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ENERGY RESEARCH

Grid-Scale Battery Storage in PJM: Introduction and Outlook

North American public webinars | March 15, 2023

Agenda

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I. Introduction to Aurora & today's session

II. Introduction to battery storage in PJM

III. Market outlook

IV. Battery investment cases

V. Next steps

Aurora's North American public webinars present an overview of our in-depth analysis across and within markets

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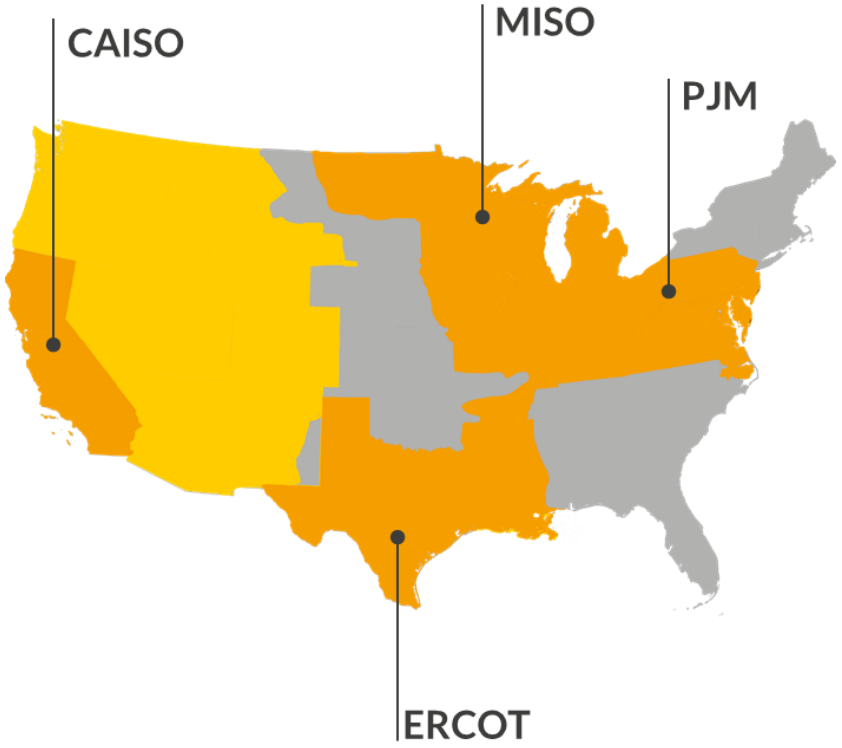

Regular detailed coverage Analytics on demand

2023-2024 Coverage Expansion: NYISO, ISONE, Alberta, WECC, SPP

Grid-Scale Battery Storage in PJM: Introduction and Outlook

- In-depth look at battery revenue streams and investment cases in PJM
- Review battery project pipeline and analysis of historical battery returns
- Modelled forecast of revenue streams and dispatch-optimized investment cases for batteries by duration, region, and in-service year

March 15th, 2023

Hydrogen Economics in Texas

- Analysis of hydrogen landscape in the United States and current policies driving interest
- Deep-dive on clean hydrogen business models in Texas, benchmarked against the cost of producing blue hydrogen
- Additional analysis on the cost of hydrogen transportation and storage

March 23rd, 2023

US Commodities Forecast, 2023 Update

- Aurora's in-house commodity forecast update for natural gas, oil, and coal prices in the short, medium, and long term
- Deep-dive on US Henry Hub gas price forecast, including impacts of European demand and long-term factors impacting US exposure to global natural gas markets

April 25th, 2023

For more information, please contact
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Meet the Aurora Team

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Today's speakers:

Julia Hoos
Head of USA East

Martin Anderson
Head of Research, USA

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Zachary Edelen
PJM Lead Associate

Oliver Kerr
Head of USA

Core PJM team:

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George Irving
PJM Energy Modeler

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

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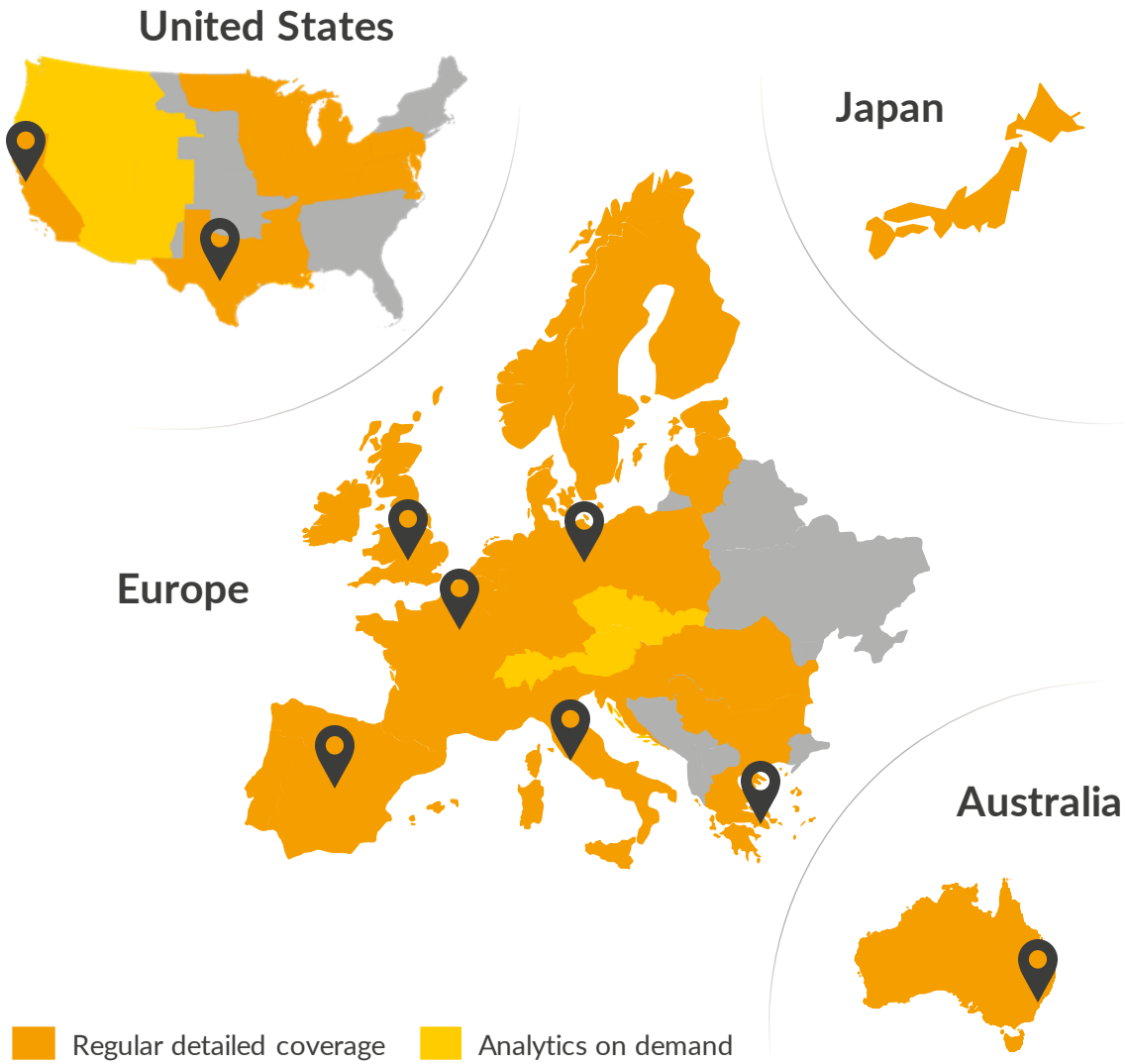
- Power markets
- Renewables
- Storage
- Electric vehicles
- Hydrogen H_2
- Carbon CO_2
- Natural gas



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Paris | Rome | Sydney | Austin | Oakland

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market experts, 40+ in the US

600+

subscribing companies

120+

transactions supported in 2021

Source: Aurora Energy Research

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

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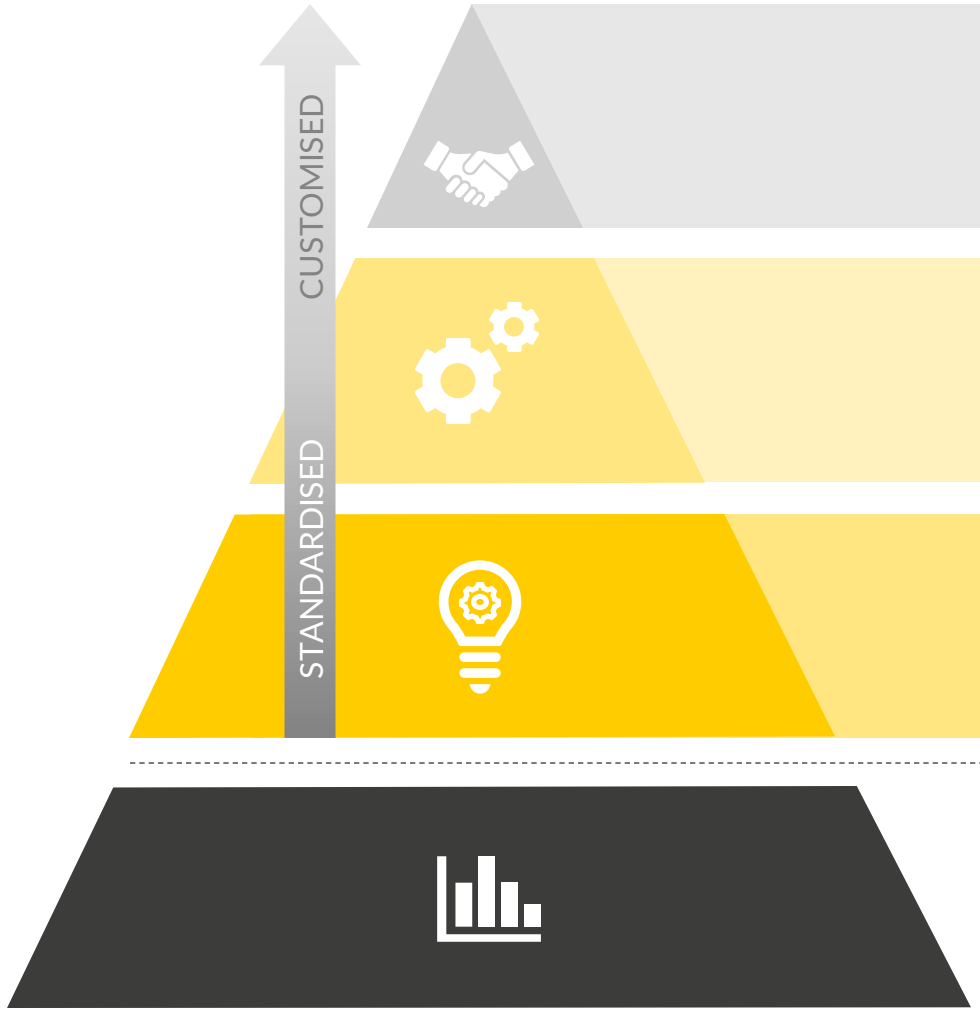

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Proprietary and continuously updated cutting-edge models populated with highest quality curated datasets

Developed over 10 years, 40+ dedicated modellers

Source: Aurora Energy Research

Modelling storage is complex. Aurora's forecasts have underpinned the deployment of over 1.5 GW of operational battery assets globally

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What is the challenge?

- Modelling a consistent set of day-ahead, real-time and Ancillary service prices accounting for opportunity costs
- Understanding and modelling detailed rules in AS markets, including responding to market changes
- Capturing the role of weather in driving scarcity and AS procurement – annual averages are irrelevant to storage economics, esp. as renewables penetration increases

Future of the market (*difficult to model*)

- Dispatching assets against multiple price series accounting for imperfect foresight, degradation, warranties, route to market, and asset characteristics

Future of the asset in the market (*easier to model*)

How do we address it?

- ✓ Offer valuations for a range of standard and bespoke market scenarios
- ✓ Work closely with clients to ensure the valuation is specific to their asset or portfolio characteristics
- ✓ Model storage margins for all major business models including arbitrage, Ancillary Services, and hybrid
- ✓ Dispatch against consistent day-ahead, real-time and AS prices
- ✓ Account for degradation and imperfect foresight
- ✓ Present results in slides and cashflow model at monthly, quarterly and annual granularity

Example transactions

2017
- Sell-side advisory for UKPR's 500+ MW portfolio of peakers and battery storage, sold to Sembcorp for £216m

2018
- Banked by Santander on first project financing of battery storage in the UK for 100 MW Zenobe portfolio
- Sell-side market advisory for then-largest operational battery storage portfolio in Europe, STEAG's 90 MW bid into the FCR market

2019
- Supported Pivot Power on sale of company and 2GW portfolio to EDF
- Supported PE fund on $50m acquisition of storage developer; bidding support for large developer for DS3 auctions

2020
- AUS $50m in debt financing for 50MW extension of Neoen's Hornsdale battery – first battery project financing in Australia

2021
- Debt and equity raise for 100 MW battery portfolio
- Development/financing of 150MW Hazelwood BESS project

2022
- Buy-side advisor on multiple equity transactions for over 1GW of battery storage projects across Texas
- Sell-side advisor for 1.1 GW of battery storage from BMES to UBS Asset Management and Cypress Creek Renewables

Source: Aurora Energy Research

Aurora is trusted as a bankable lender's advisor across US and European power markets

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

- $568MM debt financing of a 300MW Solar + Storage facility in CAISO
- $568MM debt financing of a 350MW Storage portfolio in CAISO
- $650MM debt financing of a 215MW Solar + Storage facility in CAISO
- $130MM debt financing of a 150MW Solar project in ERCOT
- Market advisor for debt financing of Gresham House's 400+MW battery storage portfolio
- Debt financing of a 826MW CCGT asset
- €28MM debt financing
  First subsidy-free wind financing in Poland
- £192MM debt financing
  Saltend CCGT with CHP. LMA for regular forecasts
- Market advisor for the financing of a portfolio of hydro and PV assets
- Sell side advisor for the largest operational battery storage portfolio within the frequency containment reserve in Europe (90 MW)
- Market advisor for first project financing of battery storage in the UK
- €48MM debt financing
  220MW Potegowo onshore wind farm of Israel Infrastructure Fund

Source: Aurora Energy Research

Aurora's battery forecasts utilize both our long-term market model and the battery asset dispatch model

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Step 1: Model the wholesale and ancillary markets

Wholesale market assumptions

- Technology, commodity, demand, policy assumptions etc.

PJM Power Market Model

- Simultaneously models wholesale, ancillary, capacity, and REC markets
  - Hourly granularity
  - Iterative modelling
- Capacity build / exit / mothballing
  - IRR / NPV driven
- Detailed technology assessments

Continuous iteration until an equilibrium is reached

Wholesale prices

- DA prices at 1-hour granularity
- RT prices at 1-hour granularity derived from DA prices

Ancillary service prices

- All main services consistent with DA prices

Capacity market prices

- Internally consistent with wholesale and ancillary service prices

All additional revenue streams

- E.g., RECs based on revenue requirements and shortfall dynamics

Step 2: Model the battery asset dispatch

Asset business models

- Business model: Energy only, Ancillary service only, optimized across markets
- Connection: Standalone/ co-located with solar/thermal/wind asset with/without DC coupling
- Location: Relevant hub price and LMP bonus

Storage asset dispatch model

- Model trading strategy against hourly prices in sequence
- Lifetime impact of degradation

Storage asset dispatch model

- Monthly and yearly granularity
- Gross margins by market

Storage technical parameters and constraints

- Technology: lithium ion/ pumped storage/ flow
- Size
- Duration
- Degradation
- Cycling constraints
- Round trip efficiency
- Co-location charging
- Location and LMP bonus

In-house model | Input | Output

Source: Aurora Energy Research

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Opinion Poll

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What is your current expectation for the business case (i.e., project returns) of batteries in PJM through 2030?

A Very optimistic – I believe the business case is as good or better than other attractive geographies in the US

B Optimistic – I believe there is a good business case, but I believe other US geographies are currently more attractive

C Not Optimistic – I believe the business case (or ability to build) is less attractive than elsewhere in the USA, and unlikely to become so

Despite low current BESS capacity, the 80 GW in PJM's interconnection queue – including in new geographies – point to expectations for new business cases

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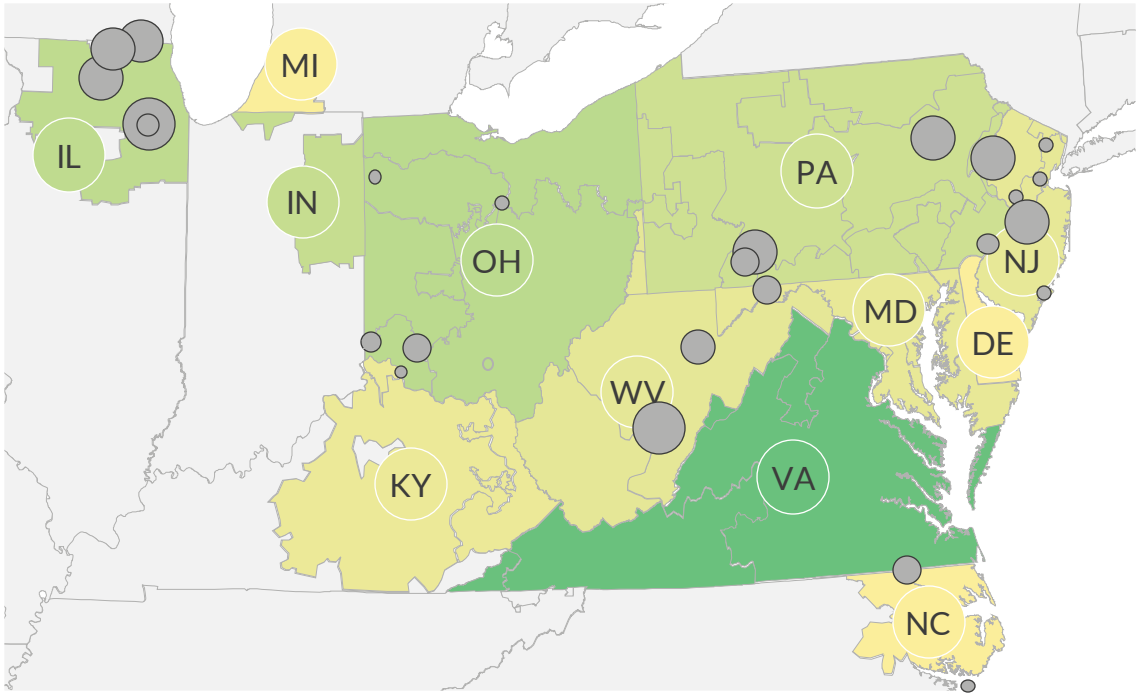
Current capacity totals 400 MW, mostly concentrated in New Jersey, Illinois, and Pennsylvania

Map of operational batteries in PJM by capacity



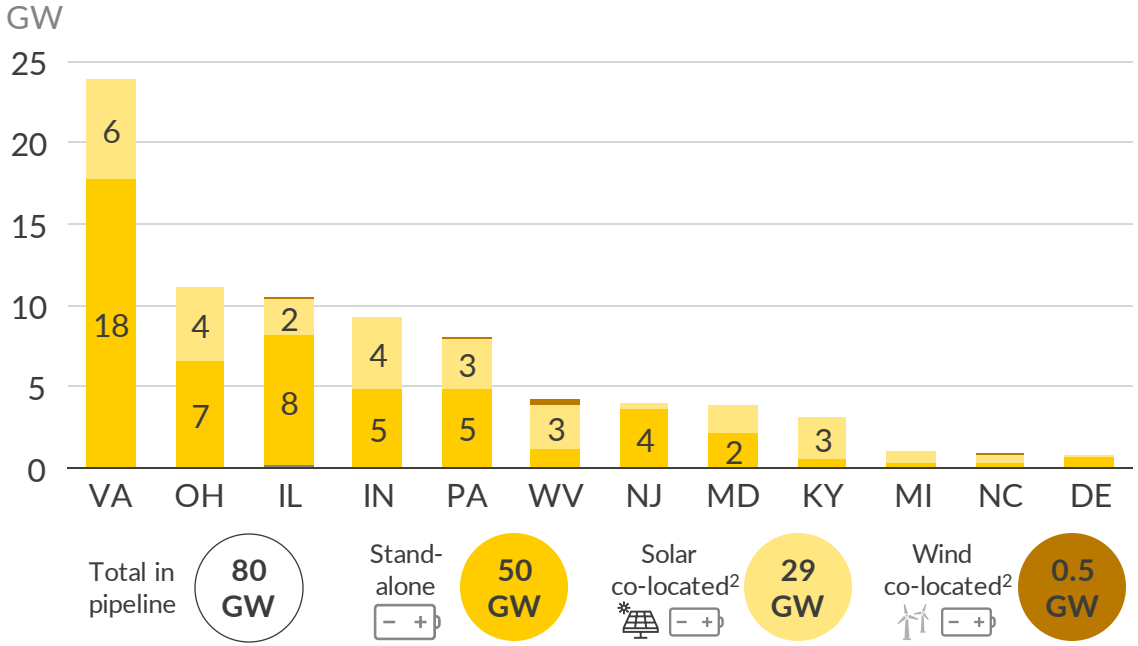
Current total capacity: 0.4 GW

Legend: battery unit capacity

2 MW · 10 MW · 18 MW

However, the 80 GW of batteries in PJM's interconnection queue attest to large interest, including in standalone storage, with the largest focus on VA

Battery capacity in PJM's interconnection queue by state[1]



Interest in battery investment is supported by:

- Increasing renewable penetration, creating a need for more flexible resources
- State decarbonization targets with explicit carve-outs for battery storage
- Optimism for ≥4-hour batteries to capture value from the capacity market

1) Approximation as of January 2023, based on project *MW Capacity* in PJM interconnection data. 2) Proportion of individual project applicable to storage vs. solar/wind is estimated.

