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ENERGY RESEARCH

Brazil's Capacity Market Auction

Challenges and Opportunities for a Secure and Decarbonized Future

18th September 2024
Public Report

Agenda

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I. **Introduction**

II. **Brazilian market: security of supply overview and key challenges**

III. **Capacity mechanism trends: international experience**

IV. **Capacity reserve auctions in Brazil**

   a. Current framework: thermal assets

   b. Opportunities for storage

   c. System-level analysis

V. **Key takeaways**

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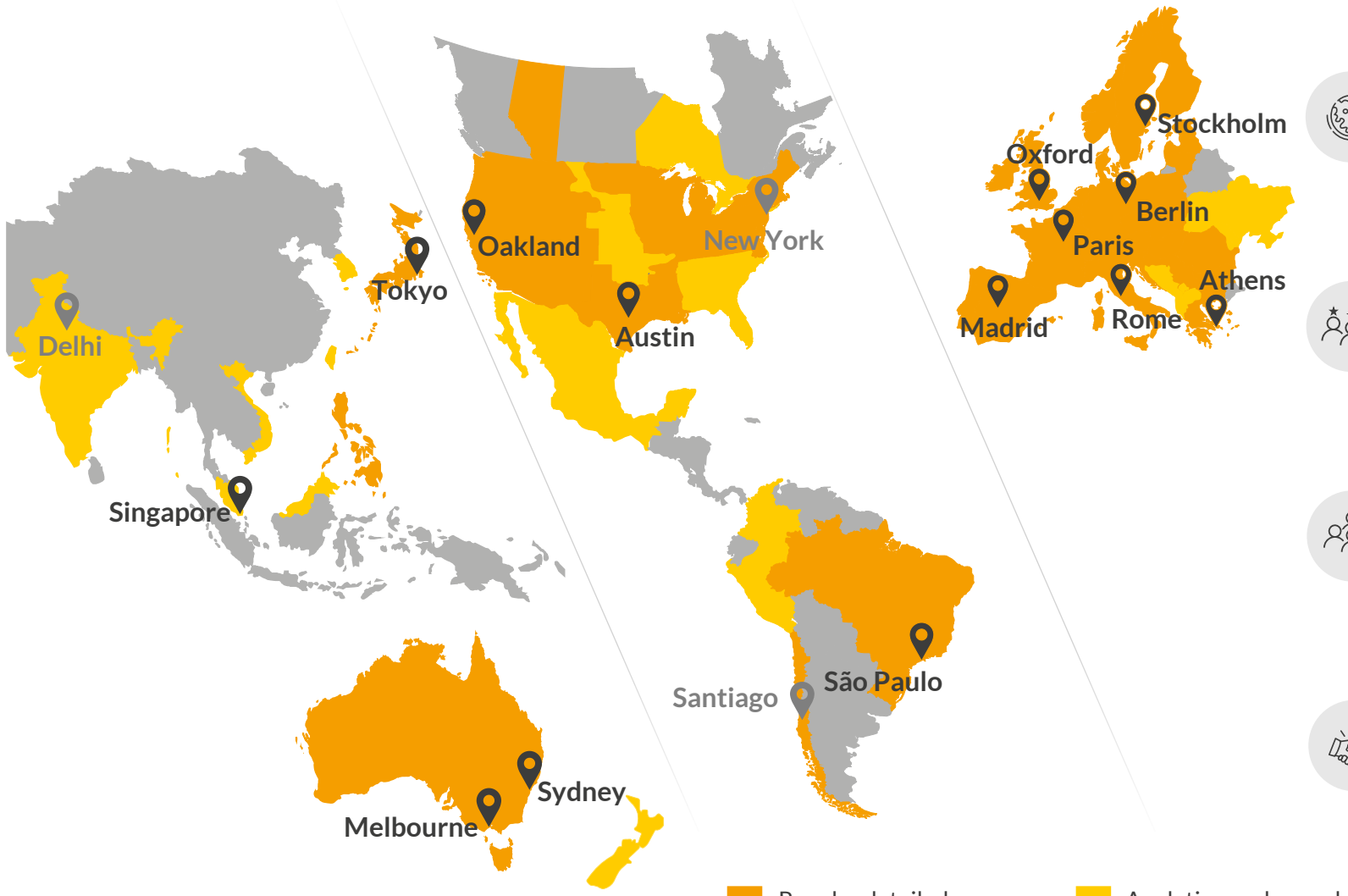
- Renewables & PPAs
- Storage
- Grid & Congestion
- Electric vehicles
- Hydrogen H_2
- Carbon CO_2
- Natural gas



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Aurora expects growth in intermittent renewables to continue, with capacity nearly doubling by 2030; this will sharpen the shape of daily demand

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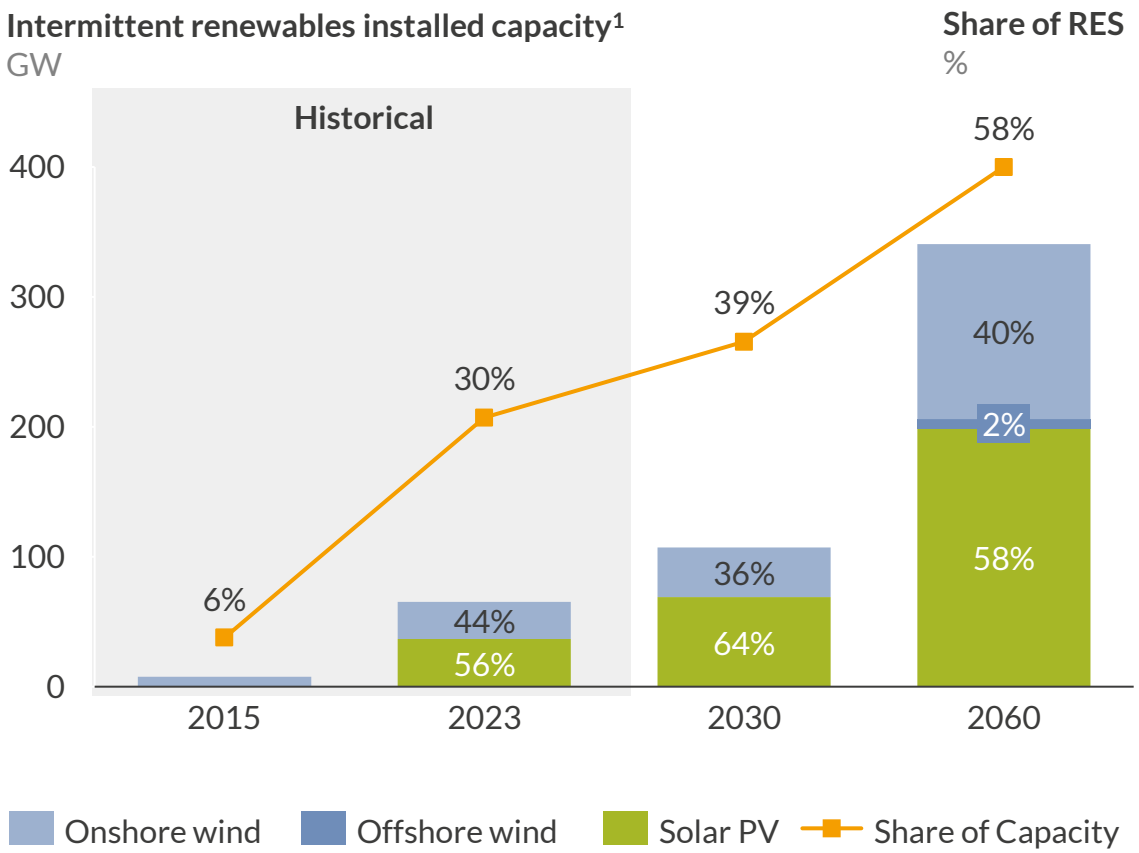
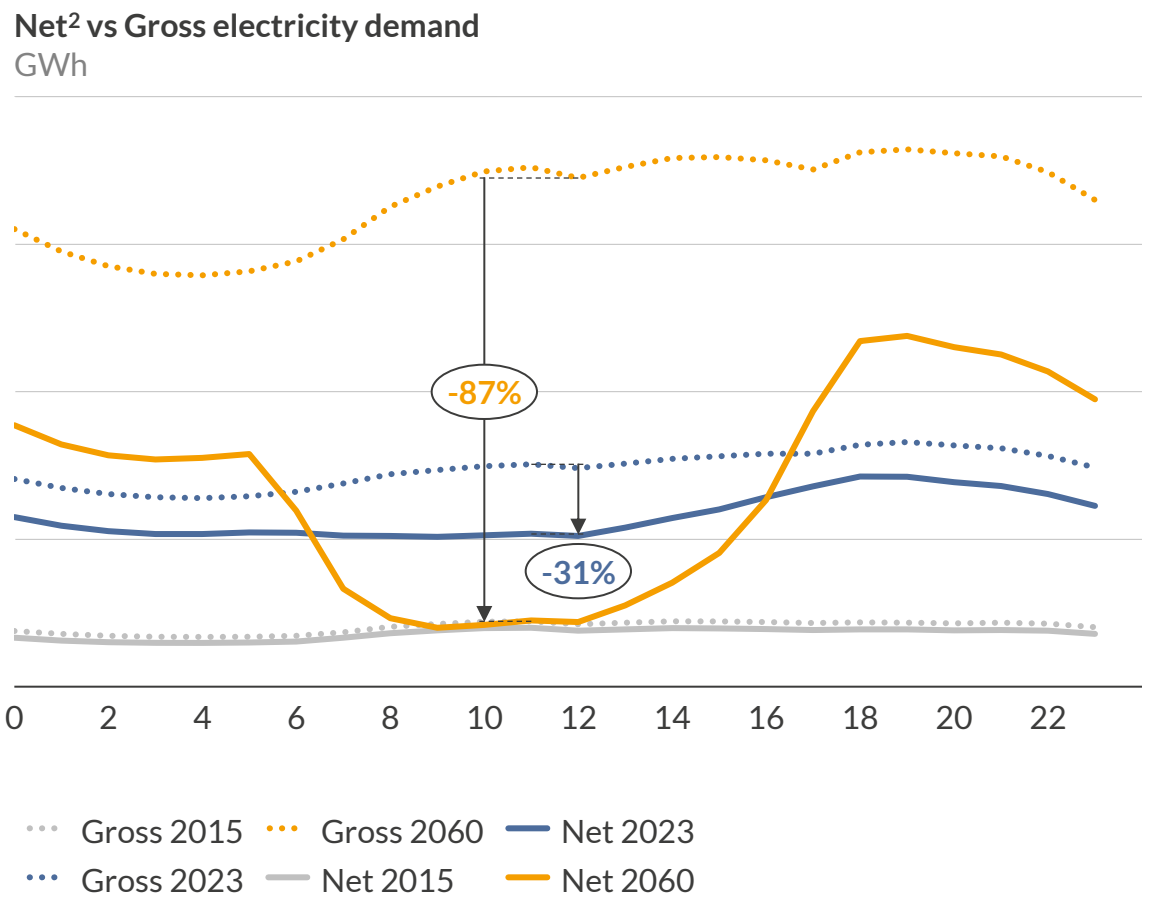
1 Over the past 8 years, 57 GW of intermittent renewables entered the Brazilian system. Aurora expects solar and wind capacity will nearly double by 2030, reaching 58% of total installed capacity by 2060

