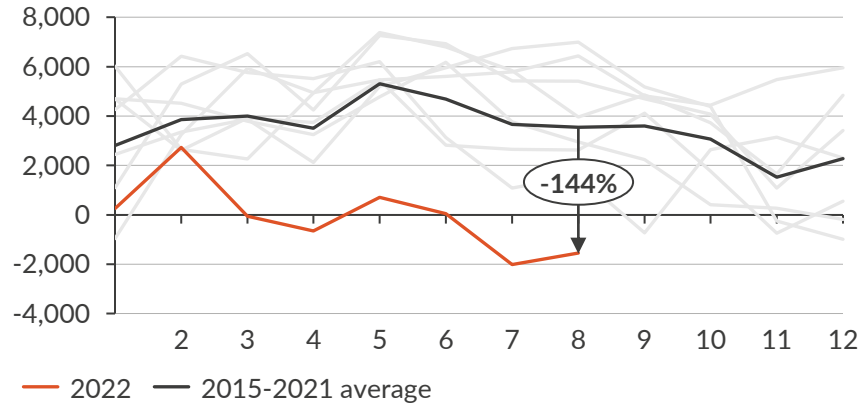
Nuclear production
GWh



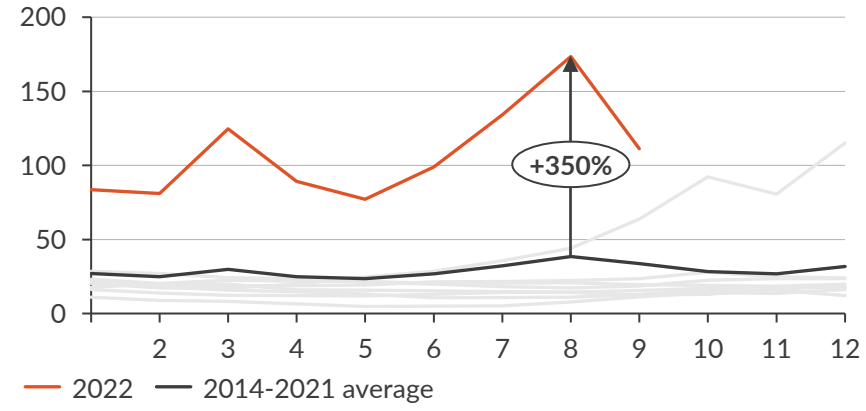
Hydroelectric production
GWh



Electricity balance
GWh



Gas prices
EUR/MWh

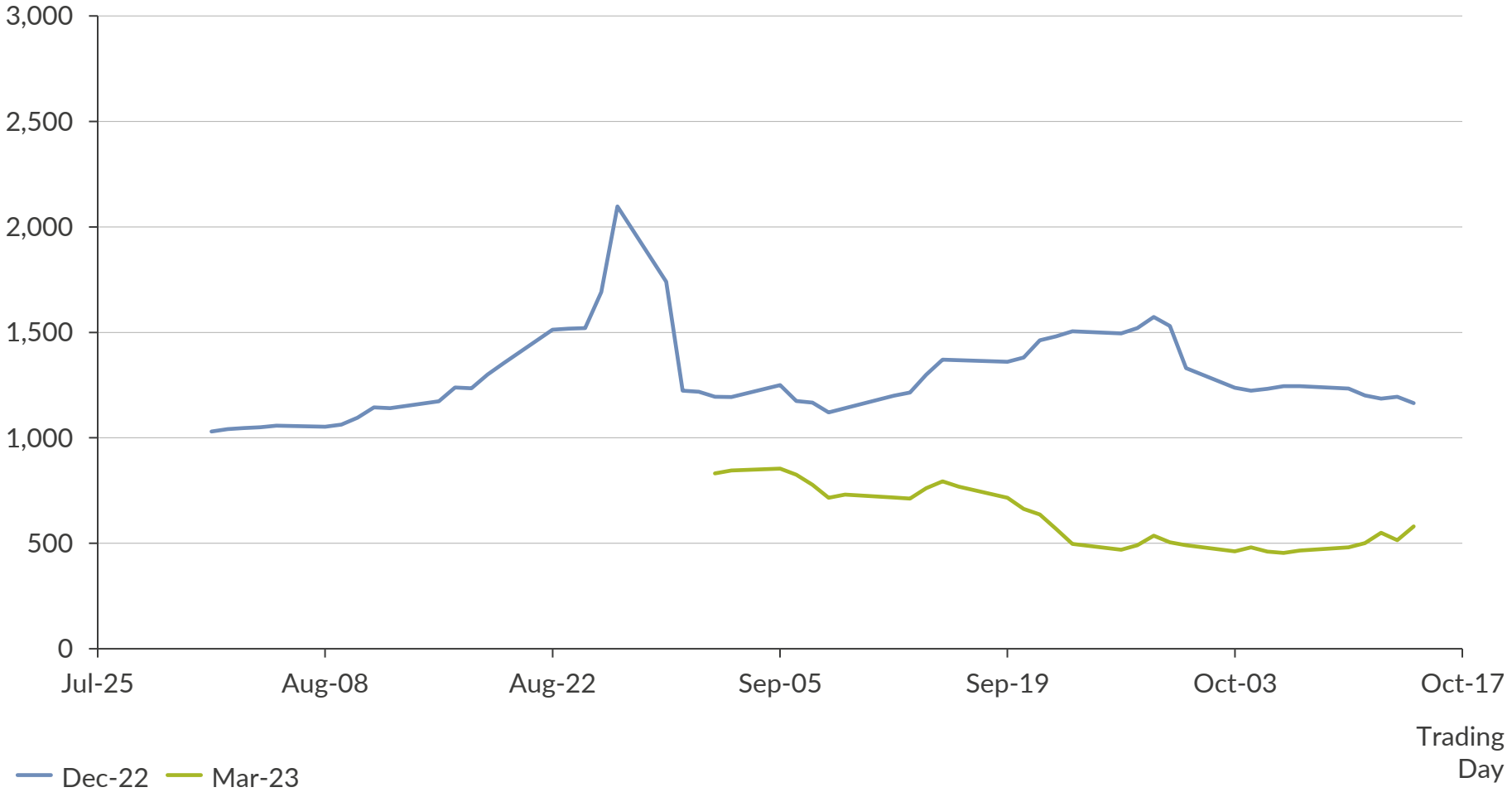


- Nuclear reactors in France have experienced exceptional levels of unavailability, as a result of three factors: a) delated maintenance following COVID lockdowns; b) decadal safety controls by the regulator and c) reactor temporary mothballing, following the discovery of signs of corrosion
- A particularly dry and hot weather in 2022 lowered hydroelectric power production levels
- Low nuclear and hydro production increased French power imports. 2022 will end up with a negative electricity balance
- As a result, the French power system has proven highly dependent on gas, and sensitive to the increase in gas prices

