AURORA
ENERGY RESEARCH

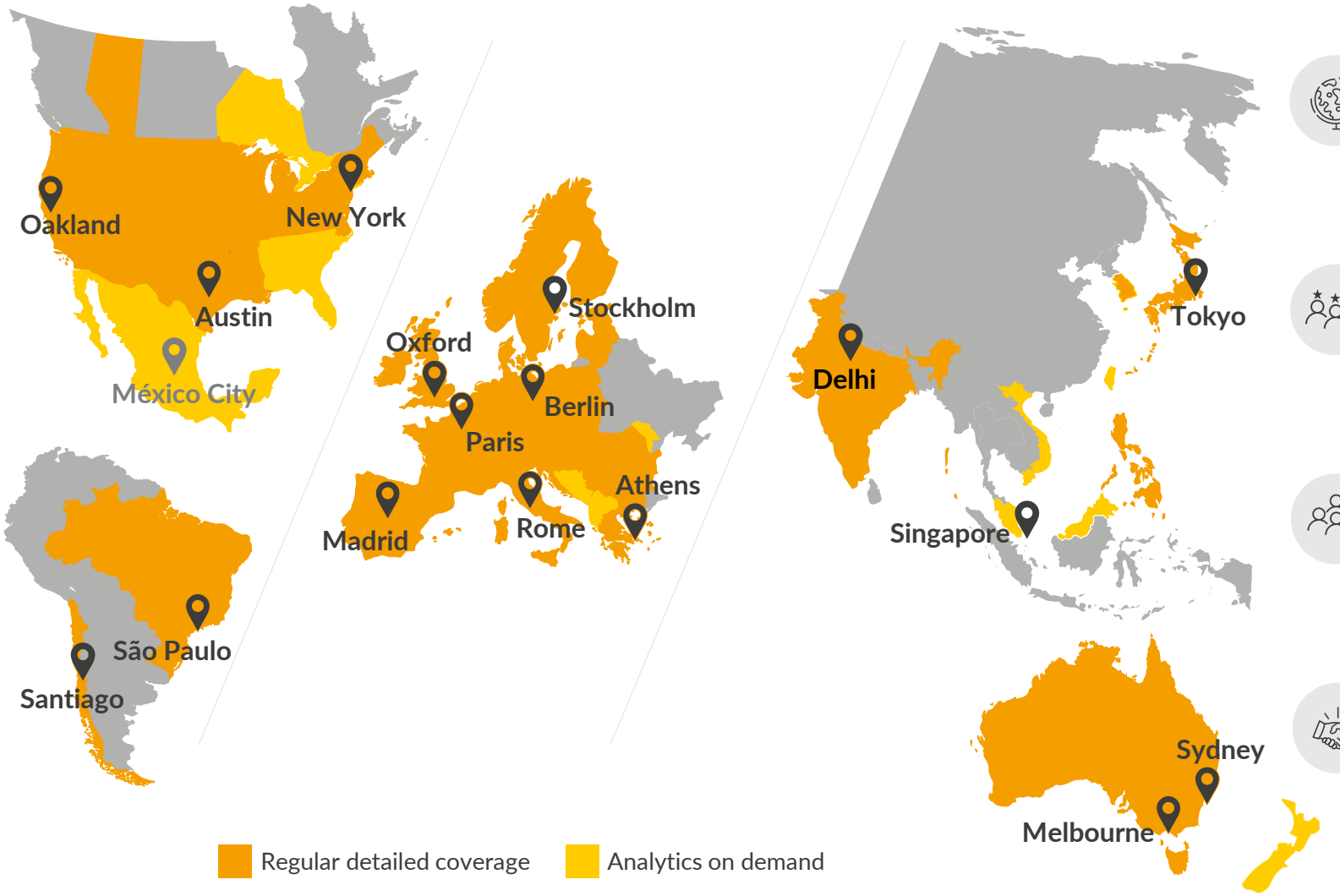
Contract designs for storage in low-carbon markets

ESIG Forecasting & Markets Workshop | June 25, 2025

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

AURORA

- Power markets
- Renewables & PPAs
- Storage
- Grid & Congestion
- Electric vehicles
- Hydrogen H_2
- Carbon CO_2
- Natural gas



17 offices

1000+ market experts

950+ subscribing companies

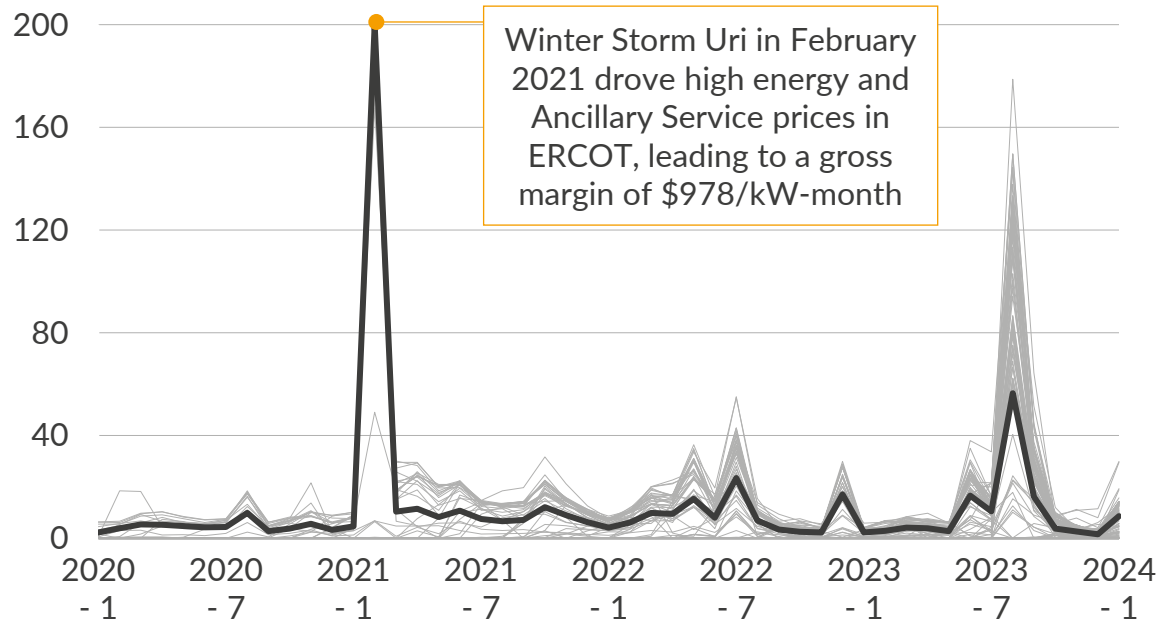
150+ transactions supported in 2024

Source: Aurora Energy Research

Battery value varies month by month; this is exacerbated in ERCOT, driving the need to secure revenue via tolling agreements

