

# Outlook on Renewable Energy Certificates in PJM

## Redacted Report



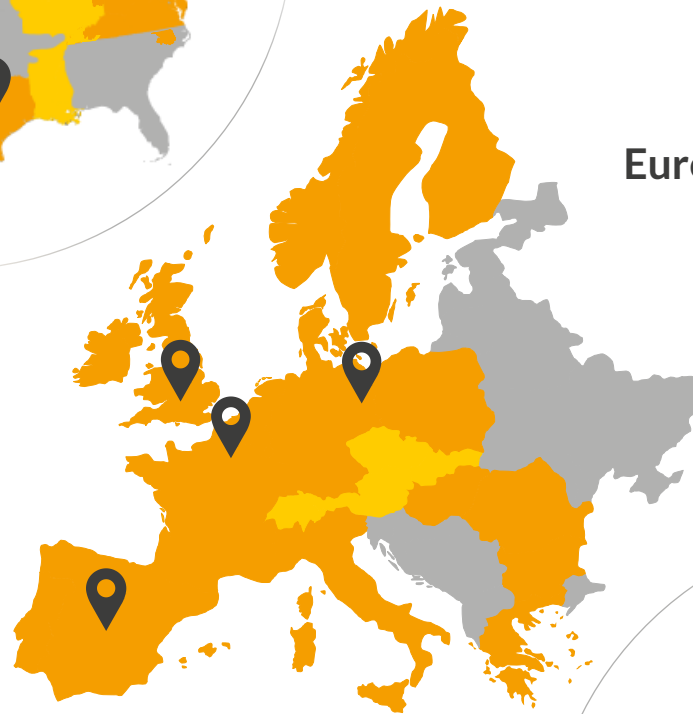
# Aurora provides data-driven intelligence for the global energy transformation

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## United States



## Europe



## Australia



 Regular detailed coverage  Analytics on demand

Power markets



Renewables



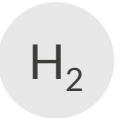
Storage



Electric vehicles



Hydrogen



Carbon



Natural gas



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Sydney | Austin | SF Bay Area



**300+**

market experts, 35+ in the US



**550+**

subscribing companies



**120+**

transactions supported in 2021

# Aurora brings a sophisticated approach to the provision of analysis and insight to the energy industry

## Research & Publications

- Industry-standard market outlook reports and bankable price forecasts for power, gas, carbon and hydrogen markets
- Strategic insights into major policy questions and new business models
- Read and constantly challenged by 350+ subscribers from all industry sectors

## Commissioned Projects

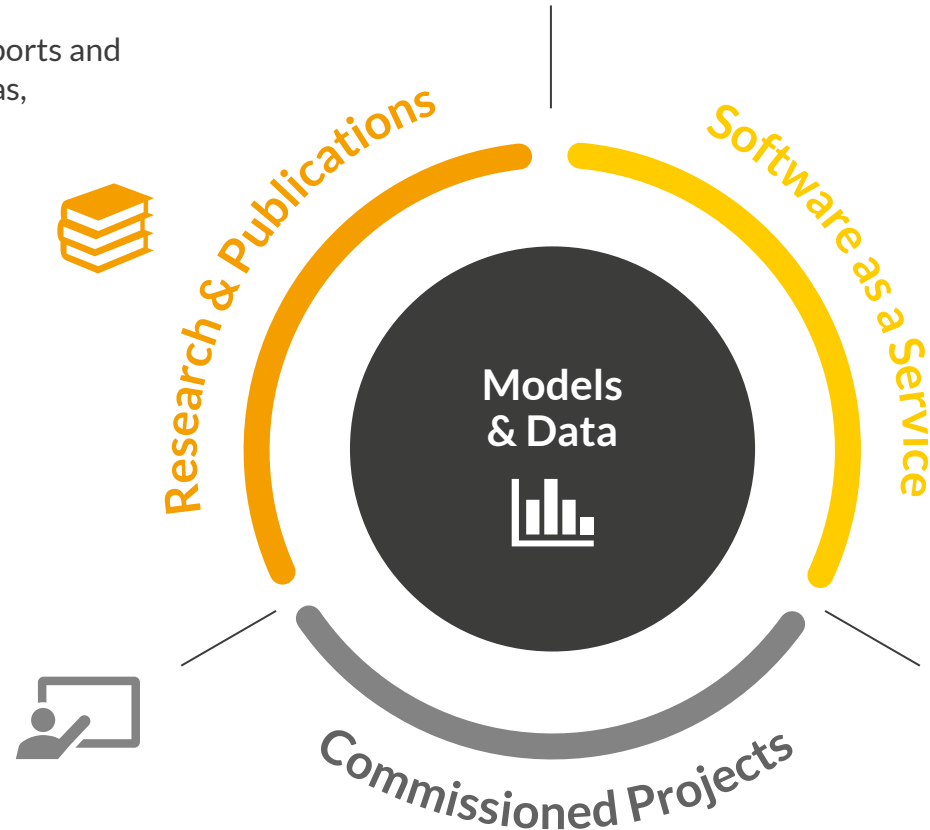
- Bespoke analysis, drawing upon our models and data
- Trusted advice for all major market participants proven in 500+ projects: transaction support, valuations, strategy & policy engagement

## Software as a Service

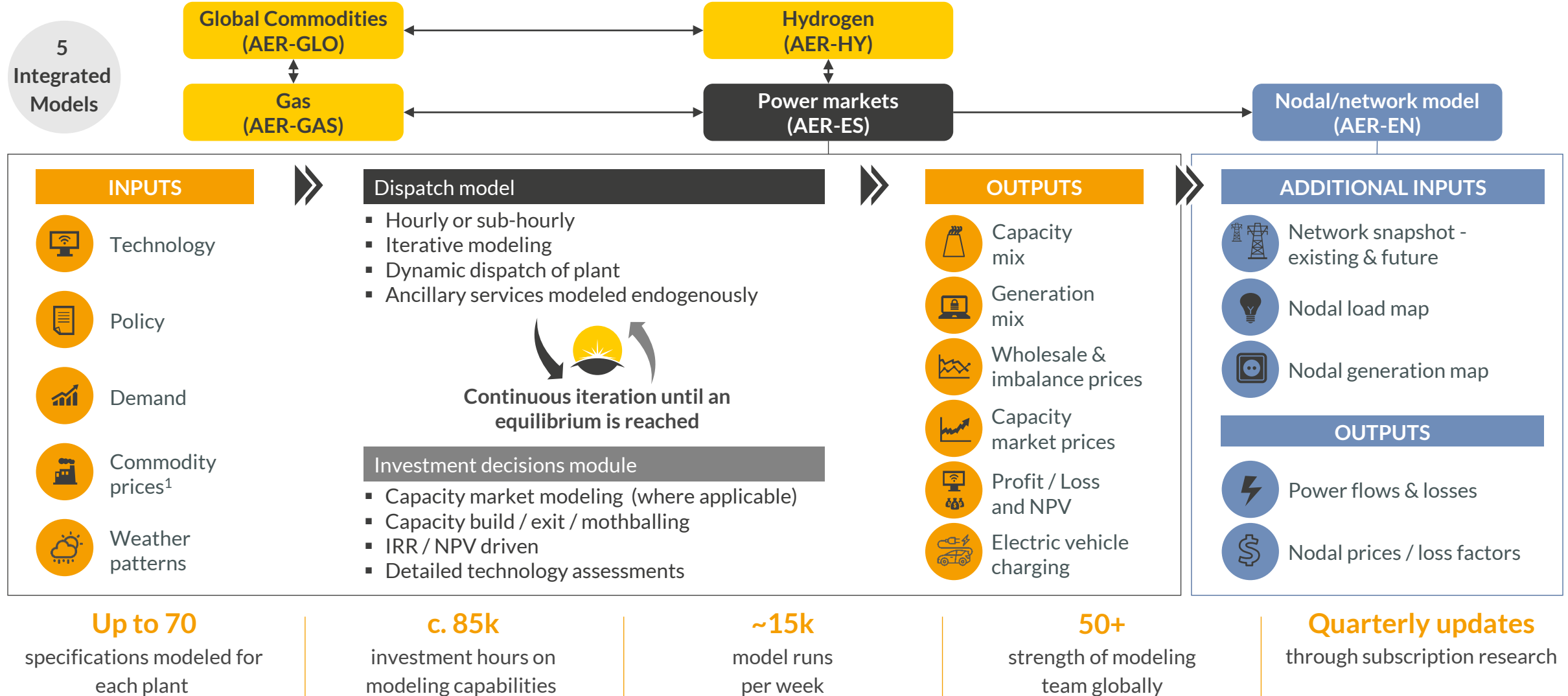
- Out-of-the-box SaaS solutions, combining cutting-edge sophistication with unparalleled ease of use
- **Origin** provides cloud-based access to Aurora's market model, pre-populated with our data
- **Amun** automates asset-specific wind farm valuations for over 30 leading funds, developers and utilities

## Models & Data

- Market-leading long-term models for power, gas, hydrogen carbon, oil and coal markets
- Continuous model improvements to reflect policy and market developments



