

# Flexible Energy Add-on

Available in MISO & PJM by December 2024



# Agenda

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## I. Overview of the Flexible Energy Add-on Service

## II. Multi-client Study: Timeline & Scenarios

## III. Sample Content

1. MISO

2. PJM

## IV. Next Steps

## V. Appendix: About Aurora



# Multi-client studies for Flex Add-on in PJM and MISO: What to know

## Common Questions

## Answers

What is a multi-client study?

- Aurora typically undertakes a collaborative effort when developing new services to test our own assumptions and ensure product relevance. In this instance, the battery-focused Flexible Energy Add-on service for PJM and MISO will be developed via two multi-client studies.

What does the Flexible Energy Add-on include?

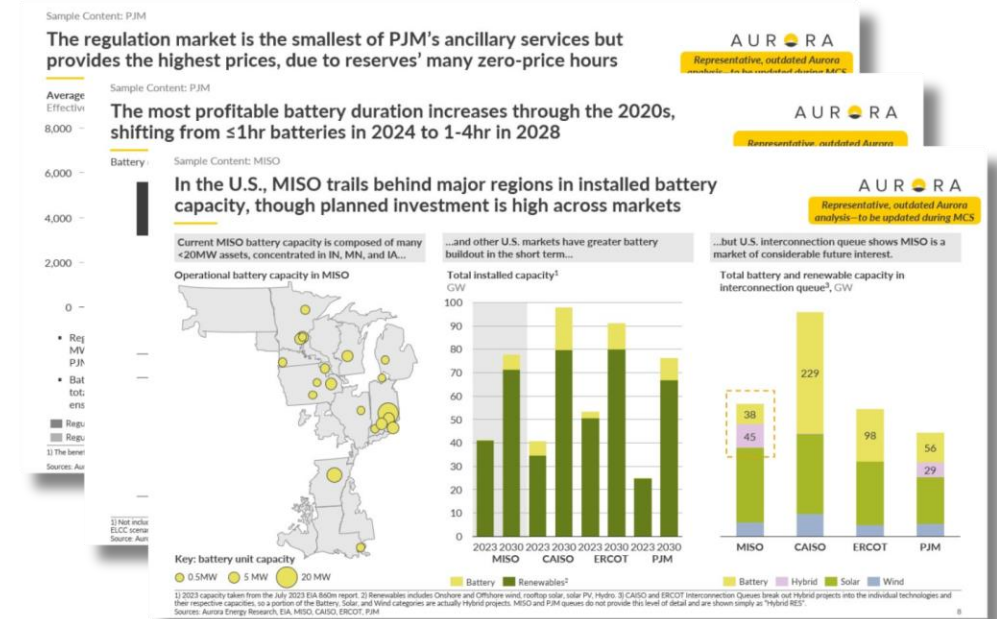
- Aurora's outlook for battery storage in the market, including granular price forecasts of Day-Ahead, Real-Time, Capacity and Ancillary Services markets, as well as detailed margin forecasts and other parameters for quick benchmarking of battery investment cases.

What does a multi-client study (MCS) entail?

- Relevant participants will engage in monthly bilateral check-ins with the Aurora research teams to discuss preliminary views.
- During these sessions, participants will provide input to make sure Aurora is prioritizing the most relevant topics for the market as well as to test Aurora's approach/views to major sensitivities.

What do I gain from participation?

- Participants will be early subscribers to our Flexible Energy Add-on rolling subscription for PJM and/or MISO, receiving access to all preliminary forecast materials and data ahead of the full service launches and enjoying the privilege of shaping the new services.



# Flexible Energy Add-on Service: Provides detailed power market analysis and investment case data for battery storage

## Flexible Energy Add-on

Go deep on battery economics and market fundamentals to build robust investment cases. Flex includes the following:

- 1 **Granular price forecasts and data** including Day-Ahead, Real-Time, Capacity and Ancillary Services
- 2 **40+ battery investment cases** with standard input parameters for quick benchmarking analysis
- 3 **Ongoing support** from our dedicated teams to help you navigate analysis

## Representative Use Cases:

- Investor seeking to understand detailed battery economics and sensitivities impacting revenues, gross margin, IRR, NPV
- Developer seeking to understand each markets' flexible asset market landscape and regulation before entering
- Asset owners reviewing historical performance to benchmark and understand competitive landscape

## Flexible Add-on Subscription Deliverables:

### 1 Granular Forecast Reports & Data

- Historical wholesale and ancillary services data
- **Detailed forecasts** of hourly Day-Ahead and Ancillary Services prices, plus 5-min Real-Time prices for each of the selected hubs/control zones
- **Key sensitivity analysis** (Central, High, Low) to 2050

### 2 Battery Investment Cases

- Detailed data of 40+ **battery investment cases** that Aurora has modeled
- **Financial metrics** (CAPEX, margins, IRRs, and NPVs) for investment cases
- **Assessment of Economics** given different battery durations and entry years across selected hubs/control zones
- Investment data provided **out to 2050**

### 3 Ongoing Analyst Support

- **Bilateral workshops** to discuss specific content pertinent to the Flex Add-on
- **Ongoing availability** (access to market experts, analysts) to address any questions

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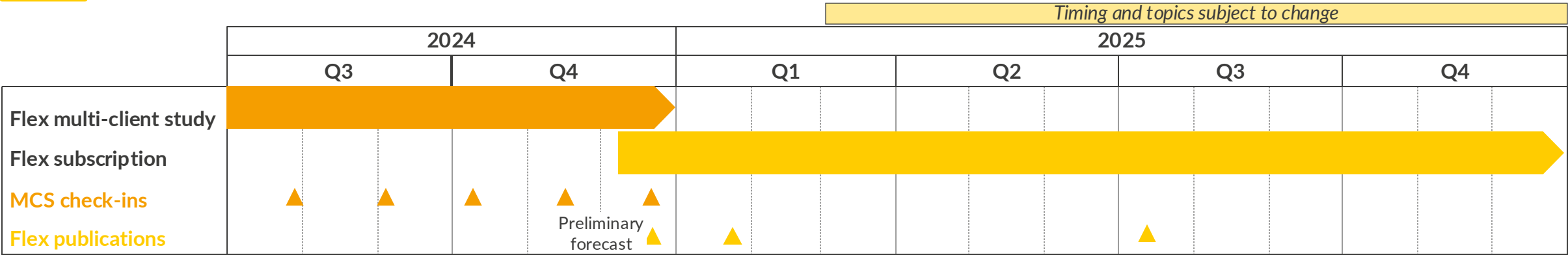
2. PJM

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# Each Flex multi-client study offers early access to collaboration and co-creation before release of the full subscription product



Deliverables

- Aurora’s outlook for battery storage, containing granular data at the settlement period level and detailed margin forecasts for 40+ investment cases. Regions for deep-dives will be determined via input from MCS group. Coverage of other technologies pending participant interest. All deliverables will be in PowerPoint and Excel backup.
- Bilateral kick-off and follow-up with each participant to test assumptions, review preliminary results, and receive input on priority topics.
- Access to first year of full subscription coverage:
  - Biannual Flexible Energy forecasts beginning in Q4 2024 (PowerPoint and Excel), including catch-up call.
  - Granular forecast databook and investment cases databook (selected entry years) included with each Flexible Energy report.

Participants

- The study will bring together US and international utilities, regulatory players, developers, investors, and banks. Regular interaction upon signing up, both bilaterally and as a group.

Project timeline

- The study will run Q3 and Q4 2024, with roll-over into regular service thereafter; after 2025, option to continue regular coverage.

# Aurora will deliver 3 scenarios under the Flexible Energy Add-on product

A U R  R A

*Representative only: Outdated and redacted analysis –to be updated during MCS*

## Central

Considers current policies alongside our internally consistent central view of technological change and commodity prices. Assumes a continuation of federal Tax Credits at lower levels after IRA expiration in 2035.

## Low

Represents a downside case, incorporating low underlying demand and low commodity prices, reflecting an overall decline in BESS economics. This envisages a world with slower overall GDP and population growth.

## High

A long-term upside case for prices, this scenario considers higher commodity prices and demand, reflecting an overall improvement in BESS economics. Higher global GDP increases demand for commodities, while demand grows at an accelerated pace due to higher rate of population and industrial demand growth.

\*Scenarios will be customized to battery upside / downside conditions.

