Weather Years and their Impact on PPAs in Brazil

Public Report

Agenda

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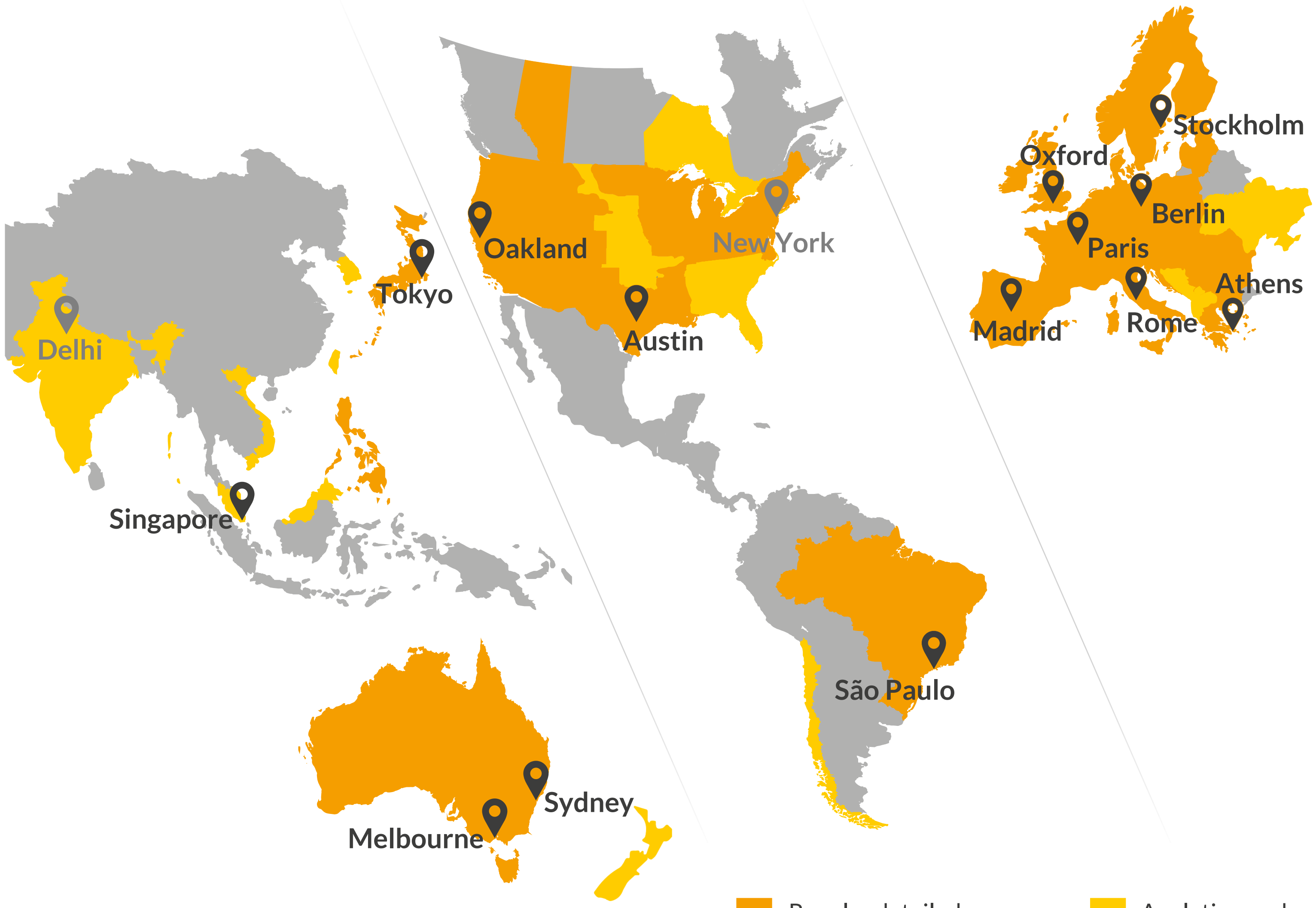

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In this report, we will investigate the impact that weather variability has on renewable generation, prices and the risks it imposes on PPAs

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Main questions	Comments
1 How have weather conditions impacted Brazil's renewable landscape?	▪ **Brazil's electrical system relies on renewable sources** and is **highly vulnerable** to **climatic factors**, resulting in **significant fluctuations in energy production** across various sources during years with varying weather conditions
2 What is the impact of weather variability on renewable generation and market prices?	▪ When we apply climate patterns from the last decade to create energy production scenarios up to 2060, we see that **renewable energy production fluctuation remains stable throughout the timeline.** ▪ The **average annual prices resulting from this variation can reach 3 times**, between the maximum and minimum values obtained from this production variation
3 To what extent gross margins are impacted by renewables' volatility under weather years?	▪ In markets with **high penetration of renewable energy**, the **variation** in profitability of renewable assets occurs **not only due to changes in the volumes** of produced energy, but also due to **fluctuations in market prices**, **which tend to have a negative correlation**
4 How to mitigate the 'weather factor' and navigate through uncertainties in PPAs?	▪ **PPAs** can be **effective** instruments for **risk mitigation**, but the **volatility** of market conditions generated by **climatic factors** can **pose financial risks** for fulfilling baseload contracts

Sources: Aurora Energy Research

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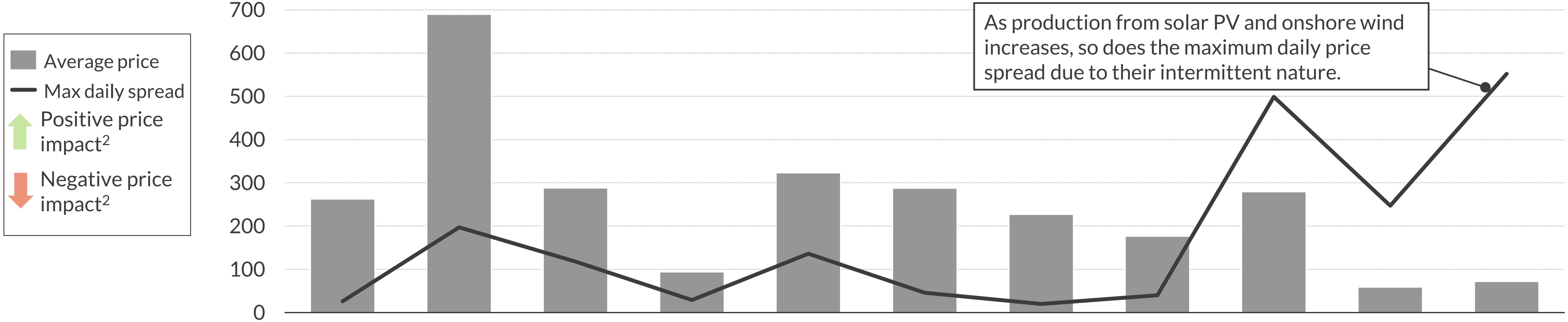
Brazilian electricity prices have varied significantly due to variations in weather, with high prices occurring in periods of low hydro production

Baseload price (PLD)[1]
R$/MWh, nominal



	Key price drivers	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Weather driver	Hydro generation TWh	413.7	391.5	381.0	398.8	394.2	408.4	409.7	404.7	372.8	437.9	442.1
	RES[3] share of demand %	82.5	75.8	76.9	85.5	80.9	84.7	84.7	85.9	76.3	88.8	90.5
Market driver	Henry hub natural gas price US$/MMBtu	3.73	4.37	2.62	2.52	2.99	3.15	2.56	2.03	3.89	6.45	2.53