# Unique, proprietary, in-house modeling underpins Aurora's superior analysis, with integrated energy, ancillary, capacity, and power flow modeling

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

# Aurora is the market leader in complex transaction support involving flexible and renewable assets accessing multiple revenue streams

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## Battery generation



### Illustrative project examples

- Buy-side advisor on multiple equity transactions for over 1.5 GW of battery storage projects across ERCOT and CAISO, including nodal modelling, ancillary service price forecasts, and solar/wind + storage co-location analysis
- Sell-side advisor for Black Mountain on 700MW asset sale to UBS Asset Management
- Sell-side advisor for Black Mountain on 400 MW asset sale to Cypress Creek Renewables
- Buy-side advisor on large portfolio of existing and greenfield wind, solar and battery projects spanning multiple ISOs
- Siting strategy analysis for battery developer to inform build locations and project valuation

## Strategic



- Debt case scenario analysis for large pension fund to inform investing and lending decisions
- Scenario modelling for international bank to inform lending criteria
- Pricing and PPA analysis for publicly listed data center company

## Renewable generation



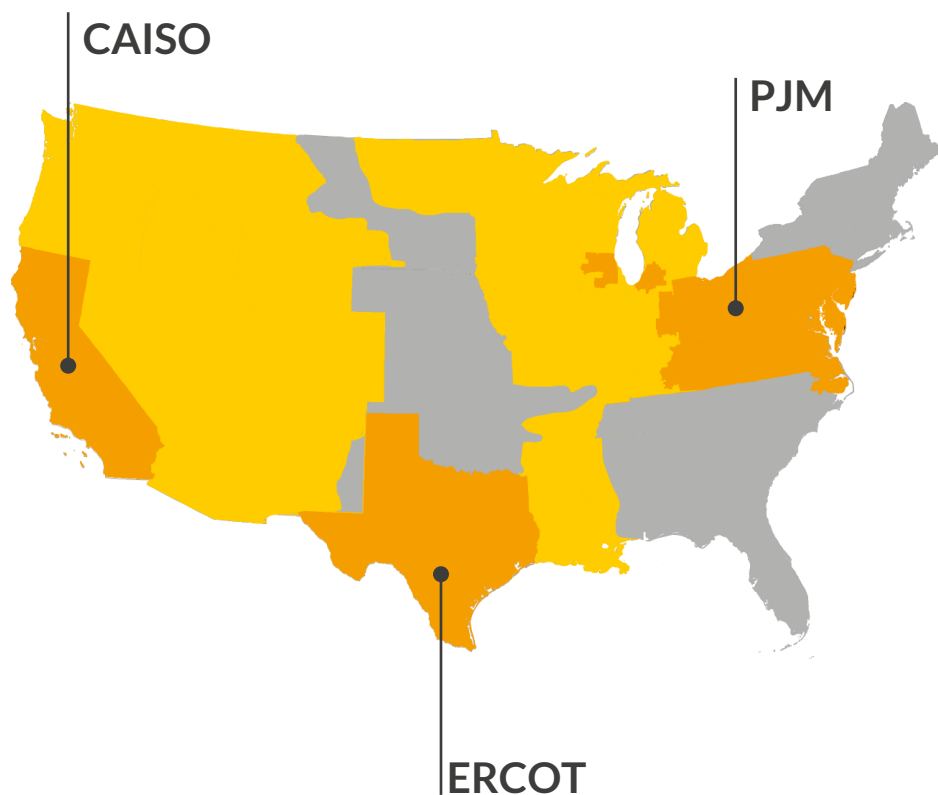
- Buy-side advisor for Wind Portfolio for investment manager for ~1 GW onshore wind portfolio across ERCOT and SPP, including nodal pricing, basis risk, and curtailment
- Buy-side support for 150 MW solar project
- Buy-side support for offshore wind project in PJM
- Asset-specific valuation of two wind and solar projects totalling 540 MW for infrastructure fund including nodal forecasting and curtailment
- Asset valuation for a large pumped hydro plant participating in the CAISO wholesale and ancillary markets

## Thermal generation



- Modelling of proposed ERCOT market reforms (e.g. dispatchable energy credits) for project developer
- Asset valuation for lender for two existing CCGT projects in ERCOT and WECC
- Sell-side advisory for 400 MW OCGT peaking plant in West Texas for large utility
- Analysis of Biden's Clean Electricity Standard design for one of US largest utilities, to engage with White House on the role of gas CCS in the energy transition

# Aurora's North America public webinars present an overview of our analysis in ERCOT, CAISO, PJM, and beyond



 Regular detailed coverage  Analytics on demand

## Flex Outlook in CAISO and ERCOT

- In depth look at the value proposition of batteries and the ROI
- Pipeline of projects across ERCOT and CAISO and analysis of historical battery returns
- Favorable investment landscape for batteries in ERCOT and CAISO with varying IRRs

## Renewable Energy Certificates in PJM

- REC pricing outlook in the short term and through 2050; how long will high prices last?
- Demand dynamics for RECs through 2050, including state RPS targets, and corporate demand
- Availability of supply, and overview of the current RES supply shortage and its implications for REC price

## Additional PJM and US market content sessions

- Coming up next across US markets: Inflation Reduction Act
- Coming up next in PJM: Outlook for the Capacity Market (Reliability Pricing Model) – stay in touch!
- Additional topics include: Flex Outlook, nodal pricing outlook, etc.

August 11th, 2022

September 13th, 2022

November 2022 +

For more information, please contact  
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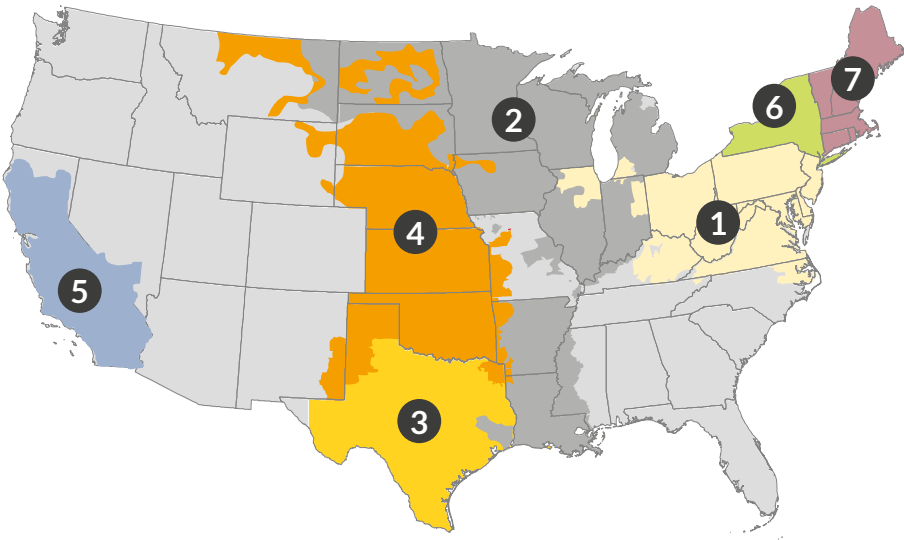
## I. PJM market dynamics and Renewable Energy Certificates

## II. REC price, supply, and demand outlook

# PJM has the highest installed capacity, reserve margin, and load of all US ISOs/RTOs, but the lowest renewables share of generation

There are seven restructured competitive markets in the lower 48 states which are run by Independent System Operators (ISOs) or Regional Transmission Organization (RTOs). ISOs/RTOs use competitive market mechanisms that allow independent power producers and non-utility generators to trade power

Map of U.S. wholesale electricity markets<sup>1</sup>



| ISO      | Installed capacity <sup>2</sup><br>GW | Annual load <sup>2</sup><br>TWh | Projected peak load growth through 2030 <sup>3</sup> | Renewables share of generation <sup>4</sup> | Reserve margin <sup>5</sup> |
|----------|---------------------------------------|---------------------------------|--|---|-----------------------------|
| PJM 1    | 221                                   | 799                             | 5.0%   | 5%  | 33.5% <sup>6</sup>          |
| MISO 2   | 199                                   | 646                             | 3.4%   | 14%   | 21.6%                       |
| ERCOT 3  | 111                                   | 380                             | 25.2%  | 25%   | 15.3%                       |
| SPP 4    | 93                                    | 260                             | 8.3%   | 36%   | 29.9%                       |
| CAISO 5  | 67                                    | 215                             | 1.7%   | 40%   | 23.8%                       |
| NY ISO 6 | 43                                    | 147                             | -0.4%  | 25%   | 27.3%                       |
| ISO-NE 7 | 39                                    | 112                             | -0.7%  | 12%   | 22.0%                       |

1) Light gray areas are regulated meaning they are vertically integrated utilities responsible for the production, transportation and sale of electricity to consumers. 2) 2020 values. Non-PJM data from 2020 NERC Long-Term Reliability Assessment. 3) Compares 2021 through 2030. 4) 2020 data, includes onshore wind and solar PV. 5) Data from 2021 NERC Seasonal Resource Assessment. 6) This number differs from the MMU reports due to a varying definition of the reserve margin  
Sources: Aurora Energy Research, FERC, NERC, individual ISOs