Sources: RTE, CNR, Aurora

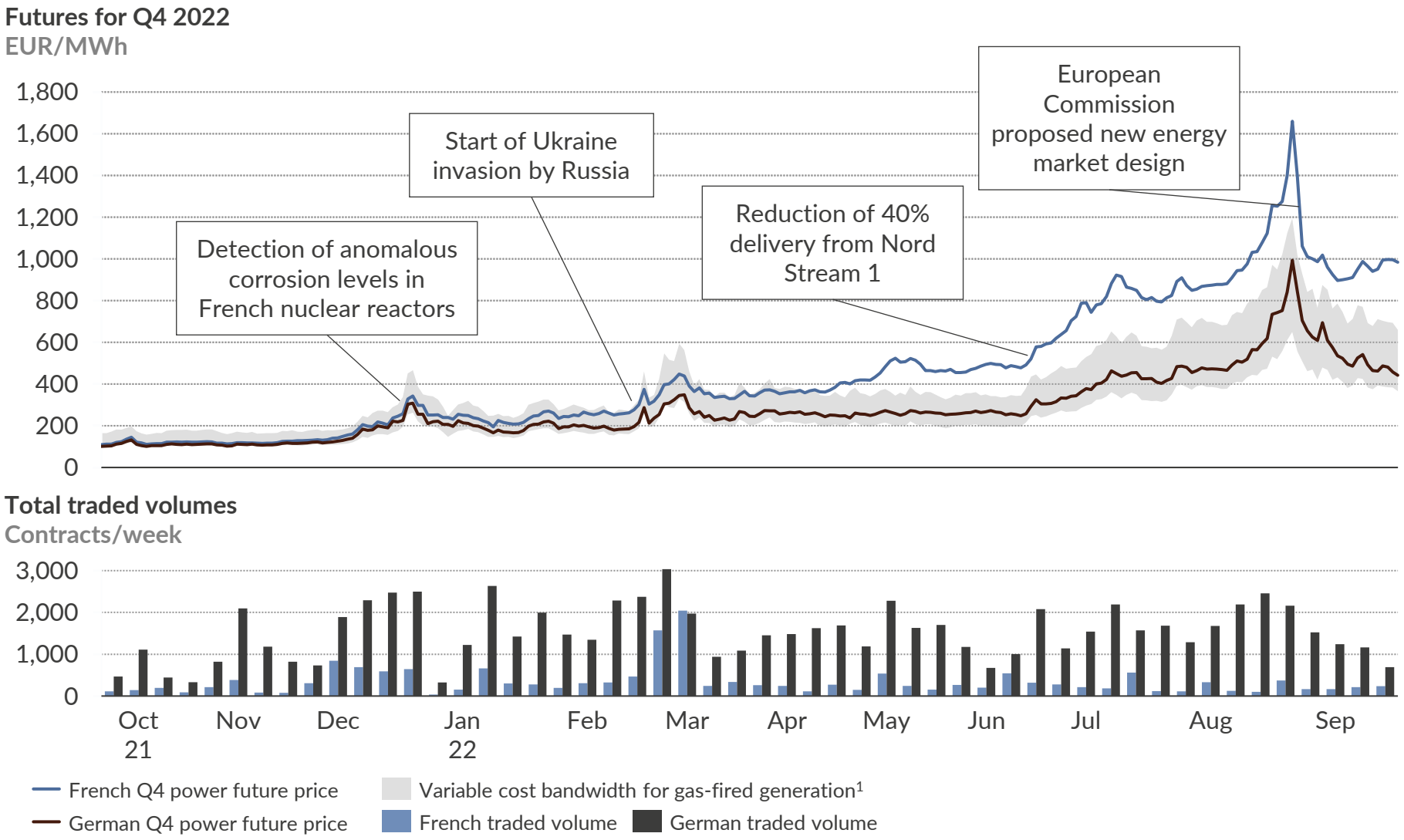
Prices have receded from 2,000 to 1,200 EUR/MWh on the futures market for December, as fears of a winter crisis have softened

Baseload monthly EEX futures for 2022-2023 winter
EUR/MWh



- Futures have steadily risen throughout the month of August, both for power delivery and for gas delivery in the winter
- Those high prices suggest expectations of high amounts of scarcity on power and gas markets, which could result from
  - Colder than expected winter
  - Additional nuclear outages
  - Short gas supply
- Volumes traded were significant, showing some element of liquidity on the market despite high prices

Contrary to Germany, price of power futures in France have decorrelated from the marginal cost of gas-fired power generation