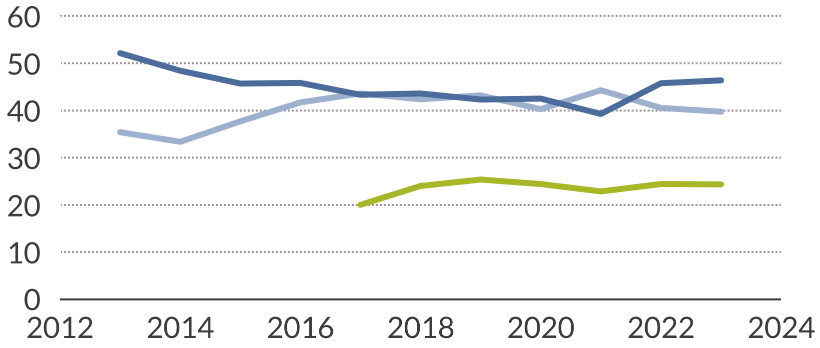
1) Average across all four subsystems; 2) For years hydro generation vary more than 23TWh from the mean and natural gas prices varies more than 0.8US$/MMBtu; 3) Includes hydro, solar PV and onshore wind

Sources: CCEE; Aurora Energy Research

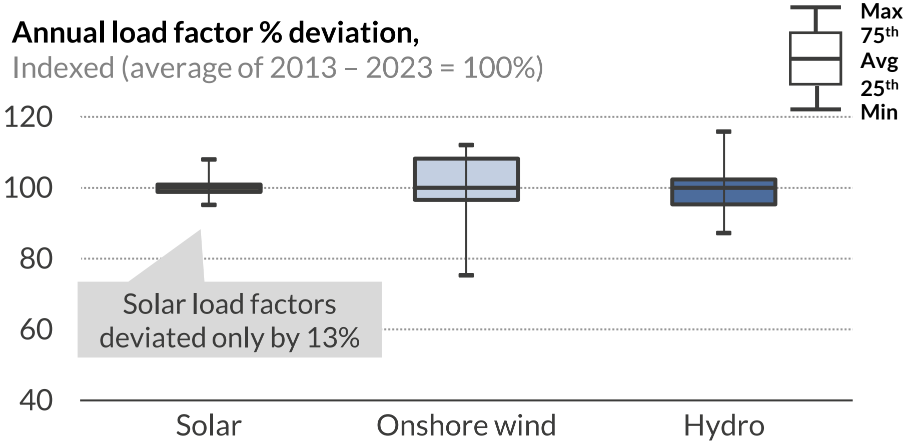
Hydro and onshore wind production have presented the highest variability in Brazil, yet they demonstrate complementary profiles

1 Annual production profiles of onshore wind and hydro have fluctuated significantly over the last decade…

Annual load factors by technology[1],
%, 2013 -2023

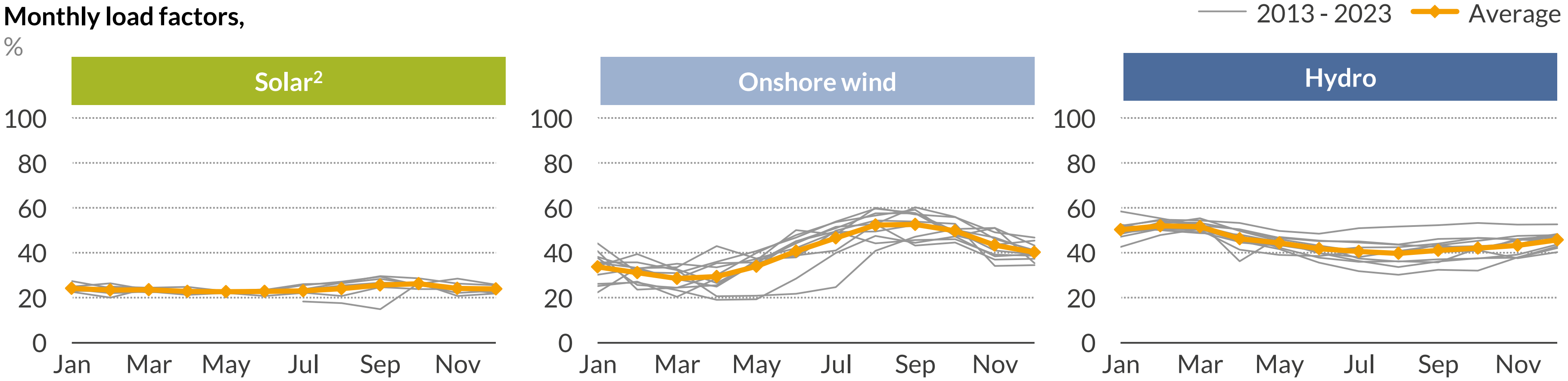


Annual load factor % deviation,
Indexed (average of 2013 – 2023 = 100%)

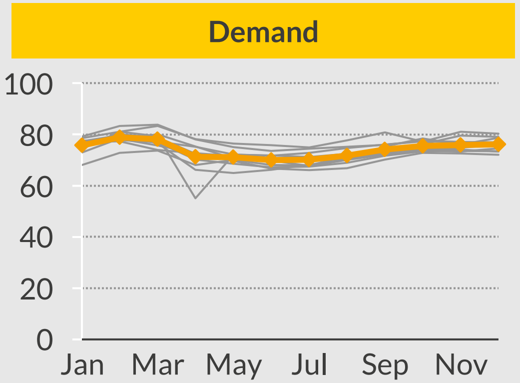


2 … this difference is more pronounced at a monthly granularity, revealing complementary patterns.

Monthly load factors,
%



Monthly demand[3],
%



- Higher demand occurs from November to March, driven by cooling appliances. This result in higher hydro production and thus load factors during these months.
- Hydro and onshore wind production complement each other throughout the year.
- Historically, we observe a positive correlation between peak demand and solar load factors.

1) Load factor is calculated as the total electricity generation in a period divided by the installed capacity of a specific technology; 2) A detailed view of regional solar PV generation is in the appendix. 3) Monthly average demand in relation to average demand.
Sources: Aurora Energy Research, ONS

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Despite increasing capacities of wind and solar PV, the variation in generation between weather years and the Central scenario remains stable