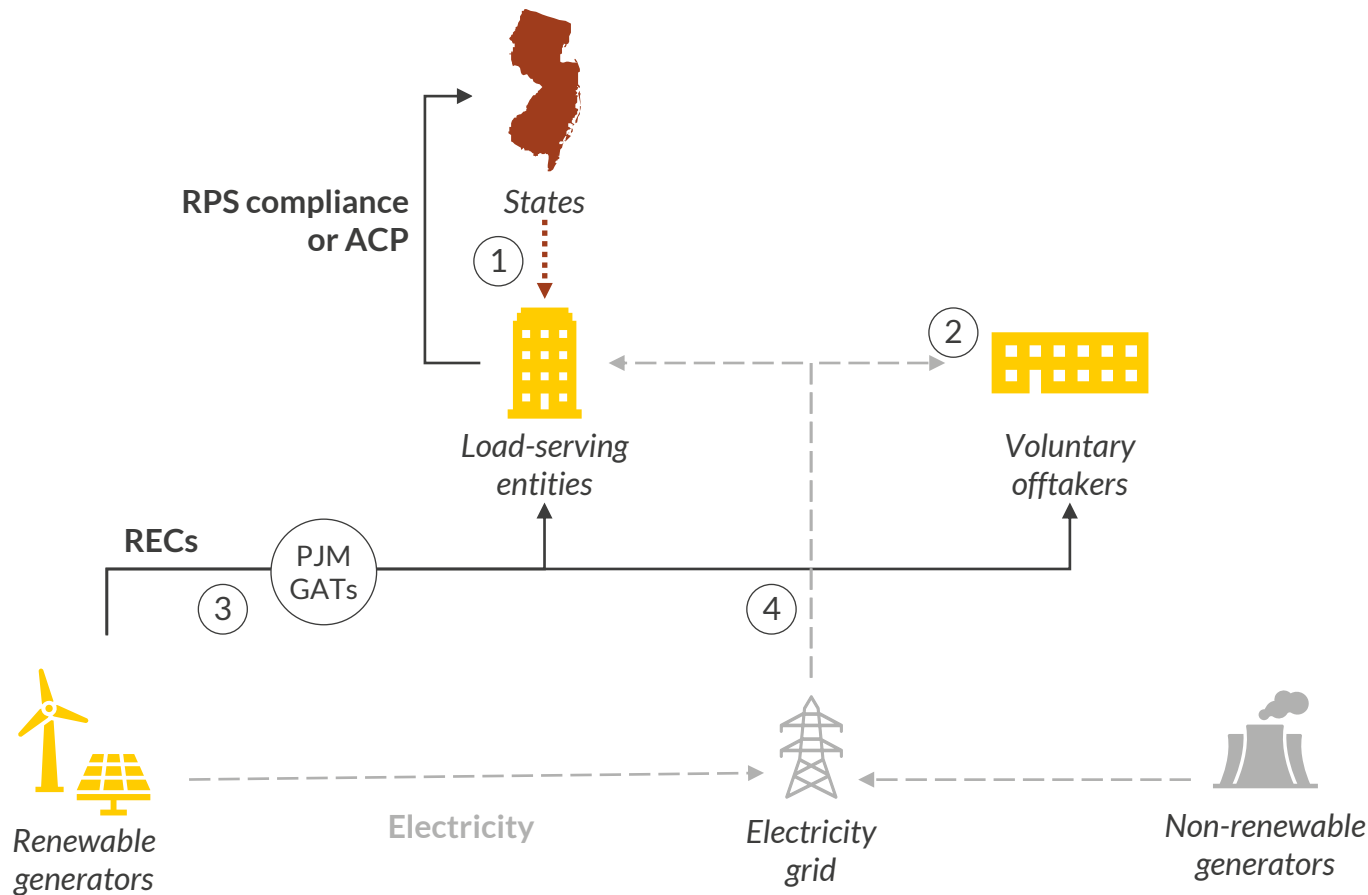
The map displays the following utility territories and locations:

- ComEd** (dark blue)
- ATSI** (medium blue)
- DLCO** (white)
- METED** (light orange)
- PENELEC** (orange)
- PECO** (yellow)
- RECO** (dark orange)
- PSEG** (light yellow)
- JCP&L** (yellow)
- AE** (light yellow)
- BGE** (yellow)
- PEPCO** (yellow)
- DP&L** (yellow)
- Dominion** (dark red)
- AP** (light blue)
- AEP** (light blue)
- DAY** (light green)
- DEOK** (dark green)
- EKPC** (dark green)
- OVEC** (light green)

Black dots are located in the following territories: PECO, PSEG, JCP&L, AE, BGE, PEPCO, DP&L, and AEP.

Sources: Aurora Energy Research, PJM

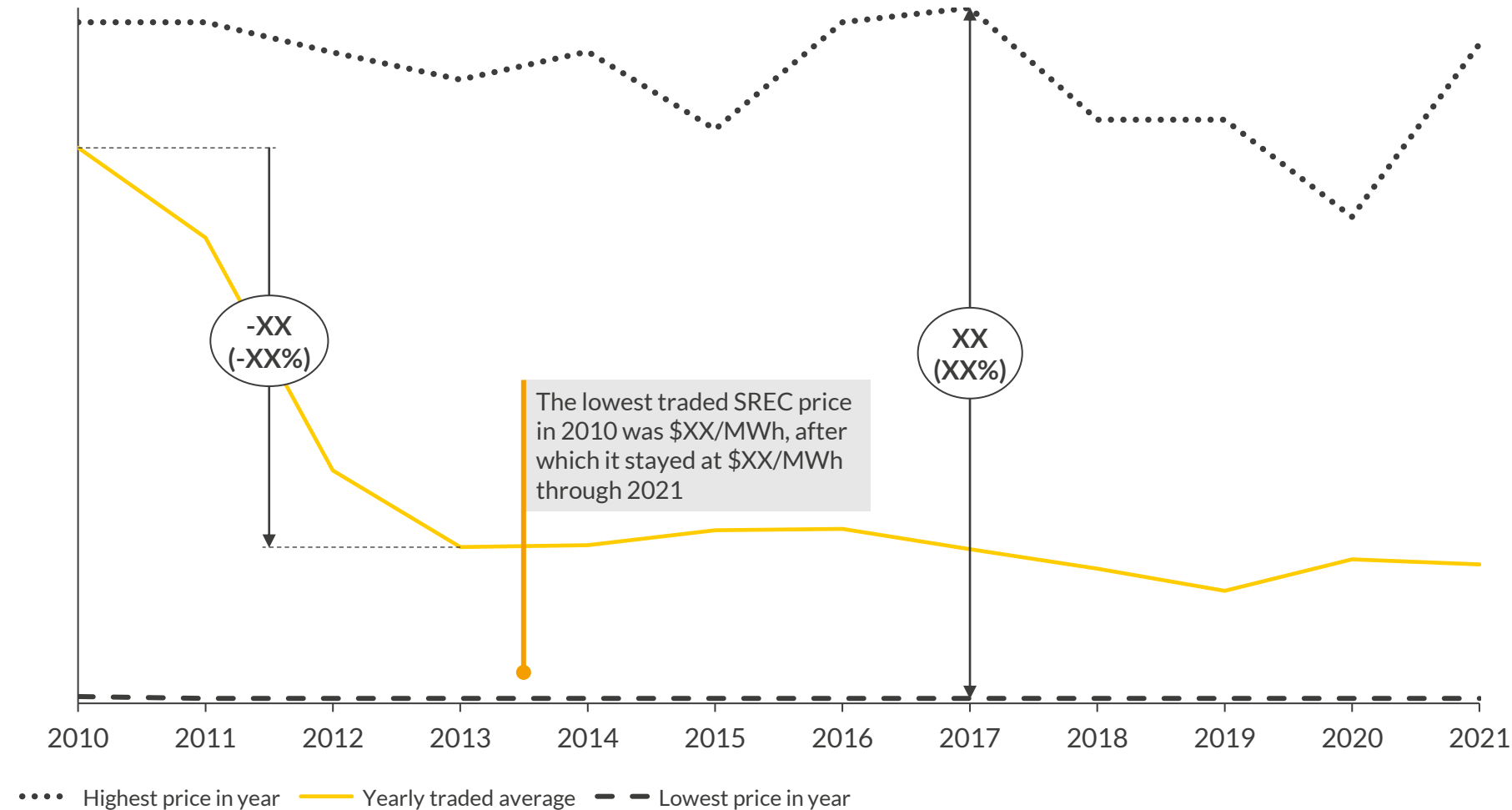
# RECs certify that the purchaser's power is renewable, while providing an additional revenue source for generators / owners



- ① A subset of states sets annual **Renewable Portfolio Standards (RPS)** targets for load-serving entities — a share of delivered electricity that must come from renewable sources. This mandates the purchase of a corresponding **number of RECs**, or else an **Alternative Compliance Payment (ACP)** in the case of non-compliance
- ② Separately, some energy consumers procure additional RECs themselves; a typical case is a **large business that has made public decarbonization commitments**
- ③ A Renewable Energy Certificate is **created for each MWh of electricity generated by a renewable asset**, assigned and tracked by PJM's Generation Attribute Tracking System (**GATS**). Sale conditions / contracts vary based on bi-lateral agreements (e.g., **PPAs, unbundles RECs**) and provide an additional revenue stream for the generator
- ④ Because physical energy from renewable and non-renewable sources is indistinguishable on the grid, RECs provide a **separate mechanism for tracking** generation, ownership, and consumption of renewable energy