ERCOT Battery value is concentrated in very few months; historically this has included both hot summers and extreme winter events

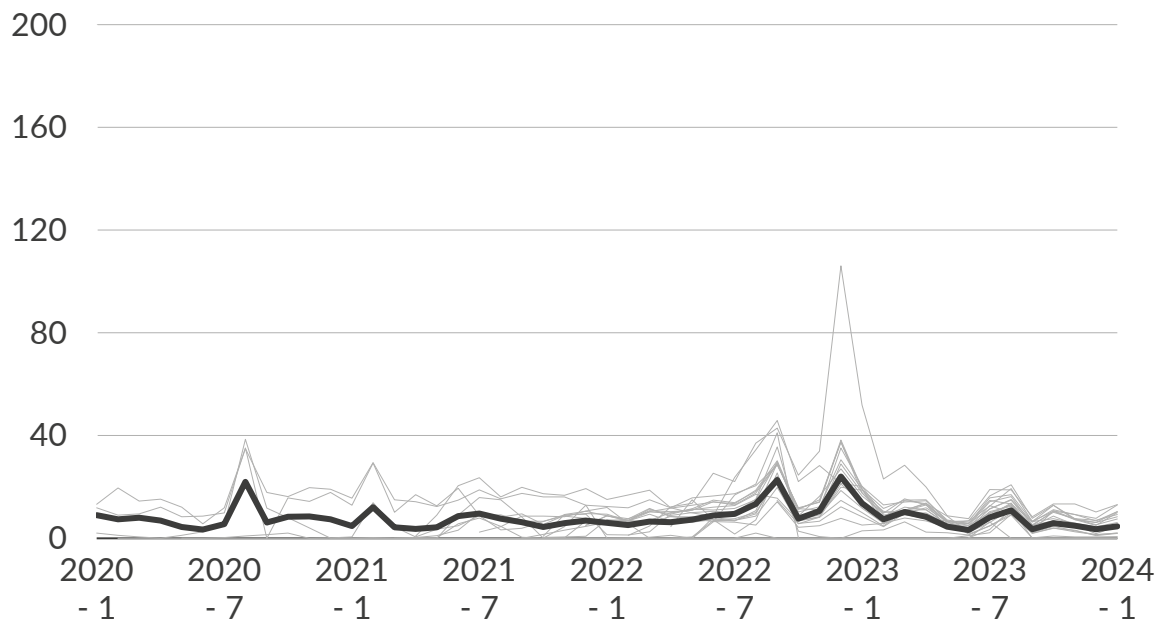
Monthly energy and Ancillary Service gross margins across battery units
$/kW-month (nominal)



- Battery value in ERCOT varies widely month to month - $978/kW-month average in February 2021 (capped in graph to $200/kW-month).
- Generally, summers see increased value due to increased demand for cooling driving scarcity value, benefitting dispatchable assets like batteries.

CAISO Value in CAISO tends to be less concentrated; value is more distributed throughout the entire year, exacerbated by RA

Monthly energy and Ancillary Service revenues across battery QSEs[1]
$/kW-month (nominal)



- Battery value is also variable month to month in CAISO, though absence of scarcity pricing adder and addition of Resource Adequacy payments reduces volatility.
- RA contracts (not shown in revenue here) provide an additional means of securing consistent revenue across all months in the year.

Battery units (ERCOT) / QSEs (CAISO) — Average

1) Data from FERC EQR, generally data is more limited; not showing results for all battery capacity in CAISO. Shows company-level granularity.

Sources: Aurora Energy Research

Battery offtake agreements have emerged as a mechanism to firm battery revenues and unlock debt financing

Landscape for battery contracting

1 Market volatility is growing across power markets

Growth in power demand, supported by decarbonization targets, emerging industries (e.g. AI datacenters) + **Phaseout of fossil fuels** driven by ageing fleet and emissions reduction targets / EPA rules + **Renewables penetration**, supported by declining costs, tax credits, clean energy procurement = **Increased market volatility**

2 Various risks across battery revenue streams may increase attractiveness for battery contracting

Wholesale market – increased pricing volatility due to above factors + **Ancillary Services** – along with battery saturation, reduced AS prices across most hours + **Capacity payments** – volatility in capacity market prices year over year, declining battery ELCCs[1] = **Increased benefit for contracting**

3 Developers and offtakers may see different incentives for contracting

Battery developers

Reasons to contract

- Ensure constant and predictable revenue stream.
- Unlock debt financing for new-build assets, lowering the cost of capital.

Offtakers

Reasons to contract

- Short and long-term price hedge.
- Potential for upside from market exposure.
- Self-balancing.
- **OEM an Optimizers –** Strategic BD

Publicly announced full toll contracts

In ERCOT

100MWh Crosset Storage

Jupiter POWER | HATCH RENEWABLES

In CAISO

1,000MWh Cormorant Energy Storage Project

AREVON | MCE

In NEM (Australia)

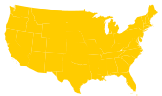
BESS and LDS projects

Capacity Investment Scheme	AEMO SERVICES
Battery developers	*Offtakers*

1) Effective Load Carrying Capability.

