AURORA
ENERGY RESEARCH

Brazilian Market Scenarios 2024

Public Report

Agenda

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I. About Aurora

II. Brazilian market context

III. Aurora's modelling methodology

IV. Alternative scenarios

We provide market leading forecasts & data-driven intelligence for the global energy transition

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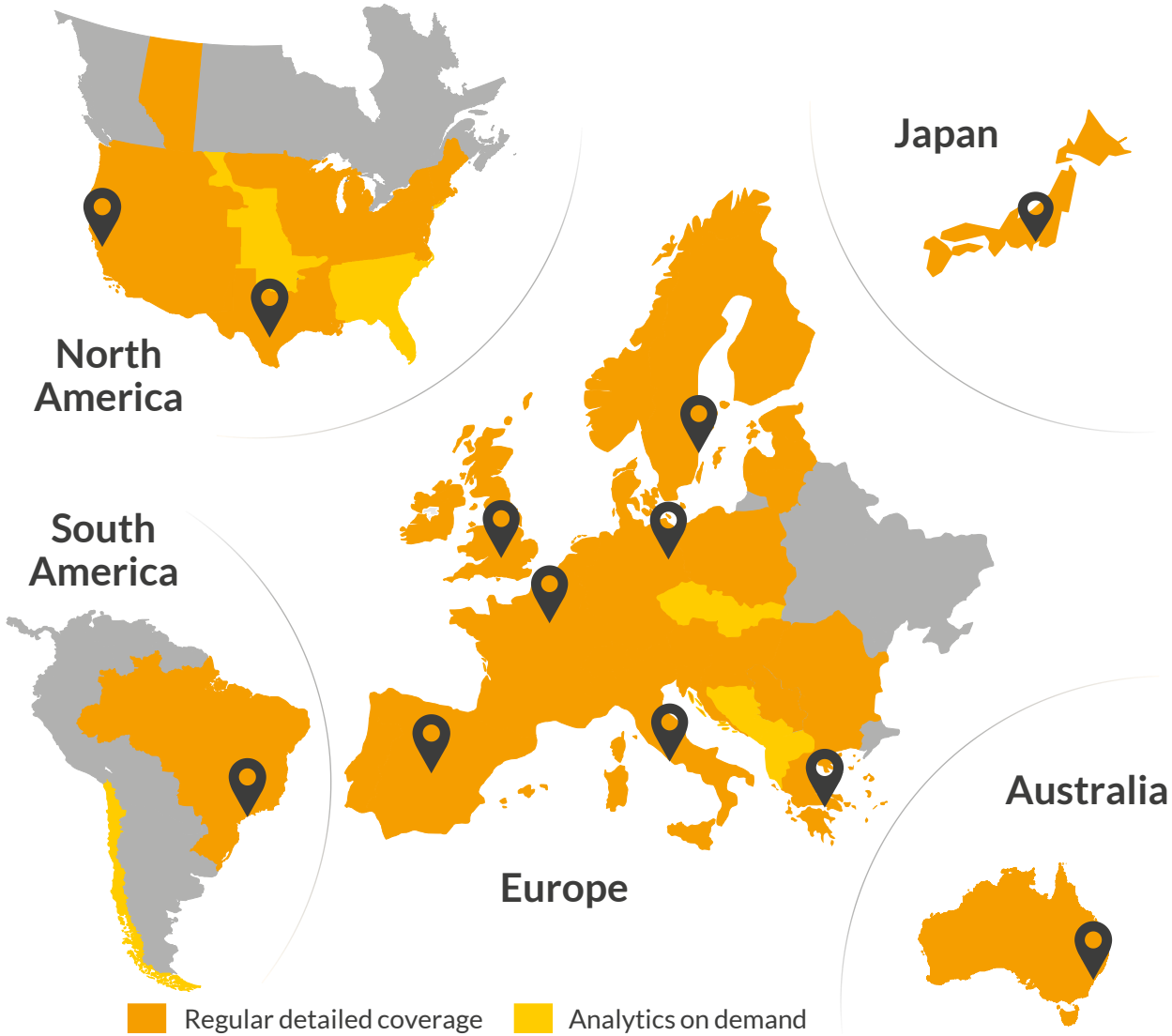
- Power markets
- Renewables
- Storage
- Electric vehicles
- Hydrogen H_2
- Carbon CO_2
- Natural gas



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150+

transactions supported in 2022

Source: Aurora Energy Research

Our market leading models underpin a comprehensive range of seamlessly integrated services to best suit your needs

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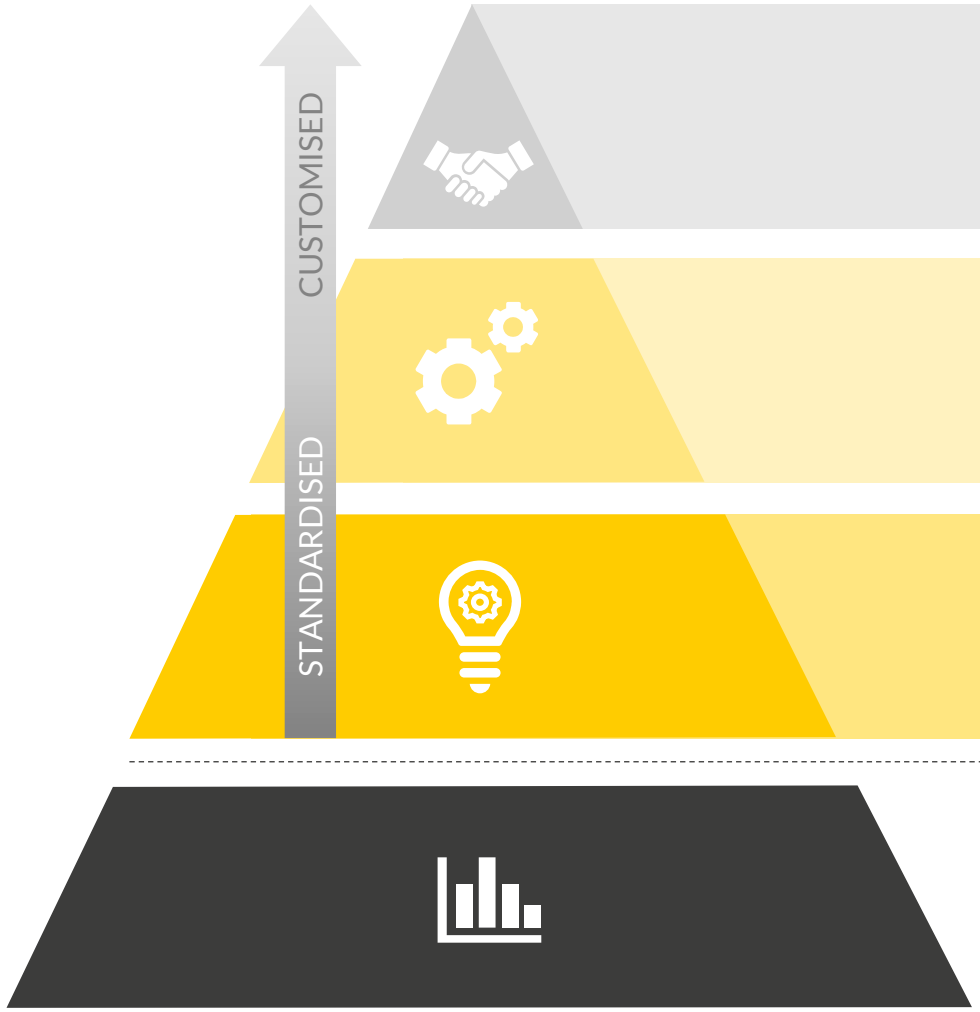

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Proprietary and continuously updated cutting-edge models populated with highest quality curated datasets

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Source: Aurora Energy Research

Introducing the Aurora speakers

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Ana Barillas

Head of Iberia and LATAM

Bruno Silva

Brazil Market Lead

Inês Gaspar

Brazil Product Manager

João Vilela

Brazil Senior Energy Modeller

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Hydro dominates the capacity and generation mix, but since 2021 that wind and solar represent most of the newly build assets