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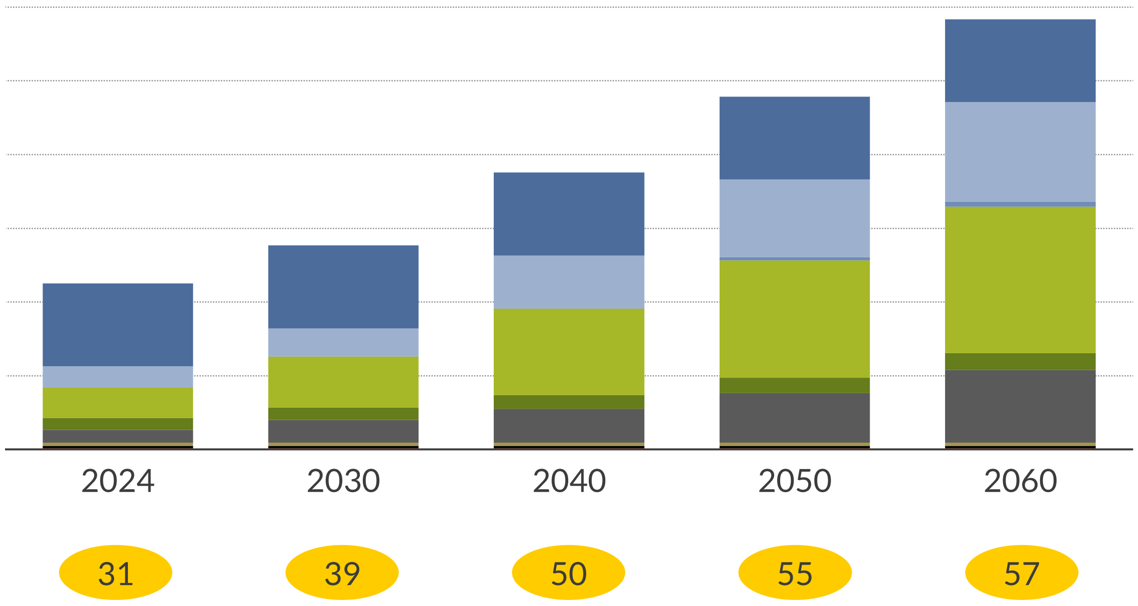
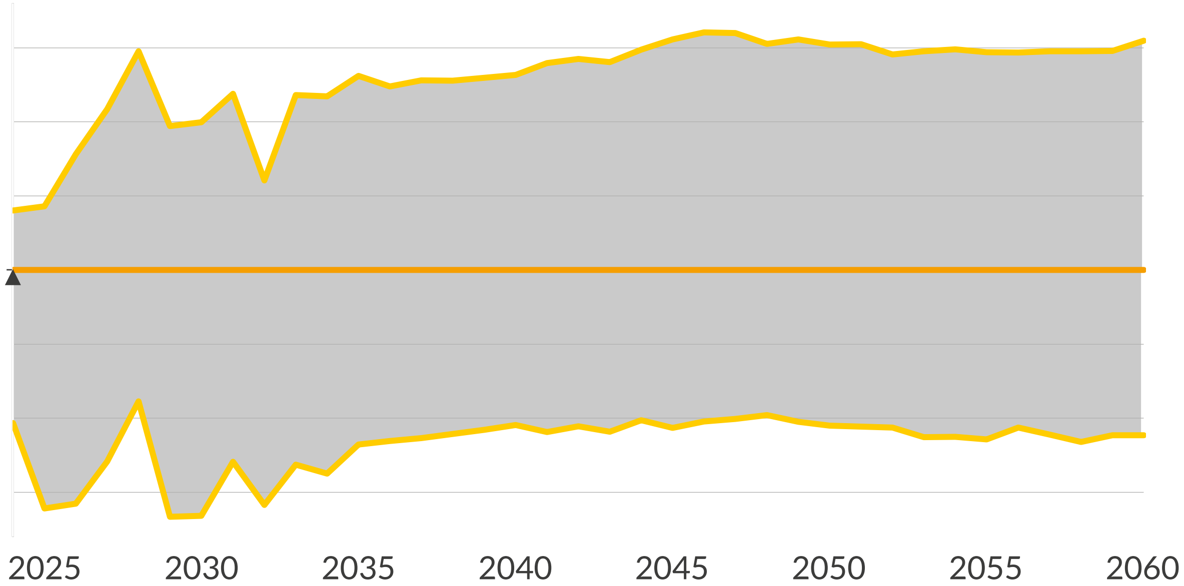
Installed capacity in Brazil – Central April 2024

GW



Difference in renewable generation[1] across weather years compared to Central

TWh



- The weather year analysis is based on the capacity mix of the Aurora Central scenario from April 2024. A single weather year outturn is assumed to be short-lived and would not affect a developer's investment decision.
- In Aurora's Central scenario, the share of solar PV and onshore wind installed capacity in the Brazilian system increases from 31% in 2024 to 57% in 2060.

- When considering the Aurora Central scenario, we expect generation from hydro, solar PV and onshore wind to double from 2024 to 2060 due to the increase in installed capacity of the last two technologies.

Percentage of onshore wind and solar PV in the Brazilian electricity mix

Hydro | Onshore wind | Offshore wind | Solar PV | Biomass | Gas CCGT | Gas/ oil peaker | Coal | Nuclear

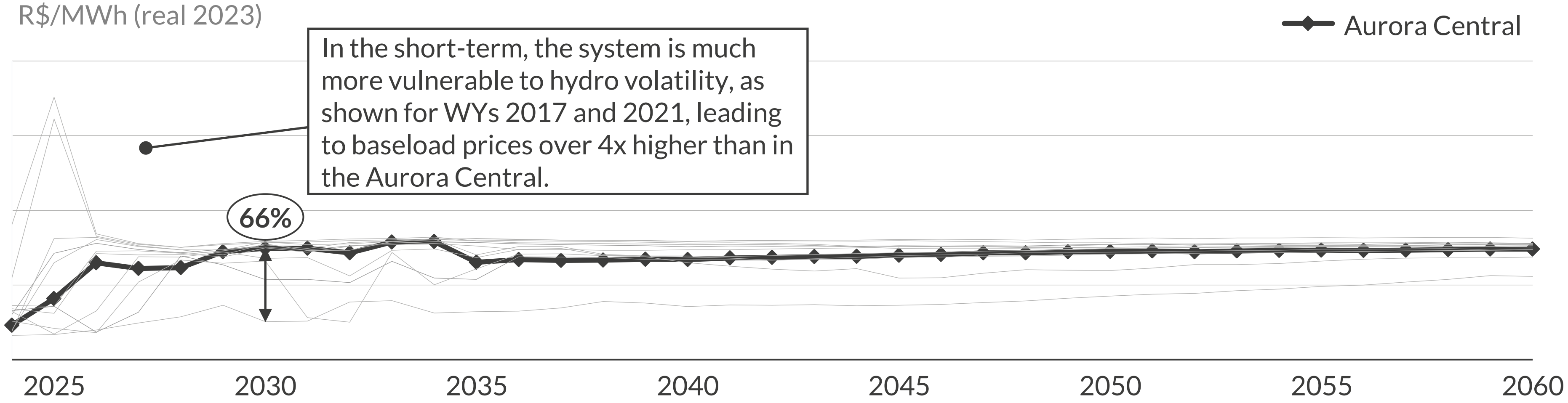
April 24 Aurora Central | Max/Min

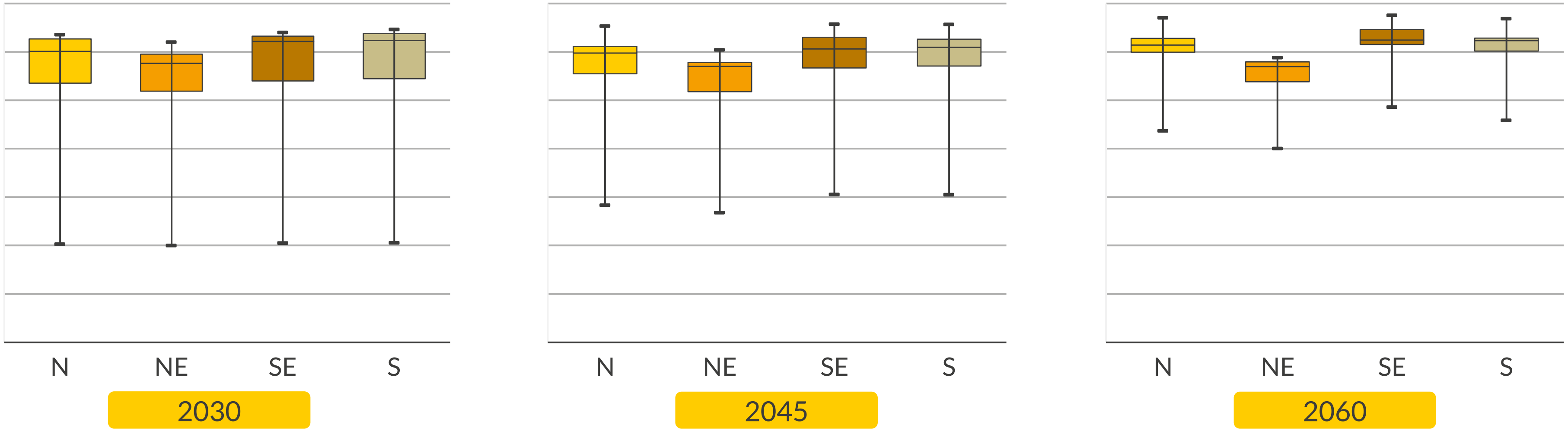
1)Includes generation from Solar PV (utility), onshore wind and hydro. Details on individual generation from Solar PV and onshore wind vs hydro can be found in the Appendix.