Sources: Aurora Energy Research, PR Newswire, Public Power Association, Consumers Energy

Various structures for battery offtake have been seen to date, with availability and prevalence varying across markets



AURORA

X *Deep dive on following slides*

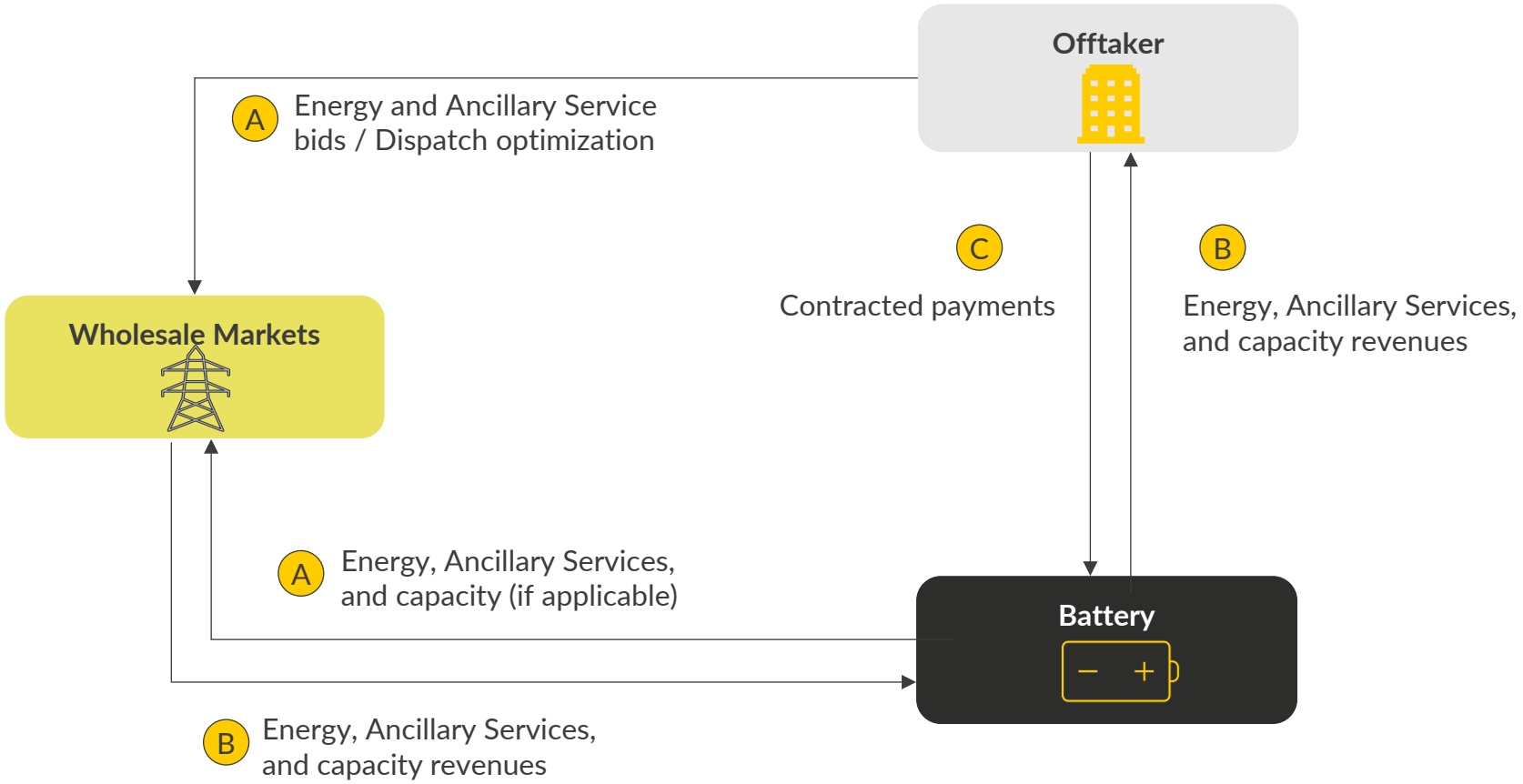
Contract type	Contract structure	Battery receives	Offtaker receives	Main markets present	Typical tenor (years)	Potential size of market
Tolling agreements	Fixed price 1	Pre-determined contract price	Asset dispatch rights; market energy and Ancillary Service revenues	ERCOT, MISO, CAISO	5 - 7	
	Floor price with profit sharing	Pre-determined contract price + share of market revenues	Asset dispatch rights; remainder of market revenues	ERCOT	5 - 7	
Financial hedges	Top / bottom spread swaps 2	Fixed rate	Floating rate based on realized top / bottom spreads	ERCOT, CAISO	1 - 5	
	Ancillary Services swaps	Fixed rate	Floating rate based on realized Ancillary Services prices	ERCOT	1 - 5	
	Revenue puts and collars	Caps and floors on market revenues	Receives market revenues above cap and pays market revenues below floor	ERCOT, AEMO	1 – 15	
Capacity sales	RA[1] contracts 3	Pre-determined contract price	Credit towards resource adequacy obligation	CAISO	10 - 15	
	Long-term capacity sales	Pre-determined contract price	Credit towards capacity market obligation	MISO, PJM	10 - 15	
State subsidies	Indexed storage payments 4	"Strike Price" (as bid by battery developer), market energy, Ancillary Services, and capacity revenues	"Reference Price," intended to reflect the market revenues over a given period (netted off from payment to battery)	NYISO	15	

1) Resource Adequacy.

Source: Aurora Energy Research

1 Under a toll, the offtaker assumes market price risk, in exchange for a fixed payment. Incentive alignment management is critical.

Tolling agreements – Fixed price



Source: Aurora Energy Research

Contract design and incentive compatibility implications

- Under a "full" tolling agreement, market revenues are passed through to the offtaker, in exchange for a fixed payment.

A Under a 100% toll the battery does not retain any economic link to market outcomes.

B Thus, the battery owner has no ongoing incentives to maximize revenues.