Sources: Aurora Energy Research, PJM

PJM batteries made an average of ~$160/kW/year from 2019-2021, and optimized their shorter duration for participation in Regulation

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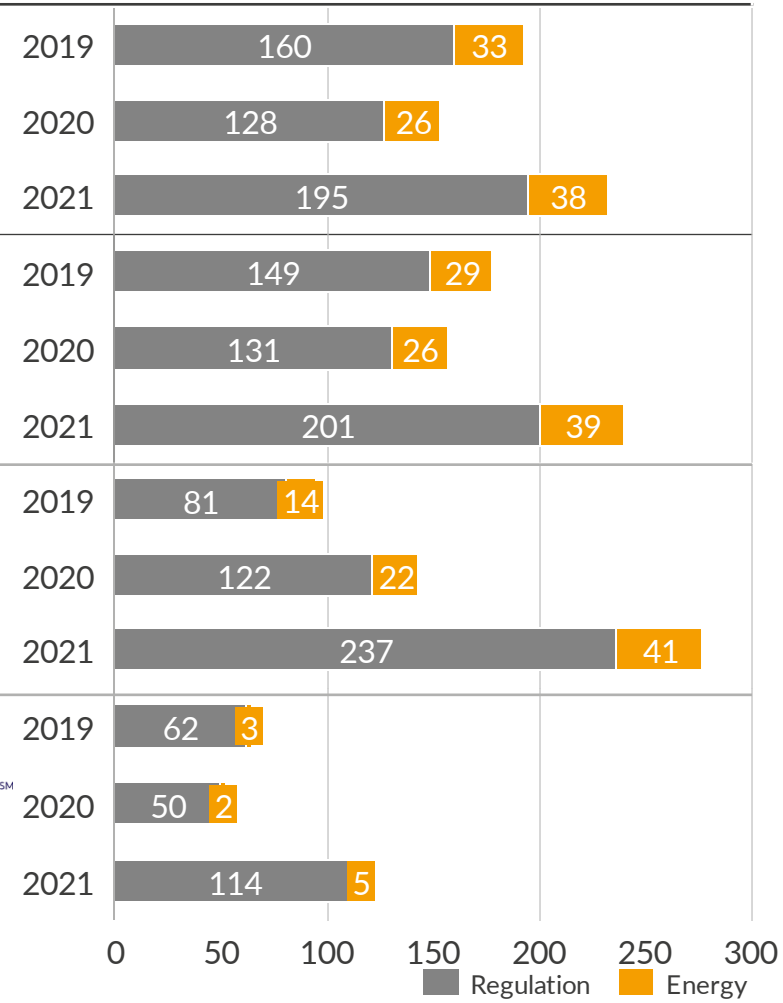
Project	Capacity MW	Duration minutes	Year of Commission	Asset Type	State	Control Zone	Owner
Plumsted	19.8	60	2019	Standalone	NJ	JCPL	ORMAT
Alpha (Stryker)	19.8	60	2019	Standalone	NJ	JCPL	ORMAT
Green Mountain Storage[2]	10.4	15	2016	Co-located with onshore wind[3]	PA	Penelec	NEXTera ENERGY
Clinton Battery	10.0	24	2016	Standalone	OH	DEOK	exelon



1) Estimated from transaction data as self-reported by asset operators to FERC; all values approximate. 2) Green Mountain Storage was built prior to PJM changing conditional neutrality to 30-minutes on January 9, 2017. PJM grants several such batteries a special settlement where they are treated as clearing the Regulation market. 3) Duration estimated from reported 4 MWh depth.

Sources: Aurora Energy Research, FERC EQR

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PJM batteries primarily receive revenues in ancillary and wholesale, with expected future revenues from capacity and state incentives

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PJM battery potential revenue streams and eligibility for different battery types

			Eligibility for <1-hour duration batteries	Eligibility for ≥4-hour duration batteries	Siting strategy impacts revenues?
	A	**Ancillary contracts and dispatch**	▪ Contracts awarded in RegD only (includes both RegUp & RegDown) as fast-acting units that can follow signal at ~60Hz ▪ Primary revenue stream for existing batteries	✓	✓	
	B	**Wholesale energy arbitrage**	▪ When top-bottom price spreads provide sufficient potential revenue, can trade between day-ahead and real time markets	✓	✓	✓
		Nodal premium to arbitrage	▪ Battery trading can benefit from additional revenue through strategic location at nodes experiencing higher volatility or spreads (e.g., near load centers or increasingly, near renewable hotspots)			
Potential ***additional revenue streams*** *in future*	C	**Capacity payments**	▪ Batteries with a minimum 4-hour duration can act as capacity resources by participating in the RPM, subject to derating for reliability	✓	✓	✓
	D	**State Incentives**	▪ Multiple state decarbonization targets contain energy storage provisions: VA Clean Economy Act, New Jersey storage target ▪ New Jersey is currently developing a framework for battery financial incentives	✓	✓	✓

Sources: Aurora Energy Research, PJM

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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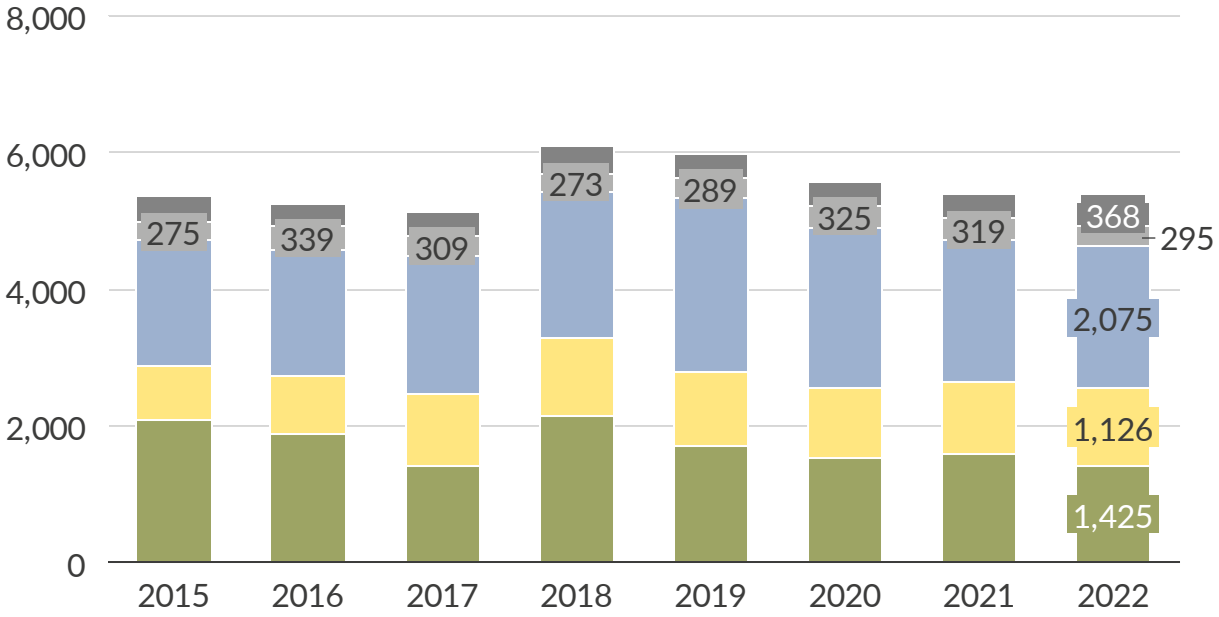
Average annual total procured ancillary services
Effective MW/h

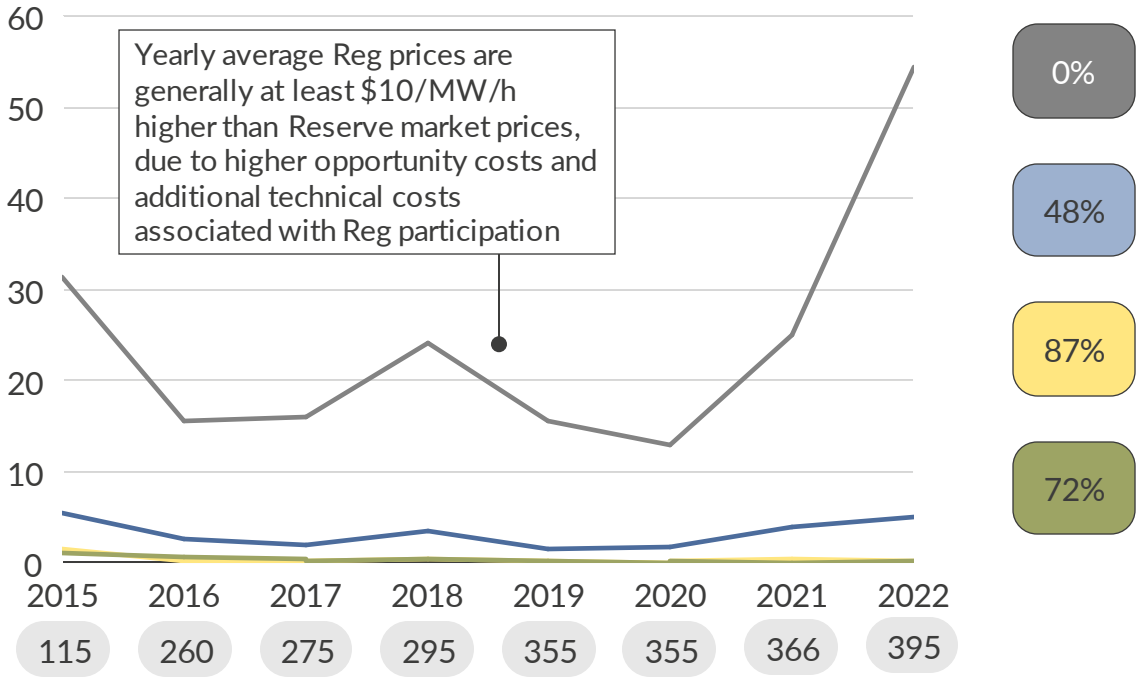


- Regulation market procurement targets toggle between 525 and 800 effective MW (avg 662 MW/year) combined total between **RegA** and **RegD** – targets set by PJM – depending on the time of day[1]
- Batteries participate solely in **RegD**, which is designed to make up around 40% [1] of total regulation 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)

Share of zero-price hours
% hours in year (2015-2022 average)



- 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

Sources: Aurora Energy Research, PJM

PJM is currently undergoing a stakeholder process to reform its Regulation market structure, with a proposal expected March 2023[1]

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Dimension	Proposal	Package 1	Package 2	Expected effects	Impact on Reg prices	Impact on battery revenues
Overall impact		✓	✓	**Reg prices** will likely **fall quickly** as batteries provide **increasing share of capacity**, eventually **setting prices**	↓↓	↓
Signal design	Remove RegA / RegD distinction and RegD capacity cap, combine into 1 signal	✓	✓	Batteries will represent a greater portion of Reg market, driving down prices	↓↓	↓
Service design	Split into RegUp & RegDown	✓		Batteries can better adapt bids to state of charge, also allowing better optimization across markets	RegUp: ↑ RegDown: ↓	↑
	Bidirectional service (status quo)		✓	Status quo	-	-
Procurement requirement	Dynamic hourly procurement based on formulaic calculation	✓	✓	Procurement rises with increasing renewable capacity, variability, load	↑ / ↓	↑ / ↓
Commitment	Add day-ahead Reg market	✓		Lower prices due to foresight, but more arbitrage opp.	↓	↑
	Rolling 15-minute commitment		✓			
Rate of substitution	Remove Benefits Factor function (i.e., capping batteries to ~40% of Reg)	✓	✓	No mechanism to stop batteries from flooding market	↓↓	↓↓

Aurora Central assumes an increasing procurement requirement in line with renewables penetration

Direction of impact: ↓ Down ↑ Up
Size of impact: ↑ <50% change ↑↑ >50% change

1) As of Jan 25, 2023, the Regulation Market Design Senior Task Force plans to finalize its decision-making across different package options in its March 21st meeting.

Source: Aurora Energy Research

Reg prices are expected to remain stable at $20-25/MW/h through the forecast horizon, with a mild uptick in early 2030s

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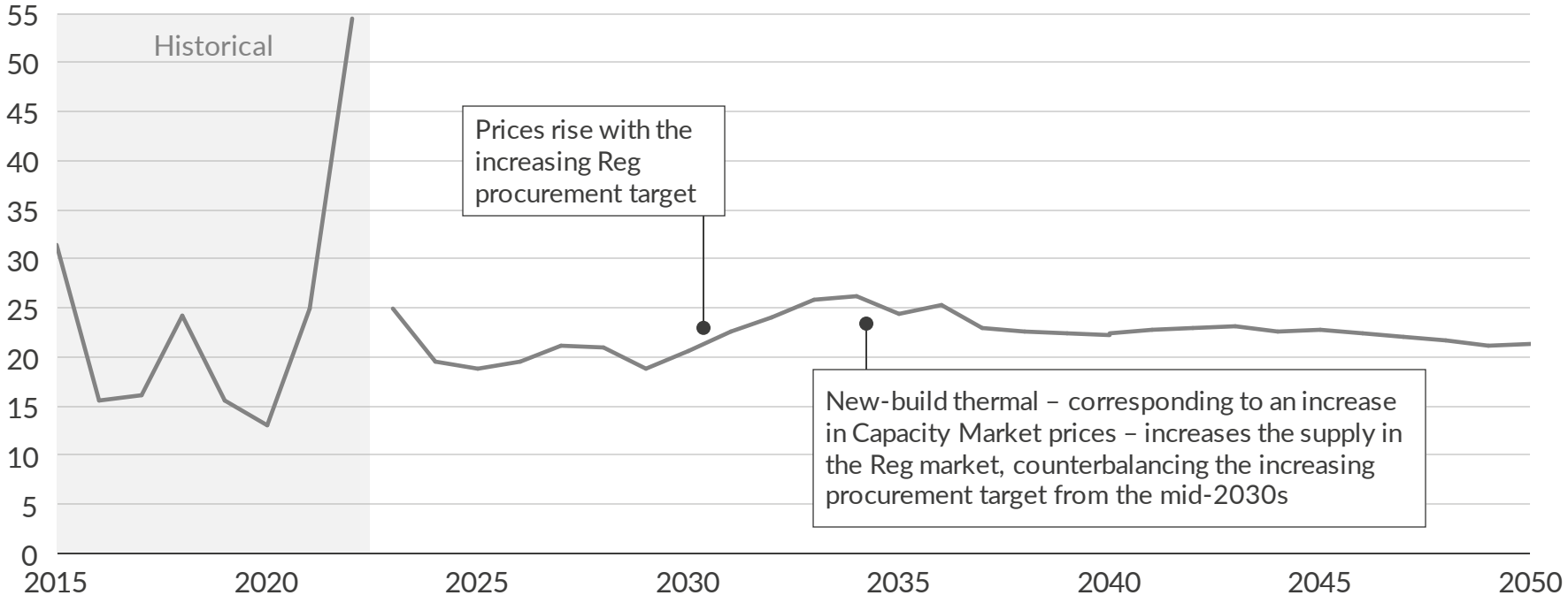
Yearly average Reg clearing price
$/MW/h (real 2021)



Battery capacity (from Aurora Jan 2023 Central)
GW

0.1	0.4	1.8	9.2	15	19	21	24

Regulation

- Reg prices roughly correlate with ATC wholesale prices through the late 2020s, hovering around $20/MW/h
- From ca. 2028 onwards, increasing Reg procurement targets put upwards pressure on prices, which reach ca. $26/MW/h by 2036
- From the mid-2030s, increased peaker build – following price signals from the Capacity Market – put downwards pressure on Reg prices, making them slowly descend to $21/MW/h by 2050
- Aurora central assumes RegD (and hence battery participation) is capped at ~40%. In this case, thermal technologies continue to set higher prices
- Proposed removal of the RegA/RegD split could see Reg prices fall to the $0-$5/MW/h range as battery capacity increases

Sources: Aurora Energy Research, PJM

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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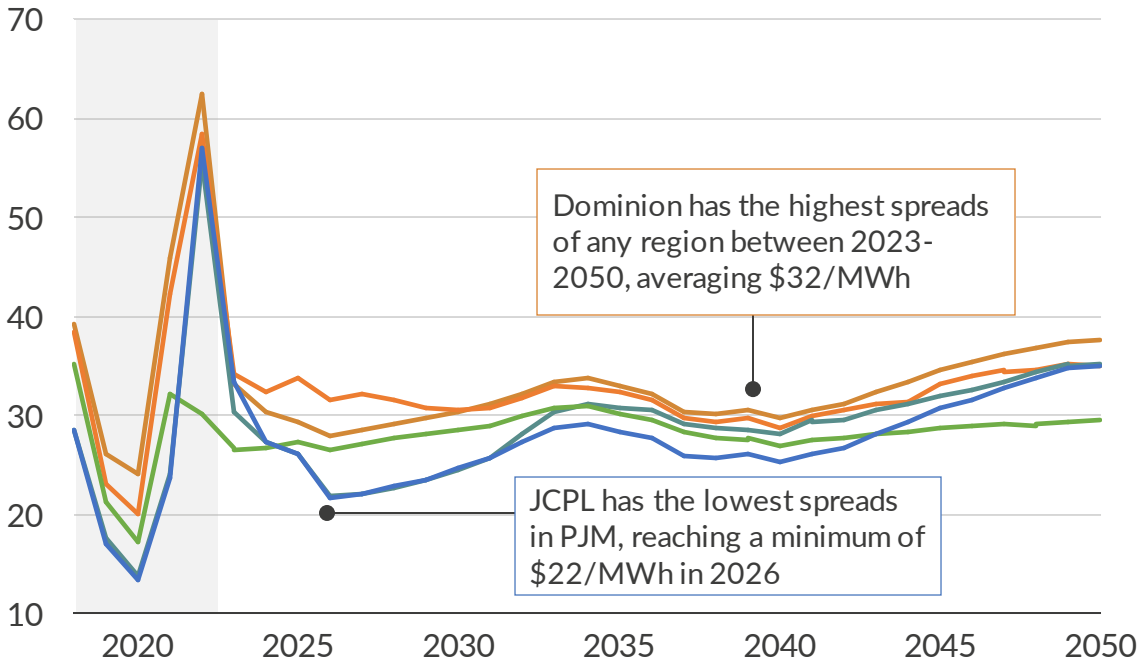
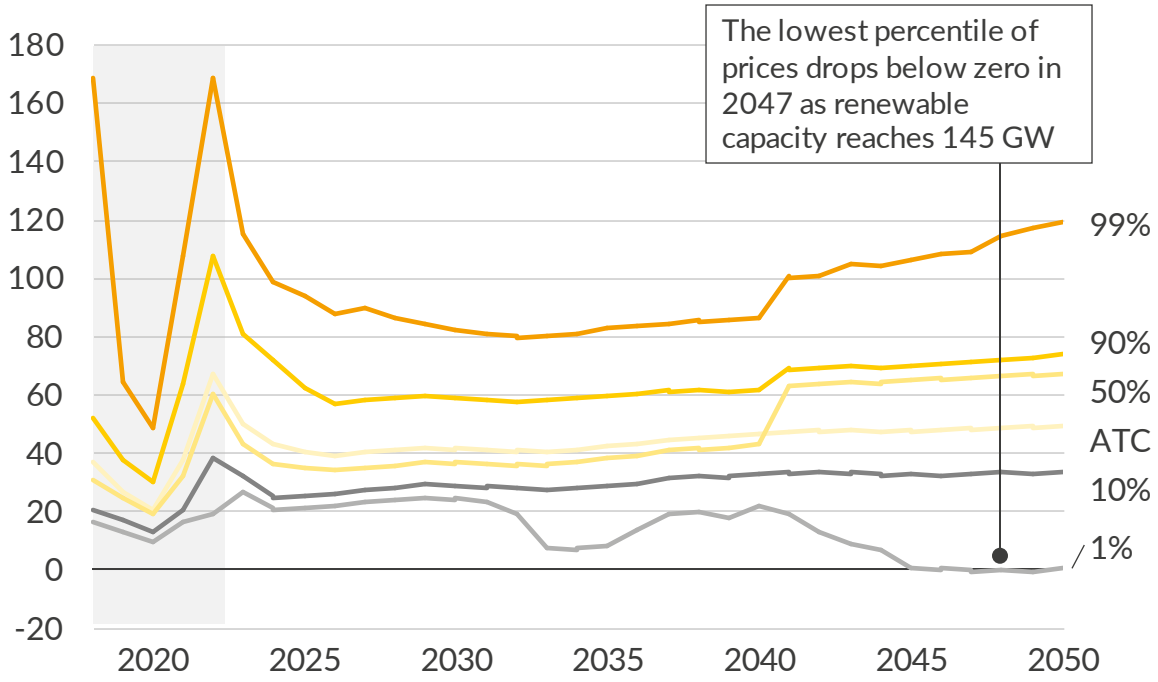
Yearly average day-ahead zonal TB1 price spreads[1]
$/MWh (real 2021)



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



- 1-hour spreads in Dominion average $31/MWh throughout the 2030's
- The regions with the highest 1-hour spreads (Dominion, MetEd, and BGE) are an average of $4.8/MWh higher than the regions with the lowest spreads (PSEG, AEP, JCPL) between 2023 – 2030

- 1-hour spreads represent the difference between the daily top and bottom prices. In Dominion, the bottom 1% of prices are $100/MWh lower than the top 99% 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.

Sources: Aurora Energy Research, PJM

Capacity market clearing prices are expected to rise, and batteries that can dispatch for 4 hours may choose to participate

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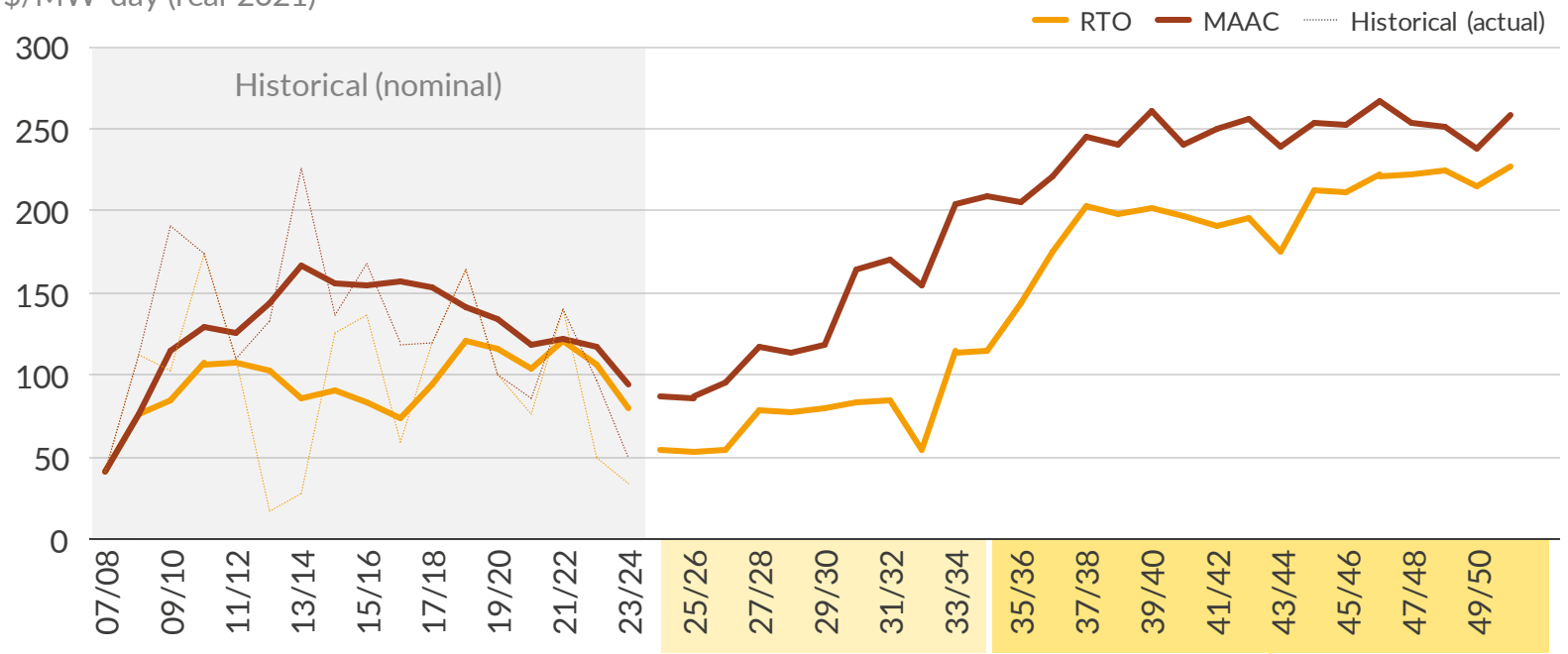
5-year rolling average clearing prices for PJM's Base Residual Auction (BRA)
$/MW-day (real 2021)



2024-2034

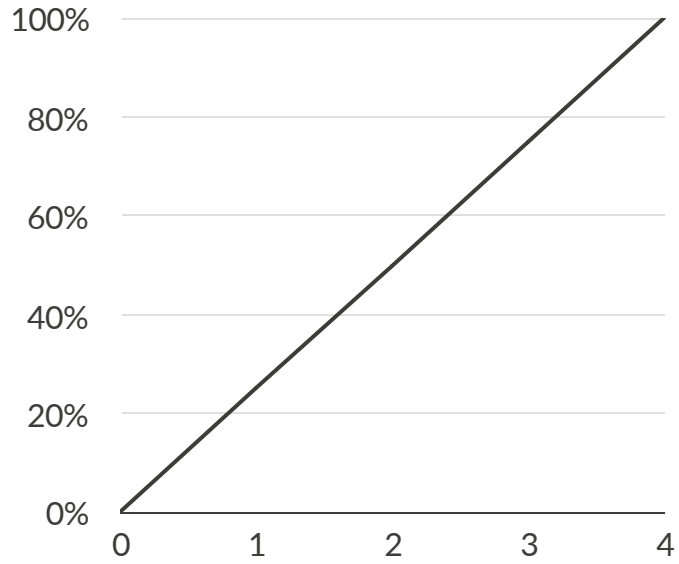
- *Clearing prices:* **$50-110/MW-day**
- *Driving factors:* Capacity oversupply removes need for new-build dispatchable generation, allowing existing generators to set the price

2035-2050

- *Clearing prices:* **$100 – $200/MW-day**
- *Driving factors:* Coal retirements and increasing procurement targets make new dispatchable capacity necessary, which bids much higher

For a deeper dive on Aurora's PJM capacity market views, see our Oct 2022 Insight Report

Portion of nameplate capacity eligible for CM[1]
% of capacity; battery duration



- Participation in PJM's Capacity Market (CM) is only allowed for batteries with a duration ≥4 hr
- However, **PJM rules allow a shorter-duration battery to bid as much capacity into the CM as can dispatch for 4 hours continuously**
- E.g., a 10 MW, 20 MWh battery could provide 5 MW of capacity

1) The nameplate capacity participating in the Capacity Market will be further reduced by the 4-hour battery ELCC when converting to "MW UCAP".