2 This will sharpen the shape of daily demand, already observed in 2023. In our forecast, solar and wind generation will significantly reduce midday net load, widening the spread between the minimum and peak load in a day





1) Solar PV includes MMGD. 2) Net Demand = Gross Demand minus solar and wind generation

Sources: Aurora Energy Research, ONS

Without new thermal and hydro builds, existing firm capacity can fall short of meeting forecasted peak demand's reserve margin range as soon as 2029

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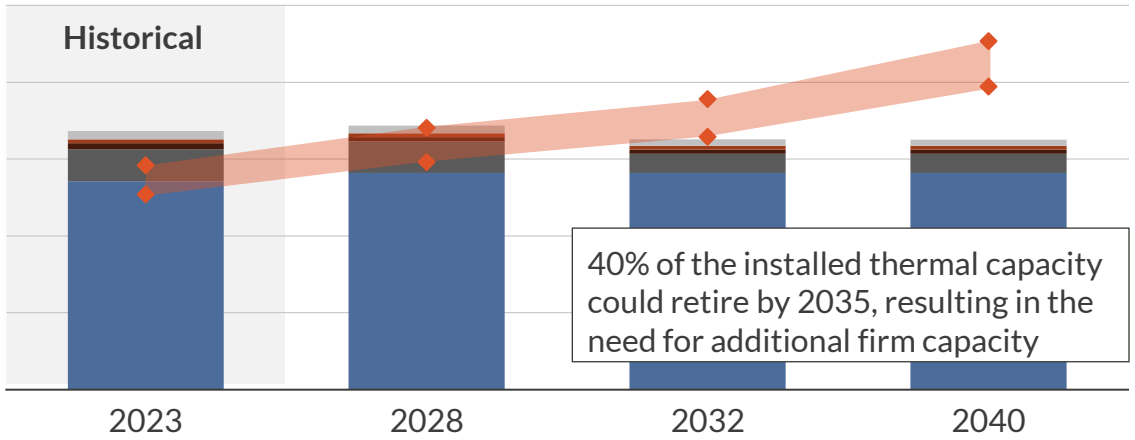
1 Due to occasional unavailability, Brazil's existing firm capacity could face gaps with forecasted peak demand ranges in the short term

Dispatchable capacity without new build[1] GW

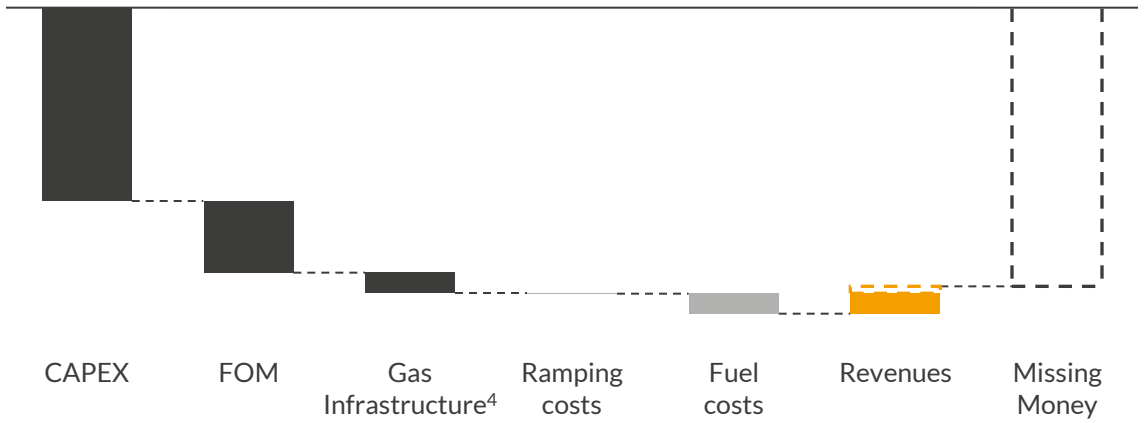
Peak demand range[2] GW



- Neither hydro nor thermal assets are continuously available at nameplate capacity, and therefore cannot be relied upon to their full capacity.
- Furthermore, to ensure security of supply, the system must be designed with a security margin on top of the forecasted peak demand.
- This widens the gap between available firm capacity and peak demand, leading to additional firm capacity requirements to avoid loss of load issues and guarantee security of supply to the system.

2 Energy market revenues alone are not sufficient to ensure the economic viability of dispatchable assets required to guarantee security to the system

Illustrative cashflow of a CCGT[3] R$/GW



- Firm capacity assets, like gas plants, typically have high CAPEX and variable costs, determined by its fuel costs and ramping costs. Their merit order positions result in limited dispatch rates.
- To become economically viable in such market conditions, and with no other markets or services available, these assets require additional revenue streams beyond the Energy Market. This gap is known as "missing money".
- Capacity markets play a crucial role in breaching the missing money gap.