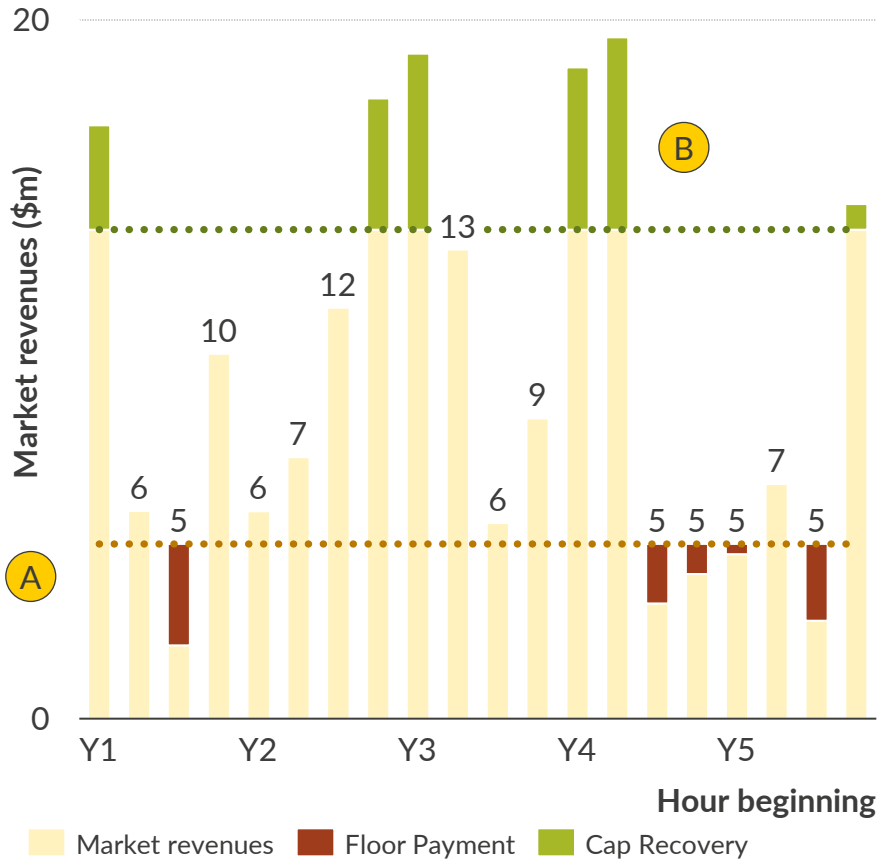
C Contract design options to retain incentive compatibility:

- **Trading rights alignment:** "right to operate and trade" follows revenues.
- **Partial toll:** where battery owner retains a share in market revenues.
- **Virtual toll:** benchmarked performance (perfentage-of-perfect).

2 'Caps & floors' contract designs seek to bound market revenues under a no-cost collar.

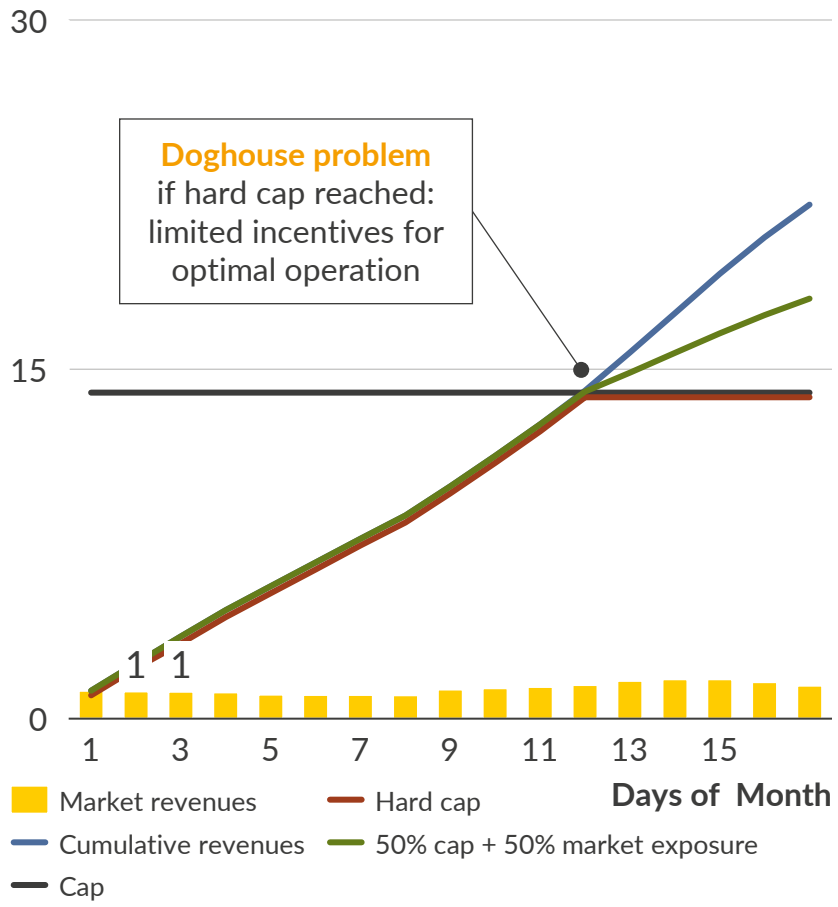
Financial hedges – Revenue 'cap & floor' or collar

Example AEMO Capacity Investment Scheme, $m



Example of the "Doghouse problem" in collar structure

$m



- Revenue 'Caps & Floors' seek to bound revenues within a range under a zero-cost collar structure.
  - A When market revenues are higher than the cap, battery pays offtaker.
  - B When market revenues are lower than the floor, offtaker pays battery.

Incentive compatibility:

"The Doghouse Problem":

- Under a **hard revenue cap w**hen the cap threshold I reached the battery has no incentives to participate optimally in the market.