Sources: Aurora Energy Research, PJM

Although future ELCCs present a large uncertainty for batteries, a reduction would be counterbalanced by CM prices, reducing risk

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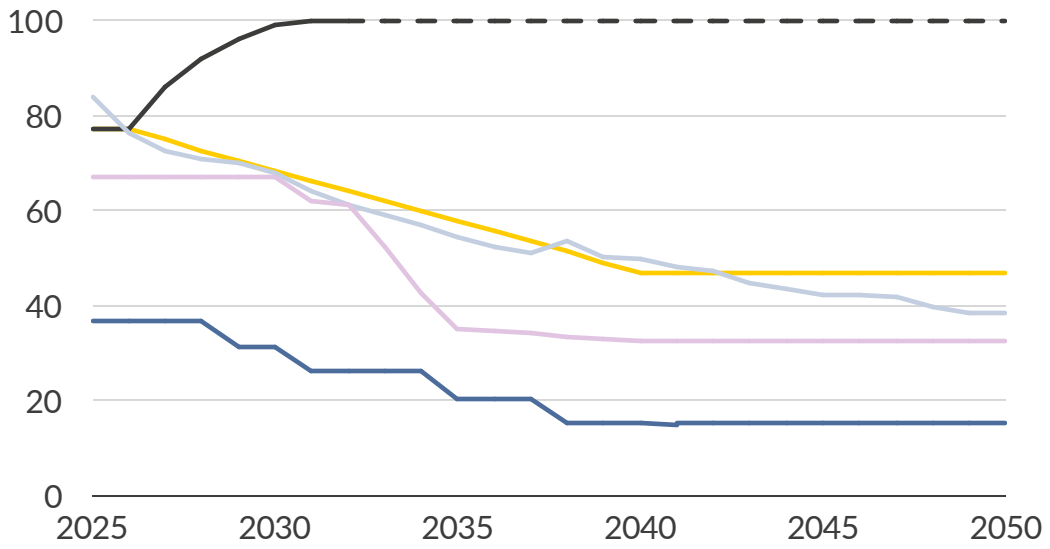
1 PJM currently expects battery ELCCs to rise to 100% by the early 2030s, but Aurora Central sees them being lowered in line with other markets

Derating factors of 4-hour batteries in various capacity markets
% of nameplate capacity; Delivery year

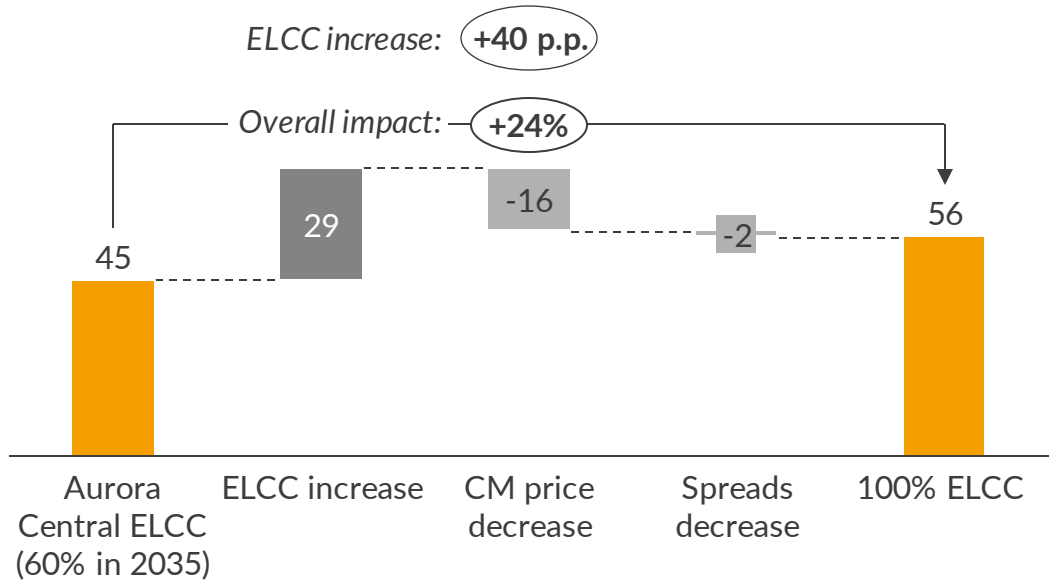


- Aurora Central assumes 4-hour battery ELCCs will fall to ~50% by 2050, which is similar to other capacity markets
- The downward trend is a product of the incremental decrease in reliability value as more batteries with a fixed duration interconnect to the system

PJM (Aurora Central) — PJM[1] — CAISO (RA) — Iberia — UK

2 Although a high ELCC would increase capacity market revenues, it would have mitigating 2nd-order effects, reducing its impact

Capacity revenues for a 4-hour battery in AE[2], 2035
$/kW nameplate (real 2021)



- Higher ELCCs would elicit more battery capacity, pushing up individual battery capacity market bids
- Newbuild batteries may become price-setters by the 2040s, driving up capacity market bids as previous business case deteriorates due to revenue cannibalization in other markets

Overall outcome — 1st-order effect — 2nd-order effect

1) PJM currently forecasts ELCCs through 2032; later numbers are extrapolated; 2) AE zone is located in New Jersey.

Sources: Aurora Energy Research, PJM

VA and NJ have both set targets for storage capacity, with incentives in place or under development

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State	Target	Deployment requirements	Incentive structure	Status

New Jersey	2 GW by 2030	▪ Physically in NJ
		▪ 4h batteries targeted
		▪ 1 GW standalone
		  ▪ Grid-scale & distributed assets allowed
		▪ 1 GW co-located
			▪ Standalone batteries utilize "Storage Incentive Program" (SIP)
			  ▪ Separate pricing structures for grid-scale and distributed
			  ▪ ≥30% of incentive: capacity-duration payment ($/kWh), subject to performance criteria
			  ▪ Rest of incentive: pay-for-performance mechanism based on abated CO_2 emissions (for grid-scale)
			▪ Co-located batteries via "Competitive Solar Incentive Program" (CSI)
			  ▪ Includes NJ BPU-recommended procurement target of 160 MWh of solar + storage (corresponding to a 4-hour battery storage pairing with 40 MW of solar)
				SIP straw proposal has received stakeholder comments; expected implementation TBD
				
				CSI passed December 2022

Virginia	3.1 GW by 2035 (EOY)	▪ ≥2.7 GW in Dominion VA ▪ ≥0.4 GW in Appalachian Power (AEP VA) ▪ ≥35% to be procured from third-party vendors	▪ Legal obligations for regulated utilities to construct or purchase 2.7 GW (Dominion) or 0.4 GW (AEP) of storage capacity by end of 2035 ▪ Legal "pre-approval" to rate-base costs of these projects to consumers by declaring them to be "in the public interest"	Passed by law in 2020 (Virginia Clean Economy Act)
Illinois	*none*		▪ Utilities obliged to provide $250-300/kWh rebate for storage paired with distributed generation resources ▪ Illinois Commerce Commission issued report in May 2022 investigating potential mechanisms for storage deployment	Passed by law in 2021 (Climate and Equitable Jobs Act)
Maryland	***Currently no target or incentive defined*** *However, recently adopted Climate Solutions Now bill (2022) mandates 60% net emissions reductions by 2031, 100% by 2045 (compared to 2006 levels)* ▪ *MD due to adopt a plan before 2024 for 1st target, which could include storage incentives*			

In our battery economics evaluations, we assume a $30/kW/y capacity payment for 4-hour batteries in Dominion VA, adjusted down for lower durations

Sources: Aurora Energy Research, New Jersey Board of Public Utilities, Virginia Clean Economy Act, Illinois Commerce Commission Energy Storage Report, Maryland Climate Solutions Now Bill

Agenda

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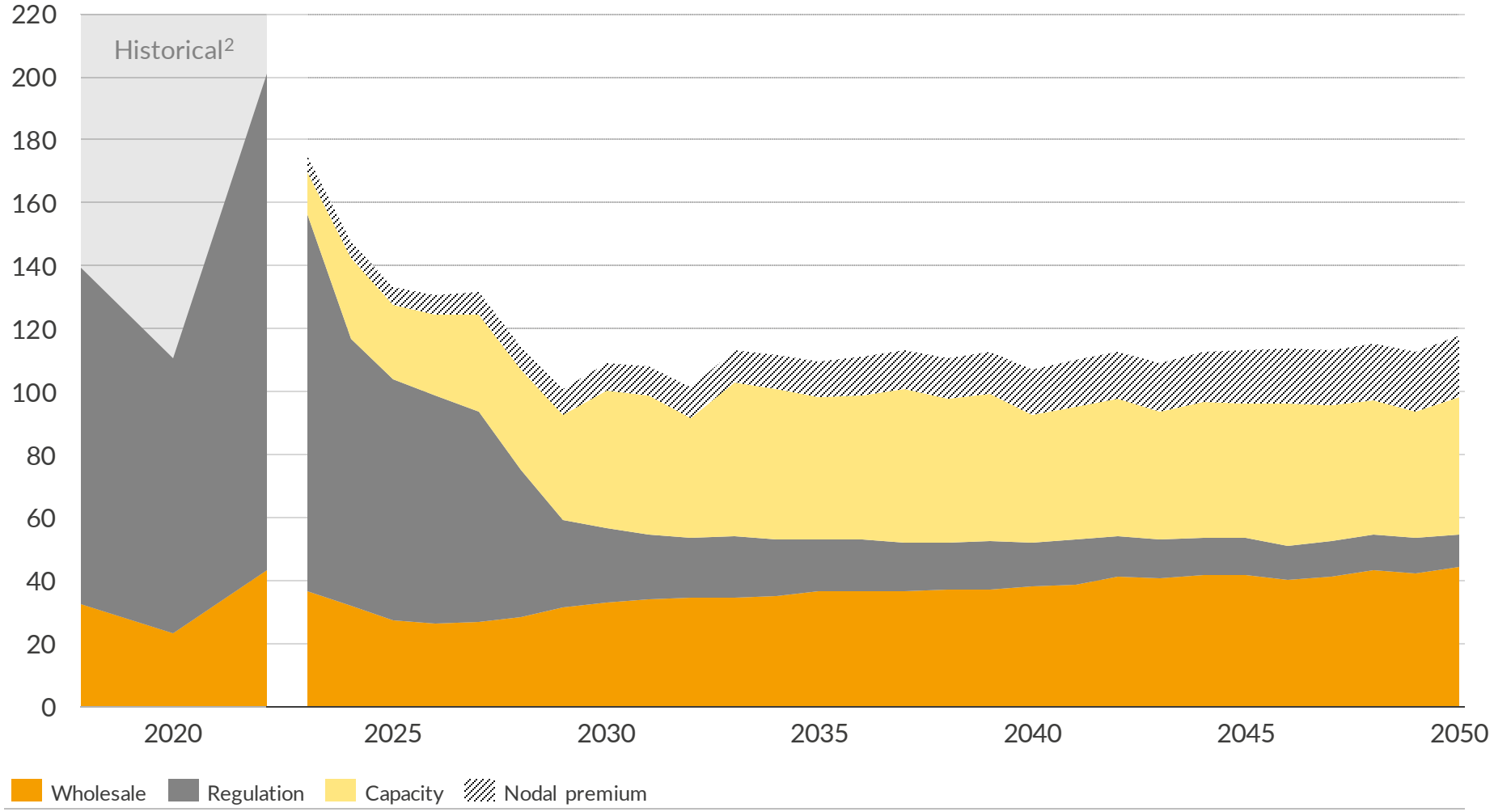
4h batteries with 50% ELCC by 2040 can expect revenues ≥$100/kW/y from the 2030s onwards, of which $45/kW/y from CM

Net revenues for a 4-hour battery in AE[1] – Aurora Central ELCC[3]
$/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.
3) Assuming 4h battery ELCCs drop to ca. 50% by 2040 from currently determined levels.
Source: Aurora Energy Research, FERC EQR

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Outlook for battery gross margins

- 4-hour batteries see revenues of ~$110/kW/y from the mid-2030s onwards, with the majority from wholesale arbitrage and the Capacity Market
- Wholesale arbitrage revenues increase from $26/kW/y in the mid-2020s to $44/kW/y by 2050
- Capacity revenues hover around $45/kW/y for most of the forecast after rising in the early 2030s with Capacity Market prices
- Placement at a node with relatively high spreads compared to the zonal average could add up to $20/kW/y in additional revenue by 2050

Batteries that receive capacity revenues – at both 4h or 1h duration – see the highest IRRs, reaching 15% by the early 2030s before the ITC ends

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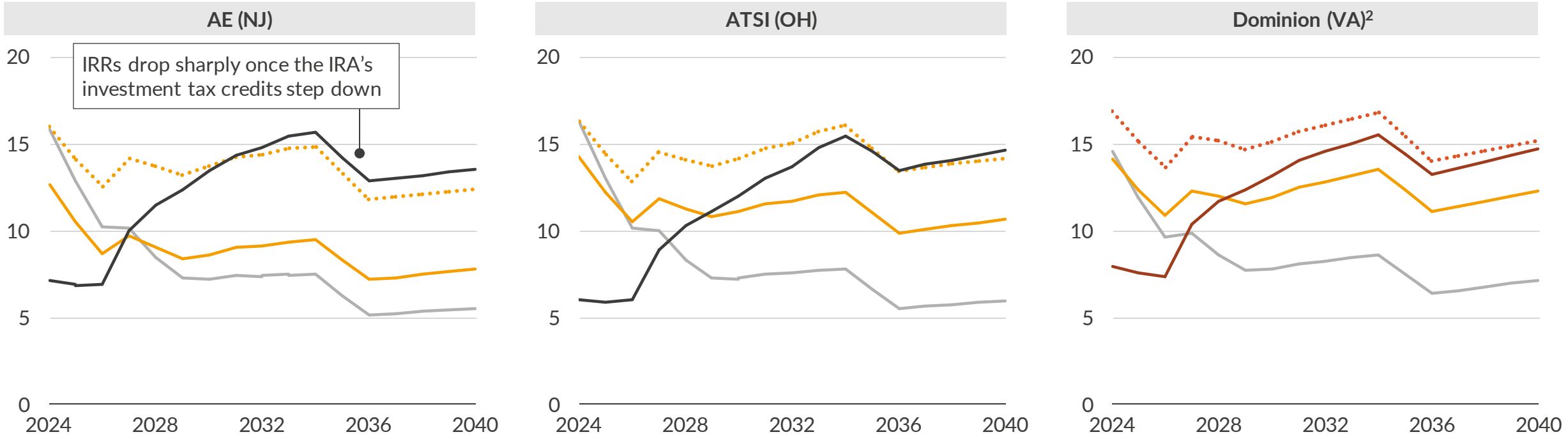
IRR for new-build battery by start year[1]

%



- 1h batteries participating in the Capacity Market show the best business case in AE in the 2020s
- 4h batteries overtake them from 2030, better capitalizing on increasing CM prices, which are higher in the MAAC region

- 1h batteries with CM revenues fare better in ATSI than AE despite lower CM prices thanks to higher spreads
- 30min batteries quickly see the lowest IRRs of all durations as the Reg market becomes saturated by increasing battery capacity

- Batteries built in Dominion Virginia can likely contract revenue payments, due to that utility's legal obligation to incorporate 2.7 GW by 2035
- IRRs will depend strongly on the level of these payments

30min · 1h (no CM) · 1h (incl. CM) · 4h (incl. CM) · 1h (incl. DOM fixed payment)[2] · 4h (incl. DOM fixed payment)[2]

1) Shown including a nodal premium corresponding to appx. the 95% percentile of nodal spreads. 2) Assuming constant annual capacity payment of $30/kW/y for 4h and $7.5/kW/y for 1h battery from DOM VA, which is legally obliged to build or procure 2.7 GW of battery capacity by 2035. DOM VA's control area is not part of PJM's Capacity Market. 3) Aurora Central assumes an ITC step-down, but the IRA allows a continuation of higher ITC levels if so decided by legislature.

Source: Aurora Energy Research

4-hour batteries built in 2024 would need ~$160/kW PV of state incentives to break even, but this need dissolves by 2028

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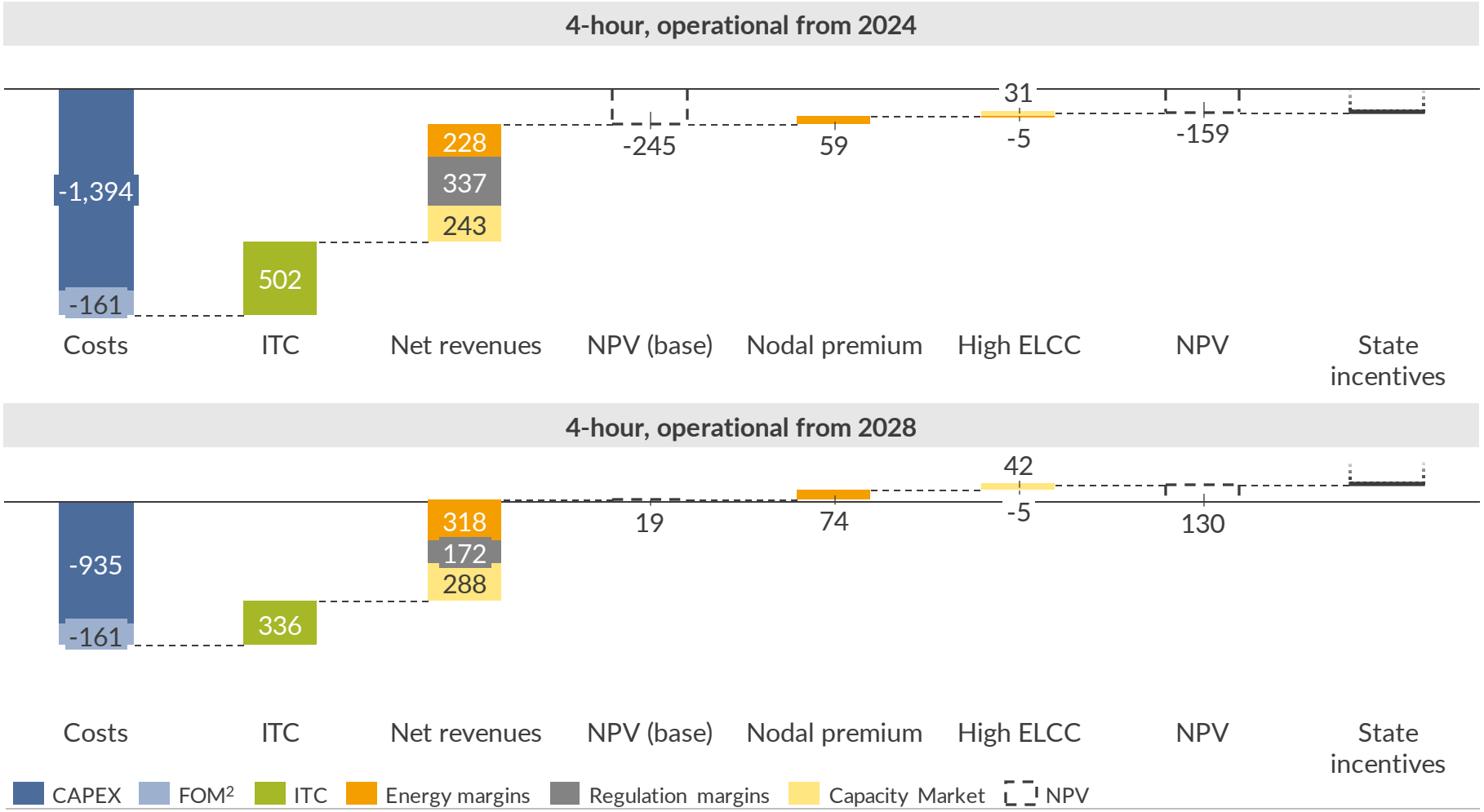
Present value of cashflows for battery built in AE[1]
$/kW (real 2021)

