

India Subscriber/Inviteonly Webinar

6th November 2024



Agenda



- Introduction to today's session
- **Indian market context**
- III. Aurora's power market forecast and key drivers
- IV. Alternative scenario results
- Next steps

Introduction to Aurora's team for today and key information for today's session









Debabrata Ghosh

Margot Roberson-Leech

Siddhant Shah

Head of India

Senior Analyst

Analyst

Aurora's bespoke offerings

For more information on scenario analysis, site-specific asset economics including comparison of revenue models, bespoke forecasting, competitor analysis and auction bidding support, please reach out at **mrunal.karnik@auroraer.com**.

Aurora welcomes today's session attendees





नवीन एवं नवीकरणीय ऊर्जा मंत्रालय MINISTRY OF **NEW AND** RENEWABLE ENERGY













































Hexa

Climate



































































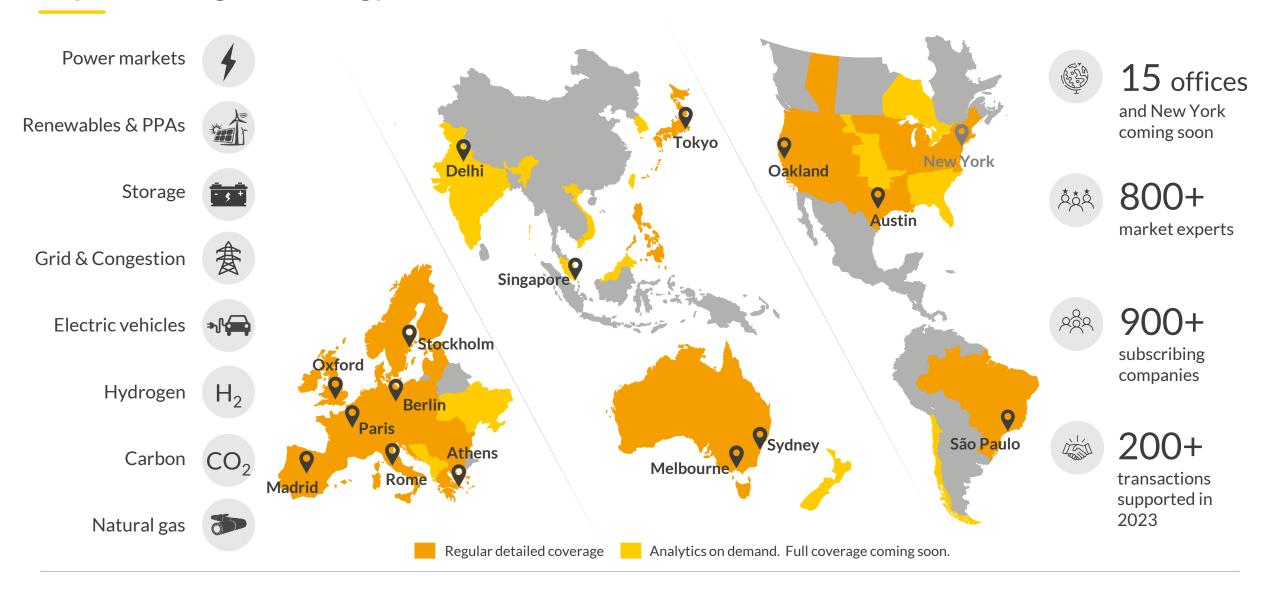






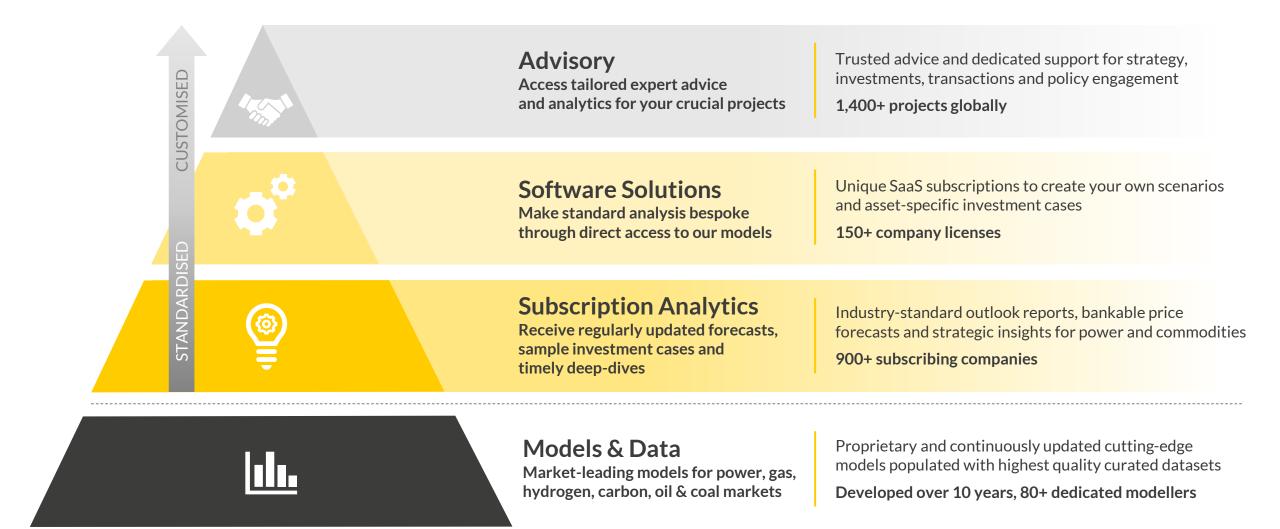
Aurora provides market leading forecasts & data-driven intelligence to power the global energy transition





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





<u>Software:</u> moving our forecasts and valuations into integrated software solutions to provide even greater value for our clients





Our asset-level tools quantify the value of your assets or sites under different configurations and market scenarios.

SEAMLESS INTEGRATION

With Origin: use your own scenarios in your valuations

With each other: value co-located assets and portfolios

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

AUR 😂 RA



"With its capabilities, intellect and with its credibility Aurora plays an essential role bringing the dialogue [in the global energy transition] to a different plane"

Ben van Beurden, CEO, Shell



"Aurora analysis and the provision of reliance was crucial for our debt funding. Their ability to explain market logics and revenue streams was vital for this successful financing."

Jeremy Taylor, Director, Green Frog Power





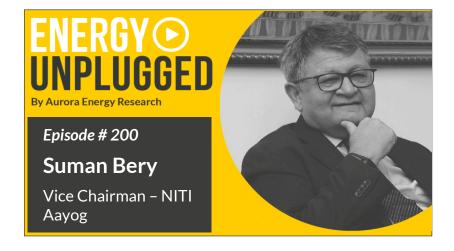


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We have already established a seat-at-the table in India.







Meeting with Hon'ble Chief Minister, Rajasthan

Speaker at RE-Invest 2024, Ahmedabad on invitation of Gujarat Government

Podcast with Mr. Suman Bery, Vice Chairman, NITI Aaayog

Indian Power & Renewables Service:



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

Power & Renewables Service

Forecast Reports & Data



Quarterly forecast reports and data updates

- Detailed forecast data for India's capacity and generation mix out to 2060, along with annual and monthly time-weighted average prices across the 13 main Indian price zones (DAM).
- A comprehensive databook containing half-hourly wholesale price forecasts in Central, High and Low scenarios.
- Renewable capture price forecasts and power sector emissions projections, offering insights into both profitability and environmental impact of renewable assets.
- Price distribution analysis and scenario-based modelling (High and Low scenarios) to help understand potential market variations and uncertainties around Aurora's Central forecast.
- Copies of Aurora's Global Energy Markets Forecast, published quarterly, providing a broader context of global energy trends alongside India-specific insights.

Strategic Insights



Strategic Insight Reports

In-depth thematic reports on topical issues, such as the economics of batteries, and the Portfolio design for FDRE auctions



Policy Updates

Timely research notes on recent changes to policy and regulation, demonstrating the impacts and opportunities for market participants



4 Group Meetings

Three Group Meeting roundtable events in New Delhi with key market participants such as developers, investors, financiers, utilities, grid operators, and government officials



Analyst Support

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

Subscription Analytics: Aurora's roadmap for India's service offerings





- Assumptions underpinning the Indian power market
- Market structure and trading arrangements
- Key policy and regulation
- Commodity prices, planned capacity, and interconnections
- Technology assumptions

- First long-term forecast Aurora's Central forecast through to 2060 covering:
- Installed capacity and generation mix; DAM prices and merchant renewable realised tariffs

Alternative scenario analysis to explore sensitivity to:

Lower GDP growth

 Official launch: first full. detailed Power & Renewables market report

Aurora's detailed, long-term view on the power market in India, containing:

Alternative scenario analysis to explore sensitivity to:

- Aurora's central scenario

- Lower GDP growth

- Batteries: the economics of storage in India
- Economics of battery storage in India
- Business models for batteries
- Impact of the introduction of ancillary markets

- Future subscriber meetings Future Group Meetings on:
- Portfolio design for FDRE auctions (May 2025)
- Power purchase agreements for utilities and corporates
- Batteries economics, hydrogen, etc.
- Bespoke grids/network constraints analysis

Key releases

Reports

Software

1st report (Central & Low) and Databook December

> Online platform access (EOS) December

Amun January Full PRMF report (all scenarios) **April**

July

PRMF report 1st flex report (storage) Q4 2025

CONFIDENTIAL 11 Sources: Aurora Energy Research

Subscription Analytics: We have developed our "Central" & "Low" scenarios, we will release our other scenarios in the April'25 PRMF



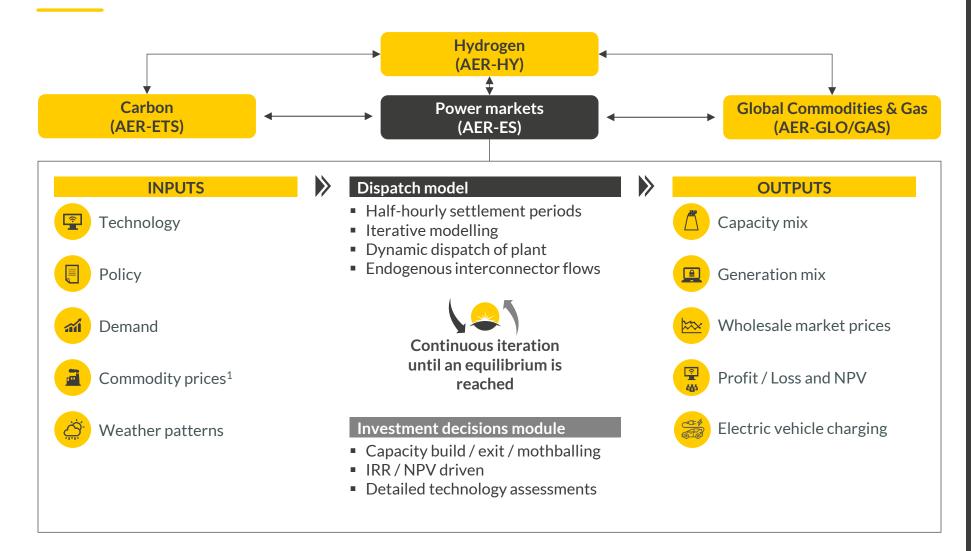
Already developed		Released in April 2025		
Aurora Central	Low Scenario	High Scenario	Messy Transition	Accelerated Decarbonisation
Aurora's central view of the evolution of the Indian electricity market to 2060	Sensitivity to reflect a downside scenario for financing	Sensitivity to reflect a upside scenario for energy users	Sensitivity to reflect the non-equilibrium nature of the energy transition	Sensitivity to reflect increased decarbonisation efforts
 Aurora's best view for the evolution of the Indian power market until 2060. 	 Represents a downside case, incorporating low demand and commodity prices. 	 Represents an upside case, incorporating high demand and commodity prices. 	 Represents a scenario in which some coal capacity in India closes unexpectedly. 	 Represents a world where India stays on track to reach the net zero target by 2070.
 Includes Aurora's central outlook for technological developments and commodity prices. Incorporates currently stated policies, alongside a conservative view of future policy objectives. 	 This envisages a world with slower overall GDP growth. Reflects a realistic scenario with lower capacity build out and lower power prices. 	 This envisages a world with higher overall GDP growth. Reflects accelerated economic growth leading to increases in costs and prices. 	 Supply chain delays lead to a slow deployment of renewables. Reflects a scenario with higher power prices and greater price spreads. 	 Reflects a scenario with faster coal phase out. Leads to greater renewable deployment.