Potential mitigations

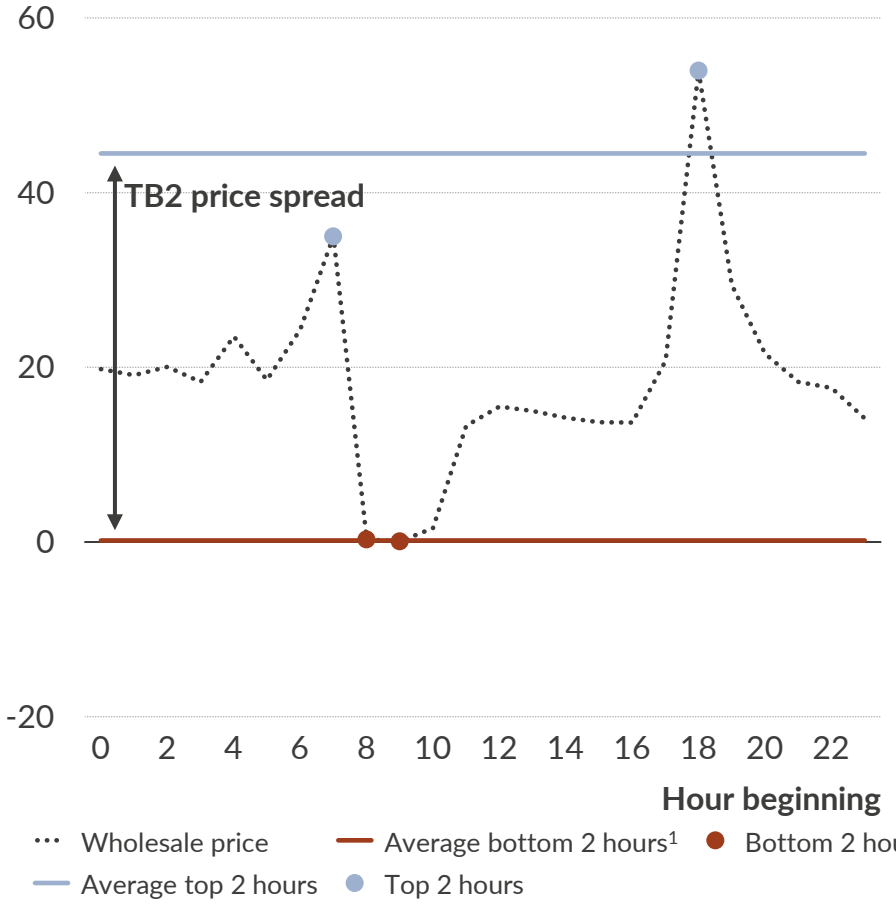
- ***Soft cap***: a revenue share rather than a hard cap mitigates.
- "***Yardstick contracts***": create a '*perfect-foresight*' benchmark rather than payouts based on *actual performance*.

Source: Aurora Energy Research

3 Top / Bottom spread swaps allow a battery to lock in energy revenues without any physical exchange of power with the offtaker

Financial hedges – Top / Bottom spread swaps

Example "Top / Bottom 2" price spread (March 3, 2023 ERCOT West hub), $/MWh



Example settlement of "Top / Bottom 2" financial swap $/MWh

- A Top / Bottom spread swap is a financial transaction where the battery receives a fixed price, based on anticipated price spreads. In exchange, the offtaker receives a "floating" payment, based on realized price spreads over the tenor of the contract.
- The fixed price allows the battery to "lock in" a price spread.
  - A When fixed price spread is higher than market price spread, offtaker pays battery.
  - B When fixed price spread is lower than market price spread, battery pays offtaker. From the battery's perspective, this loss is offset by increased energy arbitrage revenues due to higher than anticipated price spreads.
- Unlike a tolling agreement, the battery generally retains control over asset dispatch.

Source: Aurora Energy Research

3 More than 80% of batteries expected to interconnect in CAISO in the near term have signed a long-term Resource Adequacy contract

Capacity sales – RA contracts

Resource Adequacy contracts offered by California utilities

Resource Adequacy only

Product: Resource Adequacy
Structure: The utility compensates the battery only for the Resource Adequacy value. The battery maintains control over dispatch and exposure to market energy and ancillary services prices.

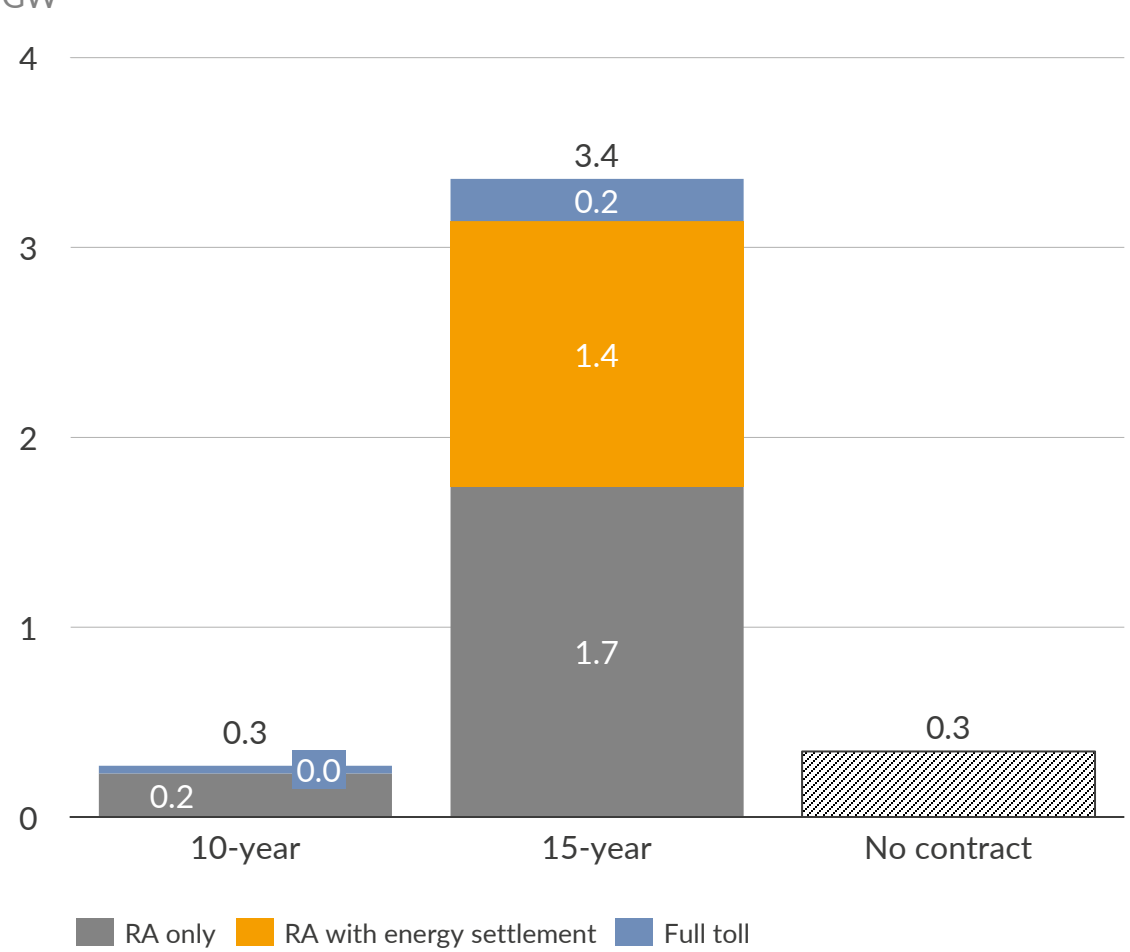
Resource Adequacy with energy settlement

Products: Resource Adequacy, energy
Structure: Energy settlement resembles a top / bottom spread swap, and thus allows the battery to lock in energy arbitrage revenues. The battery retains control over ancillary service revenues.