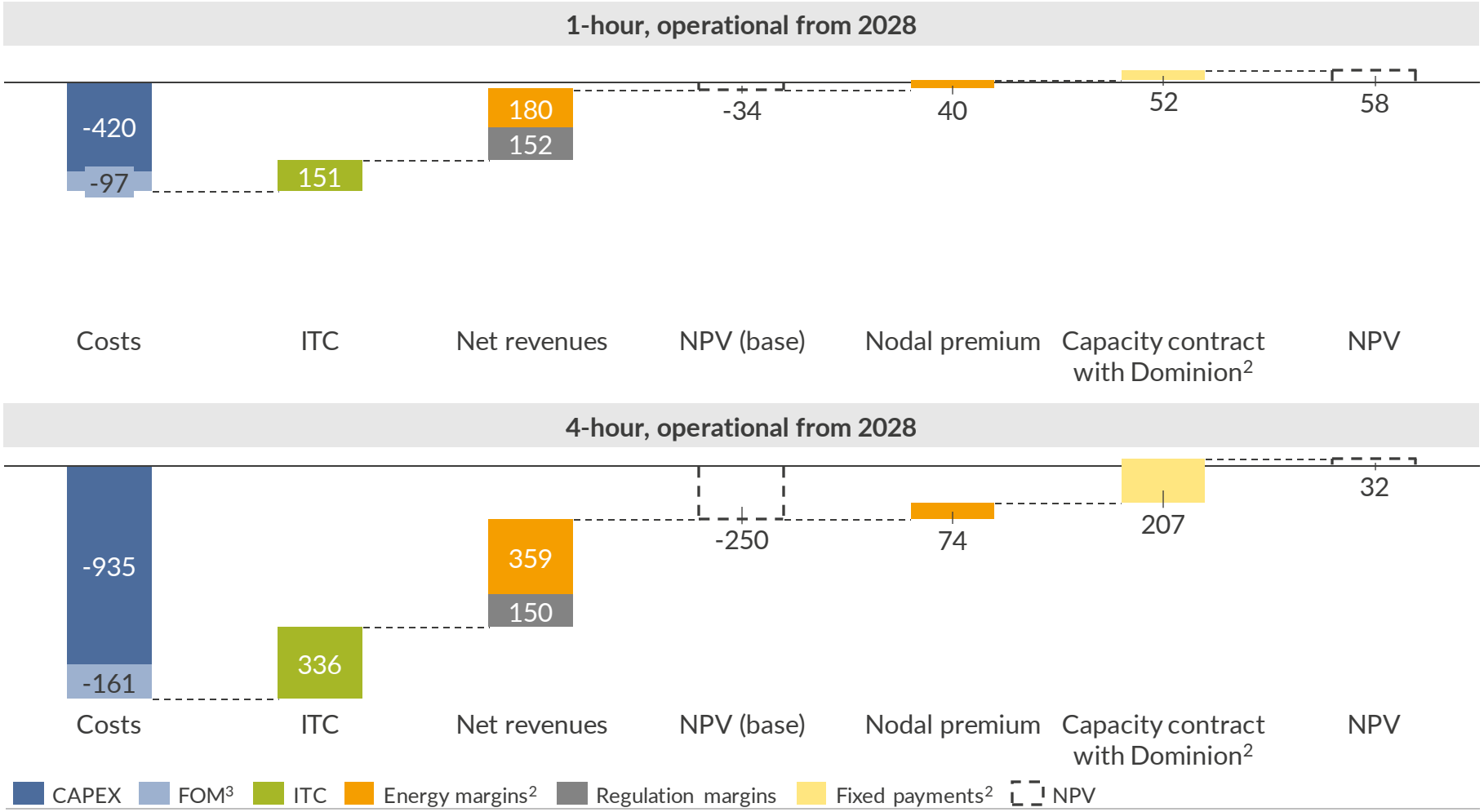


1) Analysis based on the following assumptions: CAPEX due in year preceding first operational year, 87.5% round-trip efficiency, 1 cycle per day, 20-year lifetime, CAPEX of $971/kW (2024 operation) and $624/kW (2028 operation), FOM of $22/kW/y. Cashflows discounted at 11%. 2) Fixed Operation and Maintenance.
Source: Aurora Energy Research

- 4-hour batteries see a strong improvement in NPV between 2024 and 2028 build, driven primarily by declining CAPEX
- A 4-hour battery built in 2024 in AE would need $159/kW of additional value from state incentives for a positive business case, even including good nodal location and high ELCCs
- By 2028, however, a 4-hour battery can expect a positive NPV of $19/kW even without a nodal premium or high ELCCs, although these together could add an additional $111/kW of present value

In Dominion VA, 4-hour batteries are heavily reliant on capacity contracts for positive NPVs this decade

Present value of cashflows for battery built in Dominion VA[1]
$/kW (real 2021)



1) Analysis based on the following assumptions: CAPEX due in year preceding first operational year, 87.5% round-trip efficiency, 1 cycle per day, 20-year lifetime, CAPEX of $284/kW / $624/kW, FOM of $13/kW/y / $22/kW/y for 1h / 4h battery. Cashflows discounted at 11%. 2) Assuming $7.50/kW/y constant for 1h battery, $30/kW/y for 4h battery. 3) Fixed Operation and Maintenance.
Source: Aurora Energy Research

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- A 1-hour battery built in Dominion VA in 2028 could break even without a capacity contract if placed at an optimal node, although fixed payments from Dominion would add significant upside
- 4-hour batteries are heavily reliant on fixed payments from capacity contracts with Dominion VA, needing nearly $30/kW/y to break even, with higher levels necessary if nodal placement is suboptimal
- On top of additional revenues, a capacity contract with Dominion can provide significant upside by reducing risk, potentially lowering the cost of capital for a battery project

Uncertainties in ITC have the largest impact on battery business cases, impacting IRRs by up to 260 basis points

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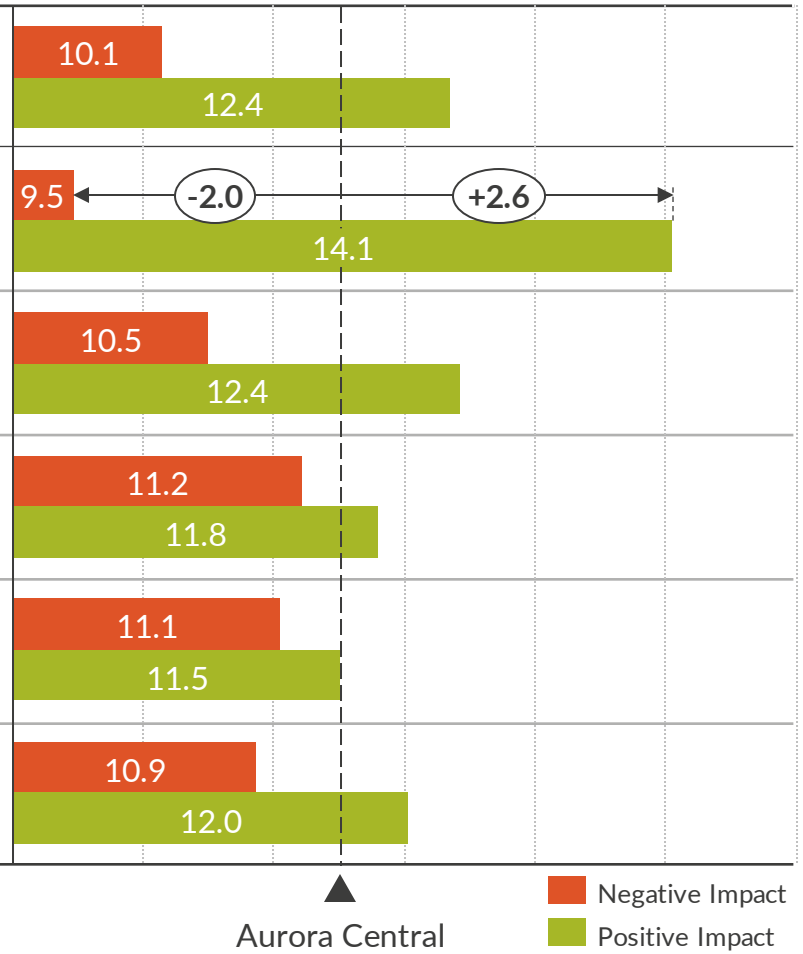
Sensitivities for 4-hour battery with 2028 entry in AE

	Sensitivity	Units	Aurora Central (2028 new build)	Sensitivity (Delta to Aurora Central)	
Business case sensitivities	ELCC (2040)[1]	%	50%	25% (-25 p.p.)	100% (+50 p.p.)
	ITC	% of CAPEX	40%	30% (-10 p.p.)	50% (+10 p.p.)
	Nodal premium (4h nodal spread delta to zonal spread)	$/MWh	19.4	9.7 (-50%)	29.1 (+50%)
Operational parameters	Degradation	%/year	2.5% (y1-y3) / 1% (after)	3.5% / 2% (+1 p.p.)	1.5% / 0.01% (-1 p.p.)
	Cycling rate[2]	#/year	365	274 (-25%)	456 (+25%)
	Round-trip efficiency	%	87.5%	82.5% (-5 p.p.)	92.5% (+5 p.p.)



1) *100% ELCC* assumes PJM's expected ELCC progression, staying at 100% after 2032. *25% ELCC* assumes linear ELCC decrease from 2029 level (77%) down to 25% by 2040, staying flat thereafter. 2) Assuming lifetime remains constant at 20 years across cycling rate sensitivities.

Source: Aurora Energy Research

Agenda

I. Introduction to Aurora & today's session

II. Introduction to battery storage in PJM

III. Market outlook

IV. Battery investment cases

V. Next steps

US Power Market Forecast: Key market analyses and forecasts for PJM, CAISO, MISO, and ERCOT power market (+ new markets soon)

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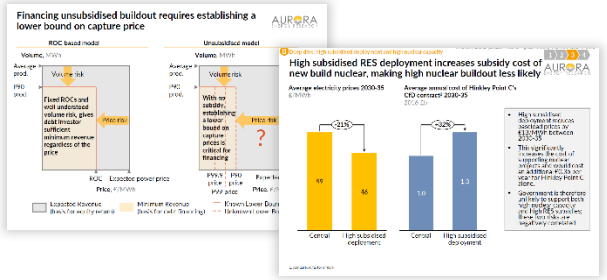
Quarterly data and market reports

- **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** – 3-5 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*



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Get in touch with us!

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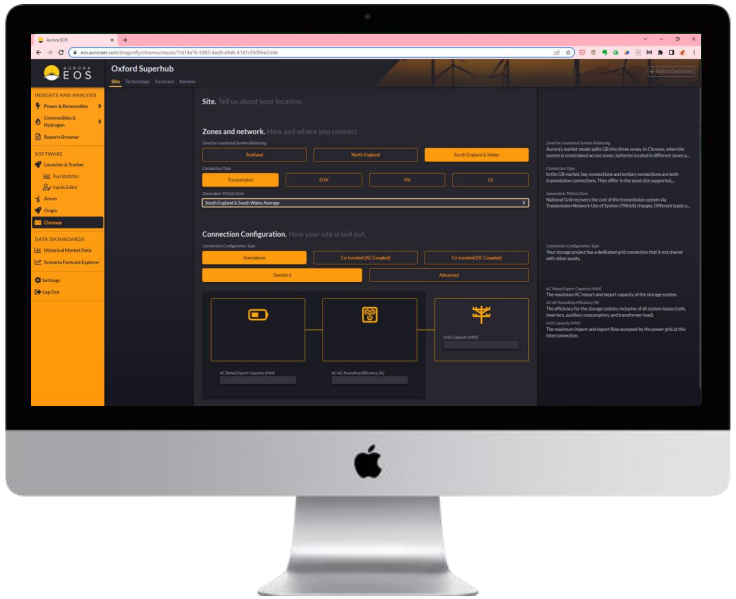
CHRONOS

The leading battery analytics software

CHRONOS allows you to evaluate any storage asset or project using Aurora's cutting-edge propriatary battery dispatch engine



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- **Reliable:** Backed by Aurora's trusted forecasts and team of experts
- **Bankable:** Methodology recognised by banks and investors, with reliance available
- **Comprehensive UX:** Beautiful interface that empowers user driven analyses
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Intuitive 4-step process:

Input your site settings → Input your technology settings → Select your market scenario → Analyse your result

What can CHRONOS be used for?

- Transactions
- Project Design Optimisation
- Portfolio Valuation
- Optimisation Benchmarking

Details and disclaimer

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Date: 15th March 2023

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Appendix

Renewables capacity in PJM increases to over 160 GW by 2050, driven by retiring baseload and state / voluntary demand

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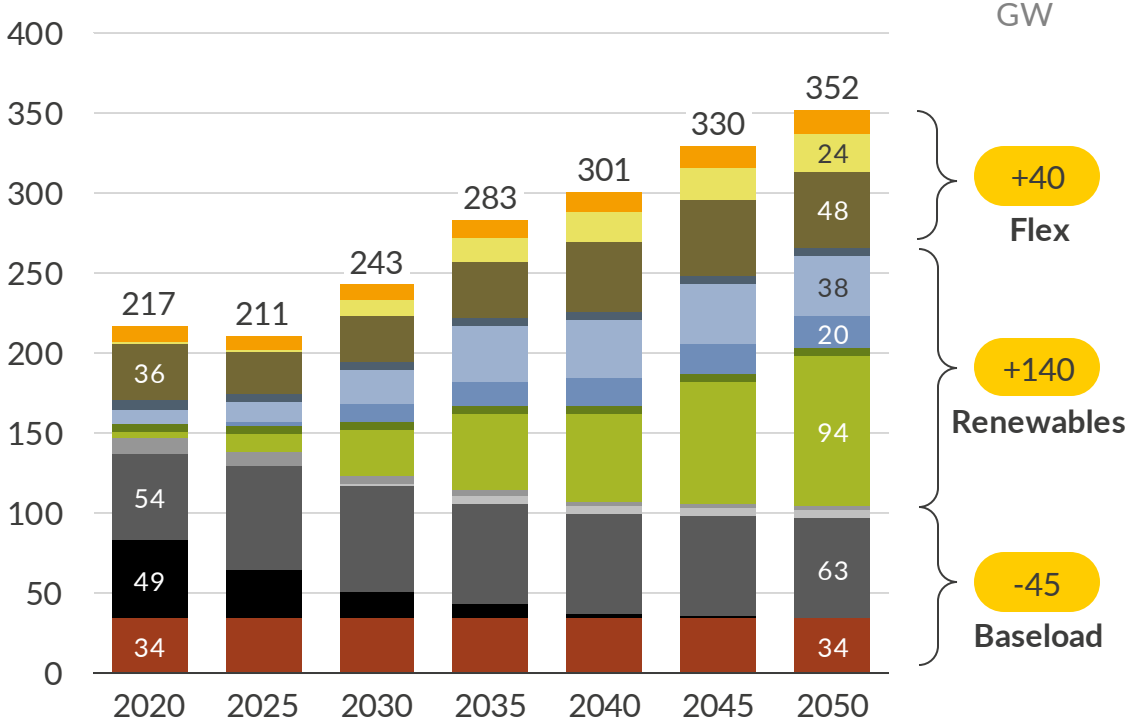
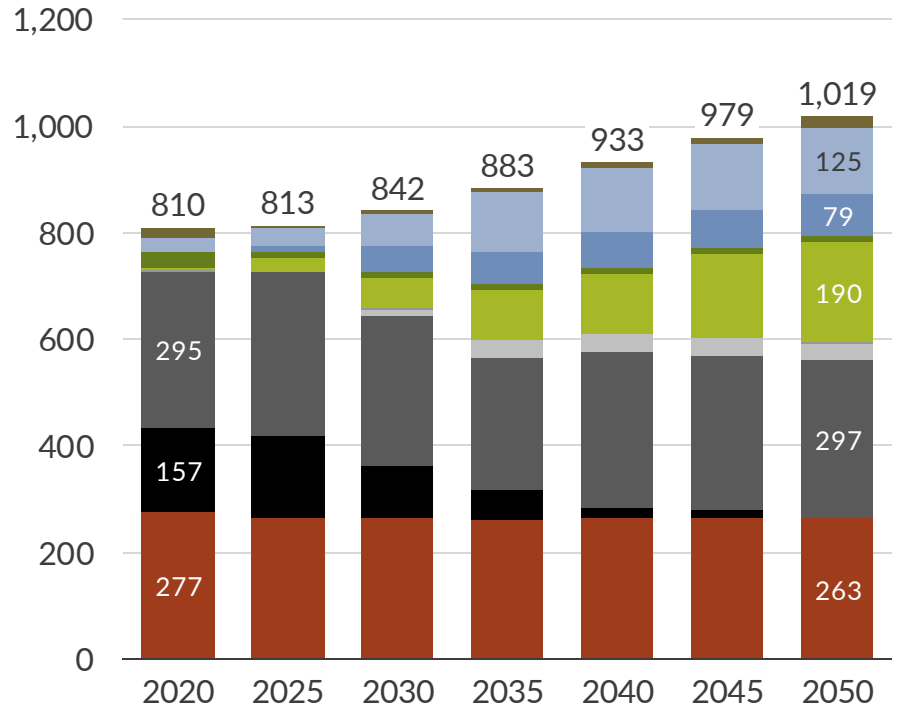
Installed capacity
GW

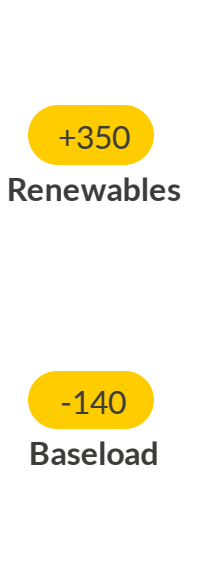


Total change 2020-2050
GW

Electricity production
TWh



Total change 2020-2050
TWh



- **Baseload** capacity decreases by 40 GW over the period, primarily due to coal continuing its current high rate of retirements – more than 30 GW of coal retired in PJM between 2010 and 2020 – caused by PA's accession to RGGI, overcapacity, competitive gas, and environmental regulations

- **Total generation** increases by 25% between 2020 and 2050, driven primarily by load from EVs and datacenters
- **RES** capacity increases by 140 GW by 2050, driven by state and voluntary REC demand, causing RES generation to increase by 500%

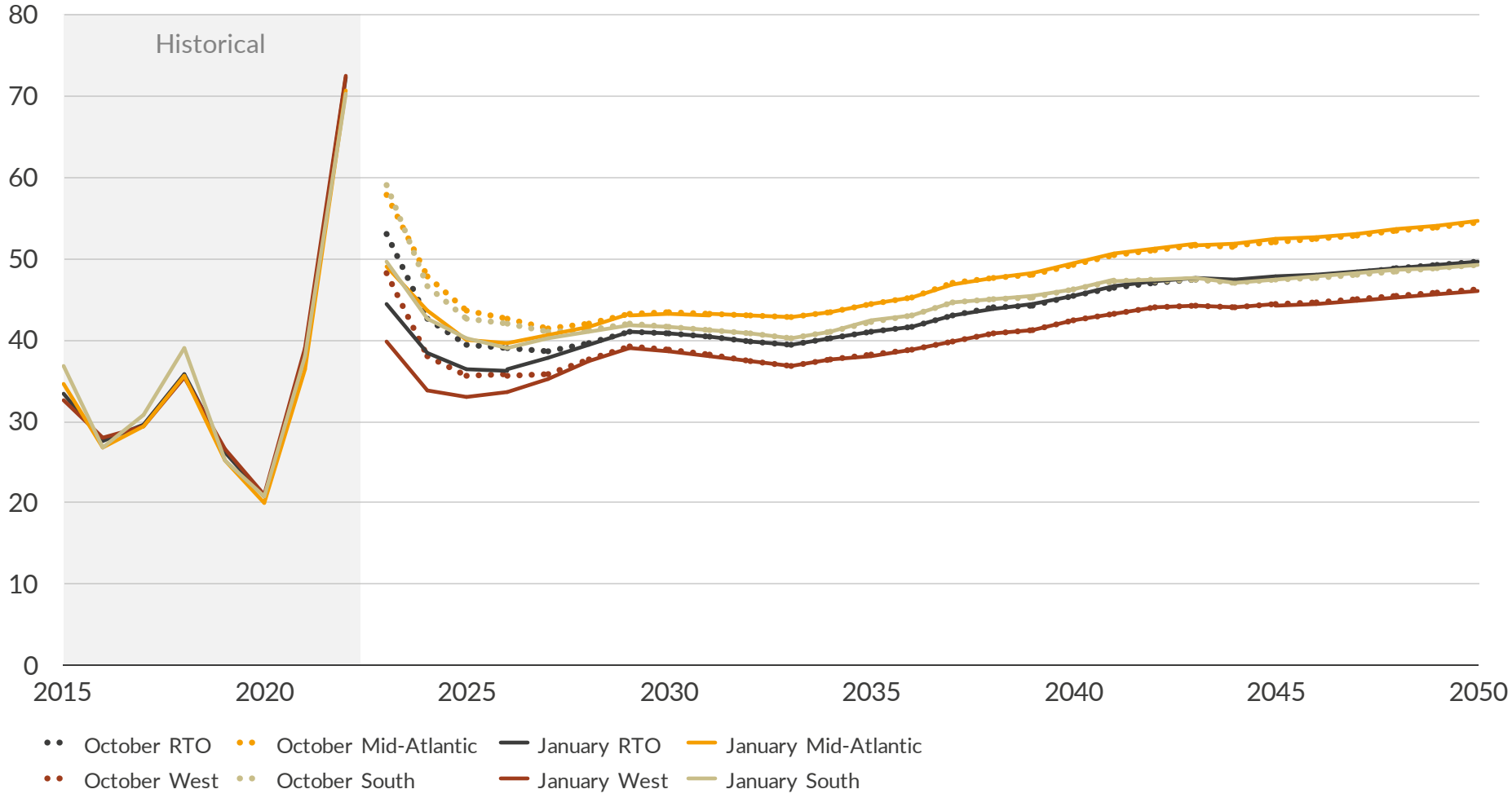
DSR | Peaking | Onshore wind | Other RES | Other thermal | Gas CCGT | Nuclear
Battery storage | Pumped storage | Offshore wind | Solar PV | Gas CCS | Coal

1) Peaking includes OCGT, reciprocating engines, and DSR. 2) Other RES includes biomass and hydro.