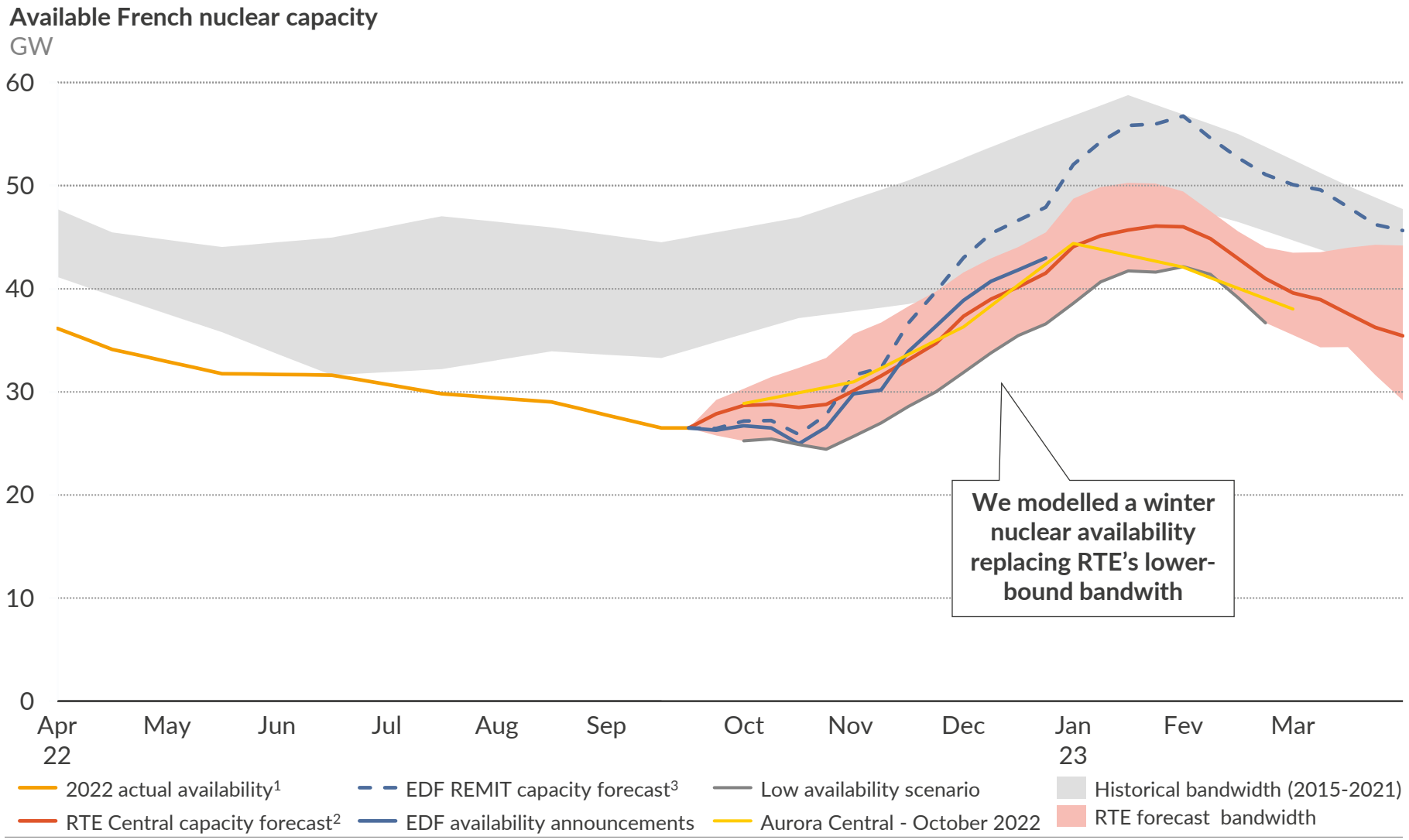


1) Calculated based on the Q4 Dutch TTF future prices based on an efficiency ranging from 30% to 56%, emission intensity of 0.4 t CO2/MWh and average carbon price of 80 EUR/t CO2.

Sources: EIKON, EEX, Aurora Energy Research

- In general, power price futures closely follow the marginal cost of gas-fired power as shown before January 2022
- From Q1 2022 onwards, French power price futures have decorrelated from this trend while market liquidity seems to remain unchanged
- Reasons for this decorrelation are unclear but could include:
  - Traders pricing in risk of loss of load as this would lead to additional costs (industry production shut-downs or even physical risks etc.)
  - Doubt about nuclear recovery
  - Speculation and fears about cost of securing natural gas deliveries in winter

French nuclear availability is at an all-time low while the recovery of the fleet for the coming winter is still uncertain



1) Last update on 21 September 2022 2) RTE is the only French TSO that publishes its own nuclear availability forecast apart from operator EDF 3) EDF's forecast of available nuclear capacity

Sources: EDF, RTE, Aurora Energy Research

- Over the past decade, nuclear power in France has met around 70% of French power demand and contributed to consistent electricity exports from France of around 50 TWh
- On the 21st of September 2022, the nuclear capacity available was 34% lower than the average historical value
- EDF's public announcements do not seem to follow their latest REMIT availability forecast nor RTE's (TSO) assessment adding uncertainty to the potential capacity available during the winter
- Lack of nuclear capacity leads to more expensive thermal generation. Uncertainty around winter temperatures, nuclear output, and demand reduction leads traders to price in risk of loss of load during winter months

Fundamental modelling of power prices given gas futures prices shows a significant gap with traded power futures prices

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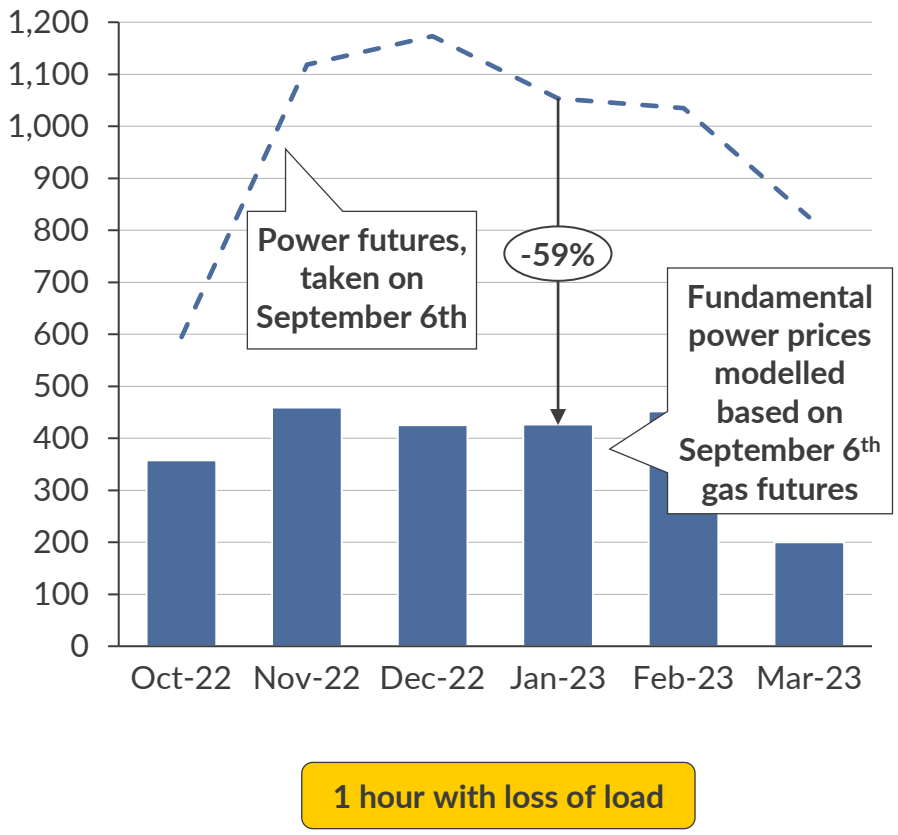
1 Scenario - Normal demand