Hydro Gas Coal Nuclear Other Peak Demand[2] Energy Market Margins Potential Ancillary Services[5]

1) According to Aurora's July 2024 Central scenario and considering a 9.9 GW thermal retirement . 2) Range considers a 15% security margin on top of forecasted peak demand. 3) For a CCGT operational from 2028 in the Northeast subsystem, with a 15-year contract and 12% WACC in Aurora's July 2024 Central Scenario. 4) Gas infrastructures, such as regasification terminals and gas pipelines, might not be necessary. 5) Potential Ancillary Services include Integral Self-restoration, secondary frequency control, synchronous generation, Special Protection System (SEP) and Operational Power Reserve Maintenance.

Sources: Aurora Energy Research, ONS

Agenda

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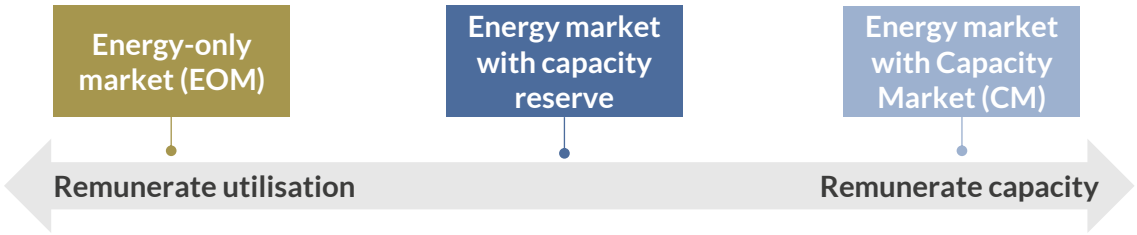
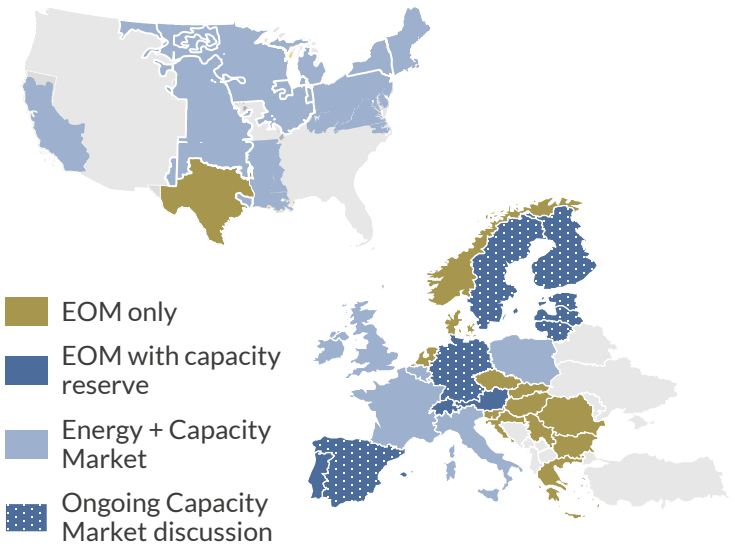
Capacity Markets are gaining maturity across geographies through continous improvements and adaptations to address local requirements

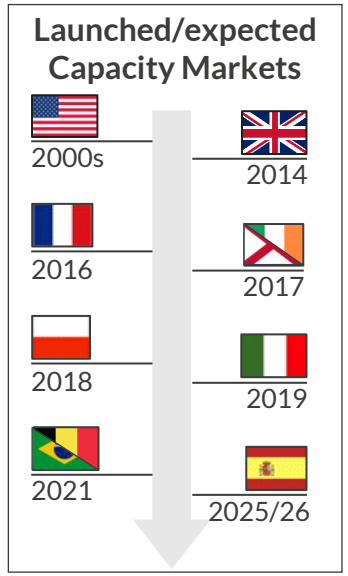
Overview of Global Capacity Markets

- A Power Market can use varied approaches to manage security of supply:



- Global markets are increasingly developing consolidated Capacity Markets





Despite maturing capacity markets for years, major geographies are constantly evolving their Market Design approach

European Union (EU):

- CMs have been introduced in six countries, with an additional seven in various stages of implementation.
- In response to the 2022 energy crisis, the EU reformed its power market design to make capacity mechanisms a structural element, rather than a last-resort measure.

Spain is at an advanced stage undergoing consultation of its proposed CM alongside EU interactions.

Germany is commited to introduce a capacity mechanism by 2028 to complemente its Power Plant Strategy.

United States (USA):

- Due to capacity changes and extreme weather events causing supply issues, several US Capacity Markets are currently undergoing revisions.

PJM[1] launched a Critical Issue Fast Path (CIFP) process to propose updates to its Capacity Market based on reliability concerns .

1) Stands for 'Pennsylvania-New Jersey-Maryland' interconnection.

Source: Aurora Energy Research, European Commission, Council of the European Union

Design elements of Capacity Markets vary across countries according to local economical, political and geographical challenges

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Basic design elements across Capacity Markets

Capacity procurement framework

Markets

- **Centralized:** Central authority holds regular auctions for system-wide capacity.
- **Hybrid:** Suppliers and central authority procure capacity individually.
- **Decentralized:** Suppliers and large consumers must secure capacity.
- **Cap futures:** Off-takers and suppliers agree to hedge for instabilities.

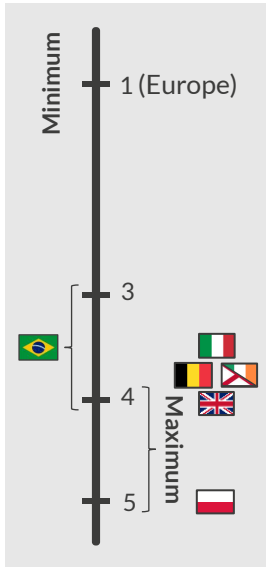
- Brazil status:

Centralized procurement:

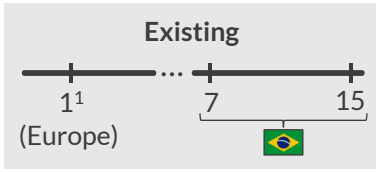
Government promotes "Capacity Reserve" auctions targeted at the broad national system operating needs.

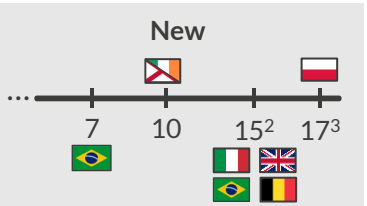
Timing & Duration

Lead time before delivery (years)



Contract Duration (by type of plant, years)





- Brazil status:

Product-oriented timing:

Duration and lead time defined at the auctioned product level.

Prices & Bid selection

- Auctions can **award capacity payments** using the following mechanisms:
  - Pay-as-bid: each successful bidder is paid the price they bid;
  - Pay-as-clear: all successful bidders are paid the price of the highest accepted bid;
- **Selection of bids** to be awarded may follow:
  - Descending clock[5]: Starts at price cap and decreases until target is met by exit bids;
  - Sealed bids: All participants submit sealed bids for funding their capacity operation;

Capacity market price caps in Europe

€/kW (nominal)

- Brazil status:

High-end cap price for pay-as bid:

The 2021 auction employed a descending clock mechanism on a pay-as bid basis and a high price cap.

1) In GBR, Demand-side Response (DSR) can be awarded multi-year contracts of up to 15 years. 2) In Belgium, new builds can apply for multi-year contracts of up to 15 years if meeting the investment thresholds. 3) In Poland, refurbishing and new plants can receive contracts of up to 7 or 17 years respectively depending on their emission intensity and investment costs. 4) In Italy, an existing plant can request to be considered a new plant if a minimum investment threshold is reached. 5) In Europe, existing assets can only drop the auction below a given threshold, while new units can exit at any price.

Sources: ANEEL, MME, MegaWhat, Aurora Energy Research

Agenda

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With parameters yet to be defined, the delayed timeline presents a challenging scenario for the Capacity Auction to take place in 2024

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Key features for 2024 Capacity Auction

New technologies and technical parameters

- Addition of new build extension to existing hydro capacity
- Technical specification of assets' operability:
  - Minimal ramp time: less or equal to 1h30/1h for up/down operation
- Batteries not included due to lack of regulation.