# To date, RECs have been volatile with opaque pricing dynamics, leading to challenges to incorporate as part of RES business cases

Historical traded solar REC price across PJM  
\$/MWh



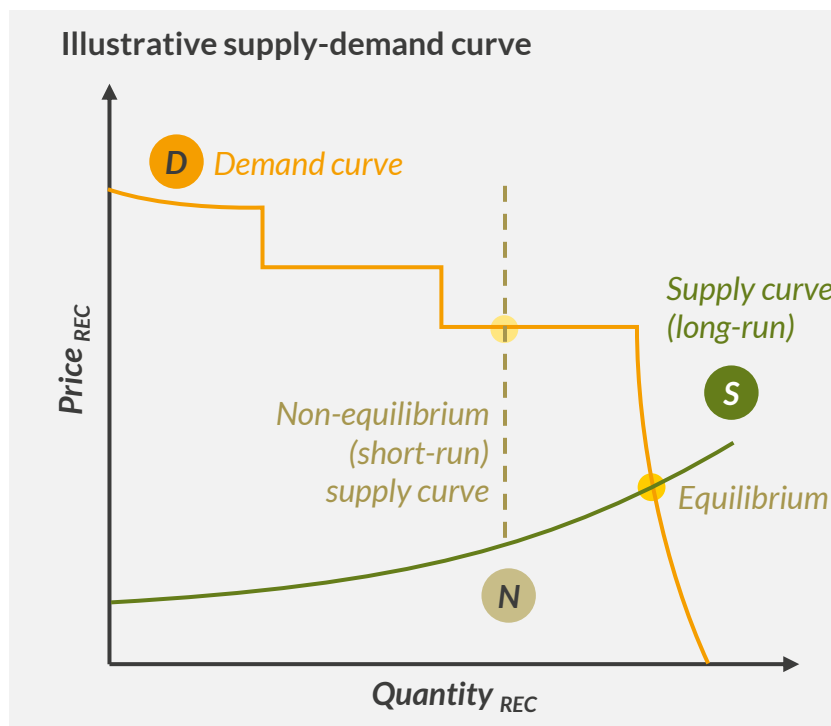
- Renewable Energy Credit (REC) prices have seen strong price swings and large spreads in traded prices historically
- In the past 10 years, solar RECs in PJM have seen traded prices between as low as \$XX/MWh and as high as \$XX/MWh in the same year, with the average traded price falling by more than \$XX/MWh – over XX% – in just 3 years
- This illustrates – and is a symptom of – the opacity and complexity of the REC market, making REC prices difficult to predict and integrate into a business case

# Fundamentally, RECs are priced at the missing money required to make renewables profitable, but shortfall periods lead to higher prices

In the long run, REC prices will settle at the level where REC demand equals supply...

## S REC supply

- Driven by renewables' **expected profitability**
  - Resulting from expected electricity, capacity, and REC revenues, with costs driven by CAPEX and cost of capital
  - RECs can cover the **gap to profitability** between costs and merchant revenues (electricity and capacity), thus pushing up supply
- Hence, we take a **missing money** approach to modelling during equilibrium, driving REC supply to meet demand



## D REC demand

- Driven by
  - State **RPS** (Renewable Portfolio Standards) **requirements**, which, for most states, together form a single “bucket” of REC demand, by all allowing REC sourcing from the entire PJM area
  - Consumers' **voluntary decarbonization ambitions**, e.g. AWS, Google
  - Constrained by sourcing requirements, **known as fungibility** (e.g. generated within PJM & neighbors only)

## N

In the short run, **supply constraints** are driven by:

- Interconnection queue processing time
- Immediate logistical constraints (supply chain hold-ups, land, local opposition)

During these **non-equilibrium periods**, prices can be pushed up to the “reserve price”, i.e.,:

- The Alternative Compliance Payment (ACP)
- Voluntary offtakers' willingness to pay, in instances where this is above ACP

# Agenda

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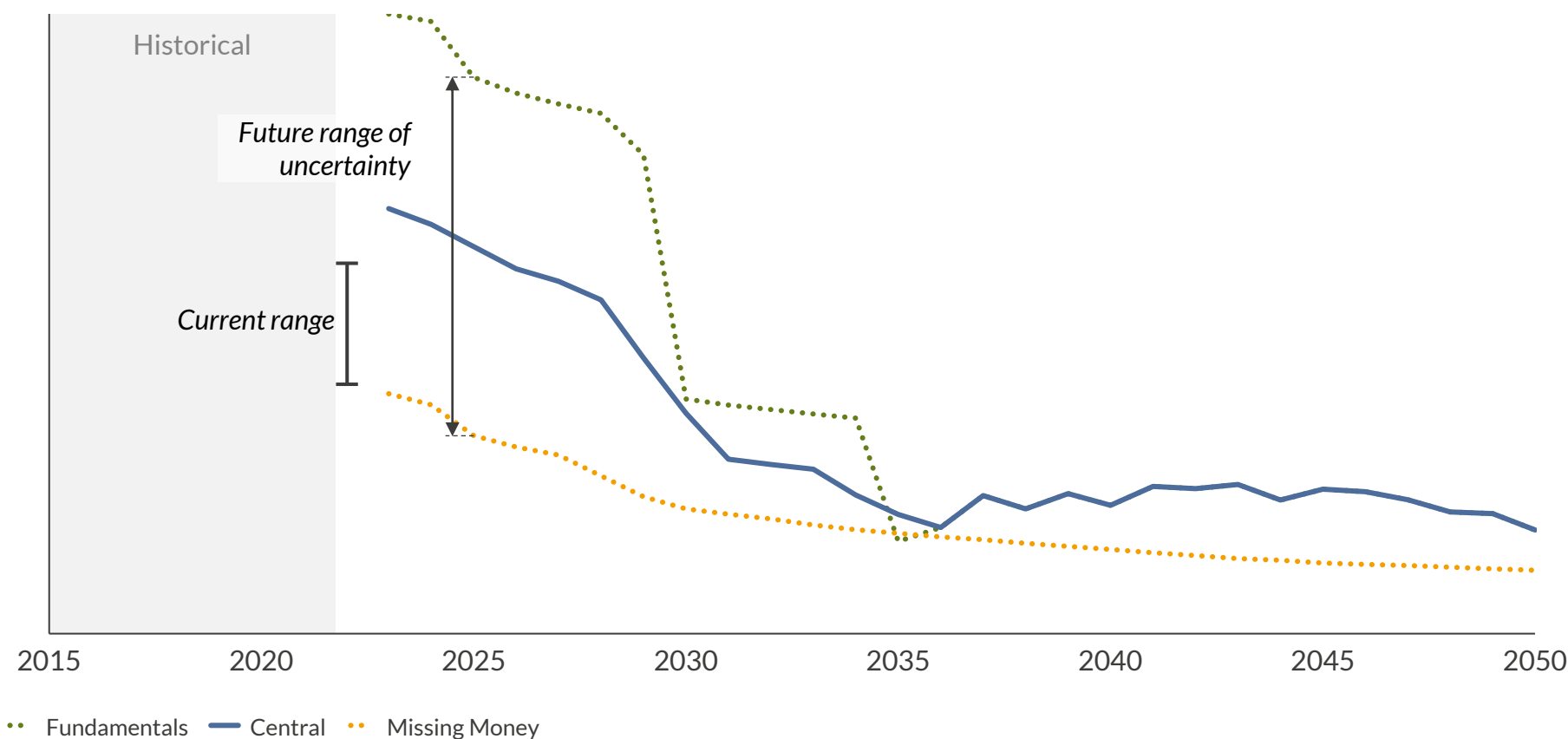
I. PJM market dynamics and Renewable Energy Certificates

II. REC price, supply, and demand outlook

# REC prices rise above \$XX in the mid-2020s, with a lower price bound set by generator missing money, reaching \$XX in mid 2030s

Alongside our **P50 Central REC forecast**, we present an **upper** and **lower** bound within the Aurora Central scenario, capturing the range of outcomes of different pricing mechanisms

Volume-weighted average Tier I REC price  
\$/MWh (real 2021)



- Our **Missing Money** forecast presents a **lower bound** to pricing within our overall Central scenario, where RECs are **priced down** to generators' reserve price to enter the market: their missing money
- Our **Fundamentals** forecast presents an **upper bound** to pricing, where RECs are **priced up** to where supply equals demand in a fully liquid market, thereby hitting ACPs when supply falls short of demand
- Our **Central** forecast is a **P50 middle ground**, taking into account factors that push prices away from these two outer bounds, including expectations, incomplete information, and REC imports