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Our analysis of the Indian power market uses our proprietary, inhouse modelling capabilities with data from official sources



Advantages of Aurora's Approach

- Flexible and nimble because we own the code
- Transparent results
- State-of-the-art infrastructure
- Zero dependence on black-box third-party software
- Constantly up to date through subscription research
- Ability to model complex policy changes very quickly
- Ability to model new technologies and demand sources

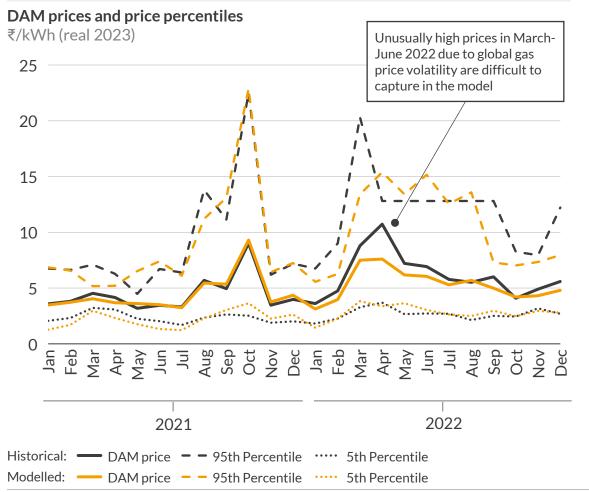
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¹⁾ Gas, coal, oil and carbon prices fundamentally modelled in-house with fully integrated commodities and gas market model.

Aurora's models accurately simulate real outcomes in the Indian market across historical months and at 30-min intervals



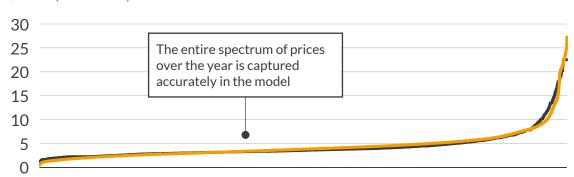
Aurora's model simulates DAM¹ prices within 1% and 14% of historical averages across 2021 and 2022, respectively



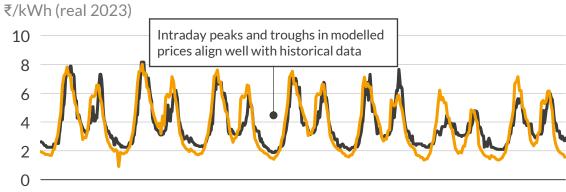
At a half-hourly granularity, Aurora's model accurately reflects intra-day trends in DAM prices

Price duration curve, 2021

₹/kWh (real 2023)



Modelled and historic DAM prices, sample week in 2021

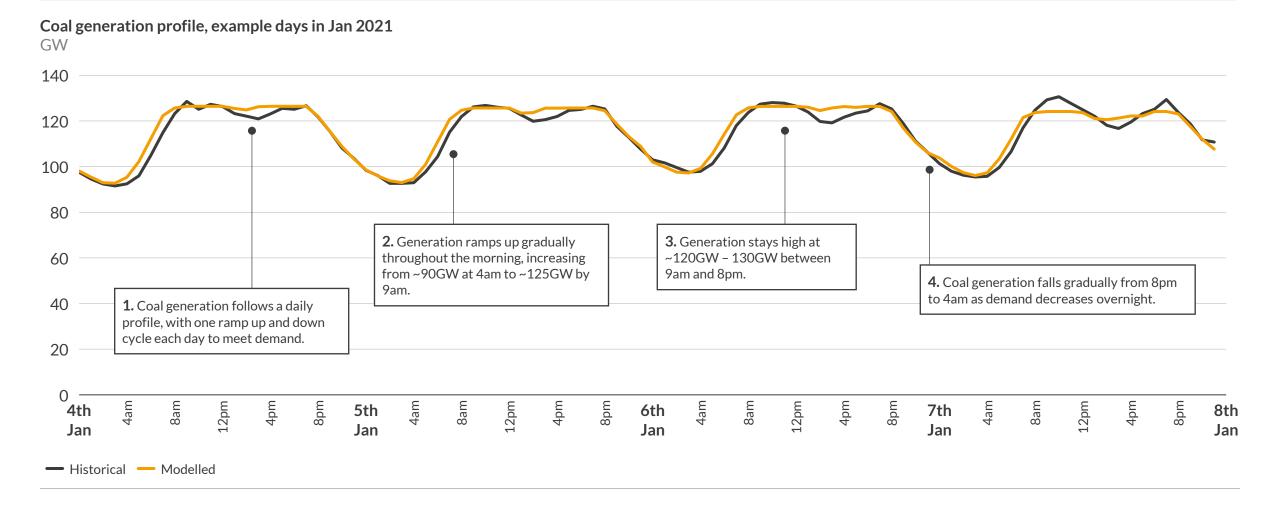


1) Day Ahead Market.

Aurora's model accurately predicts historical coal generation profiles which are used to inform coal generation in future forecast years



The average difference between the historical and modelled coal generation profiles across the example days shown is 1%. This triangulation is used to inform ramping constraints for coal generation across future forecast years, ensuring coal does not ramp up faster than is feasibly possible.

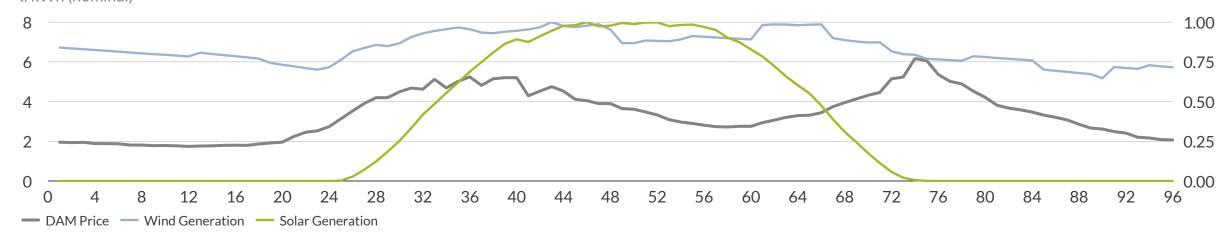


Sources: Aurora Energy Research

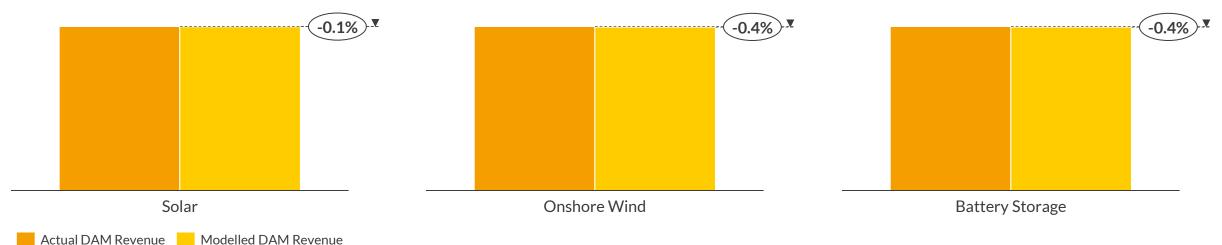
Plant revenues from prices modelled at 30-minute intervals are within 0.4% of actual values if modelled 15-minutely instead

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Average DAM prices (left axis) and normalised solar and wind generation (right axis) by settlement period for a sample week in 2022 ₹/kWh (nominal)



Actual and modelled¹ revenues for sample solar, onshore wind, and battery storage² assets for a sample week in 2022



1) Modelled revenues calculated assuming prices change every 30 minutes instead of 15 minutes; 2) 1-hour, 2 cycles per day battery considered.

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- Aurora's power market forecast and key drivers
 - 1. Aurora Central: key input drivers
 - 2. Aurora Central: Indian market outlook
- IV. Alternative scenario results
- Next steps

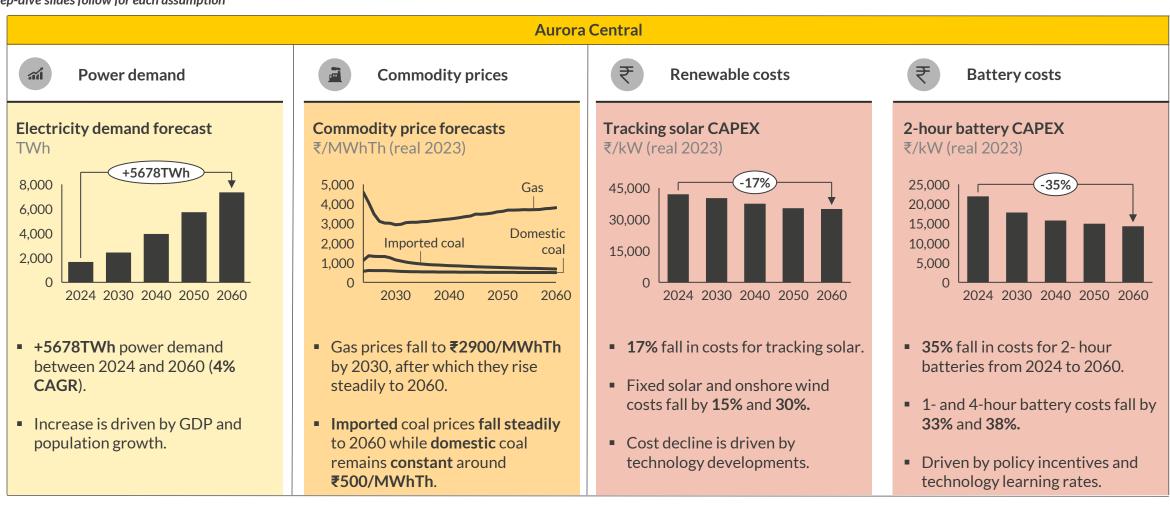
Aurora's central perspective of the Indian power market is dependent on key inputs: power demand, commodity prices, and technology costs