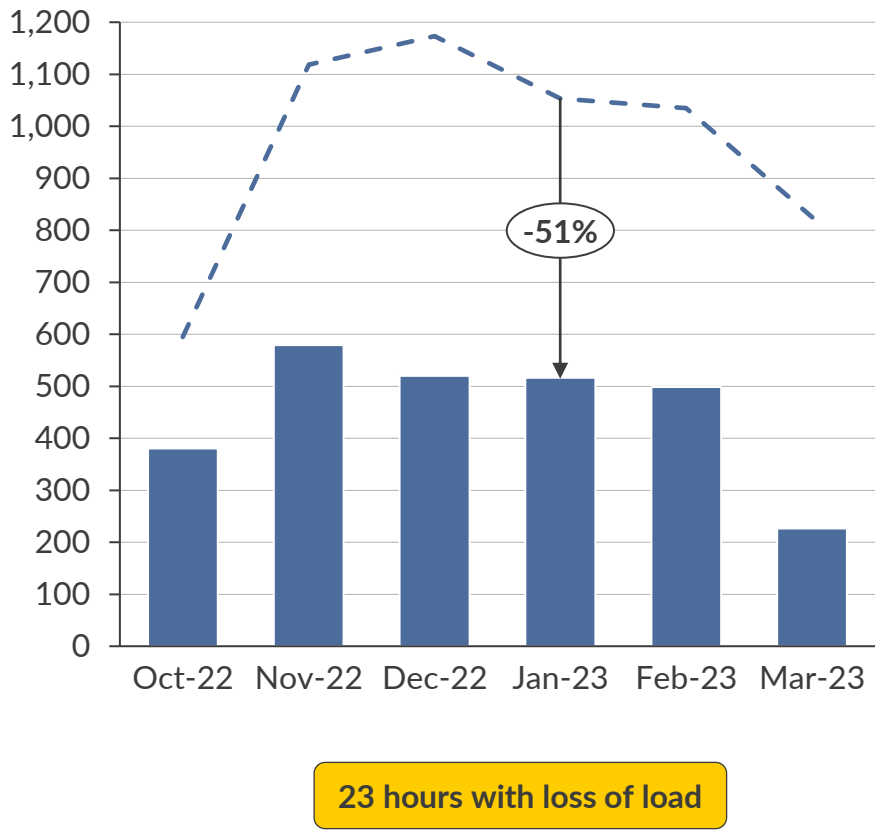
Baseload prices
EUR/MWh (2021)



1 hour with loss of load

2 Scenario - High demand

Baseload prices
EUR/MWh (2021)



23 hours with loss of load

Modelled power prices EEX Futures

Baseload and capture prices are modelled using gas futures prices as of September 6th 2022

Sources: Aurora Energy Research, EEX

- Power futures reached an average of 967 EUR/MWh for Oct-Mar delivery, on September 6th
- Based on fundamental modelling, taking gas futures, the price of electricity would be 51%-59% lower
- In a scenario with high power demand in the winter, there are 23 instances with loss of load, suggesting a highly overstressed system

A scenario of system stress, which combines low nuclear availability and high power demand, leads to loss prices of up to 830 EUR/MWh

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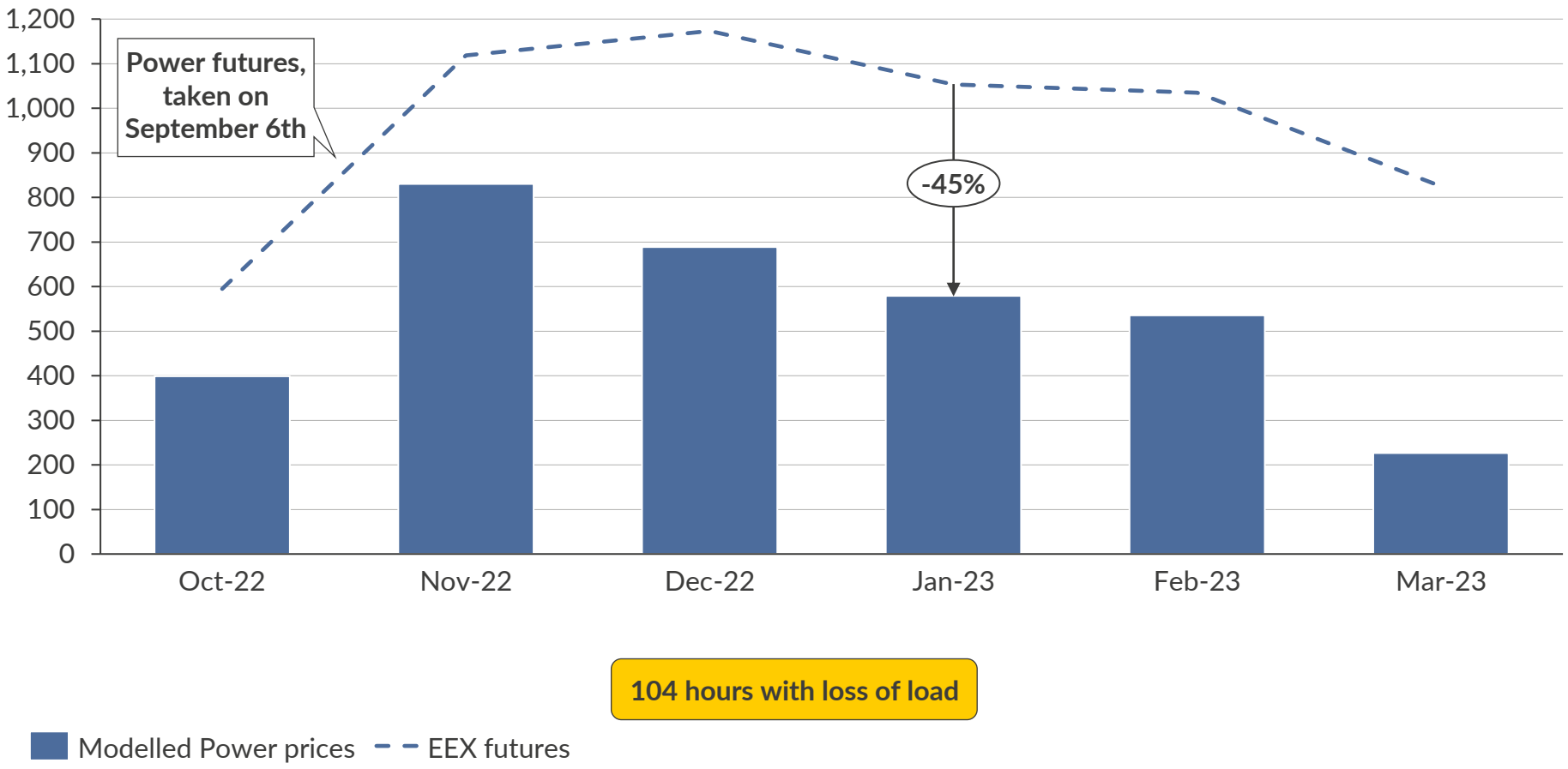
3 Scenario - High demand & lower nuclear availability

Baseload prices
EUR/MWh (2021)



Baseload and capture prices are modelled using gas futures prices as of September 6th 2022

- Under the combined effects of maintenance plans, corrosion issues and decadal safety visits, nuclear reactors have produced less than usual years
- Recent strikes will push he reactivation of five nuclear reactors
- In a “system stress” scenario, power prices are still significantly power futures for the winter, with more than 100 instances of loss of load between October and March

Power futures remain significantly higher than modelled baseload spot prices in any weather year scenario considered