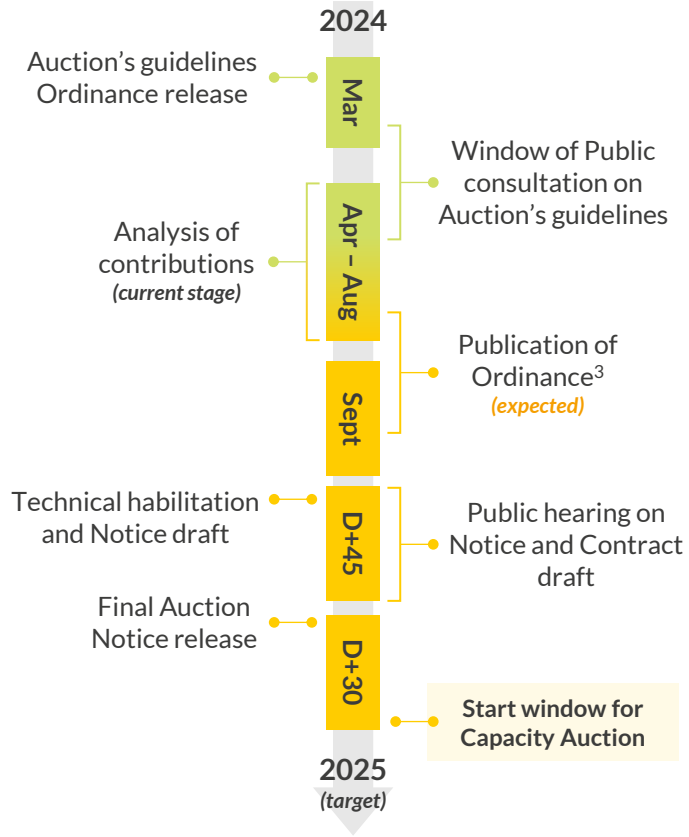
Revenue payment and penalties

- Unit commitments (ramp/minimum operation time) paid only by wholesale price (PLD).
- Dispatched generation paid by highest of PLD and marginal costs cap (CVU cap yet to be defined).
- Fixed revenue penalized by 5% of monthly pay for each missed critical hour[1] or when failing to meet power level required.

Critical hour methodology and temporal adjustments

- Availability mandatory at most critical 120h per year, limited to 4h per day.
- Approach to define of critical hours still to be settled:
  - 'Ex-ante': before they occur;
  - 'Ex-post': after event or at end of "verification period".

Timeline overview for 2024 Auction procedures



- To be held still within 2024, the Ordinance should be published **this week (mid-September)**

1) Not applicable to programmed stops (IP) if kept within Operator's schedule (but applied for non-programmed downtime – TEIF). 2) EPE: "Empresa de Pesquisa Energética"; ONS: "Operador Nacional do Sistema"; CNPE: "Conselho Nacional de Política Energética"; ANNEL: "Agência Nacional de Energia Elétrica". 3) Portaria.

Sources: ANEEL, MME, MegaWhat, Aurora Energy Research

To ensure economic viability, thermal plants' bidding strategy must cover a range of fixed and variable costs, that varies depending on each specific asset

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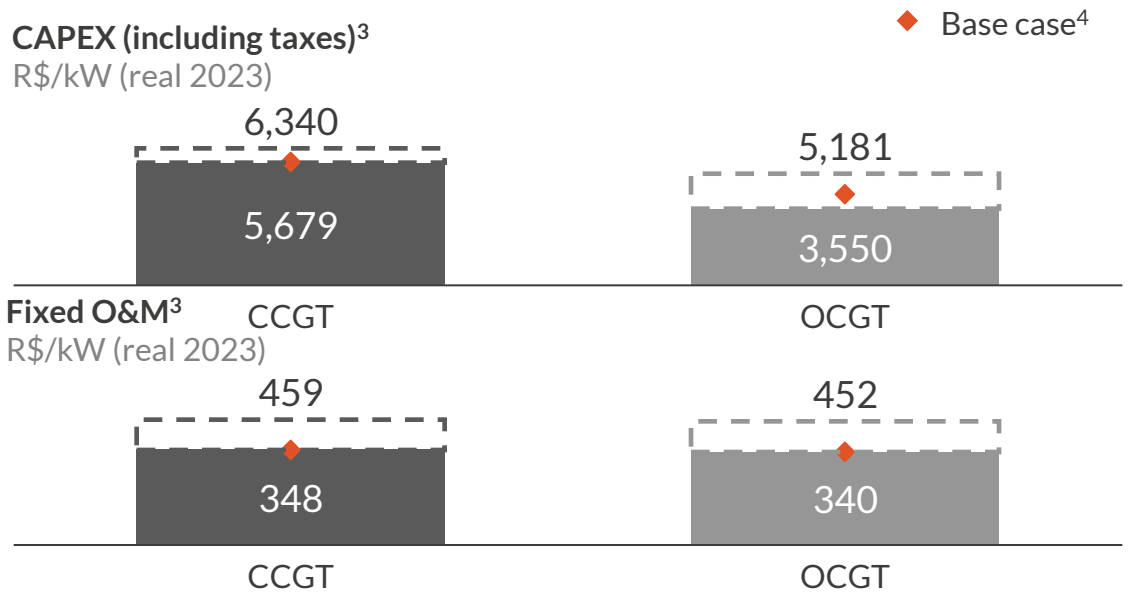
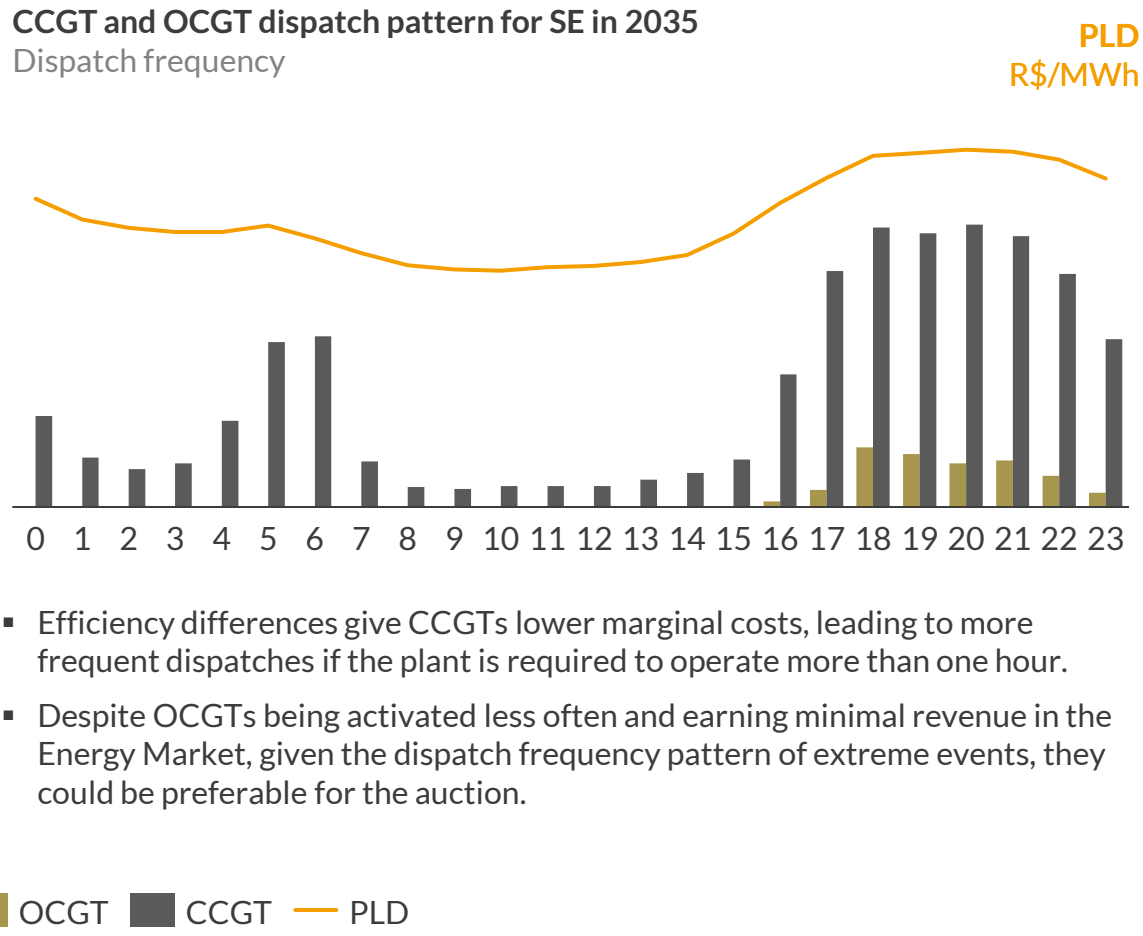
1 Each of these thermal costs can vary depending on technology, location and type of project (new or existing)