Deep-dive slides follow for each assumption

Prices Costs

Demand



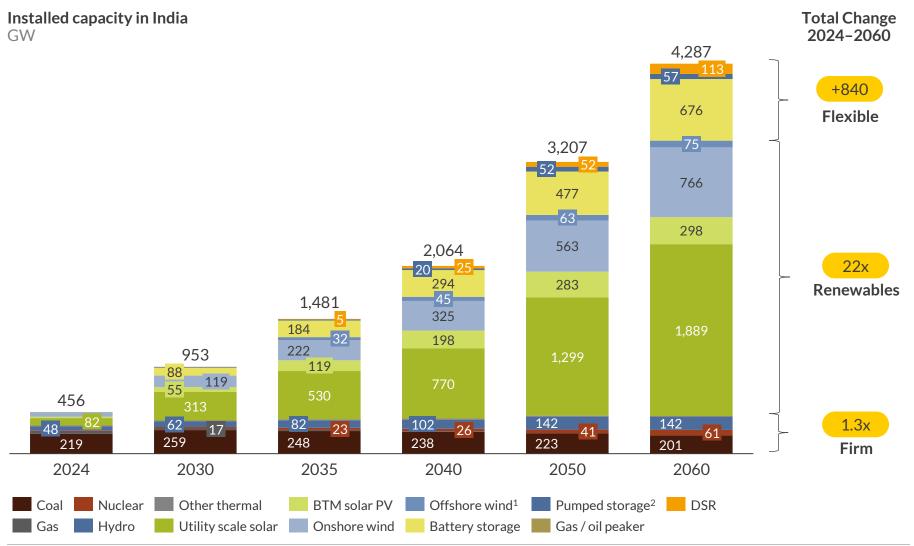
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 - 1. Aurora Central: key input drivers
 - 2. Aurora Central: Indian market outlook
 - i. Capacity and generation
 - ii. DAM prices
 - iii. Realised tariffs
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Total installed capacity in India reaches over 4.2TW by 2060, including 3TW of renewables, and 676GW of battery storage





Flexible

 Battery storage assets increase from small levels today to 676GW in 2060 with a CAGR of 13% seen from 2030 – 2040.

Renewables

- Driven by falling technology costs and policy incentives, renewables increase 21x to over 3TW 2060.
- The trajectory of growth is sharpest from 2024-2030, with a CAGR of 23%.
- Renewables make up 71% of capacity by 2060, displacing coal.

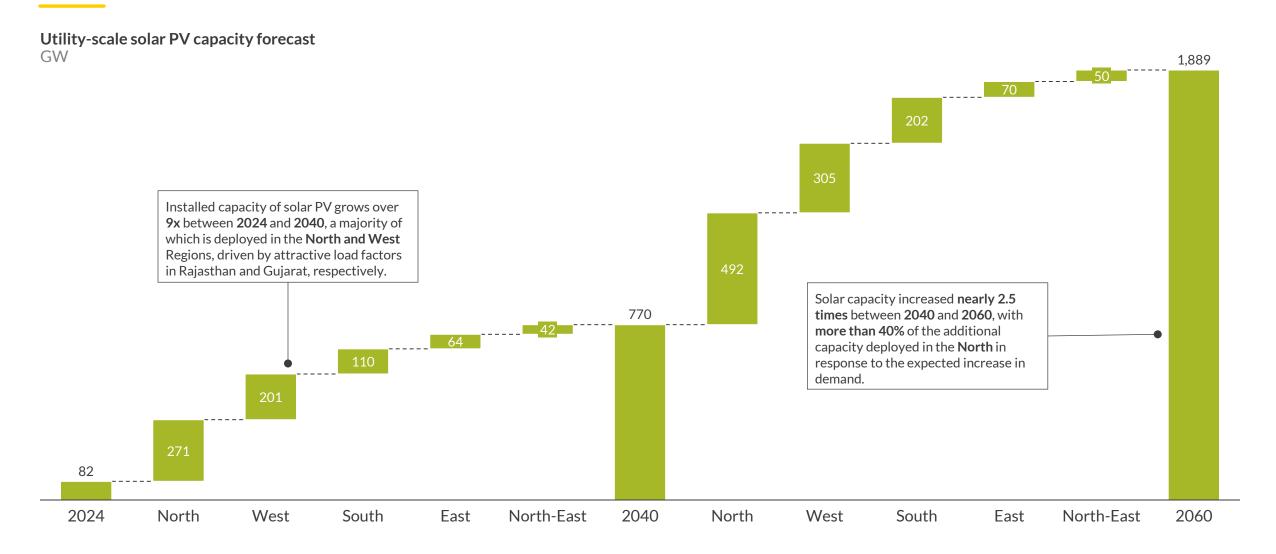
Firm

Firm capacity increases 1.3x, reaching 414GW by 2060, however, its share of the capacity mix falls from 68% in 2024 to 10% in 2060.

¹⁾ The government has $\underline{\text{set a target}}$ of 30GW offshore wind by 2030; we discount this to only 5GW in 2030, but 32GW is deployed by 2035; 2) In addition to 4.7GW of installed capacity, 2.8GW is $\underline{\text{under construction}}$ and the CEA has concurred with the Draft Project Report for a further 2.4GW – we assume this to be delivered by 2035 bringing the total to 10GW.

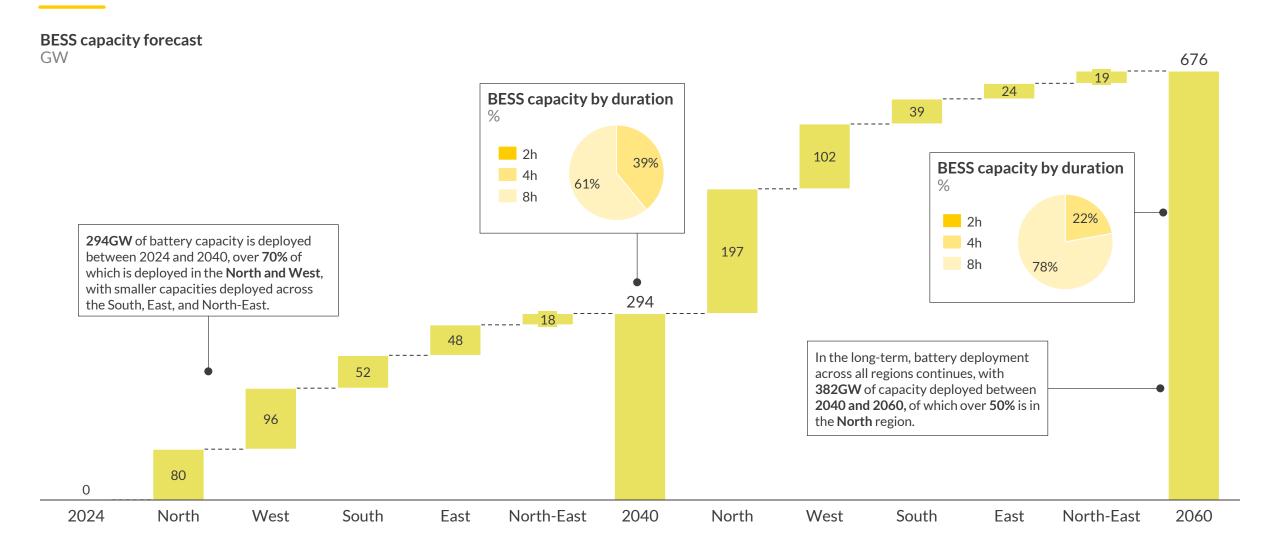
Utility-scale solar drives the capacity expansion, with nearly 1.9TW GW added by 2060



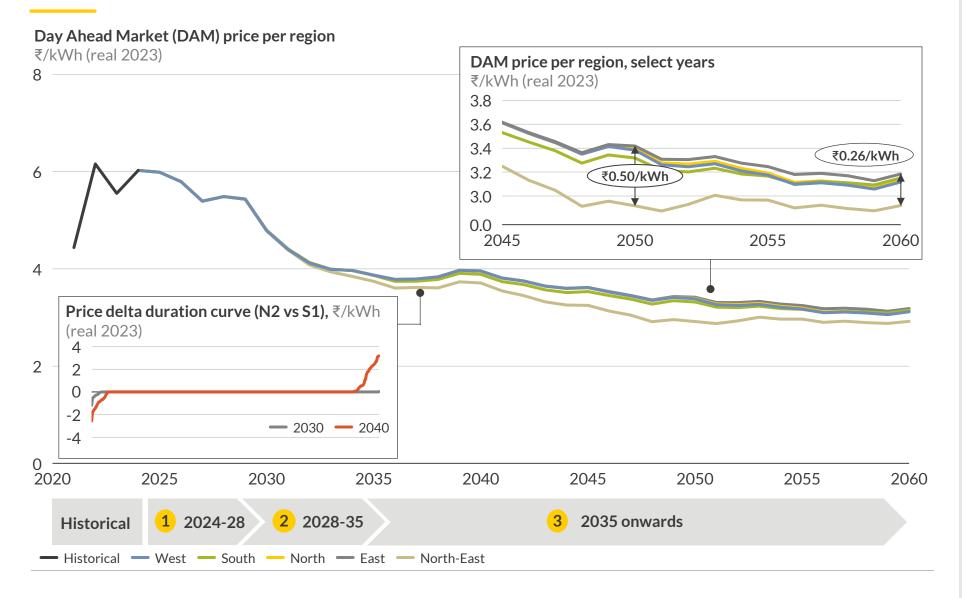


676GW of battery capacity is deployed by 2060, with more than 40% of total capacity deployed in the North





Driven by renewable buildout, power prices decrease - with price decoupling emerging from the early 2030s and widening to 2050



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Outlook for DAM prices

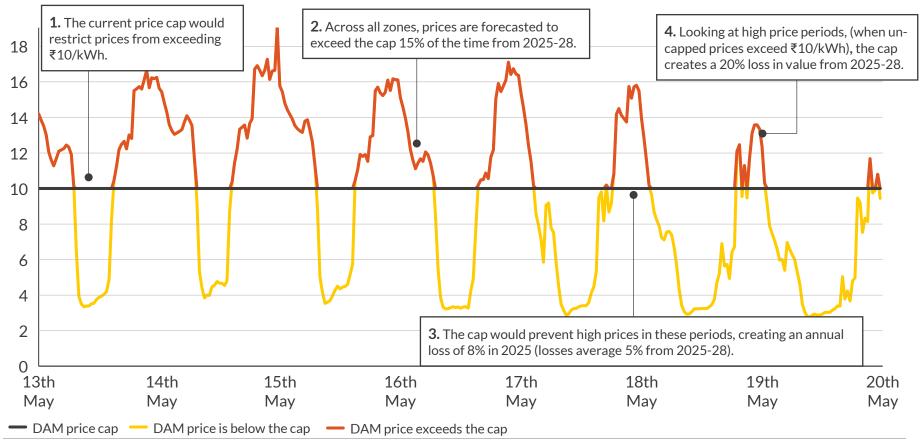
- Short-term trends
- DAM prices fall by ₹0.54/kWh but remain above ₹5.39/kWh to 2028.
- Mid-term trends
- Prices fall the most sharply between 2028 and 2035, driven by the rapid expansion of renewables.
- On average, prices fall by ₹1.64/kWh (30%) during this period.
- Price decoupling emerges from 2030 and increases to 2035.
- Long-term trends
- Prices decrease by an additional ₹0.74/kWh (19%) by 2060.
- Decoupling widens up to 2050 and then decreases due to transmission build-out.

