

Can India become the world's largest merchant power market?

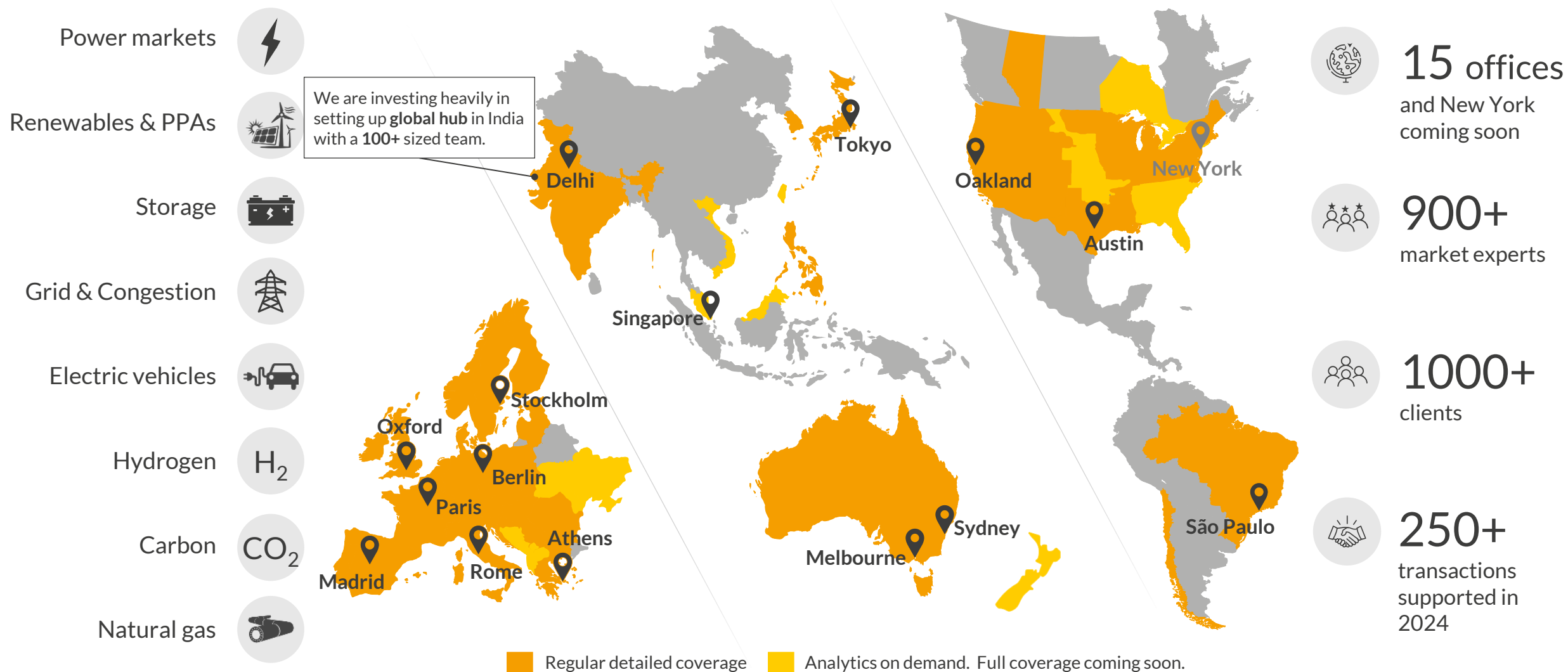
8th April 2025



- I. Introduction to today's session
- II. Aurora's Indian market offering
- III. Introduction to the Indian power market
- IV. Aurora's approach to modelling India
- V. Aurora's first forecast for India
- VI. Next steps

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

A U R  R A



Aurora has seen significant traction from a wide range of 50+ stakeholders in the Indian market

Financiers	Developers	Government
		Oil & Gas, Utilities & Industrials

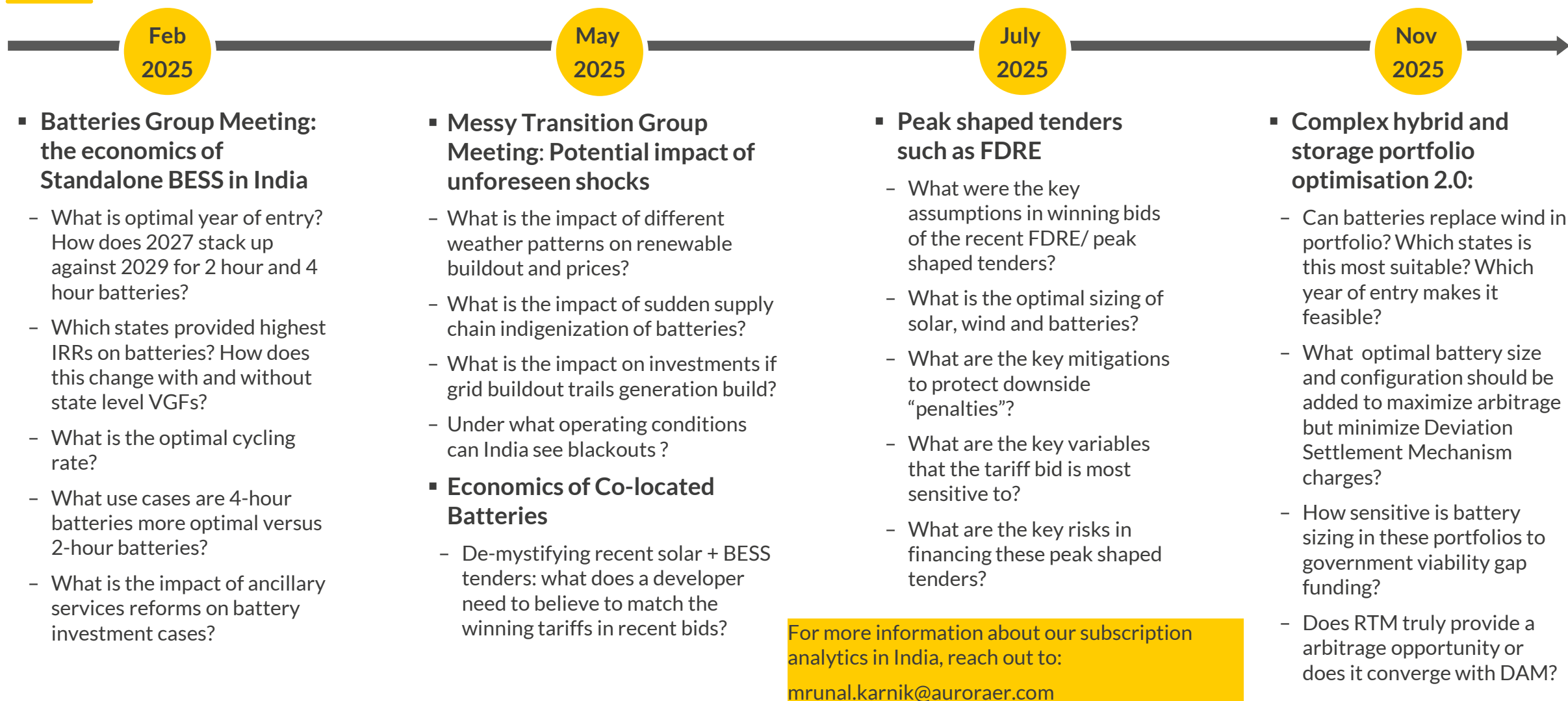
Agenda

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We have undertaken deep dives on the most critical Indian market topics

Topic	Rationale	Aurora's analytical approach
Q1 25 Battery Sizing optimization <i>duration x # of cycles x location x year of entry</i>	<ul style="list-style-type: none"> Battery deployment expedited basis CAPEX drop, wind uncertainty New optimization use cases beyond spread maximization- e.g. Deviation Settlement Mechanism penalty minimization Further inflexions on battery economics anticipated- e.g. ancillary service reforms 	<ul style="list-style-type: none"> Analysis of existing battery investment cases – including dispatch algorithms, and financial returns to date Granular forecasts of day ahead, green day ahead and real time markets, as well as other markets as they open up (e.g. ancillary markets) Standardized investment case analysis for future batteries – varying entry year, market scenarios, duration
Q2 25 Bid optimization for complex/ “peak shaped” tenders (e.g. FDRE)	<ul style="list-style-type: none"> Shift from plain vanilla tenders to complex sovereign tenders Complex tenders offer higher IRRs due to less crowding of supply Requires granular market and risk analysis, temporally and spatially Different complex offer varied optimization use cases 	<ul style="list-style-type: none"> Develop deep market view at 13-zone, 30-min granularity till 2060 Forecast DAM, GDAM and RTM market forecast basis endogenous modelling to determine capacity, generation and prices In-house model built to tackle multi-variate optimization use cases, marrying market forecast to specific tender/ contract requirements
Q2 25 Financing of complex hybrid portfolios with merchant exposure	<ul style="list-style-type: none"> Wind and solar investors are increasingly exposed to merchant price risk Significant uncertainty, amplified by regional delta in capture price risk Policy around supply chain, DSM etc. adds extra uncertainty 	<ul style="list-style-type: none"> Modelling of “P90” financing case based on key market risks and their correlations Weather year analysis to reflect range of uncertainty Analysis of portfolio effects (asset classes, price zones, weather years)
Q2 25 Complex portfolio for Commercial & Industrial PPAs	<ul style="list-style-type: none"> C&I customers require sophisticated round the clock green power New demand pools, e.g. Data Centers, have stringent needs Older C&I plain vanilla contracts being terminated by offtakers 	<ul style="list-style-type: none"> Bespoke modelling of asset/ portfolio specific problem statements to optimize hybrid portfolio sizing and economics Data Centers: Bottom-up green power sourcing optimization for Indian use cases + bringing in our global expertise from US, APAC, EU
Q4 25 Regional prices and grid bottlenecks	<ul style="list-style-type: none"> The Indian market is increasingly becoming grid constrained Expansion plans and renewables investment create significant uncertainty Project economics and risks are highly location-specific 	<ul style="list-style-type: none"> Endogenous modelling of renewables and conventional capacity decisions while reflecting grid constraints Analysis of impacts on grid expansion and renewables deployment scenarios on capture prices Network modelling to estimate grid curtailment risk

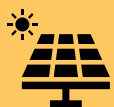
Subscription Analytics: We hold quarterly deep-dive workshops with subscribers, accompanied by quarterly market forecasts and insight reports



Subscription Analytics: We have developed our “Central”, “Low” & “Messy” scenarios, we will release our other scenarios in H2 2025

Already available		Released in April 2025	Coming soon...	
Aurora Central	Low Scenario	Messy Transition	High Scenario	Accelerated Decarbonisation
<p>Aurora's central view of the evolution of the Indian electricity market to 2060</p> <ul style="list-style-type: none"> Aurora's best view for the evolution of the Indian power market until 2060. Includes Aurora's central outlook for technological developments and commodity prices. Incorporates currently stated policies, alongside a conservative view of future policy objectives. 	<p>Sensitivity to reflect a downside scenario for financing</p> <ul style="list-style-type: none"> Represents a downside case, incorporating low demand and commodity prices. This envisages a world with slower overall GDP growth. Reflects a realistic scenario with lower capacity build out and lower power prices. 	<p>Sensitivity to reflect the non-equilibrium nature of the energy transition</p> <ul style="list-style-type: none"> Represents a scenario in which some coal capacity in India closes unexpectedly. Supply chain delays lead to a slow deployment of renewables. Reflects a scenario with higher power prices and greater price spreads. 	<p>Sensitivity to reflect a upside scenario for investors and developers</p> <ul style="list-style-type: none"> Represents an upside case, incorporating high demand and commodity prices. This envisages a world with higher overall GDP growth. Reflects accelerated economic growth leading to increases in costs and prices. 	<p>Sensitivity to reflect increased decarbonisation efforts</p> <ul style="list-style-type: none"> Represents a world where India stays on track to reach the net zero target by 2070. Reflects a scenario with faster coal phase out. Leads to greater renewable deployment.

