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ENERGY RESEARCH

Battery economics in CAISO & ERCOT

Redacted Report

Agenda

This redacted report covers the economics of battery storage in CAISO and ERCOT. The analysis and data within comes from our ERCOT AND CAISO flexible energy add-on products.

For more information, please contact
Francisco Ortega, US Commercial Manager
francisco.ortega@auroraer.com

Modeling storage is complex. Aurora's forecasts have underpinned the deployment of over 3 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?

- ✓ Integrated modelling of capacity expansion, power pricing and asset dispatch
- ✓ Consistent prices across day ahead, real time, and ancillary services at the hourly + sub-hourly level
- ✓ Ability to model different business models, trading strategies, market scenarios, and weather sensitivities
- ✓ Dispatch based on imperfect foresight, with "percentage of perfect" value capture in line with real-world outcomes
- ✓ Nodal modelling based on detailed representation of grid and power flows rather than statistics for more accurate representation of locational value

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 +
- Sell-side advisory for 400 MW OCGT peaking plant in West Texas for large utility
- Multiple buy- and sell-side transactions across ERCOT, CAISO and PJM totalling over 2.5 GW

Source: Aurora Energy Research

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

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5 Integrated Models

- Global Commodities (AER-GLO)
- Hydrogen (AER-HY)
- Gas (AER-GAS)
- Power markets (AER-ES)
- Nodal/network model (AER-EN)

INPUTS

- Technology
- Policy
- Demand
- Commodity prices[1]
- Weather patterns

Dispatch model

- Hourly or sub-hourly
- Iterative modeling
- Dynamic dispatch of plant
- Ancillary services modeled endogenously

Continuous iteration until an equilibrium is reached

Investment decisions module

- Capacity market modeling (where applicable)
- Capacity build / exit / mothballing
- IRR / NPV driven
- Detailed technology assessments

OUTPUTS

- Capacity mix
- Generation mix
- Wholesale & imbalance prices
- Capacity market prices
- Profit / Loss and NPV
- Electric vehicle charging

ADDITIONAL INPUTS

- Network snapshot - existing & future
- Nodal load map
- Nodal generation map

OUTPUTS

- Power flows & losses
- Nodal prices / loss factors

Up to 70	**c. 85k**	**~15k**	**50+**	**Quarterly updates**
specifications modeled for each plant	investment hours on modeling capabilities	model runs per week	strength of modeling team globally	through subscription research

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

Source: Aurora Energy Research

The battery dispatch model combines the outputs from the Aurora modelling suite into a consistent, nodal-calibrated, dispatch solution

Step 1: Model consistent price series across markets

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

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

Continuous iteration until an equilibrium is reached

Ancillary service prices
- All main services consistent with ERCOT DA prices

Nodal Wholesale prices
- DA prices at 1 hour granularity
- RT prices at 15 min granularity

ERCOT Network Model
- Clears least cost dispatch under transmission constraints
- Calibrated on historic prices and flows

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

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

In-house model | Input | Output

This is a redacted report, for more information contact Francisco Ortega, US Commercial Manager francisco.ortega@auroraer.com

Sources: Aurora Energy Research

Agenda

I. Modeling approach

II. Battery storage in CAISO

III. Battery storage in ERCOT

CAISO has the largest installed battery capacity nationwide at ~3 GW and has 136 GW of prospective projects in the interconnection queue

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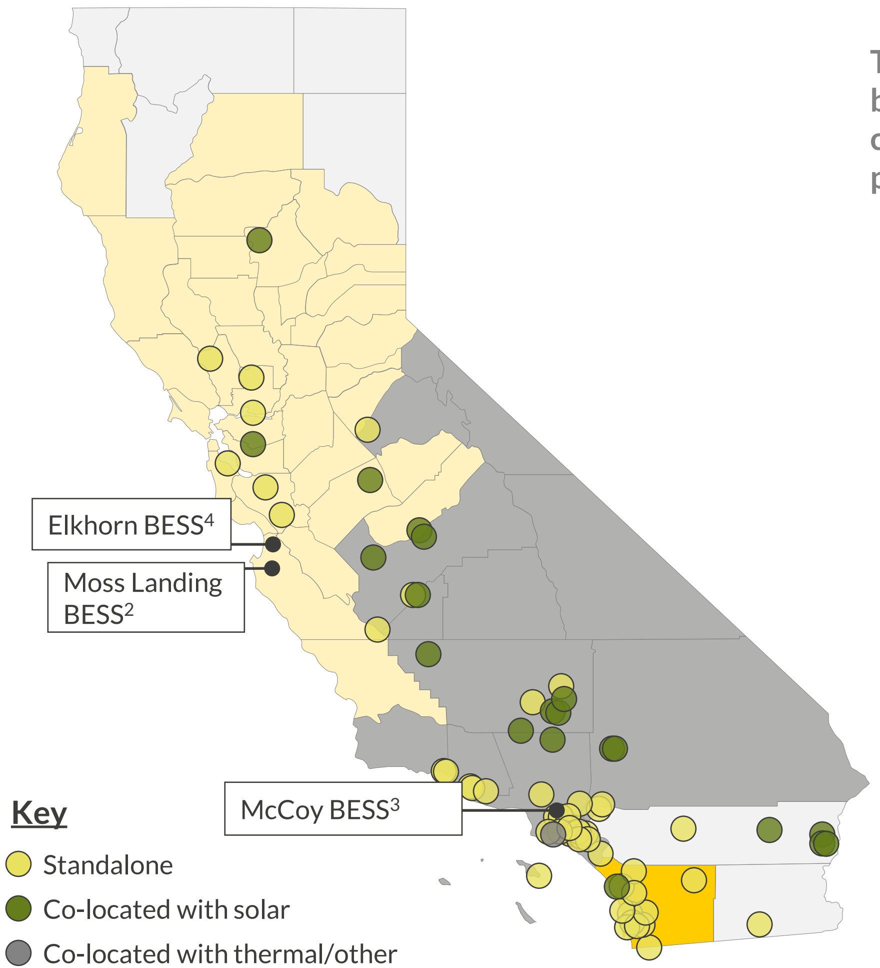
Map of operational batteries in CAISO



Key

- Standalone
- Co-located with solar
- Co-located with thermal/other

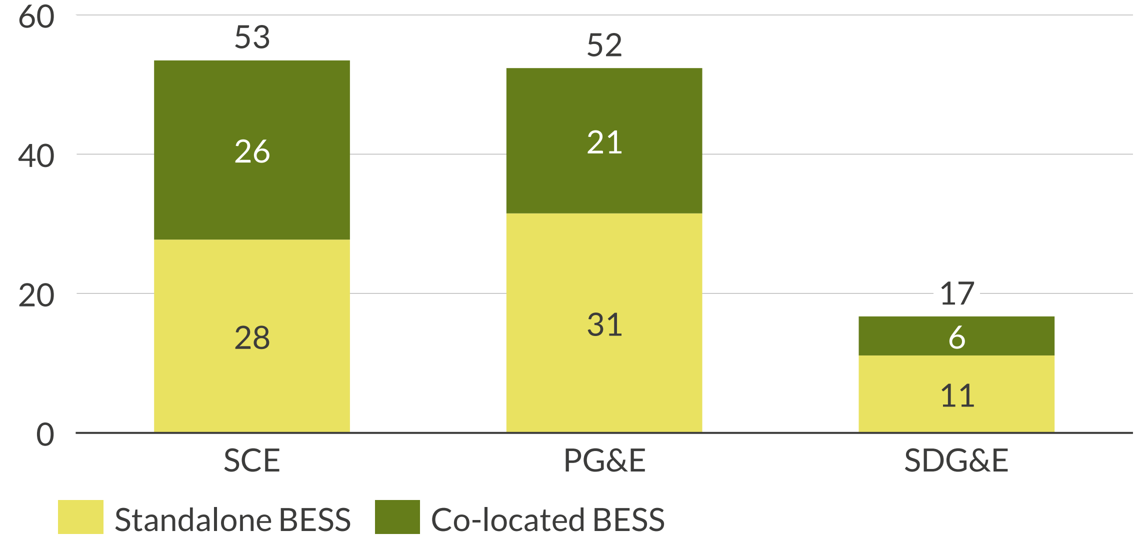
PG&E | SCE | SDG&E

Total battery capacity in pipeline: **136 GW**

71 GW

65 GW[2]

Total battery capacity in CAISO's generator interconnection queue[1]



- Currently, there is 1 GW of co-located and 2 GW of stand-alone storage capacity; in total these projects make up 11.6 GWh of energy storage volume
- Most stand-alone batteries are located in SP15, driven by energy prices in there being more volatile than in NP15 allowing for larger realized spreads
- More than 136 GW of battery storage projects are in the pipeline, 84 GW of which are located in southern California

1) Graph does not include interconnection applications for GLW, VEA, IID, DCRT, and DSLK utilities. 2) Moss Landing BESS in currently the world's biggest battery storage facility with 400 MW / 1,600 MWh capacity. 3) McCoy BESS is currently the second largest battery in California with 230 MW / 920 MWh capacity. 4) PG&E's Elkhorn battery, commissioned in June 2022 consists of 256 Tesla Megapacks and is the 3rd largest battery active in CAISO with 182.5 MW / 730 MWh capacity.

Sources: Aurora Energy Research, CAISO

These 4 projects illustrate the current operational use cases of batteries in CAISO

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Project	Capacity MW	Duration hours	Year of Commission	Asset Type	Region	Operator	2021 estimated gross revenue by market[1] $/kW
Gateway Energy Storage	250	4	2020	Stand-alone	SP15	LS POWER	
Ventura Energy Storage[2]	100	4	2021	Stand-alone	SP15	Southern California Edison – Energy for What's Ahead	
Pomona Energy Storage	20	4	2016	Stand-alone	SP15	ORMAT	
Vista Energy Storage	40	4	2018	Stand-alone	SP15	LS POWER	

1) Other includes tolling energy, uplift, and other. 2) Ventura Energy Storage was commissioned in April 2021.

Sources: Aurora Energy Research, FERC EQR

Battery revenues are between $120-220/kW/year over the forecast horizon as energy arbitrage becomes a larger portion of the total

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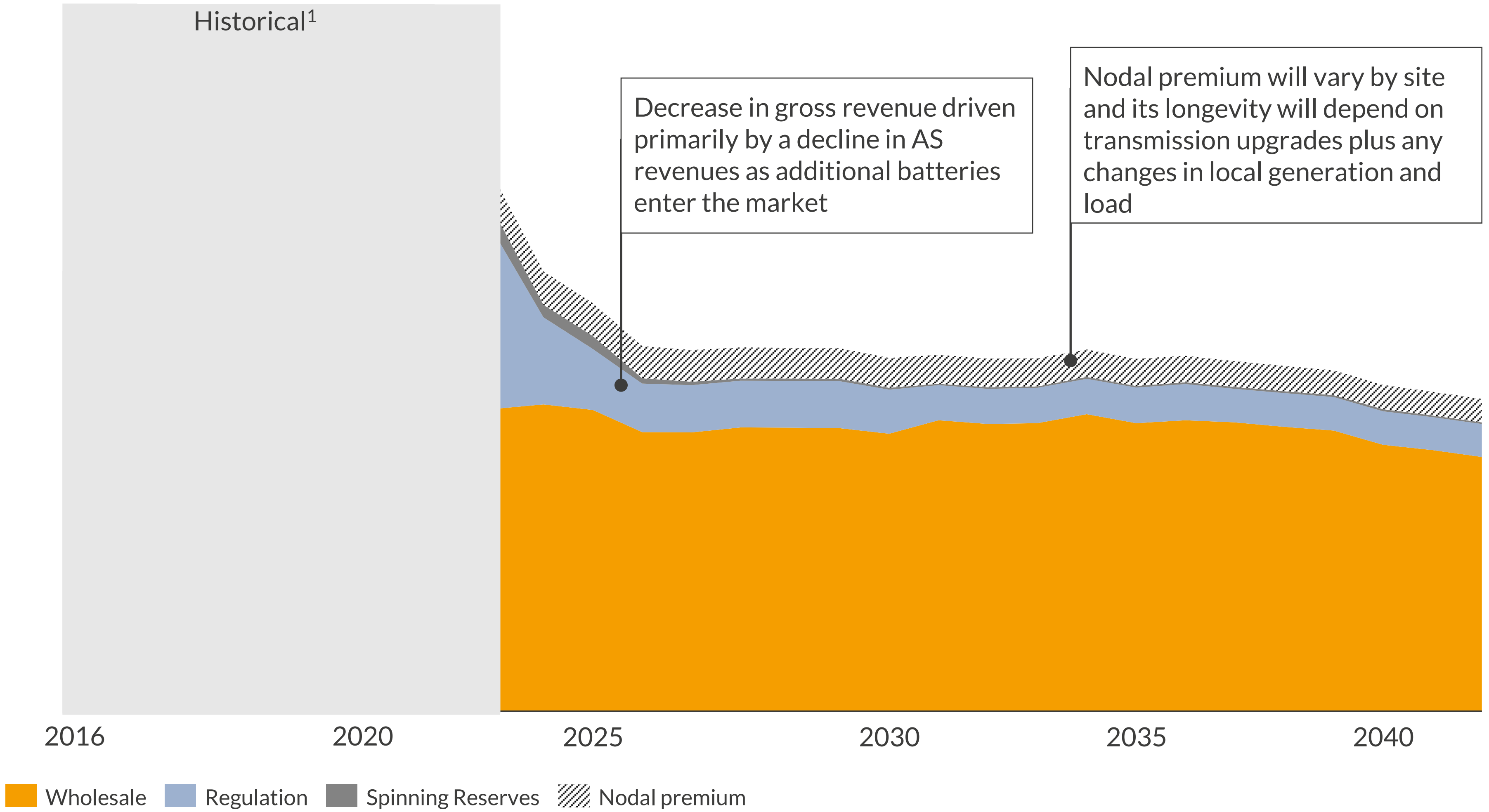
Historic total annual revenue Pomona Energy Storage and forecasted 4-hour battery gross revenue in SP15
$/kW/year, real 2021



1) Includes nodal premium

Sources: Aurora Energy Research, FERC EQR

Outlook for battery gross margins

- Gross revenue for a 4-hour battery in SP15 declines from $[redacted]/kW/year between 2023-2025 to an average of $[redacted]/kW/year from 2030 onwards
- AS prices are expected to decline as the markets saturate with increased battery penetration
- In the long-term, revenue from wholesale arbitrage is expected to make up a larger proportion of a battery's gross margins, rising to [redacted]% by 2030
- Decreases in capex from 2023 onwards means assets become more economically viable with lower gross margins

Regional differences are less impactful than duration and entry year decisions for asset profitability

Evolving nodal upsides differentiate the regions and can cause their relative profitability to shift over time and between durations. 4-hour batteries remain the most profitable, and near-term declines in CAPEX will further accentuate short-duration profitability.