The current DAM price cap would inhibit high prices, creating value loss and reducing the economic viability of key green technologies

The current ₹10/kWh DAM price cap will cause a 5% loss in value in the Indian power system from 2025 – 2028, with losses increasing to 20% when looking at high price periods only...

DAM price and cap, N2 - example week in May 2025

₹/kWh (real 2023)



...This leads to a reduction in the economic viability of key tech1



Reduction in annual revenue for onshore wind



Reduction in annual revenue for tracking solar



Potential reduction in value capture for batteries²

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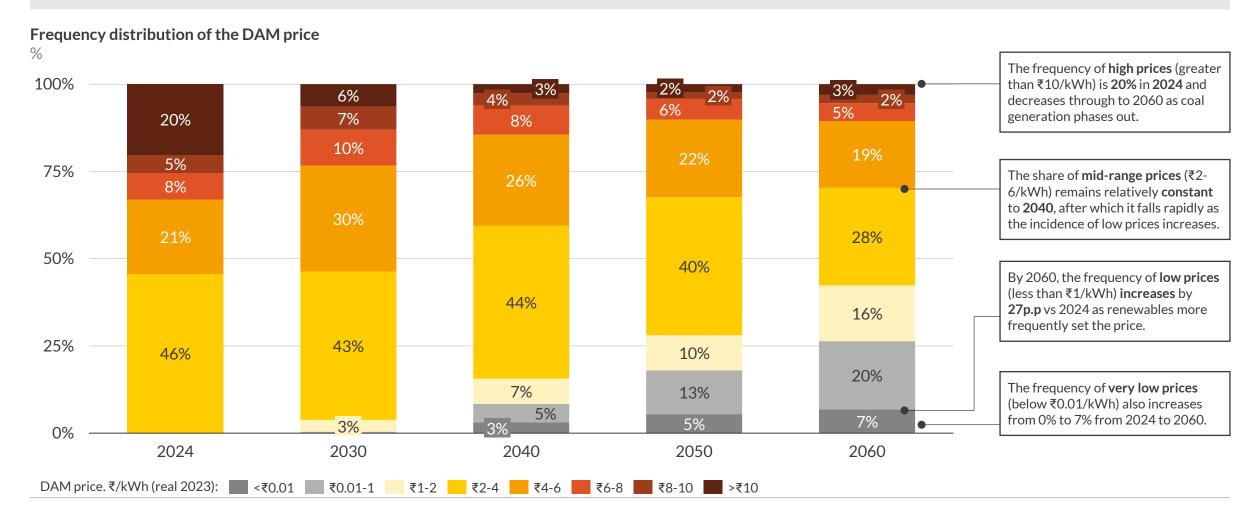
¹⁾ Figures for wind and solar shown for price zone N2 in 2025; 2) Shows value lost in high price periods as a result of the cap in 2025. Exact revenue loss will depend on a particular battery asset's ability to discharge in these high price periods.

The increase in intermittent capacities results in a growing incidence of bottom prices



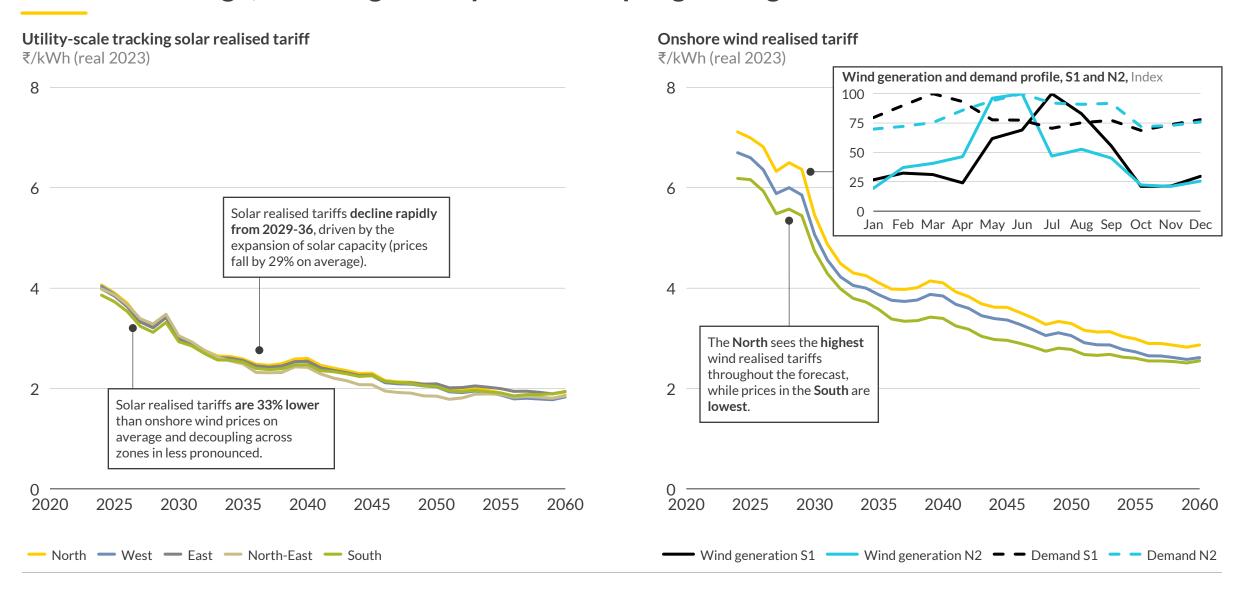


The deployment of renewables drives an increase in the occurrence of low power prices from 2040 as cheaper renewables more frequently set the price. At the same time, the incidence of high prices reduces as renewable deployment displaces coal which sets higher prices during earlier years.

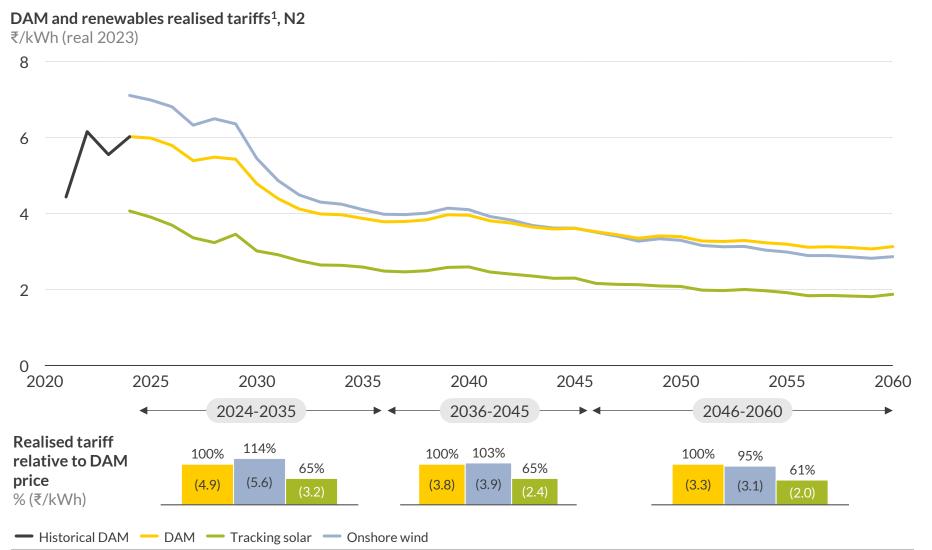


Onshore wind realised tariffs are 1.5x higher than tracking solar realised tariffs on average, and see greater price decoupling through to 2060





In N2, realised tariffs for onshore wind fall from 18% above 8% below the DAM price, while tracking solar discount averages 37%



¹⁾ The realised tariff premium for onshore wind is a result of not implementing the DAM price cap in the model, which enables onshore wind plants to capture some of the higher prices which would otherwise be capped.

Sources: Aurora Energy Research

AUR 🚇 RA

N2

Realised tariff outlook

Tracking solar

- Tracking solar realised tariffs follow a similar trend to DAM prices through to 2060.
- The solar realised tariff discount to DAM increases from 32% lower in 2024 to 40% lower in 2060, with an average discount of ₹1.45/kWh (or 37%).

Onshore wind

- N2 has the highest realised tariffs for onshore wind of all price zones.
- Realised tariffs remain above the DAM price until 2045.
- The price premium decreases from 18% above in 2024 to 8% below by 2060.

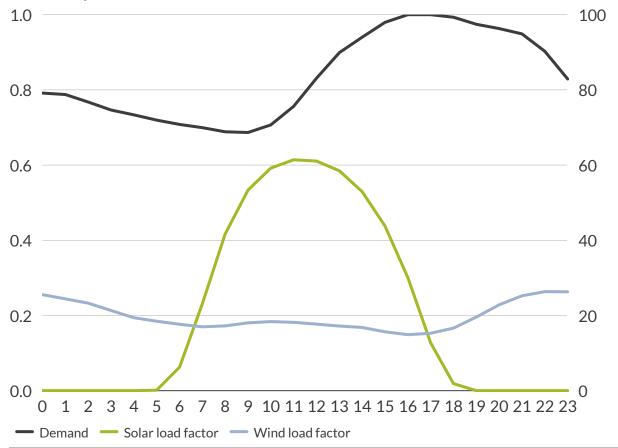
As solar penetration increases, a duck curve appears, causing average midday prices to fall below ₹2.50/kWh by 2030



S1

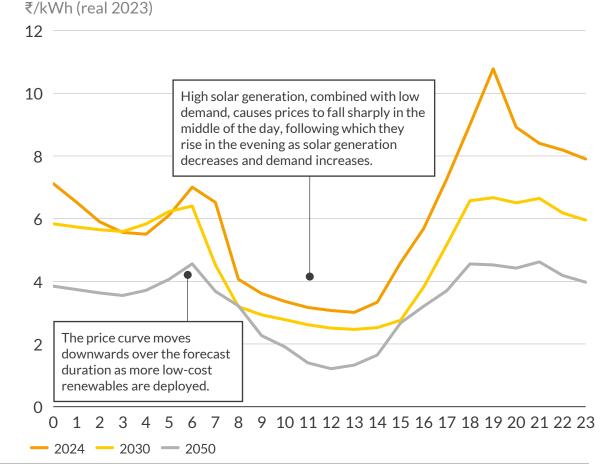
Demand is higher in the morning and evening, during periods of low solar generation, and is relatively lower during periods of high solar generation...