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# In the U.S., MISO trails behind major regions in installed battery capacity, though planned investment is high across markets

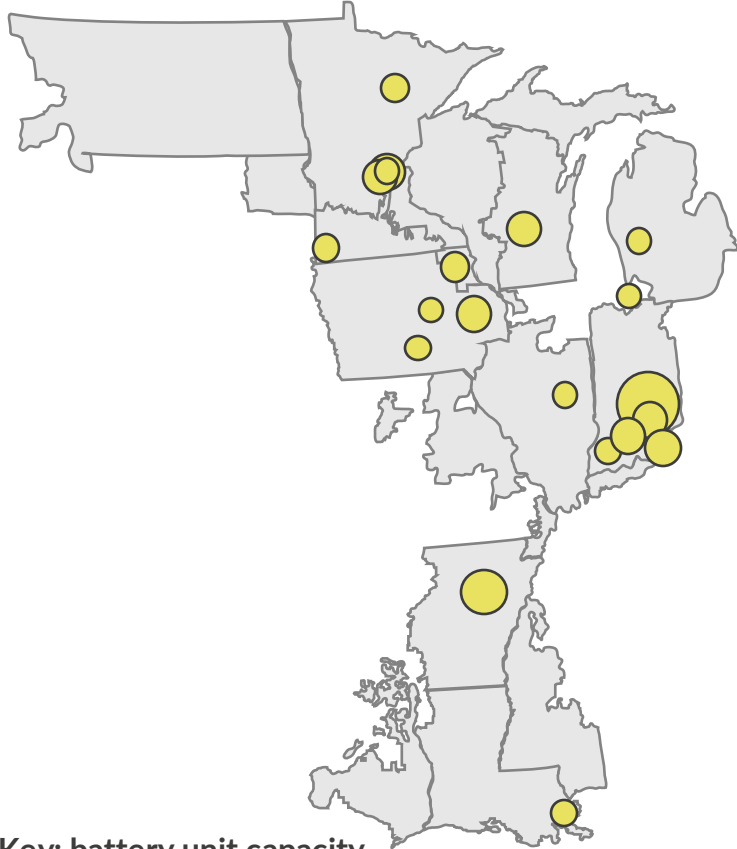
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Current MISO battery capacity is composed of many <20MW assets, concentrated in IN, MN, and IA...

...and other U.S. markets have greater battery buildout in the short term...

...but U.S. interconnection queue shows MISO is a market of considerable future interest.

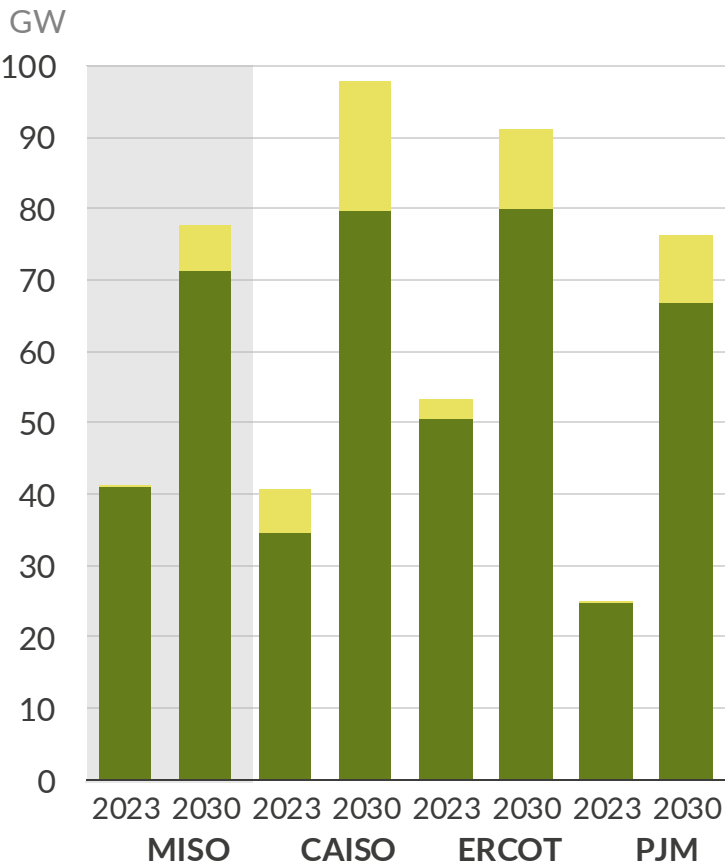
Operational battery capacity in MISO



Key: battery unit capacity



Total installed capacity<sup>1</sup>



Battery Renewables<sup>2</sup>

Total battery and renewable capacity in interconnection queue<sup>3</sup>, GW



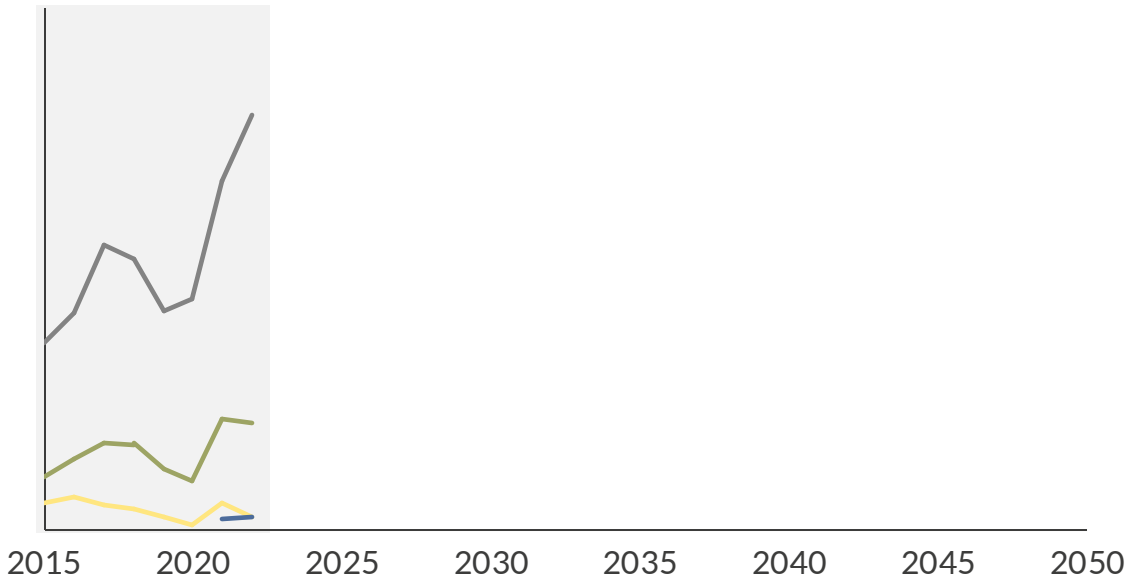
Battery Hybrid Solar Wind

1) 2023 capacity taken from the July 2023 EIA 860m report. 2) Renewables includes Onshore and Offshore wind, rooftop solar, solar PV, Hydro. 3) CAISO and ERCOT Interconnection Queues break out Hybrid projects into the individual technologies and their respective capacities, so a portion of the Battery, Solar, and Wind categories are actually Hybrid projects. MISO and PJM queues do not provide this level of detail and are shown simply as "Hybrid RES".