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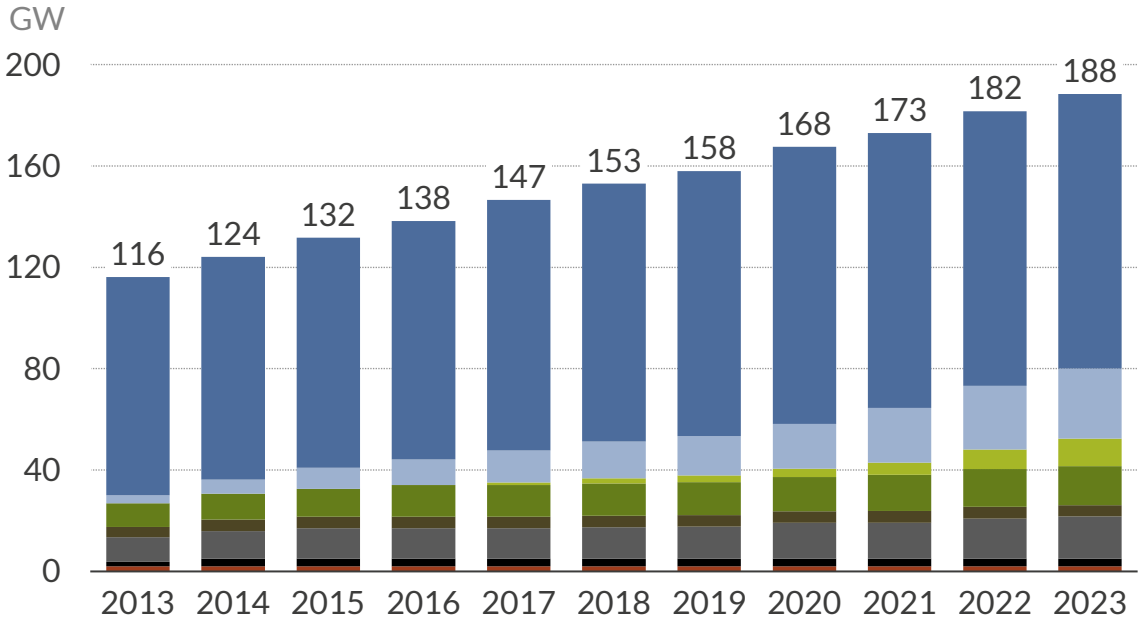
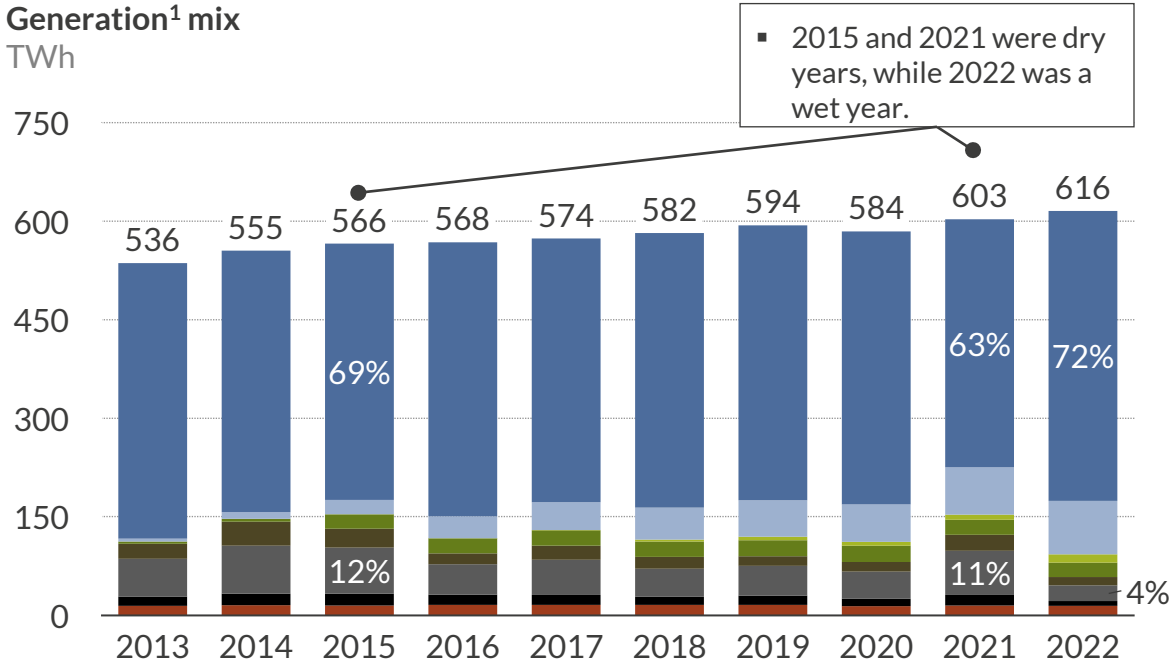
Installed centralised capacity



- By 2013, hydro represented 74% of the installed capacity. Since then, the hydro share has fallen to 63% by 2023.
- Until 2020, hydro still represented 46% of the new additions followed by wind.
- This trend started to change by 2021, with wind and solar representing 80% of 15 GW of new assets. Gas CCGT additions come second to this but represent only 12% of newly-added capacity.

Generation[1] mix



- Over the last 10-years, hydro generation represented 63-78% of the mix, leading to an already significantly decarbonised power system.
- Since 2013, CO_2-emitting assets have only represented between 7% and 23% of the mix. CO_2 emissions depend on hydro availability and thus typically peak in drought years.
- Wind and solar generation have grown quickly in the last years, with a combined 15% share of the country's electricity generation by 2022.

Hydro[2] | Onshore wind | Solar PV[3] | Biomass | Other thermal[4] | Gas CCGT | Coal | Nuclear

1) For both capacity and generation, we are only considering centralised figures. We are not accounting for distributed solar (MMGD). Historical generation for the full year of 2023 not updated at the time of release of the report. 2) Hydro includes reservoir and run of river. 3) Only considering centralised solar ground mounted. 4) Other thermal includes oil and diesel plants.

Sources: Aurora Energy Research, ONS

The Brazilian interconnected power system supplies over 99% of the country's demand and is divided in four subsystems

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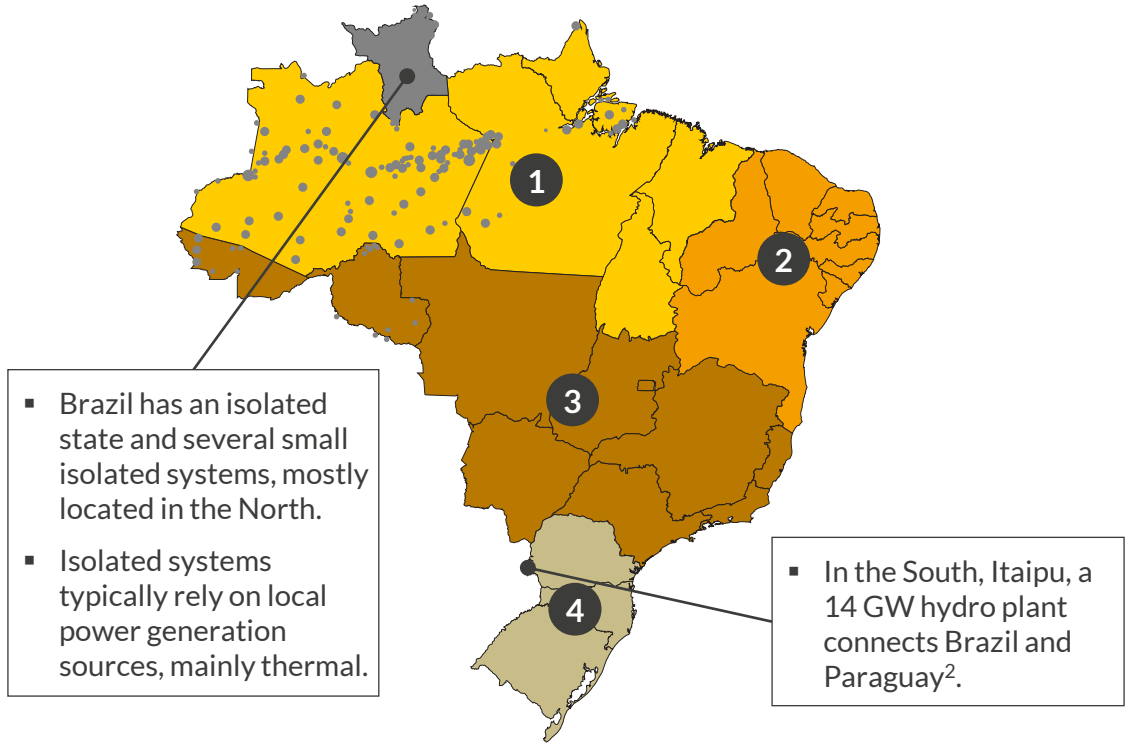
The Brazilian interconnected power system[1] supplies over 99% of the country's electricity demand. Although Boa Vista (Roraima) is the only state capital that is not connected, there are still 212 isolated systems across seven states. Brazil's most relevant international interconnection is with Paraguay via a 14 GW binational hydro plant[2].

Map of the Brazilian interconnected power system[3]



- Brazil has an isolated state and several small isolated systems, mostly located in the North.
- Isolated systems typically rely on local power generation sources, mainly thermal.

- In the South, Itaipu, a 14 GW hydro plant connects Brazil and Paraguay[2].