- CAPEX varies by plant size, with costs like regasification terminals and pipelines potentially increasing initial estimates.
- Fixed O&M costs are influenced by a plant's gas infrastructure setup, including pipeline connections, private terminals, or third-party services, plus grid charges and taxes.
- Variable O&M covers ramping and fuel costs, with operational efficiencies of 30%-37% for OCGT and 48%-57% for CCGT.

2 Technology type impacts thermal dispatch, with OCGTs and CCGTs' yielding different merit order positions



- Efficiency differences give CCGTs lower marginal costs, leading to more frequent dispatches if the plant is required to operate more than one hour.
- Despite OCGTs being activated less often and earning minimal revenue in the Energy Market, given the dispatch frequency pattern of extreme events, they could be preferable for the auction.

1) For a CCGT operational from 2028 in the Northeast subsystem, with a 15-year contract and 12% real WACC in Aurora's July 2024 Central Scenario. 2) Potential Ancillary Services include Integral Self-restoration, secondary frequency control, synchronous generation, Special Protection System (SEP) and Operational Power Reserve Maintenance. 3) Range includes values from Aurora's Brazilian subscribers, EPE, Aurora internal team, IJGlobal database and LRCAP 2021. 4) Costs for the Southeast subsystem. 5) Grid charges related to transmission connection and usage costs are also considered, according to ANEEL's generation TUST database.

Sources: Aurora Energy Research, IJ Global

OCGTs may hold an advantage in current auctions, but existing CCGTs can compete through strategic upgrades

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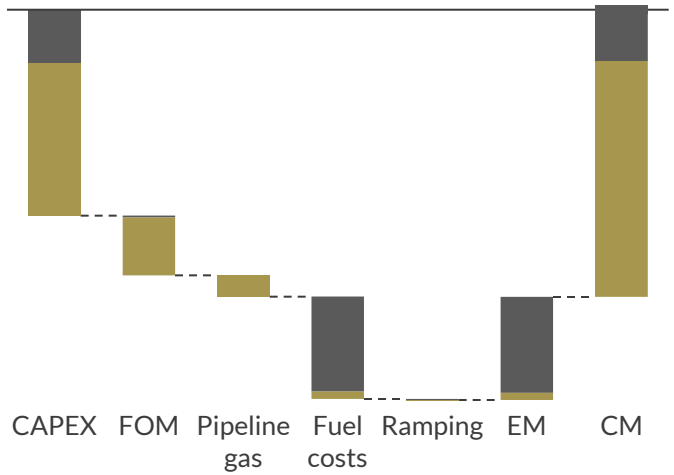
1 OCGTs have lower CAPEX but higher OPEX, potentially offering advantages in the bid framework…

Cashflow[1] for a new CCGT and OCGT in Southeast
NPV R$/kW (real 2023)

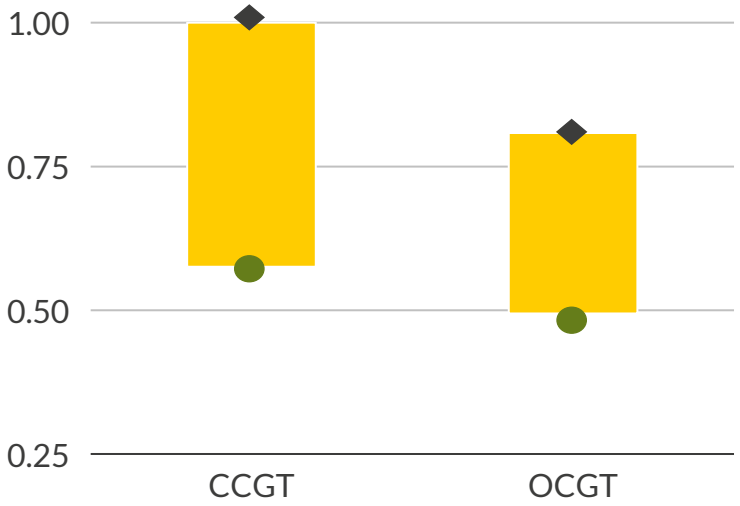


- OCGTs may have a competitive advantage in capacity payment bids due to their greater operational flexibility and lower investment requirements.

OCGT CCGT

2 …however, CCGTs can remain competitive if they are existing and only require retrofit[2] or minor upgrades to remain operational (and potentially increase its efficiency)

Bid in the capacity market for SE subsystem
Relative Bid in respect to New CCGT (base = 1)



- In the 2021 auction[3], CCGTs emerged as predominant winners because bidders were able to use existing thermal plants, which required less investment in retrofit.

New plant Retrofit

Existing CCGTs:

- By 2028, at least 5 GW of existing CCGTs will be merchant or uncontracted and are expected to be competitive in the auction.

Oil and Diesel:

- Due to their typically lower CAPEX, these plants could also be competitive if they can secure marginal costs[4] below R$600/MWh (upper-bound value allowed in the last auction)[5], which would be possible if fuel prices were equal or below R$159/bbl and R$141/bbl, respectively.

Biomass:

- By 2027, 897 MW of biomass capacity will be uncontracted from the regulated market.
- Biomass plants face challenges due to seasonal generation. If they can address this limitation—such as by integrating biogas with natural gas to provide year-round supply—they could improve their competitiveness in future auctions.

1) Real WACC = 12%. 2) Retrofit of existing plants, leveraging infrastructure from projects nearing the end of their contractual life, with a CAPEX of approximately 40% of greenfield projects(EPE PDE 2030). 3) 5 of the 7 CCGT plant winners in the last auction were existing ones. 4) Supposing a heat rate of 1bbl =1.702MWh for diesel and 1bbl=1.586MWh for oil with efficiency of 40% and 42%, respectively. 5) In the LRCAP 2021, 5 oil plants and 2 diesel plants managed to originally win the auction, supported by court injunctions, despite having marginal costs 75% to 242% above the authorized threshold. However, they were later declassified and not awarded contracts in the auction.

Sources: Aurora Energy Research

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When looking at what might fill the security of supply gap, there is no "silver bullet" technology

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Battery Storage (BESS)

Deliverability by 2030	Contribution to security of supply	Alignment with net zero
◔	◔ - ◔	●

- Batteries offer flexibility and rapid response, but it's contribution for security of supply depends on the duration of the events.
- In Brazil, alongside with current technology cost concerns, a regulatory framework is still lacking.

Pumped Storage

Deliverability by 2030	Contribution to security of supply	Alignment with net zero
◑	●	●

- With the world's second-largest hydro capacity, Brazil offers significant potential but also faces social and environmental risks.
- Globally, about 179 GW of pumped storage are in APAC (55%), Europe (30%) and NORAM (12%).

Demand Side Response (DSR)

Deliverability by 2030	Contribution to security of supply	Alignment with net zero
◑	◑	●

- DSR can shift or reduce consumption during peak times but relies on consumer participation and may not address longer shortages.
- Brazil has a mechanism in place, with a regulatory sandbox for a competitive mechanism under study.

Interconnections

Deliverability by 2030	Contribution to security of supply	Alignment with net zero
◔	◑	◔

- Interconnections can increase security of supply by allowing imports between regions.
- However, they rely on the availability of surplus energy elsewhere during shortages, and may face infrastructure challenges.