Normalised demand (left axis), and solar and wind load factor (right axis) by hour of day



... causing DAM prices to follow a duck curve with high prices in the morning and evening, along with low prices in the middle of the day

Average DAM price forecast by hour of day



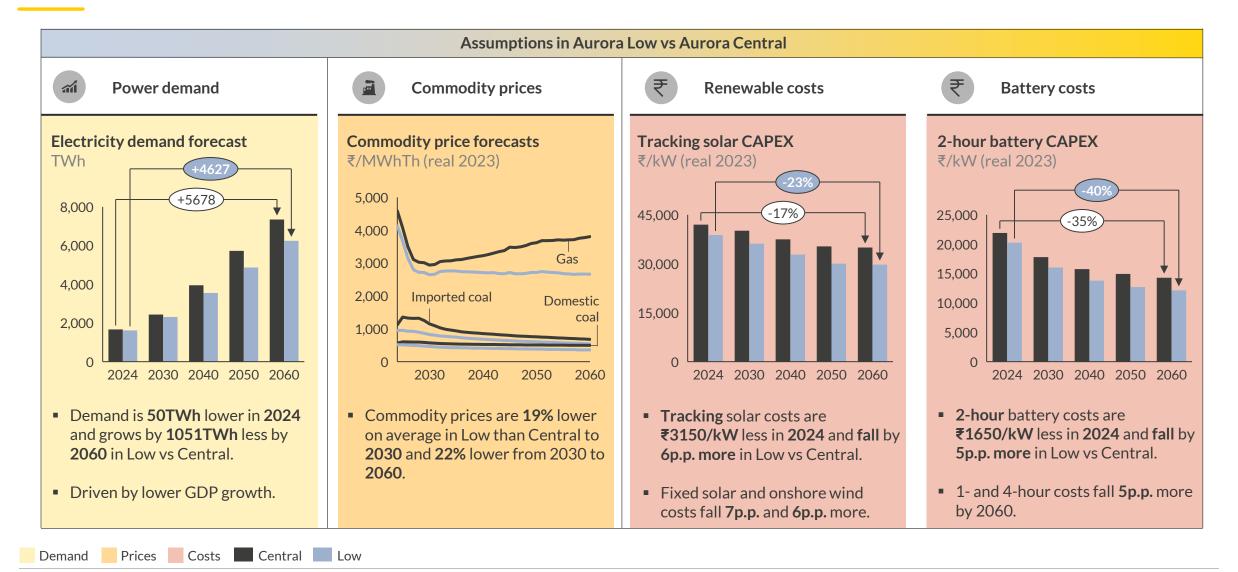
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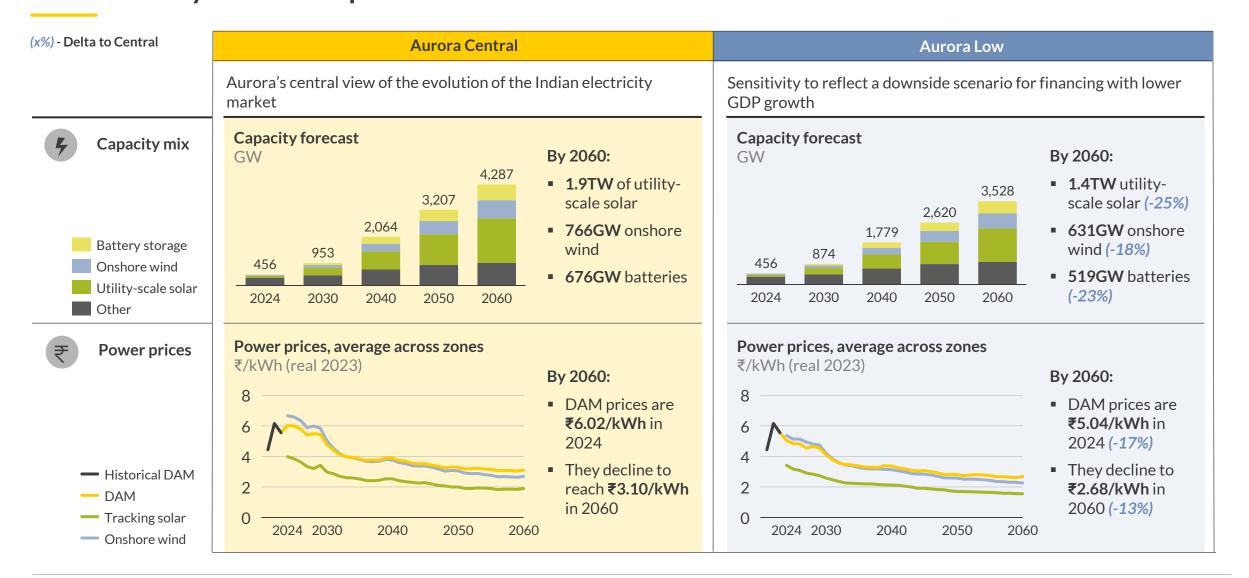
Aurora's Low Scenario sees lower demand growth, commodity prices, and technology costs than Aurora Central





Aurora's India-specific scenarios model a range of market uncertainties across all key-model outputs



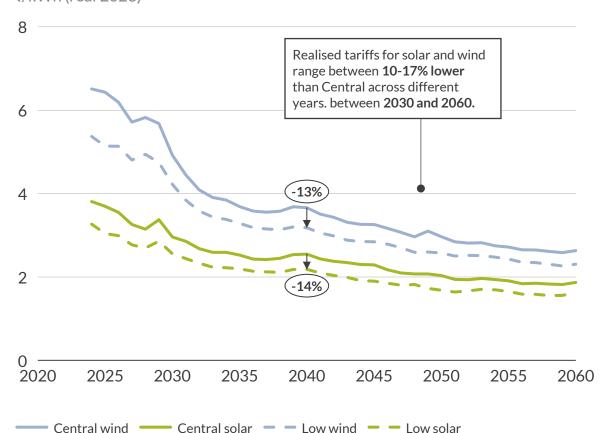


The Low Scenario sees lower electricity demand and realised tariffs, leading to 467GW less solar and 135GW less wind capacity by 2060

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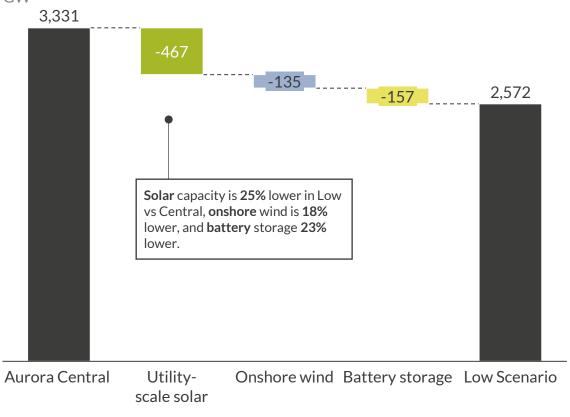
Solar and wind realised tariffs are 14% lower in the Aurora Low relative to Aurora Central on average over the forecast duration...

Realised tariffs¹ in Aurora Central and Aurora Low ₹/kWh (real 2023)



...This leads to 467GW less solar, 135GW less wind, and 157GW less battery storage capacity build by 2060 relative to Aurora Central

Solar, wind, and battery capacity in 2060 in Aurora Central and Aurora Low $\mbox{\ensuremath{\mbox{GW}}}$



1) Average across all zones.

Key takeaways



- A rapid deployment of renewables and storage is required to ensure that demand is met, with an additional 450GW of solar PV and 180GW of batteries required in the system by 2035
- Whilst pumped storage is built at pace, only 20GW can be deployed by 2040, leaving a need for over 180GW of storage at 8-hours or longer duration
- The deployment of renewables will outpace the growth of the transmission network as generation capacity expands, leading to a decoupling of prices in the 2030s, which widens in the 2040s
- Realised tariffs for renewables are highly dependent on the granular profiles and asset location, as a high correlation with demand and low correlation with other assets boosts profitability
- Beyond 2040, CAPEX and WACC are the key drives behind power prices ensuring these remain low is crucial to ensuring low costs for consumers and industry

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Thank you to all the participants for attending today's session

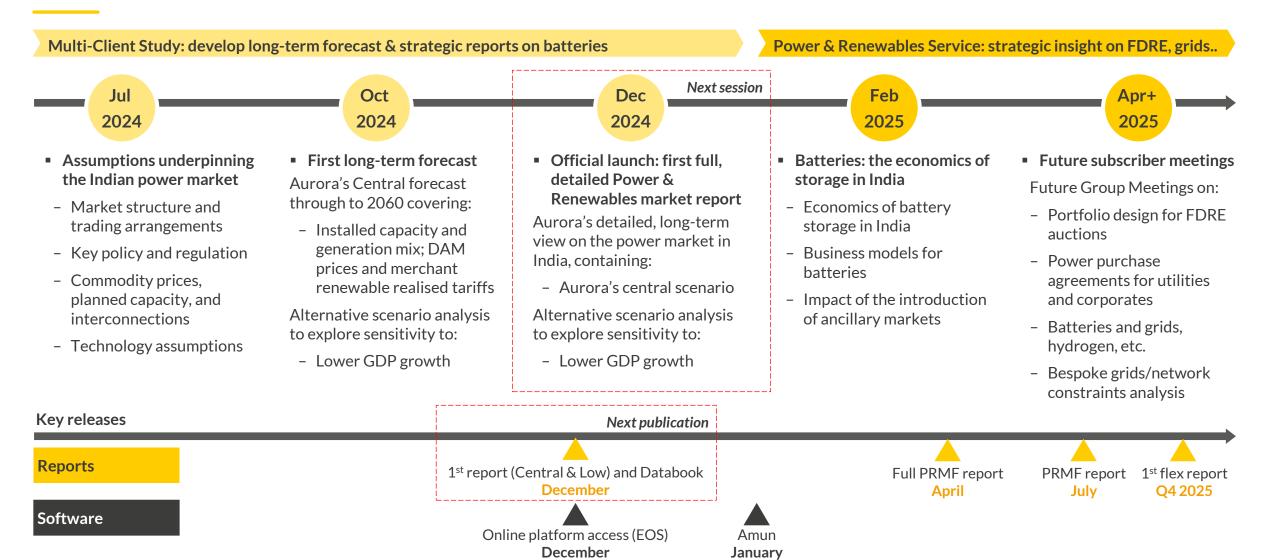
We invite all participants and their teams to send us comments on our Central and Low Scenario outputs.

For all comments and questions, please reach Ashutosh Padelkar at ashutosh.padelkar@auroraer.com.

We will publish the full report and databook with Central and Low scenarios in December 2024.