Source: Aurora Energy Research

Weather variability is reflected in baseload prices, which from 2030 onwards can vary by up to 66% compared to Central

Average baseload prices
R$/MWh (real 2023)





- In the short-term, the high share of hydro in the mix translates into a significant impact of inflow variability on price formation, causing prices to vary by over four times in some weather years compared to Central.
- From the 2030s onward, weather-related price variability tends to decrease as generation from onshore wind and solar PV grows, offsetting hydro variation.
- On a regional level, prices remain quite close among all subsystems, except for the Northeast. Price divergence in the Northeast is driven by expected growth in onshore wind generation, which benefits from better conditions in this subsystem.

Source: Aurora Energy Research

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1 Weather conditions influence both asset generation and wholesale prices, presenting a two-dimensional risk for producers

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Merchant assets are exposed to weather-driven volume and price uncertainties

- The revenue of merchant assets (or the merchant portion of an asset's revenue stack) is the direct result of production (in MWh) and the price associated with each MWh of production
- In systems with high renewable penetration, volume and prices tend to move in opposite directions: periods with high renewable generation often result in low prices and vice versa.
- Therefore, the net impact of weather on an individual's asset gross margins will depend on:
  - How much market prices are directly driven by renewable generation
  - The impact of weather on the asset's production
  - The correlation of the asset's production to the rest of the fleet

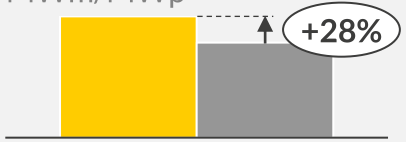
Illustrative examples of the impact of different weather years on gross margins

More windy year (2021)
Less windy year (2014)

- We selected **2045** as the **reference year** to test how different **onshore wind** production patterns in the **Northeast** can drive changes in market prices and wholesale gross margins for the generators

I

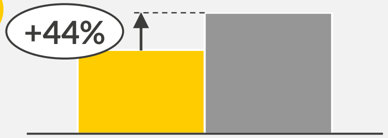
Average onshore wind load factor
MWm/MWp



- Weather years 2021 and 2014 had the highest and lowest load factors for onshore wind, respectively, in Brazil.
- In the Northeast, the load factor of onshore wind was 28% higher in weather year 2021 compared to 2014.

II

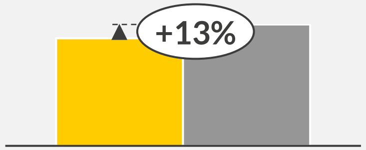
Generation weighted average prices for onshore wind (GWA)
R$/MWh (real 2023)



- Replicating these extreme load factors in the projected capacity for the year 2045 shows a rise in the baseload price in the less windy year profile compared to the windier year profile.
- This leads to a higher GWA price in a less windy year, a 44% increase compared to the windier year.

III

Wholesale gross margins
R$/kW (real 2023)

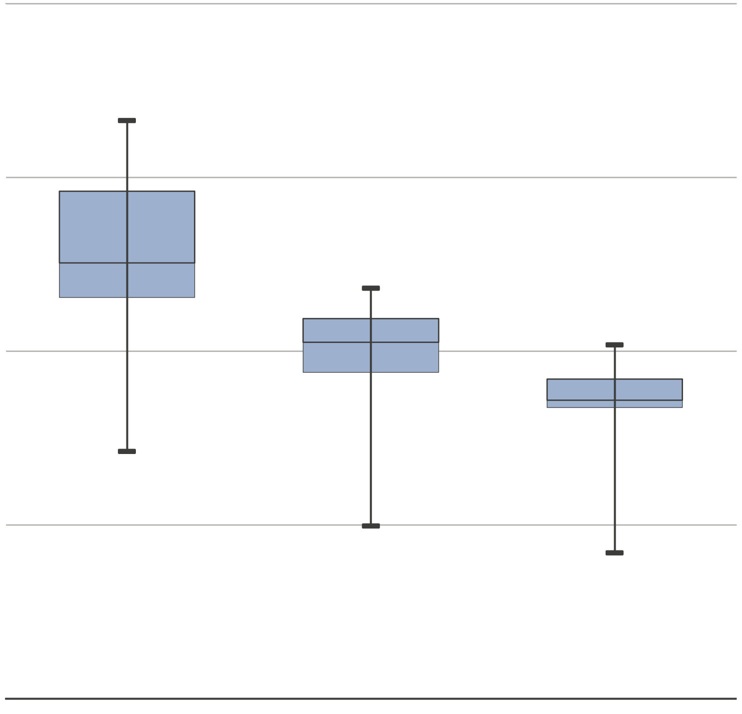


- Despite the higher GWA prices in the less windy year, the gross margin does not experience a corresponding increase, as it is offset by lower production.
- The impact on assets with a production profile less correlated to the fleet may differ, as their hourly output could lead to a different average price capture

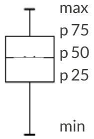
Source: Aurora Energy Research

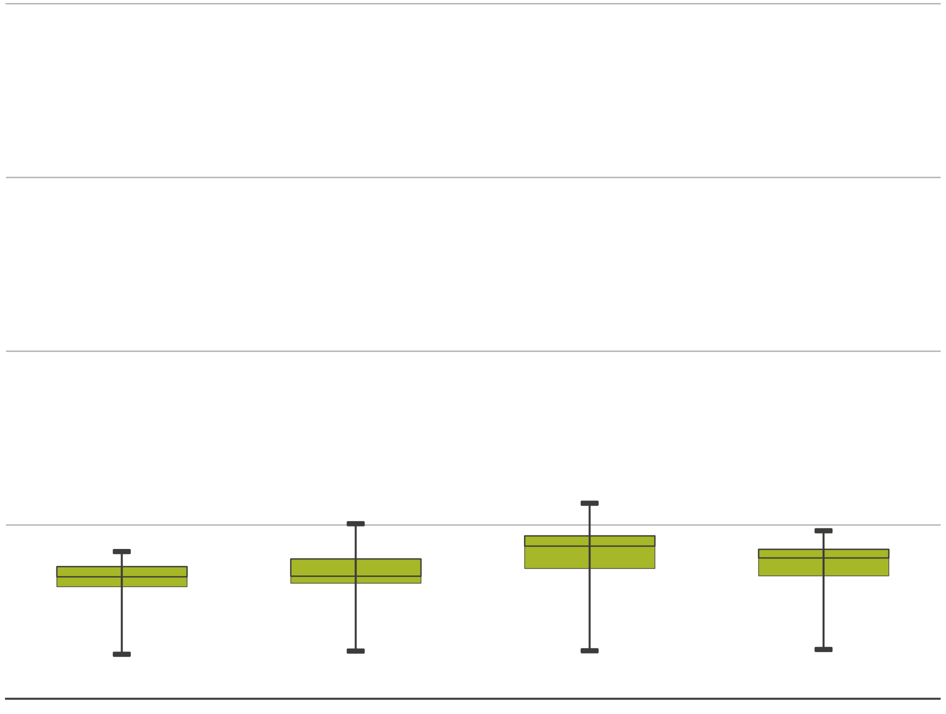
Despite higher absolute weather-year variation for wind, the impact of weather years is higher for solar relative to its P50 gross margins

Onshore wind wholesale gross margins in 2045 across weather sensitivities[1]
R$/kW (real 2023)



Solar wholesale gross margins in 2045 across weather sensitivities[1]
R$/kW (real 2023)





Standard deviation in wholesale gross margins in 2045 across weather sensitivities as a percentage of Aurora's Central
Standard Deviation as % of Aurora Central

	Wind NO	Wind NE	Wind SU	Solar NO	Solar NE	Solar SE	Solar SU
	21%	20%	20%	21%	29%	28%	27%

Source: Aurora Energy Research

Onshore wind

- In absolute terms, wind generators experience greater weather-driven fluctuations in gross margins across all subsystems.
- However, the negative correlation between wind production and baseload prices at a system level , helps mitigate the net impact of weather variability on wind gross margins.