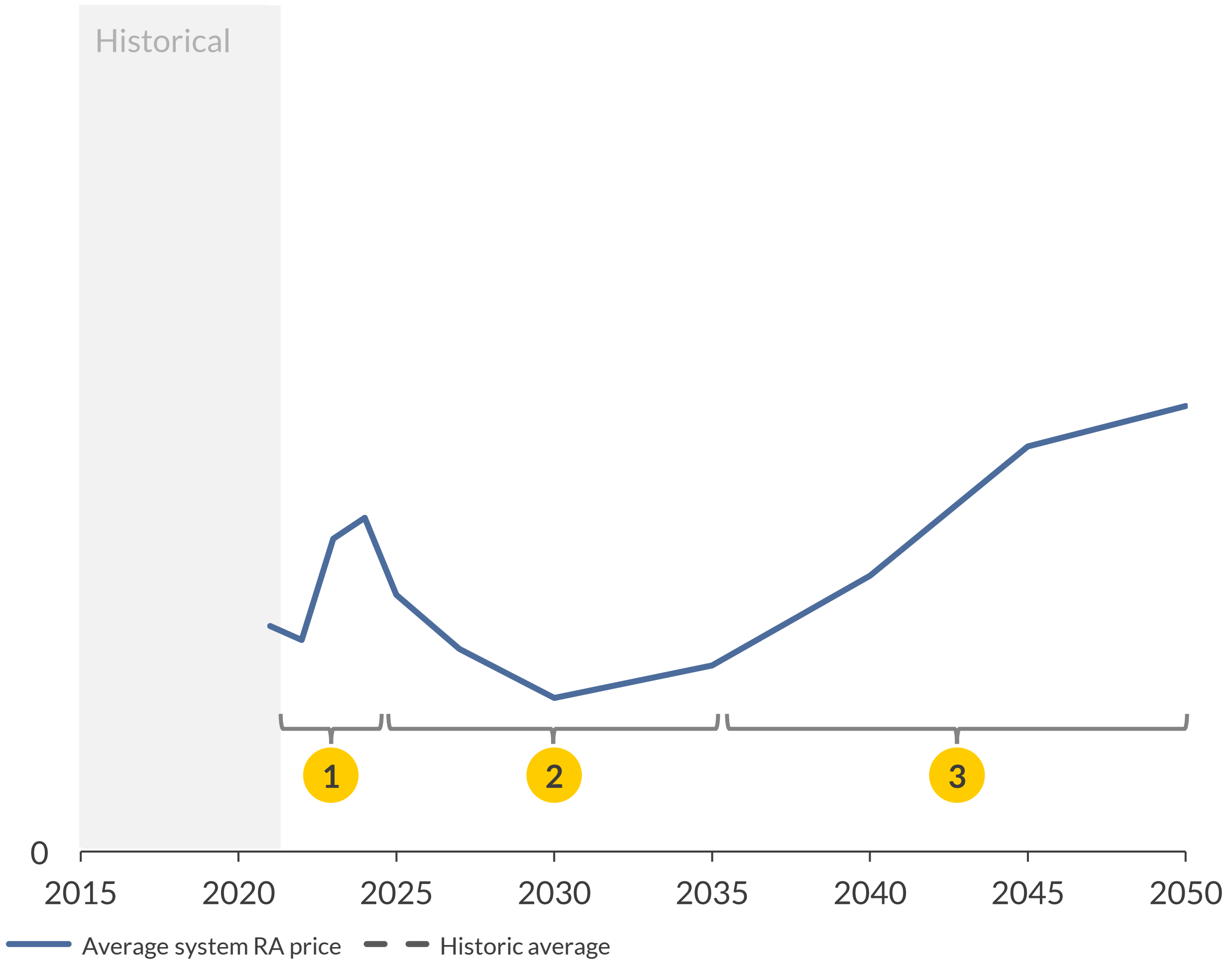
Entry Year	Scenario	Duration	Present Value of Margins[1,2] ($/kW)			IRR (%)			Payback Period (yrs)		
			NP15	*ZP26*	*SP15*	*NP15*	*ZP26*	*SP15*	*NP15*	*ZP26*	*SP15*
2023	Central	4 hour									
		6 hour									
		8 hour									
2026	Central	4 hour									
		6 hour									
		8 hour									

1) Discount rate of 11%, and 15% for high price periods (>$500/MWh for WM prices or $200/MW/h for AS prices). Does not include OPEX. 2) Batteries receive the weighted average system RA price, irrespective of duration. Longer duration batteries may require premiums on RA to make project economics stack up.

Sources: Aurora Energy Research

System RA prices will continue to be driven by batteries, setting prices between $[redacted]/kW-month as ELCCs and other revenue streams fluctuate

Forecast weighted average system RA price[1,2,3,4]
$/kW-month, real 2021



1. RA prices increase significantly due to transmission connection delays and supply chain cost increases. Existing uncontracted plants are able to sign contracts to capture short-term RA payments at a premium

2. As short-term issues are relieved, RA prices are expected to see a gradual decline into the 2030s. This is driven by 1) lower premiums due to connection queue issues being relieved, and 2) continuous declines in battery CAPEX

3. Expectations of ELCCs for storage dropping to 55% by 2050 outweigh CAPEX reductions, putting upward pressure on RA prices in the long-term

Resource Adequacy

- BESS projects entering the market today are signing 10-to-20-year contracts for RA, with operational agreements varying by contract and LSE
- Although a long-term contract locks in a $/kW-month price for the duration of the contract period, the eligible capacity under contract is subject to CPUC and CAISO's decision on its capacity attributes to the Resource Adequacy program
- Two 8-hour long-duration battery storage projects have been procured as part of CPUC's Mid-term Reliability requirement, with expected delivery dates in 2025 and 2026
- These two 8-hour assets are expected to have secured significant premiums on the average system RA prices
- Due to supply chain issues, many battery projects with RA contracts due for delivery in 2022 are experiencing delays or simply unable to deliver

1) RA price by contract year – project deliver in the next year. 2) Based on NQC capacity. 3) Historic prices are nominal. 4) 11% WACC; 22-30% ITC is applied depending on entry years; assume the project RA contract length is 15 years; average ELCC reduces from ~100% to 45% by 2050; 1-year construction period; factor in CAPEX spending on cell upgrades through degradation.
Sources: Aurora Energy Research

RA contract prices and future ELCC levels represent two areas for material upside in BESS business cases

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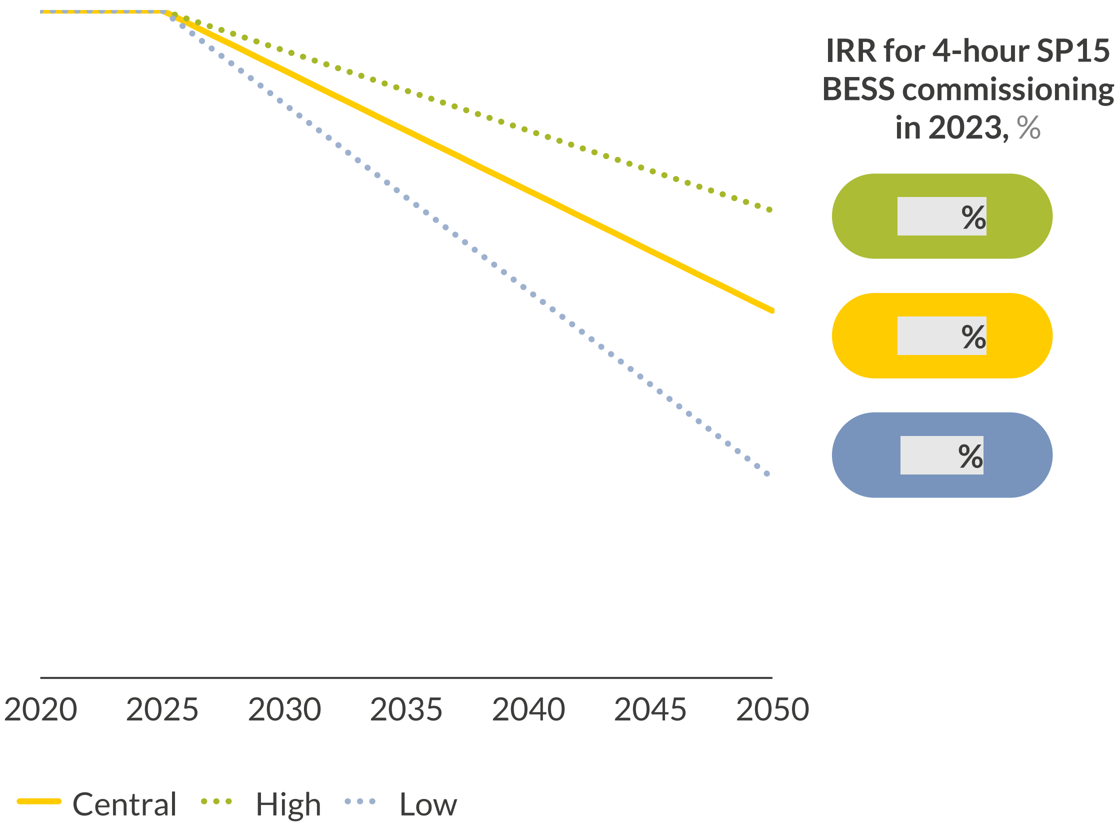
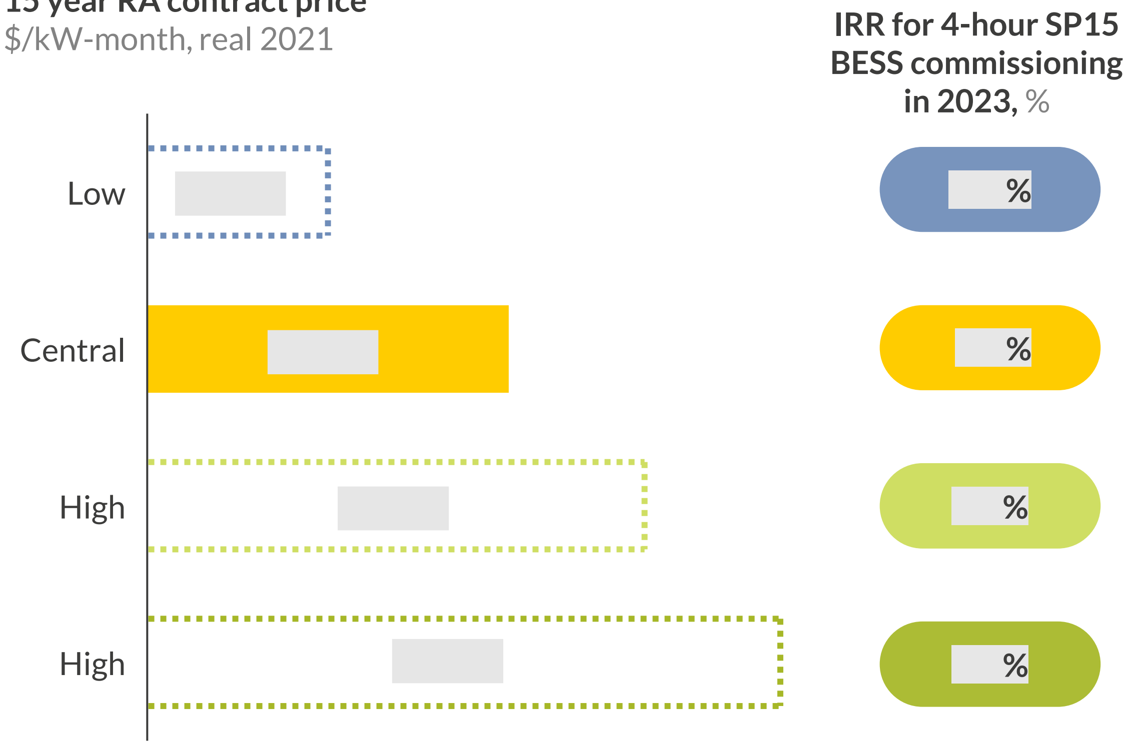
1 Uncertainty around effective load-carrying capability (ELCC) levels for a 4-hour BESS represents a small but non-negligible upside for battery IRRs