Full tolling agreement

Products: Resource Adequacy, energy, Ancillary Services
Structure: The utility compensates the battery for energy and ancillary services at a fixed price, controls asset dispatch, and is exposed to market energy and Ancillary Services prices.

New battery capacity anticipated to connect by 2026[1]



1) Aurora assumes battery projects with announced RA contracts, as well as projects CAISO lists as ready to connect on current transmission in their near-term connection report (which may not have RA yet) will connect by or within 2 years of their planned online date.

Sources: Aurora Energy Research, CAISO, Energy Storage News, PG&E, SCE, SDG&E

4 New York Index Storage Credit System aims to provide storage projects with revenue certainty and any necessary subsidization

State subsidies – Indexed storage payments

A NY's 2024 6GW Energy Storage Roadmap proposes the implementation of NYSERDA-led programs towards procuring an additional 4.7GW of new storage projects.

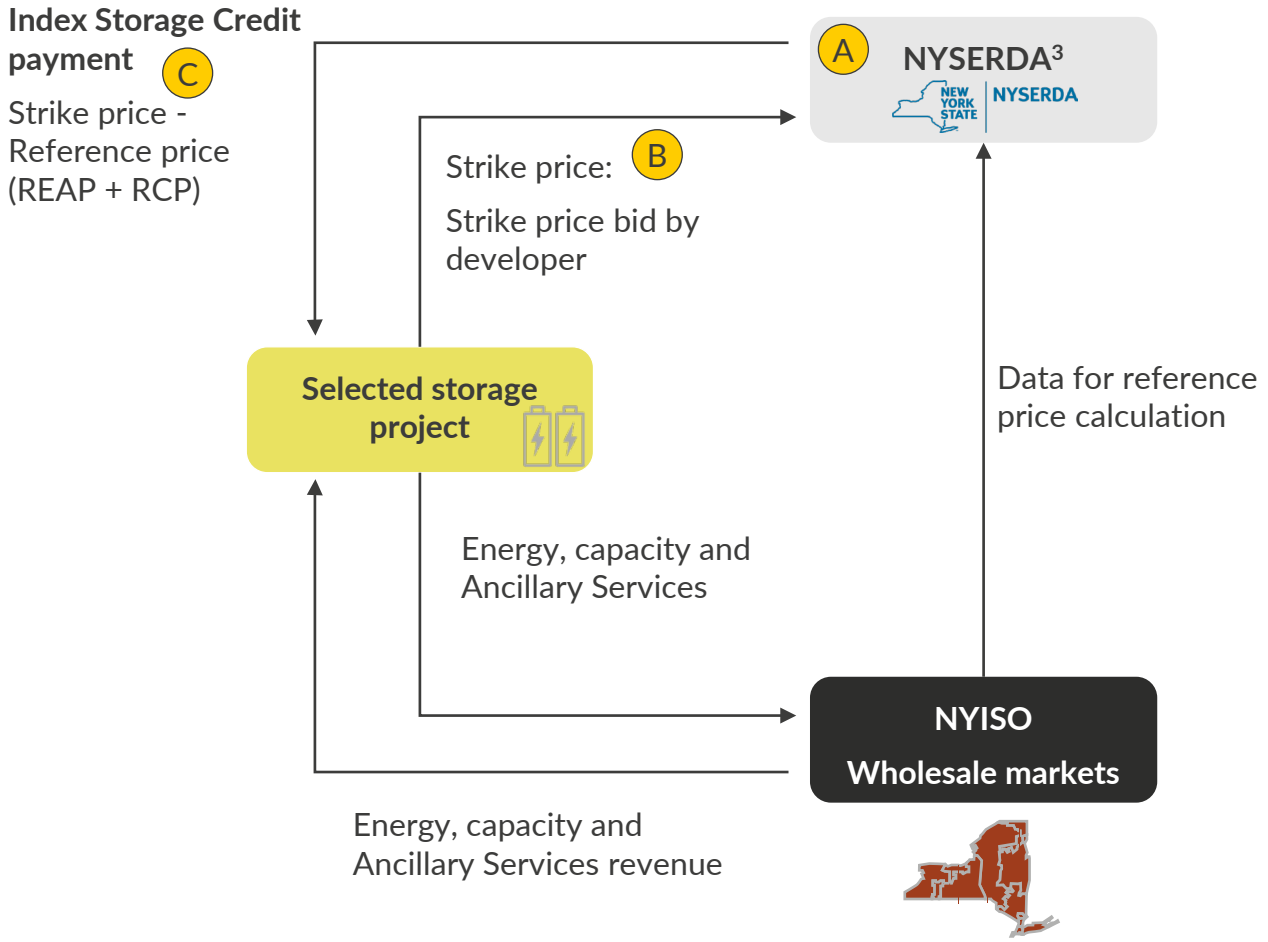
- After reviewing various options, NYSERDA[3] suggested (and NYDPS[4] approved) **implementing the Index Storage Credit (ISC) to procure 3GW bulk storage.**

B Under the proposal ESR[1] projects in yearly bids would offer a Strike Price, a crucial factor for NYSERDA's project selection; aiming to reflect the project's revenue needs.

C Chosen projects would earn revenue calculated as the gap between the Strike Price and the Reference Price, which approximates an ESR's anticipated service market value by combining the **Reference Energy Arbitrage Price (REAP) and the Reference Capacity Price (RCP**).