Market snapshot[5] by 2023

Subsystem (or region)	Installed capacity GW	Share %	Annual demand TWh	Share %
1 North	28	13%	63	10%
2 Northeast	55	26%	106	16%
3 Southeast/ Midwest	100	47%	367	56%
4 South	30	14%	110	17%
Isolated systems[4]	1.2	0.6%	3.9	0.6%

1) "Sistema Interligado Nacional", or SIN. 2) Brazil is also interconnected with Argentina and Uruguay via 2.2 GW and 0.57 GW of transmission lines, respectively. Brazil operates at 60 Hz and Paraguay, Argentina and Uruguay at 50 Hz thus converters are required. There is also an interconnection with Venezuela and the Roraima grid, which is not part of the interconnected power system. 3) Grey areas are not connected to the power system. 4) Data on isolated systems is from 2022, no update available yet. 5) Reported by ONS.

Sources: Aurora Energy Research, ONS, EPE, ANEEL

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Unique, proprietary, in-house modelling capabilities underpin Aurora's superior analysis

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Gas (AER-GAS)[1] ⟷ **Power markets (AER-ES)** ⟷ **Global Commodities (AER-GLO)[1]**

INPUTS

- Technology
- Historical hydro inflows and risk metrics
- Demand and MMGD
- Commodity prices[1]
- Policy

Dispatch model

- Hourly
- Iterative modelling
- Stochastic hydropower modelling
- Dynamic dispatch of plant
- Endogenous interconnector flows

Continuous iteration until an equilibrium is reached

Investment decisions module

- Capacity build / exit / mothballing
- IRR / NPV driven
- Detailed technology assessments

OUTPUTS

- Capacity mix
- Generation mix
- Wholesale market (PLD) prices
- Profit / Loss and NPV
- Endogenous demand sources

● Official assumptions[2] ● Modelled in-house

1) Gas, coal, oil (and carbon prices, if applicable) fundamentally modelled in-house with fully integrated commodities and gas market model. 2) Assumptions from National System Operator (ONS) and other key institutions (see slide 9). Details in the following slide.

Source: Aurora Energy Research

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Our modelling capabilities allow us to provide a range of alternative scenarios exploring market uncertainties, alongside Aurora Central view

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	Scenario	Description
	Aurora Central	▪ Aurora's best view for the evolution of the Brazilian power market until 2060, our Central is the result of a P50 weather scenario under the following considerations: – Aurora's internally consistent Central outlook for technological developments and modelled commodity prices. – Incorporating currently stated policies, alongside a view of conservative future policy objectives, economic and market developments that have been tested through discussions with key stakeholders (including policy makers, developers and financial institutions).
Focus of today's session	**Low**	▪ Considering a combination of the plausible range of individual market and policy factors, and their correlation, Aurora's Low scenario reflect realistic price deviations which equity and debt investors rely on for financing assets. ▪ We adjust commodities prices, demand and CAPEX to account for the lower downward risk in the lower risk in Low scenario.
Focus of today's session	**Constrained transmission**	▪ We have built a scenario to simulate the effect of delays in the expansion of transmission, considering the following context: – Brazil is a country of continental dimensions that generate complexity for the operation of the interconnected electrical system. – The greatest potential for the development of renewables is located in the northeastern region of the country, while the majority of consumption is located in the Southeast and South regions. – Delays in the expansion can create an imbalance between supply and demand, resulting in the increase of price spreads within Brazil.
Focus of today's session	**Weather cycles**	▪ Climate events such as El Niño generate variability in the cyclical patterns of water inflow into reservoirs. In this scenario, we are testing the impact of these variations in the coming years by simulating a rainfall cycle observed between 2012 and 2023.

Click here to access our Central Scenario Report

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Sources: Aurora Energy Research

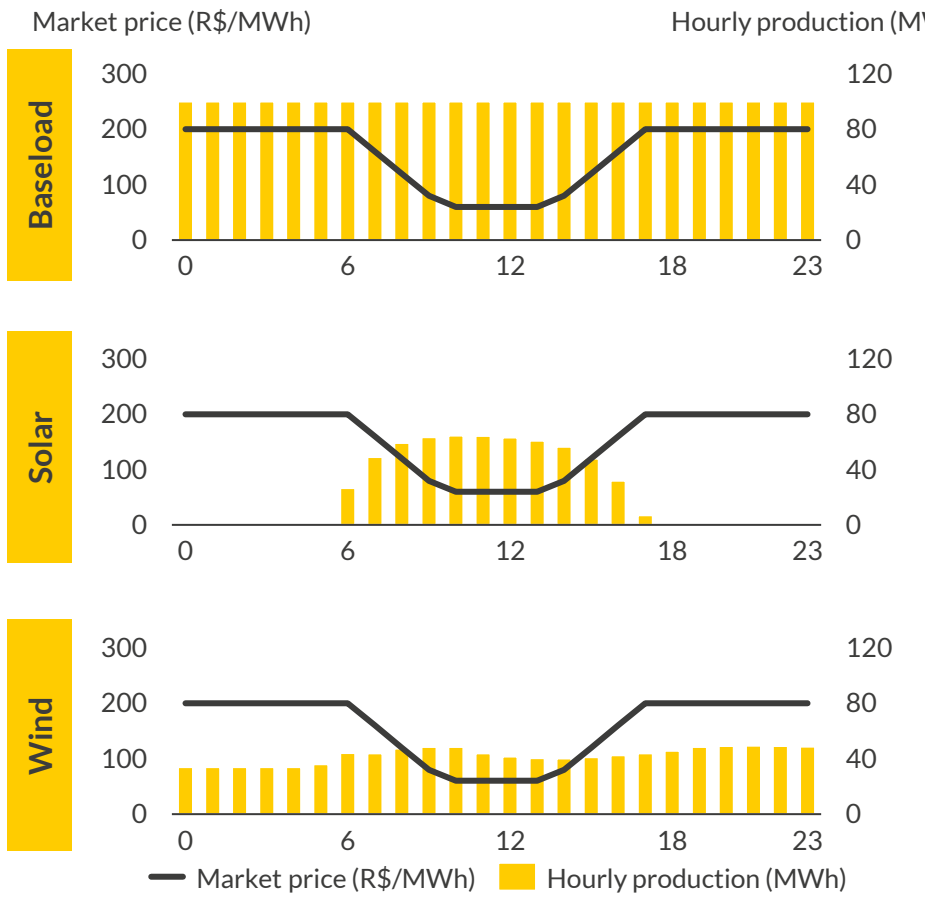
Revenues achieved by different types of technologies can be significantly different from baseload prices

Not all technologies will be able to "capture" hourly prices equally, so prices need to be weighted according to the production profile

- Generation-weighted average prices, or capture prices, represent the average market price earned by power generators over a certain period
- These prices vary can significantly depending on the hourly production profile: a baseload asset will have a price significantly different than the generators of intermittent sources like wind and solar
- To calculate capture prices:
  1. Multiply each period's electricity price by the amount generated
  2. Sum these values to obtain the gross revenue
  3. Divide by the total electricity produced to obtain the capture price

- **In this webinar we will present baseload and generation-weighted average prices for the main technologies**

Illustrative examples of generation-weighted average (GWA) prices for different hourly profiles for a 100 MW asset



	Gross revenue R$	÷	Electricity production MWh	=	GWA prices R$/MWh
Baseload	376,000		2,400		157
Solar	57,637		597		97
Wind	158,874		1,022		155

Sources: Aurora Energy Research

Aurora Low scenario is constructed using a combination of plausible deviations in electricity demand, commodity prices and renewable CAPEX

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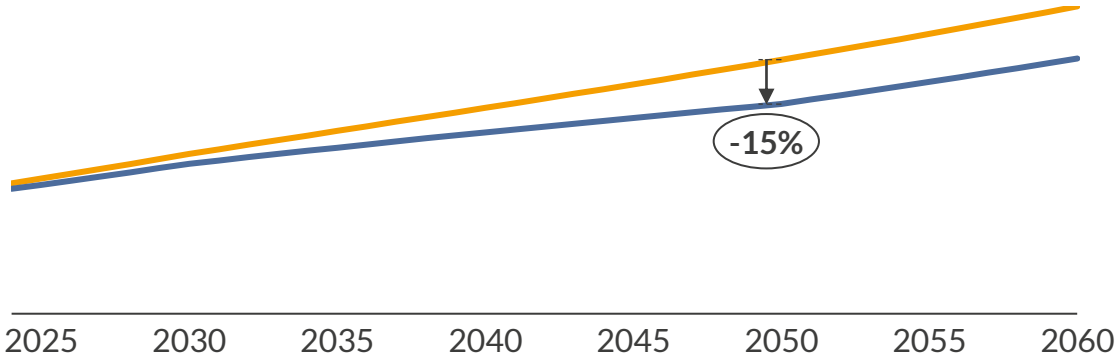
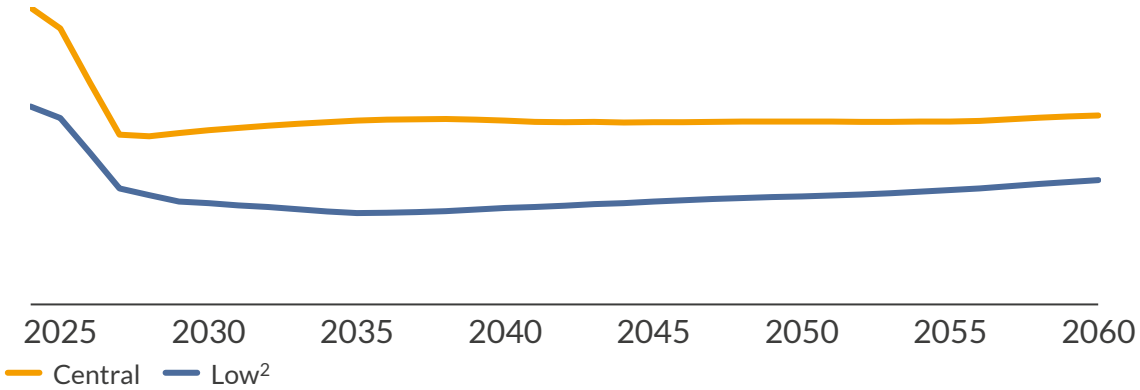
A Electricity demand