Advisory services: We offer a wide spectrum across market assessment, transaction support and asset/ portfolio optimization



Complex
Auction
Support

Rationale

- Government auctions imposing increasingly stringent conditions

Use case

- Asset sizing
- Auction support
- Post auction optimisation



Merchant
portfolio

Rationale

- Evaluating non-contracted revenue stream in a predominant PPA driven market

Use case

- Site evaluation
- Final Investment decision
- Underwriting debt



Market
assessment
/ Location
assessment

Rationale

- Emergence of regional price decoupling & impact on revenue realisation of RE project

Use case

- Site shortlisting
- Transmission congestion



Power
procurement
sale/strategy

Rationale

- Need for complex asset structuring

Use case

- PPA price evaluation
- Procurement strategy
- Asset optimization for suppliers
- Growth strategy for C&I platforms



Transaction
support

Rationale

- Evaluating current and future commercial performance in M&A transactions and financing

Use case

- Commercial due diligence
- Asset gross margin assessment
- Scenario modelling



BESS
Business
Case

Rationale

- Increasing need for grid stability

Use case

- Standalone BESS economics
- Collocated BESS economics

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The Indian power sector has evolved from a state-controlled monopoly to an increasingly competitive landscape with growing private participation

Timeline of power market reforms in India (not exhaustive)...

Electricity Supply Act (1948)

- Mandated the **state** oversees all new power generation, transmission, and distribution projects.
- Gave **State Electricity Boards (SEBs)** responsibility for **tariff** setting.

Electricity Laws Act (1991)

- Allowed **private companies** to **set up power plants** and enter long-term power purchase agreements (PPA).
- Provided **incentives** for **independent power producers (IPPs)**.

Electricity Act (2003)

- Increased the **ease of licensing** for private generators.
- **Unbundled SEBs** into separate entities for generation, transmission and distribution.
- **Established SERCs¹** for determining tariffs.

Power exchange (2008)

- Created a **transparent, real-time** marketplace for electricity trading.
- Markets for green energy trading and high price energy trading introduced in 2020-21 and 2023-24.

Further reform (2008-24)

- Privatisation of some DISCOMs.
- Electricity Act reform.
- Increasing open access.
- PPA reform to facilitate private investment.

... and their impact on the competitive landscape

1990

Monopolistic and government-controlled, with limited private participation



Generation, transmission, and distribution handled by SEBs (controlled by states).



Minimal private participation due to a lack of investment incentives, regulation, and heavy insulation from competition.



Chronic electricity shortages, low investment, and, and financial issues with SEBs.

2010

Post-reform era with private participation emerging in generation



SEB unbundling enabled private companies to enter specific market segments independently.



Private generation increased, with 18% of installed capacity privately owned by 2009-10.



DISCOMs remained state-controlled and financially stressed due to high losses and operational inefficiencies.

2024

Increasingly competitive landscape with private and foreign investment



Introduction of exchanges has increased private participation in the short-term market.



52% of capacity is privately owned, with increasing private presence in T&D².

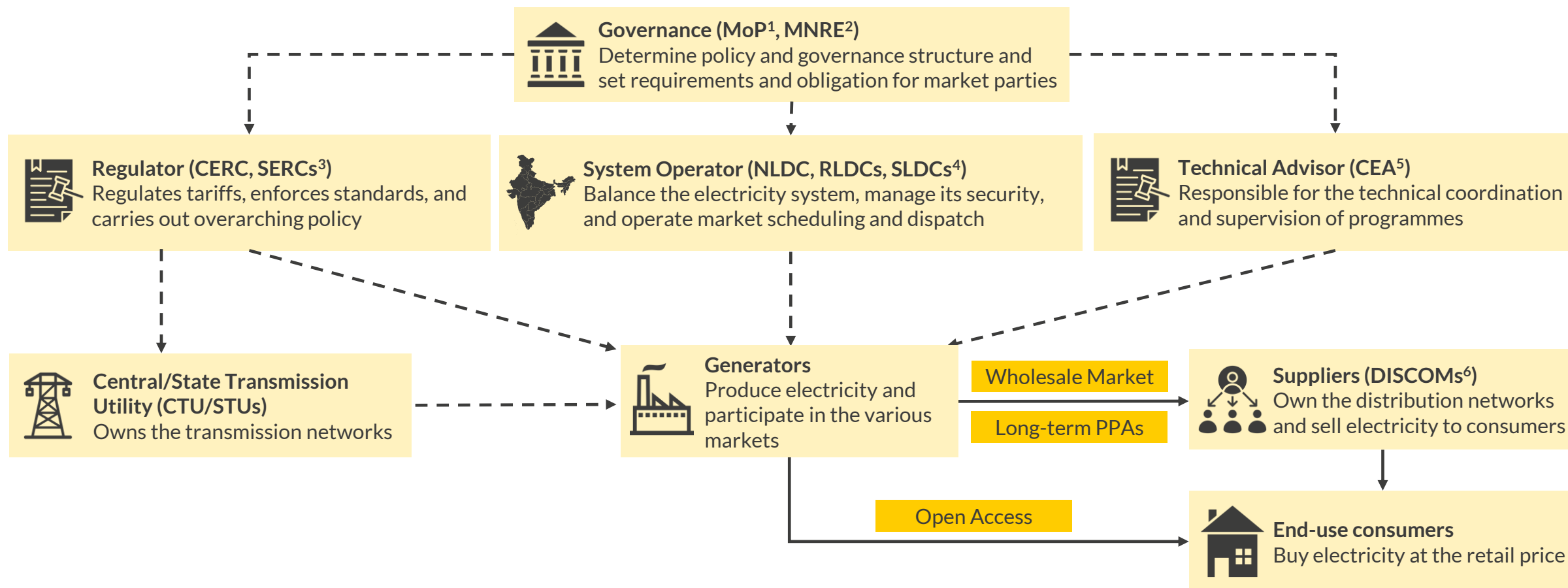


DISCOMs remain financially stressed and grid connection and keeping up with demand present additional challenges

1) State Electricity Regulatory Commissions. 2) Transmission and distribution.

Regulatory authority is currently divided between the Central and State governments through various bodies

Current power market structure in India



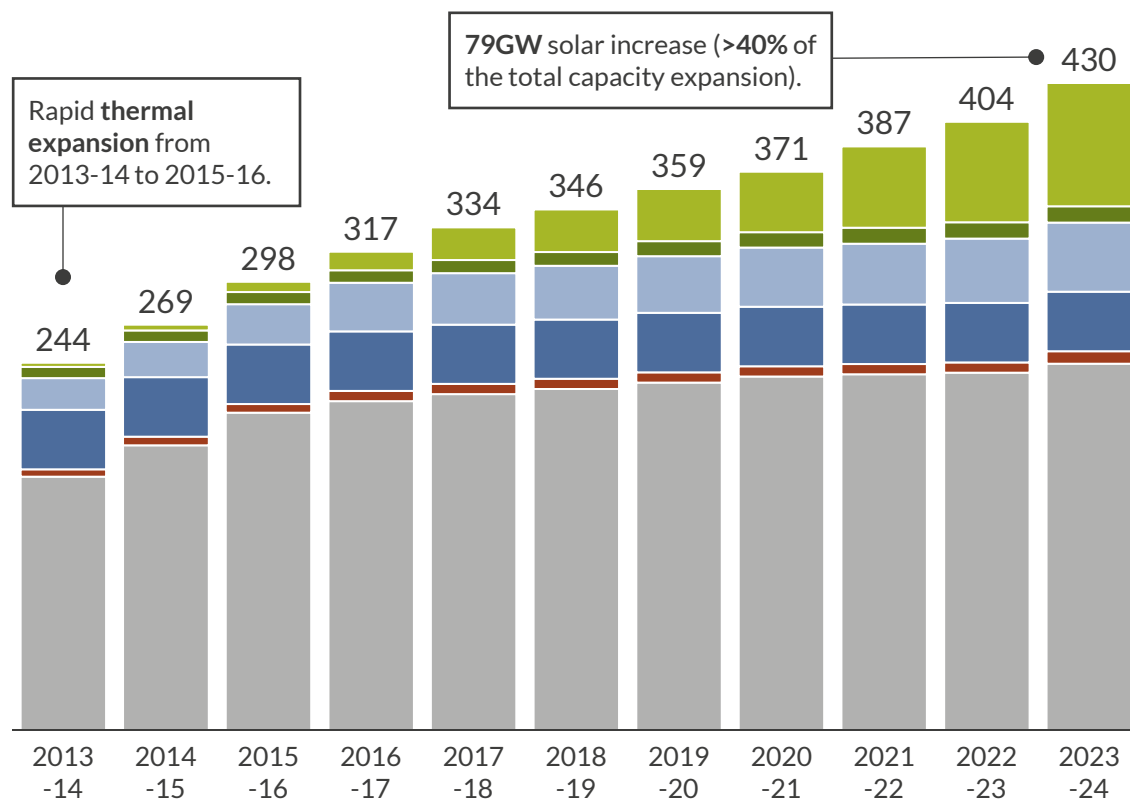
1) Ministry of Power; 2) Ministry of New and Renewable Energy; 3) Central/State Electricity Regulatory Commission; 4) National/Regional/State Load Despatch Centre; 5) Central Electricity Authority; 6) Distribution Company.