ELCC for a 4-hour BESS
% of nameplate capacity



2 Current supply chain issues are creating scarcity in the resource adequacy (RA) market which potentially allow BESS assets to lock in the premium

15 year RA contract price
$/kW-month, real 2021



Sources: Aurora Energy Research, CAISO

Lifetime, cycles, round-trip efficiency, and degradation can also impact project IRRs

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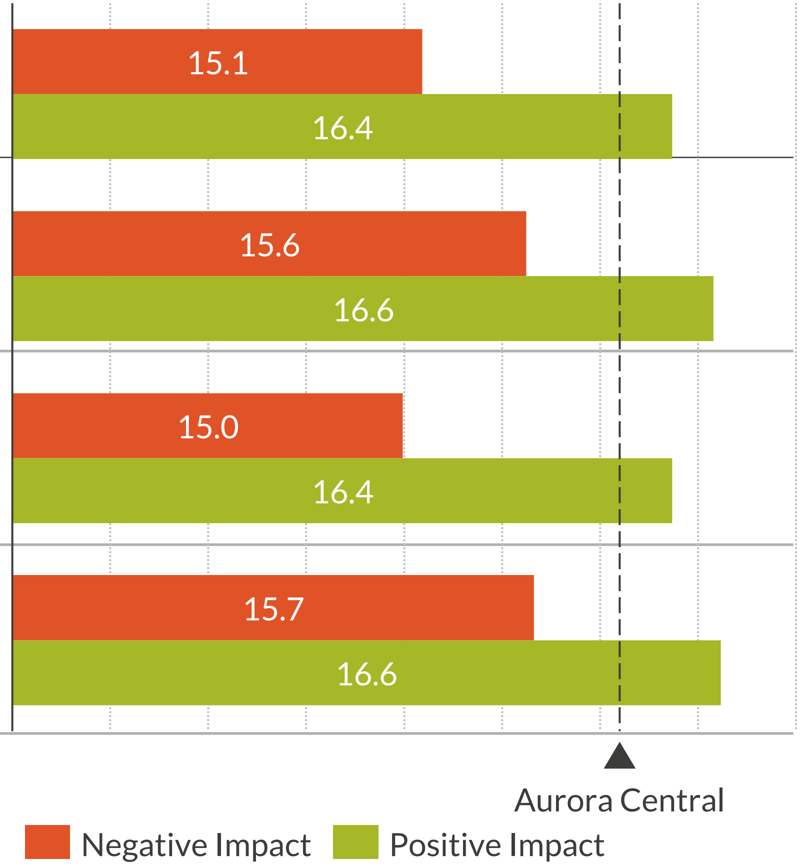
Sensitivity to technical parameters for 4-hour battery, 2023 entry, SP15[1]

Sensitivity	Units	Aurora Central (2025 new build)	Change from Aurora central		Impact on IRR relative to Aurora Central (16.1%)	
Lifetime	year	20	-5	+5	15.1	16.4
Round Trip Efficiency (RTE)	%	86	-5	+5	15.6	16.6
Cycles	#/year	365	-91 (-25%)	+91 (+25%)	15.0	16.4
Degradation[2]	%/year	4% p.a. for first 3 years, 1% p.a. thereafter	+1	-1	15.7	16.6

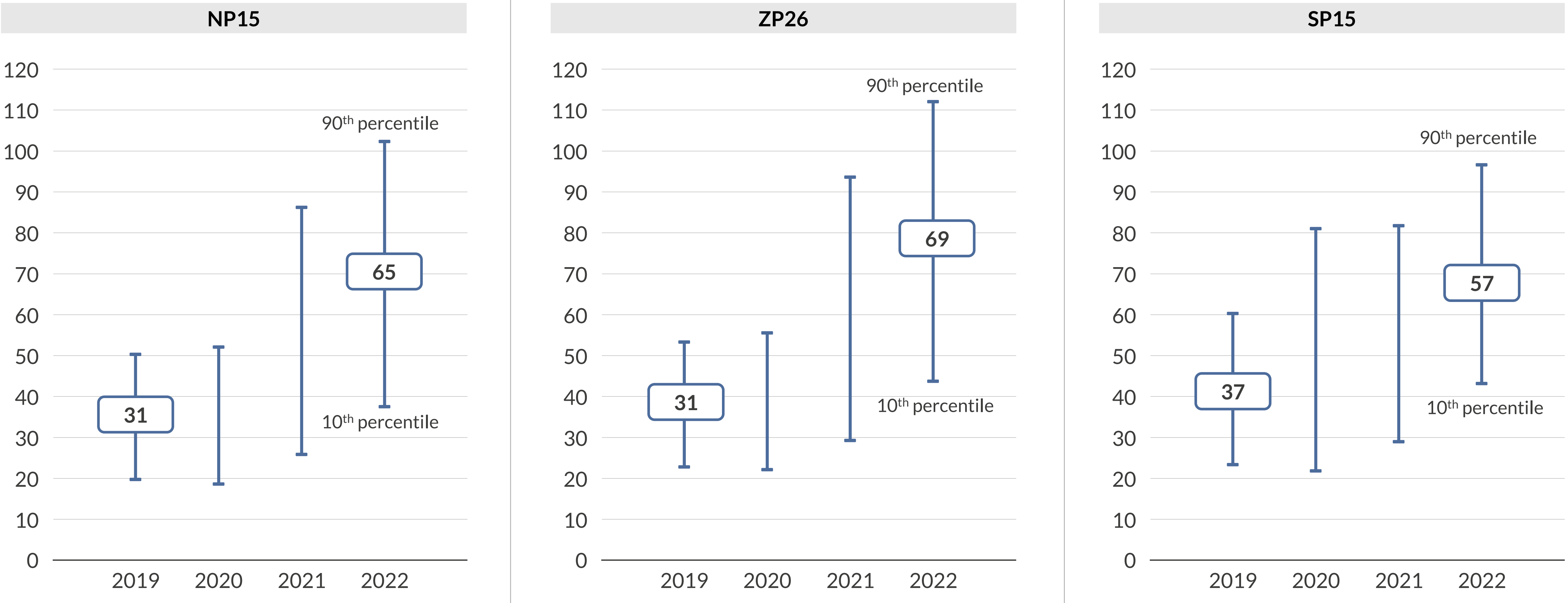


1) Assumed 1 cycle per day unless otherwise specified. 2) In upside case, assumed 3% p.a. for first 3 years and 0.1% p.a. thereafter.

Sources: Aurora Energy Research

The variability in nodal prices has significantly increased in recent years as renewables have built out and grid congestion has risen

Average historic daily 90th and 10th percentile nodal spreads by hub
$/MWh



Sources: Aurora Energy Research, CAISO

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56 GW of prospective battery projects are in the pipeline with more than one quarter of projects co-locating with a wind or solar asset

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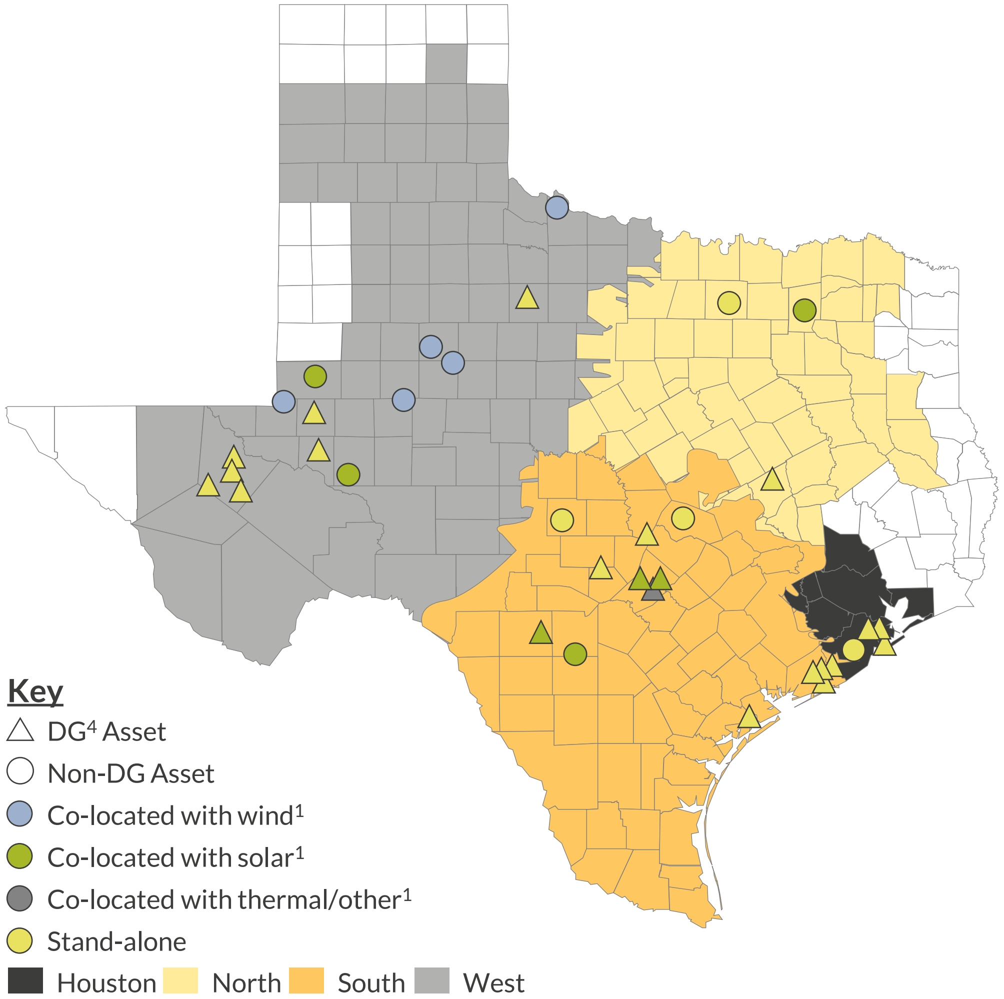
Map of operational batteries in ERCOT as of June 2022[2]



Total in pipeline[2]: 56.2 GW

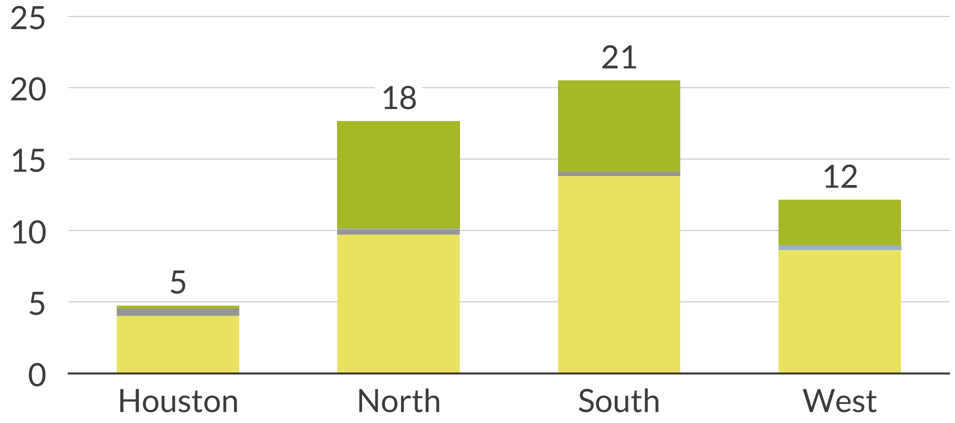
36.2 GW

18.2 GW

0.4 GW

Cumulative battery storage pipeline for ERCOT zones with completion date before end of 2024[3,5]