Sources: Aurora Energy Research

ATC prices will fall with declining natural gas prices to $36/MWh in 2025, then rise steadily to $50/MWh by 2050

ATC wholesale price[1] by PJM region
$/MWh (real 2021)



1) Around The Clock wholesale power price, also known as the Time-Weighted Average or baseload price. Load-Weighted Averages of Control Zone TWA prices. Historical prices through 2022; forecast from 2023.
Sources: Aurora Energy Research

- In 2022, power prices in PJM averaged the historically high value of $72.2/MWh due to high natural gas prices caused by the Russian invasion of Ukraine
- Aurora Central sees these prices fall to $36/MWh by 2025, due to natural gas prices falling to $3.7/MMBtu
- Rising prices after 2025 are driven by increasing natural gas and CO_2 prices as well as increasing demand, offsetting strong renewables deployment
- Throughout the horizon, prices are highest in the Mid-Atlantic due to CO_2 pricing — the region is entirely within RGGI since Pennsylvania's accession in July 2022 — and high winter gas prices caused by congestion

While PJM has 4 real-time ancillary service markets, batteries participate primarily in RegD

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Ancillary Markets						
Day-ahead:	Primary Sync (DA)		Primary Non-Sync	Secondary		
Real-time:	Primary Sync		Primary Non-Sync	Secondary	Regulation	
					Split into two signals based on response time, cleared as one market (w/ one price)	
Characteristics						
Purpose:	Backup for if a generation unit or other infrastructure fails				Small load-generation mismatches	Frequency control
Subsets:	Tier 1	Tier 2			RegA	RegD Limited to ~40% of Reg market
Characteristics:	Units with spare capacity due to wholesale dispatch	Capacity withheld from wholesale market	Non-dispatched capacity that can ramp within 10 minutes	All capacity that can ramp within 30 minutes	Slower-reacting units following signal sent every 2s	Fast-reacting units that can follow signal at ~60 Hz
Speed:	10 mins		10 mins	30 mins	seconds	~ 1/60 s
Typical technologies:	all				Steam, CC, CT	Storage, Hydro, CT

Sources: Aurora Energy Research, PJM

Battery participation in the Reg market is limited to ~40% of demand, effectively guaranteeing that thermal units set the price

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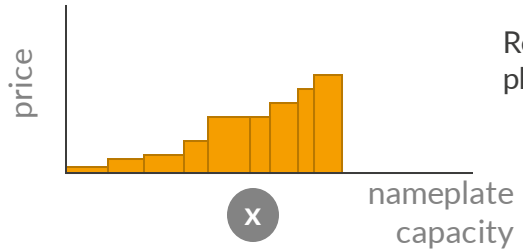
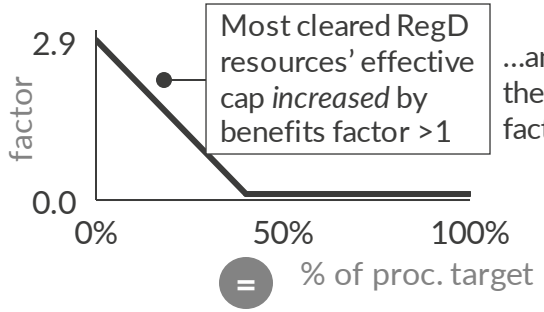
1 RegD's restricted offer capacity…
PJM's Regulation market structure limits RegD participation to ~40% using an adjustment curve

Unadjusted RegD bids



RegD offers are placed in order…

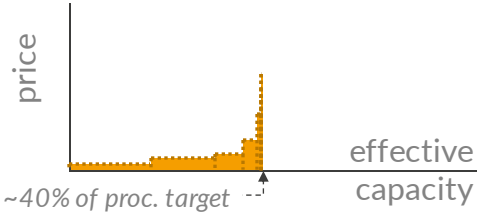
Benefits factor function



Most cleared RegD resources' effective cap *increased* by benefits factor >1

…and multiplied by the "benefits factor" function…

Adjusted RegD bids

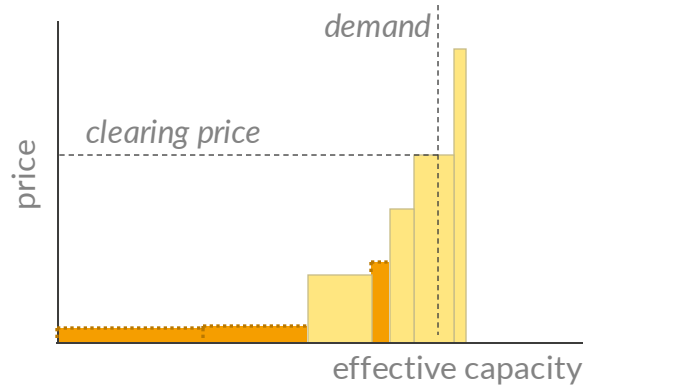


…which caps offered RegD capacity to 40% of overall Reg target, but also increases effective capacity of cleared bids.

2 …and RegA's higher bid levels…
Thermal units incur higher costs than batteries by participating in Reg, resulting in higher bids

Signal	Typical technologies	2020 avg bid range $/effective MW/h
RegD	▪ Storage ▪ Hydro ▪ Peakers	0–2 12–16 10–80
RegA	▪ CCGTs ▪ Steam turbines ▪ Peakers	5–11 6–20 10–80

Illustrative resulting supply stack and demand



3 …mean Reg prices — in the current structure — will stay high compared to other markets…

Impacts:

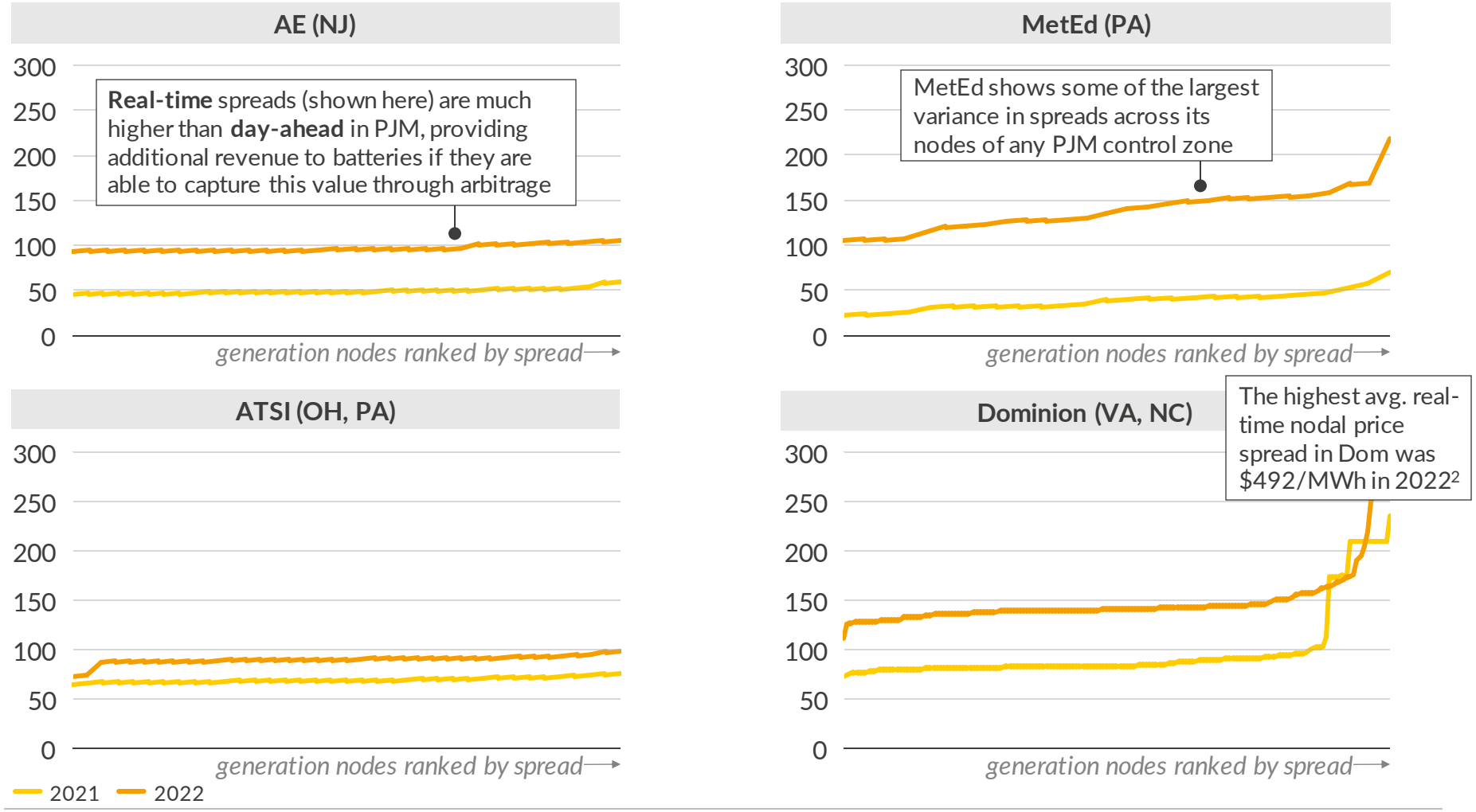
- Batteries cannot provide all of Reg; some thermal in RegA will always clear
- Reg prices will stay >$15/MW/h, thanks to higher-bidding thermal participants
- Knowing this, batteries can effectively bid 0 in an attempt to undercut competition, resulting in non-price factors determining the merit order among batteries in RegD
- Battery revenues from Reg will consequently become increasingly thin-spread, reducing individual batteries' revenues despite stable Reg prices

4 …but PJM is considering removing the split into RegA and RegD signals, which would likely see prices quickly drop.

Source: Aurora Energy Research

Price spreads vary materially across control zones and at the nodal level, reaching as high as $492/MWh in 2022

Yearly average real-time TB1 spreads by node, ranked[1]
$/MWh (real 2021)



1) Shown only for generation nodes in the respective control zones. "TB1" spreads refer to the price difference between the one highest-price and one lowest-priced hour in the day. 2) Not shown on graph to improve clarity.
Sources: Aurora Energy Research, PJM

PJM energy spreads over the past two years have generally been high, and METED and DOM show strong intra-zone nodal variation

- High energy spreads across zones point to good opportunities for energy arbitrage going forward
- The greatest difference is seen when comparing year to year energy prices as well as prices across zones
- Certain zones, such as Dominion, have a greater variability in spreads between nodes, partially due to covering a larger service territory with more geographic and grid-related diversity, though also pointing to areas with potentially high congestion

1-hour spreads increase in line with rising wholesale prices, with the highest spreads seen in Dominion, MetEd, and BGE

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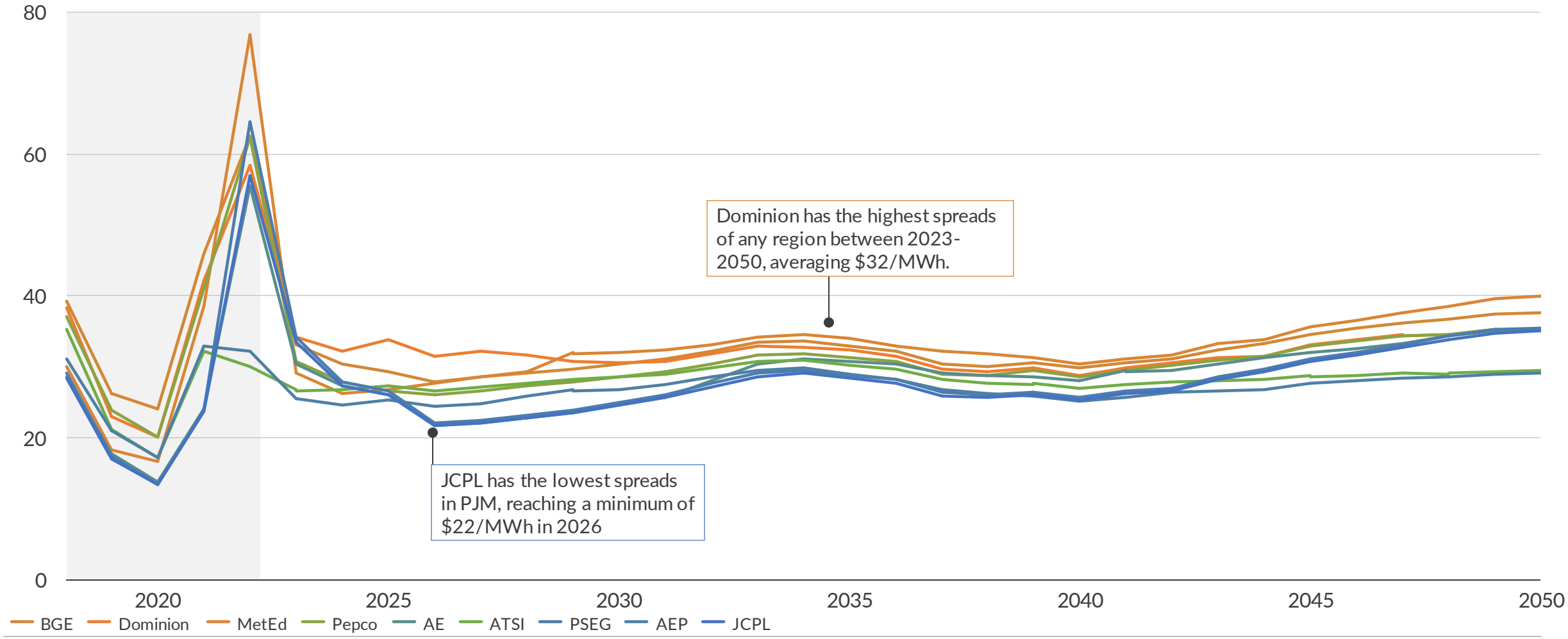
Yearly average day-ahead zonal TB1 spreads[1]
$/MWh (real 2021)



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

Sources: Aurora Energy Research, PJM

Price percentiles increase in line with rising wholesale prices; price spreads increase with the growth of renewables

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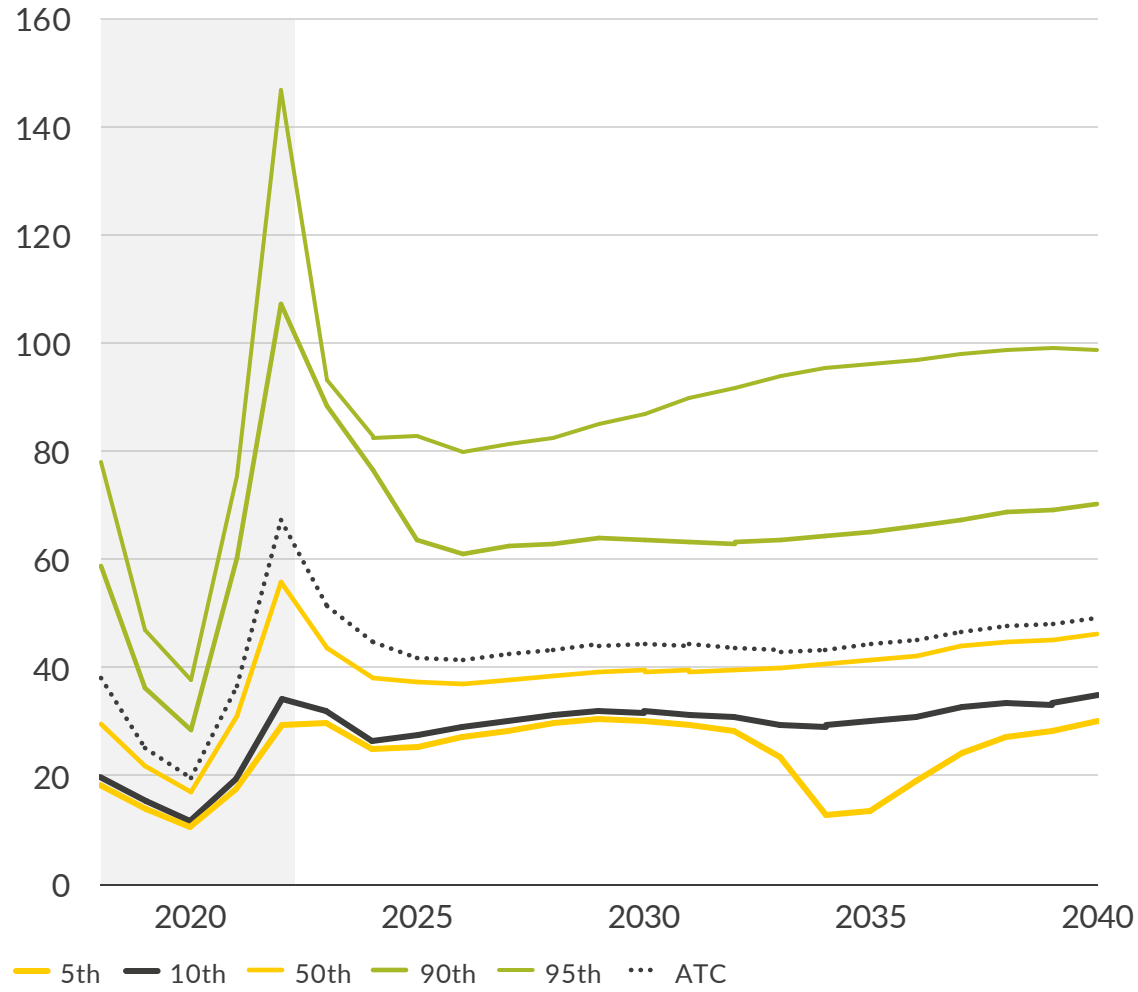
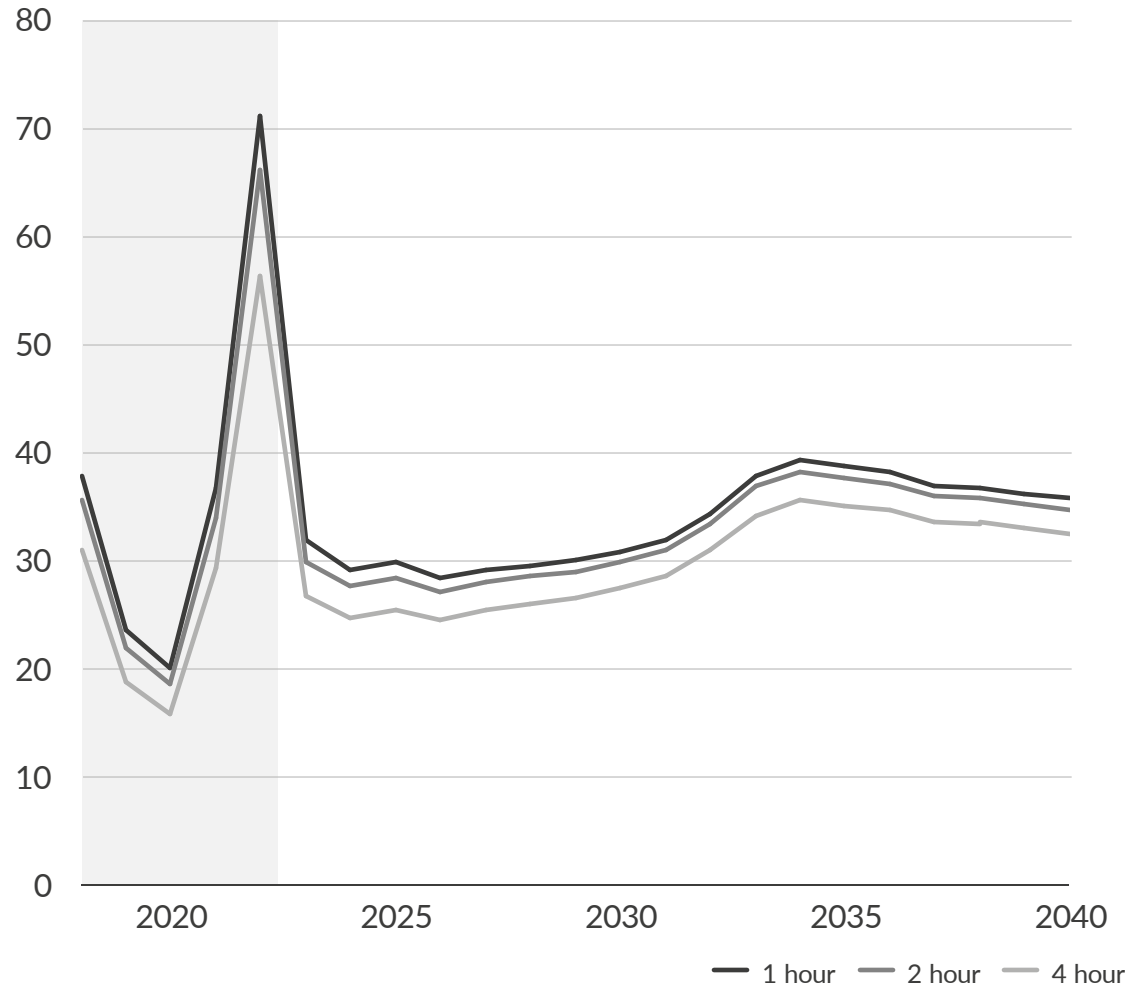
Wholesale day-ahead zonal price percentiles for DPL
$/MWh (real 2021)



Yearly average day-ahead zonal TB4 price spreads for DPL[1]
$/MWh (real 2021)



1) "TB4" spreads refer to the average price difference between the four highest-price and four lowest-priced hours in the day.