Thermal and solar expansions have driven a 186 GW increase in capacity since 2013-14, however, thermal's share of the generation mix has remained steady

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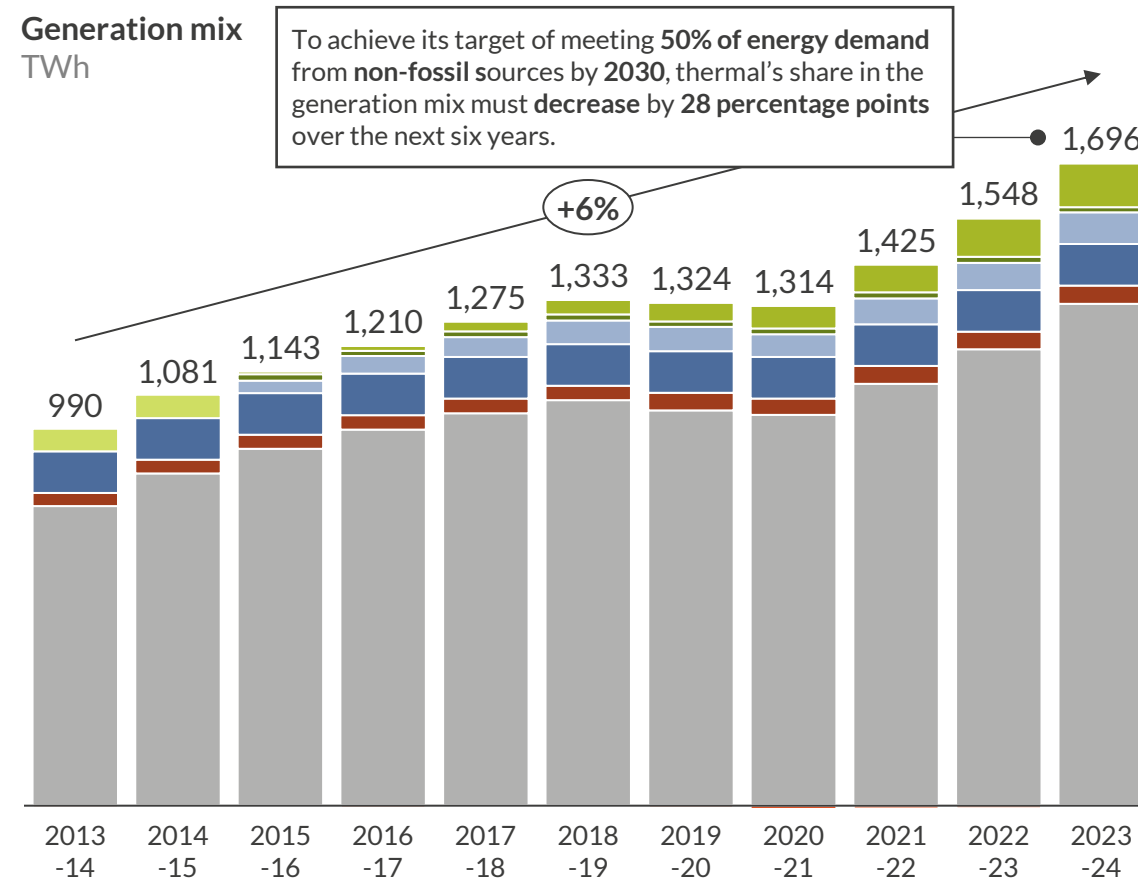
- 1 Installed capacity has grown by 76% since 2013-14, with solar capacity experiencing the fastest expansion at a CAGR of 41% ...

Installed generation capacity
GW



- 2 ...Despite this, in 2023-24 thermal sources still accounted for 78% of the generation mix and have remained steady at ~80% for the last decade.

Generation mix
TWh



Thermal¹ Nuclear Hydro² Wind Bio-power Solar RES total³ Others Bhutan import

1) Coal, lignite, natural gas, and oil. 2) Includes small hydro plants (<25MW). Small hydro had 5GW of capacity in 2023-24. 3) Total RES generation is not separated by technology (wind and solar) until 2015-16.

Power can be traded either through direct bilateral agreements or through power exchanges



Bilateral trade agreements/contracts

Overview

- Exchange of electricity between a **specific buyer and seller**. The exchange can occur **directly** or via a trading **licensee**, with energy delivered to and from specified points.

Types of contract

- Bilateral trades can be **short** (less than 1 year), **medium** (1 to 5 years), or **long term** (greater than 5 years, often up to 25 years).
- Most generation in India is traded through long- and medium-term contracts, with 6% generation traded in short term contracts.

Contract specifications

- Contracts are tailored for specific delivery needs, such as:
- Round-The-Clock (**RTC**): **ensures** power **supply** for all 24 hours of the day
- Firm, Dispatchable, Renewable Energy (**FDRE**): guarantees delivery of **renewable** energy in a **predictable** and firm manner.



Power exchanges

Overview

- Organised **platforms** for trading electricity where buyers and sellers transact power in various timeframes, with **Open Access** (OA) Rules enabling consumers to buy power directly from power generators.

India's power exchanges

- India has **three power exchanges**. The largest, the Indian Energy Exchange (**IEX**), accounted for **83.7%** of exchange-traded power in 2023-24.
- The other two, the Power Exchange India Limited (**PXIL**) and Hindustan Power Exchange (**HPX**) accounted for 7.6% and 8.7%, respectively.
- **121TWh** was traded on exchanges in 2023-24, including **11TWh** purchased by **Open Access customers**.

Market specifications

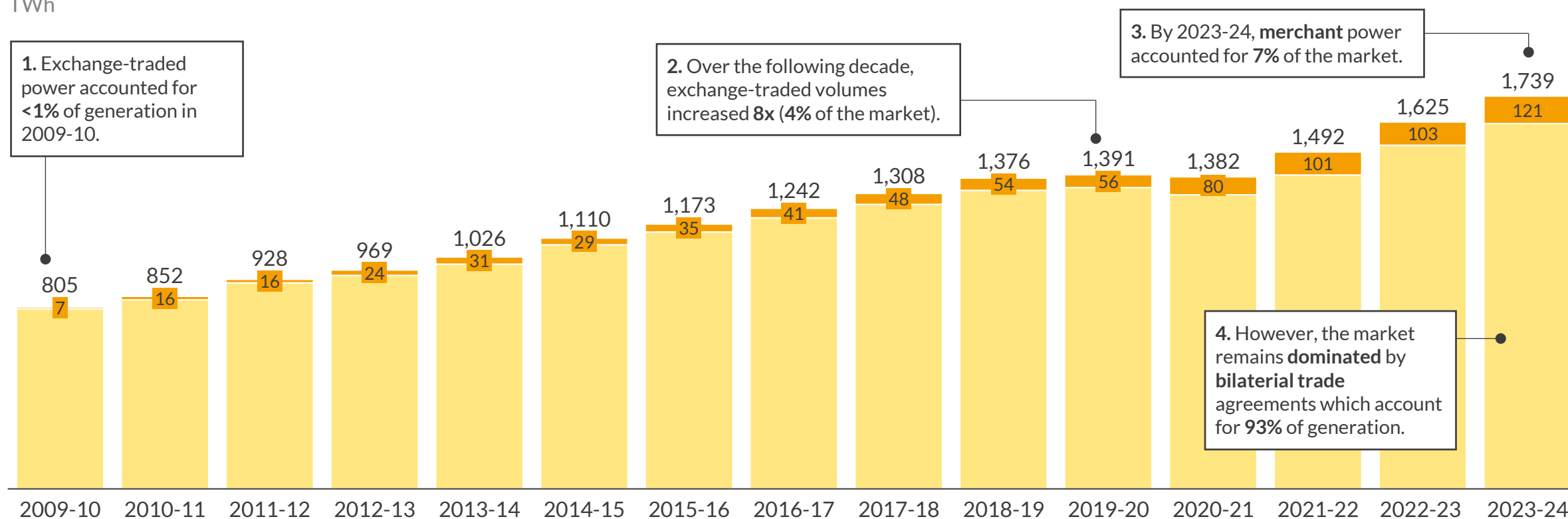
- Power is traded on several markets, with response time varying from **several days** to **minutes** ahead of delivery.

Bilateral trades remain the primary delivery mechanism; however, the merchant opportunity has increased 4x in the last decade

Since India introduced power exchanges, exchange-traded volumes have grown at a 22% CAGR. In 2023-24, these volumes reached 121TWh, making up 7% of the market. Bilateral trades including PPAs accounted for the remaining 1618TWh (93%).

Total electricity generation in India, split by trade mechanism

TWh



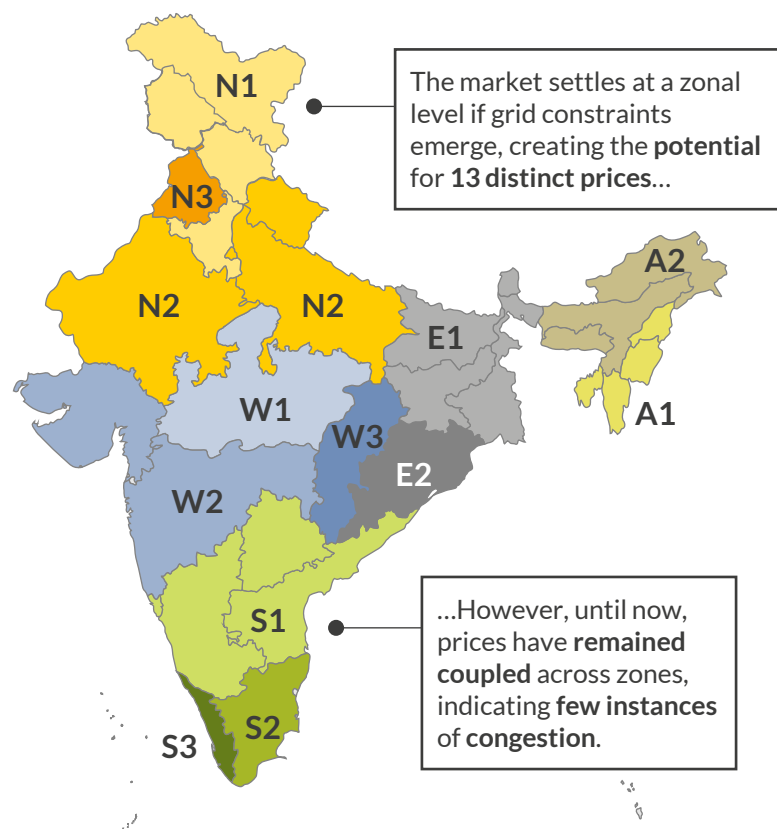
■ Power traded through bilateral agreements ■ Power traded through exchanges

1) Refers to contracts of less than one-year for electricity transacted bilaterally through Inter-State Trading Licensees.