GW

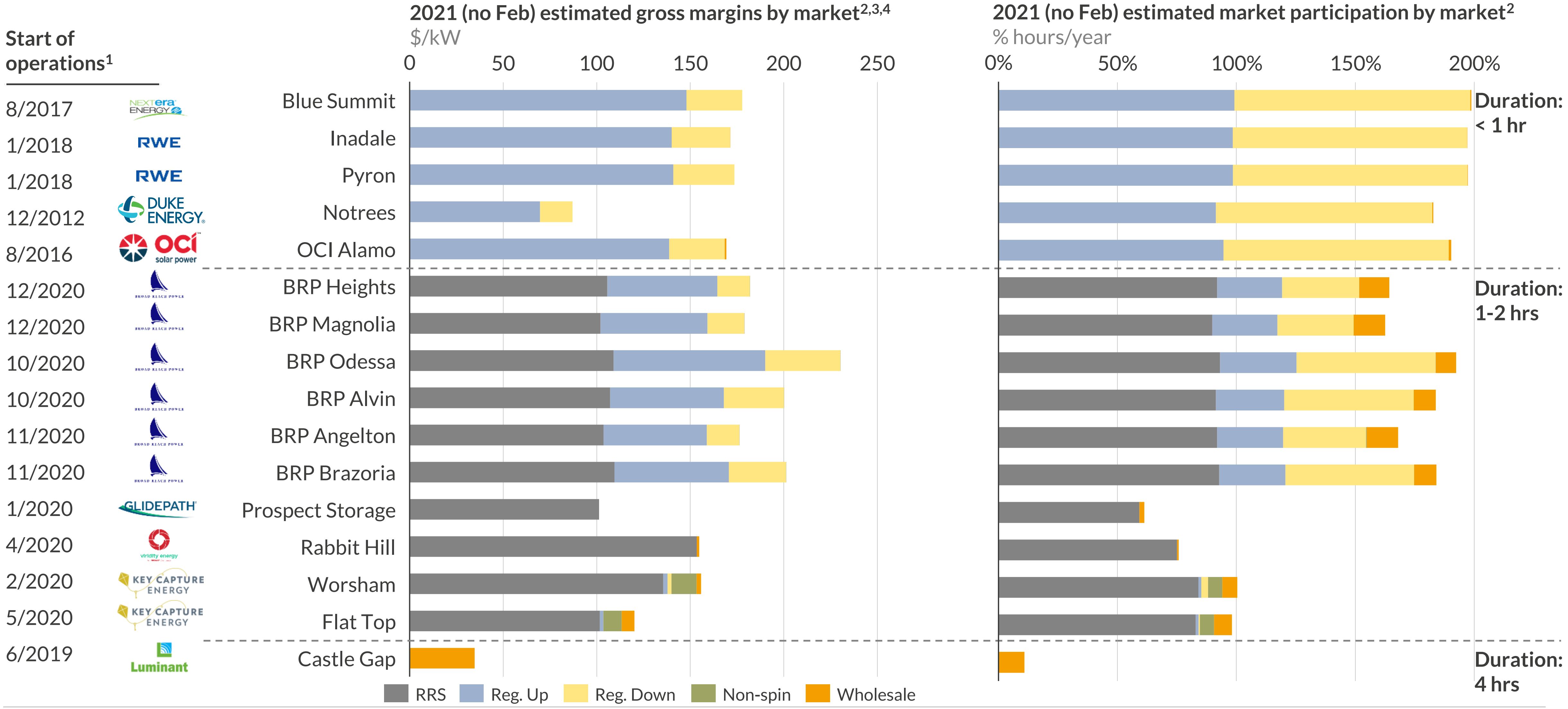


- Currently, there is 206 MW of co-located[1] and 1126 MW of stand-alone storage capacity; totalling 1.3 GW of energy storage capacity in ERCOT[6]
- Most stand-alone batteries are located close to load centers with 6 in Houston, 4 in San Antonio and Austin, and others around DFW and the Permian Basin
- More than 50 GW of battery storage projects are in the pipeline, 32 GW of which are located in the South or West

1) Includes standalone resources on same site as another generator, does not include AC/DC-coupled resources 2) Does not include batteries under 10 MW in capacity or DG connected assets 3) As of June 2022. 4) Distributed Generation. 5) ERCOT does not have information to confirm if the co-located projects will be operated as AC/DC-coupled resources, or independently. This will be remedied by RRGRR023, due in 2022. 6) Includes DG resources; future pipeline does not account for DG resources.

Sources: ERCOT, Aurora Energy Research

In 2021[4], high ancillary service prices drove margins above $150/kW for some batteries, with BRP capturing the highest revenue in the fleet

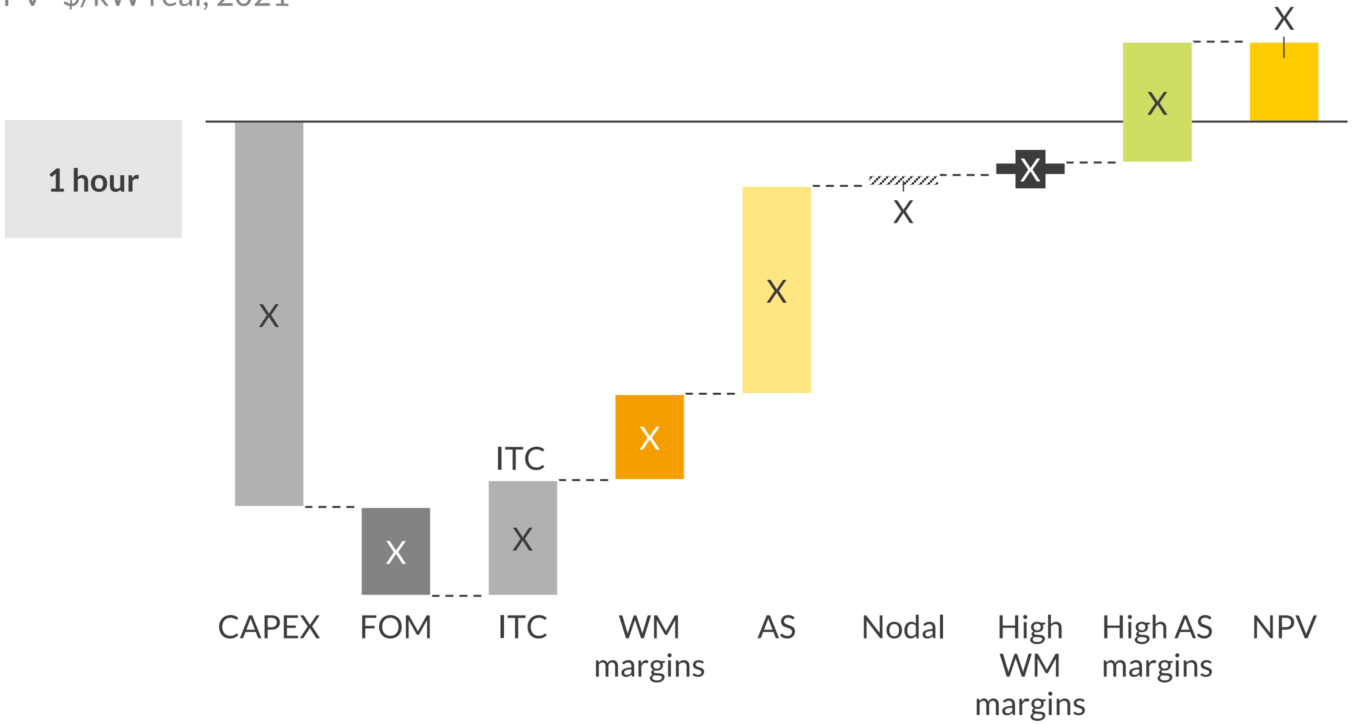


1) Self-reported from EIA 860M report, or ERCOT GIS. 2) Total market participation percentages can exceed 100% due to participation in multiple markets in the same period. 3) Energy revenues calculated at the batteries' trading hubs. 4) Excluding February 2021,

Sources: Aurora Energy Research, ERCOT, EIA

A new build 1-hour battery in the West can achieve a positive NPV and an IRR of %

Economics for new-build battery (West zone, 2023 entry year, no repower)
PV[1] $/kW real, 2021



PV of Margins[1]	NPV[1]	Project IRR	Payback period
$ /kW	$ /kW	%	yrs

- Wholesale margins make a small contribution for a 1-hour battery entering the market in 2023. Ancillary services will be the dominant revenue stream supporting the project
- High prices in the wholesale and ancillary markets contribute $ /kW to the Net Present Value, and are discounted at a higher discount rate than during low price periods

1) Discount rate of 11% for revenues and costs, and 15% for high price periods (>$500/MWh for WM prices or $200/MW/h for AS prices)

Source: Aurora Energy Research

Regional differences are less impactful than duration and entry year decisions for asset profitability

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Evolving nodal upsides differentiate the regions and causes their relative profitability to shift over time and between durations. The West zone will emerge as the most profitable region for new build batteries, given the highest nodal premium, with an IRR of about 1% higher than other zones for 2026 entry. 1 hour batteries remain the most profitable, and near-term declines in CAPEX will further accentuate short-duration profitability.

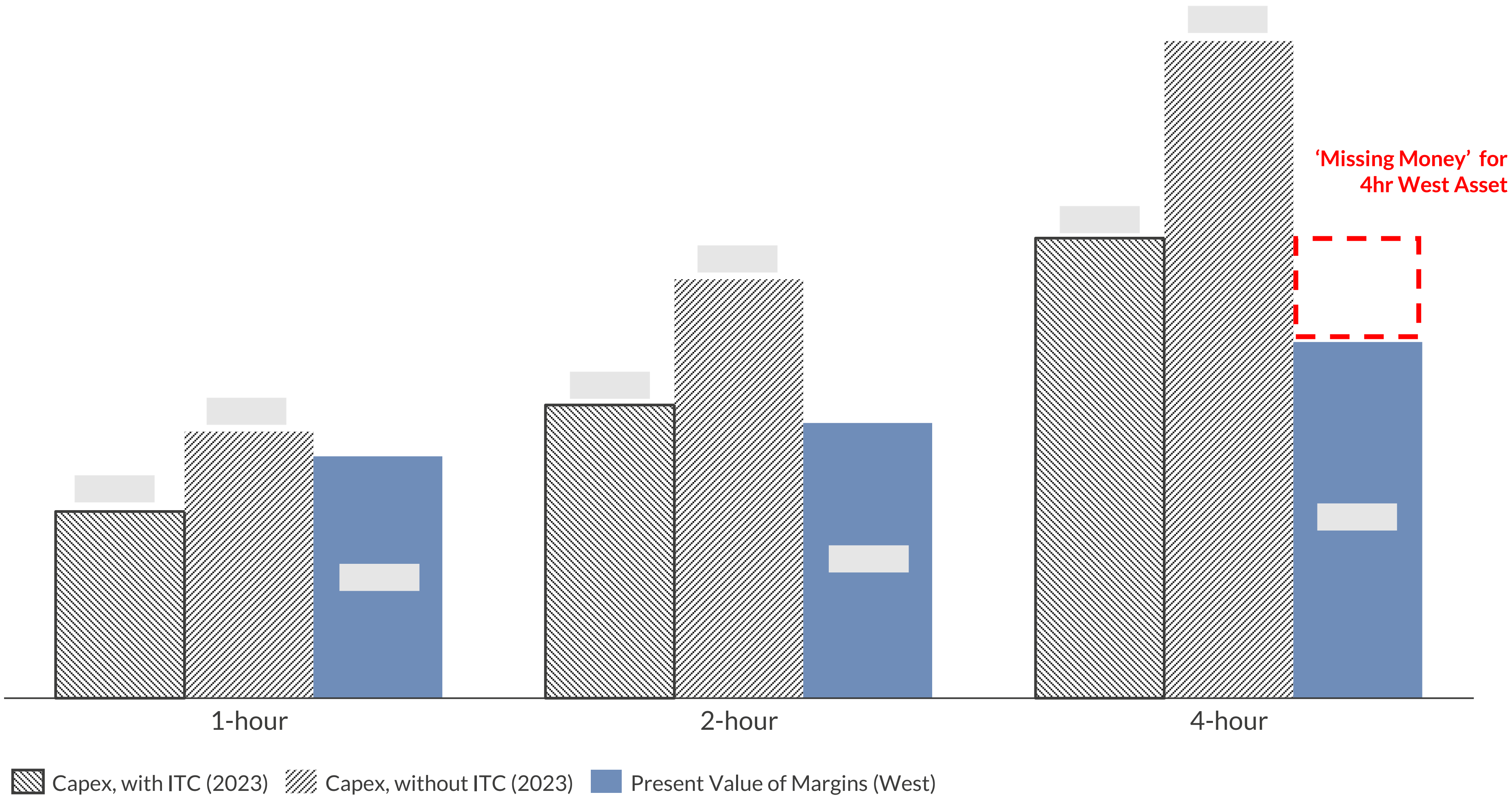
Entry Year	Scenario	Duration	Present Value of Margins[1] ($/kW)				IRR (%)				Payback Period (yrs)			
			Houston	*North*	*South*	*West*	*Houston*	*North*	*South*	*West*	*Houston*	*North*	*South*	*West*
2023	Central	1 hour												
		2 hour												
		4 hour												
2026	Central	1 hour												
		2 hour												
		4 hour												

1) Discount rate of 11% for revenues and costs, and 15% for high price periods (>$500/MWh for WM prices or $200/MW/h for AS prices)

Source: Aurora Energy Research

Increasing battery durations lead to lower marginal return, long duration fully merchant investment cases do not yet stack up

Present Value[1,2,3] of Gross Margins and Capex for West batteries of various durations (2023 Entry Year)
$/kW, real 2021