Solar PV

- Despite lower standard deviations in absolute terms for solar, the impact of weather years has a higher relative impact on solar than wind.
- This is due to the fact that in periods of higher solar production, prices also tend to be higher, exacerbating the impact of weather uncertainties.
  - The positive correlation of solar generation with prices is the result of higher cooling demand during high solar irradiation periods.

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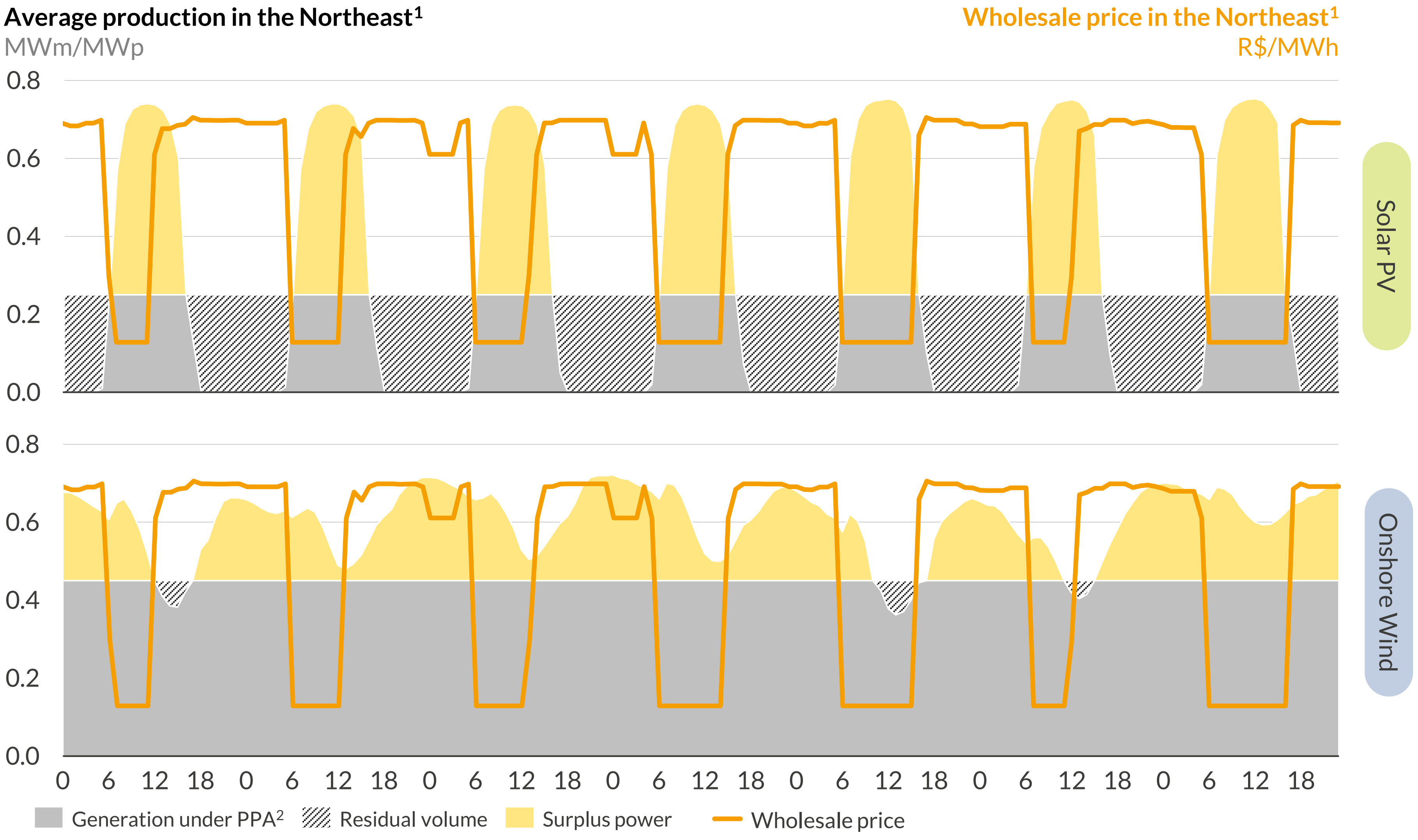
Solar production peaks during the middle of the day, coinciding with lower prices; this increases the cost of residual volume for solar



1) For the week between 02/10/2045 and 08/10/2045; 2) For a PPA volume at 100% of the physical guarantee.