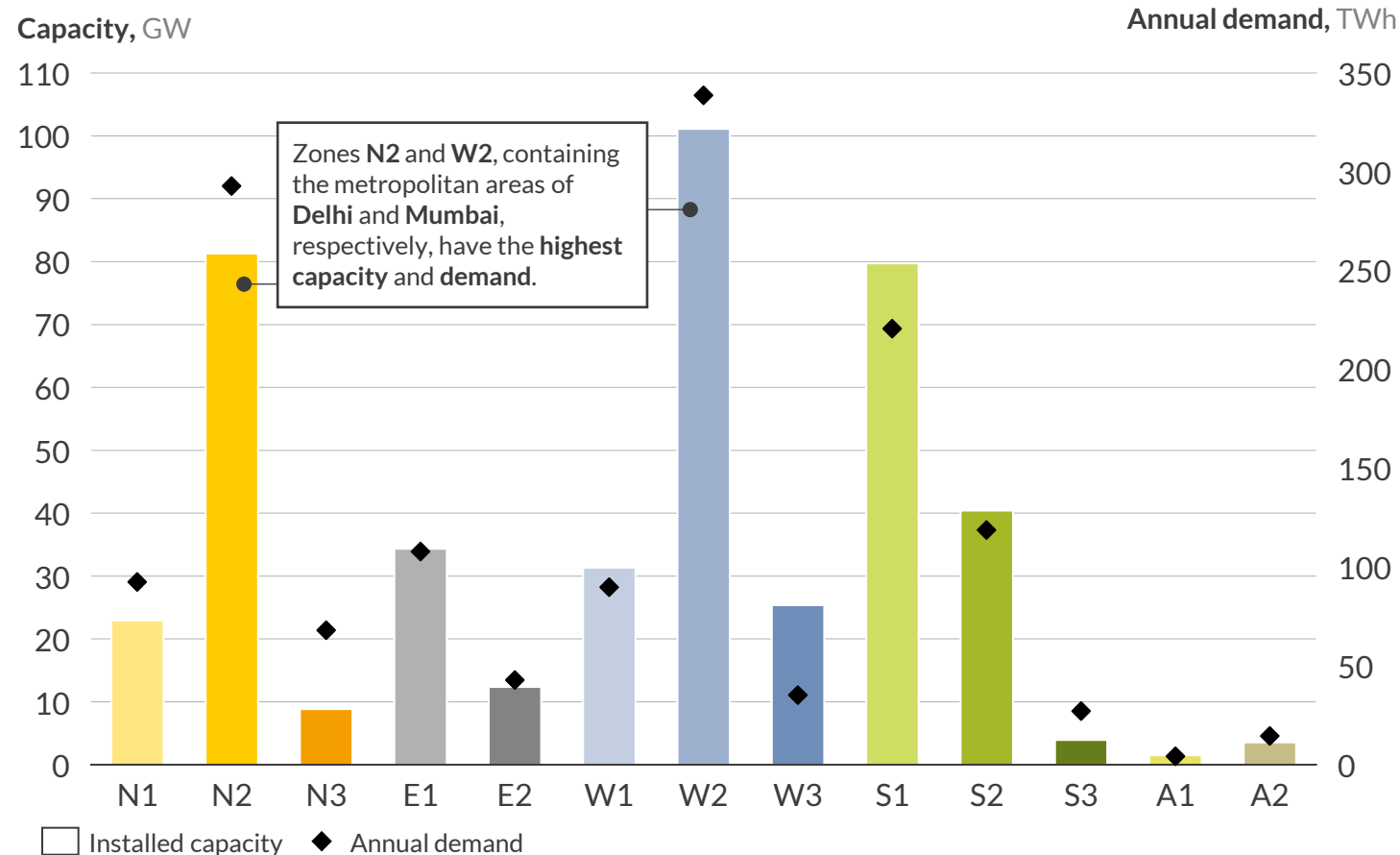
The merchant power market in India is split into 13 internally and externally interconnected 'bid areas,' creating 13 separate price zones

The Indian power system consists of 13 price zones, which are aggregated into 5 regions (North, East, West, South, North-East.) Each region is interconnected internally, with additional cross-border connections to Nepal, Bhutan, and Bangladesh¹.

Map of the Indian interconnected power system



Snapshot of capacity and generation²

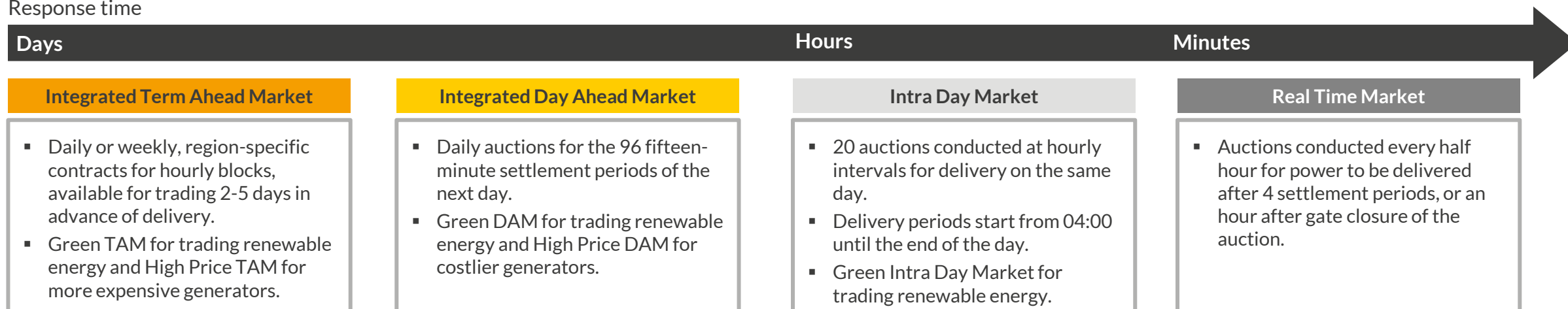


1) An additional 1GW HVDC interconnection with Sri Lanka is planned. 2) Installed capacity as of May 2024, demand in the year 2022.

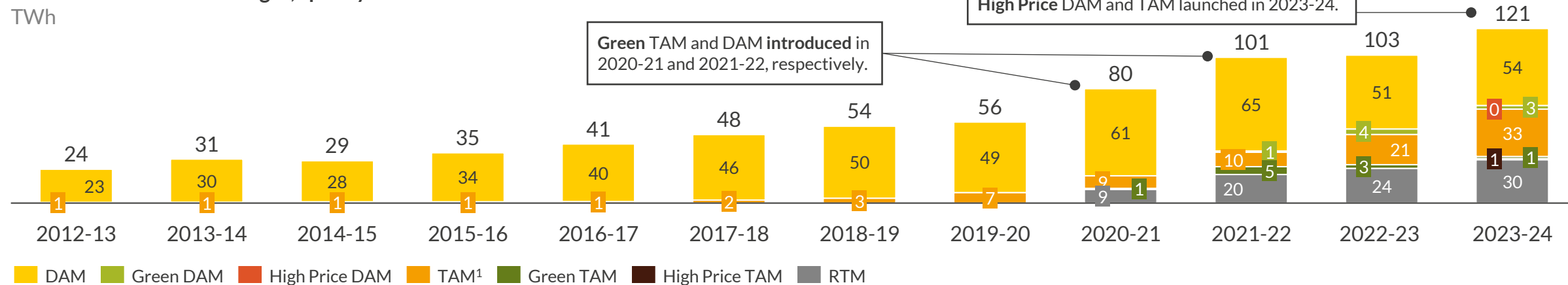
Merchant power is traded on several markets, with the Integrated Day Ahead Market accounting for nearly half of current volumes

Overview of key markets for trading merchant power in India

Response time



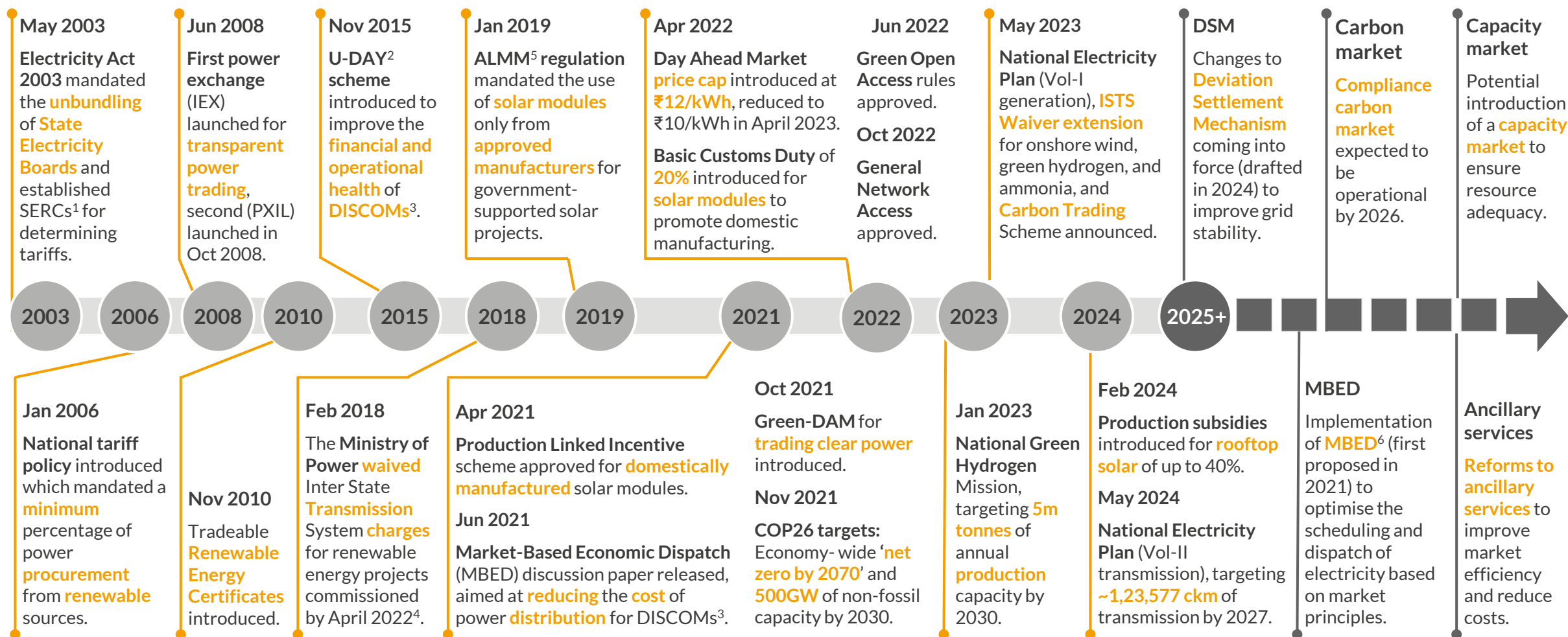
Volumes traded on exchanges, split by market



1) Intra Day Market (IDM) volumes are included within TAM bucket. IDM volumes were 0.24TWh in 2023-24.