Annual electricity demand[1],
TWh



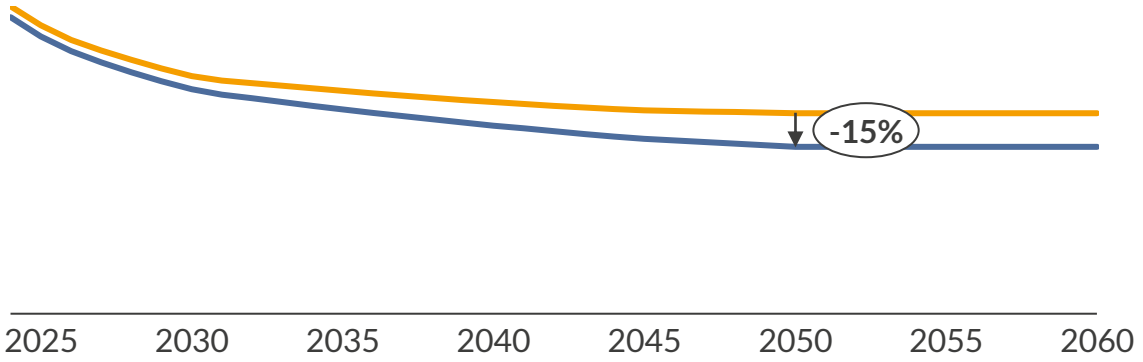
B Commodities prices (gas)

Gas prices
R$/MMBtu (real 2022)

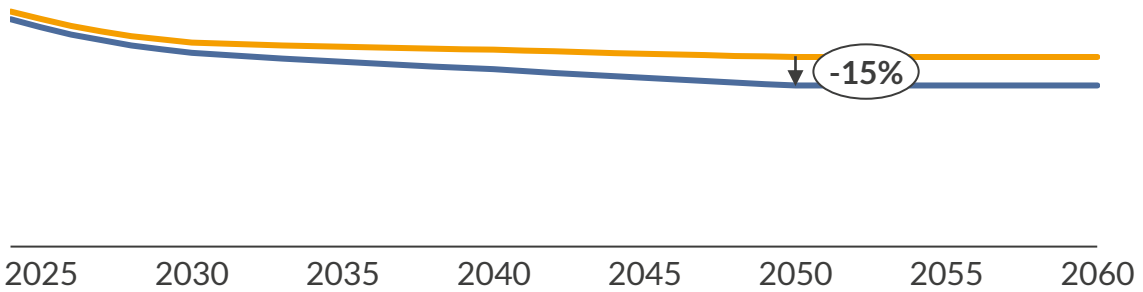


C CAPEX (solar PV and onshore wind)

Solar PV CAPEX
R$/kW (real 2022)



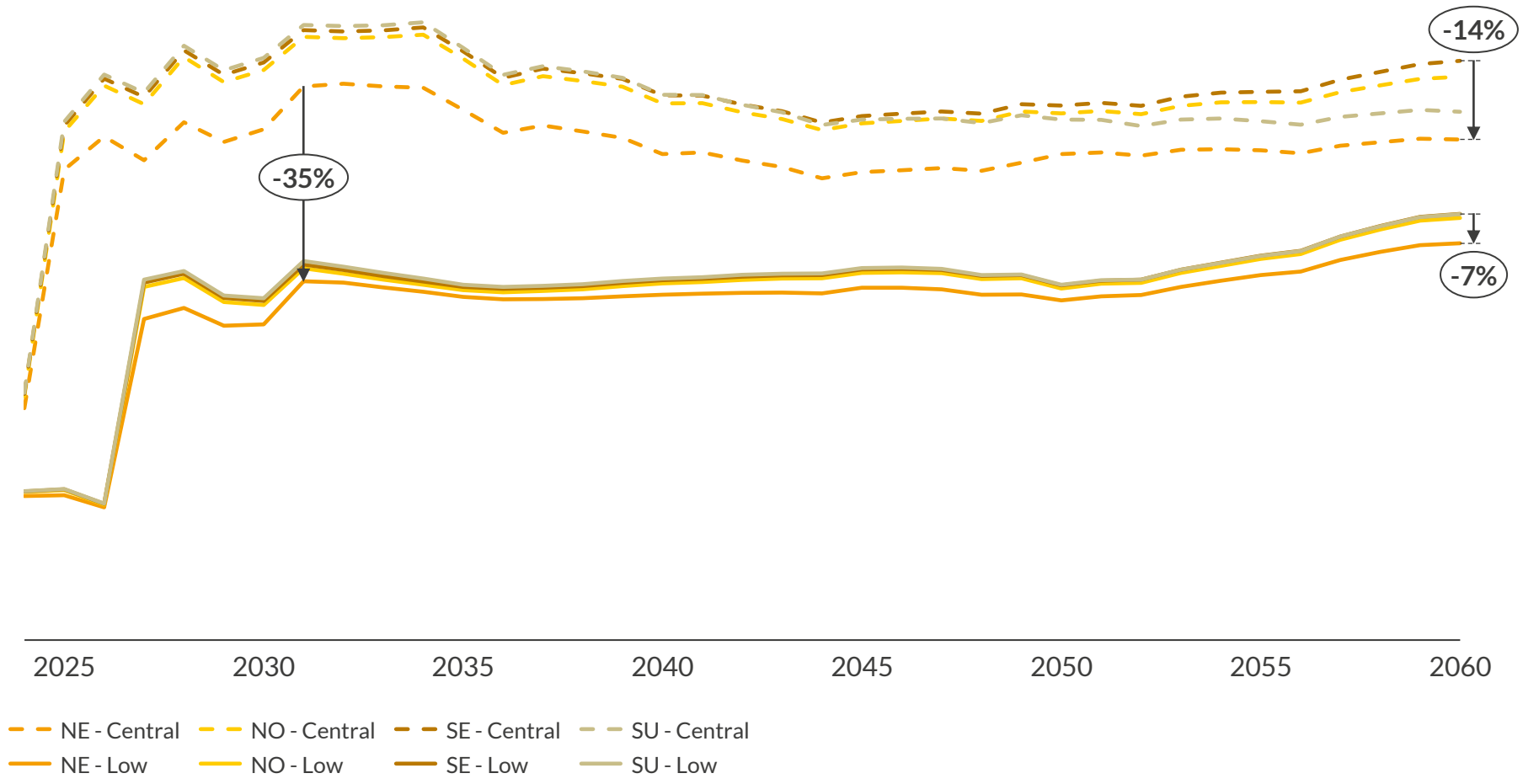
Onshore wind CAPEX
R$/kW (real 2022)



1) Includes all electricity demand components disclosed in section III, residential, commercial, industrial, others and MMGD , but does not include transmission losses. 2) GDP annual growth for Low scenario lower compared to Central. Distributed solar (MMGD) and population growth are the same as in Central.
Sources: Aurora Energy Research

Lower demand, commodity prices and renewable CAPEX lead to prices about 32% lower in the Low scenario compared to Central

Baseload prices
R$/MWh (2022 real)



- The lower demand delays the increase of prices in the Low scenario, keeping prices close to the floor until 2026.
- The Low scenario shows a discount of 32% compared to the Central due to the deceleration in demand growth and decreased commodity prices.
- As in the Central scenario, the Northeast presents the lowest prices due to the high installed capacity of RES combined with a relatively low demand.
- Lower demand, compared to Central, leads to fewer constraints on transmission lines and decreases the price spread between subsystems.
  - By 2060, the spread between Southeast and Northeast reduces from 14% in the Central to 7% in Low.