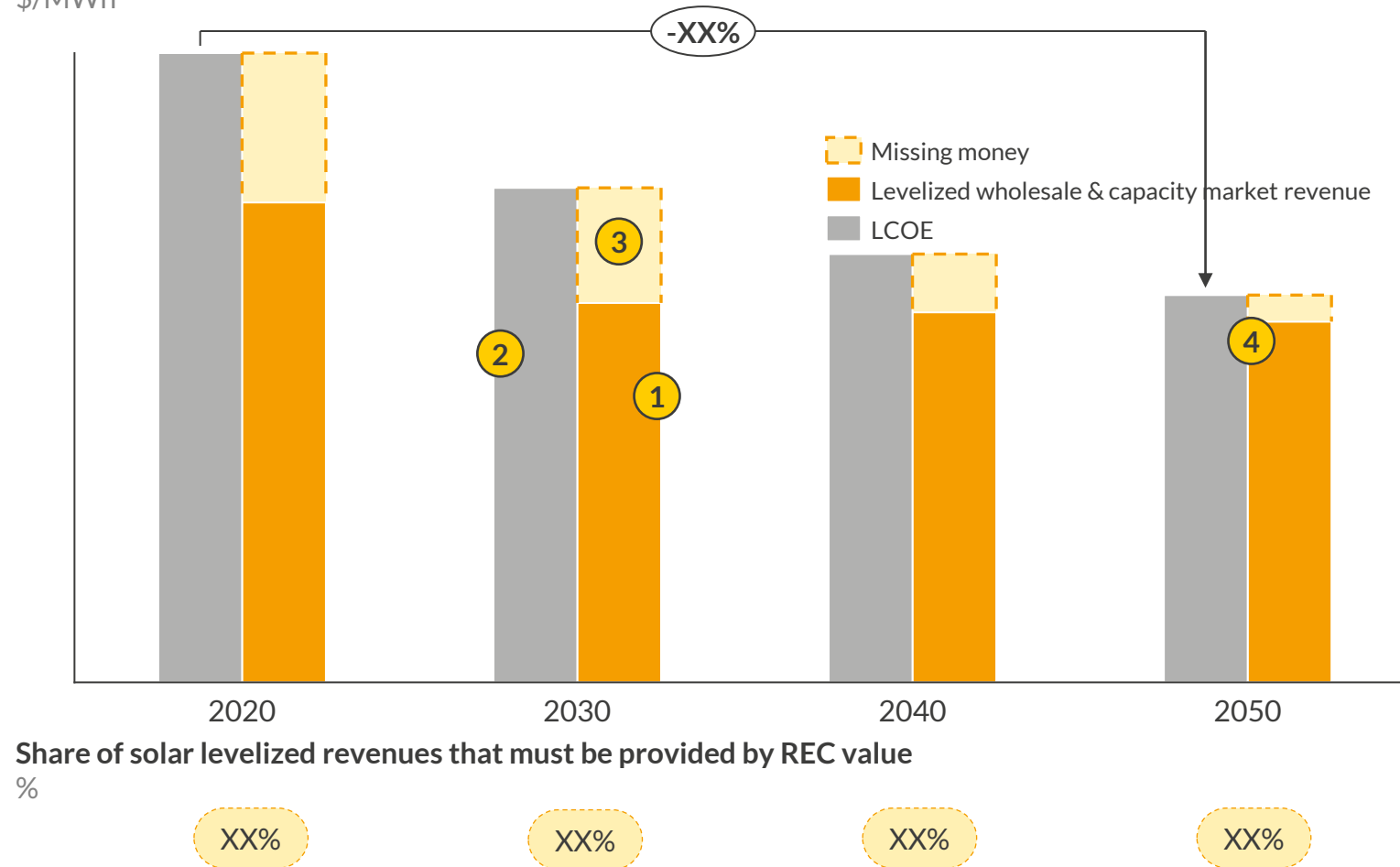
# Supply | RECs are important to the renewables business case, and will need to account for at least XX% of revenues through 2050

As the business case for renewables in PJM evolves:

- 1 Increasing cannibalization (lowering GWAs<sup>1</sup>) and strongly declining ELCCs<sup>2</sup> will cause renewables' wholesale and capacity revenues respectively to decline over time
- 2 Renewable LCOEs<sup>3</sup> will decline more quickly still, as CAPEX continues to drop through technological and production innovations
- 3 This will bring renewables' levelized merchant revenues increasingly close to LCOE, decreasing the amount of missing money that must be covered by (indirect) subsidies
- 4 Nonetheless, LROE will remain below LCOE across PJM, with on average at least XX% of levelized revenues needing to be covered — explicitly or implicitly — by REC value

As a result, it is crucial for renewables' business cases to correctly account for future REC price development in PJM, the related risks and underlying drivers.

Lifetime expected solar LCOE and LROE by build year  
\$/MWh



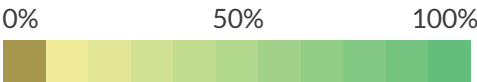
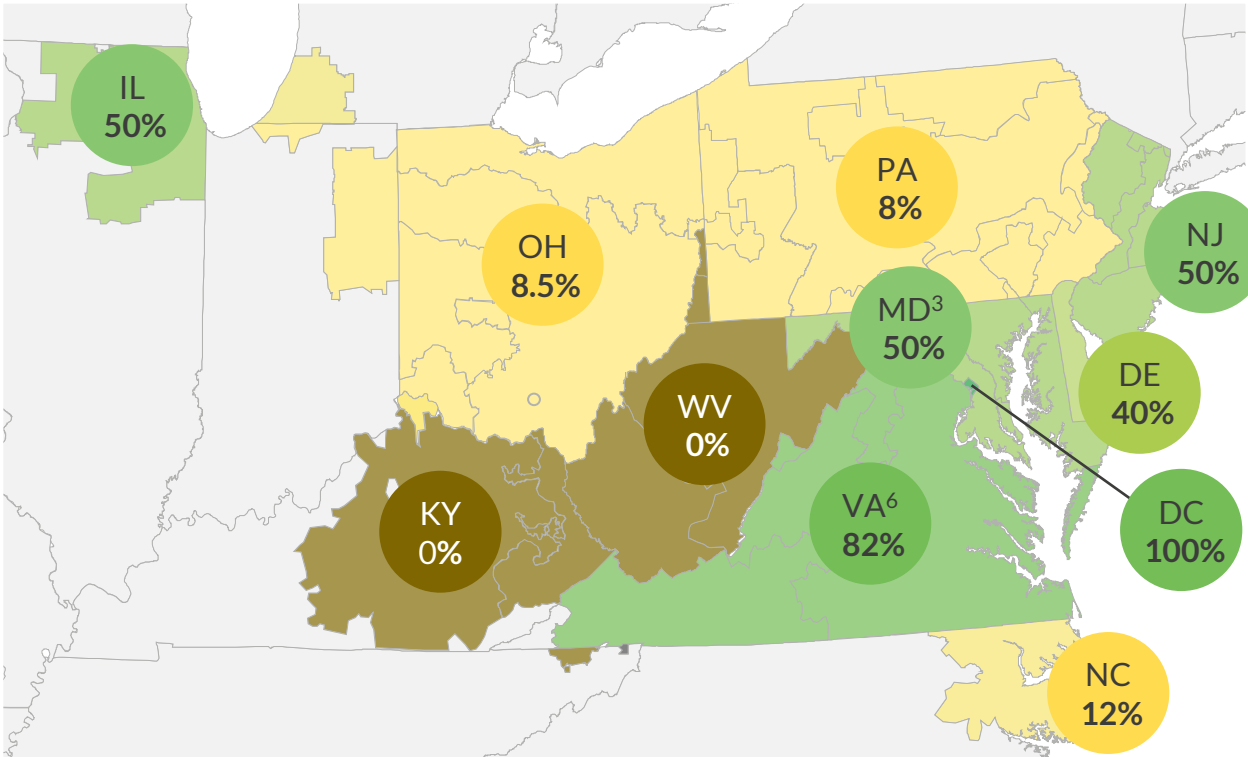
1) Generation-weighted average price 2) Effective Load Carrying Capacity, which PJM uses as renewables' derating factors in the capacity market 3) Levelized Cost of Electricity; includes tax credits



# Demand | 36% of PJM load (~360 TWh) is legally mandated to be from renewables by 2050, based on RPS targets in 9 states and D.C.

PJM states have widely varying RPS, ranging from none at all to fully decarbonized generation by 2050. Two states, Maryland and New Jersey, have the ambition to achieve carbon neutrality by 2050 or earlier, but have not translated this into corresponding RPS targets. Aurora Fundamentals assumes only currently legislated RPS.