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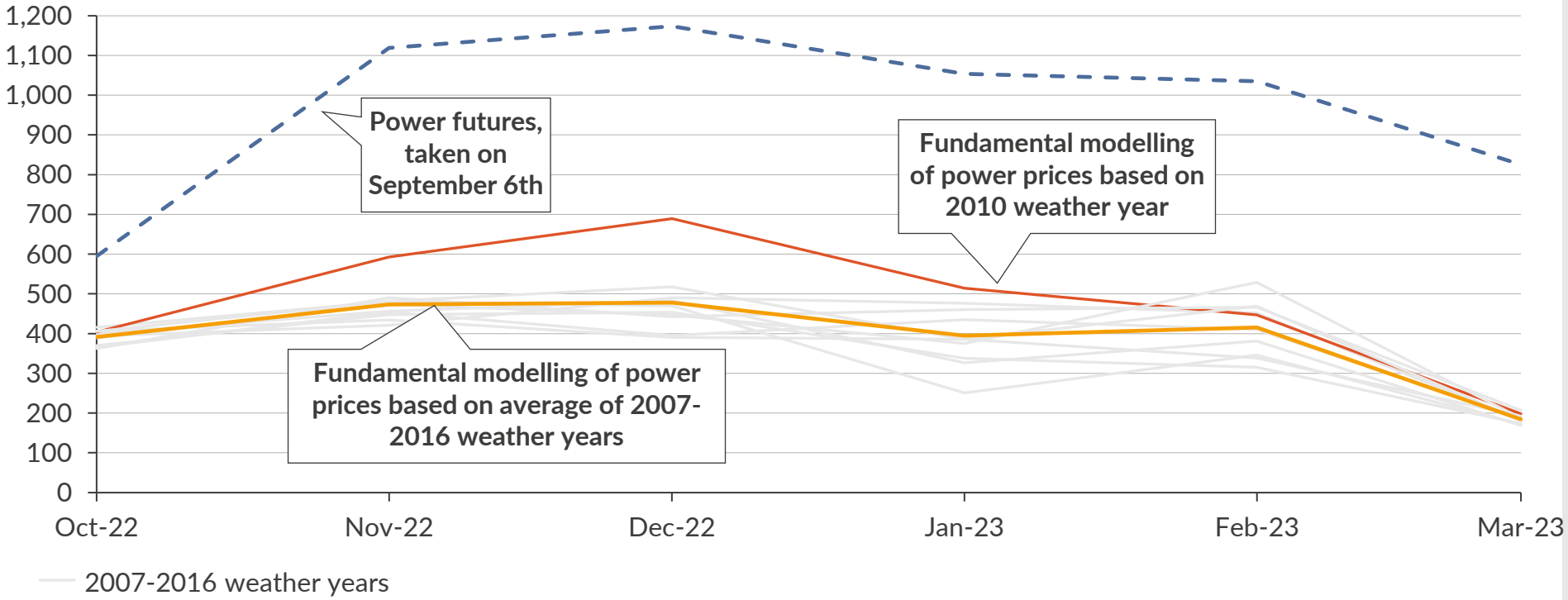
4 Scenario - Central demand in 10 weather years

Baseload prices
EUR/MWh (2021)



- Weather conditions can have significant effects on electricity markets. Weather affects both the supply of electricity, through renewable generation, and the demand for electricity
- Using load factors, weather patterns (irradiation, hydrometry, wind patterns, demand levels) seen across 10 different weather years, between 2007-2016, we can model the way in which prices respond to weather variations
- Power futures remain significantly higher than any weather year modelled

Baseload and capture prices are modelled using gas futures prices as of September 6th 2022

Additional factors can explain the gap between fundamental power price modelling and futures prices

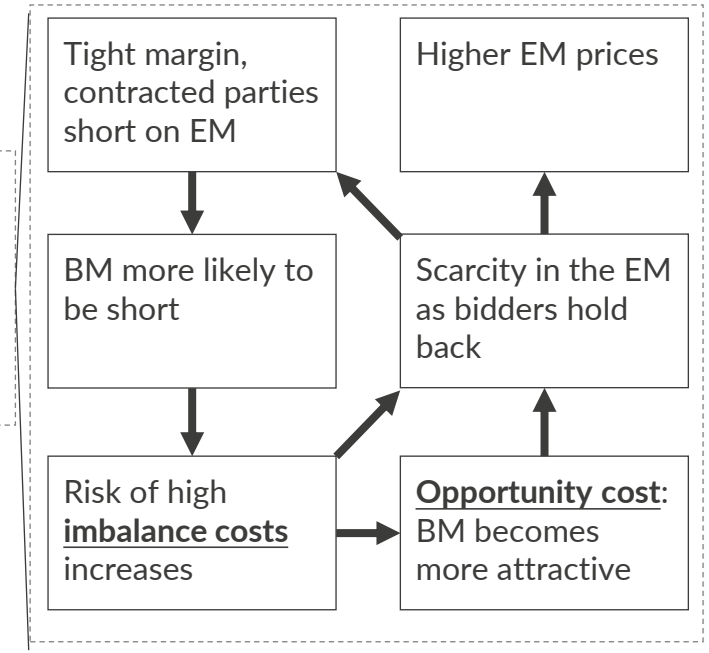
A similar situation was observed in the winter of 2016-2017 in Great Britain. As system margins weaken, price spikes become increasingly hard to predict. Several factors contributed to the uplift of electricity prices above system marginal cost:

Ramping costs: the additional costs from increasing output to deliver at peak times. Ramping costs tend to account for most of the price uplift on average, but contribute little to the very top prices ✓

Imbalance costs: as prices rise, the cost and risk of being out of balance increase for generators, and must be priced in by generators bidding in the wholesale market ✓

Opportunity costs: the trade off between bidding in the wholesale market vs. the balancing markets becomes more favorable to the latter (potentially higher reward and no risk of penalty) ✗

Imperfect competition: the ability to price above marginal price due to weak competition, portfolio concentration and/or asymmetry ✓



Additional factors specific to this winter may further explain the uplift:

Opportunity costs of hydro: with risks of shortages this winter extending to 2023 due to fear of shortage of gas supply, the cost of opportunity and price at which hydro bids significantly increases. In 2019, hydro was the marginal technology ~15% of the time in France. ✓

Additional factors explain part of the gap between system marginal cost and electricity prices

However, they are not sufficient to explain all of the gap

RTE, the French TSO, came to similar conclusions in September

This decorrelation suggests that power purchasers include a risk premium attributable only to an anticipation of significant loss of load (several hundreds of hours), which RTE doesn't expect

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Can renewables capture those prices this winter?