Sources: Aurora Energy Research, PJM

Price percentiles increase in line with rising wholesale prices; price spreads increase with the growth of renewables

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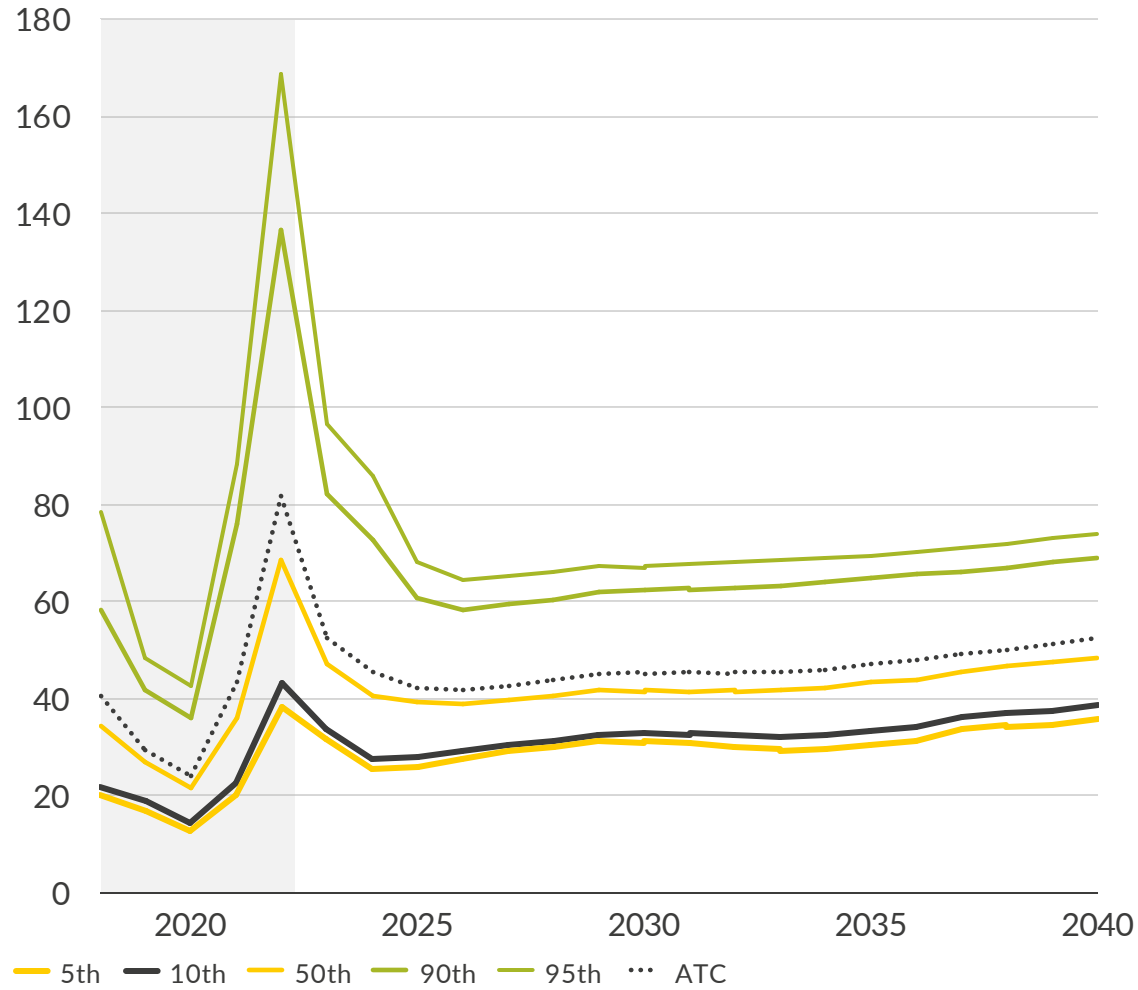
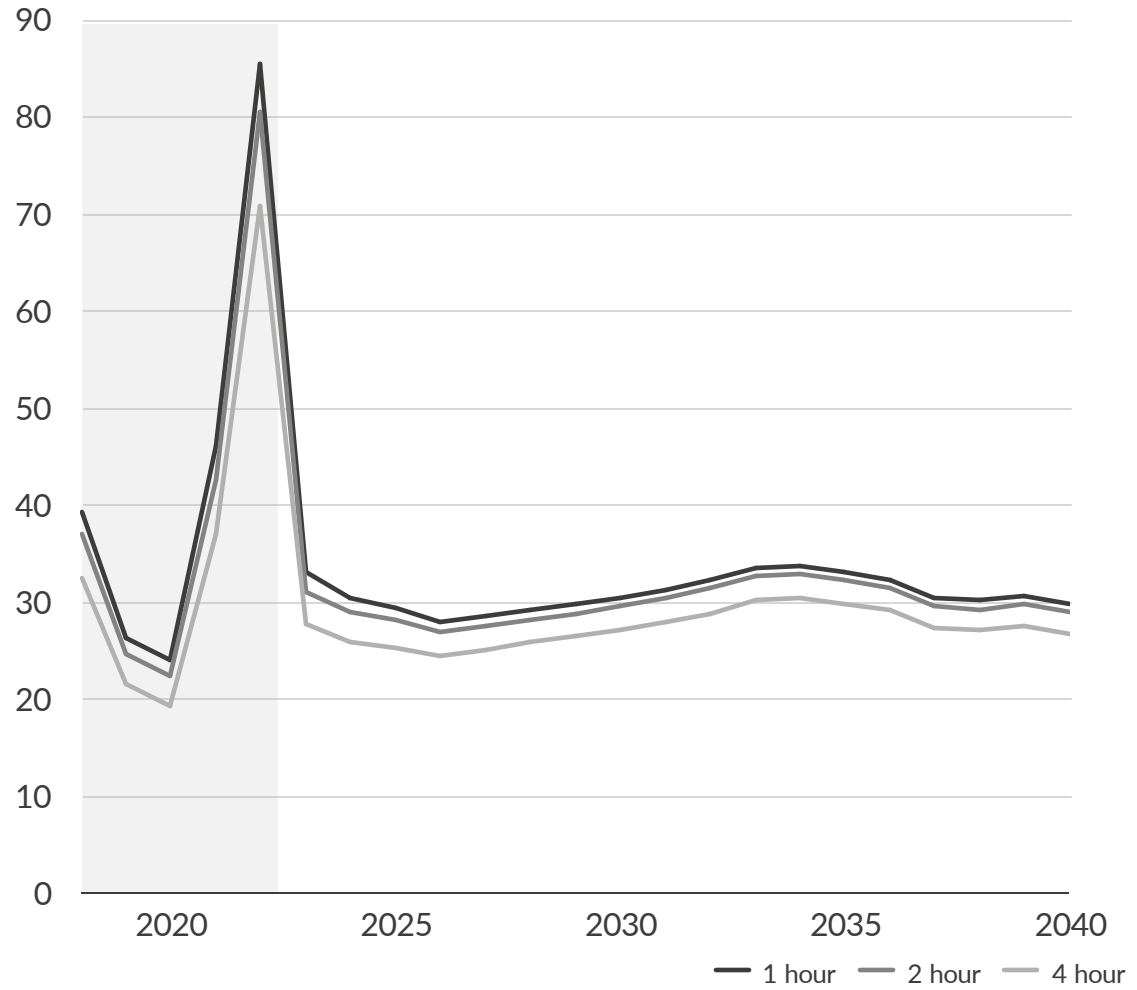
Wholesale day-ahead zonal price percentiles for BGE
$/MWh (real 2021)



Yearly average day-ahead zonal TB4 price spreads for BGE[1]
$/MWh (real 2021)



1) "TB4" spreads refer to the average price difference between the four highest-price and four lowest-priced hours in the day.

Sources: Aurora Energy Research, PJM

Technical battery and financial parameters assumed under Aurora's standard investment cases

	Standard battery parameters[1]	Impact on revenues	Comment
Entry year	2024 / 2028		Later entry means lower AS prices, although potentially offset by lower capex and higher wholesale energy spreads
Duration	30 min / 1 hour / 4 hour		Longer durations add more revenue, particularly in energy arbitrage, but this is not a linear increase
Lifetime	20 years		Longer life means more opportunity to earn capacity revenues
Round-trip efficiency	87.5%		This typically has little impact, unless this is a very high/low value
Degradation per year	3% (y_1-y_3) 1% (after)[2]		Both the average rate of degradation and the year-on-year trajectory matter for wholesale margins
% available for Regulation	100%		Battery's capacity fully available for Reg, but it may reduce this to participate in the energy market or due to state of charge constraints
Regulation assumed dispatch[3]	10%		Determines the revenues and change in state of charge from regulation participation
Reserves assumed participation	0%		Due to the relatively low clearing prices in PJM's reserve markets, batteries are assumed not to participate (as evidenced by history)
Maximum annual cycles	365		This determines available throughput for wholesale and regulation trades
Availability	99%		This typically does not have a major impact, unless outages coincide with high price events
WACC	11%		Aurora assumes 11% WACC across all cases, but assets may be able to secure lower rates for contracted capacity revenues from Dom VA

1) State of charge restrictions not included in this modelling but should also be considered. 2) Higher rate of degradation in first 3 years of battery life. Annual rates correspond to 0.0069%/cycle and 0.0028%/cycle respectively. Overall assumptions result in 22% degradation over the course of battery's 20y lifetime. 3) Based on historical mileage data.

Source: Aurora Energy Research, PJM

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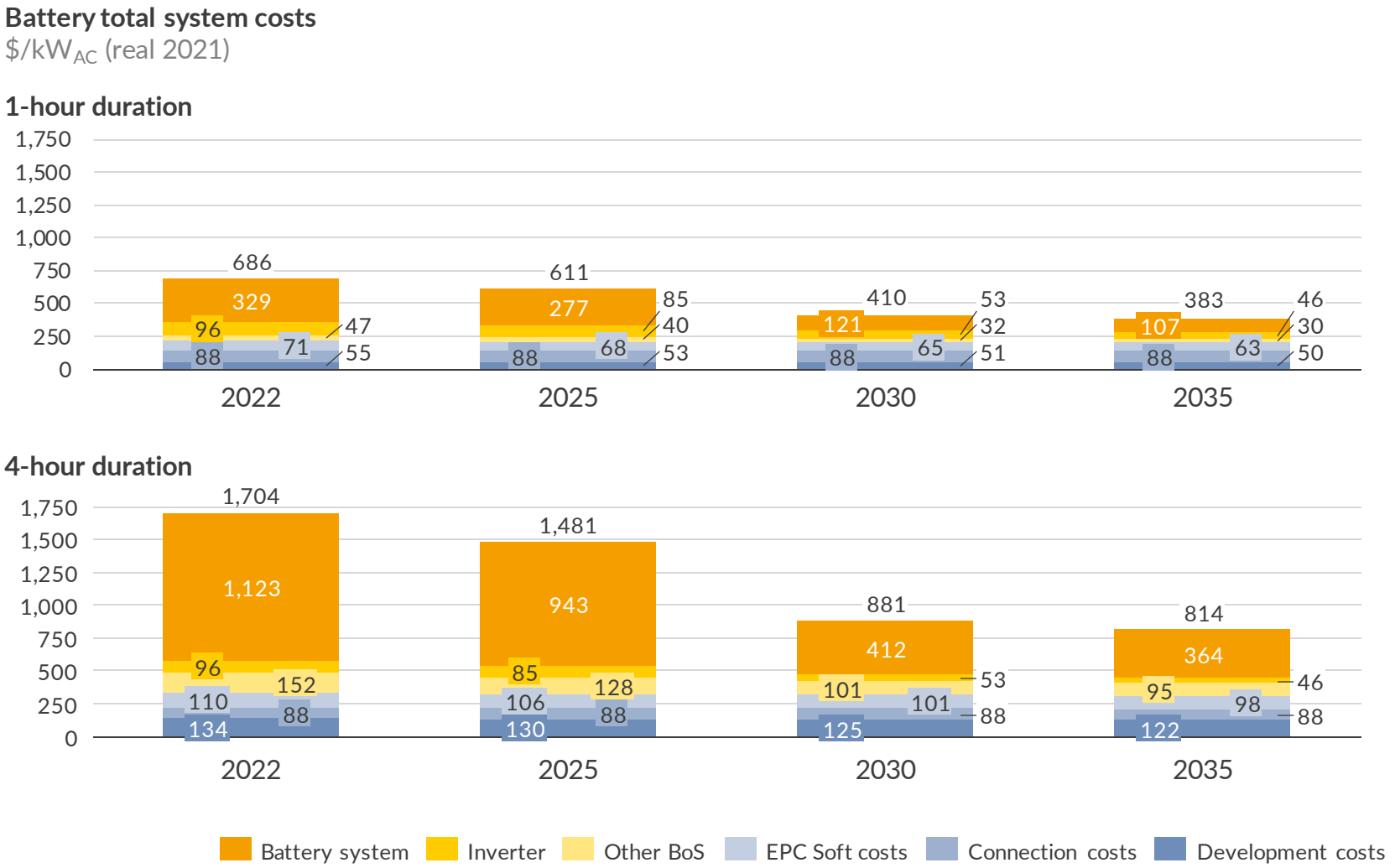
Battery parameter inputs

- When analyzing battery investment cases, there is a wide range of technical input parameters that can influence outcomes
- These parameters vary across manufacturers, battery use cases, market rules, etc.
- This table represents the typical parameters that Aurora has seen for grid scale storage across markets and is based on extensive transaction support and broader collaboration with clients and battery suppliers

Aurora Central expects total system costs of 1-hour batteries to decline by 44% and 4-hour batteries by 52% between 2022 and 2035

- Although battery CAPEX had been historically declining, uncertainty remains around the duration of current supply chain issues that could slow the continuation of this decline
- Battery CAPEX declines more quickly for 4-hour batteries than for 1-hour batteries making longer duration batteries increasingly more profitable over time. Individual component decreases driven by:
  - Cell cost declines are expected to continue as EV production scales up
  - Balance of System components benefit from the scaling up of the solar industry, with inverter costs declining 37% between 2022 and 2035
- Greater cost decreases are expected before 2030. 4-hour battery costs decline 40% between 2025 and 2030, versus 8% from 2030 to 2035



Source: Aurora Energy Research

Standalone battery storage is now eligible for the Federal ITC, reaching 60% if all sourcing, labor, and locational requirements are met

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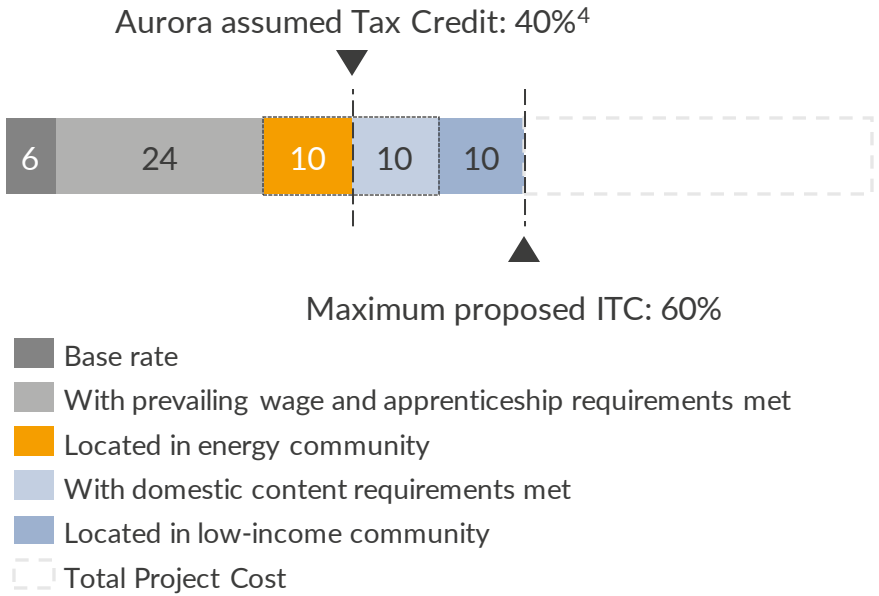
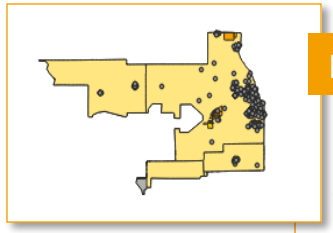
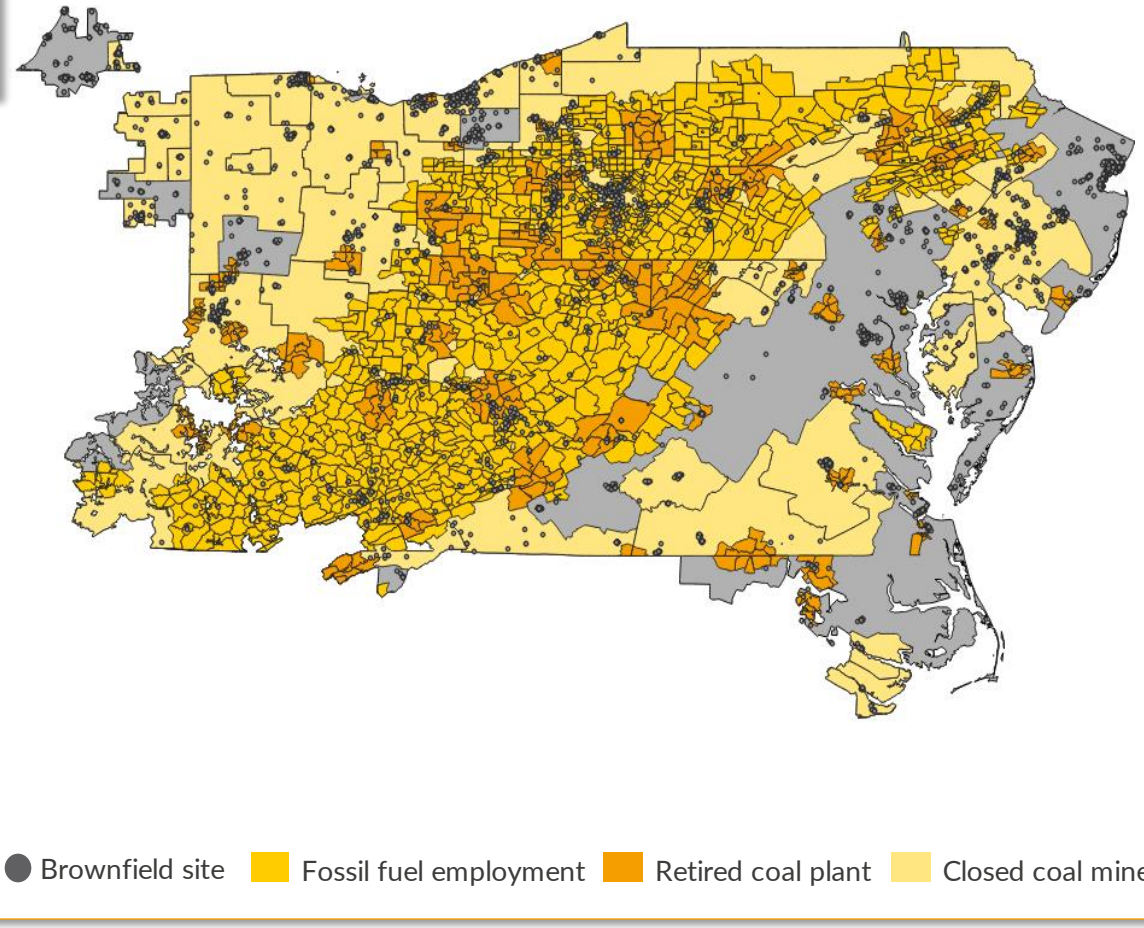
Proposed ITC credit rate breakdown[1,2,3]
% of capital expenditure





PJM Energy Communities



Standalone batteries are now eligible for the Investment Tax Credit (ITC)

- With domestic content, energy community, and low-income community requirements met, the ITC could reach as high as 60% through 2033
- The 10% bonuses for domestic content and energy communities are contingent on meeting prevailing wage and apprenticeship requirements. Without prevailing wage/apprenticeship requirements met, the domestic content and energy community bonuses are reduced to 2%

1) For construction start years 2022-2033. 2) Rates are inflation-linked. 3) In 2025 the ITC becomes technology-neutral, available to any power generation that is net-zero. 4) We assume that standalone storage will be located either in an energy community or meet domestic content requirements to get up to the 40% tax credit level (4% of the Tax Credit is forfeit due to transaction costs).
Sources: Aurora Energy Research, US Department of Labor, Foley & Lardner LLP

A battery's business model, location and technical parameters determine the value for an individual asset

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Step 1: Model the wholesale and ancillary markets

Wholesale market assumptions
- Technology, commodity, demand, policy assumptions etc.

PJM Power Market Model
- Simultaneously models wholesale, ancillary, capacity, and REC markets
- Hourly granularity
- Iterative modelling
- Capacity build / exit / mothballing
- IRR / NPV driven
- Detailed technology assessments

Continuous iteration until an equilibrium is reached

Wholesale prices
- DA prices at 1-hour granularity
- RT prices at 1-hour granularity derived from DA prices

Ancillary service prices
- All main services consistent with DA prices

Capacity market prices
- Internally consistent with wholesale and ancillary service prices

All additional revenue streams
- E.g., RECs based on revenue requirements and shortfall dynamics

Step 2: Model the battery asset dispatch

Asset business models
- Business model: Energy only, Ancillary service only, optimized across markets
- Connection: Standalone/ co-located with solar/thermal/wind asset with/without DC coupling
- Location: Relevant hub price and LMP bonus

Storage asset dispatch model
- Model trading strategy against hourly prices in sequence
- Lifetime impact of degradation

Storage asset dispatch model
- Monthly and yearly granularity
- Gross margins by market

Storage technical parameters and constraints
- Technology: lithium ion/ pumped storage/ flow
- Size
- Duration
- Degradation
- Cycling constraints
- Round trip efficiency
- Co-location charging
- Location and LMP bonus

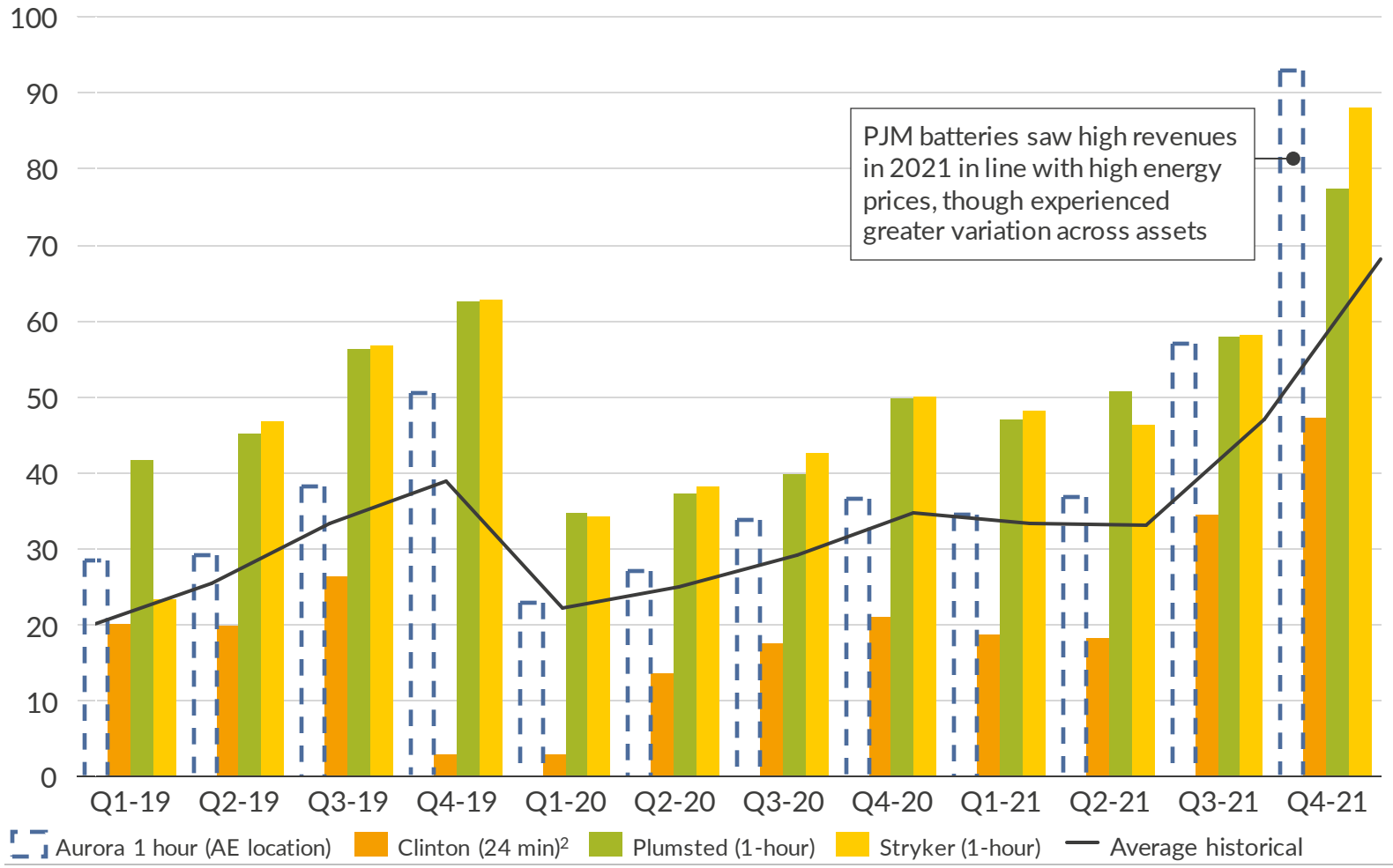
Focus of this section

In-house model | Input | Output

Source: Aurora Energy Research

Aurora's battery dispatch shows similar revenues to existing battery estimates

Quarterly gross revenues for 2019 - 2021 (Historical vs. Aurora 1-hour)[1]
$/kW/quarter (real 2021)



Avg. Revenue
$/kW/quarter

Aurora 1 hour (AE location)	40.6
Average historical	39.9
Clinton (24 min)[2]	20.2
Plumsted (1-hour)	49.9
Stryker (1-hour)	49.6