Source: Aurora Energy Research

In response to the decreased demand and lower capture prices, about 80 GW less of wind and solar PV enter the Brazilian market by 2060

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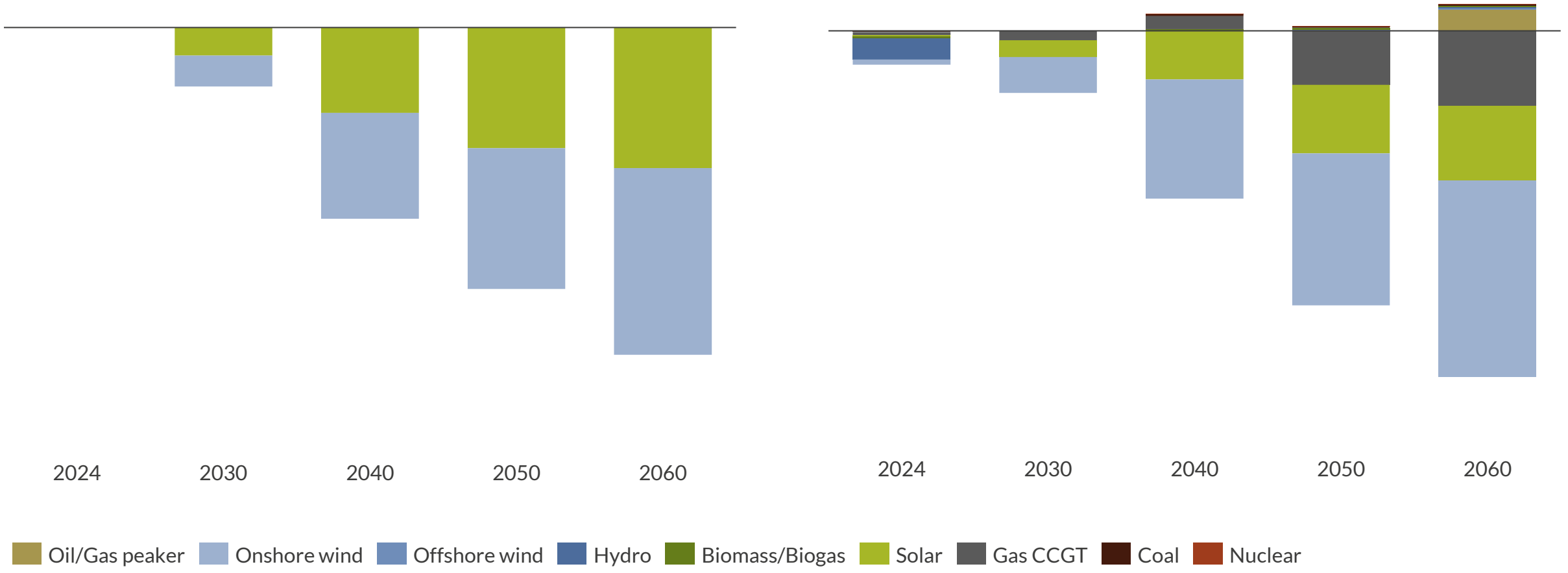
Installed capacity compared to the Central Case
GW

Generation compared to the Central Case
TWh

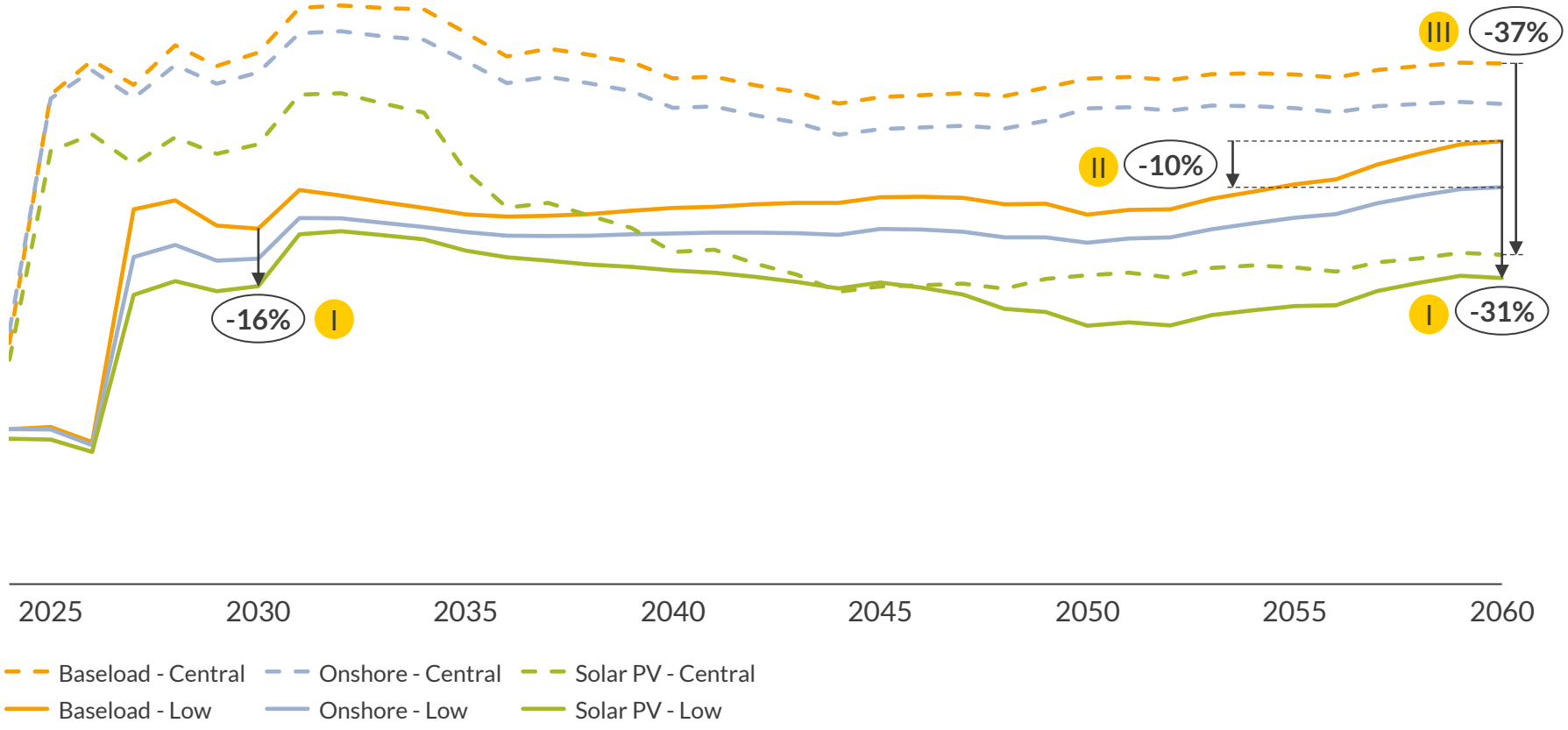


Source: Aurora Energy Research

Discount to baseload for solar assets decreases in the Low case, driven by a less ambitious renewable build out

Baseload, wind and solar generation weighted average prices
R$/MWh (2022 real)

Northeast



I Solar PV presents the highest discount to baseload, ranging from 16% in 2030 to 31% in 2060, mainly due to the high buildout of the technology and strong correlation among solar PV plants, leading to cannibalisation.

II Wind onshore, on the other hand, presents a discount of only 10% compared to baseload in 2060. The lower discount can be explained by the low correlation of production from the onshore wind parks in the Northeast.

III The discount to baseload for Solar PV is 31% in Low vs 37% in the Central as the former has less renewable capacity being deployed, reducing the risk of cannibalisation.