- **Can solar and onshore wind assets capture those prices?**
- **What discount to baseload should RES developers expect in the winter?**

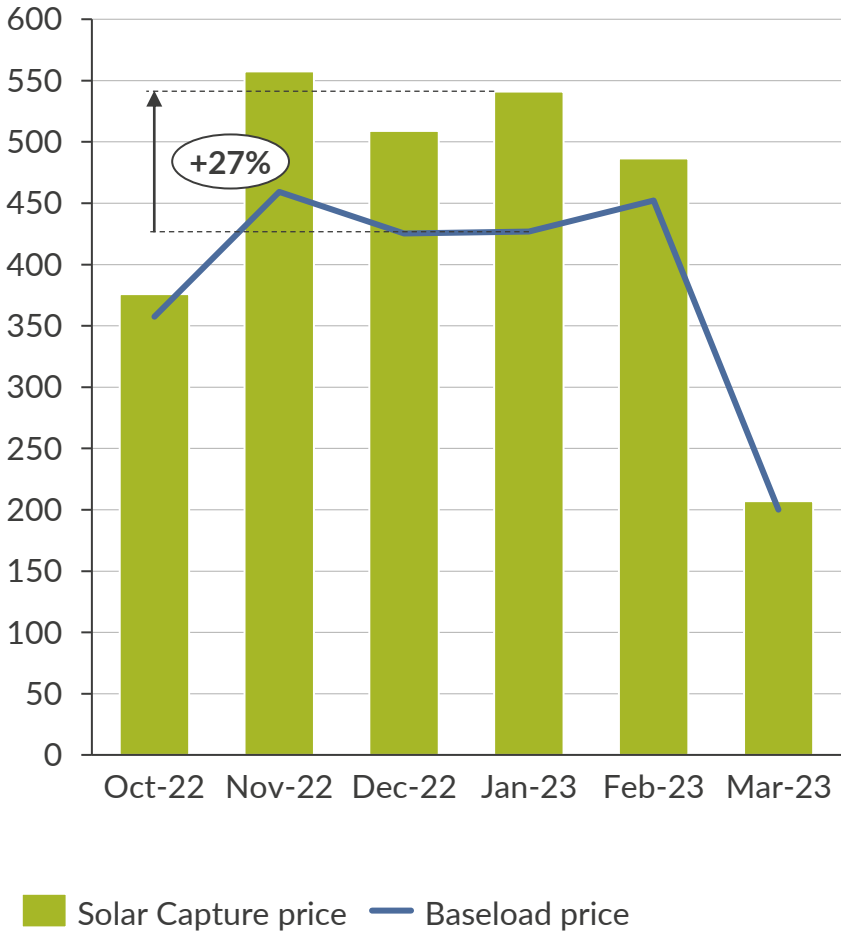
The implications of France's energy sobriety plan

- What measures are planned to reduce power demand?
- What impact will they have on power market prices and loss of load expectations?

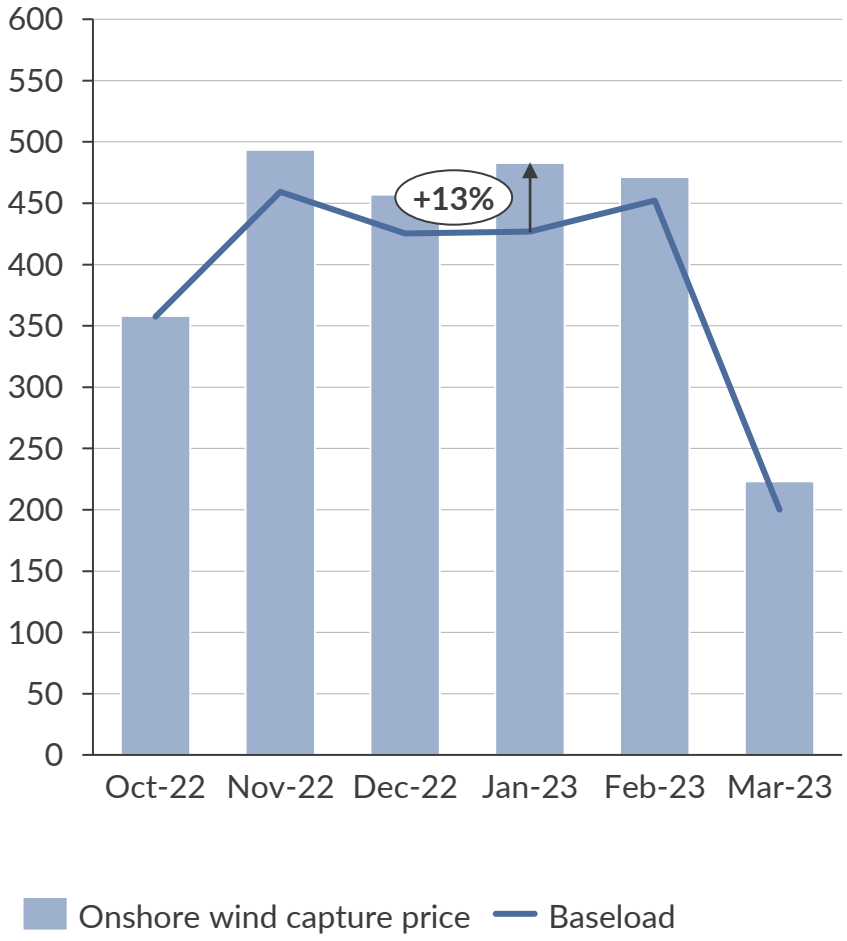
Source: Aurora Energy Research

In a scenario of high demand, solar capture prices outperform baseload prices as demand and gas prices set high peakload prices

Solar capture prices
EUR/MWh (2021)



Onshore wind capture prices
EUR/MWh (2021)



- In France, power demand tends to be higher during day-time (from heating), benefitting solar in particular
- With little installed solar capacity, solar cannibalisation is lower than wind cannibalisation.

Baseload and capture prices are modelled using gas futures prices as of September 6th 2022