  - **REAP** = Difference between the top four and bottom four priced hours of the day-ahead zonal LBMPs[2].
  - **RCP** = The adjusted ICAP spot auction price considering the Capacity Accreditation Factor.

- The NYSERDA/DPS filing suggests that if the Strike Price surpasses the total of REAP and RCP, NYSERDA pays the difference to selected projects. **If the combined REAP and RCP exceed the Strike Price, the project pays NYSERDA.**

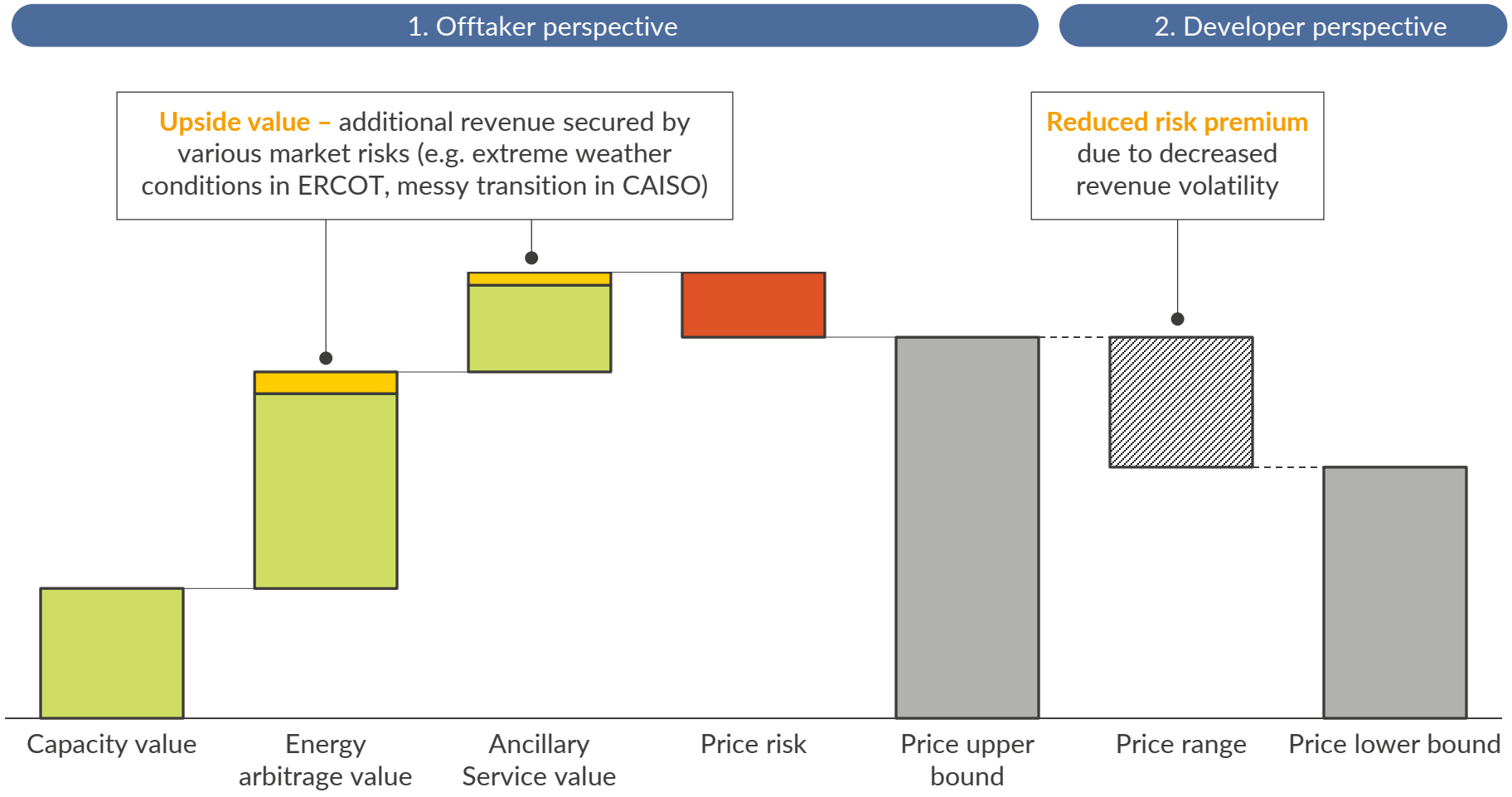


1) Energy Storage Resource. 2) Locational based marginal prices. 3) New York State Energy Research and Development Authority. 4) New York Department of Public Service.

Sources: Aurora Energy Research, NYSERDA

Methodology: The tolling agreement price is bounded by the value to the offtaker and battery, respectively

Tolling agreement price calculation
$/kW-month



1) The ensuing calculations assume zero nodal premium.