# Regulating Reserve prices are expected to decline with increasing battery penetration before 2035

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Yearly average ancillary service clearing prices  
\$/MW/h (real 2022)



Battery capacity  
GW

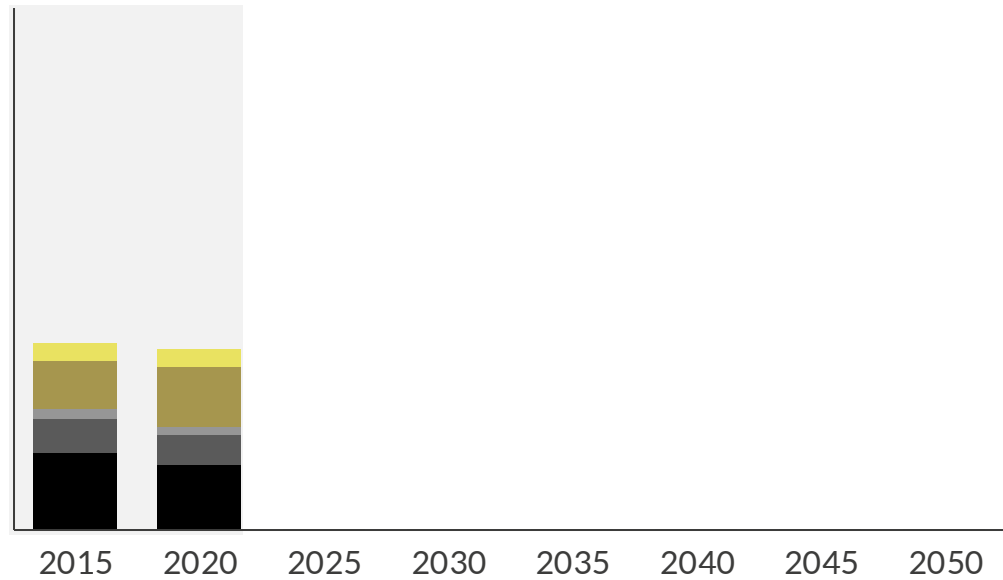


- Anticipated changes indicate a XX% decrease in Regulating Reserve prices between 2025 and 2035 due to the significant growth in installed battery capacity, escalating from less than XXGW to nearly XXGW.

— Regulating — Spinning — Supplemental — STR¹

1) Short-term Reserve.

Technology mix of Regulating Reserve  
MW



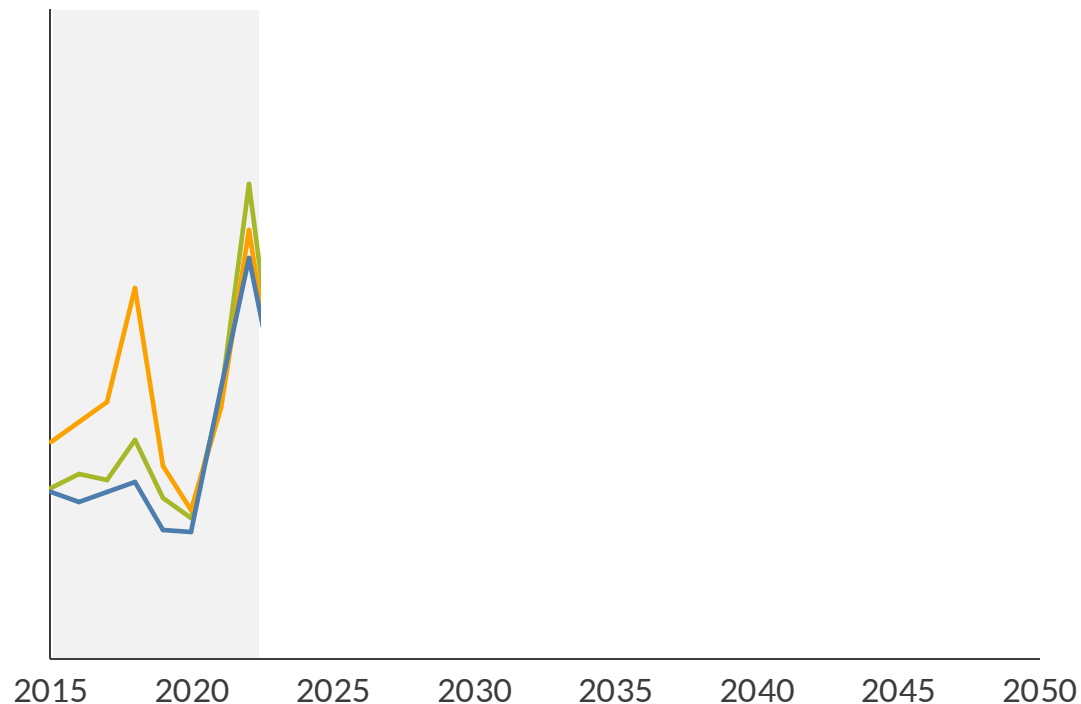
- Batteries will clear more than XX% of the Regulation procurement target beyond 2025, as thermal technologies phase out of Regulating Reserve.
- After 2035, batteries will clear over XX% of the Regulation procurement targets while excess battery capacity restrains Regulating Reserve prices.

■ Battery storage ■ Peaking ■ Other thermal ■ Gas CCGT ■ Coal

# Spreads rapidly increase between 2025 and 2030, in line with intensifying duck curves, with the highest spreads observed in Louisiana

*Representative only: Outdated and redacted analysis –to be updated during MCS*

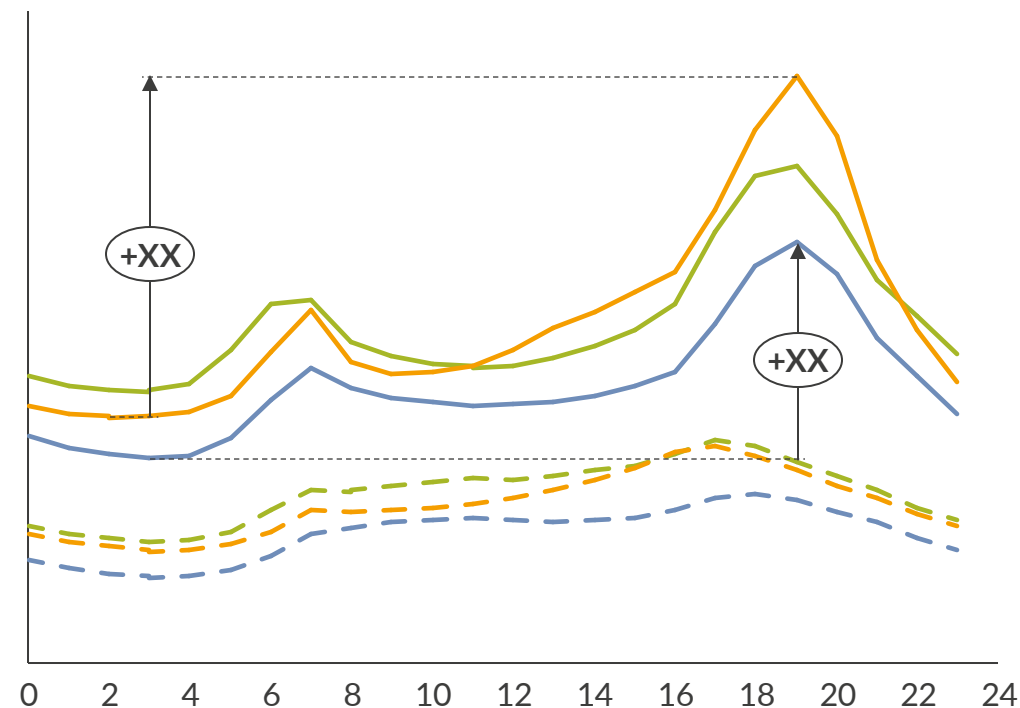
Yearly average day-ahead zonal TB1 price spreads  
\$/MWh (real 2022)



- The price spreads in 3 selected regions increase rapidly from 2025 to 2030 mainly because of significant solar buildout during this period.
- 1-hour spreads in MISO LA exceed \$XX/MWh beyond 2030, ~\$XX/MWh higher than two other regions.