State effective “primary”<sup>1</sup> RPS targets by 2050  
% of load to be met using RES by 2050



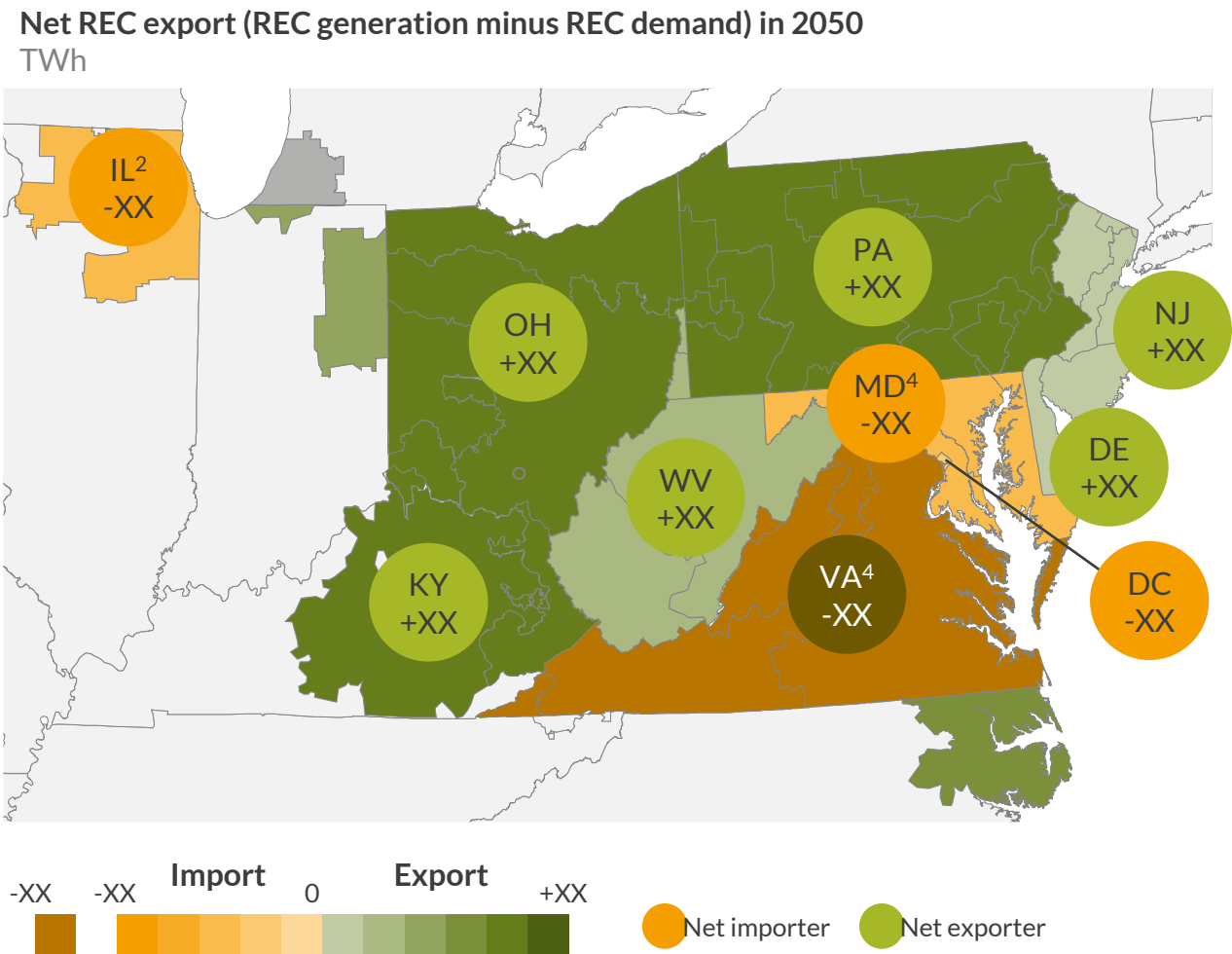
| State           | Effective LSE REC demand to satisfy RPS (2050), TWh | Comments                                       |
|-----------------|---|--|
| DC              | 2 16  | 100% RPS by 2032                               |
| DE              | 2 7   |  |
| IL              | 70  | recently raised in 2021 law                    |
| IN              |   | participation in CPS <sup>2</sup> is voluntary |
| KY              |   | no RPS   |
| MD              | 15 53   | likely to be raised in 2023 <sup>4</sup>       |
| MI              | 1   | less than 3% of MI's load in PJM <sup>3</sup>  |
| NC              | 2   |  |
| NJ              | 7 56  | likely to be raised by 2030 <sup>5</sup>       |
| OH              | 13  | reduced in 2019 by HB6                         |
| PA              | 1 13  | Alternative Energy Portfolio Std.              |
| VA <sup>6</sup> | 134   | RPS for load net nuclear gen.                  |
| WV              |   | no RPS   |
| Total           | 363 TWh   |  |

■ Tier I renewable (wind, solar PV, and others, depending on state) ■ Solar carveout<sup>7</sup>

1) Tier 1 or equivalent. 2) Clean Portfolio Standard. No utilities in IN currently participate. 3) Only 3% of MI's population lives in PJM and most industry is concentrated around Detroit in the east. 4) MD's SB 528 obliges that a plan be adopted by 2023 EOY to reduce GHG emissions by 60% by 2031. 5) NJ has ambition of carbon neutrality by 2050, but RPS targets currently only rise through 2030. 6) VA's 100% RPS by 2050 applies to load net nuclear generation. 7) Minimum amount to come from solar PV.

# Demand | State rules on fungibility will improve RPS obligations’ feasibility by allowing REC sourcing from anywhere in PJM in most cases

“Fungibility” refers to the tradability of RECs across state borders for the purposes of RPS compliance, which is a function not of the REC itself, but of the offtaker’s requirements. Most states in PJM allow Tier I RECs to be sourced from anywhere in PJM (plus states or zones bordering PJM), while some are more restrictive.



| State           | Allowed REC origin |           | REC demand and generation (2050) <sup>1</sup><br>TWh               |
|-----------------|--------------------|-----------|--|
|                 | Tier I             | Solar     |  |
| DC              | PJM                | Neighbors | <div><div></div><div></div><div></div><div></div><div></div></div> |
| DE              | PJM                | PJM       | <div><div></div><div></div><div></div><div></div><div></div></div> |
| IL <sup>2</sup> | Neighbors          | -         | <div><div></div><div></div><div></div><div></div><div></div></div> |
| IN              | -                  | -         | <div><div></div><div></div><div></div><div></div><div></div></div> |
| KY              | -                  | -         | <div><div></div><div></div><div></div><div></div><div></div></div> |
| MD <sup>4</sup> | PJM                | In-state  | <div><div></div><div></div><div></div><div></div><div></div></div> |
| MI <sup>3</sup> | PJM                | -         | <div><div></div><div></div><div></div><div></div><div></div></div> |
| NC              | PJM                | PJM       | <div><div></div><div></div><div></div><div></div><div></div></div> |
| NJ              | PJM                | In-state  | <div><div></div><div></div><div></div><div></div><div></div></div> |
| OH              | In-state           | In-state  | <div><div></div><div></div><div></div><div></div><div></div></div> |
| PA              | PJM                | In-state  | <div><div></div><div></div><div></div><div></div><div></div></div> |
| VA <sup>5</sup> | 50:50 <sup>5</sup> | -         | <div><div></div><div></div><div></div><div></div><div></div></div> |
| WV              | -                  | -         | <div><div></div><div></div><div></div><div></div><div></div></div> |
| Voluntary       | PJM                | -         | <div><div></div><div></div><div></div><div></div><div></div></div> |

1) Tier 1 or equivalent. 2) Illinois RECs must come from within the state unless approved by the Illinois Power Agency (IPA). 3) Only 3% of MI’s population lives in PJM and most industry is concentrated around Detroit in the east. 4) MD’s SB 528 obliges that a plan be adopted by 2023 EOY to reduce GHG emissions by 60% by 2031. 5) VA requires 75% of Dominion’s RECs to be procured in-state, which equals approx. 50% of overall state REC procurement  
Sources: Aurora Energy Research

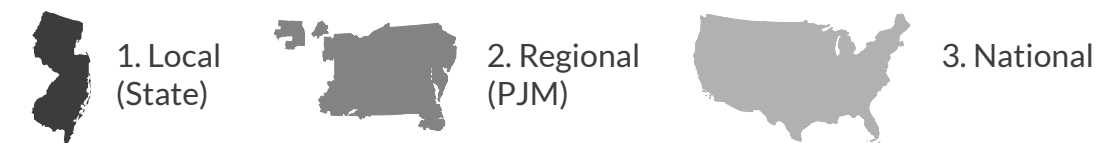
# Demand | Corporate decarbonization ambitions, primarily among large datacenter operators, drive another XX TWh of REC annual demand by 2050

Prominent business renewable energy goals, especially from large datacenters, are currently being satisfied via RECs, with a preference for local procurement