1) Discount rate of 11% for revenues and costs, and 15% for high price periods (>$500/MWh for WM prices or $200/MW/h for AS prices). 2) Aurora's in-house capex assumption, inclusive of recent 15% capex increases due to raw materials prices and supply chain issues.
Source: Aurora Energy Research

Comparison of various durations

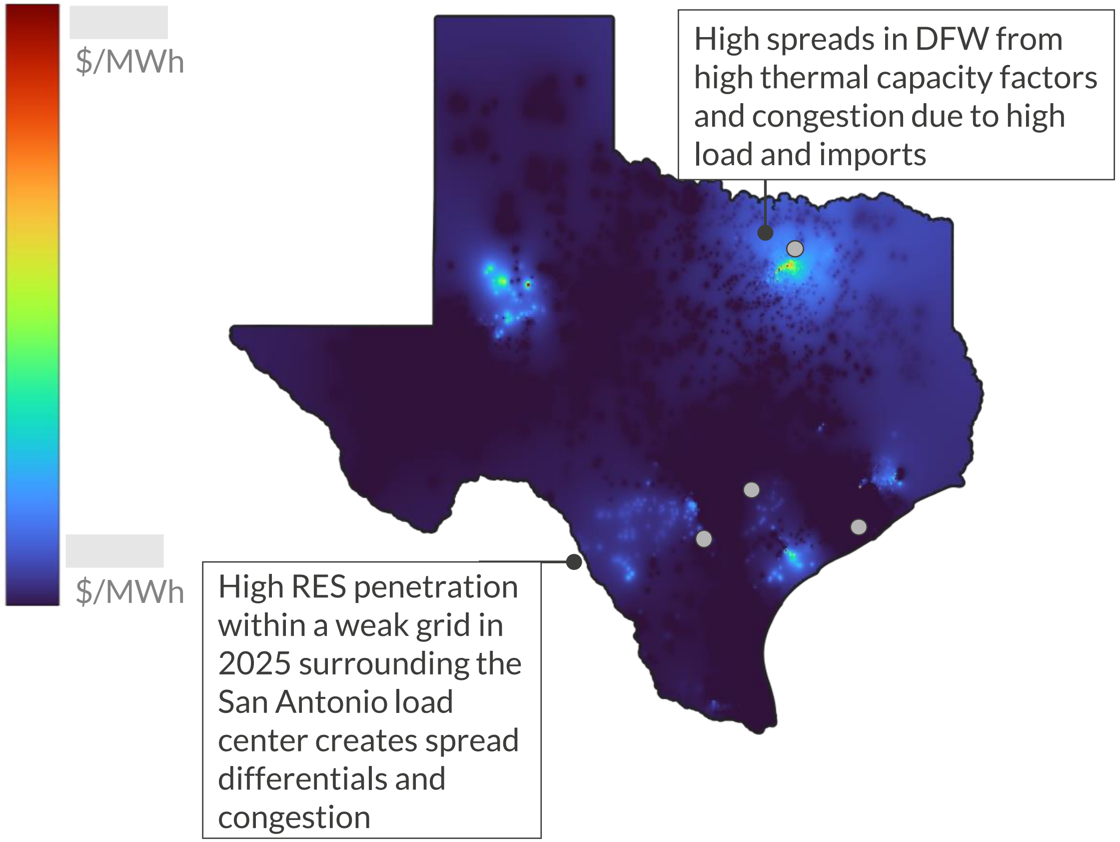
- The concept of 'missing money' is the difference between the battery's Capex and the Present Value of the battery's revenue
- Capex increases incrementally by [redacted]% moving from 1- to 2- to 4-hour batteries. Assuming a 30% ITC, this amounts to a $[redacted]/kW additional cost for a 4-hour battery compared to a 1-hour battery
- However, battery revenues only increase by $[redacted]/kW for a 4-hour West battery and by $[redacted]/kW for a 4-hour Houston battery compared to their 1-hour counterparts
- These diminishing returns manifest in $[redacted]/kW of missing money for a 4-hour West battery and $[redacted]/kW of missing money for a 4-hour Houston battery, whereas their 1-hour counterparts both produce IRR's over [redacted]%

Line upgrades, proximity to load centers and renewables deployment will impact the local spreads available to batteries

Growing load and changing network landscape drives shifts in spread "hotspots", although persistent value maintained in notable areas

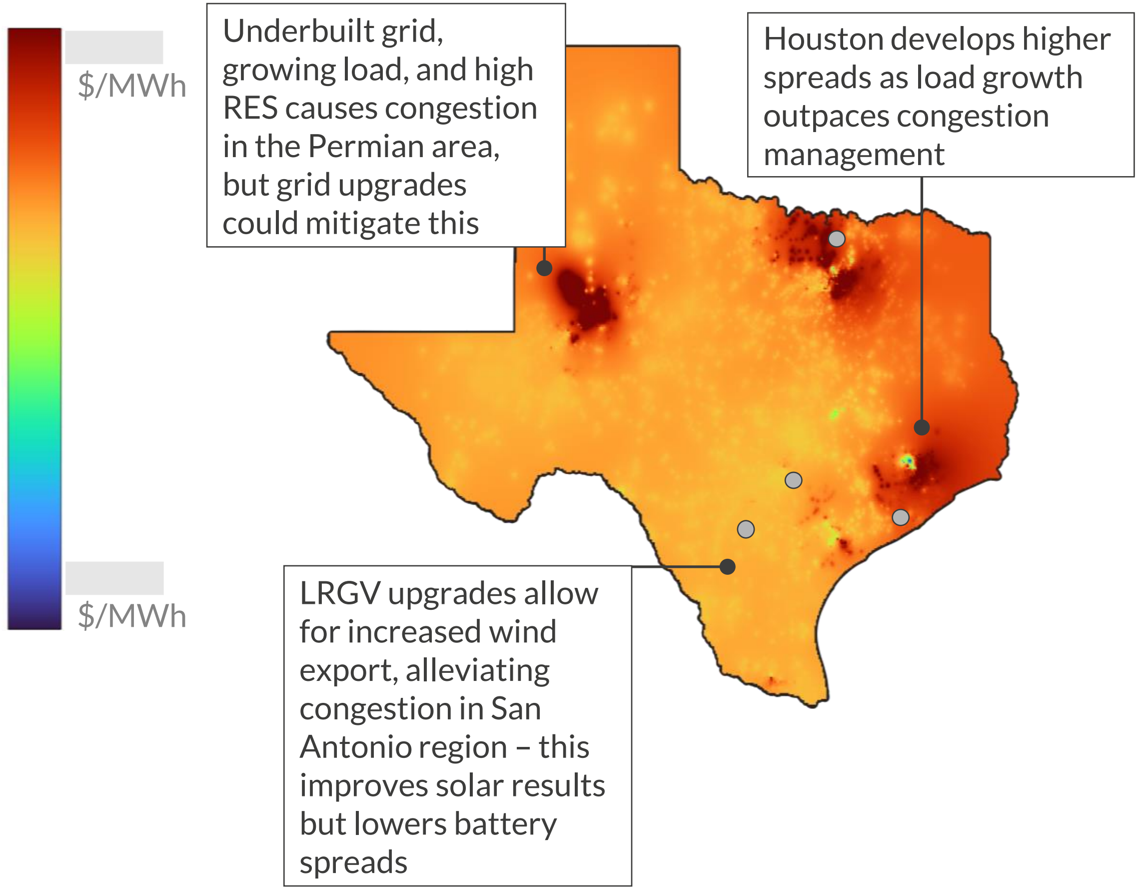
Day-Ahead TB1 spreads with N-1 contingency grid conditions, 2025

$/MWh (real 2021)



Day-Ahead TB1 spreads with N-1 contingency grid conditions, 2030

$/MWh (real 2021)



Sources: Aurora Energy Research, ERCOT

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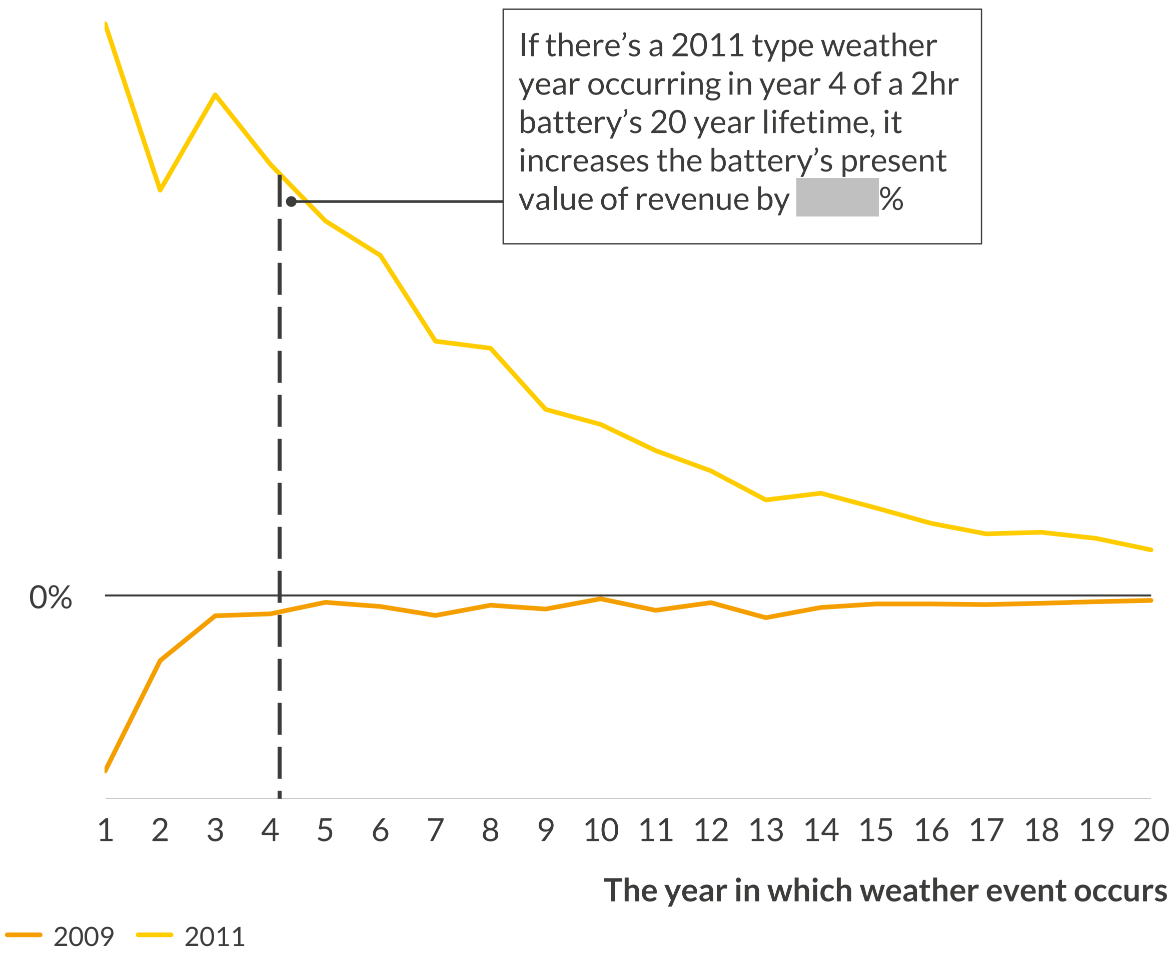
The timing and frequency of weather events creates a significant range in potential upside

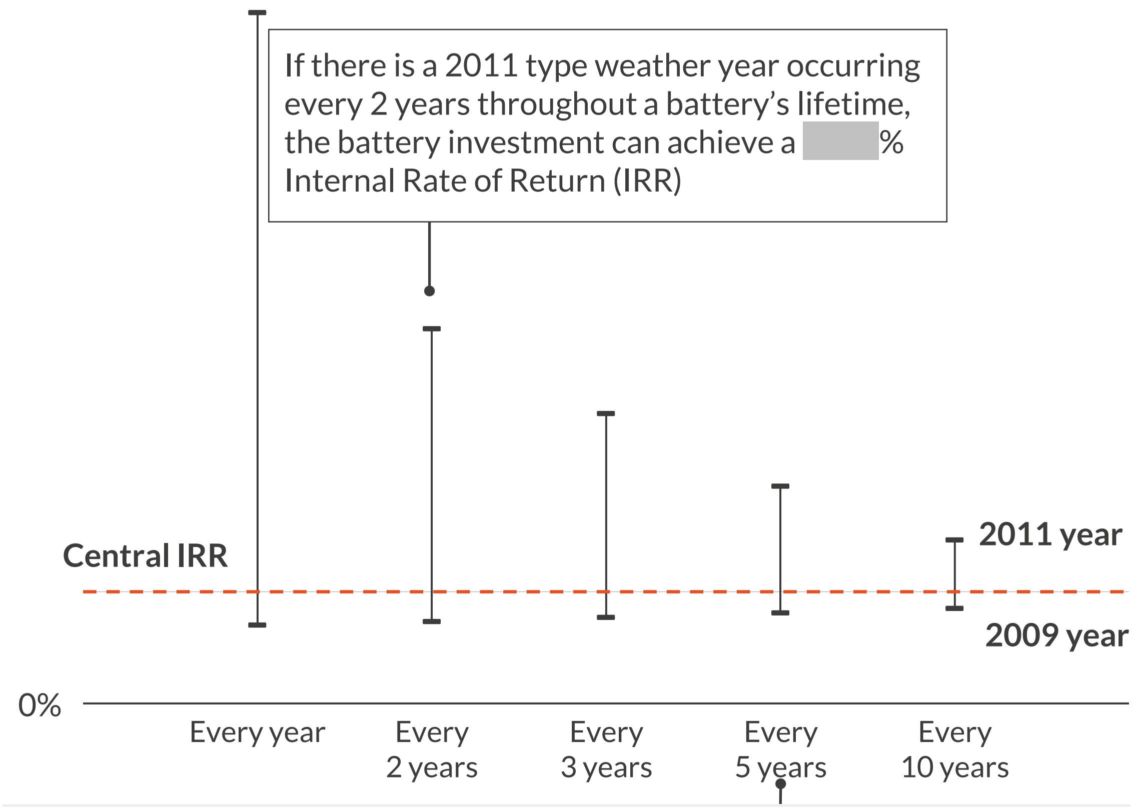
Impact on present value[1] of revenue from a weather event – 2hr North battery[2]