The Indian government has introduced major power market reform in the last two decades, with significant developments on the horizon

Timeline of key historical and upcoming policy developments in the energy sector in India

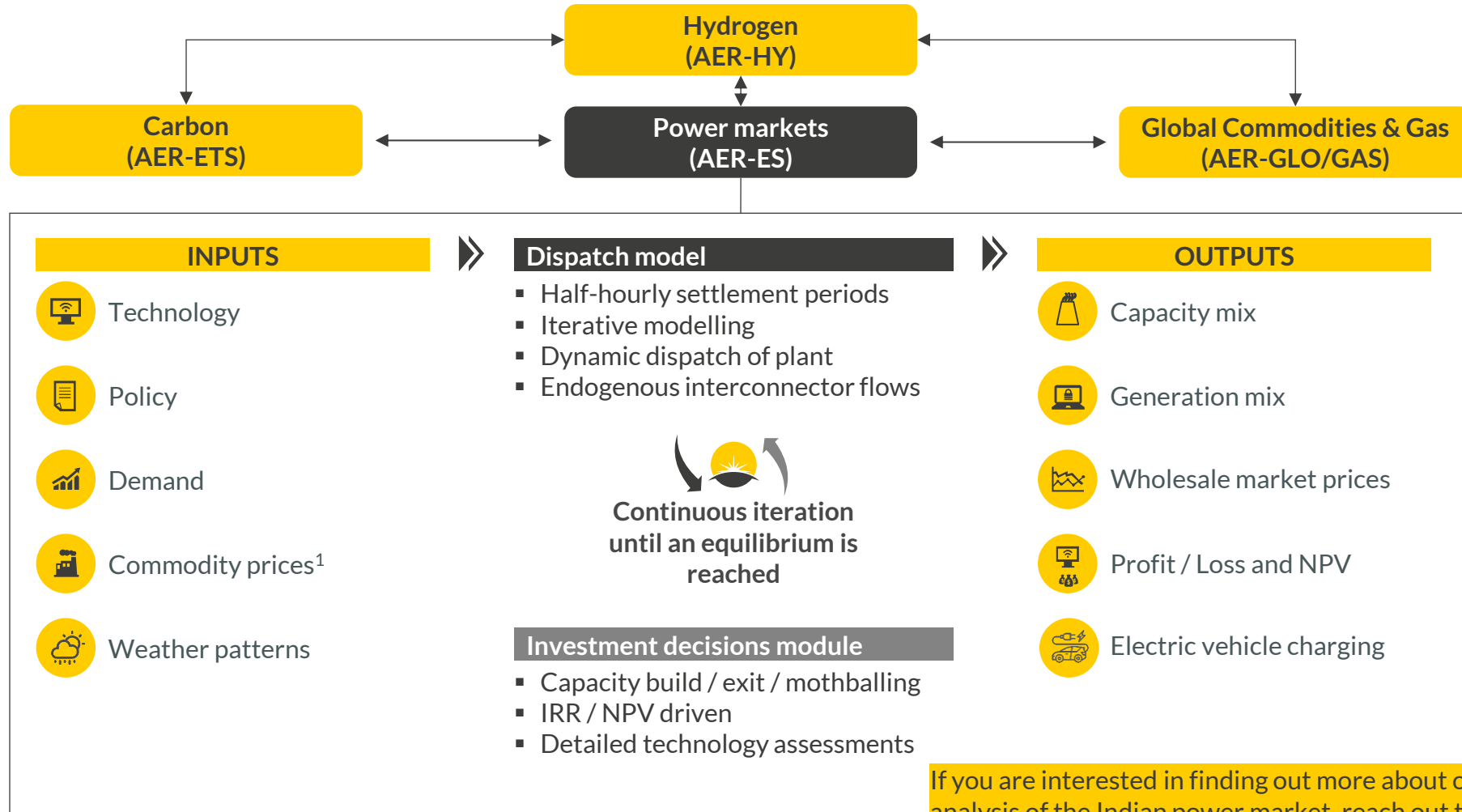


1) State Electricity Regulatory Commission. 2) Ujwal DISCOM Assurance Yojana. 3) Distribution company. 4) Dates have since been extended. 5) Approved List of Models and Manufacturers. 6) Market-Based Economic Dispatch.

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Our analysis of the Indian power market uses our proprietary, in-house 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

If you are interested in finding out more about our analysis of the Indian power market, reach out to: mrunal.karnik@auroraer.com

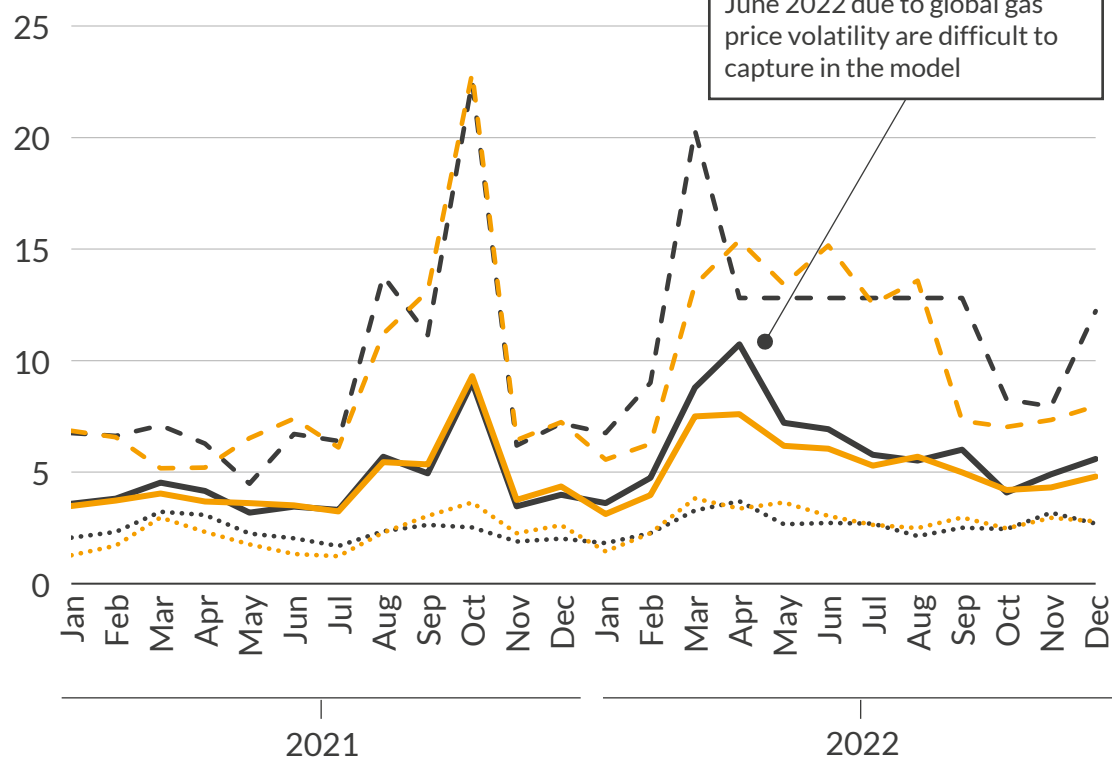
1) Gas, coal, oil and carbon prices fundamentally modelled in-house with fully integrated commodities and gas market model.

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

DAM prices and price percentiles

₹/kWh (real 2023)



Historical: — DAM price - - 95th Percentile 5th Percentile

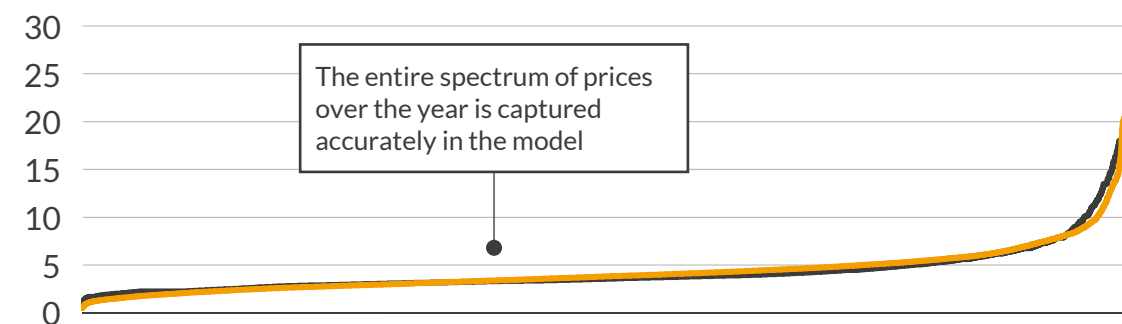
Modelled: — DAM price - - 95th Percentile 5th Percentile

1) Day Ahead Market.