Source: Aurora Energy Research

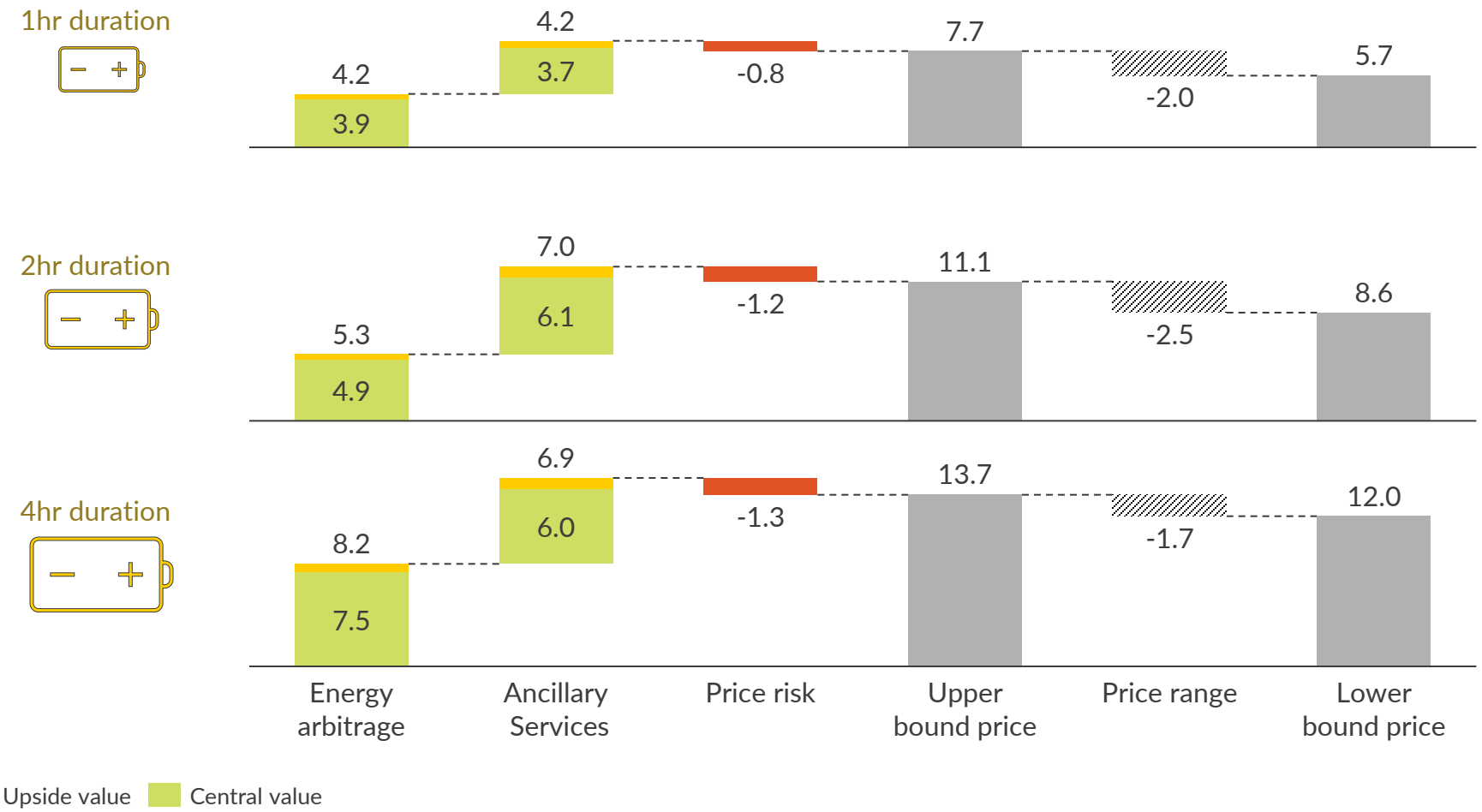
AURORA

Waterfall components

- For the **offtaker**, the maximum willingness to pay depends on the value of the revenue streams.
  - Levelized value of expected **capacity** (if applicable), **energy**, and **Ancillary Services revenues**
  - Any incremental value associated with the project's node[1]
  - **Upside value**
  - **Price risk** discount, reflecting the uncertainty in the realization of revenue streams
- For the **developer**, the minimum acceptable price is calculated with hurdle rate that reflects a decrease in risk premium.
- The ultimate price is a function of supply-demand dynamics, impacted by the number of offtakers relative to batteries.

ERCOT: The fair price for a 7-year tolling agreement in the West hub ranges from $5.7/kW/month (1-hour) to 13.7/kW/month (4-hour)

ERCOT: 7-year tolling agreement in West Hub starting in 2025 – by various durations, $/kW-month, nominal



Source: Aurora Energy Research

AURORA

Drivers of valuation

- Tolling agreement fair prices are higher for longer-duration batteries, though not proportionally (i.e., the fair price for a 4-hour battery is less than 2x the fair price for a 2-hour battery).
- Although revenues from Ancillary Services are expected to decline over time as markets saturate, Ancillary Services still comprise a significant portion of tolling agreement value across all durations.
- 2-hour and 4-hour batteries see higher Ancillary Service value than 1-hour batteries, primarily due to the 2-hour duration constraint for the ECRS product.

Key takeaways on standalone battery storage contracting

AURORA

1. Market or centrally based hedging schemes essential to risk management of volatile revenue streams for storage market participation. Hedge frameworks assist with revenue support and enable financing and investment.

2. Multiple contract forms exist with respect to storage including tolls, revenue *caps* & *floors*, and spread (top-bottom difference) contracts. Incentive compatibility issues need to be actively managed through innovative contract design, alignment of operational rights, and ensuring 'skin-in-the-game' through shared exposure.

3. Valuation of complex hedging contracts require consideration of 'two sides of the coin': The developer's perspective based on a 'capital recovery' approach and an offtaker's perspective based on a 'fair value' approach.

Sources: Aurora Energy Research

Details and disclaimer

General Disclaimer
This document is provided "as is" for your information only and no representation or warranty, express or implied, is given by Aurora Energy Research Limited and its subsidiaries Aurora Energy Research GmbH and Aurora Energy Research Pty Ltd (together, "**Aurora**"), their directors, employees agents or affiliates (together, Aurora's "**Associates**") as to its accuracy, reliability or completeness. Aurora and its Associates assume no responsibility, and accept no liability for, any loss arising out of your use of this document. This document is not to be relied upon for any purpose or used in substitution for your own independent investigations and sound judgment. The information contained in this document reflects our beliefs, assumptions, intentions and expectations as of the date of this document and is subject to change. Aurora assumes no obligation, and does not intend, to update this information.

Forward-looking statements
This document contains forward-looking statements and information, which reflect Aurora's current view with respect to future events and financial performance. When used in this document, the words "believes", "expects", "plans", "may", "will", "would", "could", "should", "anticipates", "estimates", "project", "intend" or "outlook" or other variations of these words or other similar expressions are intended to identify forward-looking statements and information. Actual results may differ materially from the expectations expressed or implied in the forward-looking statements as a result of known and unknown risks and uncertainties. Known risks and uncertainties include but are not limited to: risks associated with political events in Europe and elsewhere, contractual risks, creditworthiness of customers, performance of suppliers and management of plant and personnel; risk associated with financial factors such as volatility in exchange rates, increases in interest rates, restrictions on access to capital, and swings in global financial markets; risks associated with domestic and foreign government regulation, including export controls and economic sanctions; and other risks, including litigation. The foregoing list of important factors is not exhaustive.

Copyright


AURORA
ENERGY RESEARCH