%



2hr North Battery IRRs[1] with varying frequency of weather years occurring

%



'Every 5 years' means years with different weather are: 1, 6, 11 & 16

1). Assume a discount rate of 11%. 2) Does not take into account degradation and availability

Sources: Aurora Energy Research

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

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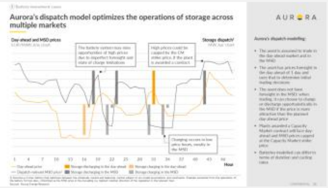
Bi-annual Forecast Reports & Data

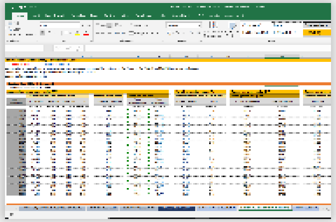
Technology and Market Development Reports

- **Historical battery analysis –** Provides an analysis of existing battery storage assets' parameters and profitability metrics from both a wholesale and ancillary service perspectives (plus market specific capacity markets if applicable)
- **Market outlook –** Contains a market overview focusing on flexible capacity, Aurora's estimated battery build-out, and CAPEX trajectory
- **Standard battery investment cases –** Detailed costs and revenue streams for archetypal battery duration across various configurations, reflecting revenue-stacking opportunities



Forecast Data and Databook

- Summary of battery KPI metrics
- Historical wholesale and ancillary services data
- Aurora's half-hourly/hourly wholesale, ancillary service price forecasts markets (RRS, Reg Up, and Reg Down), and real time prices to 2050 across key scenarios (Central, Low)



Investment Cases

Standalone Batteries and Co-locating

- Detailed data of each of the individual **25+ battery investment cases** that Aurora has modeled in ERCOT and CAISO
  - Gross margins, IRRs, and NPVs provided for battery storage investment cases
  - Cases consider 3 battery durations across all load zones with years of entry in 2023 and 2025
  - Gross margin data provided for all years out to 2050 in the supporting data book
- **Key sensitivities around nodal location, co-location, and weather year analysis** are also analyzed

Ongoing Analyst Support

- **Bilateral workshops** to discuss specific content pertinent to the Flex/ Storage add-on
- **Ongoing availability** (access to market experts, modelers) to address any questions

For more information, please contact
Francisco Ortega, US Commercial Manager

✉ francisco.ortega@auroraer.com
☎ +1 415-258-8864 / +49 30 700107983

US Power Market Forecast Services Key market analysis and forecasts for all participants in the PJM, CAISO, and ERCOT power market

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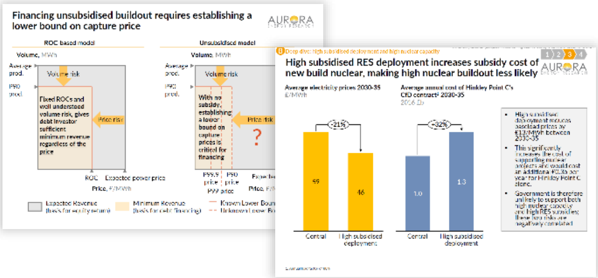
Quarterly data and market reports

- **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** – 6 consistent scenarios that reflect key uncertainties
- **Investment case analysis** – costs and revenue streams under different scenarios
- **Data in Excel** – all forecast data easily downloadable in Excel format
- **Data online** – view forecasts and historical data on our online EOS platform

Quarterly strategic insight reports and group meetings

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



Regular interaction through workshops and bilateral support

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

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

For more information, please contact
Francisco Ortega, US Commercial Manager
francisco.ortega@auroraer.com
+1 415-258-8864 / +49 30 700107983

Aurora provides data-driven intelligence for the global energy transformation

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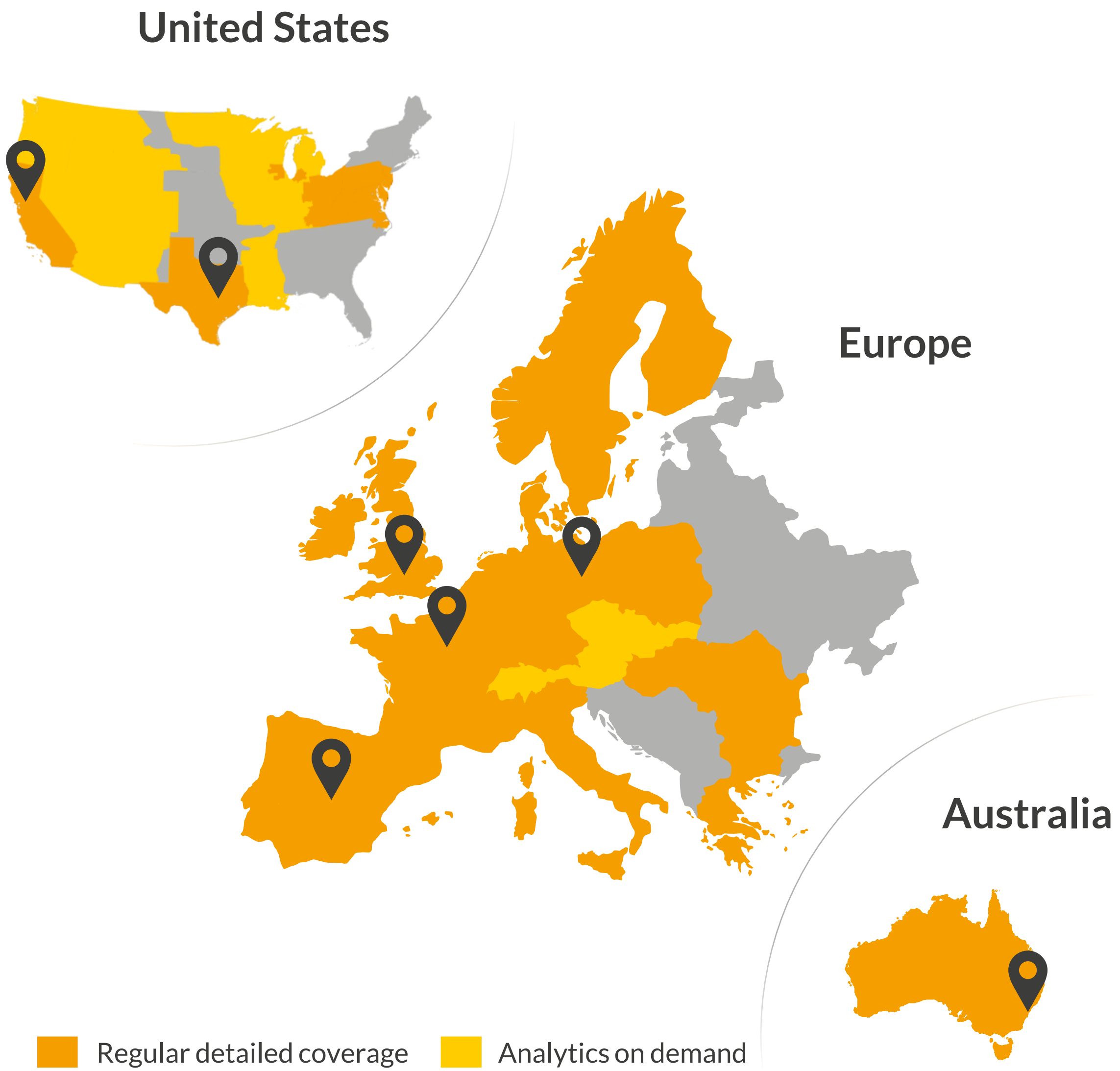
- Power markets
- Renewables
- Storage
- Electric vehicles
- Hydrogen (H_2)
- Carbon (CO_2)
- Natural gas



7 Offices
Oxford | Berlin | Madrid | Paris
Sydney | Austin | SF Bay Area

300+
market experts, 35+ in the US

550+
subscribing companies

120+
transactions supported in 2021

Source: Aurora Energy Research

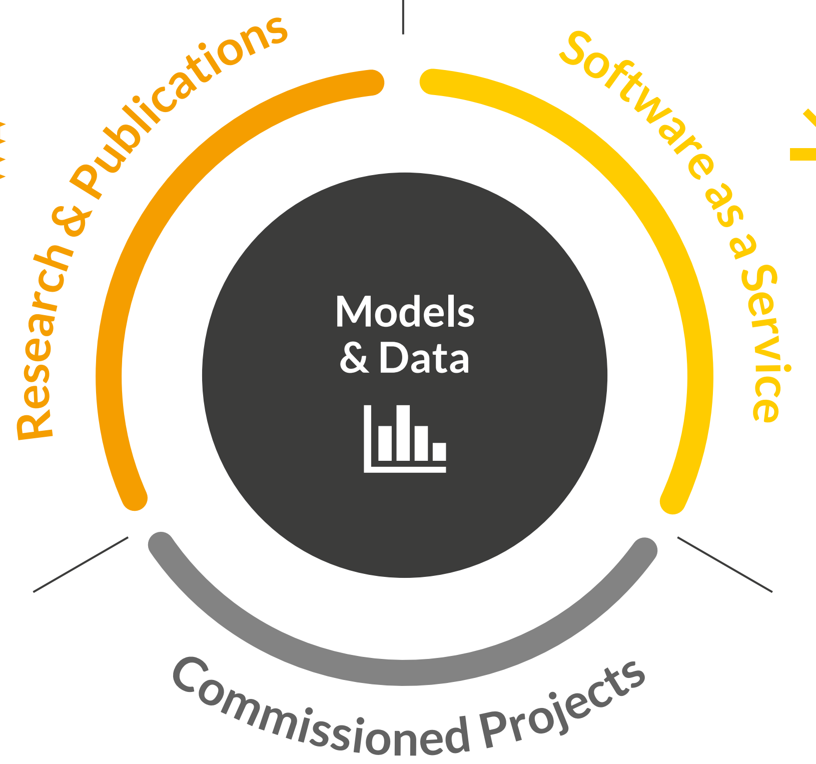
Aurora brings a sophisticated approach to the provision of analysis and insight to the energy industry

Research & Publications

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

Software as a Service

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



Commissioned Projects

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

Models & Data

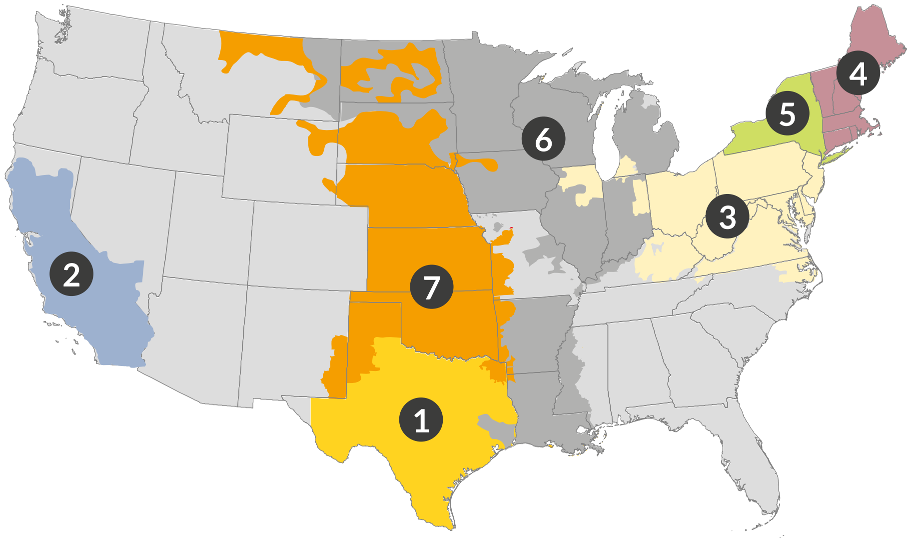
- Market-leading long-term models for power, gas, hydrogen carbon, oil and coal markets
- Continuous model improvements to reflect policy and market developments

Source: Aurora Energy Research

ERCOT is one of seven competitive regional wholesale power markets in the United States

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

Map of the U.S. wholesale electricity markets[1]



ISO	Installed capacity[2] GW	Annual load[2] TWh	Projected peak load growth through 2030[3]	Renewables share of generation[4]	Reserve margin[5]
ERCOT 1	**111**	**380**	**25.2%**	**25%**	**15.3%**
CAISO 2	67	215	1.7%	40%	23.8%
PJM 3	217	755	5.0%	5%	33.5%
ISO-NE 4	39	112	-0.7%	12%	22.0%
NY ISO 5	43	147	-0.4%	25%	27.3%
MISO 6	199	646	3.4%	14%	21.6%
SPP 7	93	260	8.3%	36%	29.9%

1) Light gray areas are regulated meaning they are vertically integrated utilities responsible for the production, transportation and sale of electricity to consumers. 2) ERCOT data from Aurora, other data from 2020 NERC Long-Term Reliability Assessment. 3) Compares 2021 through 2030. 4) 2020 data, includes onshore wind and solar PV. 5) Data from 2021 NERC Seasonal Resource Assessment.