Aurora's first full detailed Power & Renewables market report and the accompanying databook will be released in December



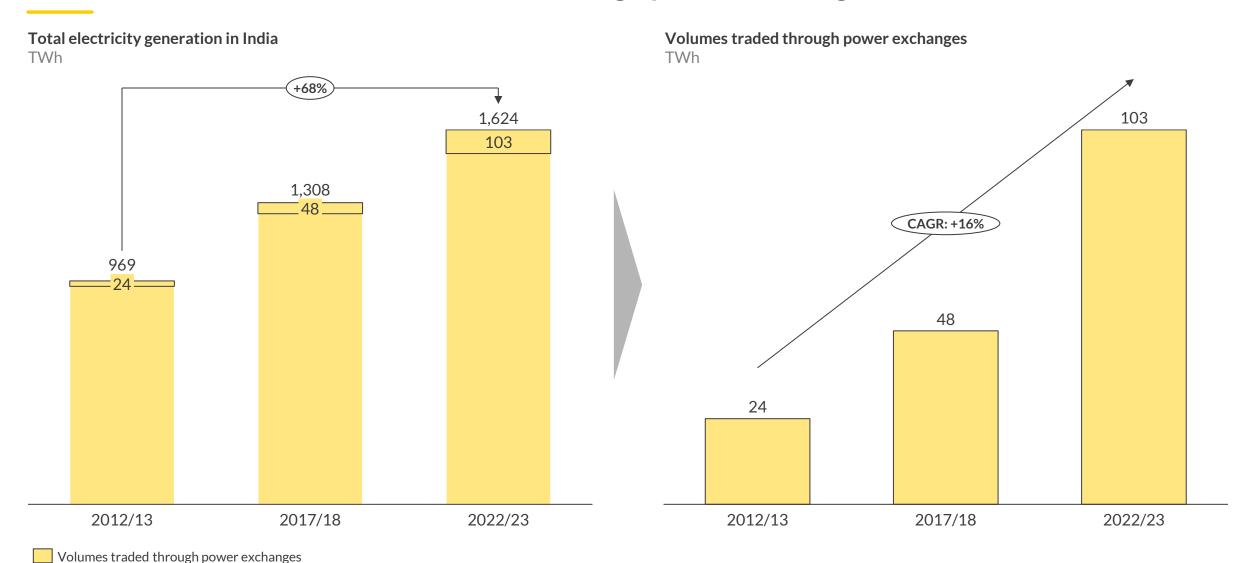




Appendix

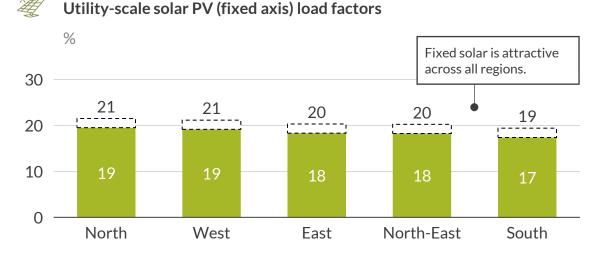


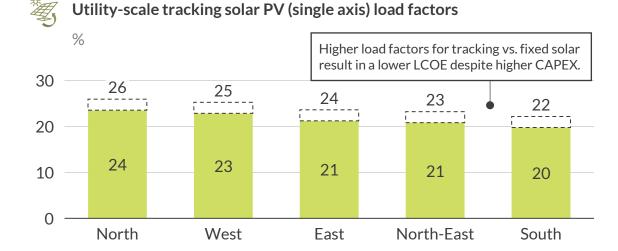
Power demand has grown by 68% in the decade to FY2022/23, with an annual AUR RA increase of 16% YoY in volumes traded through power exchanges

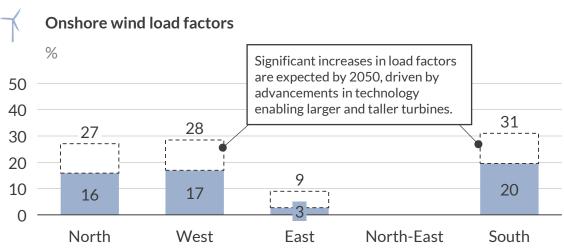


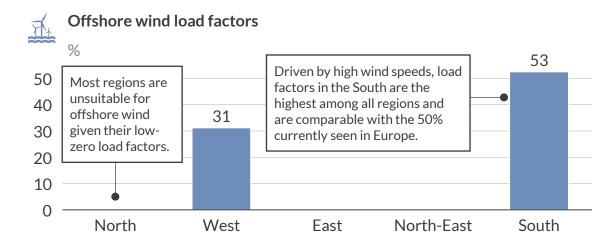
India's attractive load factors for solar are boosted by a single-axis tracker, which increases the lifetime profitability by helping to reduce the LCOE











Current average¹ [2050 expected load factor for new builds

Sources: Aurora Energy Research, AMUN, NITI Aayog

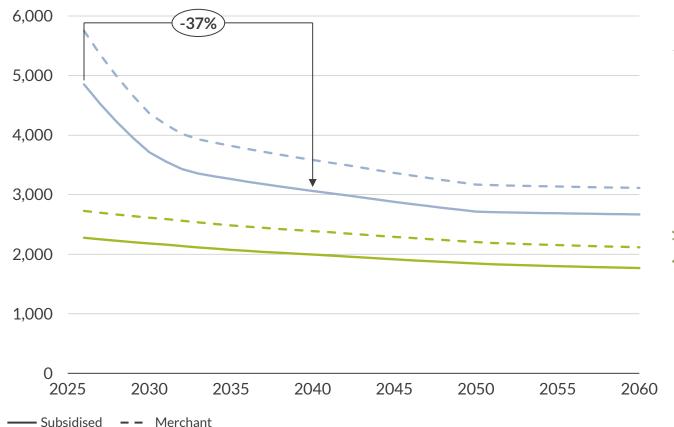
Solar is expected to remain the most competitive technology with LCOEs for merchant projects falling below ₹2.50/kWh by 2035



The levelised cost of electricity (LCOE) shows the relative economic competitiveness of utility scale renewable technologies with different market entry years. As well as projected cost changes, load factors and cost of capital assumptions (which vary based on the route to market type) strongly influence the forecasted LCOE curve.

Renewable LCOE trajectories¹

₹/MWh (real 2023)





Onshore wind

Larger turbines and higher hub heights in part leads to a 37% fall in LCOE between 2026 and 2040.

Assumptions: 100 MW utility scale, S1 price zone, 25-30% load factor, 30-year lifetime, 9% subsidised WACC², 11.5% merchant WACC².



Tracking Solar PV

LCOE falls by 12% between 2026 and 2040.

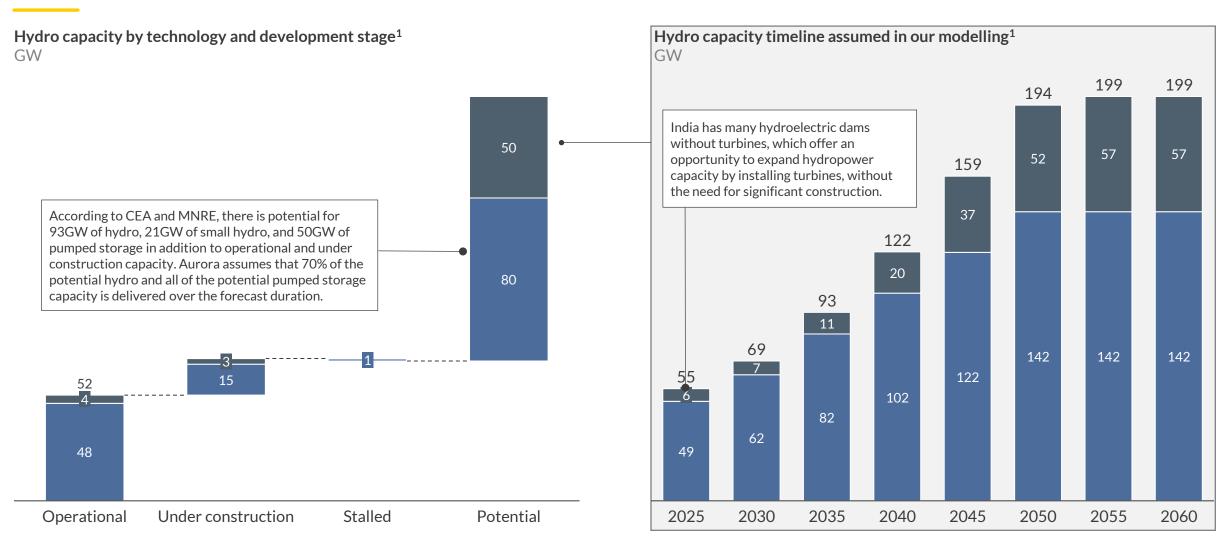
Assumptions: 50 MW utility scale, N2 price zone, 24-26% load factor, 35-year lifetime, 9% subsidised WACC², 11.5% merchant WACC².

Sources: Aurora Energy Research

¹⁾ LCOEs for a representative new build asset pre-curtailment, shown at Commercial Operation Date (COD) January 1st and consider 2 years construction time for wind assets and 1 year construction time for solar assets with respective CAPEX taken from years prior COD. 2) WACCs are in real terms and pre-tax.

India has 17GW of hydropower capacity under construction in addition to the 52GW of installed capacity



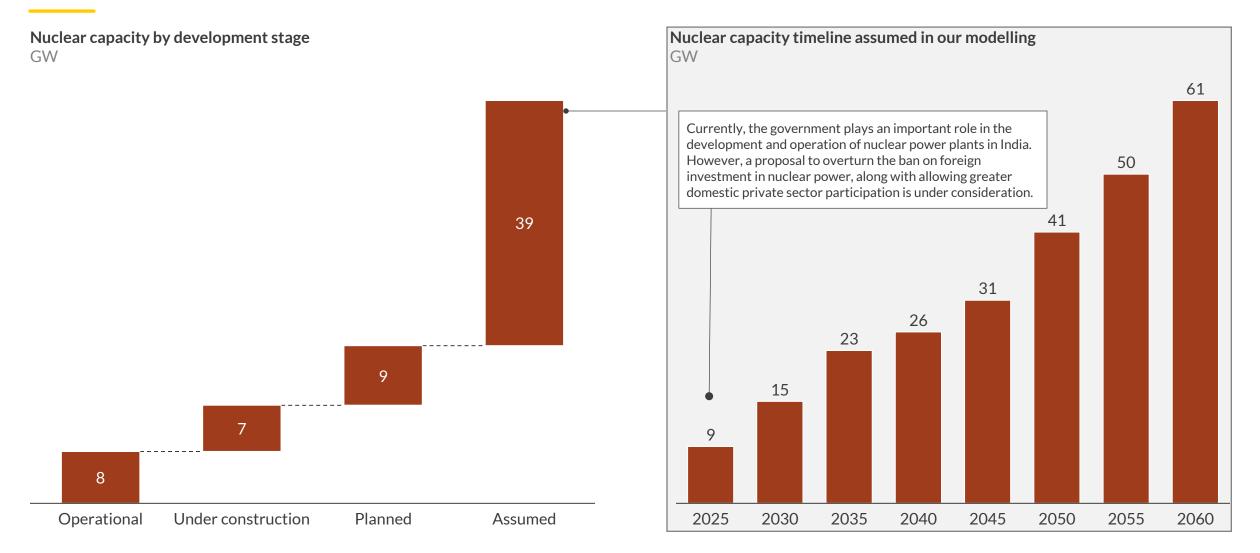


1) Includes small hydro plants.