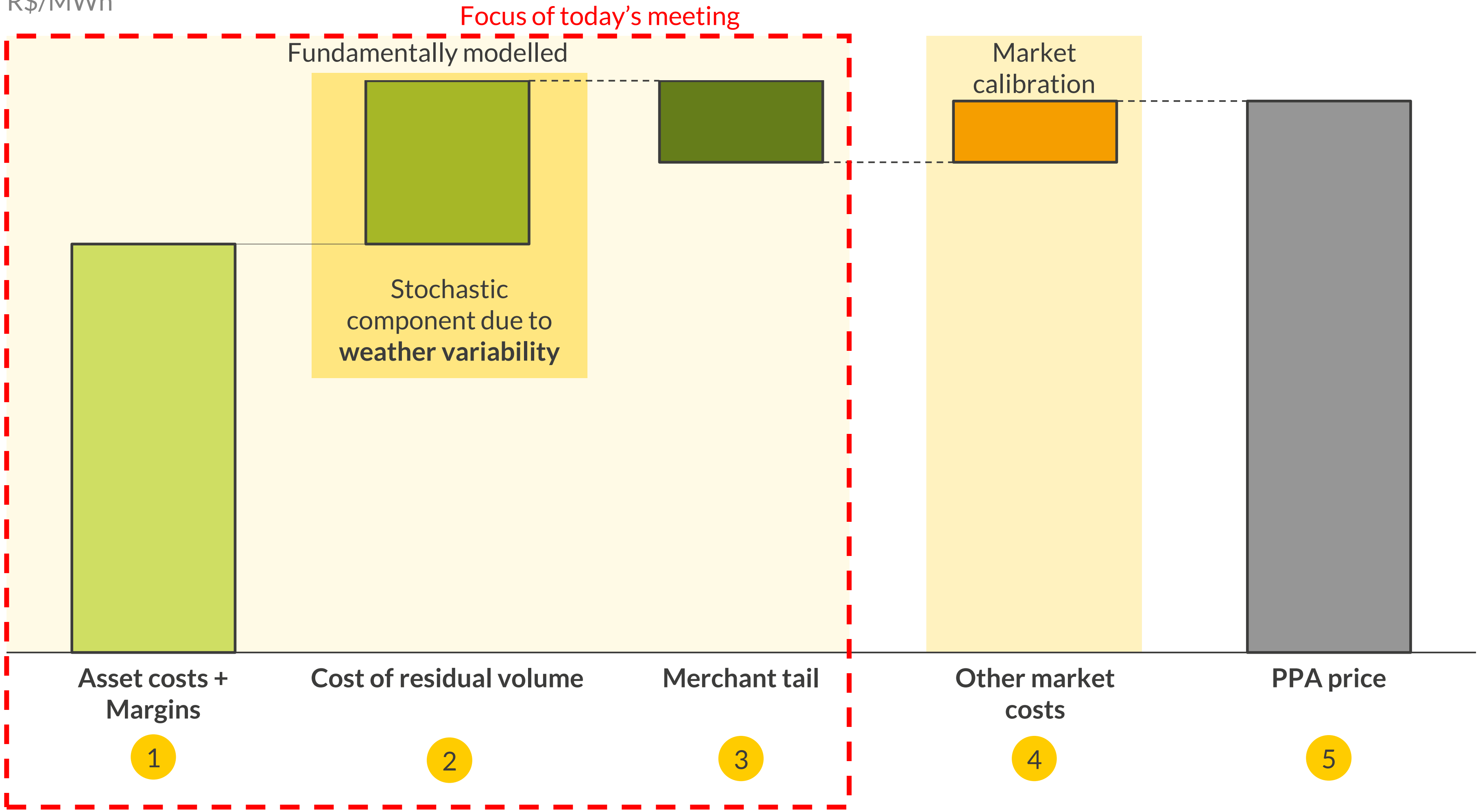
Source: Aurora Energy Research

Each technology has a different exposure to residual costs

- The cost of residual volume is the difference between the revenue generated from surplus generation at a given hourly price and the cost to purchase electricity when production falls below the PPA hourly volume.
- Solar PV production peaks during the middle of the day, coinciding with lower prices, and ceases during periods with the highest prices. This profile, under a scenario of growing solar capacity in the system, leads to increasing residual costs.
- Onshore wind, on the other hand, reaches high levels of generation during more expensive hours of the day, and lower production during lower price hours; consequently, an onshore wind asset would incur comparatively lower residual costs.

The PPA valuation includes costs for development and operation of the RES asset, as well as the risks associated with weather variability

PPA Price Calculation: waterfall components
R$/MWh



Comments

1. Minimum revenues required to pay off the investments on the selected asset(s).
2. The difference between the revenue from hours in which the asset produces more than the hourly PPA volume, and the costs from procuring electricity in the wholesale market in hours where production is lower than the PPA volume.
3. Revenues from selling the asset's generation in the wholesale market between the end of the PPA contract and the asset's end of life.
4. There are other costs that we don't cover in our analysis, such as transaction costs and taxes, that need to be added exogenously.
5. Estimated PPA price required for a developer to break even.

Source: Aurora Energy Research

We perform a stochastic analysis of the residual volume, allowing for the weather risk to be properly considered

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Phase 1: Data processing

Baseload prices, capture prices and asset production captured from scenarios.

Yearly normal distributions, modelled for baseload, capture prices and generations in each scenario.

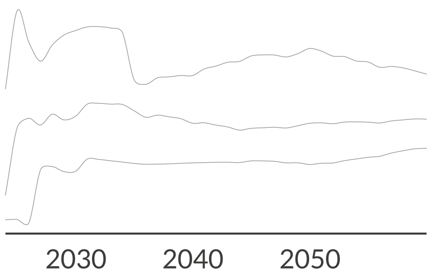
For:

Aurora's standard High, Central and Low

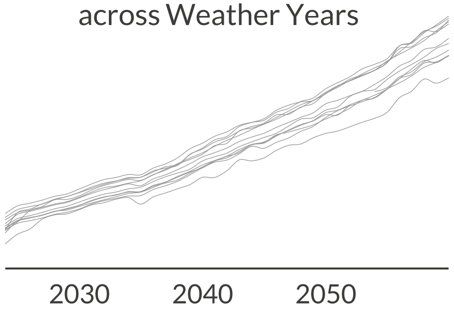
Aurora's Weather Years scenarios

Input examples:

Baseload prices' forecast across scenarios



Renewables' generation forecast across Weather Years



Phase 2: Simulation (High, Central, Low)

Baseload and capture prices picked from normal distributions.

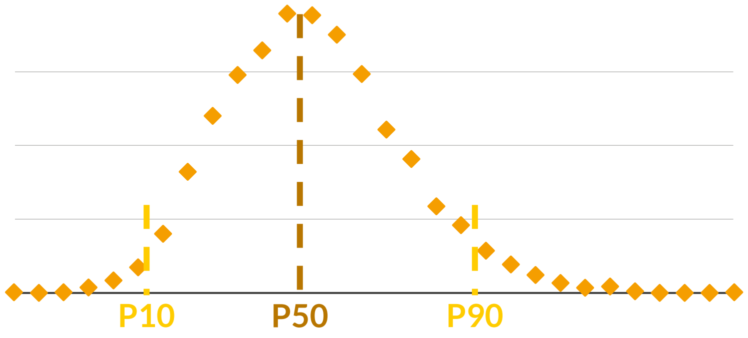
Monte Carlo simulation executed to account for uncertainty.

Phase 3: Combination (Weather Years)

Weather Years deviations calculated for baseload, capture price and generation.

Deviations matched and combined to respective features and simulations from Phase 2.

Cost of residual volume:



Our methodology:

- The price distribution is built by attaching a probability percentile to each Aurora scenario:
  - High scenario: P90
  - Central: P50
  - Low: P10

How is this useful:

- It provides a confidence interval for the **cost of residual volume**, based on weather uncertainty and PPA parameters.

Results of the stochastic analysis

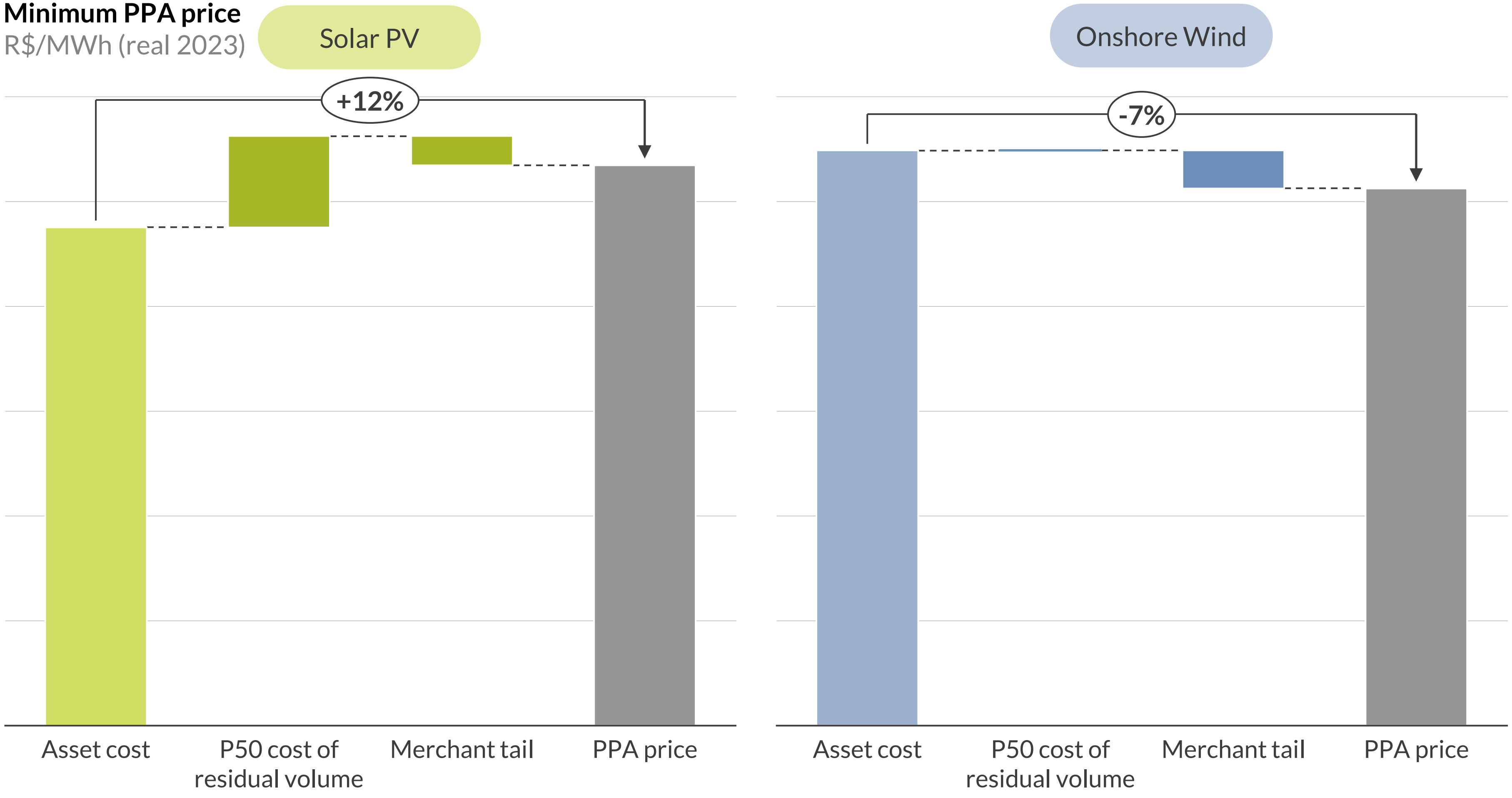
- The result is a component of the PPA price that covers the cost of residual value for a certain probability percentile.
- A higher percentile (P90) corresponds to a low-risk strategy, and a low percentile (P10) corresponds to a high-risk strategy.