— IN — LA — MN

Average daily shape forecast  
\$/MWh (real 2022)

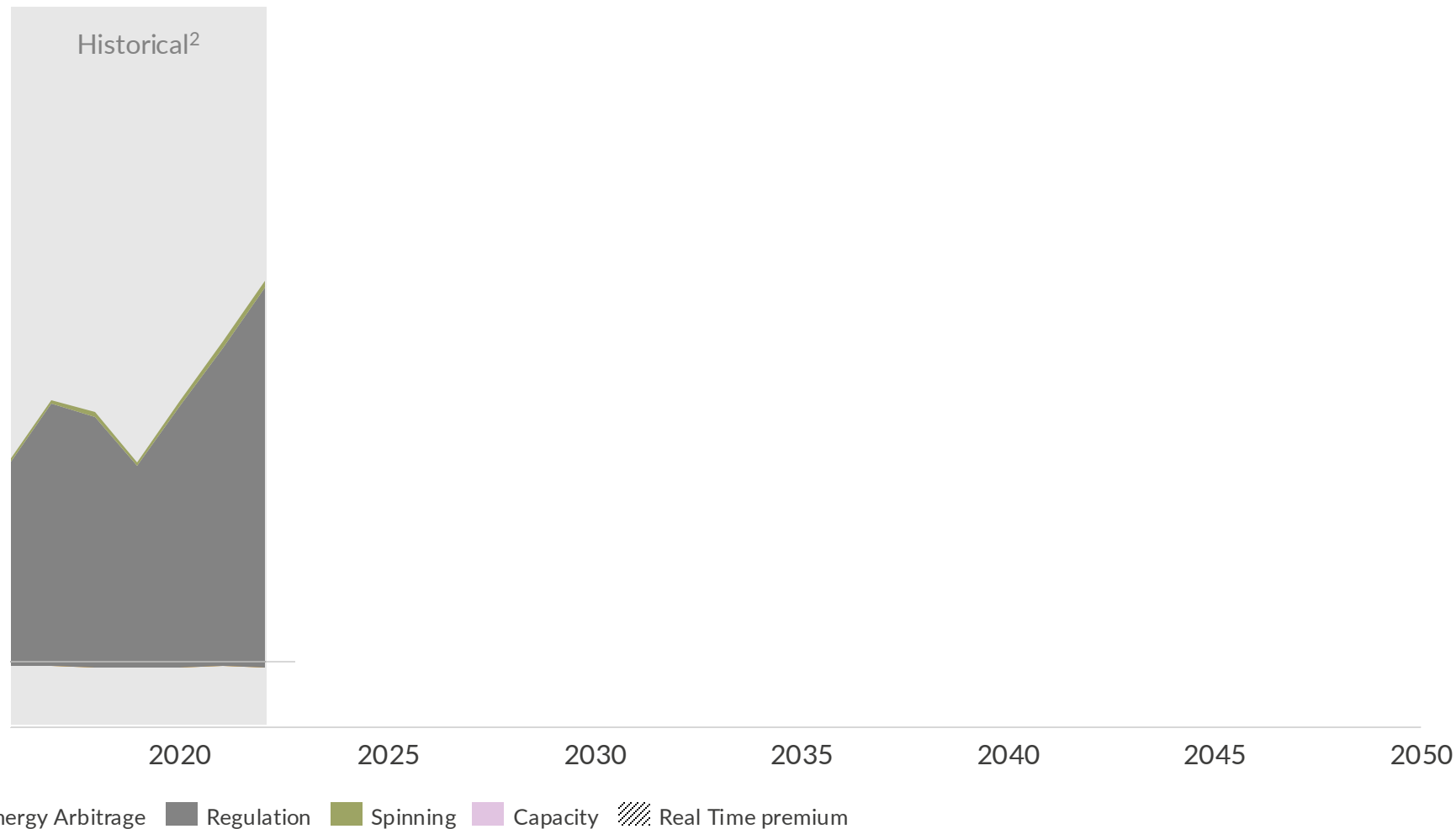


- The average daily spread of MISO LA is ~XX% higher than MISO MN and MISO IN in 2030.
- The pronounced duck curve arises from extensive solar penetration which creates large evening net load ramping requirements and elevates spreads.

— IN — LA — MN — 2030 daily shape --- 2020 daily shape

# 1-hour batteries rely on Ancillary Service revenues short-term, then shift to energy arbitrage among increased market competition

Undegraded gross margins for a 1-hour battery in MN<sup>1</sup>  
\$/kW/year (real 2022)



1) Targeting a 1x per day cycle rate. 2) Backcast results using Aurora's Chronos battery dispatch engine against historical Regulation, Spinning, and Energy prices. 2020 is interpolated.

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## Outlook for MN battery gross margins

- 1-hour battery gross margins in MN fall from \$XX/kW/y in 2024 to ~\$XX/kW/y by 2035.
- Regulation and Spinning revenues decline as more batteries come online, oversaturating the market and decreasing individual batteries' probability of clearing.
- Arbitrage revenues start negative until 2025 as the trader simply uses it to charge while primarily selling capacity into the Regulation market. By 2035, they've increased to ~\$XX/kW/y, as thermal retirements increase spread value and Ancillary Services become saturated.
- 1-hour batteries can participate in the PRA at 25% capacity. This capacity revenue provides up to \$XX/kW/y by 2028 in MN.

# Cost declines and increasing PRA revenues make 4-hour batteries most profitable in the long-term

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The most profitable battery business cases in MISO will be those that can capitalize on larger tax credits and higher PRA revenues: the 4-hour battery in IN does this best and earns an XX% IRR by 2029 entry year; batteries in MN, while they see the highest PRA payments, have lower availability of ITC adders; batteries in LA have high Energy Community ITC adder potential but do not see substantial early PRA revenue.

Entry Year	Scenario	Duration	Present Value of Gross Margins <sup>1</sup> (\$/kW)			IRR <sup>1</sup> (%)			Payback Period <sup>1</sup> (yrs)		
			MN	IN	LA	MN	IN	LA	MN	IN	LA
2025	Central	1-hour	\$XX	\$XX	\$XX	XX%	XX%	XX%	XX	XX	XX
		4-hour	\$XX	\$XX	\$XX	XX%	XX%	XX%	XX	XX	XX
2029	Central	1-hour	\$XX	\$XX	\$XX	XX%	XX%	XX%	XX	XX	XX
		4-hour	\$XX	\$XX	\$XX	XX%	XX%	XX%	XX	XX	XX

1) Assumptions: CAPEX due in year preceding first operational year, 1 cycle per day, 20-year lifetime, CAPEX of \$452/kW (1-hour) and \$1029/kW (4-hour), FOM of \$11/kW/y (1-hour) and \$19/kW/year (4-hour), including a 27% (for MN) or 36% (for IN and LA) net ITC. Cashflows all discounted at 11%. Includes a premium from partial participation in the RT market and the relative spread value in the RT versus DA market. 4-hour battery ELCCs to fall from 95% in 2024 to 57% by 2050.  
Source: Aurora Energy Research

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# In the USA, PJM trails behind major regions in installed battery capacity, though planned investment is high across markets

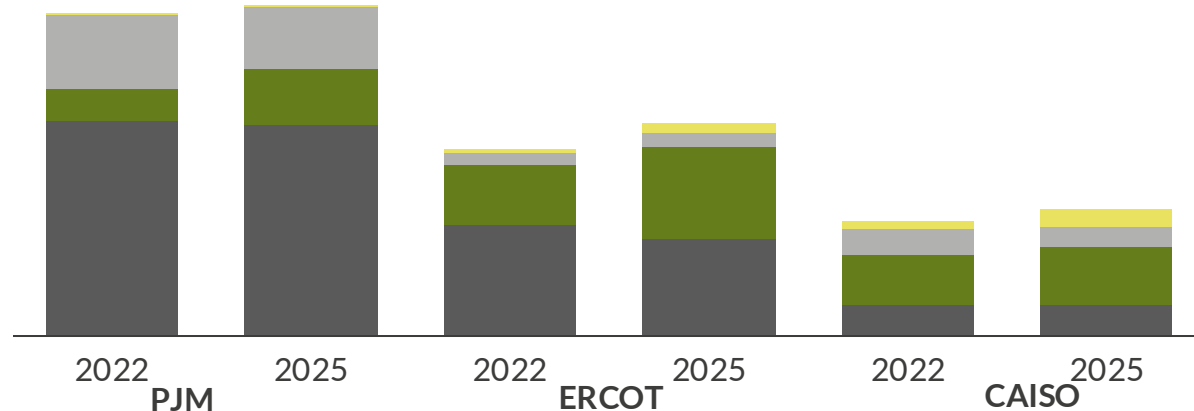
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Other U.S. markets have greater existing battery storage and buildout in the short term, both nominally and as a proportion of the total capacity

## Total installed capacity

GW



## Primary drivers of strong battery build-out:

### ERCOT

- Significant ancillary procurement, supported by high levels of renewables and load increase
- Wholesale scarcity pricing leads to arbitrage opportunities

### CAISO

- Mandated energy storage procurement has increased financial incentives
- Resource adequacy payments have enabled 4-hour+ investment
- Early solar adoption increased the need for flexible resources