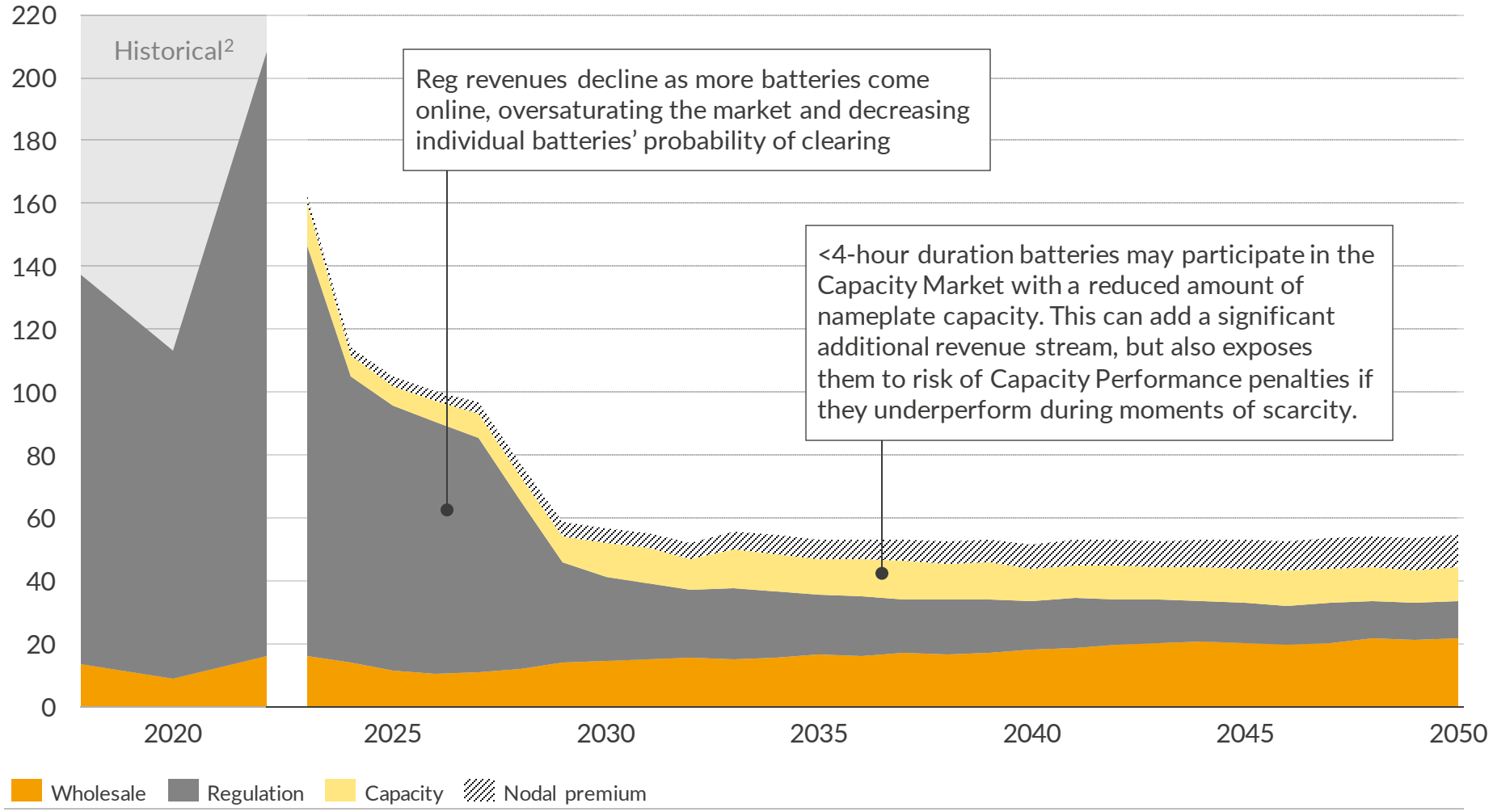
1) Historical battery revenues are approximate based on self-reported data. 2) Estimated from reported 4 MWh depth.

Sources: Aurora Energy Research, FERC

- PJM batteries have historically performed within a narrow band, experiencing high revenues in 2021, and increased annual revenue in the fourth quarter; the similarity in behavior likely reflects similar trading behaviors focused on Regulation
- The Aurora trader mirrors historic battery trading behavior to forecast/backcast expected revenues; in the 2019 - 2021 period, the trader averaged $40.6/kW/quarter versus an average of $39.9/kW/quarter for the selected batteries
- Existing PJM assets may engage in behavior that the trader does not model:
  - Intra-hour trading
  - Hedges, buy-backs and other virtual financial instruments

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[1]
$/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.

Source: Aurora Energy Research, FERC EQR

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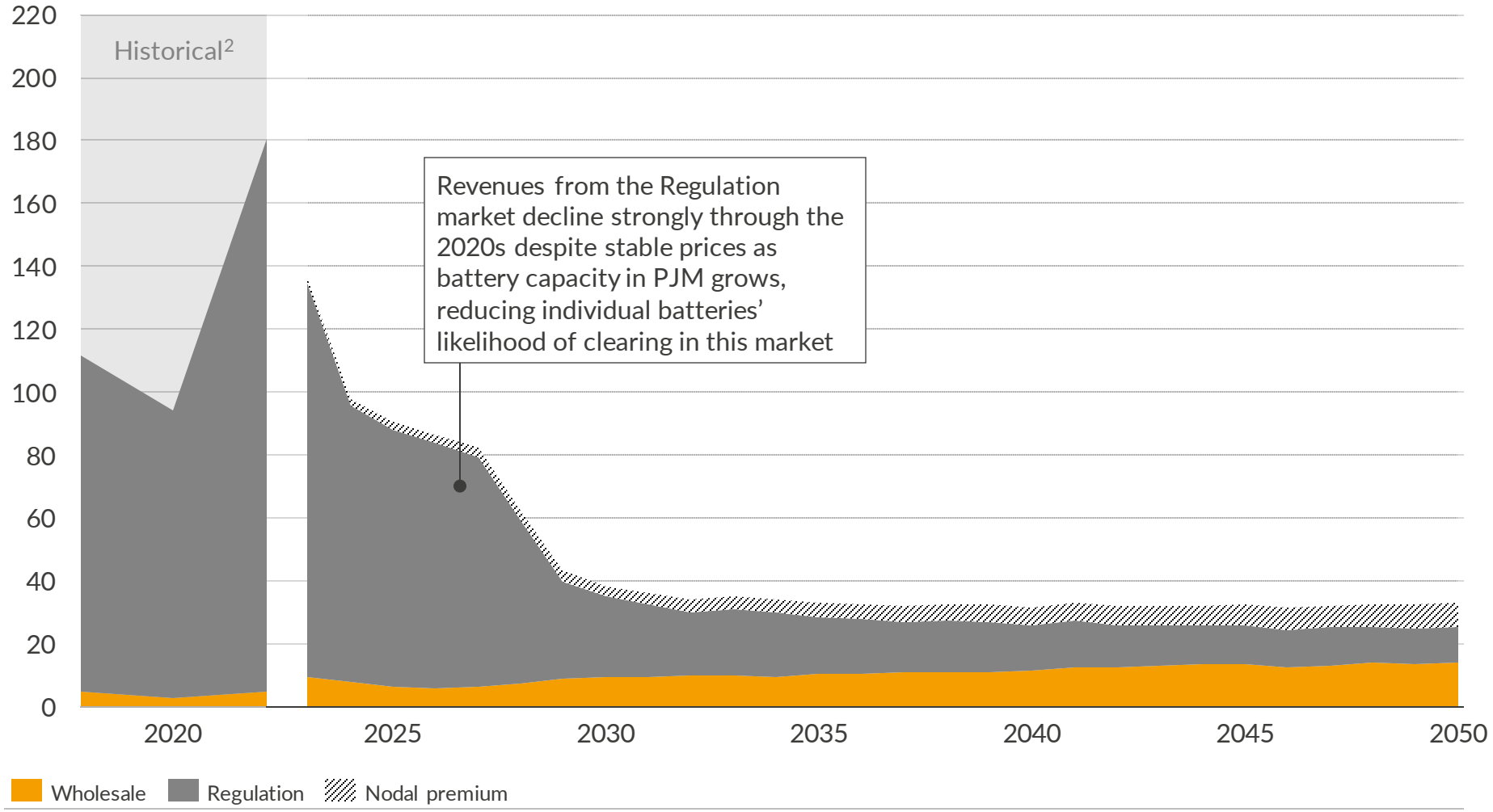
Outlook for battery gross margins

- 1-hour battery revenues fall from ~$150/kW/y in 2023 to ~$50/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 fore-cast, from $11/kW/y in the mid-2020s to $22/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 $12/kW/y by the 2030s in capacity revenues for a 1-hour battery

30 min batteries see decreasing revenues from Reg market due to strong competition from ≥1h batteries

Net revenues for a 30-minute battery in AE[1]
$/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.

Source: Aurora Energy Research, FERC EQR

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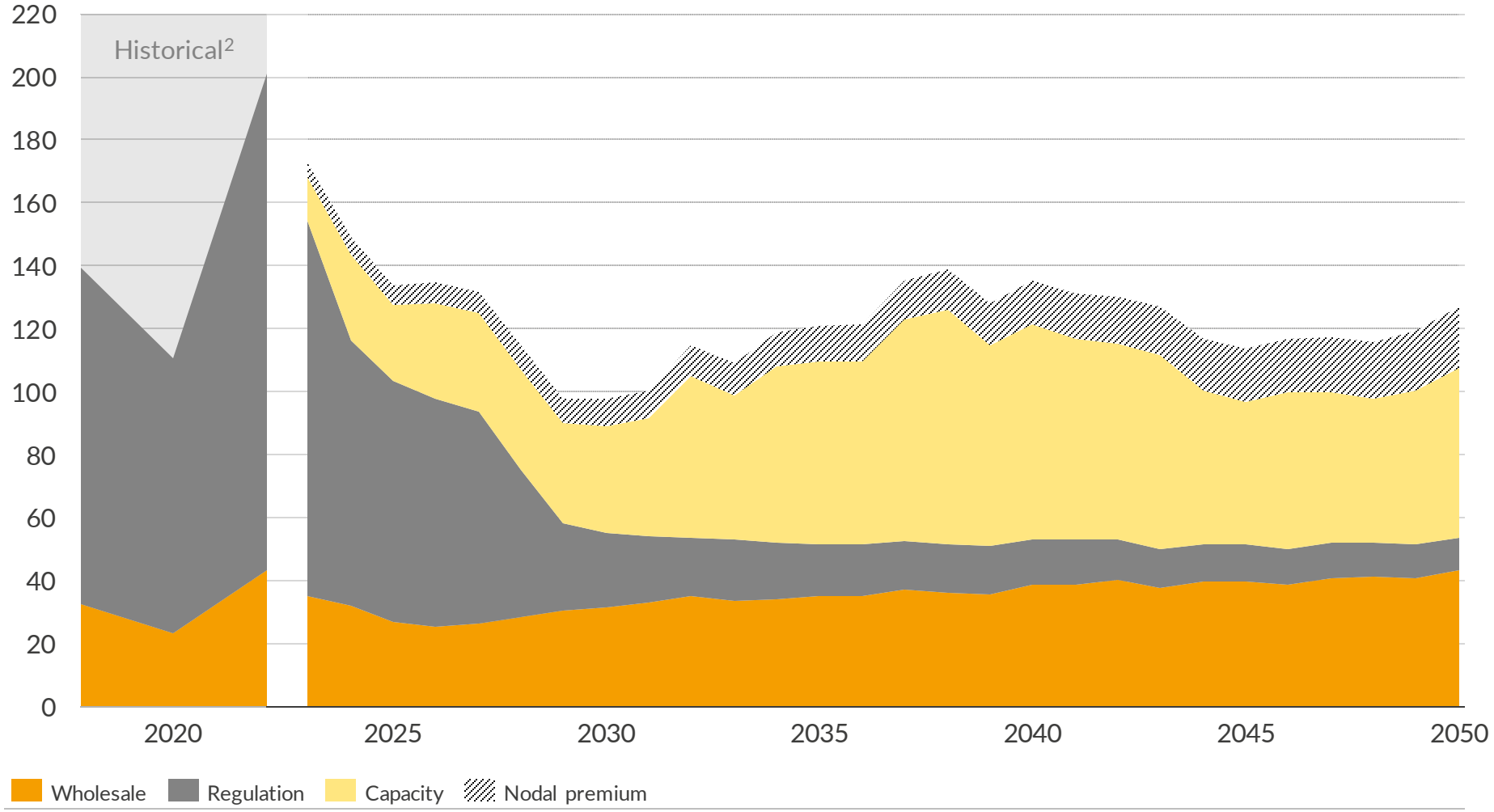
Outlook for battery gross margins

- 30-minute batteries are best-suited to primarily participating in the Reg market, in which PJM keeps a 30-minute conditional neutrality for battery state of charge
- However, revenues from the Reg market decline steeply through the 2020s down to ~$20/kW/year by the early 2030s as battery capacity in PJM increases, decreasing a battery's probability of clearing in the market
- Revenues from energy arbitrage in the Day-Ahead and Real-Time markets increases steadily over the forecast, from $6/kW/y in the mid-2020s to $14/kW/y by 2050, as renewable penetration increases

A 100% ELCC would increase capacity revenues, bringing 4h total net revenues to peak at $140/kW/y in MAAC in 2038

Net revenues for a 4-hour battery in AE[1] – 100% ELCC[3]
$/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.
3) Assuming 4h battery ELCCs progress according to PJM expectations, staying at 100% thereafter.
Source: Aurora Energy Research, FERC EQR

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Outlook for battery gross margins

- Although Aurora Central sees battery ELCCs declining to 50% by 2040—consistent with other markets around the world—PJM's current method sees ELCCs hitting 100% by the early 2030s (although these values are not published beyond 2032)
- However, the impact of increased ELCCs is mitigated by decreasing CM prices, as increased effective battery capacity and more battery build-out increases supply on the Capacity Market
- Overall, ELCCs for batteries following this trajectory and staying at 100% could raise capacity revenues up to $74/kW/y in the best years, providing a significant upside

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

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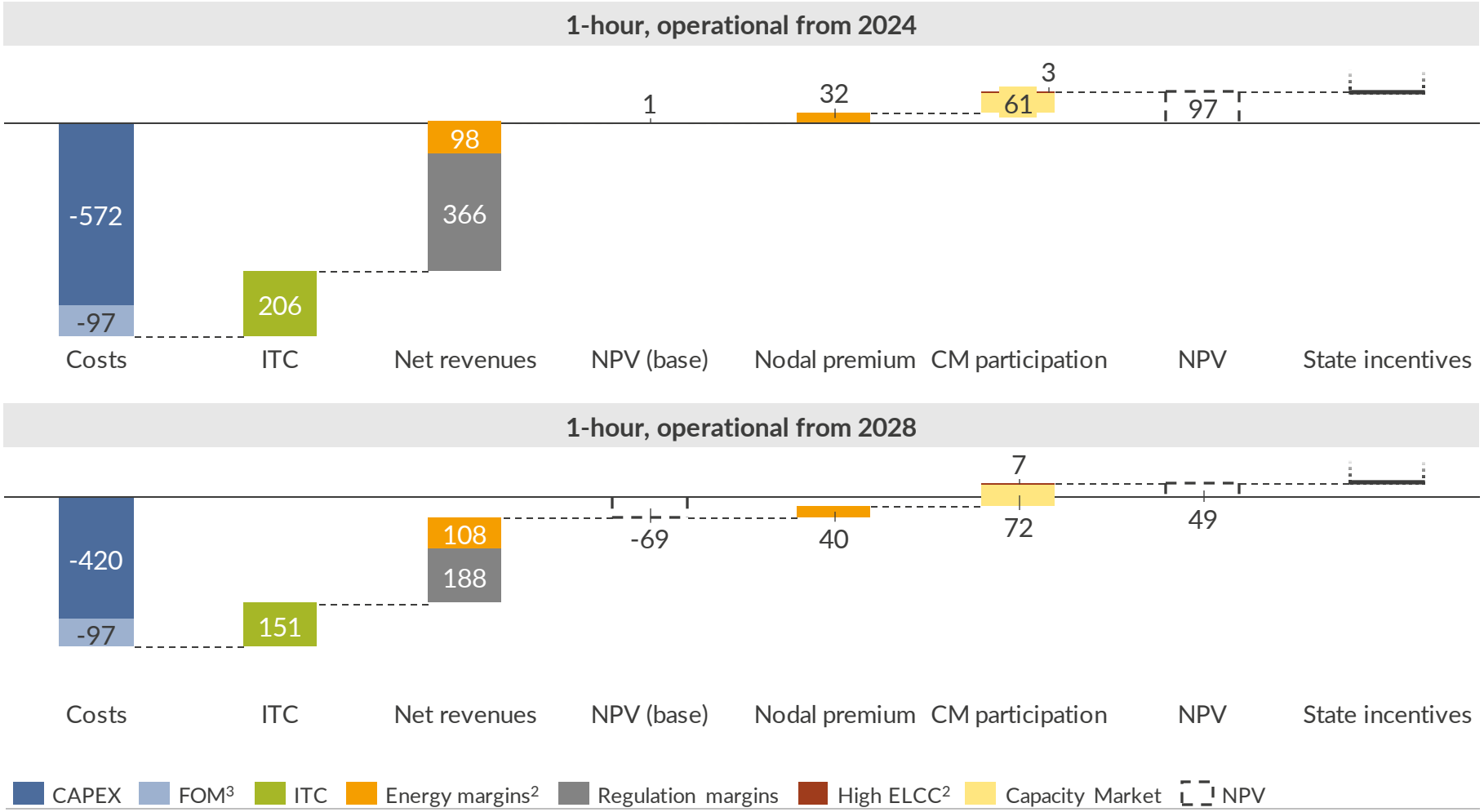
Battery cases shown include nodal premium and assume 11% cost of capital, with CAPEX due in year preceding entry year.

Entry Year	Scenario	Duration	Present Value of Gross Margins[1] ($/kW)			IRR (%)			Payback Period (yrs)		
			AE (NJ)	ATSI (OH)	DOM[2] (VA)	AE (NJ)	ATSI (OH)	DOM[2] (VA)	AE (NJ)	ATSI (OH)	DOM[2] (VA)
2024	Aurora Central	30 minute	352	355	334	16%	17%	15%	4	4	5
		1 hour – excl. CM	399	424	420	13%	14%	14%	5	5	5
		1 hour – incl. CM	460	462	472	16%	16%	17%	5	5	5
		4 hour – Aurora ELCC[3]	707	656	756	7%	6%	8%	10	12	10
		4 hour – 100% ELCC[4]	690	725	900	8%	9%	12%	11	10	7
2028	Aurora Central	30 minute	192	186	186	9%	8%	8%	9	10	10
		1 hour – excl. CM	239	265	275	9%	11%	11%	9	8	8
		1 hour – incl. CM	311	312	327	14%	14%	15%	7	7	7
		4 hour – Aurora ELCC[3]	617	577	630	11%	10%	12%	8	9	8
		4 hour – 100% ELCC[4]	620	677	788	12%	14%	17%	8	8	6

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

1-hour batteries need to rely on good nodal placement and CM participation for a robustly positive NPV this decade

Present value of cashflows for battery built in AE[1]
$/kW (real 2021)



1) Assumptions: CAPEX due in year preceding first operational year, 87.5% round-trip efficiency, 1 cycle per day, 20-year lifetime, CAPEX of $399/kW (2024 operation) and $284/kW (2028 operation), FOM of $13/kW/y. Cashflows discounted at 11%. 2) Combined impact of higher ELCCs, resulting lower CM prices, and resulting lower spreads. 3) Fixed Operation and Maintenance.
Source: Aurora Energy Research

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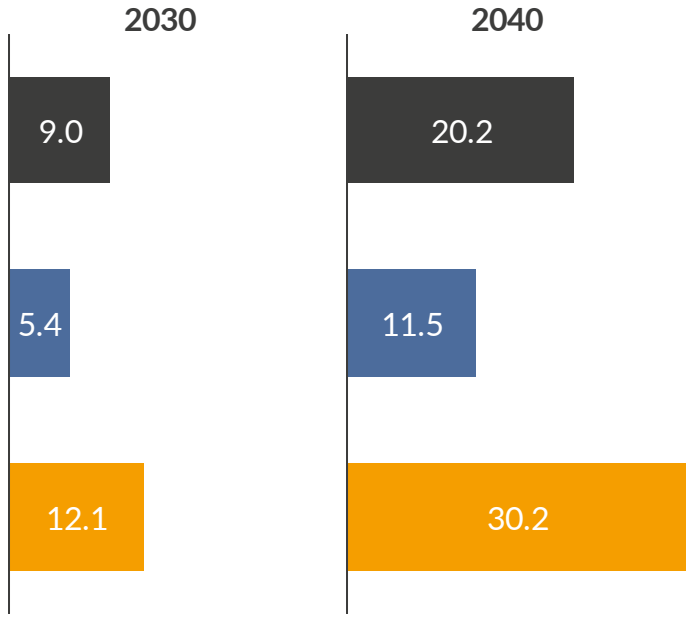
- A 1-hour battery built in 2024 in AE can expect a roughly zero NPV through Regulation revenues and arbitration on zonal spreads alone
- Placement at a high-spread node, participation in the CM, and high ELCCs can together provide up to $96/kW of additional present value
- These factors become crucial for the viability of a 1-hour battery built in 2028, bringing its NPV from negative to positive
- On top of the shown factors, state incentives, such as NJ's Storage Incentive Program currently under development, may provide further revenues still

We explore key market uncertainties through a range of market scenarios

Scenario	Description
Central	Considers current policies alongside a view for future policy intervention, and our internally consistent central view of technological change and commodity prices. Assumes tax credits extended indefinitely, though with credit value declining over time
Low	Represents a downside case, incorporating low underlying demand and low commodity prices. This envisages a world with slower overall GDP and population growth while other assumptions, such as renewables support mechanisms, are maintained as in Aurora's Central
High	A long-term upside case for prices, this scenario considers higher commodity prices and load. Higher global GDP increases demand for commodities, while load grows at an accelerated pace due to higher rate of population and industrial demand growth