Pumped Storage Hydro

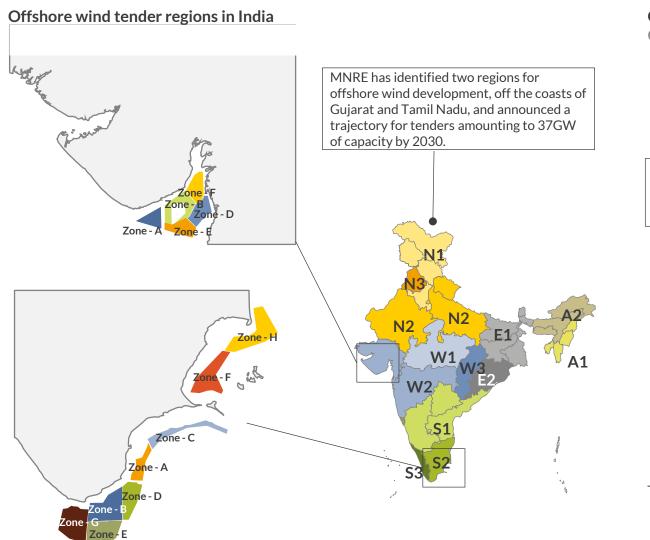
7GW of nuclear capacity is under construction and a further 9GW has received approval, in addition to the 8GW of installed capacity



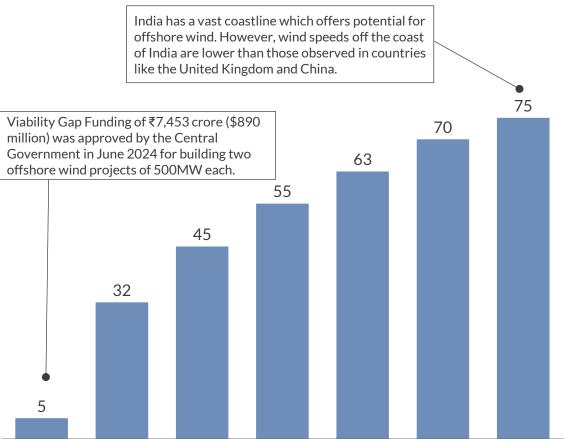


MNRE is holding its first tenders for up to 1GW of offshore wind capacity in 2024, with a capacity of 75GW expected by 2060



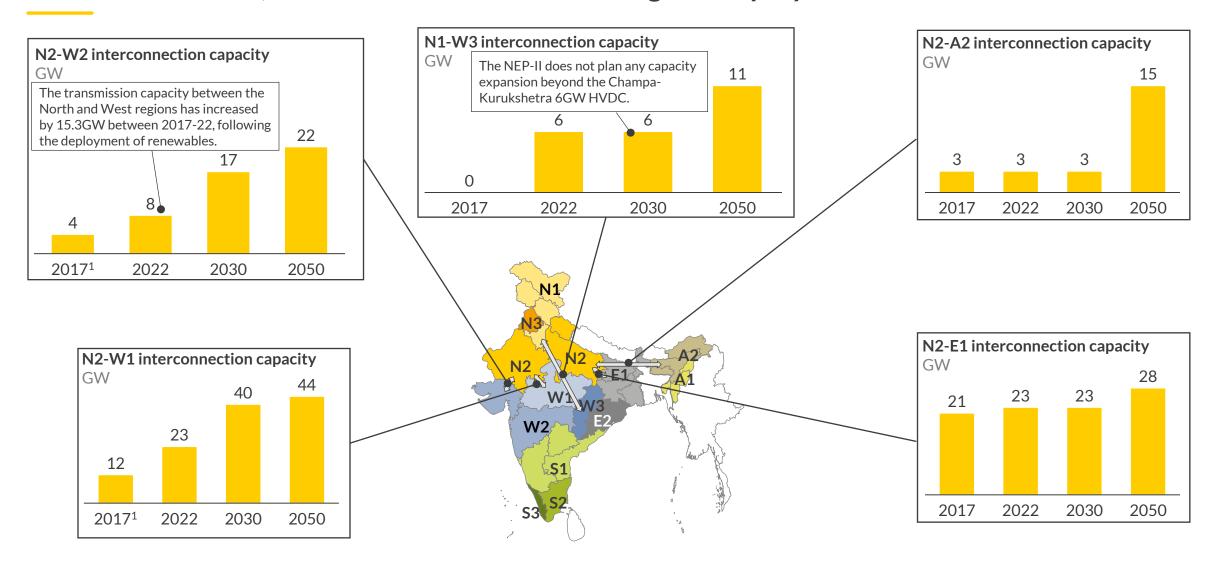


Offshore wind capacity timeline assumed in our modelling \mbox{GW}



Sources: Aurora Energy Research, MNRE CONFIDENTIAL 44

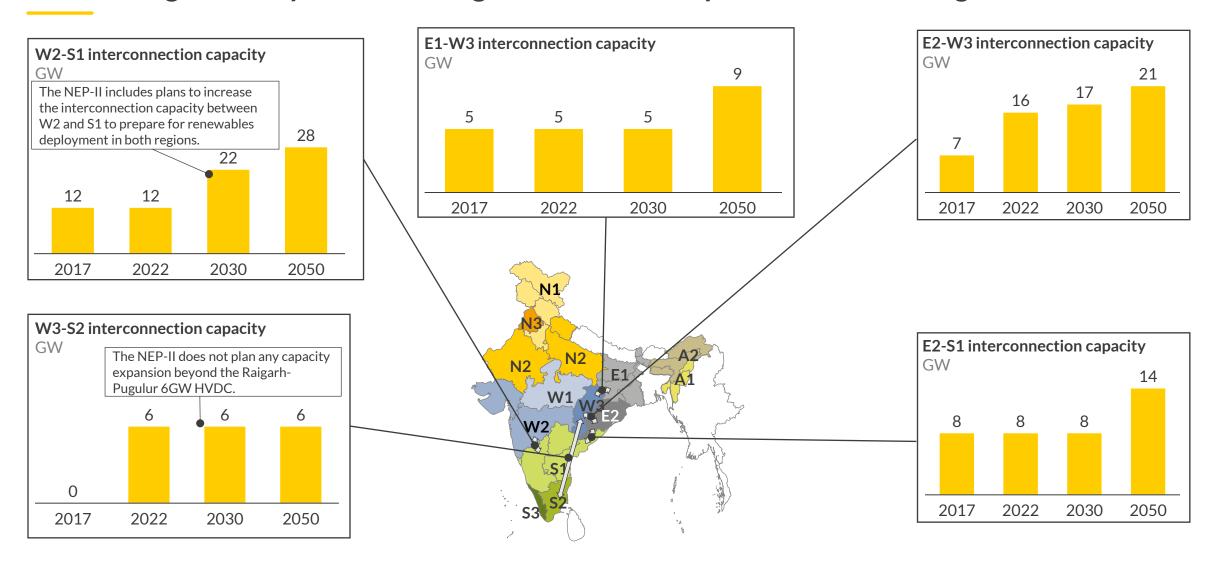
The transmission capacity between the North and West has grown by 130% A U R R A between 2017-22, this trend continues following the deployment of renewables



¹⁾ Total capacity between North and West regions split on the basis of the 2022 split between N2 and W1/W2;

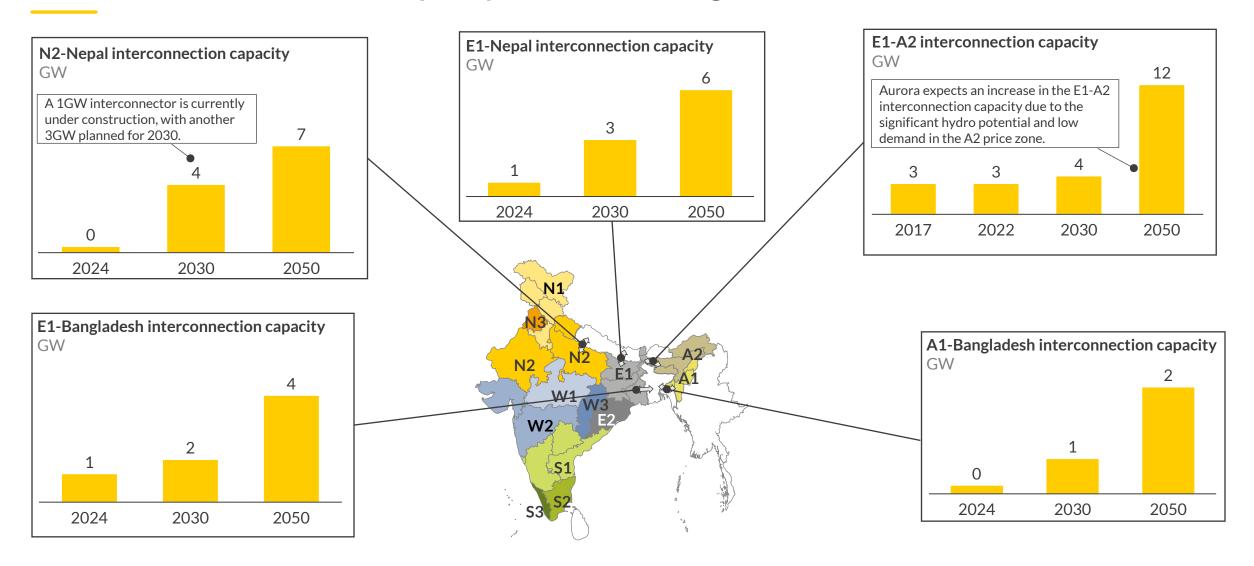
Sources: Aurora Energy Research, CEA, CTU CONFIDENTIAL 45

The transmission capacity between the West and South regions is expected to AUR RA increase significantly due to the high solar and wind potential in both regions