■ Batteries ■ Flex<sup>1</sup> ■ Renewables<sup>2</sup> ■ Baseload<sup>3</sup>

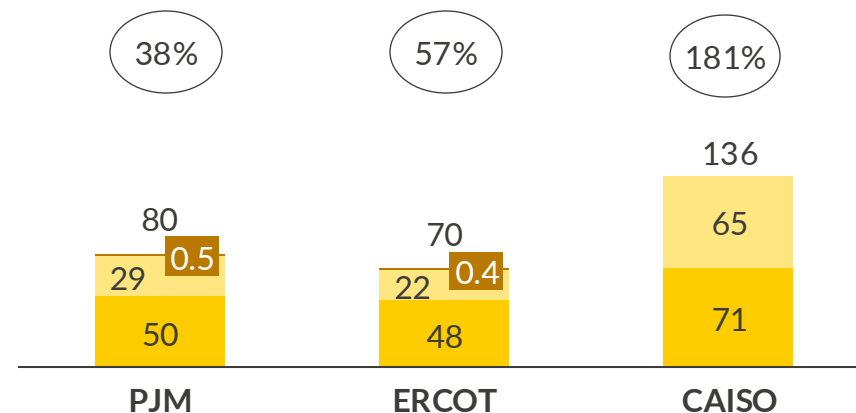
1) Flex includes OCGTs, reciprocating engines, DSR. 2) Renewables include solar, onshore wind, offshore wind, biomass, and hydro. 3) Baseload includes Nuclear, coal, Gas CCGT, Gas CCS, and other baseload thermal.

Capacity of battery projects in interconnection queues is consistently high, representing e.g., 180% of current installed capacity in CAISO

## Total battery storage capacity in interconnection queue

GW

*Batteries in the interconnection queue as percentage of 2022 total market installed capacity*



- Current interest, as demonstrated in interconnection queues per market, remains consistently high in ERCOT & CAISO – markets that have seen early battery build-out
- Despite relatively lower investment to date, capacity in PJM's queue is comparable to these historically more active markets

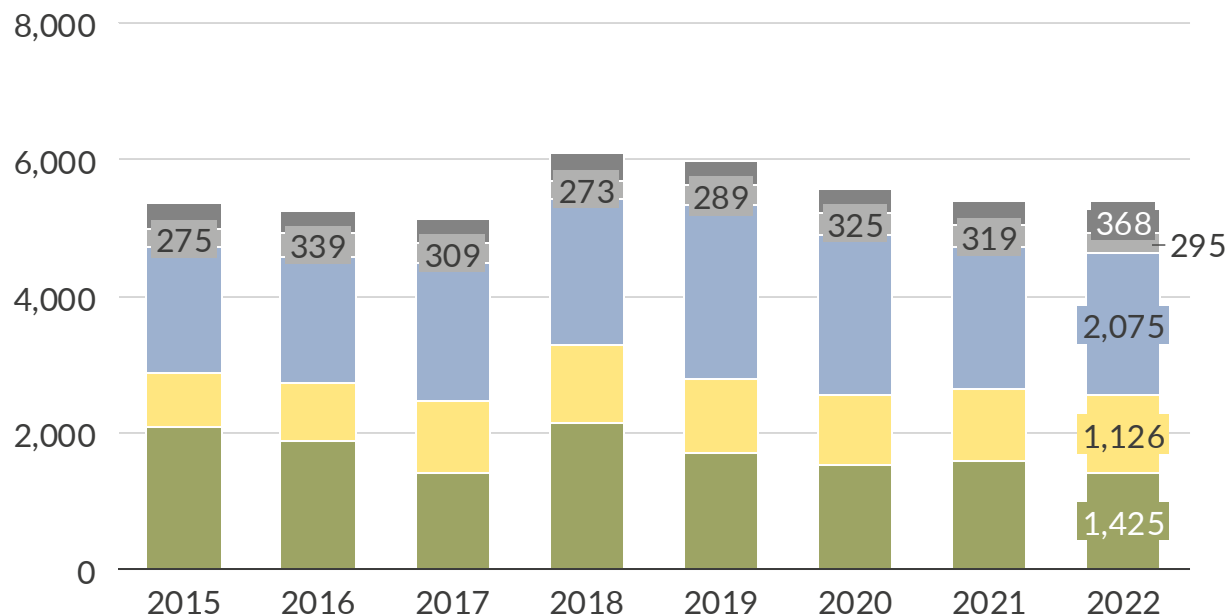
■ Standalone ■ Solar co-located ■ Wind co-located

# The regulation market is the smallest of PJM's ancillary services but provides the highest prices, due to reserves' many zero-price hours

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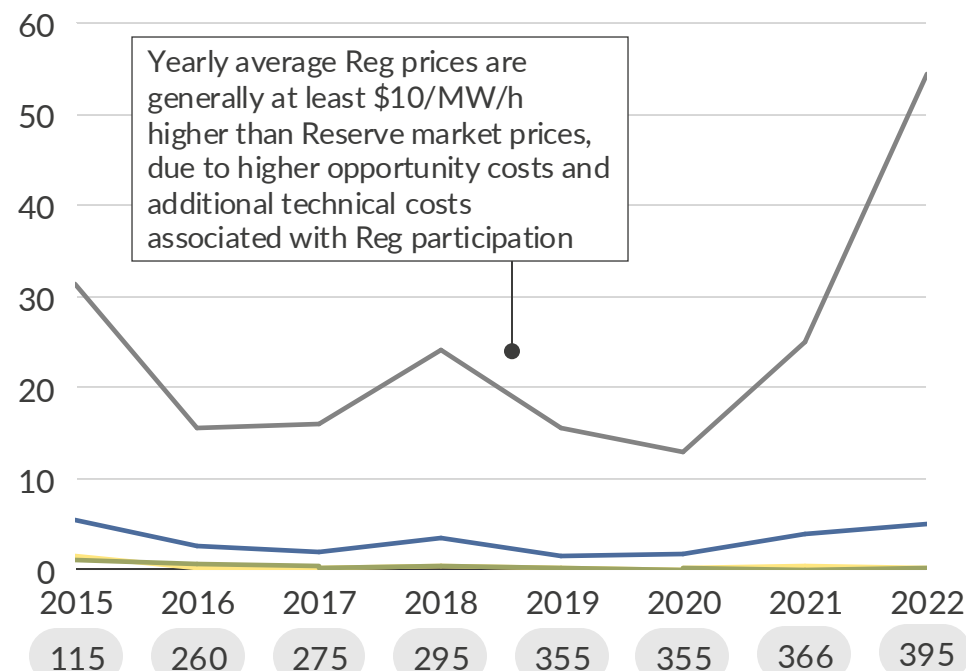
Average annual total procured ancillary services  
Effective MW/h



- Regulation market procurement targets toggle between 525 and 800 effective MW (avg 662 MW/year) combined total between **RegA** and **RegD** – targets set by PJM – depending on the time of day<sup>1</sup>
- Batteries participate solely in **RegD**, which is designed to make up around 40%<sup>1</sup> of total regulation market procurement (about 210 to 320 effective MW). This ensures ~60% is reserved for other technologies such as CCGT

■ Regulation A    ■ Primary Sync Reserve    ■ Secondary Reserve (excl. Primary)  
■ Regulation D    ■ Primary Non-Sync Reserve

Average AS market price  
\$/MW/h (real 2021)



- Reserve markets clear below \$5/MW/h on average, due to a combination of low bids and a high proportion of zero-price hours, caused by low opportunity costs (due to unused capacity being available for economic reasons)
- Average regulation clearing prices range from \$10 to \$40/MW/h. Thermal opportunity cost to participate in RegA keeps prices above \$0/MW/h

xx Battery installed capacity in PJM (MW)

1) The benefits factor is designed to apportion 40% of regulation market procurement to RegD; graph shows effective MW after PJM modelled adjustment.s

