Storage Design and Modeling

Uplift & Default Energy Bids, and State-of-Charge Management

Stakeholder Meeting

July 22, 2026
1 pm – 4 pm

Engagement Best Practices

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The facilitator will provide guidance for comments and questions to ensure a productive flow. Please keep remarks succinct and avoid revisiting points that have already been covered, allowing space for all voices.

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CAISO Policy Initiative Stakeholder Process

Learn more in the Stakeholder Process Guide

Agenda

Time	Topic	Presenter
1:00 – 1:05	Welcome and today's agenda	Brenda Marquez
1:05 – 1:10	Meeting Goals and Initiative Overview	Sergio Dueñas Meléndez
1:10 – 2:00	Straw Proposal on Storage Default Energy Bid Enhancements	Sergio Dueñas Meléndez
2:00 – 2:35	Straw Proposal on Hybrid Default Energy Bid	Dinesh Das Gupta
2:35 – 2:50	Open Discussion	
2:50 – 3:00	Break	
3:00 – 3:45	Discussion of NGR bidding concept	Sergio Dueñas Meléndez
3:45 – 4:00	Open Discussion	

MEETING GOALS AND INITIATIVE OVERVIEW

Meeting Goals

- Discuss the approaches detailed in the straw proposal to modify the storage default energy bid
- Discuss the straw proposal to develop a default energy bid methodology for hybrid resources
- Discuss the non-generator resource bidding concept included in the recently published paper and explore key questions with stakeholders

Overview of near-term proposal timeline *

- **July 22nd:** Hybrid meeting
- **August 5th:** Comments due
- **September 2nd:** Revised Straw Proposal on Uplift & DEB and SOC Management
- **September 16th:** Hybrid meeting
- **September 30th:** Comments due
- **October 28th:** Draft Final Proposal on Uplift & DEB and SOC Management
- **November 4th:** Hybrid meeting
- **November 18th:** Comments due

**All dates are tentative until confirmed through a notice in the ISO's Daily Briefing.*

OPEN DISCUSSION

STRAW PROPOSAL ON STORAGE DEFAULT ENERGY BID ENHANCEMENTS

In the following slides, the ISO details two alternatives to enhance the energy storage default energy bid: the time-of-day approach and the static approach.

- The time-of-day approach incorporates elements of the hydro default energy bid and provides a consistent framework that can be leveraged across EDAM and WEIM, with minimal methodological differences.
- The static approach minimizes differences across energy-limited resources and geographies by leveraging a hydro-based framework.
- Currently, the ISO sees the time-of-day approach as the alternative that best addresses known default energy bid challenges while remaining practical to implement.

Today, the storage default energy bid accounts for batteries' round-trip efficiency and duration and includes three cost components

$$\text{Storage DEB} = \text{Max}\left\{\left[\text{Max}\left(\text{En}_{\delta/\eta}, 0\right) + \rho\right], \text{PB\_OC}_{\gamma}\right\} * \text{DEB Multiplier}$$

Where:

En:	Energy Cost
η:	Round-Trip Efficiency
δ:	Energy Charging Duration
γ:	Energy Discharge Duration
ρ:	Variable Storage Operations Cost
PB_OC:	Price-Based Opportunity Cost
DEB Multiplier	110% Multiplier

Today, the storage default energy bid accounts for batteries' round-trip efficiency and duration and includes three cost components

1. Energy costs: estimates the average cost of energy needed to charge the storage resource

   – For the day-ahead default energy bid, the energy costs are sourced from the day-ahead locational marginal price from the market power mitigation run at the relevant pricing node for the same trading day

   – For the real-time default energy bid, the energy costs are sourced from day-ahead locational marginal prices from the integrated forward market run at the relevant pricing node for the same trading day

Today, the storage default energy bid accounts for batteries' round-trip efficiency and duration and includes three cost components

2. Price-based opportunity costs: estimates the market opportunity cost when determining whether to discharge stored energy at various hours during the day

   – For the day-ahead storage default energy bid, the price-based opportunity cost uses advisory prices from the market power mitigation process

   – For real-time storage default energy bid, the price-based opportunity cost is set at the value of the highest day-ahead locational marginal price corresponding to the discharge duration of the resource

Today, the storage default energy bid accounts for batteries' round-trip efficiency and duration and includes three cost components

3. Variable storage operations cost: used to represent cycling and other variable operational costs

   – If a non-zero variable storage operations cost is desired, Scheduling Coordinators should submit an Inquiry ticket via CIDI to register their variable storage operations cost

   – If the Scheduling Coordinator does not wish to register a non-zero variable storage operations cost, the CAISO will enter a default value of $0/MWh to the Master File

Today, the storage default energy bid accounts for batteries' round-trip efficiency and duration and includes three cost components

- Today, WEIM-only storage resources (those not participating in EDAM) are not able to utilize the Storage DEB option because the Storage DEB calculation relies on day-ahead LMPs, which are not calculated for non-EDAM participating resources
  - Today, such storage resources must pursue the Negotiated DEB option, or pick any of the other DEB options for which they are eligible