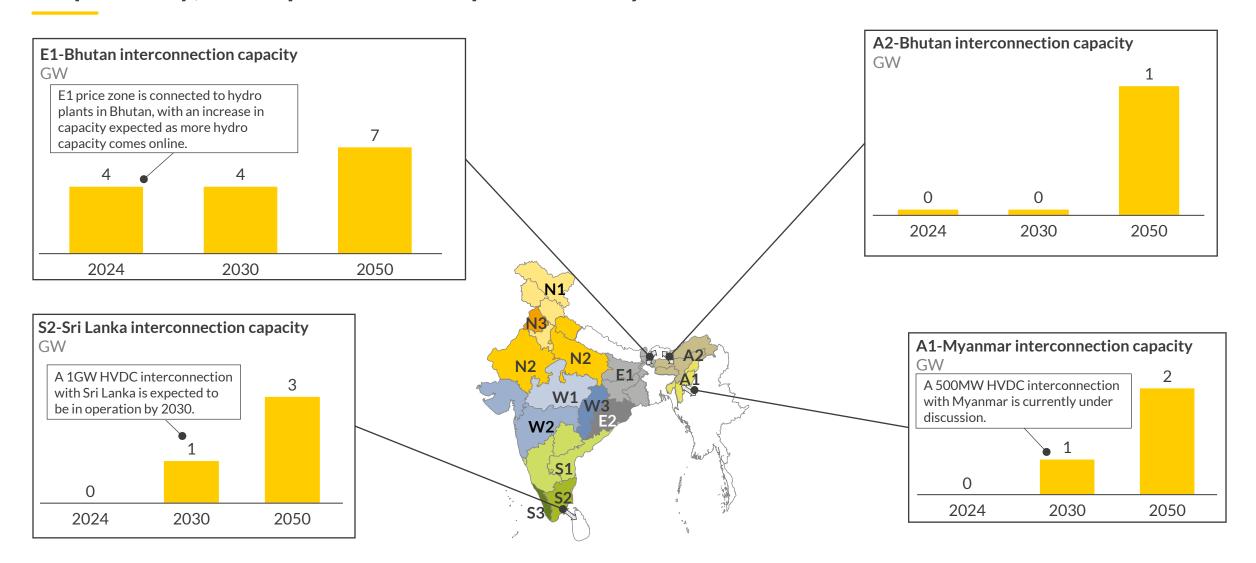
Sources: Aurora Energy Research, CEA, CTU CONFIDENTIAL 46

The 50GW of potential hydro capacity in the North-East region necessitates AUR RA an increase in transmission capacity with the East region to avoid curtailment



The planned 1GW and 500MW HVDC links with Sri Lanka and Myanmar, respectively, are expected to be operational by 2030

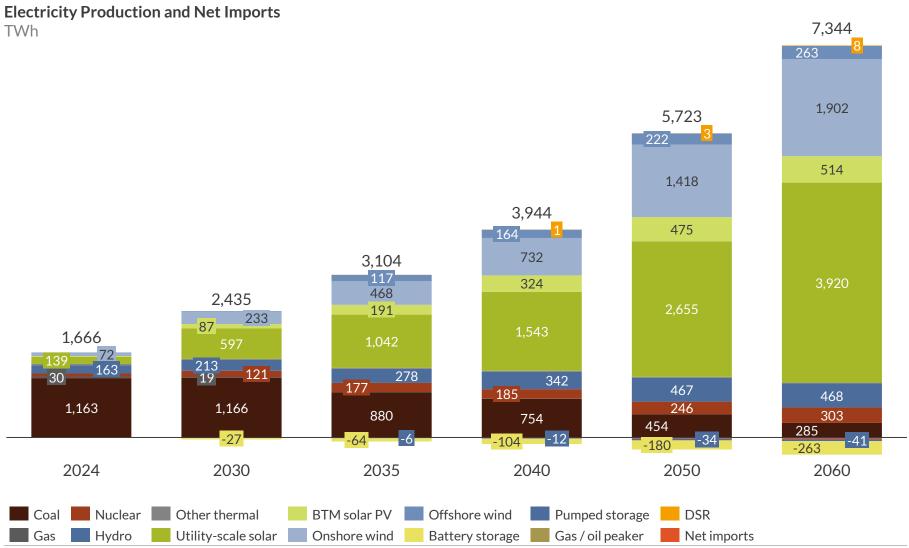




Sources: Aurora Energy Research, CEA, CTU

Solar and wind make up over 85% of generation by 2060, as the share of coal in the generation mix declines from 70% in 2024 to 4% in 2060

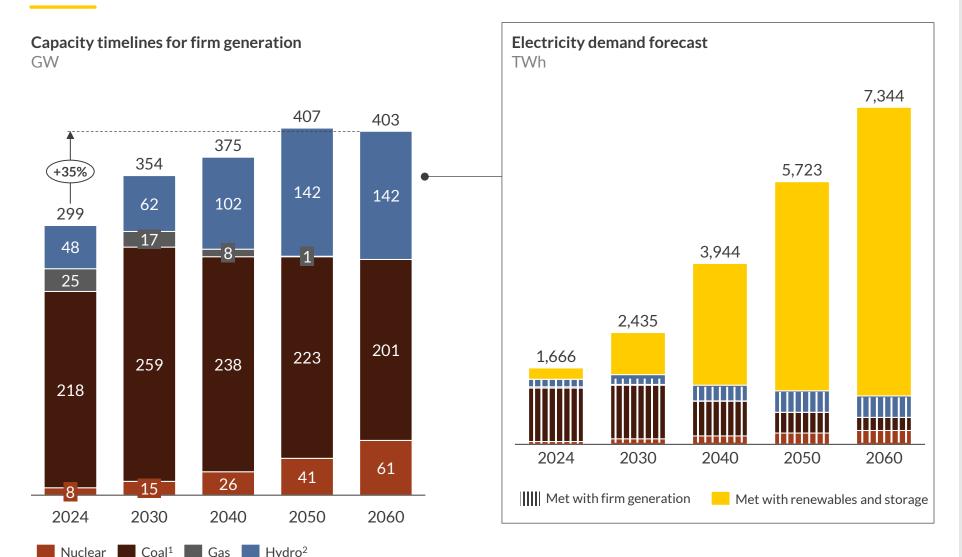




- Net power generation is expected to rise from 1,666TWh in 2024 to 7,344TWh in 2060 (a 4.4x increase from 2024) and low carbon generation¹ is expected to make up the majority with a 96% share of total generation, up from 27% in 2024.
- Generation from utility-scale solar, BTM solar, onshore wind, and offshore wind increases from 231TWh in 2024 to 6,599TWh in 2060, making up over 85% of total generation
- The continued rise in low carbon generation displaces coal generation which falls by 878TWh to make up only 4% of total generation in 2060 compared to 70% in 2024.

1) Includes nuclear, hydro, utility-scale solar, BTM solar PV, onshore wind, and offshore wind.

We anticipate a 35% increase in firm generation capacity which meets 14% of India's power demand by 2060



Firm capacity outlook

- Firm capacity increases by 104GW, reaching 403GW in 2060.
- However, the share of demand met with these assets decreases, falling from 85% to 14% between 2024 and 2060.
- The role of coal in providing baseload power decreases from 2030 as nuclear and hydro deployment accelerates.

Methodology overview

- Firm generation capacity is driven by policy, rather than economics.
- The firm capacity timelines are based on a combination of system cost-minimisation and government ambitions for different technologies.

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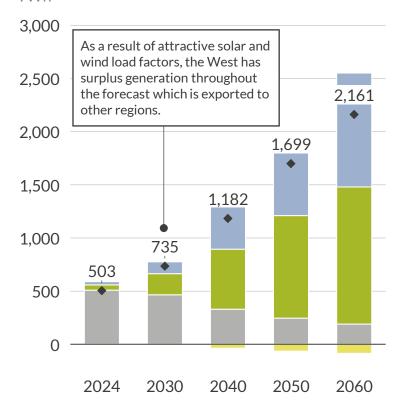
¹⁾ Includes lignite plants; 2) Includes small hydro plants.

The deployment of solar and wind in the West leads to power exports of 304TWh in 2060 to other regions with insufficient capacity



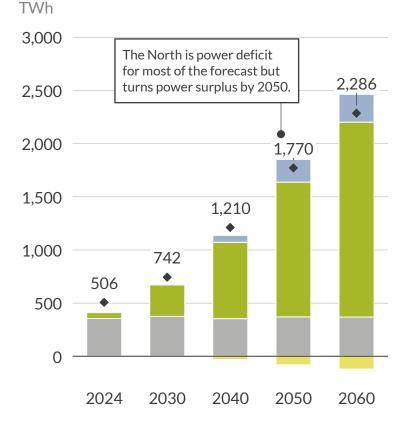


Demand and generation in the West RegionTWh



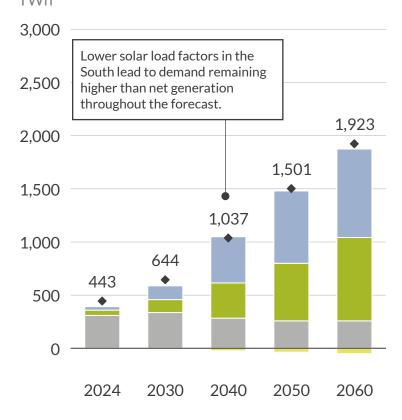
Demand growth in the Northern region outpaces capacity build up to 2050

Demand and generation in the North Region



Regional demand outpaces capacity growth in the South leading to imports of 102TWh by 2060

Demand and generation in the South Region TWh

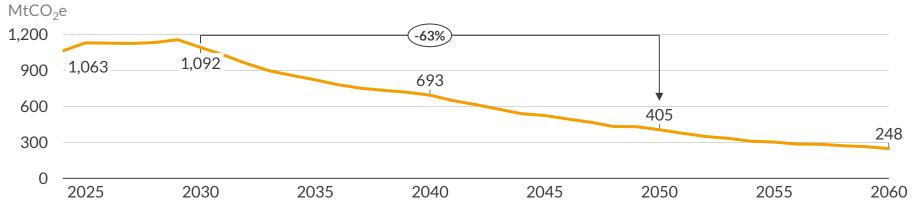


• Regional demand forecast Wind ¹ Solar² Other generation Storage³

¹⁾ Includes onshore and offshore wind; 2) Includes utility-scale and rooftop solar; 3) Includes battery and pumped storage.

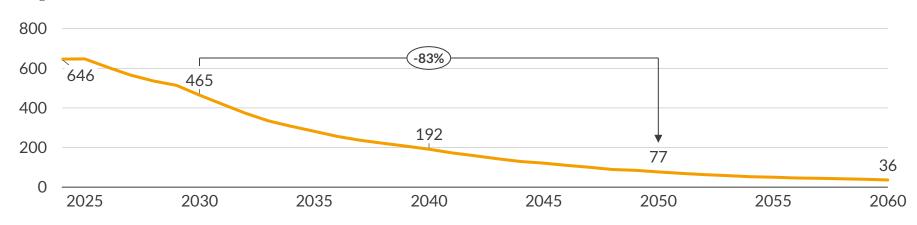
Carbon emissions from the power sector decline due to the rapid deployment of renewables, reaching 248 MtCO₂e in 2060

Power sector carbon emissions



Power sector carbon intensity

gCO₂/kWh



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- Power sector emissions increase from 1,063 MtCO₂e in 2024 to 1,155 MtCO₂e in 2029, before they start declining.
- Total emissions decline 63% between 2030 and 2050, driven by the large-scale deployment of renewables and batteries, and reach 248 MtCO₂e by 2060.
- On the other hand, the carbon intensity of the power sector declines more rapidly, as the share of thermal generation declines.
- Power sector carbon intensity decreases by 83% between 2030 and 2050, before further declining to reach 36 gCO₂/kWh in 2060.



Details and disclaimer

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Prepared by Siddhant Shah (siddhant.shah@auroraer.com) Margot Roberson-Leech (margot.roberson-leech@auroraer.com)

Approved by Ashutosh Padelkar (ashutosh.padelkar@auroraer.com) Debabrata Ghosh (debabrata.ghosh@auroraer.com) Dan Monzani (dan.monzani@auroraer.com)

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