Source: Aurora Energy Research

We model a Constrained Transmission scenario in which interconnections across subsystems remain stagnant post-2032

Transmission export capacity in the Brazil interconnected system[1]
GW

1) For 2024 and 2060, bars report total capacity of all systems summed. Export capacities represent the energy flows as suggested by the legend. Import capacities represent the energy flows in the opposite direction to that suggested in the legend
Source: Aurora Energy Research

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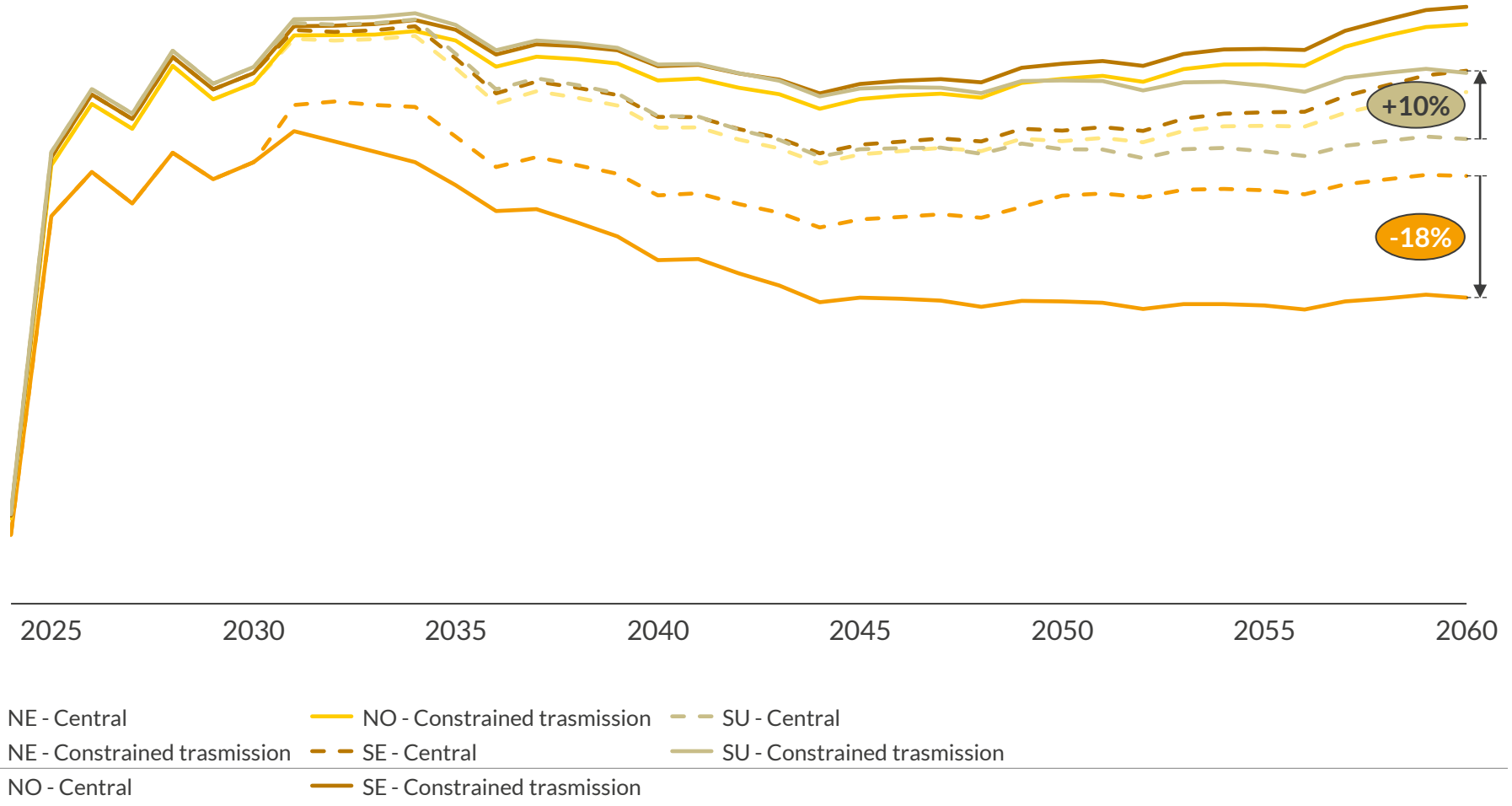
- In Brazil, the greatest potential for the development of renewables is located in the northeastern region of the country, while the majority of consumption is located in the Southeast and South regions.
- Delays in the expansion of the system can create an imbalance between supply and demand across subsystems, resulting in the increase of price spreads within the country.
- In the constrained transmission scenario, we model a scenario in which transmission across subsystems remains stagnant post-2032, considering solely the already planned upgrades.

Reducing transmission capacity would further increase the price gap between the Northeast and other regions compared to Central

Baseload prices
R$/MWh (2022 real)

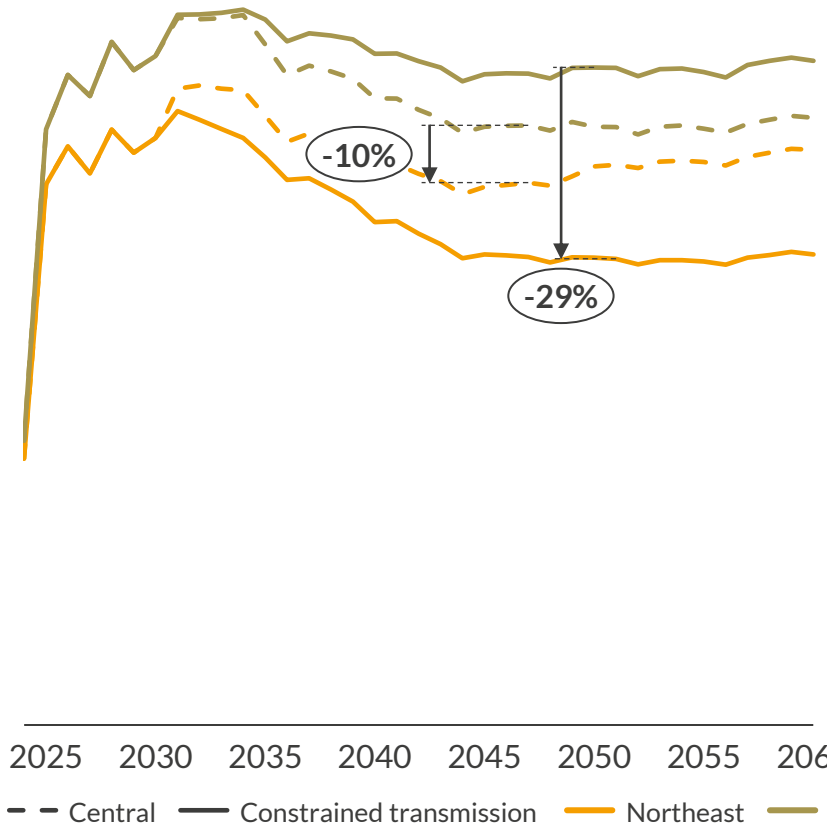


Source: Aurora Energy Research

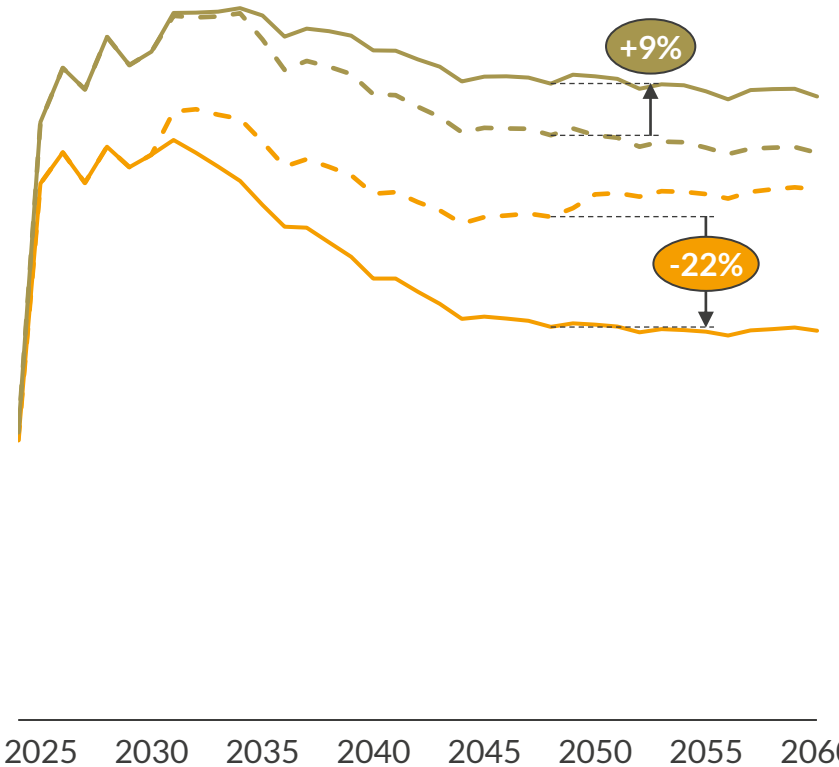
- The majority of transmission investments expected for the 2024-2060 period are directed towards increasing the transport capacity from the northeast to the southernmost part of the country.
- In a scenario of restricted transmission investment, there is a surplus of renewable energy in the Northeast region, pushing local prices down while exerting upward pressure on prices in other regions of the country.
- Prices in the Northeast subsystem are expected to be 18% lower in 2060 compared to Central, while prices in the rest of the subsystems are projected to be higher.