Sources: Aurora Energy Research, FERC, NERC, individual ISOs

We explore key market uncertainties through a range of scenarios

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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
Central & CO_2 Price	Central case with the addition of a carbon price from mid 2020s, increasing out to 2035 in line with decarbonization efforts
Build Back Better	Explores the effects of the passage of the Biden administration's Build Back Better plan, which aims to aid in the rapid decarbonization of the nation's energy sector. The plan includes extended and expanded tax credits for renewable energy, energy storage, nuclear energy, CCS, EVs and transmission
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 EV uptake, are maintained as in Aurora Central
Green New Deal	Explores a greater push for decarbonization in ERCOT. Alongside a carbon price, pollution standards hasten coal's exit, and there is increased power demand from space cooling/heating and transportation. Network upgrades allow for greater renewables build out in constrained regions of ERCOT
Low Scarcity	Stress tests the role of scarcity pricing on the value of power in ERCOT. This scenario sees a lower number of instances of scarcity and therefore lower prices, relative to Aurora Central

Sources: Aurora Energy Research

ATC prices in the scenarios range between $ and $ /MWh in 2030 with the highest prices in the Green New Deal scenario

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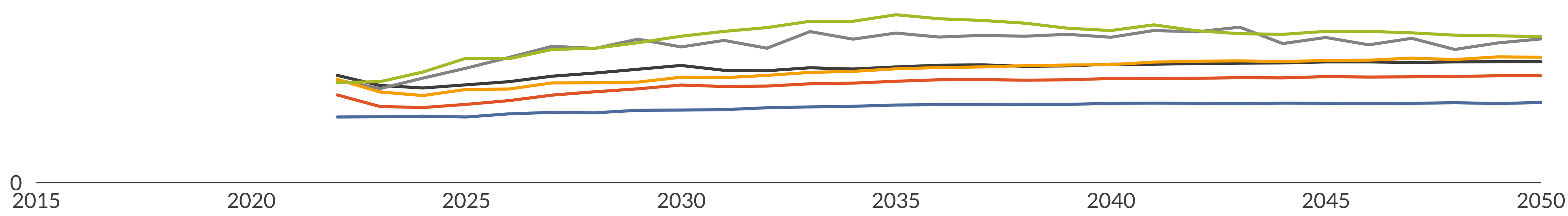
ERCOT-wide ATC price
$/MWh (real 2020)



Scenario	Brief description	Typical use case
Central	Aurora's Central view of the market, current legislated and budget-funded policies	Equity financing, strategy analysis
Central & CO_2 Price	Central assumptions with additional carbon pricing	Test impact of carbon price
Build Back Better[1]	Immediate introduction of provisions included in the Biden administration's Build Back Better plan	Test impact of introduction of Build Back Better legislation
Low	Low demand and commodity prices	Debt financing/sizing, strategy analysis
Green New Deal	Carbon pricing and other policies are enacted resulting in faster decarbonization of power sector and the wider Texas economy	Test impact of major shift to green economy
Low Scarcity	Central assumptions with increased firm margins	Test impact of oversupply or out-of-market reliability units on price formation

Historical — Central — Central & CO2 — Build Back Better — Low — Green New Deal — Low scarcity ··· Previous forecast

1) No previous Build Back Better scenario for comparison.

Sources: Aurora Energy Research

We explore key market uncertainties through a range of market scenarios

Scenario	Description	Battery capacity deployment, GW: 2025	Battery capacity deployment, GW: 2030
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	10.3	25.7
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	11.3	20.6
Persistent Scarcity	Models persistent challenges to security of supply – e.g., low hydro availability, delays to inter-regional transmission, long interconnection queues, more cooling days, etc	9.7	25.1

Sources: Aurora Energy Research

Summary of scenario input assumptions

As per *Central* scenario unless otherwise indicated

		Aurora Central	Low	Persistent Scarcity
Demand	Underlying Demand	X TWh in 2023 increasing to X TWh by 2050, driven by population and industrial growth	15% decrease in energy demand by 2050	10% increase in energy demand by 2050
	EVs	X million EVs in 2030 and X million in 2050		X million EVs in 2030 and X million in 2050
	Rooftop Solar	X GW in 2023 increasing to X GW in 2030 and X GW in 2050		
	BTM Battery	X GW in 2023 increasing to X GW in 2030 and X GW in 2050		
	Hydrogen electrolysis	No large scale demand for grid-connected hydrogen electrolysis		
Commodities	Gas price[1,2]	Henry Hub forecast increased up to $X/MMBtu in 2022 and California Citygate prices average $X/MMBtu in 2030 and $X/MMBtu in 2050	$X/MMBtu in 2030 and $X/MMBtu in 2050	$X/MMBtu in 2030 and $X/MMBtu in 2050
	Carbon price	Carbon price increases to $X/ton by 2035 and levels off at $X/ton	Auction reserve carbon price of $X/ton in 2035 compounding X% annually on top of inflation	
Technology	Renewables	Between 2022 and 2050, wind CAPEX falls by X%, solar by X%, and 4-hour batteries by X%; X GW off-shore wind in the Morro Bay call area starting in 2040		No Offshore or Wyoming wind
	Hydro	P60 hydro availability in CAISO		P90 hydro availability
Policy	Pollution standards	Plants face increasing environmental costs at end of lifetime but are not mandated to close		
	Reliability	New entry determined by market economics; 22.5% PRM in 2024	Imports increase to X GW in 2023	X% PRM in 2024; Imports reduced to XGW in 2023
	Renewables incentives	Extension of PTC and ITC for wind and solar and introduction of ITC for batteries		No ITC applied for battery capex
	Transmission upgrades	CAISO 20-year transmission plan assumed, which enables a average cumulative 5.5 GW/year technical limit of new renewables[3]		Pipeline plant commission dates delayed average of 2 years due to delays in CAISO interconnection; new-build renewables restricted to reflect transmission bottlenecks; X% import and export transmission availability

1) Average of Northern and Southern California Citygate prices. 2) Scenarios assume an additional in-state transportation fee for Natural gas after the Citygate prices ($1.57/MMBtu for PG&E and $0.31/MMBtu for SoCal Gas). 3) Including additional transmission upgrades on Path 15 and Path 26 from the late 2030s to avoid significant disparity of SP15 and NP15 trading hub prices due to congested transmission lines.

Sources: Aurora Energy Research

ATC prices and 4-hour spreads vary by around [redacted]-[redacted]$/MWh across these three market scenarios

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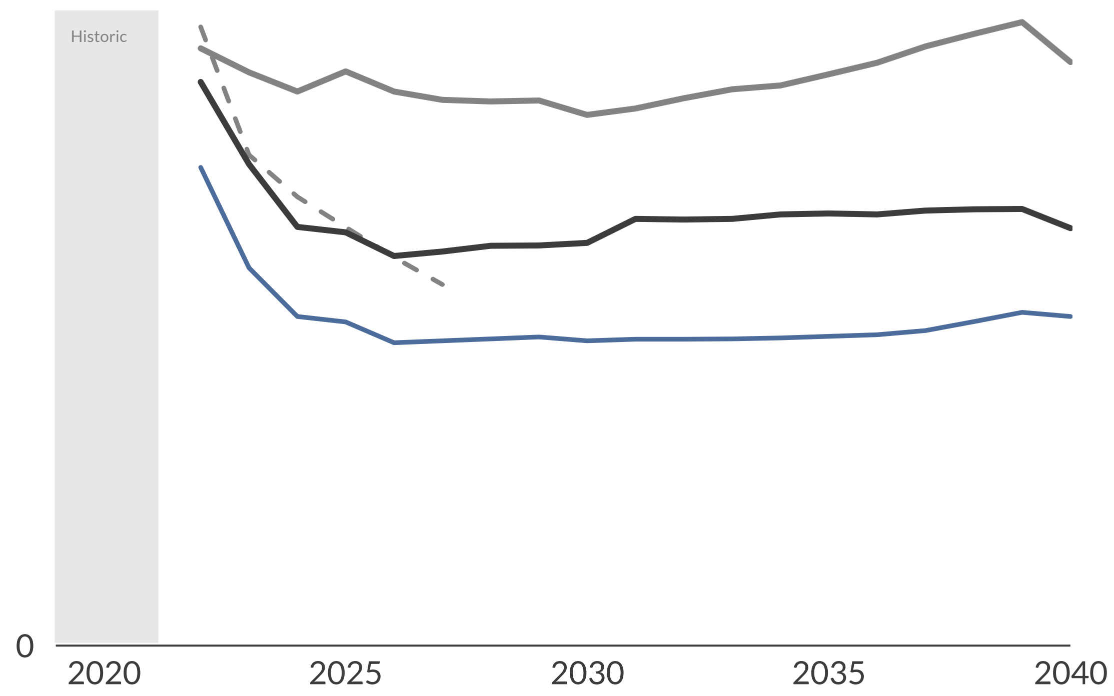
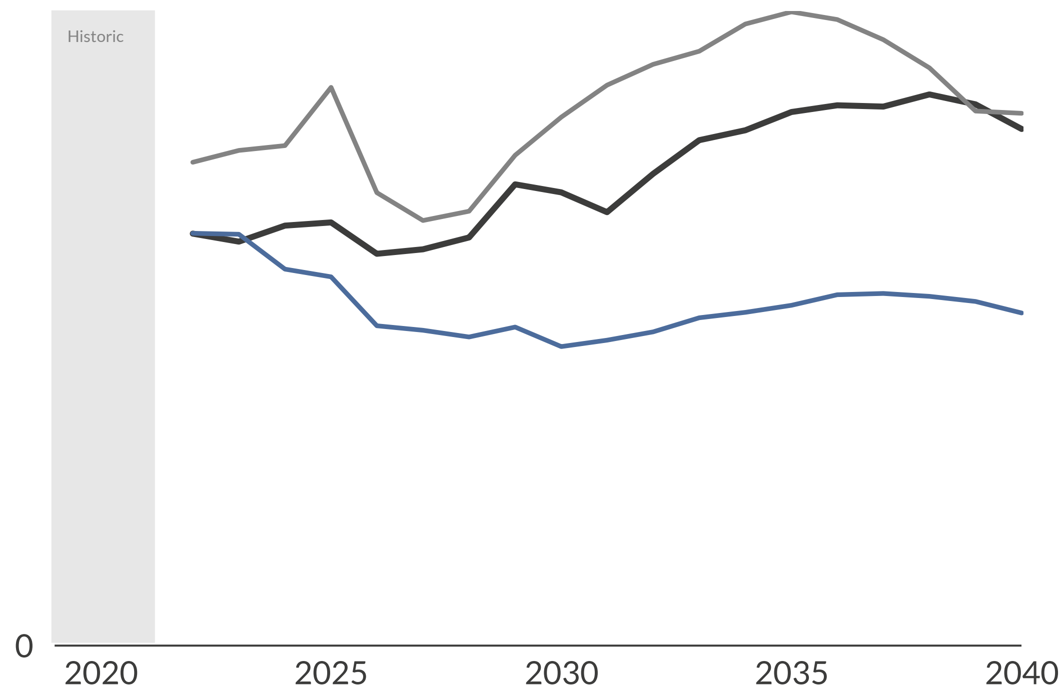
CAISO-wide ATC[1] price
$/MWh (real 2020)



CAISO-wide average 4-hour daily spread
$/MWh (real 2020)



- Under Aurora Central, CAISO-wide ATC prices decrease from $[redacted]/MWh in 2022 to $[redacted]/MWh in 2030 as supply chain issues and interconnection delays are resolved

- Spreads are lowest under Aurora's Low scenario as lower natural gas prices result in lower prices in the shoulder hours, which eat away at spreads batteries are able to capture

Historical CAISO-wide futures Central Low Persistent Scarcity

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

Sources: Aurora Energy Research

Ancillary service prices vary by up to $ /MW across scenarios with the lowest prices in the low scenario