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

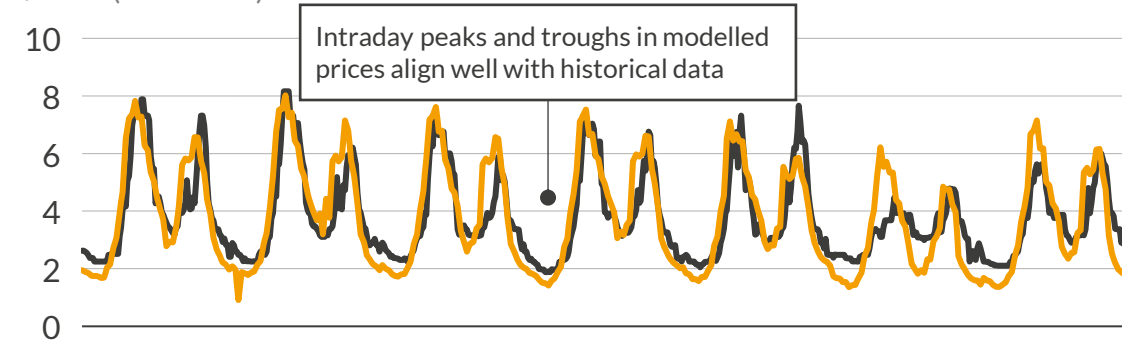
Price duration curve, 2021

₹/kWh (real 2023)



Modelled and historic DAM prices, sample week in 2021

₹/kWh (real 2023)



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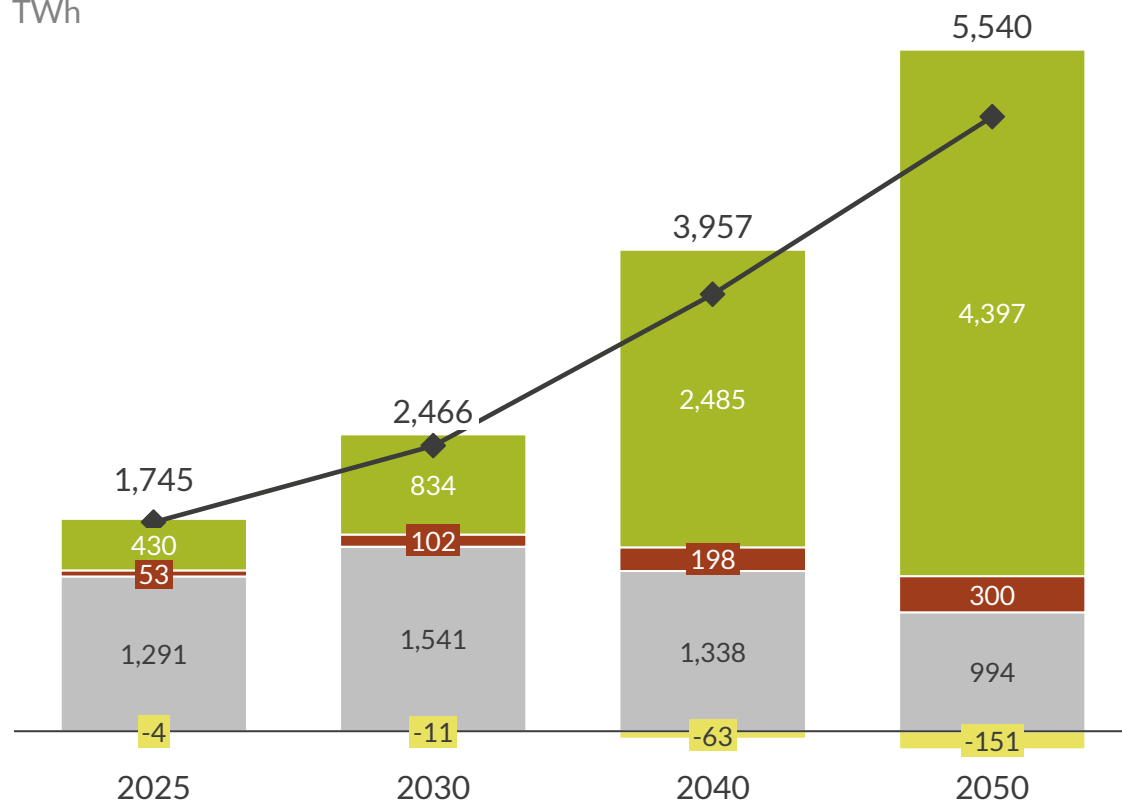
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Total installed capacity in India reaches nearly 2.8TW by 2050, including 1.9TW of renewables and over 500GW of flexible assets

Granular data available in full report

- 1 Power demand in India is expected to grow at a CAGR of 4.2% from 1,745TWh in 2025 to 5,130TWh in 2050...

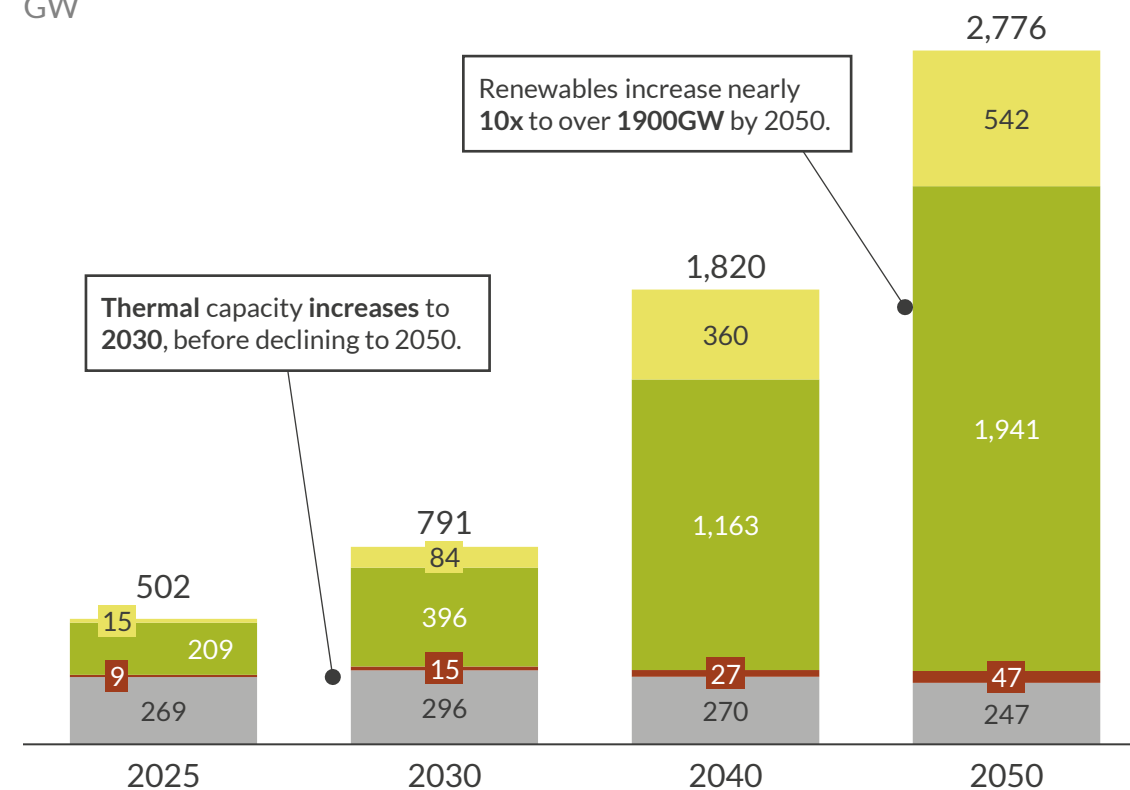
Demand and generation mix
TWh



Thermal Nuclear Renewables Flexible Demand

- 2 To meet the growing demand, generation capacity increases by over 2.2TW, driven by the expansion of renewables.

Installed capacity
GW

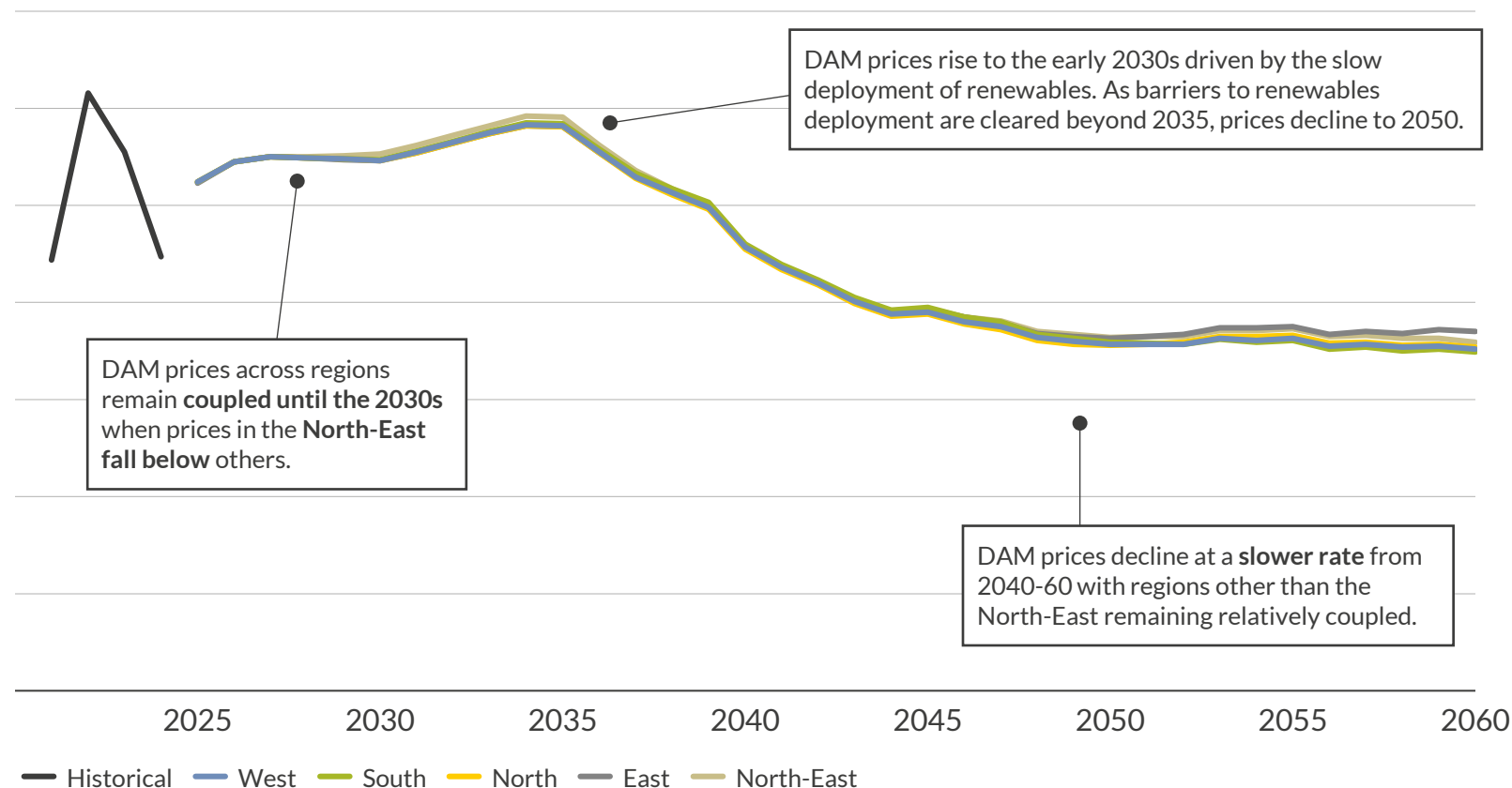


Power prices rise from 2025-35 driven by the slow-buildout of renewables, before declining out to 2050, as market-splitting emerges