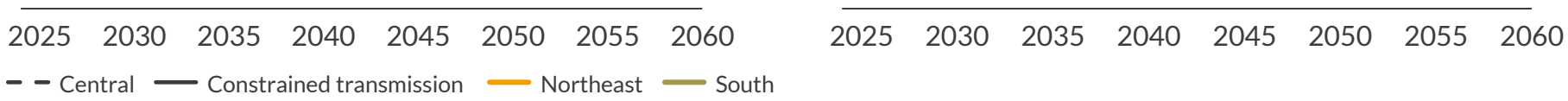
In this scenario, price divergence between the Northeast and South widens from -8% to -26%, on average, compared to the Central

Baseload prices
R$/MWh (2022 real)



Wind generation-weighted average prices
R$/MWh (2022 real)





- After 2032, transmission remains stagnant, leading to distinct baseload prices in each subsystem when comparing the Constrained Transmission and Central scenarios.
- While in the Central scenario, baseload price divergence between the Northeast and South averages at -8%, in the Constrained Transmission scenario, it averages at -26% post-2032.
- Inability to export renewable generation from the Northeast to the demand-intensive southern subsystems leads to a decrease of about 20% in wind generation-weighted average prices, while wind assets in the South subsystem see a positive impact.

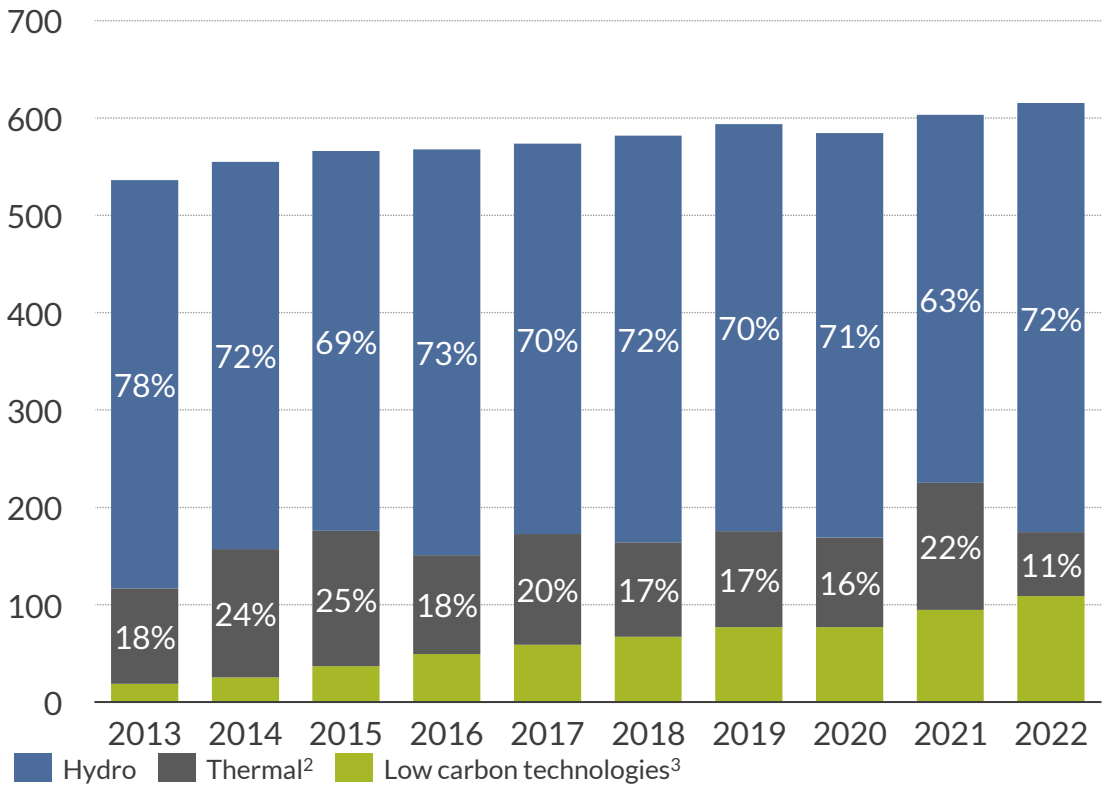
Source: Aurora Energy Research

Drawing upon historical data, we analysed an annually varying inflow sensitivity against our Central scenario

Historically, weather cycles with varying rainfall levels have affected each of the four Brazilian subsystems differently. Hydro inflows, which determine water availability for power generation, have exhibited significant year-on-year variations. In this sensitivity, rather than taking a P50 approach like in our Central scenario, Aurora uses historical cycles and analyses its impact in the evolving Brazilian power system.

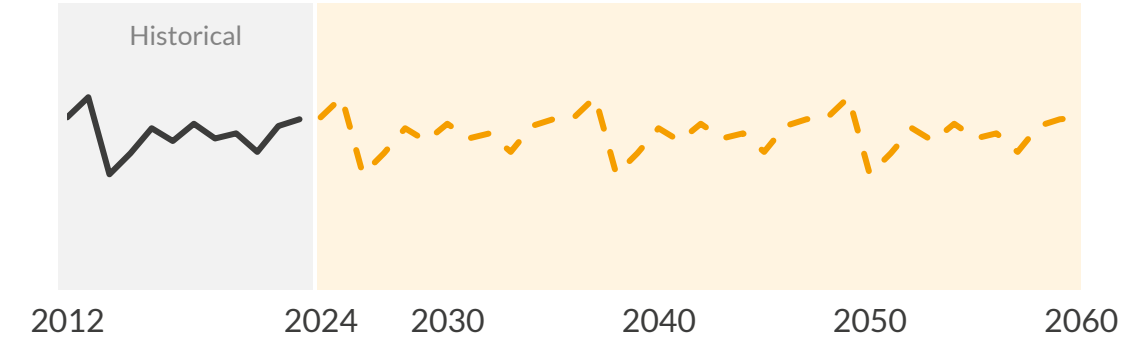
Generation mix for the Brazilian system over the last 10 years

TWh

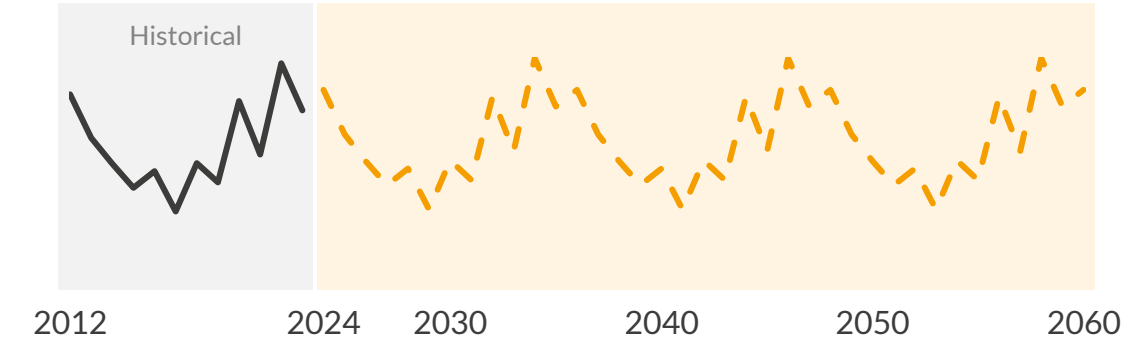


Inflows[1]

Southeast / Midwest subsystem



Northeast subsystem

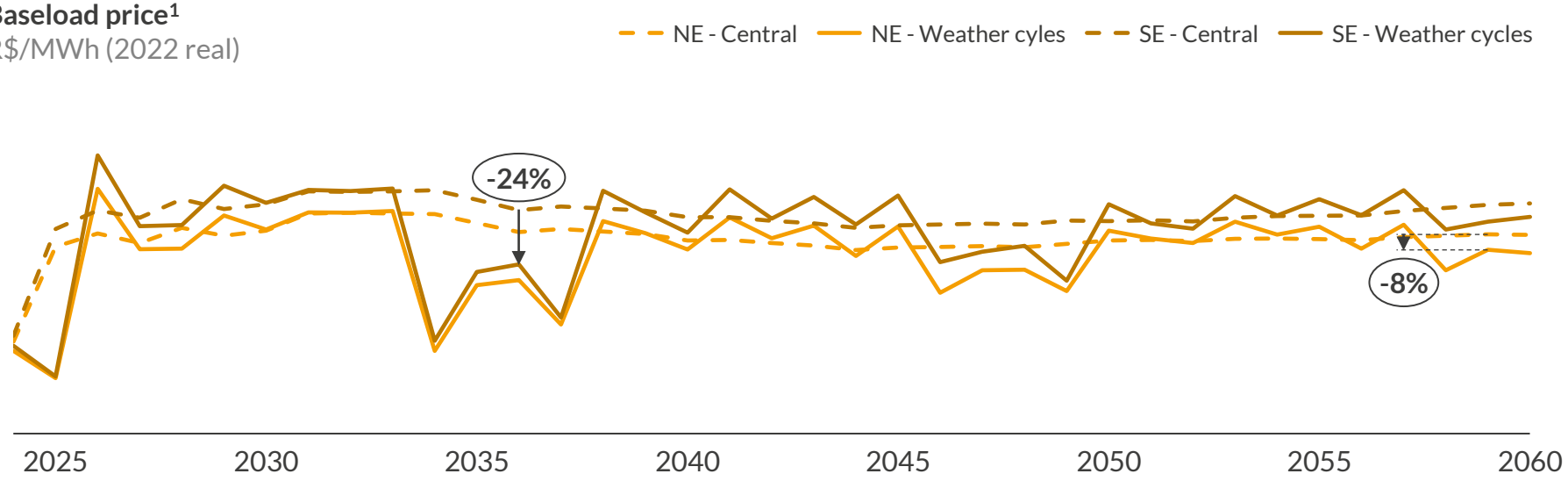


1) Relative to P50. Based on historical affluent natural energy of the hydro plants. 2) Thermal includes biomass, gas, coal, oil and diesel. 3) Low carbon includes solar PV, onshore wind and nuclear.