### Selected corporate decarbonization ambitions

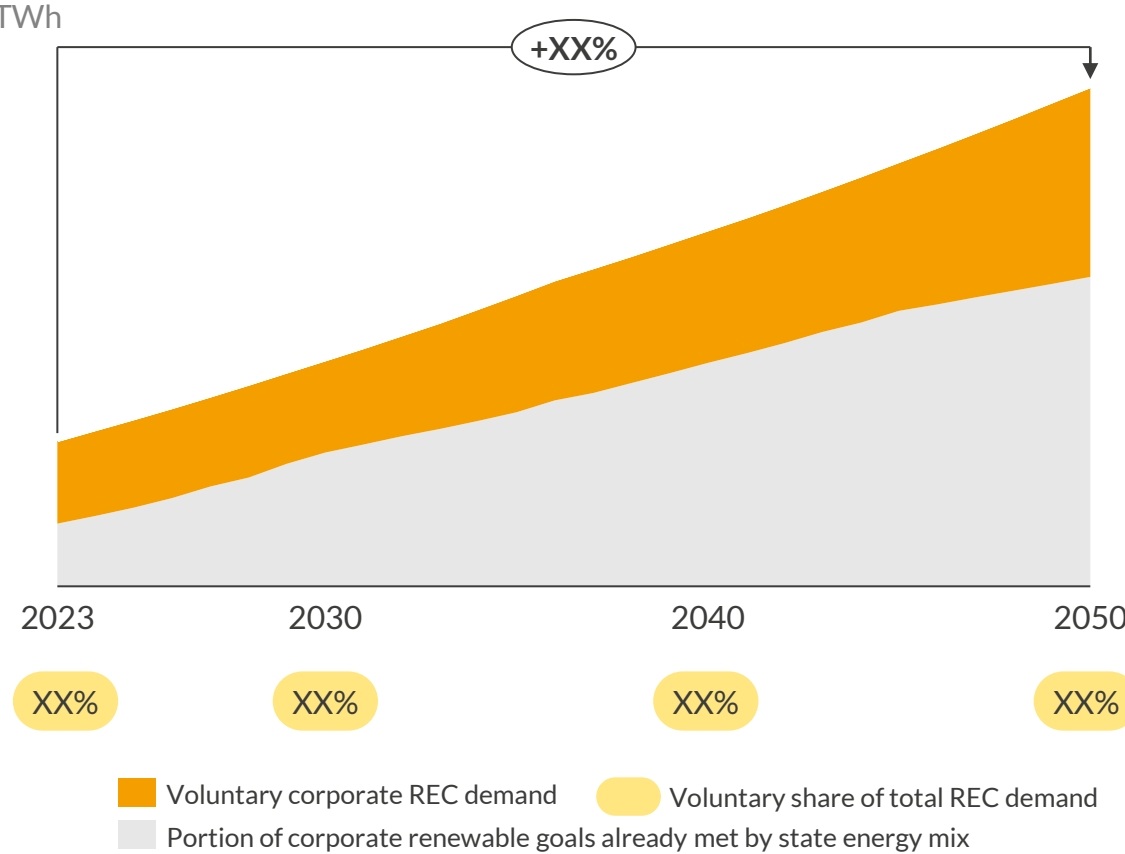
| Company                         | Estimated load in PJM, TWh/y | Ambition level | Target year       |
|---------------------------------|------------------------------|----------------|-------------------|
| Google                          | 1.6                          | 100%           | 2017              |
| Meta (Facebook)                 | 1.7                          | 100%           | 2020              |
| Digital Realty (datacenter op.) | 1.3                          | 64%            | 2021 <sup>1</sup> |
| CyrusOne (datacenter op.)       | .65                          | 100%           | 2040              |
| Microsoft                       | 1.3                          | 100%           | 2025              |

### Corporate preference for REC origin



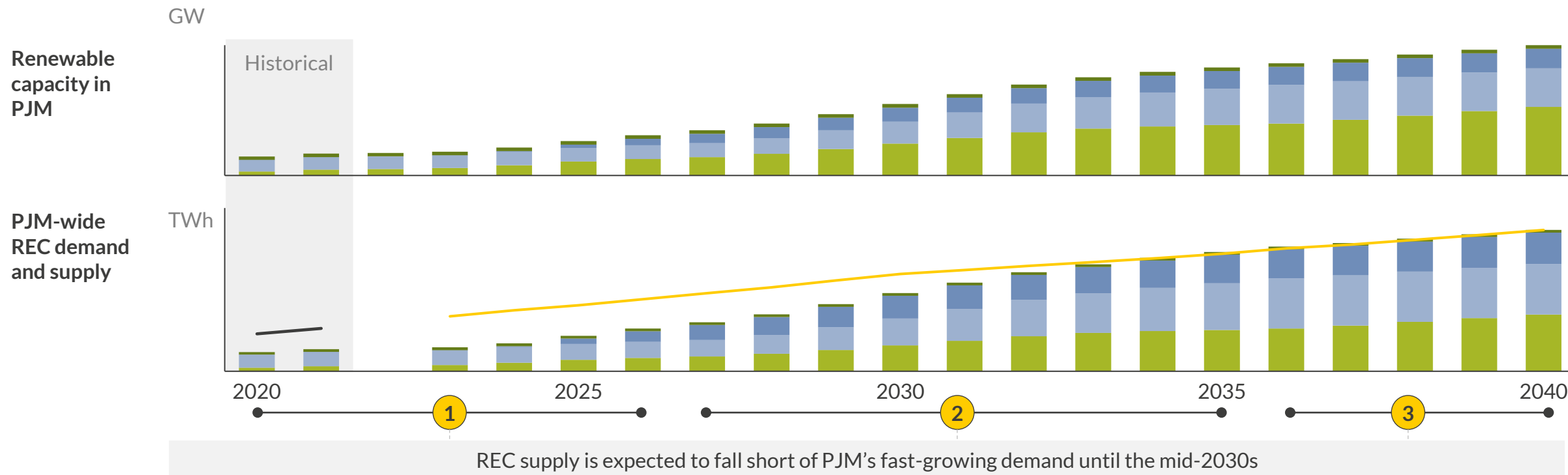
Future demand estimated based on commercial demand growth and decarbonization targets. As RPS increase, a decreasing share of “voluntary” offtakers’ targets will need to come from their own REC purchases

### Estimated voluntary REC demand from corporates in PJM



1) Digital Realty does state their ambition to reach 100% in their ESG report, however they do not list a year

# Shortfall | Early high REC prices are due primarily to a REC generation shortfall in PJM, which will last until 2035







The current **interconnection queue delay results in shortfalls**. The reform proposes:

- About 450 proposals are expected to clear in “fast lane” process by 2025
- Two “transition” review processes expected mid-2025, and mid-2026
- New applications are **reviewed starting 2026**

Build-out is expected to accelerate post PJM's interconnection queue reforms, but will still be constrained by e.g., land availability & supply chains. Considering historical build speed and future acceleration, Aurora estimates that up to **ca. XX GW of solar PV and XX GW of onshore wind capacity** can be built per year.

By the mid-2030s, renewable capacity is expected to have risen enough for **REC supply to match demand**.

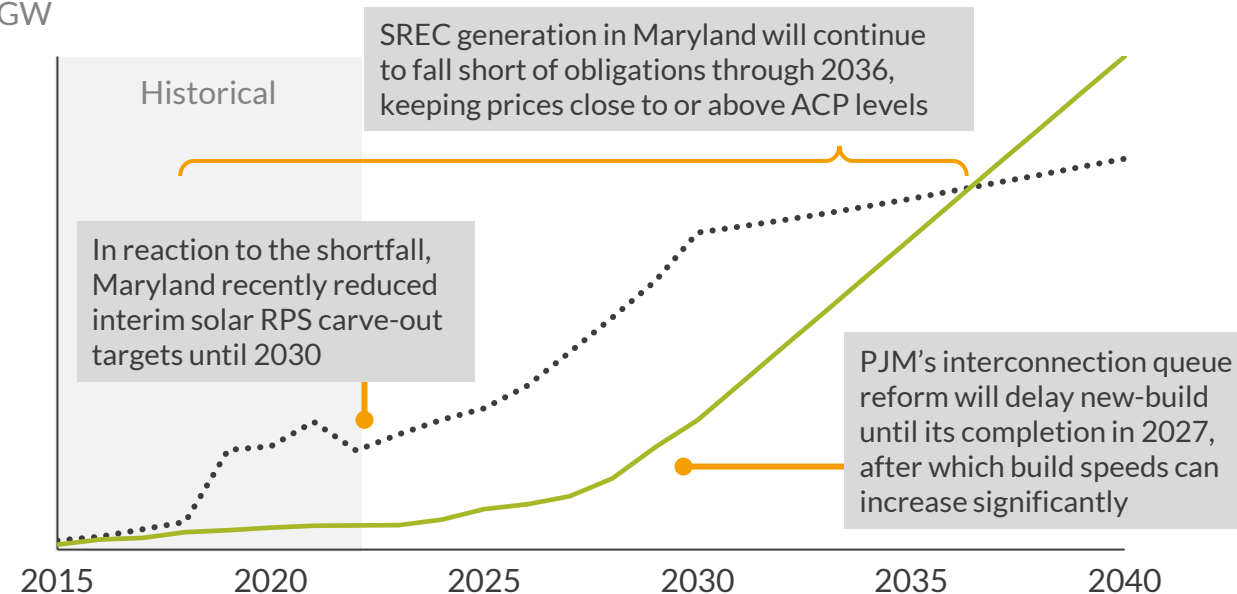
 Solar  Onshore wind  Offshore wind  Other  REC demand

1) Renewables capacity includes solar PV, onshore and offshore wind, run-of-river hydro, and biomass

# Shortfall | Such dynamics are seen, for example, in Maryland, where SREC prices are currently \$40-\$60, abutting its ACP