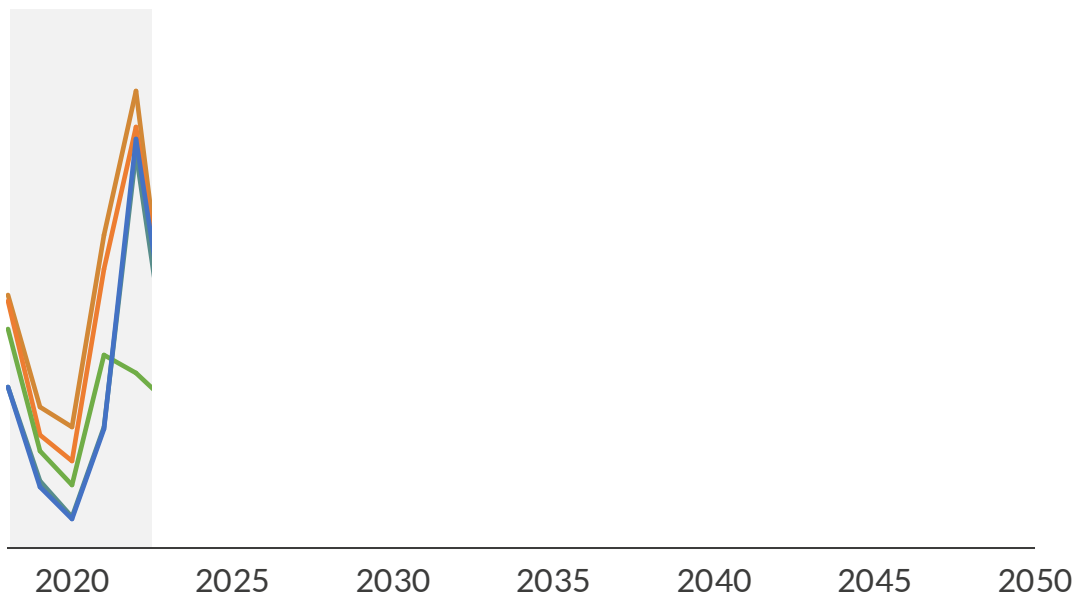


# 1-hour spreads moderately increase between 2025 – 2050, in line with rising wholesale prices, with the highest spreads seen in Dominion, MetEd, and BGE

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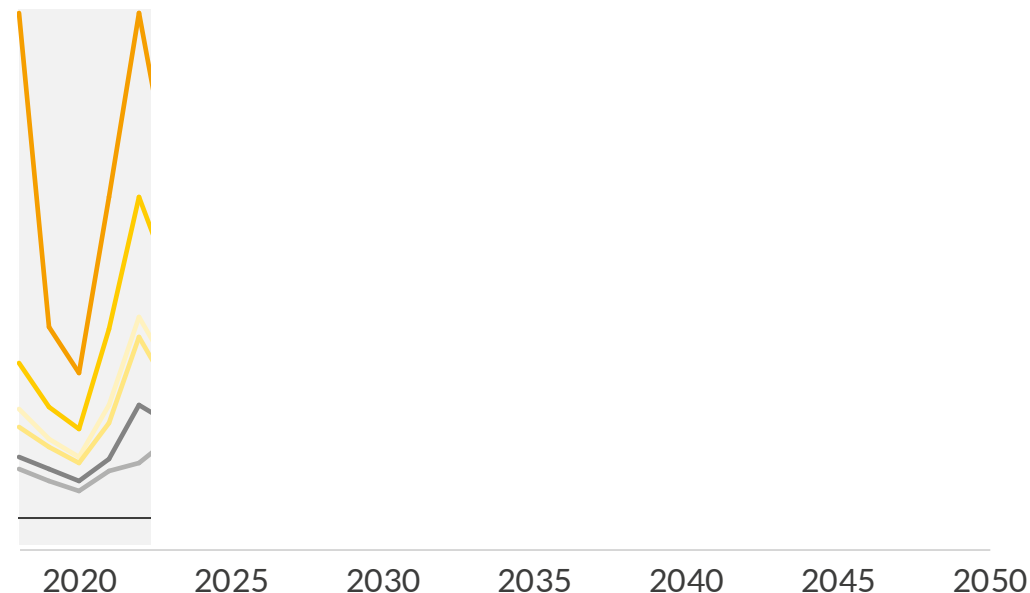
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Yearly average day-ahead zonal TB1 price spreads<sup>1</sup>  
\$/MWh (real 2021)



- 1-hour spreads in Dominion average \$XX/MWh throughout the 2030's
- The regions with the highest 1-hour spreads (Dominion, MetEd, and BGE) are an average of \$XX/MWh higher than the regions with the lowest spreads (PSEG, AEP, JCPL) between 2023 – 2030

Day-ahead price percentiles for Dominion  
\$/MWh (real 2021)



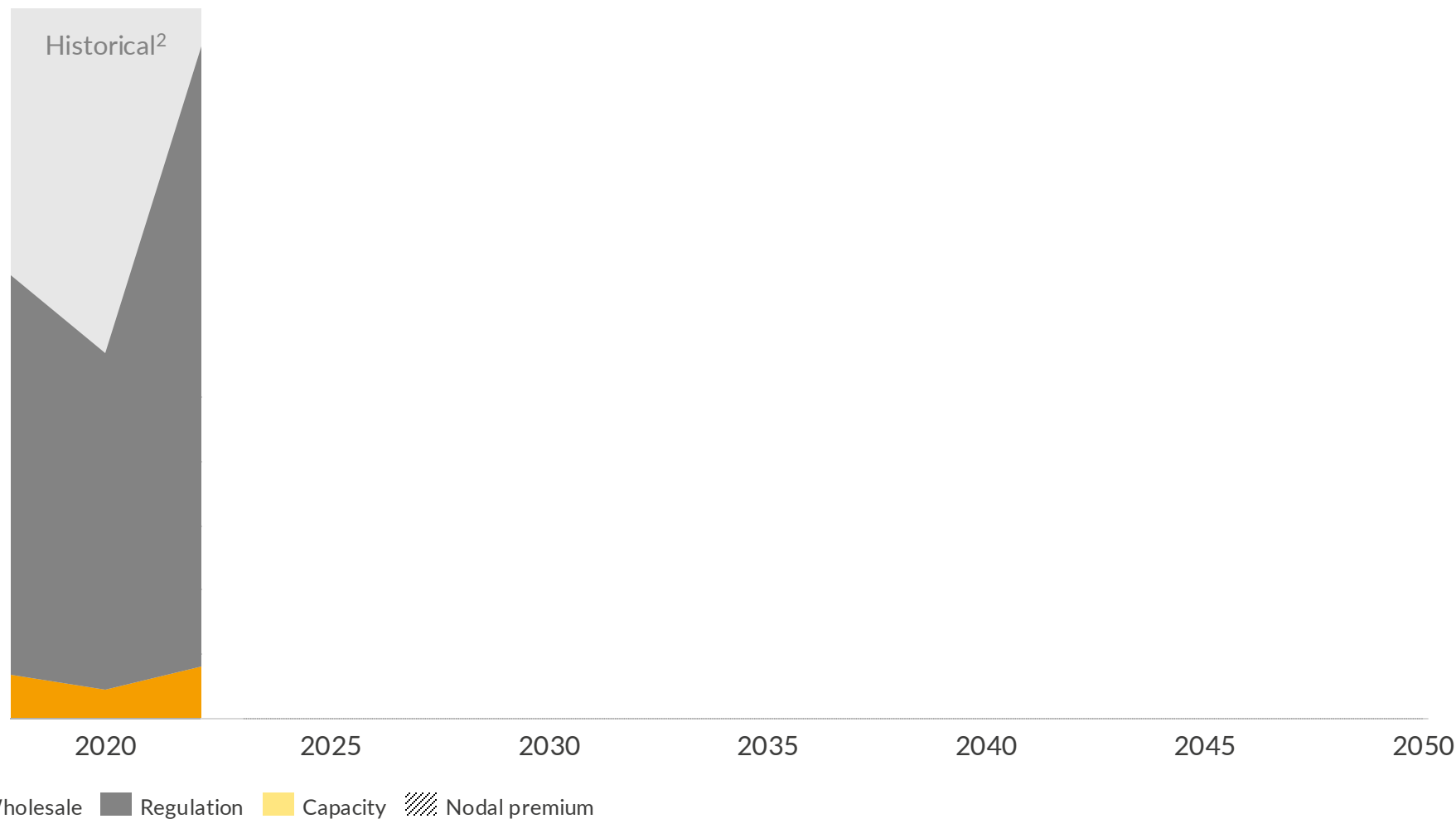
- 1-hour spreads represent the difference between the daily top and bottom prices. In Dominion, the bottom XX% of prices are \$XX/MWh lower than the top XX% of prices between 2040 – 2050

— BGE — Dominion — AE — ATSI — JCPL

1) "TB1" spreads refer to the price difference between the one highest-price and one lowest-priced hour in the day.