Source: Aurora Energy Research

Despite lower asset costs for solar PV, its residual volume costs can lead to higher PPA prices compared to onshore wind

Input parameters	Subsystem= NE	Start year = 2026	Tenor = 20 years	WACC = 11%	# Simulations = 5000

Minimum PPA price
R$/MWh (real 2023)



- For solar PV, the starting point of asset costs is lower than for onshore wind, but the cost of residual volume more than compensates for that difference.
- The merchant tail for onshore wind is slightly higher than for solar PV due to higher generation and generation weighted capture prices.
- While current forward prices reach up to R$140/MWh in the next 3-5 years, our estimates differ for a number of reasons:
  - Short-term PPA prices do not reflect the level needed to make new investment decisions.
  - We believe the market is underestimating the costs of residual volumes.
  - The current low price environment sets a low benchmark for short-term PPAs.

Source: Aurora Energy Research

Baseload PPA profile and residual volume costs assumed by a producer can be mitigated by reducing the contracted generation or through hybridisation

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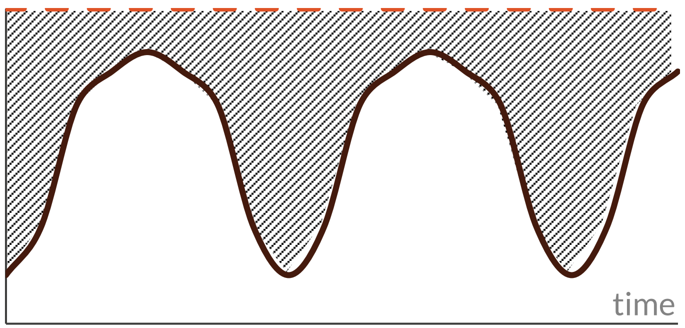
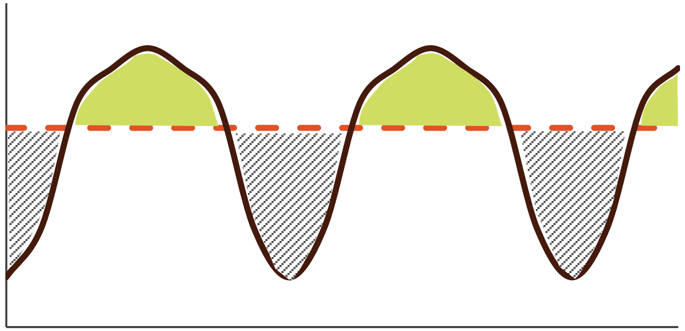
A Power contracted relative to asset size

Risk: Low asset generation vs. baseload volume

Generation



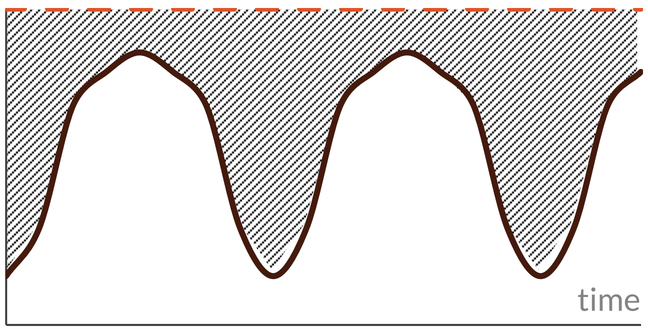
Mitigation: Lowering the contracting percentage of physical guarantee as baseload volume