SREC generation shortfalls in Maryland will persist into the 2030s

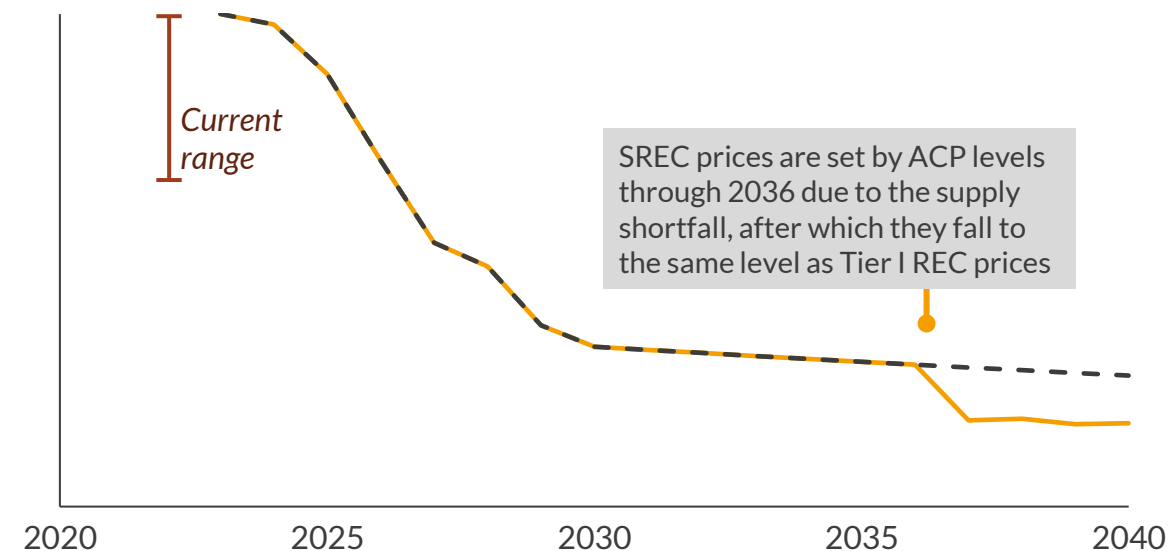
## Effective RPS solar carve-out obligation and eligible generation capacity GW



- Due to Maryland's ambitious solar RPS carveout yet slow solar build-out, as well as the stipulation that compliance RECs effectively come from in-state, SREC generation has fallen short of RPS requirements since at least 2019
- Despite Maryland recently lowering interim solar RPS carve-out targets, this shortfall will persist until around 2036, as targets nonetheless rise continuously yet solar build lags behind, impeded by PJM's interconnection queue reform process, expected to finish by 2027

This has driven up prices, which will persist until the shortfall is closed

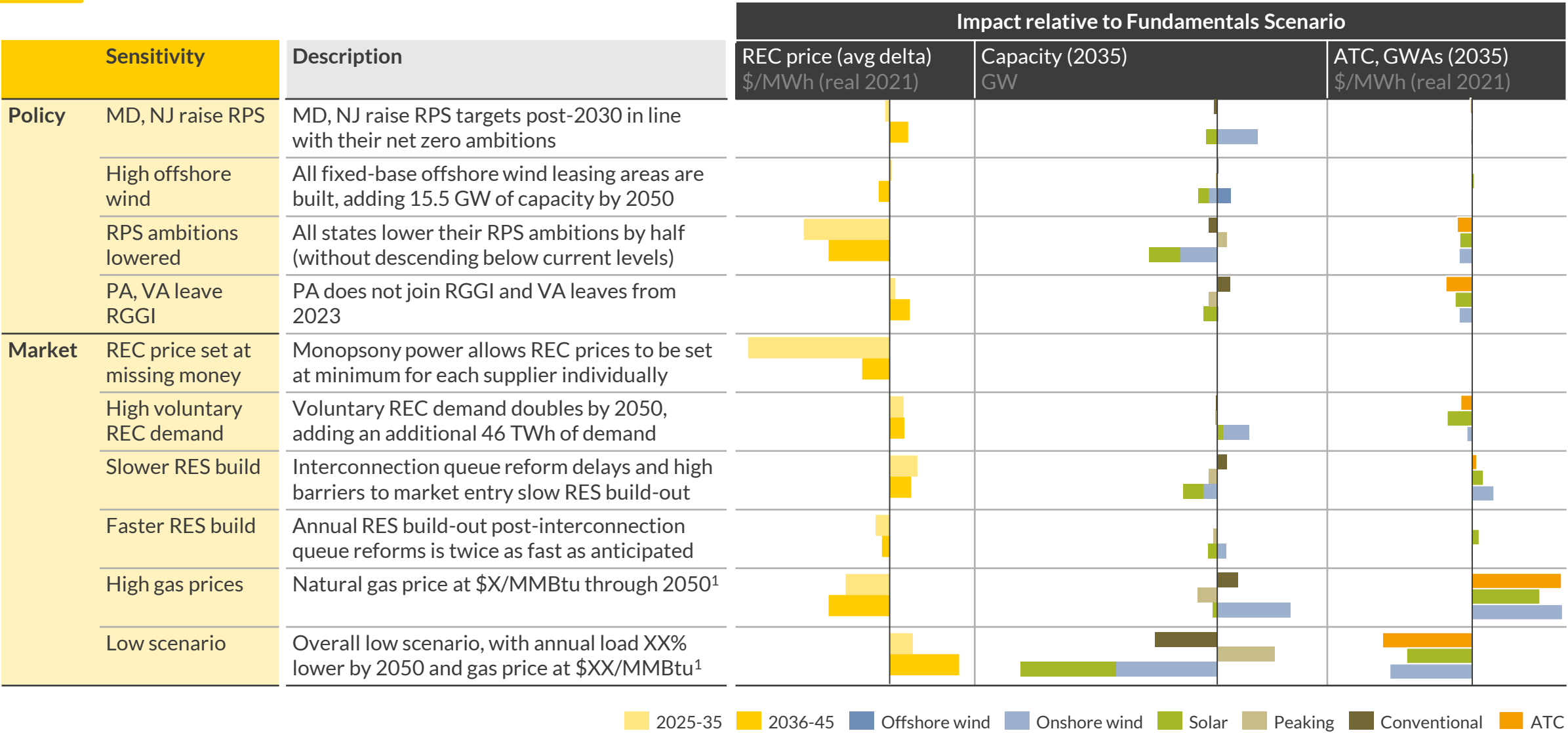
## Forecasted average SREC price and REC price offered by newbuild assets \$/MWh (real 2021)



- This persisting shortfall—currently pushing prices up to \$XX-\$XX—will keep SREC prices at carveout ACP levels, although these will drop to below \$XX by 2030
- Demand for Maryland's SRECs has been increased further still recently by high voluntary demand for RECs, exacerbating the supply shortfall

•• sRPS obligation — Solar capacity — Maryland SREC price — — Solar carve-out ACP

# Key uncertainties surround REC policy and market dynamics and may impact REC prices around 2040 by up to \$-X/MWh



1) Henry Hub. Gas hubs in PJM see both structural and seasonal delta to Henry Hub.



# Aurora Service Offering





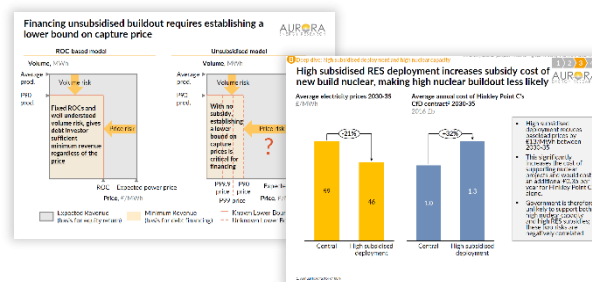
# US Power Market Forecast Services: Key market analysis and forecasts for all participants in the PJM, CAISO, and ERCOT power market (+ new markets soon)

## Quarterly data and market reports

- **All the latest trends and forecasts** – recent market developments and full policy and technology outlook
- **Key market outcomes to 2050** – monthly price forecasts, capacity and generation mix to 2050
- **Regional and technological detail** – prices by hub and generation by load zone
- **Scenario analysis** – 6 consistent scenarios that reflect key uncertainties
- **Investment case analysis** – costs and revenue streams under different scenarios
- **Data in Excel** – all forecast data easily downloadable in Excel format
- **Data online** – view forecasts and historical data on our online EOS platform

## Quarterly strategic insight reports and group meetings

- **In-depth thematic reports** on topical issues for the renewables industry
- **Four multi-client roundtable discussions** per year in person / virtual to network and discuss hot topics
- **Topics based on client demand** e.g.
  - *REC pricing and impact on power markets*
  - *Investment cases for battery storage and flex assets*
  - *Regional prices and grid bottlenecks*
  - *Implications of market reform for power pricing*
  - *Capacity Market short & long-term price dynamics*



## Regular interaction through workshops and bilateral support

- **Bilateral workshops** to discuss specific issues on the market that are of particular interest to you
- **Ongoing support** from our experts to address any questions about Aurora's forecasts or the market more broadly – save time by speaking with one of our experts



**All intelligence for a successful business, based on bankable price forecasts**



## Get in touch with us!

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