# 1h batteries see Reg revenues drop significantly by 2030 due to strong competition, but compensated by increasing energy arbitrage

Net revenues for a 1-hour battery in AE<sup>1</sup>  
\$/kW/year (real 2021)



1) Excluding battery degradation over time; targeting a 1x per day cycle rate. 2) Backcast results using Aurora's Chronos battery dispatch engine and historical Regulation and Energy prices.

*Representative only: Outdated and redacted analysis –to be updated during MCS*

## Outlook for battery gross margins

- 1-hour battery revenues fall from ~\$XX/kW/y in 2023 to ~\$XX/kW/y from the late 2020s onwards, due to large amount of new battery capacity coming online, decreasing an individual battery's probability of clearing the market
- Wholesale revenues for 1-hour batteries double over the forecast, from \$XX/kW/y in the mid-2020s to \$XX/kW/y by 2050
- Batteries with a <4-hour duration may participate in the Capacity Market with that portion of their capacity at which they can dispatch for 4 hours continuously, leading to up to \$XX/kW/y by the 2030s in capacity revenues for a 1-hour battery

# The most profitable battery duration increases through the 2020s, shifting from $\leq 1$ hr batteries in 2024 to 1-4hr in 2028

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Battery cases shown include nodal premium and assume 11% cost of capital, with CAPEX due in year preceding entry year.

Entry Year	Scenario	Duration	Present Value of Gross Margins <sup>1</sup> (\$/kW)			IRR (%)			Payback Period (yrs)		
			AE (NJ)	ATSI (OH)	DOM <sup>2</sup> (VA)	AE (NJ)	ATSI (OH)	DOM <sup>2</sup> (VA)	AE (NJ)	ATSI (OH)	DOM <sup>2</sup> (VA)
2024	Aurora Central	30 minute	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX
		1 hour – excl. CM	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX
		1 hour – incl. CM	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX
		4 hour – Aurora ELCC <sup>3</sup>	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX
		4 hour – 100% ELCC <sup>4</sup>	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX
2028	Aurora Central	30 minute	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX
		1 hour – excl. CM	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX
		1 hour – incl. CM	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX
		4 hour – Aurora ELCC <sup>3</sup>	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX
		4 hour – 100% ELCC <sup>4</sup>	XXX	XXX	XXX	XX%	XX%	XX%	XX	XX	XX

1) Not including ITC payments. 11% WACC assumed across all cases, although lower rates may be possible for contracted capacity payments. 2) Assumes \$7.5/kW/y fixed payment from Dominion for 1h batteries, \$30/kW/y for 4h batteries under Aurora ELCC scenario, and \$60/kW/y for 4h batteries under 100% ELCC scenario. 3) Assumes 4h battery ELCCs to fall from 77% in 2026 to ~50% by 2040, staying constant thereafter. 4) Assumes ELCCs follow PJM expected trajectory, staying at 100% after 2032.  
Source: Aurora Energy Research

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## How to get in touch

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▶ We look forward to continuing the conversation via bilateral sessions.

▶ For all questions to Aurora, you can reach JT Wood at [jt.wood@auroraer.com](mailto:jt.wood@auroraer.com), and Kyndal Mayes at [kyndal.mayes@auroraer.com](mailto:kyndal.mayes@auroraer.com).

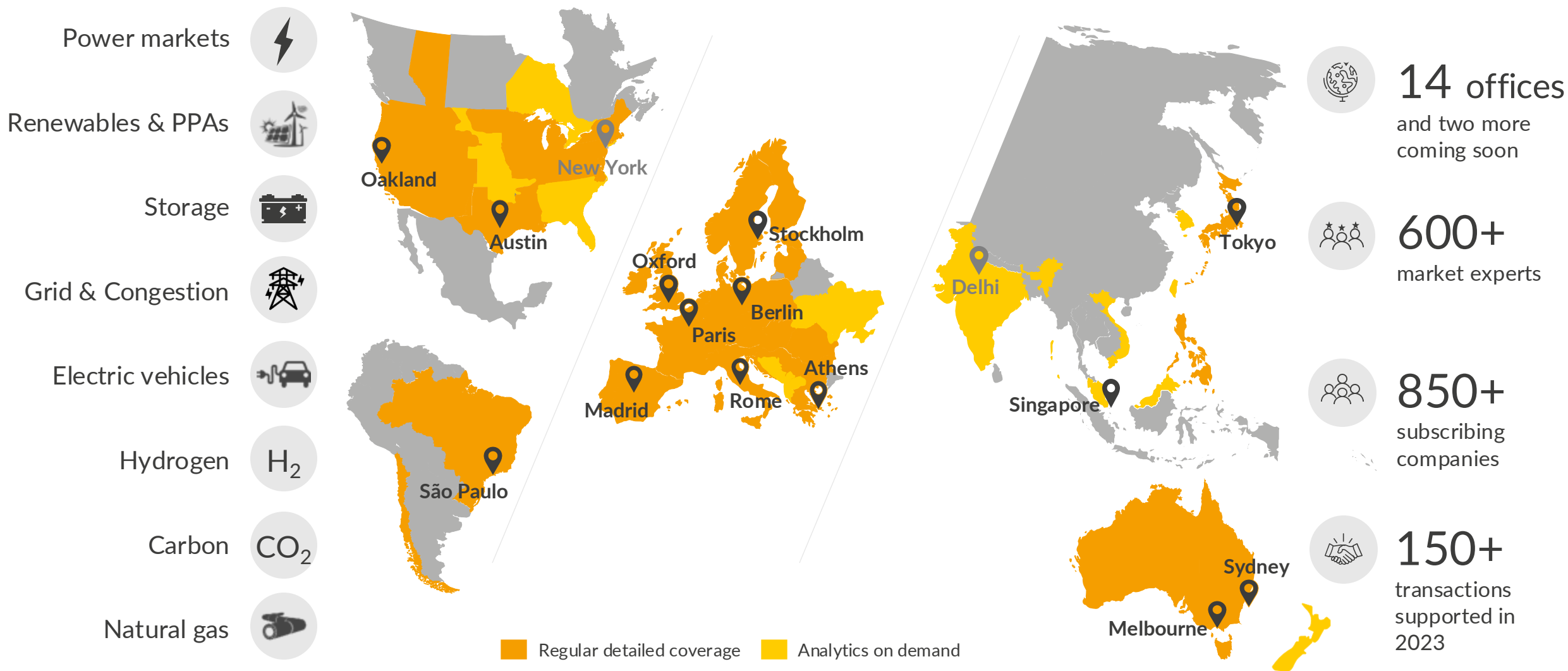
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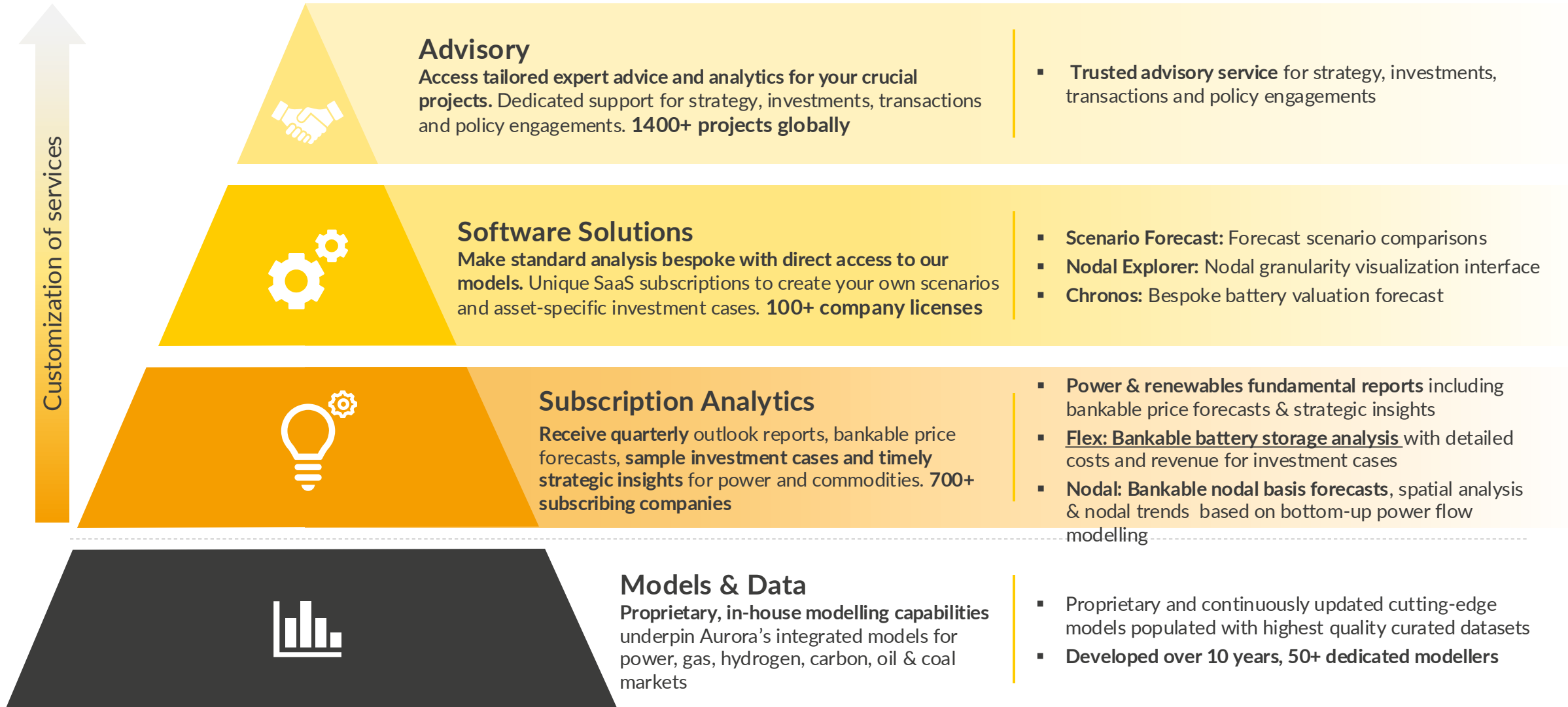
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# Aurora provides market leading forecasts & data-driven intelligence for the global energy transition