Granular data available in full report

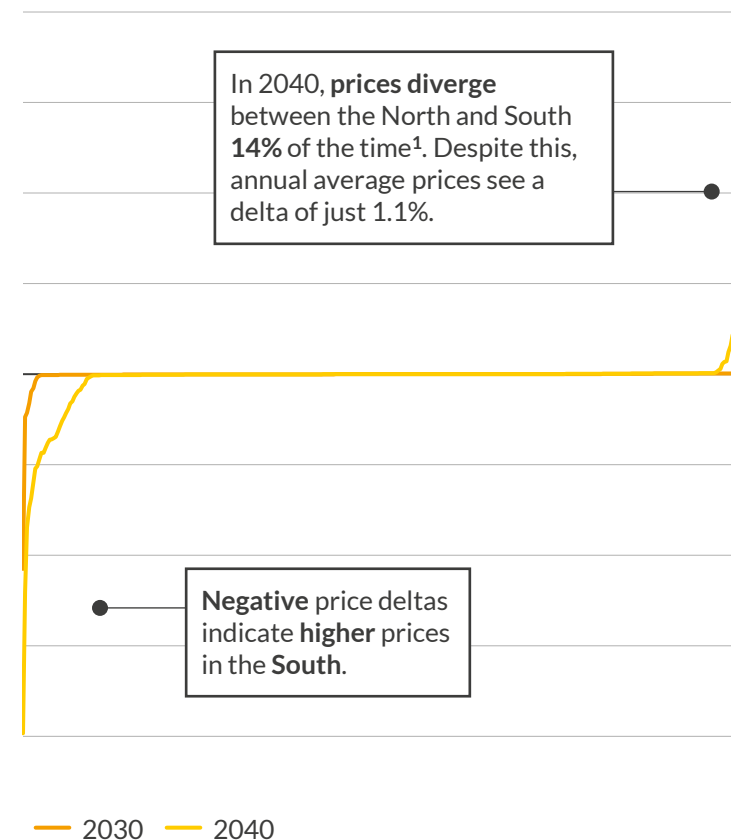
- 1 Average annual prices remain coupled across most regions through to 2060. The North-East sees some decoupling, with prices falling below other regions due to land constraints limiting transmission capacity.

Day Ahead Market (DAM) price per region
₹/kWh (real 2024)



- 2 However, half-hourly data shows market splitting in regions even where annual averages equalise

Price delta duration curve (North vs South)
₹/kWh (real 2024)



1) Prices are different in 14% of half hours in that year.

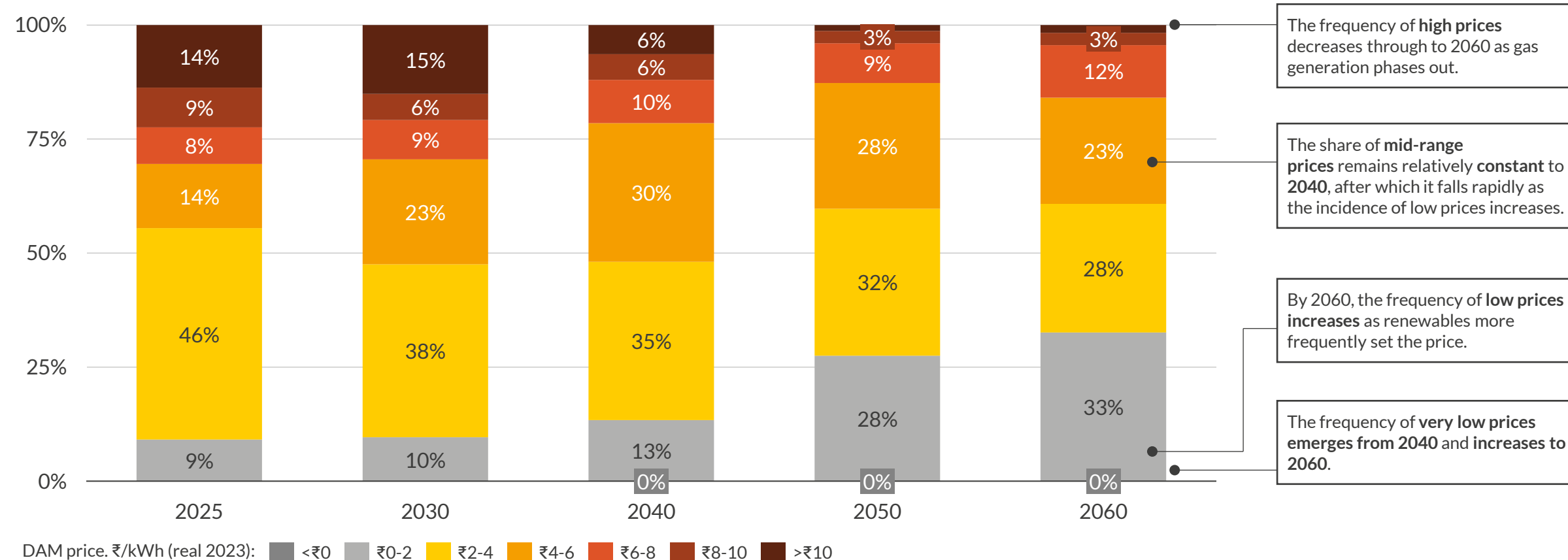
The increase in intermittent capacities results in a growing incidence of bottom prices

Granular data available in full report

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.

Frequency distribution of the DAM price in W2

%



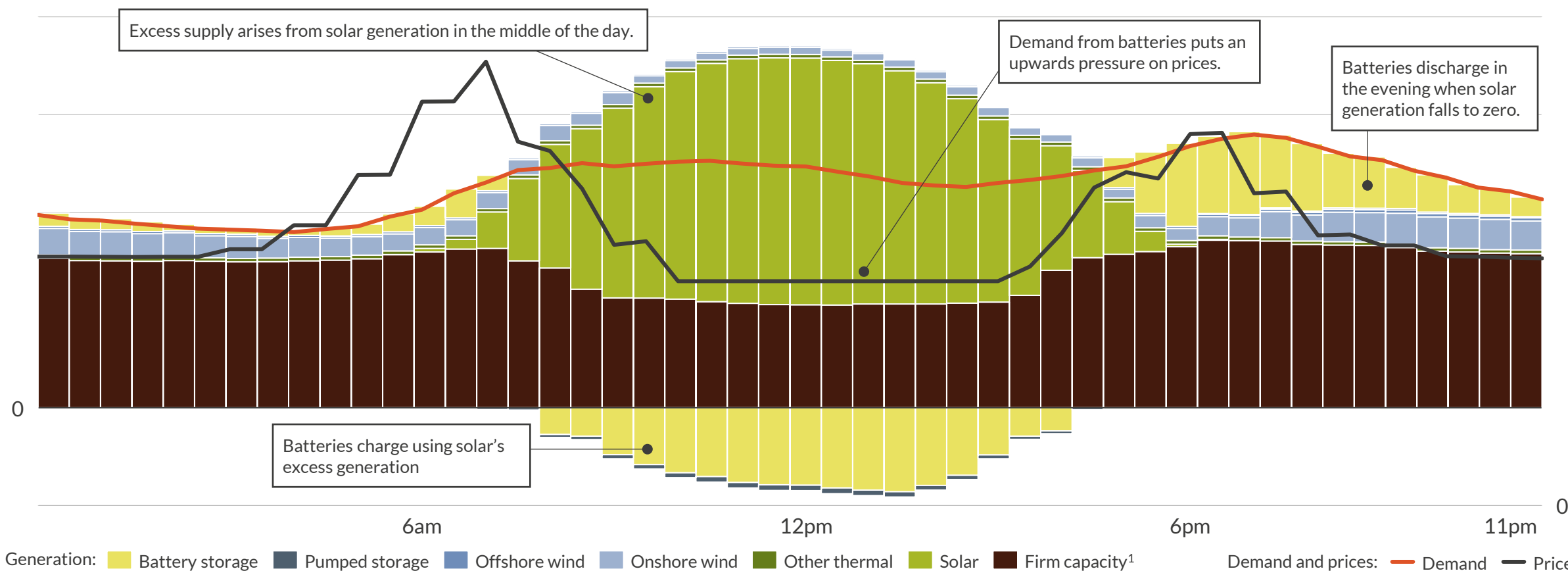
Excess solar generation in the middle of the day is absorbed by batteries, which put upwards pressure on prices in these hours

Granular data available in full report

A 'duck curve' appears in the daily price profile as excess solar generation during midday, when demand is low, pushes prices down. Prices then spike in the evening when demand is higher, and solar is not generating.