Sources: Aurora Energy Research

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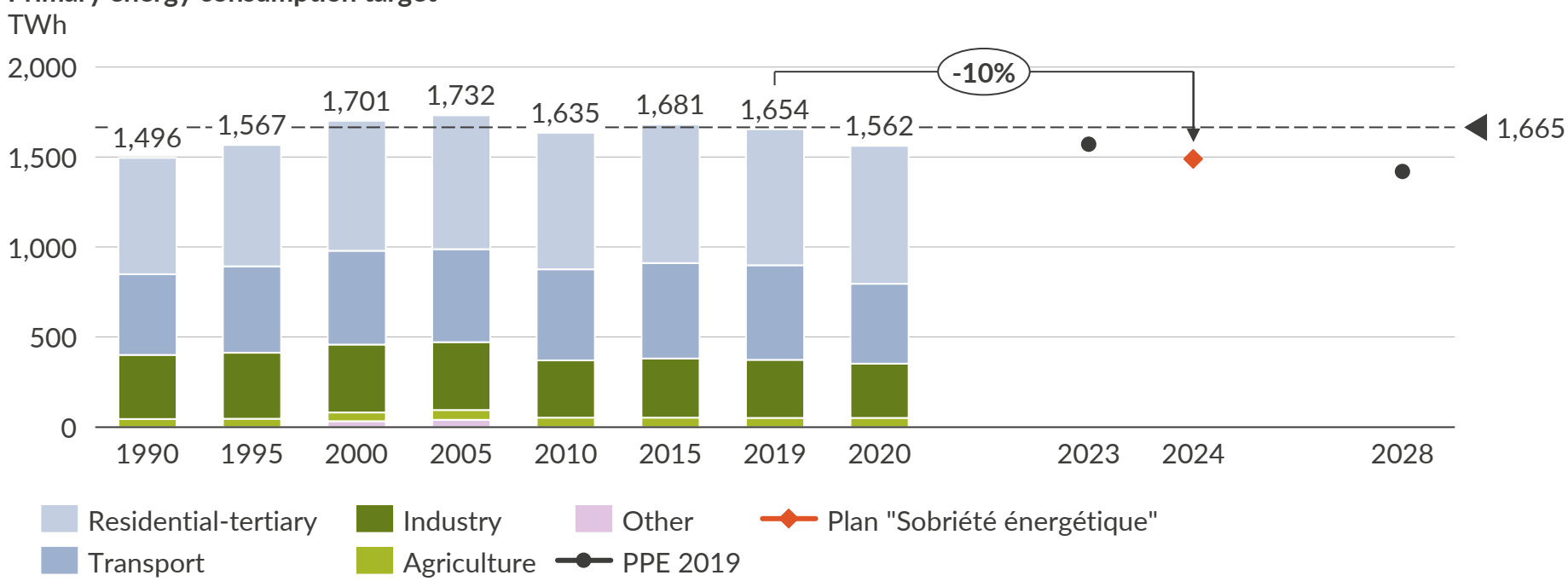
- **What measures are planned to reduce power demand?**
- **What impact will they have on power market prices and loss of load expectations?**

Source: Aurora Energy Research

France's "Plan sobriété" aims to reduce primary energy consumption by 10% by 2024, relative to 2019

Primary energy consumption target



Timeline

- A number of levers are envisaged to reduce energy demand
  - Remote work
  - Reduction of highway speed
  - Energy efficiency of buildings
  - Limitation of AC/heating at <19 degrees and >26 degrees
- A number of working groups are currently discussing ways in which this reduction could materialise
- Note that this objective concerns primary energy consumption, and is not limited to electricity.
- The details of the Plan Sobriété will be worked out in consultation in 8 working groups by sector

Sources: Bilan énergétique de la France, Aurora

RTE relies on the "Ecowatt" traffic-light system to manage demand and minimise safeguard measures for the coming Winter

The "Ecowatt" system is designed to inform consumers of strains on the grid for a 4-day window, with traffic-light signals

- Green: consumption is reasonable
- Orange: the grid is under pressure and demand reduction actions are welcome
- Red: if consumers do not reduce consumption during targeted periods, planned power cuts are to be expected

1 Ecowatt activations depend on the scenario and weather

- RTE forecasts that if consumption is reduced during "Ecowatt" red signals, most of the risk can be avoided, even in a very cold winter

Number of Ecowatt red signal activations in RTE scenarios

	Degraded scenario	Intermediate scenario	High scenario
Warm Winter[1]	4-7	0	-
Median Winter[2]	6-12	0-2	-
Cold Winter[3]	12-20	1-2	0-1
Very cold winter[4]	20-28	3-6	1-3

2 RTE ranked measures to respond to « Ecowatt » signals

- Businesses and communities are relied on the most to reduce consumption (RTE has signed business partnerships)
- Heating is the main targeted source of reduction

Estimated impact of measures in response to Ecowatt signals

	8pm – 1pm	6 pm – 8pm
Reducing heating	1.5 GW	1.2 GW
Limiting ventilation	0.1 GW	0.1 GW
Reducing lighting	1 GW	0.8 GW
Shifting EV charging	0.1 GW	0.1 GW
Switching off luminous displays	0.1 GW	0.1 GW

1) Based on 2019 and 2020 weather years; 2) Median value of weather simulations; 3) Based on 2012 and 2013 weather years: 4) Based on 2010 and 2011 weather years.

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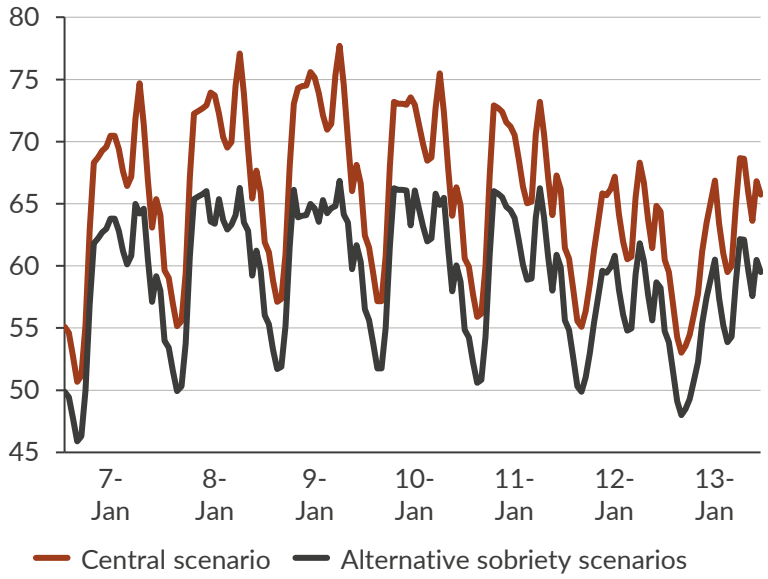
- The first action plan to manage demand is the sobriety plan ("Plan sobriété") rolled out by the French government, which aims to reduce and shift demand
- The "Ecowatt" system is aimed to signal stress periods on the grid and to punctually reduce demand from residential and tertiary consumers in response to orange and red signals
- The goal of the "Ecowatt" system is to reduce electricity consumption by 1 to 5% to avoid planned power cut occurrences ("délestage"), as an extra safeguard measure
- If consumers respond efficiently to "Ecowatt" signals, this could considerably reduce the number of safeguard measures activated by RTE to ensure grid stability

We modelled three scenarios of demand reduction, based on France's and the EU's announcements, to verify the impact on prices and security of supply