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





# We are working with key US and international utilities, investors, lenders, developers and government



AURORA



*"Part of our policy role is to understand the data behind the system and reading your documents and getting insight from y'all at Aurora is fantastic. Thank you." – Jimmy Glotfelty, PUCT Commissioner*

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

## *Illustrative project examples*

### Battery generation



- Buy-side advisor for Engie's successful acquisition of Broad Reach Power
- Sell-side advisor for Black Mountain on ~1.5 GW asset sales to UBS Asset Management, Cypress Creek Renewables, Brookfield Renewable, & East Point Energy
- Siting strategy analysis for battery developer to inform build locations and project valuation
- 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

### Strategic



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

### Renewable generation



- Buy-side advisor for Boralex's acquisition of 840 MW of onshore wind from Blackrock, including nodal pricing, basis risk, and curtailment
- Buy-side financing for 470 MW solar project in ERCOT by SocGen
- Buy-side support for 150 MW solar project
- Asset-specific valuation of two wind and solar projects totalling 540 MW for infrastructure fund including nodal forecasting and curtailment











### Thermal generation























- Asset valuation for a large pumped hydro plant participating in the CAISO wholesale and ancillary markets
- 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 continues to develop our North American financing track record to reach the same depth of bankability as in Europe and APAC

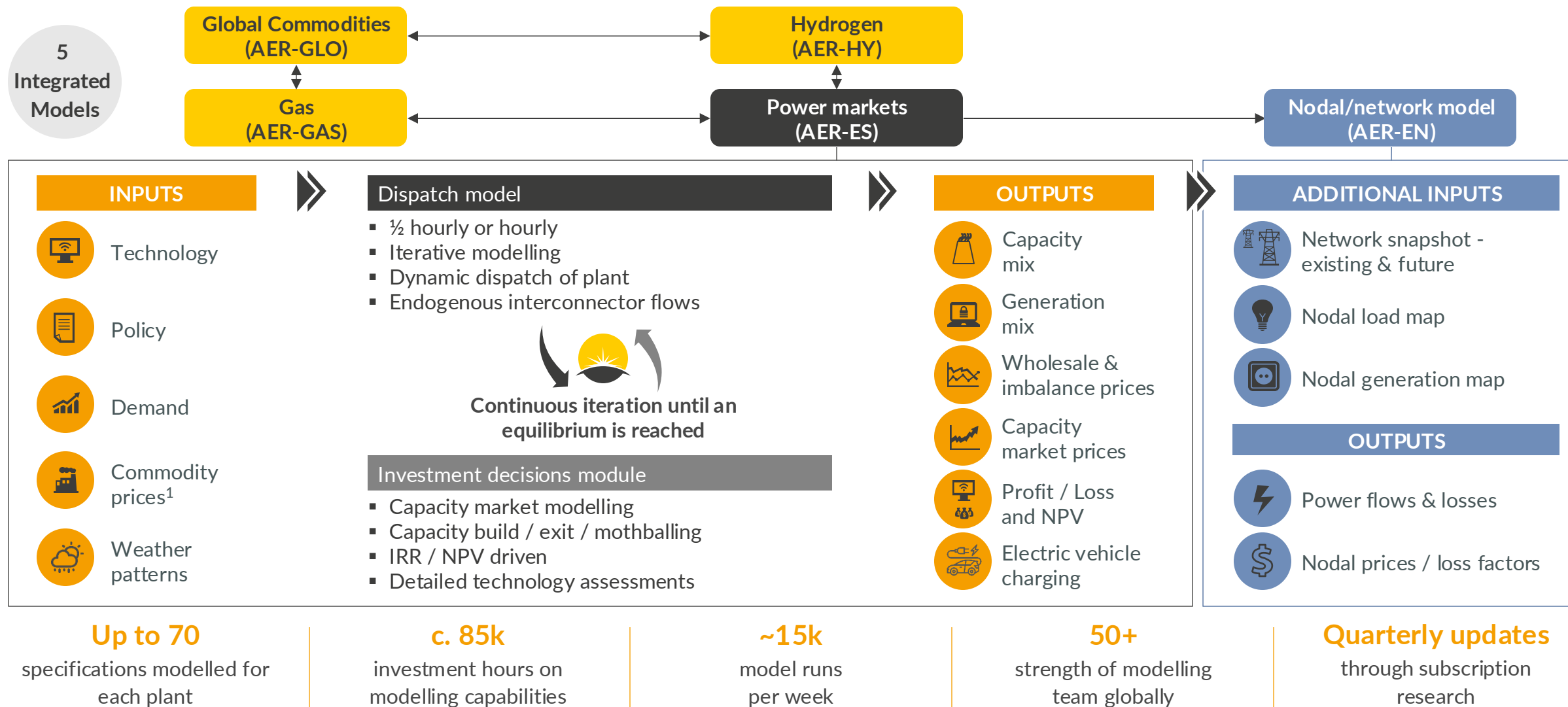
Aurora's price forecasts have been relied upon by lenders in recently completed transactions:

  471 MW Solar financing in ERCOT leveraging market forecast and transmission modelling	  288 MW Solar financing in ERCOT leveraging market forecast, transmission modelling, and due diligence	  Lender advisor to Commerzbank for a 215MW Solar + Storage facility financing in CAISO	  Lender advisor to Commerzbank for a 350MW Storage portfolio financing CAISO	  Lender advisor to Commerzbank for 150MW Solar project financing in ERCOT
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## Ongoing financing projects:

  Lender advisor for Solar asset financing in WECC	  Market forecast, transmission modelling for debt financing of 350MW Solar + 1,500MW Storage assets in CAISO for developer	  Debt financing and sell side support for 250MW Solar + 150MW Storage project in CAISO for developer	  Debt financing of 600 MW onshore wind farm in ERCOT for developer	  Market forecast and transmission modelling for debt financing of Solar + Storage assets in ERCOT for global project developer
  Lender advisor providing structural floor pricing analysis for term loans	  Tax equity raise support for Solar + Storage project developer in CAISO	  Debt and tax equity raise support for Solar + Storage projects in ERCOT and CAISO for developer	  Tax equity due diligence for Storage project in CAISO for financial institution investor	  Market forecast and transmission modelling for debt financing of Storage asset in ERCOT for developer

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



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

AURORA



ENERGY RESEARCH