Carbon Capture, Utilisation and Storage

Deliverability by 2030	Contribution to security of supply	Alignment with net zero
◔	◑	◔

- Economic barriers, significant infrastructure investment, long construction timelines, and upskilling of workers all hinder deployment.
- The most likely plants will be refurbishing CCGTs, thereby not solving the fundamental problem.

Hydrogen

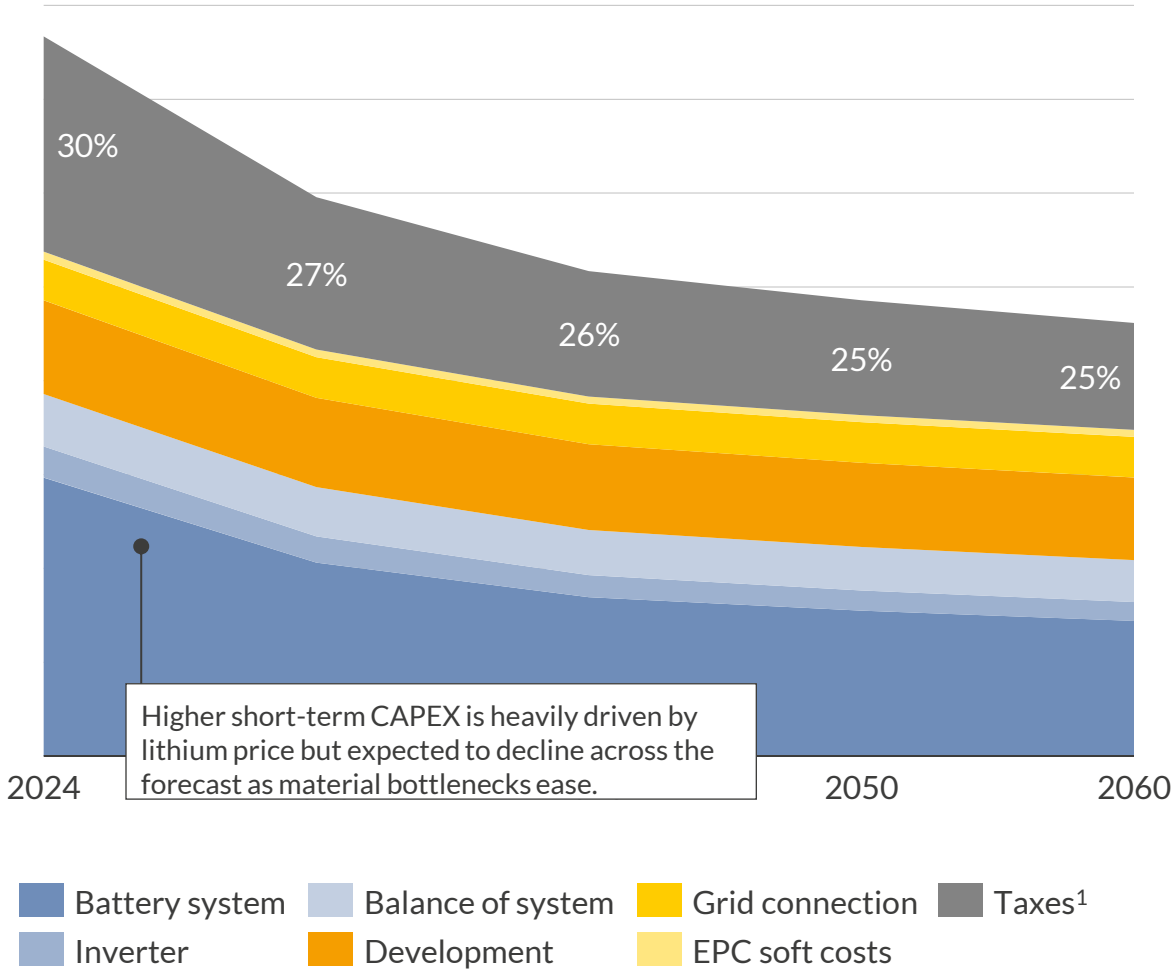
Deliverability by 2030	Contribution to security of supply	Alignment with net zero
◔	◔	◑ - ●

- Brazil's policy framework was approved in August 2024, but it does not address security of supply.
- Production and infrastructure are still in early stages, making it a long-term rather than an immediate solution for securing supply.

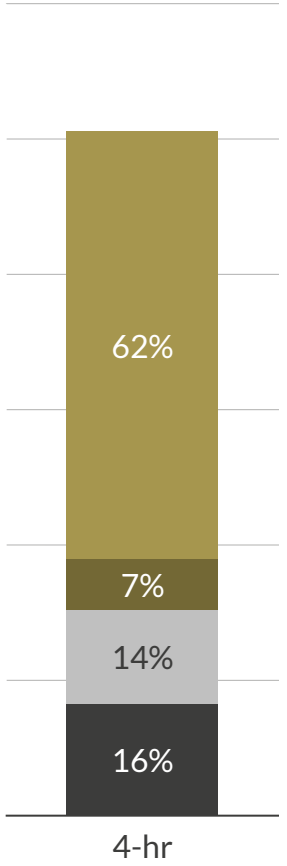
Source: Aurora Energy Research, EDF

The cost of batteries consists of various components; in Brazil, taxes are the second largest component of CAPEX while grid charges drive OPEX

Li-ion battery total CAPEX – 4-hr asset
R$/kW (real 2023)



Li-ion battery total OPEX – 4-hr asset
R$/kW (real 2023)



Component	Description
O&M fixed expense	Includes costs such as scheduled maintenance, performance monitoring and extended performance guarantees.
Insurance	Can include liability, environmental, property, and other insurances such as cyber security etc.
Land lease	Agreement allowing use of land in exchange for rent.
Grid charges and taxes	Considers consumption grid charges to the usage of the transmission system (TUST)[1], which can vary significantly depending on the location. Includes PIS/COFINS and ICMS[2].

1) Import taxes (II, IPI, PIS, COFINS) for battery system and inverter calculated by government simulator under NCM numbers 8507.60.00 and 8504.40.30, respectively. ICMS calculated as a national average across subsystems (NO/SU subsystems calculated as most cheap/expensive, with average ratios of 19.8% and 17.83%, respectively).

Sources: Aurora Energy Research, Receita Federal, CEIC, Statista, Simtax

Brazil's prices consider upper and lower limits, restricting battery's profitability from price arbitrage by ~20% when compared to shadow prices