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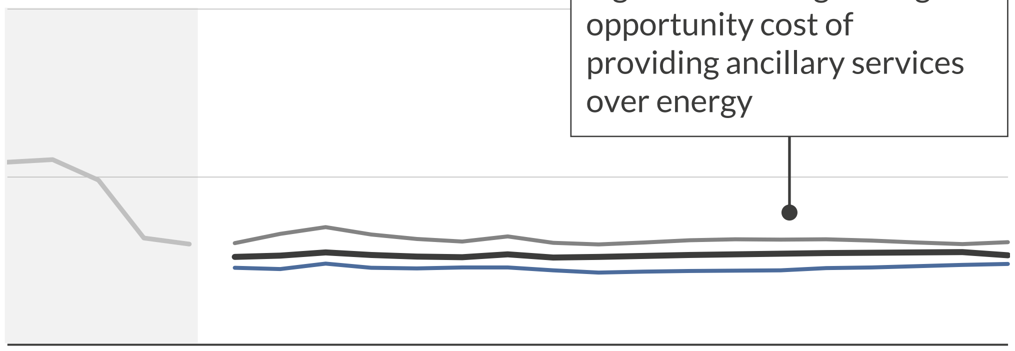
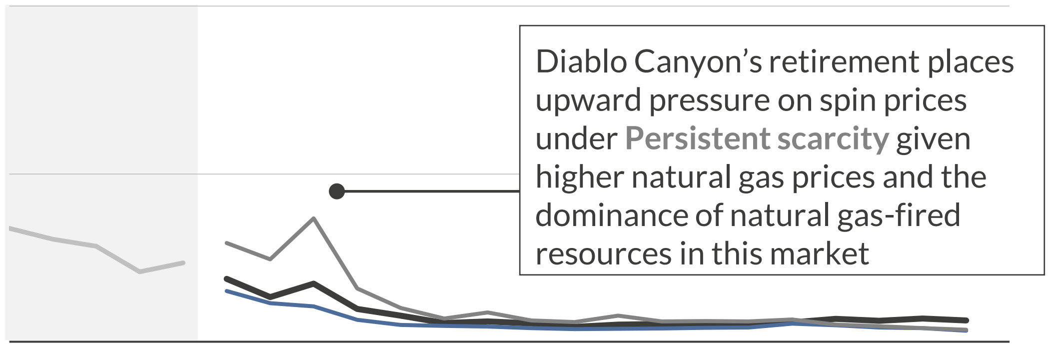
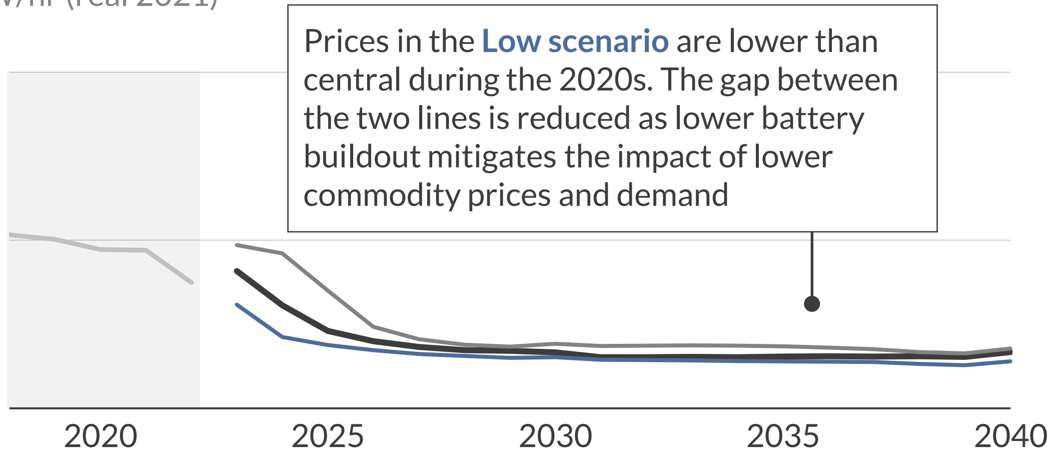
Regulation Up yearly average price
$/MW/hr (real 2021)



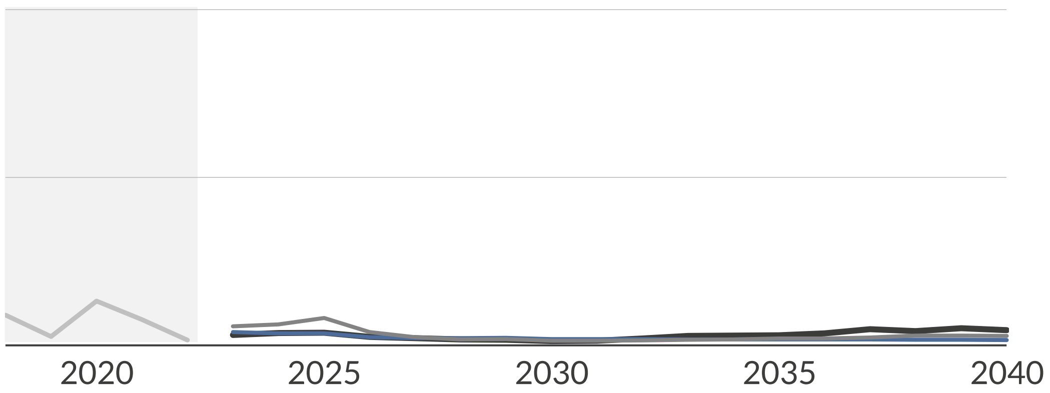
Spinning Reserve yearly average price
$/MW/hr (real 2021)



Regulation Down yearly average price
$/MW/hr (real 2021)



Non-spinning reserve yearly average price
$/MW/hr (real 2021)



Historical — Central — Low — Persistent Scarcity

Sources: Aurora Energy Research

IRRs vary by around basis points across the scenarios, reflecting the inherent volatility in BESS investments

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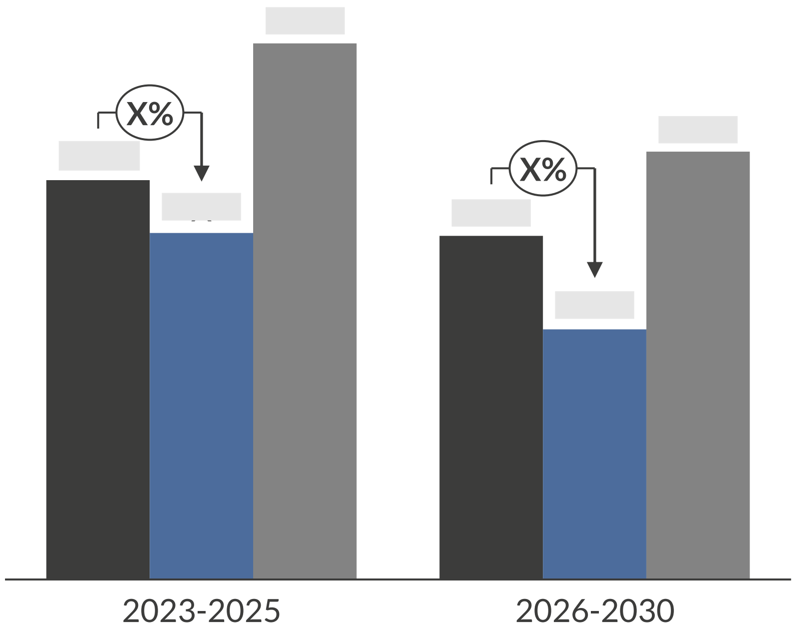
Average annual battery gross margins (4-hour duration, SP15, 2023 entry)

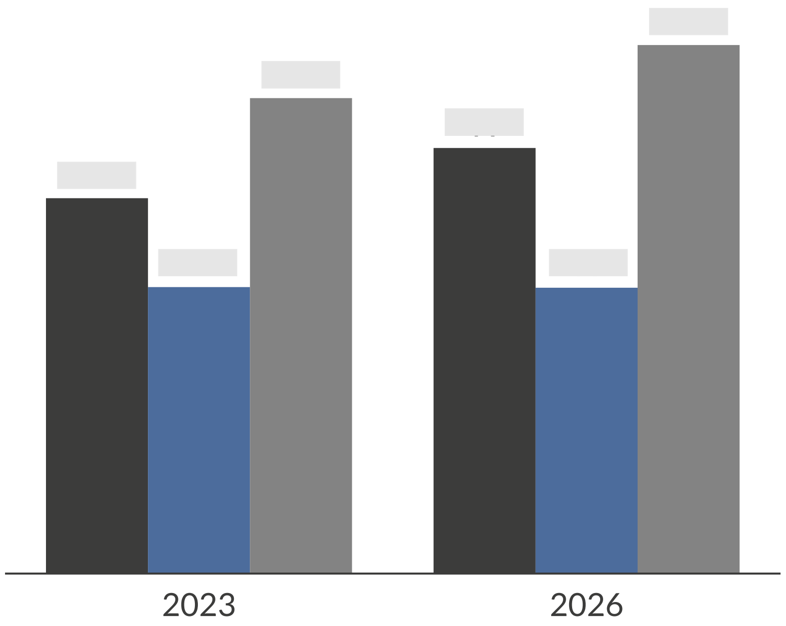
$/kW



- Gross margins are impacted by both the lower wholesale spreads and the lower ancillary returns.
- Margins are % lower under the Low scenario, but % higher under persistent scarcity

IRR for a new build battery by entry year (4-hour duration, SP15)

%



- Project IRRs correspondingly fall with low returns being seen in the low scenario
- Under persistent scarcity, a new build battery in 2026 could see a significant upside, with IRRs at ~ %

Aurora Central | Low | Persistent Scarcity

Sources: Aurora Energy Research

Lifetime, cycles and round-trip efficiency can influence PV of revenue by more than [redacted]%

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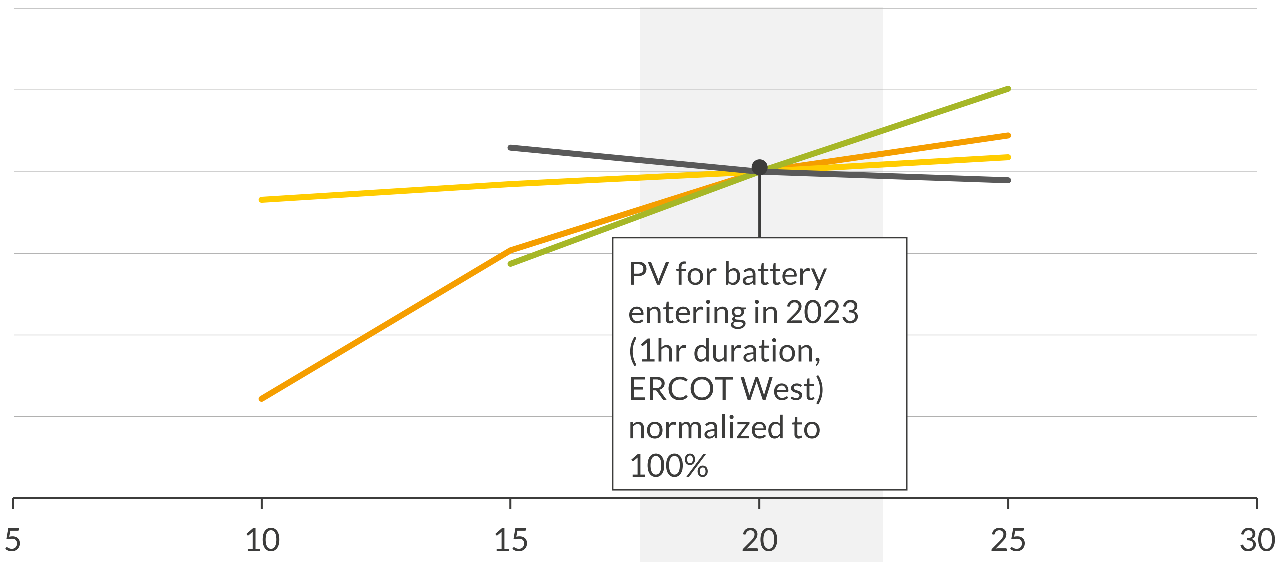
PV[1] of margins relative to central assumptions for new build battery (1hr, 2023 entry in West Hub)

%



Lifetime	Years				
RTE[2]	%				
Cycles	#/year				
Degradation[3]	% p.a.		[redacted]% pa, for 3 years, [redacted]% pa thereafter	**[redacted]% pa for 3 years, [redacted]% pa thereafter**	[redacted]% pa for 3 years, [redacted]% pa thereafter

- Aurora selected 4 input assumptions to test the sensitivities for a change in the Present Value of revenues
- A change in the round-trip efficiency of the battery causes a relatively minor delta in the Present Value of revenue – until the efficiency drops below [redacted]%. With an efficiency of [redacted]%, the PV of the revenues are [redacted]% of those with [redacted]% efficiency as both arbitrage and ancillary revenues are impacted
- The impact of different cycling rates should be considered alongside degradation and lifetime as these measures are relatively interdependent

1) Discount rate of 11%, and 15% for high price periods (>$500/MWh for WM prices or $200/MW/h for AS prices). Does not include OPEX. 2) Round Trip Efficiency. 3) Assuming 365 cycles per year

Sources: Aurora Energy Research

Details and disclaimer

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