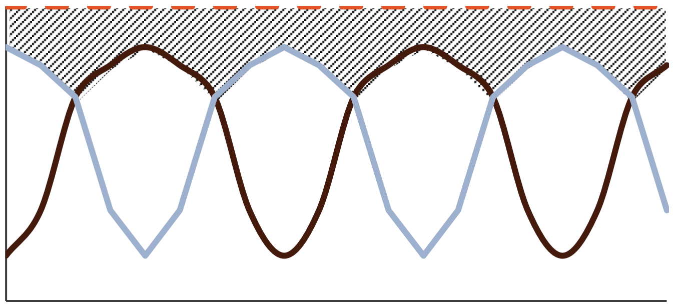
B Combination of generating assets

Risk: Low generation from single asset

Generation



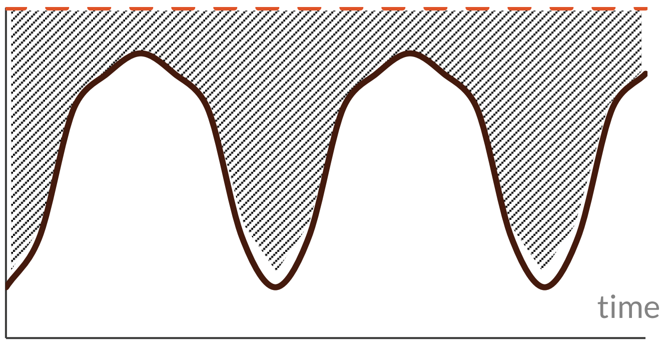
Mitigation: Generation from two assets



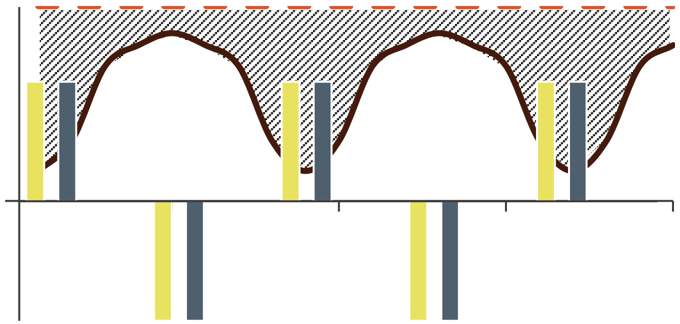
C Combination of RES assets and storage

Risk: Low generation in a specific hour

Generation



Mitigation: Adding a battery/pumped hydro storage asset



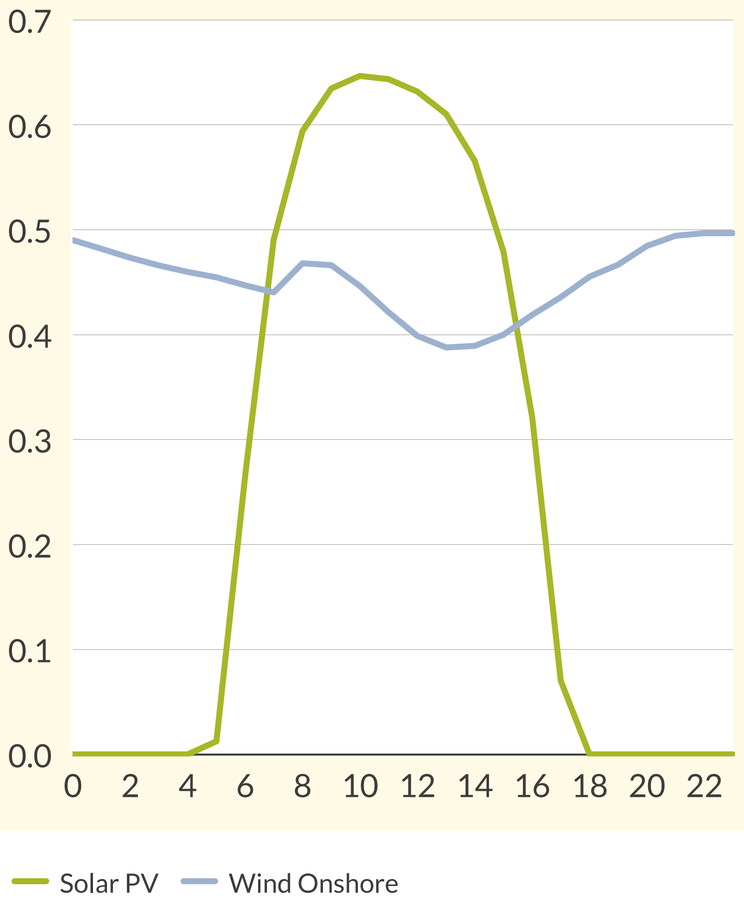
Residual power | Surplus power sold on the market | Baseload volume | Generation of RES asset (s) | Generation shifted | Battery/pumped hydro storage

Source: Aurora Energy Research

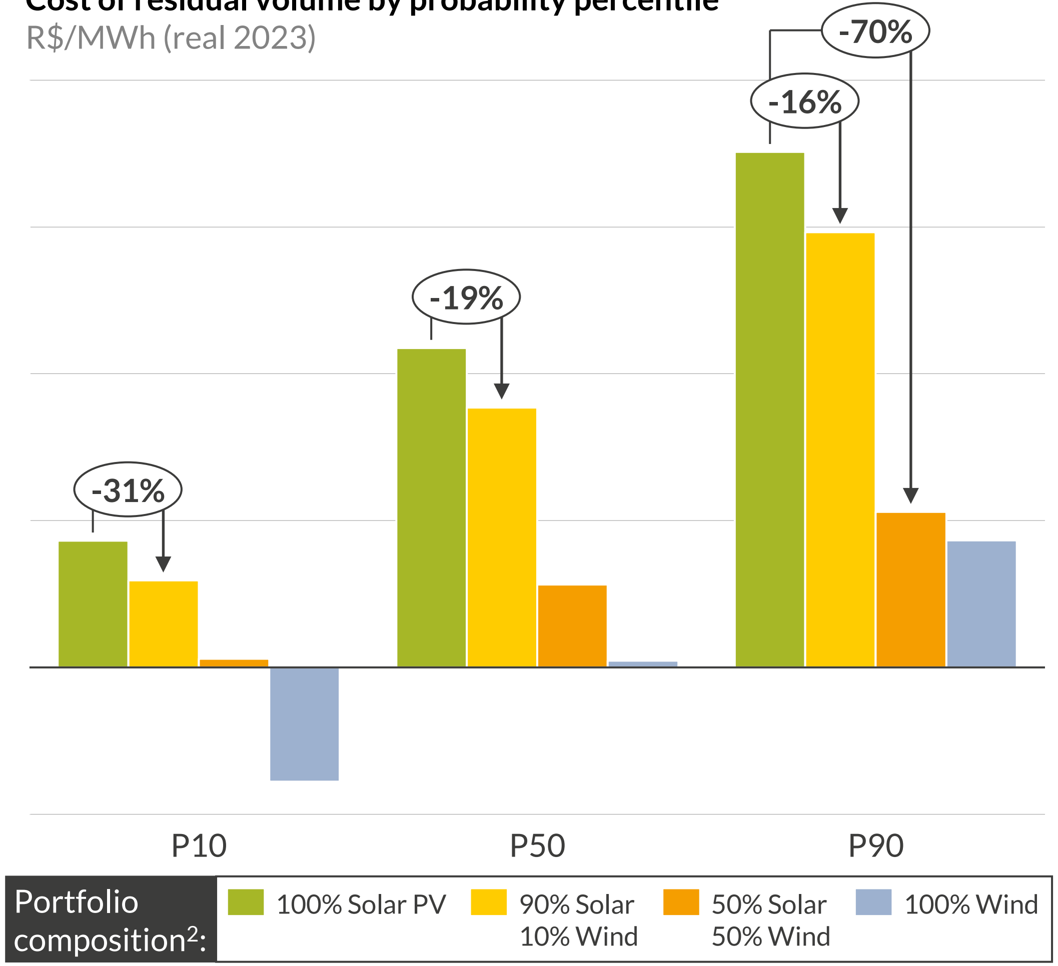
Adding just 10% of onshore wind decreases the cost of residual volume by 16% for a low-risk strategy, compared to 100% solar PV

Input parameters	Subsystem =NE	COD = 2026	Tenor = 20 years	Volume = 100% of PG[1]	WACC = 11%	# Simulations = 5000

Average load factor per hour of day in the NE
MWm/MWp



Cost of residual volume by probability percentile
R$/MWh (real 2023)



- Onshore wind and solar PV are complementary technologies in the Northeast, as one presents higher production in periods when the other has lower production.
- When closing a baseload PPA, the seller can make use of the complementarity of the two technologies to mitigate the risk of residual volume.
- Compared to a solar-only strategy, a portfolio with 10% onshore wind reduces the cost of residual volume by 16%, for a 10% value at risk, and 50% onshore wind leads to a 70% reduction.

Find out more:

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1) Physical Guarantee (Garantia Física); 2) By installed capacity

Source: Aurora Energy Research

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In a country dominated by renewable energy, the complementarity of different technologies helps reduce risks in both system and asset levels

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1. Despite increasing renewable capacity in the long-term, the variability of renewable generation remains stable due to the complementarity of hydro generation in the Southeast/Midwest and onshore wind in the Northeast.

2. Weather conditions influence both wholesale prices and renewable generation and can cause asset gross margins to vary by up to 68% compared to the Aurora Central. Gross margin risks for individual hydro assets are mitigated by the MRE.

3. PPAs can be an effective instrument to mitigate weather risk depending on the allocation of volume and price risks between offtakers and developers.

4. Baseload PPAs, still common in Brazil, can carry a significant risk to the seller due to the cost of buying the residual power needed to firm up a baseload profile.

5. With generation-weighted prices for solar expected to decline over time, the cost of residual power purchases for solar PPAs is expected to increase and significantly exceed those for wind PPAs.

6. A PPA backed up by a combination of wind and solar can significantly reduce the costs of residual power purchases, lowering the break-even price for PPAs.

Source: Aurora Energy Research

Brazilian Power & Renewables Service:
Dive into key market analysis and forecasts for the Brazilian power and renewables markets

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Power and Renewables Service

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Upcoming developments for subscribers of the Aurora's Brazilian services

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2024

July

Quarterly update of the Power and Renewables Market Forecast
- Updated to reflect near-term commodity price changes

September

11/09 Second subscriber Group Meeting 2024
- On the topic of offshore wind (TBC)

October

Quarterly update of the Power and Renewables Market Forecast
- Updated to reflect near-term commodity price changes

December

03/12 Third subscriber Group Meeting 2024
- Topic to be confirmed

2025

January

Quarterly update of the Power and Renewables Market Forecast
- Updated to reflect near-term commodity price changes

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Source: Aurora Energy Research

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**

“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**

Power & utilities

Energy consumers

Financial sector & investors

Oil & gas

Project developers

Policy & regulation

Source: Aurora Energy Research

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