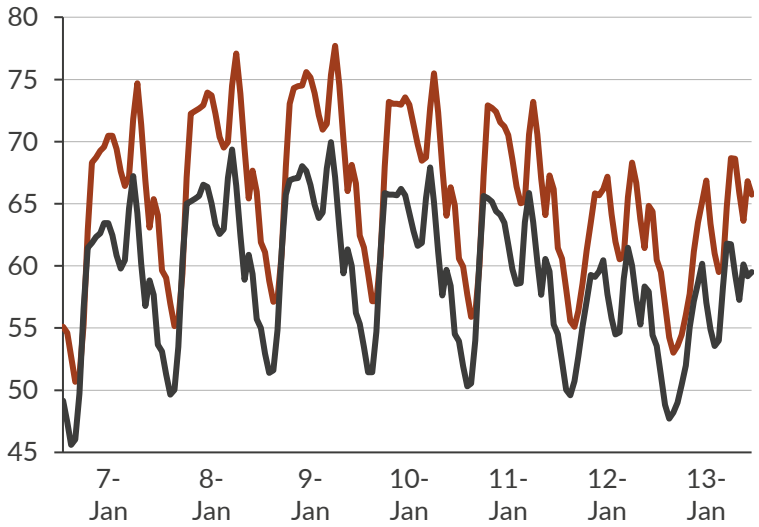
We modelled three scenarios in which energy sobriety is factored in:

1 Scenario - 10% reduction; + 5% peak hours

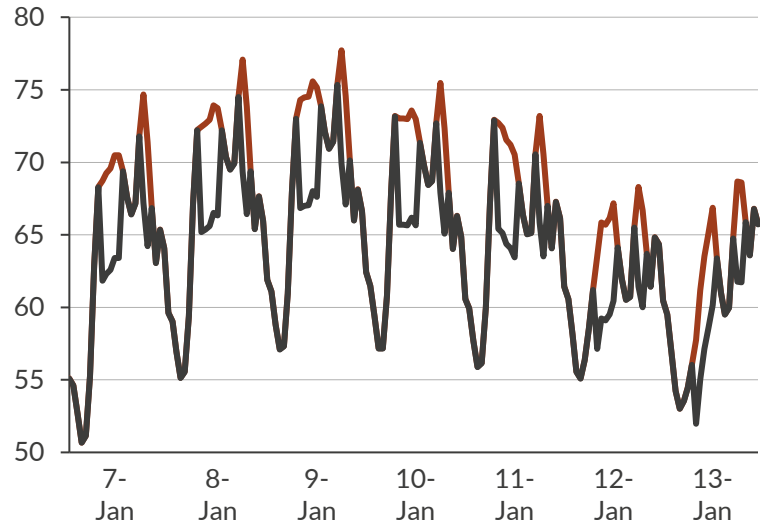
Weekly power demand
GWh



2 Scenario - 10% homogenous reduction



3 Scenario - 10% reduction during peak hours



1 The European Commission's plan consists in two targets:

- a **10% overall demand reduction** (non-binding)
- a 5% reduction of **peak power demand during the 10% weekly peak hours** (binding)

France announced its own sobriety plan, with the objective of reducing power demand by 10% over 2 years. This was followed by a press conference by RTE which emphasised the need to reduce system stress during Ecowatt hours (8am-1pm, 6pm-8pm). We modelled two ways in which the sobriety plan could materialise:

2 10% electricity demand reduction

3 10% electricity demand reduction **during Ecowatt peak hours only**

Sources: Aurora

Reducing demand on a continuous basis will be critical in avoiding loss of load and high electricity prices

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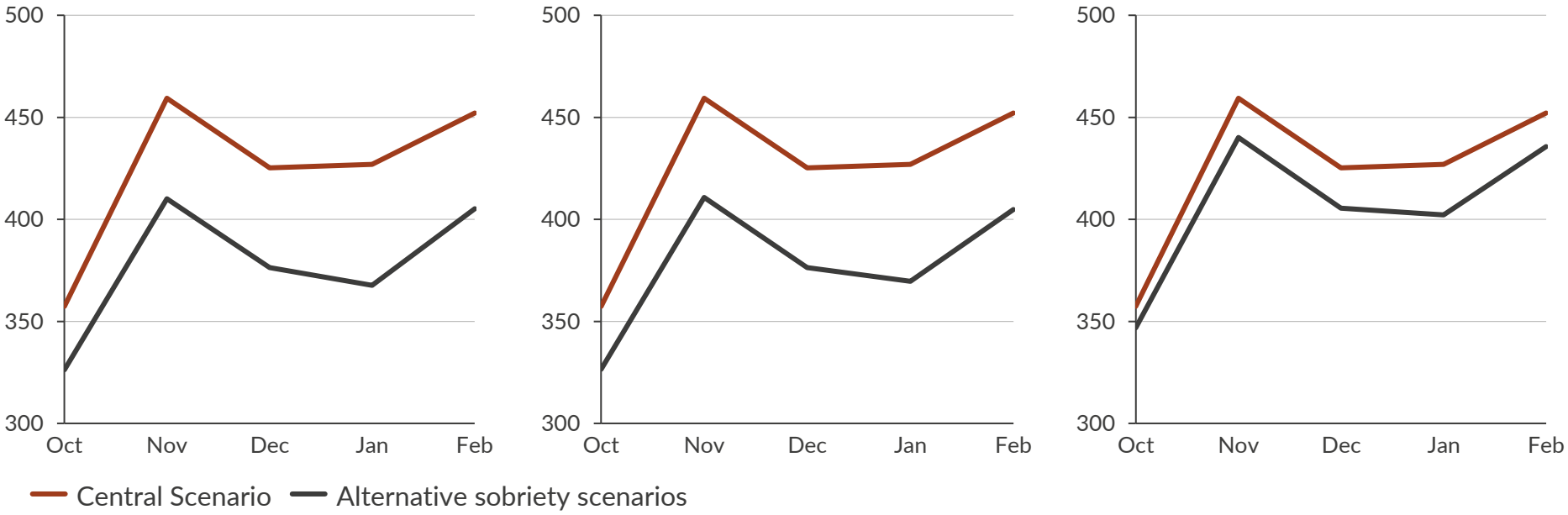
1 10% reduction +5% during peak hours

2 10% homogenous reduction

3 10% reduction during peak hours

Baseload prices
EUR/MWh



Average reduction in power prices	-10%	-10%	-4%

- Demand reduction during peak Ecowatt hours should be sufficient to avoid loss of load
- However, continuous reduction in power demand will have a much greater impact on power prices

Sources: Aurora

Key takeaways from Aurora's modelling

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1. The 2022 presented specific characteristic affecting weather conditions, nuclear availability and hydroelectric production, and gas supply levels. This has resulted in significantly higher power and gas futures as usual

2. With or without higher-than-usual power demand, power prices remain significantly lower than those seen on the EEX futures market, suggesting worst case scenarios have been priced in

3. Renewables are set to capture prices at least as high as baseload prices, as high winter demand and little installed capacity to date minimise the impact of renewables cannibalisation.

4. The European Commission and France have announced a set of measures aimed at reducing overall demand and peak demand levels, in the hope of reducing the risk of blackouts and market prices. Our research suggests that continuous demand reduction is best suited to reduce both prices and risks of loss of load

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