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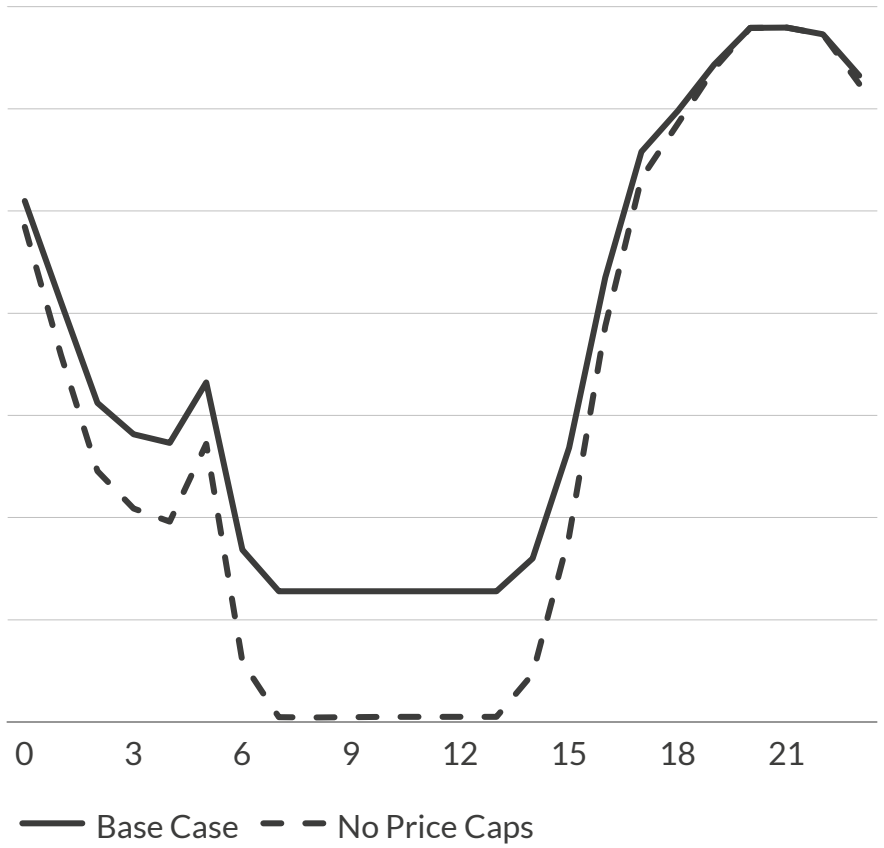
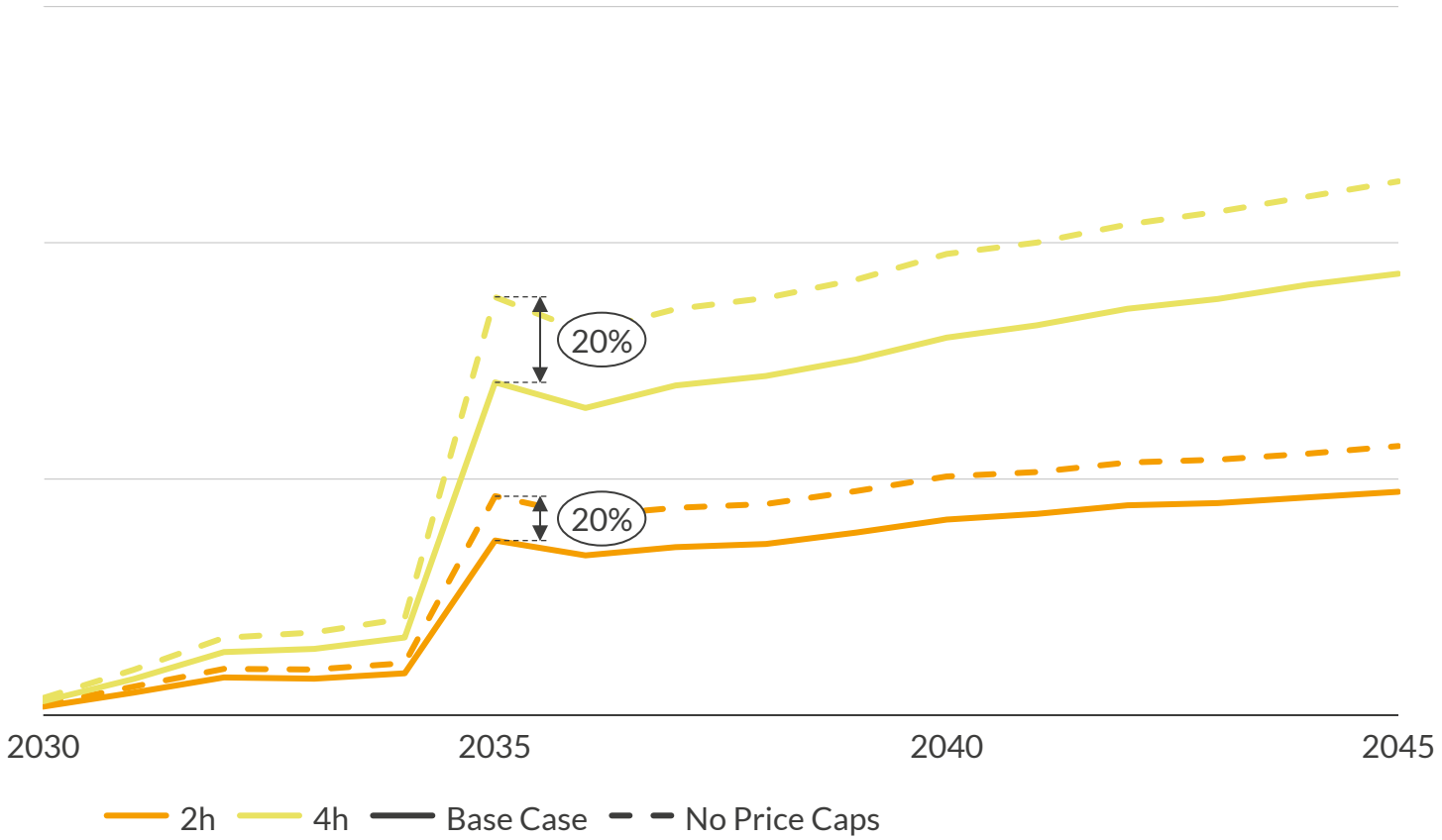
1 **Without PLD price caps, battery systems can arbitrage the higher range of shadow[1] prices**

Illustrative prices – Feb/2035 in the Southeast[2]
R$/MWh (real 2023)



2 **The access to higher spreads increases arbitrage margins, especially from 2035, when the high share of solar capacity in the system increases intraday volatility**

Gross margins for battery systems in the Southeast
R$/kW (real 2023)



1) " Preço sombra ". 2) Base case relates to Aurora's Central July 2024 scenario.

Sources: Aurora Energy Research

In a scenario with reduced taxes and no price caps, the 'missing money' for batteries would be 21% lower compared to the base case

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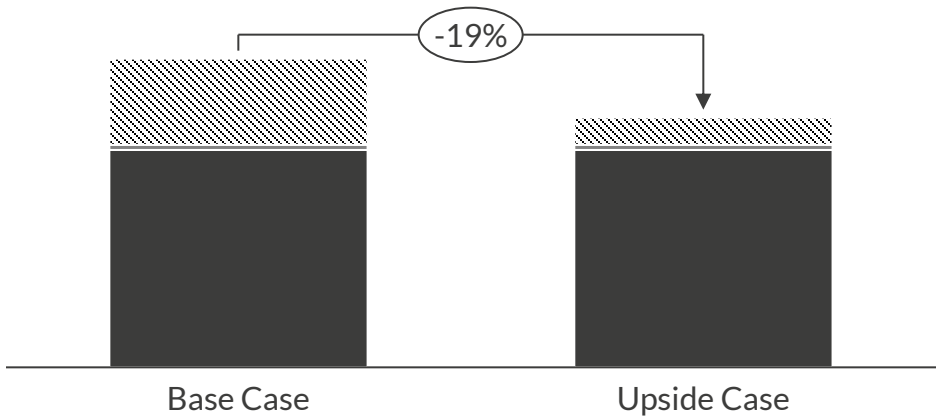
1 Brazil's high tax burden on batteries significantly increases their costs, raising them by 39%

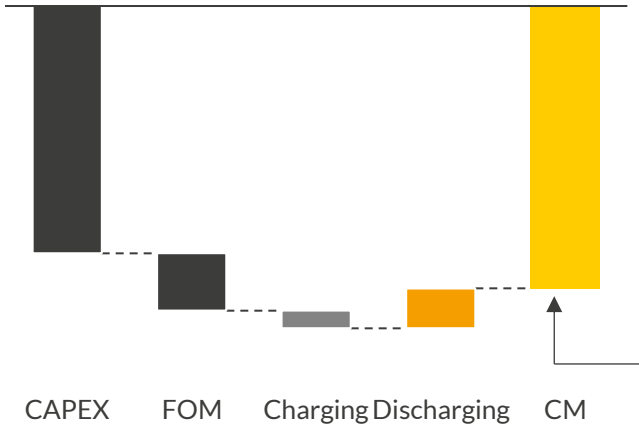
Costs (CAPEX and OPEX[1]) for a 4h BESS
R$/kW (real 2023)



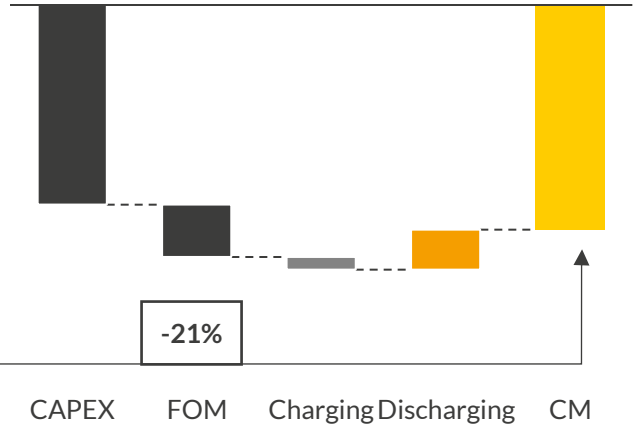
- Federal and State taxes represent 27 % of CAPEX and 48% of OPEX for 4-hour batteries (Base Case).
- For the Upside Case, we consider the removal of price caps, as well as a 69% tax reduction. This is in line with tax exemption policies already applied to solar assets[2] in Brazil.
- CAPEX decreases 19% while OPEX, 9%.