Generation by technology on 10 January 2030 by half-hour of day
GWh

Day-Ahead Market price in N2
₹/kWh

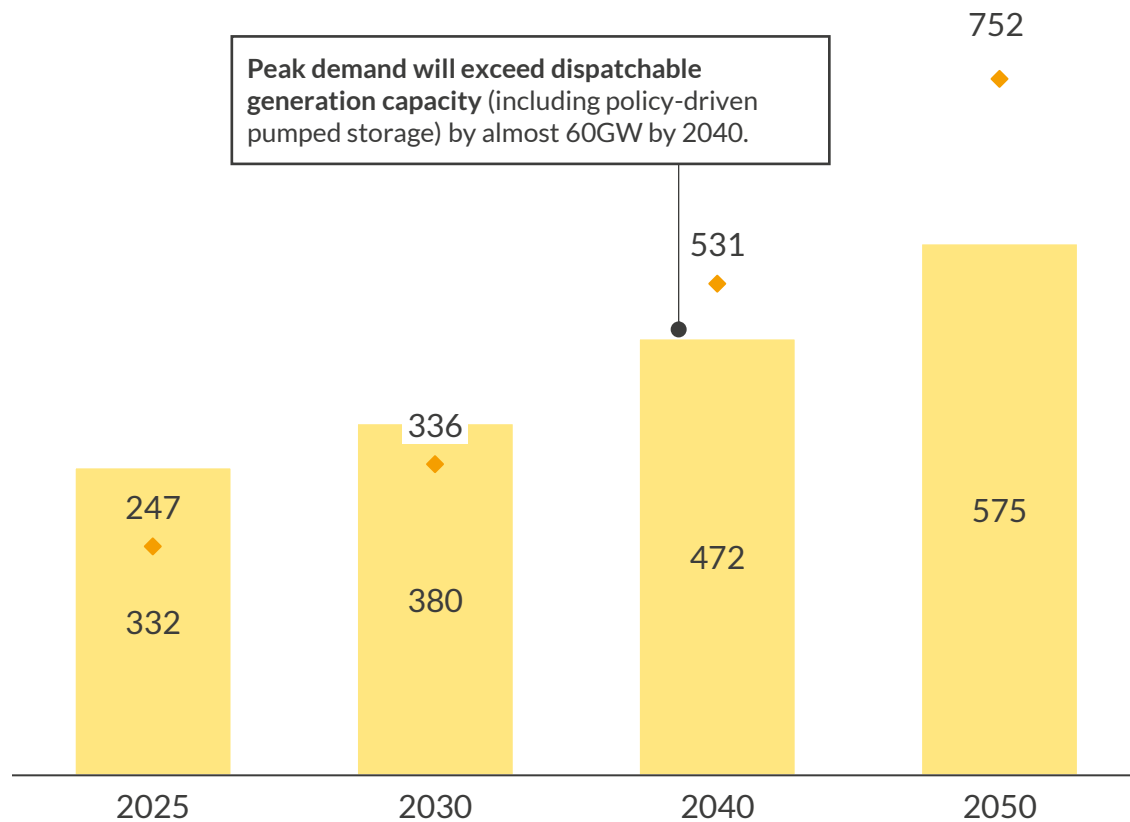


1) Coal, lignite, gas, nuclear, and hydro.

Storage will play a critical role in managing the hourly mismatch between supply and demand, driven by the growth in renewables capacity and demand

- 1 Dispatchable generation capacity will lag the growth in rapidly rising peak demand; peak demand will be greater than dispatchable capacity by 2040

Dispatchable generation capacity and peak demand
GW

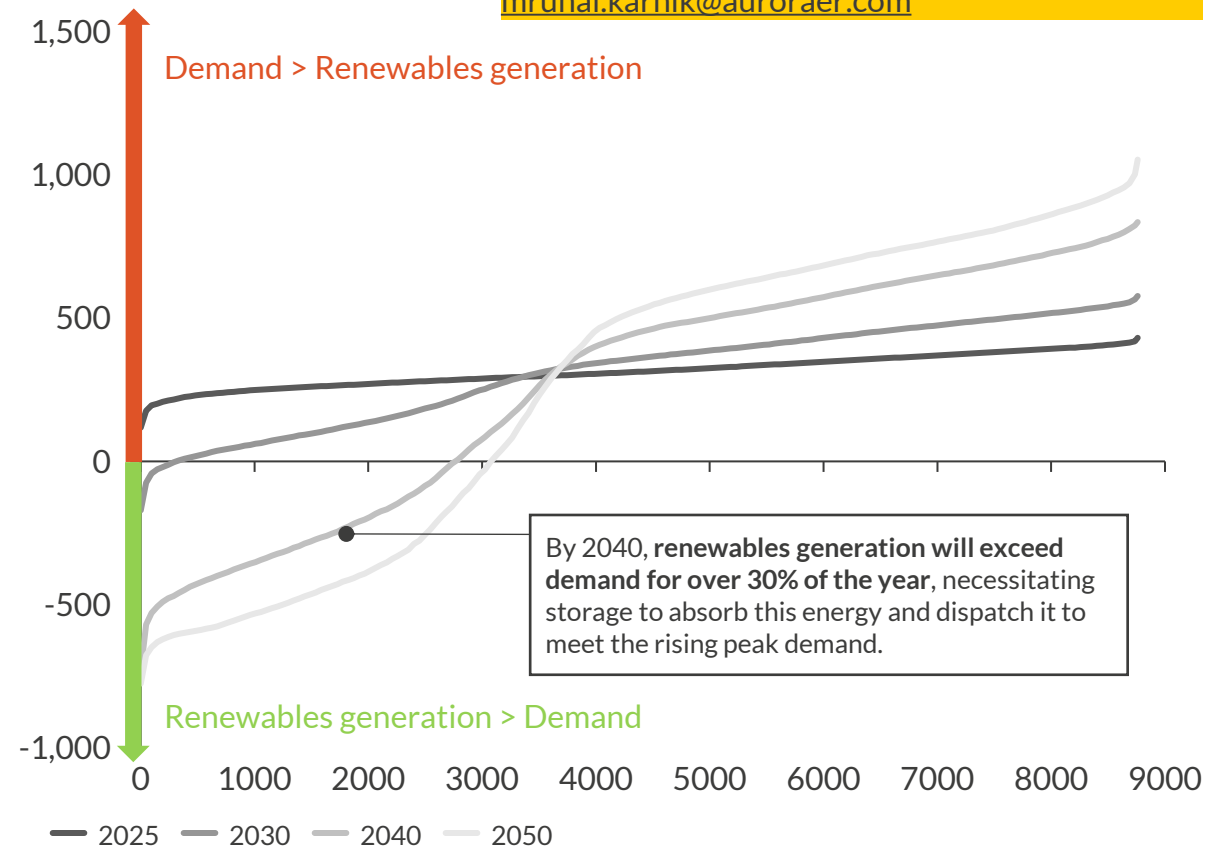


◆ Peak Demand ■ Dispatchable Generation Capacity¹

1) Includes nuclear, coal, gas turbines, reservoir hydro and pumped storage; 2) Residual demand is the demand net of renewable technologies like solar PV and wind.

- 2 Flexibility is critical in integrating the rapidly expanding renewable capacity and bridging the gap between supply and demand

Residual demand²
GW

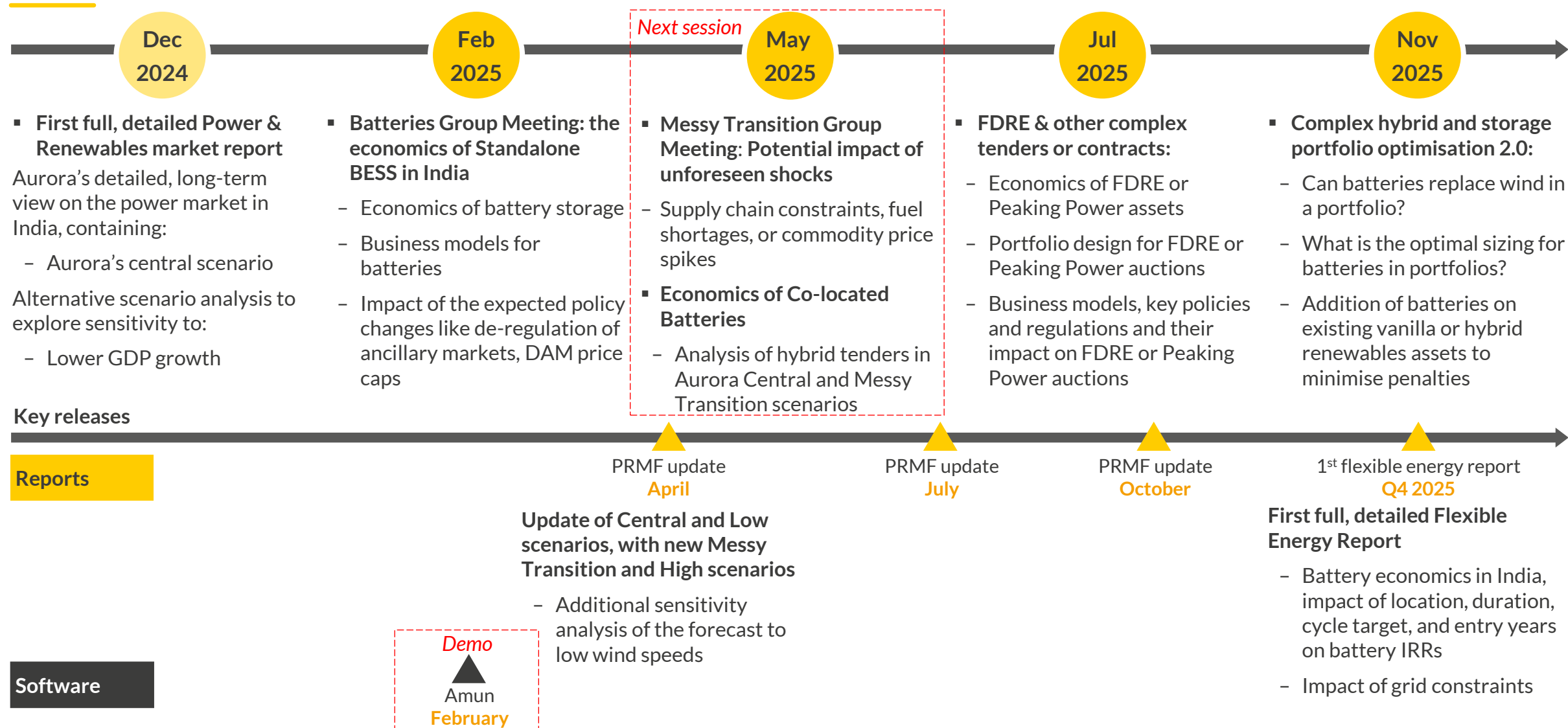


- 1 The Indian power market has undergone significant change, with increasing liberalisation and privatisation since 2003 paving the way more complex asset portfolios with increasing merchant exposure
- 2 Bilateral trade agreements (mostly PPAs) remain the dominant mechanism for trading power (93%) however the merchant opportunity has increased 4x in the last decade
- 3 Aurora's approach to modelling the merchant power market in India is robust and accurately simulates historical market outcomes
- 4 The rapid deployment of renewables and storage is crucial to meet growing demand, with over 550GW of renewables and nearly 100GW of flexible assets needed by 2030
- 5 Renewable deployment is expected to outpace transmission growth, causing price decoupling from the 2030s which widens in the 2040s

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Our wind valuation software, Amun, is available for India now, and the next session in May 2025 will present our Messy Transition scenario



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

▶ We invite all participants to reach out to us for any clarifications and queries

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

▶ We will publish our April Power and Renewables Market Forecast with the full report and databook later this month.

▶ If you are interested in discussing a Power & Renewables subscription with us, reach out to Mrunal Karnik at mrunal.karnik@auroraer.com

Details and disclaimer

Publication

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