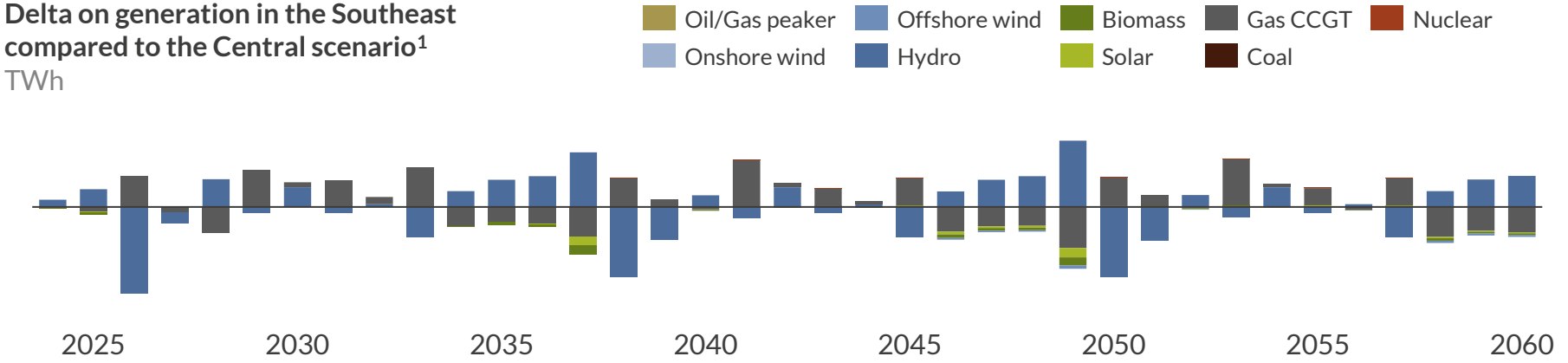
Sources: ONS

In this scenario, variable inflows affect dispatch, causing inter-annual price variations that gradually decrease over time

Baseload price[1]
R$/MWh (2022 real)



Delta on generation in the Southeast compared to the Central scenario[1]
TWh



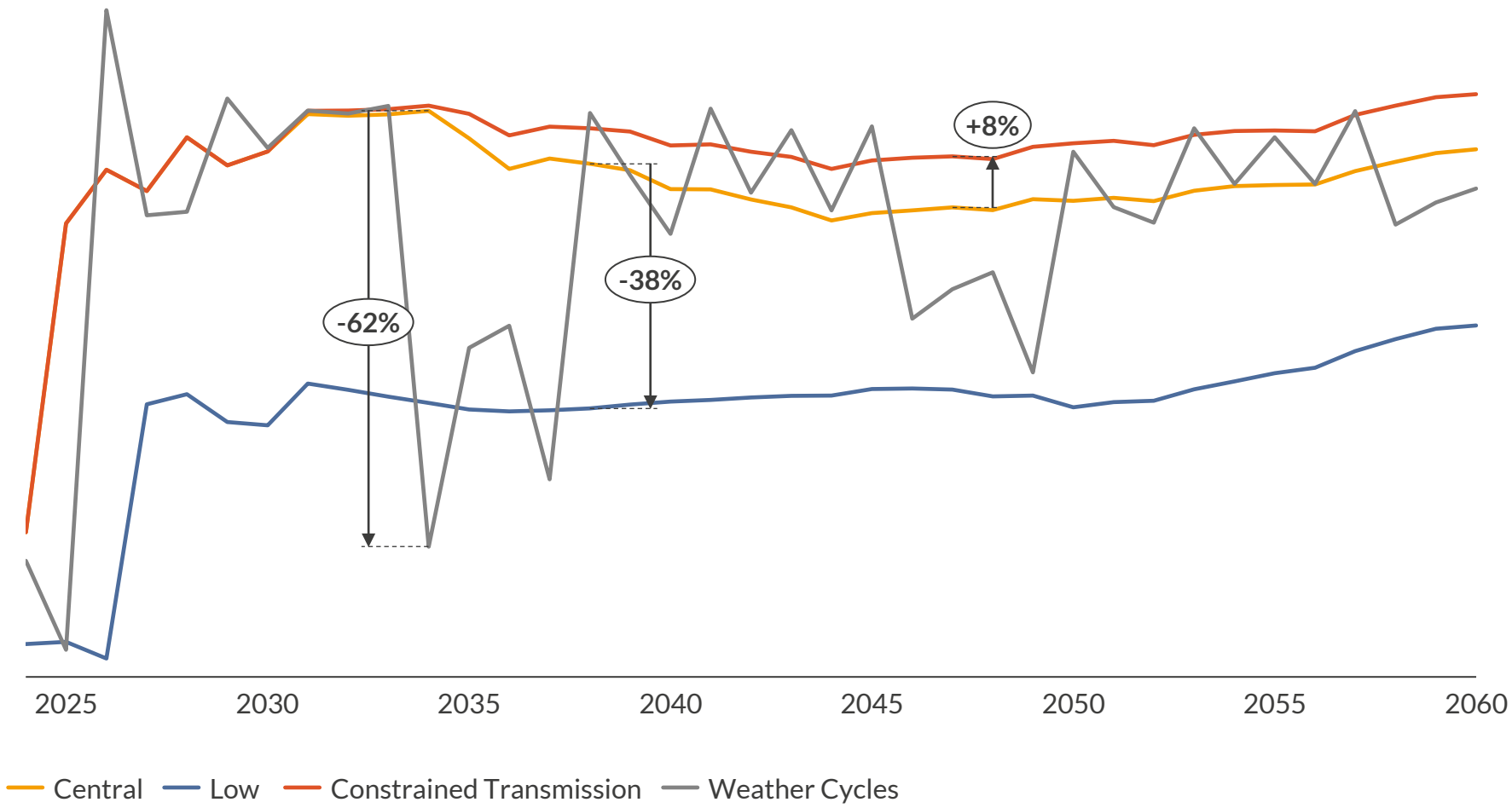
- In this scenario, yearly changes in inflows shift the generation mix in each subsystem, impacting dispatch.
- In a wetter year for the Southeast, hydro is dispatched more compared to Central. Conversely, in a drier year, thermal plants are dispatched more in this scenario than in the Central.
- This annual variation in the generation mix causes inter-annual price fluctuations of up to 66% compared to Central.
- However, over time, the decreasing share of hydro in the mix translates into a lower impact of inflow variability on price formation.
- This can be observed in the average price difference between the Central and Weather Cycles scenarios, which decreases from 66% in the 30s to 11% in the 50s[2].

1) Results for all subsystems and all scenarios can be found in the full report and databooks for Aurora subscribers for Brazil in the "Results" and "Scenario and sensitivity analysis" sections.

Source: Aurora Energy Research

Key takeaways of Aurora scenarios vs Central

Baseload price[1]
R$/MWh (2022 real)



1) Results for all subsystems and all scenarios can be found in the full report and databooks for Aurora subscribers for Brazil in the "Results" and "Scenario and sensitivity analysis" sections.

Sources: Aurora Energy Research

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Low

- Lower demand, commodity prices and renewable CAPEX lead to prices about 38% lower in the Low scenario compared to Central.

Constrained Transmission

- After 2032, transmission remains stagnant. In the Southeast, inability to import renewable generation leads to an increase in prices compared to Central.

Weather Cycles

- In this scenario, yearly changes in inflows shift the generation mix, impacting dispatch and causing inter-annual price fluctuations of up to -62% compared to Central.

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For more information, please contact

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We work with a very broad range of clients … their constant challenge keeps us up on our toes and ensures our independence

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> *"Very excited to see Aurora investments in the country (Brazil). It is very good for us to bring a global expert to help us navigate these new times we have ahead of us"* **Igor Fonseca, Head of Power, Project Finance, Santander**

Santander

> *"With a vast expertise in the energy sector, Aurora has been promoting relevant discussions and providing valuable insights to our business in Brazil. Always grounded in data intelligence, it is helping companies to make strategic decisions towards the global energy transition"* **Rogério Jorge, CEO, AES**

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Power & utilities

Energy consumers

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Project developers

Policy & regulation

Source: Aurora Energy Research


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