2 Lower taxes on batteries, along with higher arbitrage gross margins in an uncapped market, lead to a 21% reduction in the missing money gap

Cashflow[3] for a 4h BESS – Base Case
NPV R$/kW (real 2023)



Cashflow[3] for a 4h BESS – Upside Case
NPV R$/kW (real 2023)



- Assuming lower taxes is the primary driver for the missing money reduction in the Upside Case.
- Uncapped prices lead to cheaper charging, increasing energy arbitrage gross margins by 23% compared to the Base Case.
- This results in a 21% lower Capacity Payment than in the Base Case.
- More competitive bids from batteries can support firm capacity while offering benefits like co-location with renewables, reducing curtailment, and enabling fast grid frequency response.

CAPEX (w/o taxes) OPEX (w/o taxes) Taxes on CAPEX+OPEX

1) CAPEX and OPEX (only for 1-year of operation) for a battery in 2030. 2) Solar cells (NCM 8541.40.32) present a 6% import tax (II), 0% industrialized product tax (IPI), and 11.75% PIS/COFINS. Solar system's Inverters (NCM 8504.40.90) present a 11.2% import tax (II), 9.75% industrialized product tax (IPI) and 12.75% PIS/COFINS. ICMS was also exempted for the upside case. 3) Real WACC = 12%.

Agenda

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I. Introduction

II. Brazilian market: security of supply overview and key challenges

III. Capacity mechanism trends: international experience

IV. Capacity reserve auctions in Brazil

a. Current framework: thermal assets

b. Opportunities for storage

c. System-level analysis

V. Key takeaways

Allocating 40% of new capacity contracts to 4-h batteries, rather than to a mix of gas plants, would cut consumer costs by 5-24% and emissions by 37-99%

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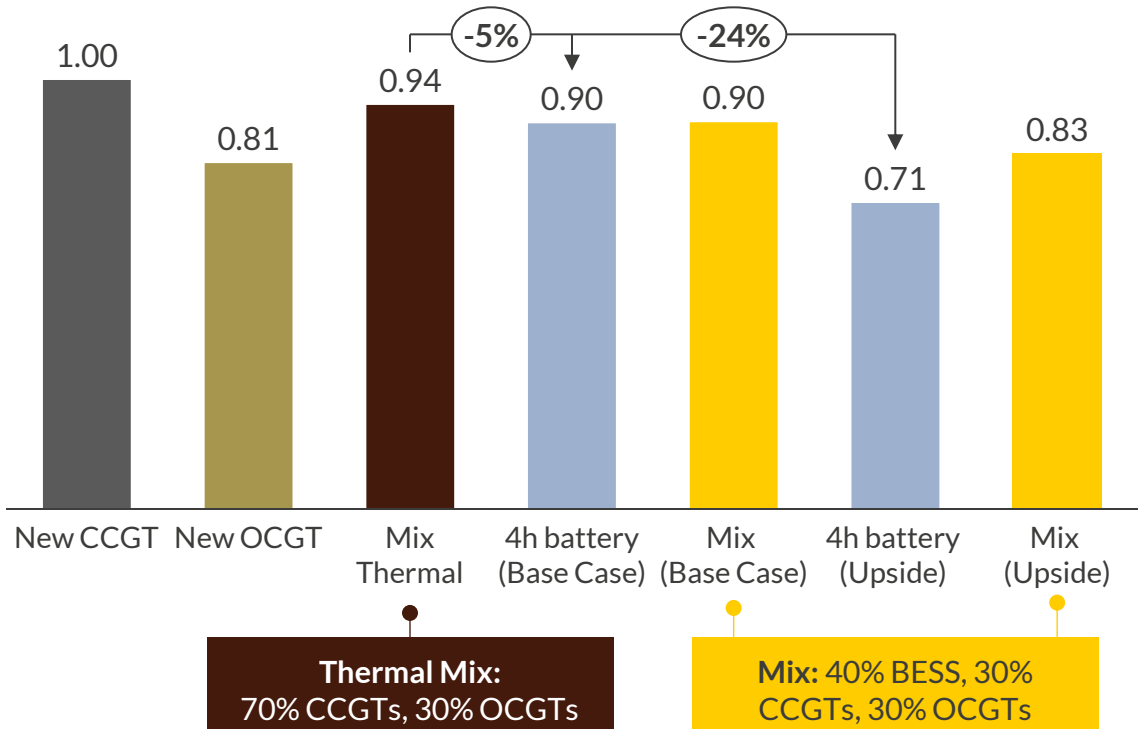
Capacity market costs passed on to consumers

Relative Cost/MW in respect to New CCGT (base = 1)



Direct carbon emissions per technology[1] for the 120 critical hours

tCO_2/MW-year

New CCGT	New OCGT	Mix Thermal	4h battery (Base Case)	Mix (Base Case)	4h battery (Upside)	Mix (Upside)
15.3	20.0	16.7	0.1	10.6	0.1	10.6

Risks and benefits across technologies

1 CCGT vs OCGT

- Combined cycle gas plants present higher efficiencies and lower operating costs compared to open cycle gas plants.
- OCGTs present lower investment costs and response times as quick as 5 minutes, suitable to respond to unexpected spikes in demand.

2 Gas vs BESS

- CCGTs and OCGTs are mature gas technologies, while storage faces uncertainties regarding policy, regulatory framework and taxation.
- Batteries offer faster response times (milliseconds), aren't exposed to fuel cost risks, and present lower emissions (charging in low-emission grid periods), as well as other benefits for co-located assets.

3 Diverse portfolio

- Allocating new firm capacity through a technology neutral market approach helps distribute the risks associated with each option while enhancing system security of supply.
- On the other hand, in Brazil's case, this diverse portfolio can increase system's total costs due to current regulatory and cost framework for batteries (vs OCGTs only case), and increase direct carbon emissions (vs BESS only case).

1) Considering efficiencies of 48% for CCGTs, 37% for OCGTs and 88% for BESS. For gas plants, we assume 0.1809 tCO_2/MWh.

Sources: Aurora Energy Research

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AURORA

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V. **Key takeaways**

A technology-neutral approach to security of supply can minimize costs; a robust market design is critical to mitigate risks and unintended consequences

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1. Despite holding its second auction, Brazil still is in early stages of design for its own Capacity Market with good lessons to be learned from other geographies; key areas for improvement include promoting technology diversification and considering shorter contract terms for existing assets.

2. The selection of gas plant technology is crucial for determining competitiveness in the upcoming auction. Open Cycle Gas Turbines (OCGTs), in particular, are more attractive due to their operational flexibility, reliability, and lower investment costs, despite their infrequent dispatch and limited Energy Market revenue.

3. By 2028, at least 5 GW of existing Combined Cycle Gas Turbines (CCGTs) will become uncontracted; these units could be retrofitted and are expected to be competitive in auctions, even when up against new OCGTs.

4. Even under current battery taxation, batteries are expected to have a ~10% lower 'missing money' gap than CCGTs, positioning them to outcompete CCGTs within the next 5 years.

5. Allocating 40% of new capacity contracts to 4-h batteries, rather than to a mix of gas plants, would cut consumer costs by 5-24% and emissions by 37-99%

Source: Aurora Energy Research

Brazilian Power & Renewables Service:

Dive into key market analysis and forecasts for the Brazil power and renewables markets

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Analyst Support

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

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