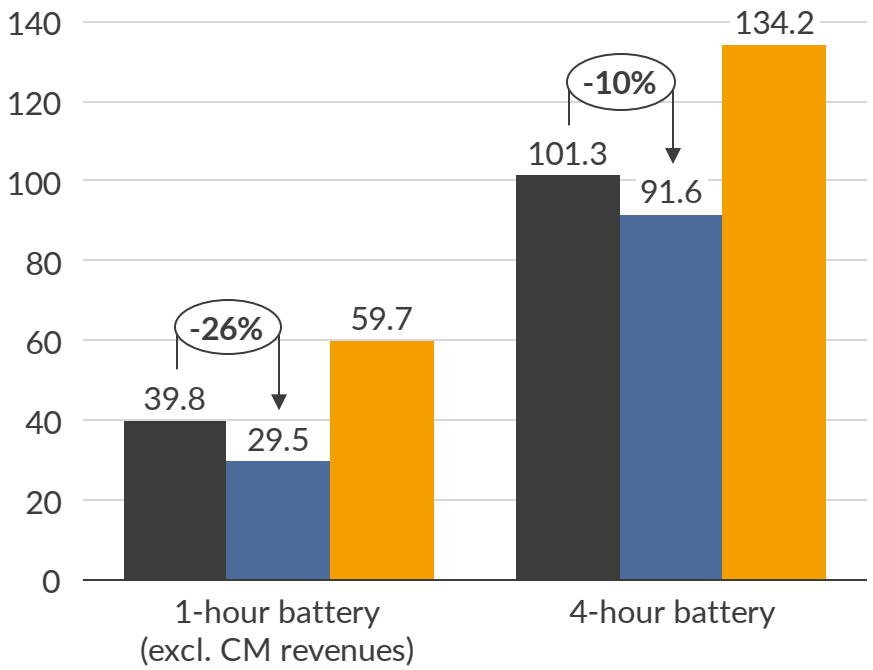
RTO-wide battery capacity deployment, GW



Source: Aurora Energy Research

Downside risk is mitigated by CM participation, thanks to capacity prices' counterbalancing of energy prices through the mid-2030s

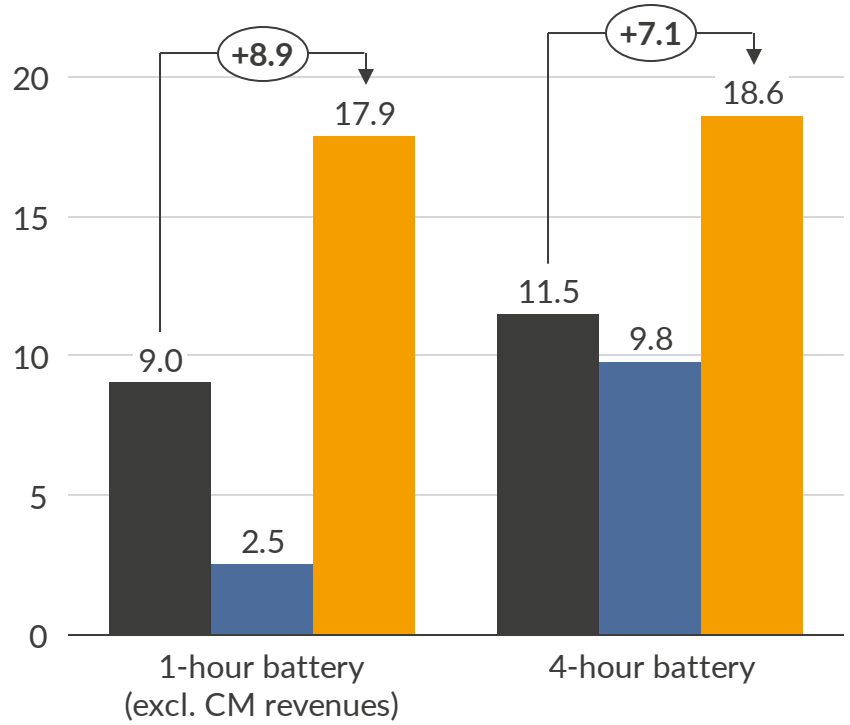
Average annual battery gross margins (2028 entry, 2030-2040 margins)
$/kW (real 2021)



- Gross margins are impacted by both the lower wholesale spreads and the lower ancillary returns in our Low scenario
- However, Capacity Market prices are higher in Low than in Central through 2033, dampening Low's impact for a 4h battery receiving capacity revenues (-10%) compared to an energy-only 1h battery (-26%)

Aurora Central Low High

IRR for a new build battery by duration (2028 entry)
%



- Project IRRs fall correspondingly to gross margins in the Low scenario
- Simultaneously, batteries see strong upside potential from the High scenario, with IRRs rising by up to 8.9 p.p.
- A 1h energy-only battery sees stronger upside from High than a 4h battery receiving capacity mirroring the 1h battery's higher downside risk from Low

Source: Aurora Energy Research

ATC prices vary by $30-40/MWh across these three market scenarios, but spreads remain similar until the mid-2030s

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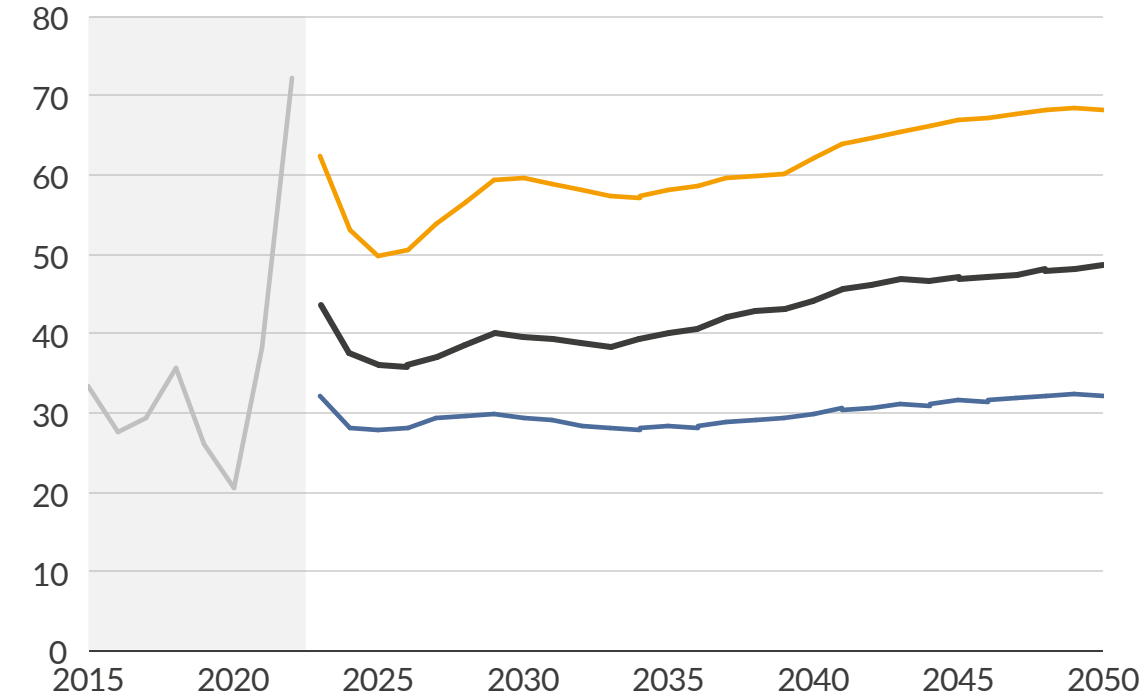
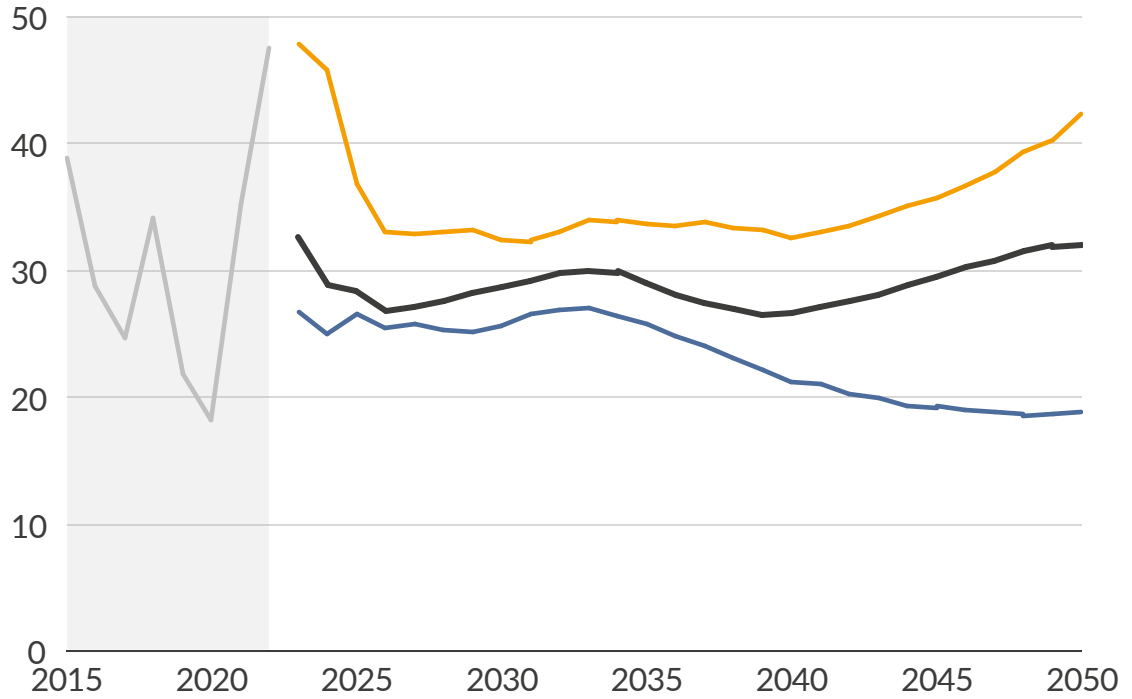
PJM-wide ATC[1] price
$/MWh (real 2021)



PJM-wide average 1-hour daily spread
$/MWh (real 2021)



- ATC prices vary by up to $30/MWh across Aurora's High and Low scenarios, averaging ~$60/MWh in High and ~$30/MWh in Low after 2030
- The primary drivers for these differences are commodity prices and load, although renewables build and policy also have a lesser impact

- Spreads vary little between High and Low — by up to ~$6/MWh — in the mid to late 2020s, due to only small differences in renewable generation
- After 2030, spread differences between the scenarios increase as renewable capacity diverges, falling to $20/MWh in Low by 2040 but rising in High to $33/MWh

Historical Central Low High

1) Around the Clock, also known as the Time Weighted Average (TWA).

Source: Aurora Energy Research

Regulation and Capacity Market prices vary by up to $45/MWh and $130/MW-day respectively across these scenarios

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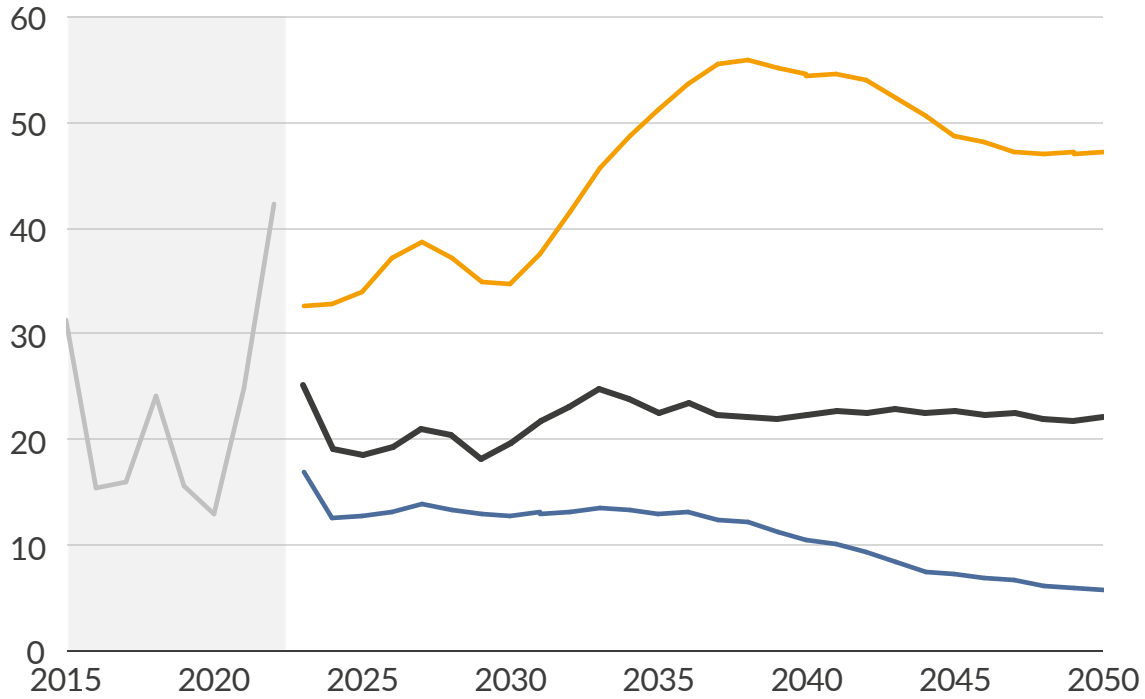
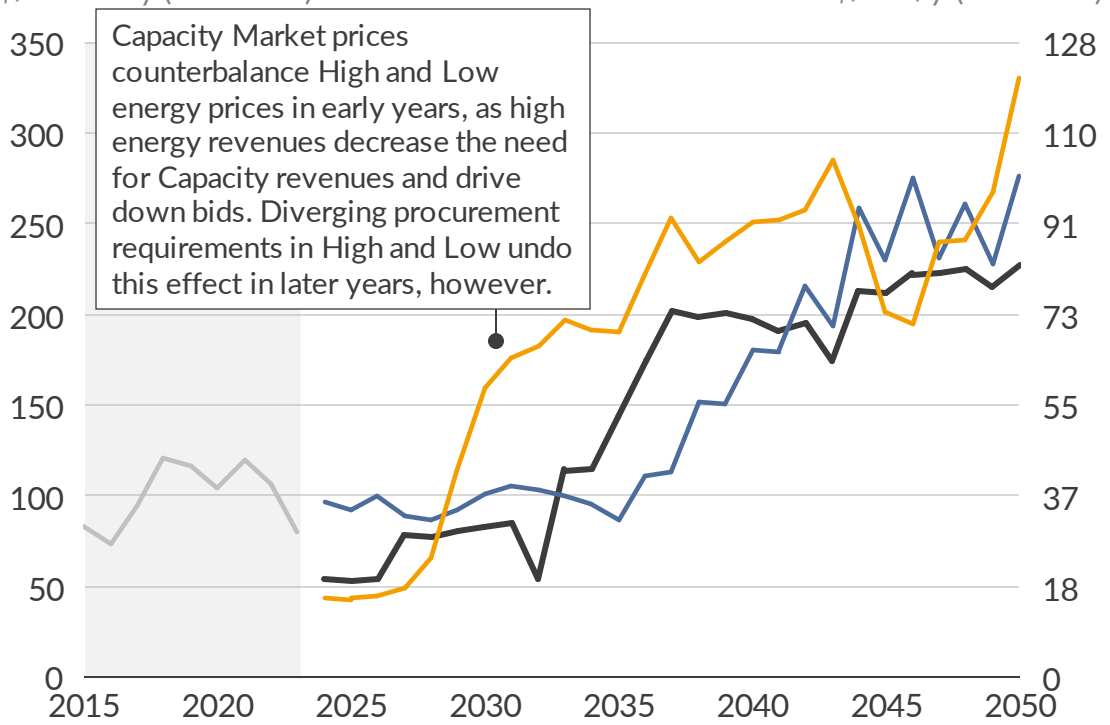
Regulation market clearing price

$/MW/h (real 2021)



Capacity Market clearing price (RTO)[2]

$/MW-day (real 2021) $/kW/y (real 2021)



- Regulation prices vary strongly between High and Low — by up to $45/MW/h in 2040 — driven apart by both diverging power prices and Regulation procurement requirements

- Capacity Market prices show less relative variation than Regulation, with the largest divergence — ~$130/MW-day — in the early 2030s as prices rise to new-build bid levels in High sooner than in Central or Low
- Variation is lower before and after this period, at ~$50/MW-day in the mid-2020s and ~$70/MW-day by 2040

Historical Central Low High

1) Around the Clock, also known as the Time Weighted Average (TWA) . 2) 5-year rolling average.

Source: Aurora Energy Research

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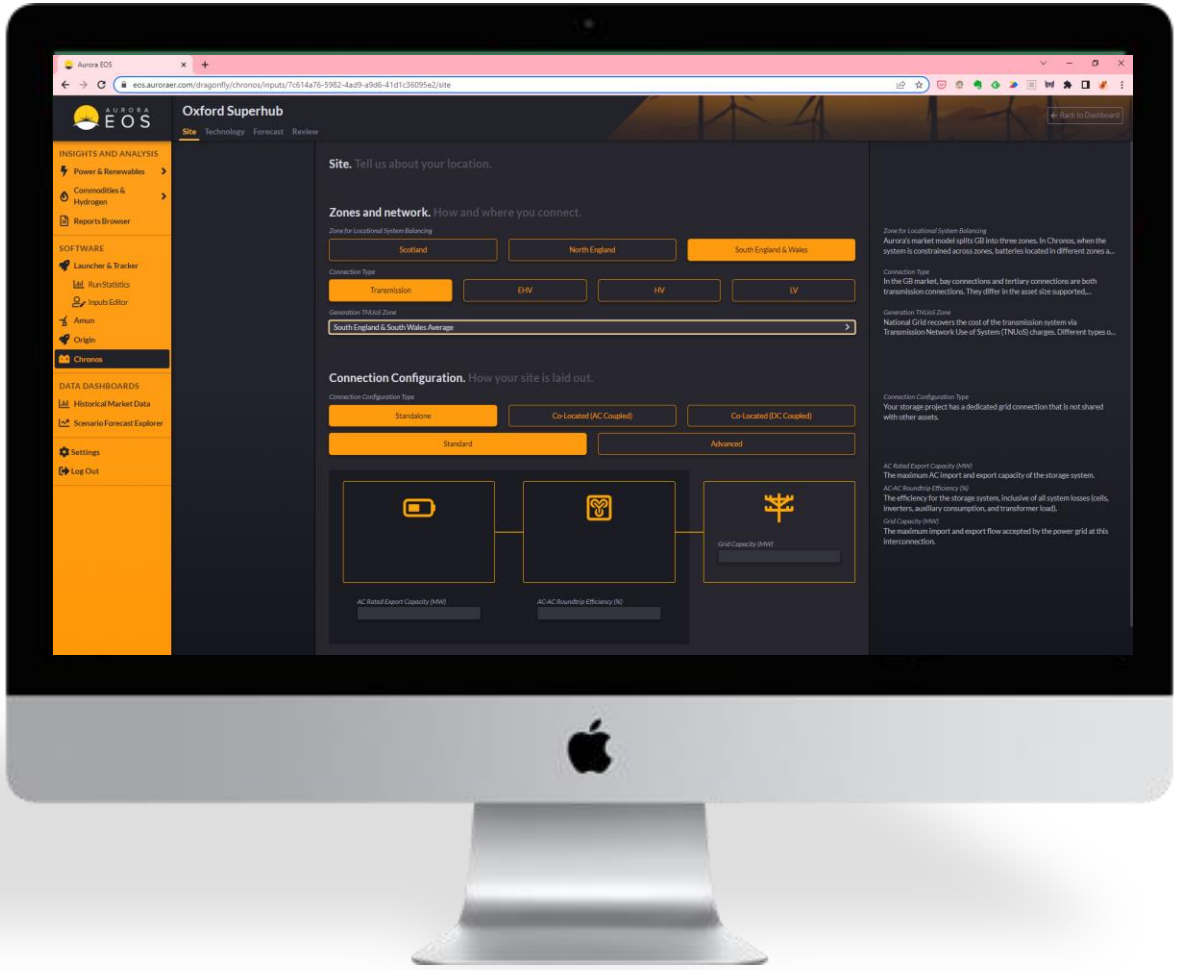


Transactions

Project Design Optimisation

Portfolio Valuation

Optimisation Benchmarking

CHRONOS delivers Aurora's state-of-the art battery investment case analysis with unmatched ease of use and speed

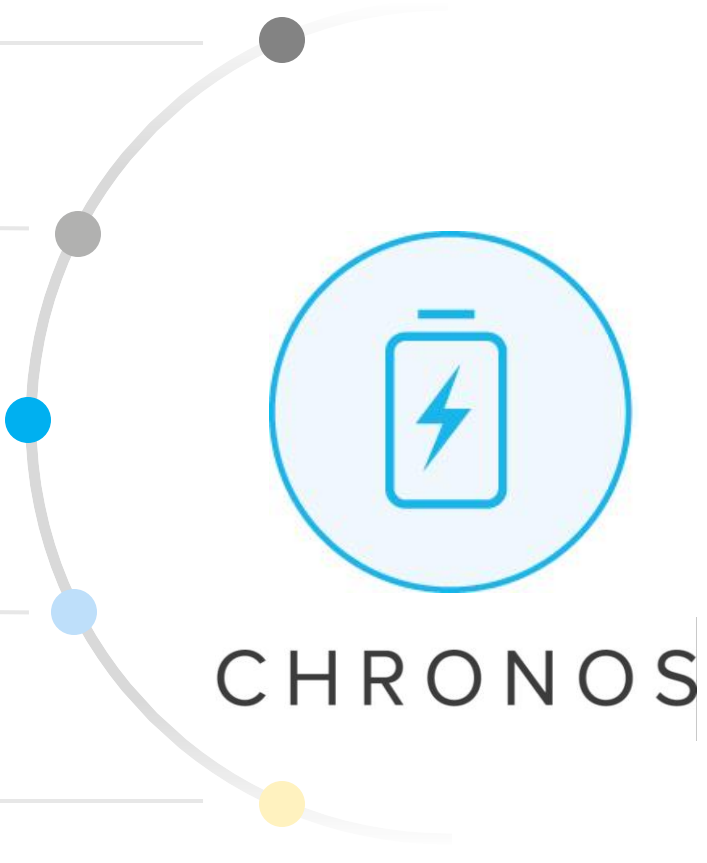
Aurora's trusted data
Underpinned by Aurora's bankable market forecasts used by and relied on by 350+ companies globally

Simple, intuitive, user-centric
User-friendly, and simple, requiring minimal training and no sophisticated in-house modelling capabilities

Exact same state-of-the-art model we use ourselves
Asset dispatch model integrated with our fundamental market forecast which structurally accounts for imperfect foresight

Cost-effective
Our simplicity and unique cloud-based SaaS architecture means large cost savings on set up, maintenance and licenses themselves

Always up-to-date
Easily update your portfolio's value forecast based on Aurora's latest market forecast



CHRONOS' simple 4 step process produces consultancy-standard results without the wait time

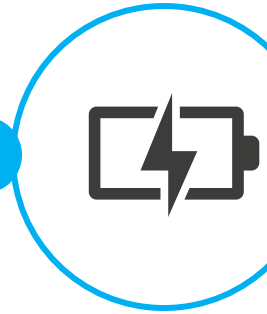
1 Input your site settings

Location

Grid connection type

Project configuration and project sizing, including co-location with other assets

2 Input your technology settings



Duration

Roundtrip efficiency

Cycling constraint

Degradation

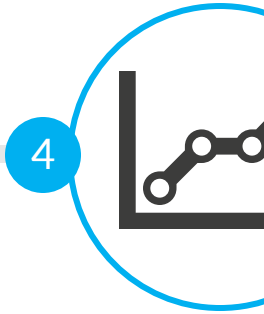
Repowering strategy

3 Select your market scenario

Aurora market scenarios

Business model, including locational system balancing
Commercial operations date

4 Analyse results



Margins by market

Cycle count and degradation

Indicative IRR, using Aurora's default costs or custom cost assumptions

Summary of all inputs