Default Energy Bids: Problem Statement

- The storage default energy bid's dependence on outputs from prior market runs creates challenges since:
  - Those values may be "stale" in the market the DEB is used
  - With an expanding footprint, some resources that are not part of the day-ahead market cannot readily leverage the storage default energy bid option

- A static real-time storage default energy bid has the potential to over- or under-estimate opportunity costs at different hours of the day

Default Energy Bids: Guiding Principles

- The storage default energy bid should be designed in a way that allows for the reflection of changing real-time opportunity costs, ensuring the correct placement of storage within the bid stack, even under mitigation

- The storage default energy bid should be calculated in a way that all storage resources, regardless of location, should be able to readily leverage a default energy bid option

- The storage default energy bid should be designed in a way that minimizes the risks of charging-side mitigation

Feedback following the May 2026 meeting showed broad support for storage default energy bid reform, but key design elements were subject to discussion.

- Broad stakeholder support for a scaling process to address "stale" values.
- Strong support for adding a gas floor, with some exceptions.
- Opposition to time-of-day multipliers below 1, with some exceptions.
- Requests for transparency regarding how multipliers and scaling factors would be calculated, updated, and validated.
- Several commenters viewed the time-of-day approach as overly complex and favored a simpler hydro-based static alternative.
  - Division on the appropriate price proxy for opportunity cost estimation (LMPs vs. trading hubs/DGAPs).

In the Straw Proposal, the ISO details two approaches to enhance the storage default energy bid" the time-of-day approach and the static approach

	Time-of-Day	Static
Addresses the "stale" value issue	Yes	No
Creates a default energy bid that WEIM-only storage can readily leverage	Yes, albeit with different cost proxies being leveraged	Yes
Allows for the reflection of changing opportunity costs	Yes	No
Ensures the correct placement of storage within the bid stack when mitigated	Yes	Partially since it does not reflect changing opportunity costs in real-time
Minimizes the risk of charging-side mitigation	Yes	Yes

The time-of-day approach incorporates elements of the hydro default energy bid and provides a consistent framework that can be leveraged across EDAM and WEIM, with minimal methodological differences.

- Incorporates key elements of the hydro DEB methodology.
- Introduces upward-only scaling of price proxies to better reflect conditions.
- Revises the current 1.1 multiplier structure to better align with hydro DEB.
  - Retains a 1.1 multiplier for gas floor and variable O&M cost components.
  - Applies a 1.4 multiplier to the opportunity cost component in day-ahead calculations.
  - Adds a real-time time-of-day multiplier of either 1.0 or 1.4 to reflect changing intraday opportunity costs.
- Defines the charge DEB as the discharge DEB minus variable operating costs.

Time-of-Day Approach Formulation

$$DA\ Discharge\ DEB = Max(Variable\ Operations\ Cost * 1.1, PB\_OC * 1.4, Gas\ Floor * 1.1)$$
$$DA\ Charge\ DEB = (DA\ Discharge\ DEB - Variable\ Operations\ Cost)$$

$$RT\ Discharge\ DEB = Max(Variable\ Operations\ Cost * 1.1, PB\_OC * 1.4, Gas\ Floor * 1.1) * TOD\ Multiplier$$
$$RT\ Charge\ DEB = (RT\ Discharge\ DEB - Variable\ Operations\ Cost)$$

Where:

- $Variable\ Operations\ Cost$: Represents cycling and other operational costs
- PB_OC: Price-based Opportunity Cost
  - In DA for EDAM, calculated by scaling the MPM outputs based on differences relative to DA LMPs
  - In RT for EDAM, calculated by scaling DA LMPs based on differences relative to RT LMPs
  - In RT for WEIM, calculated by scaling DGAP based on differences relative to RT LMPs
- $TOD\ Multiplier$: A value of 1.4 before the hour that set the price-based opportunity cost and 1 after the hour that set the price-based opportunity cost (only in real-time)
- $Gas\ Floor$: 11,068 MMBtu/MWh * Fuel region gas price

The static approach minimizes differences across energy-limited resources and geographies by leveraging a hydro-based framework.

- Promotes consistency across energy-limited resources and geographic regions by closely aligning with the existing hydro default energy bid methodology.
- Excludes the long-term component from the discharge bid calculation because most storage resources only have daily-use limitations.
- Discharge bid is based on the greater of either the gas floor times a 1.1 multiplier or the short-term component times a 1.4 multiplier

The static approach minimizes differences across energy-limited resources and geographies by leveraging a hydro-based framework.

- Short-term component is based on the day-ahead power price index at the local default electric pricing hub, consistent with the hydro default energy bid.
  - Represents wholesale market opportunity cost rather than node-specific storage opportunity cost.

- Charge bid equals discharge bid minus variable operating cost.
  - Variable operating costs are provided by Scheduling Coordinators and maintained in the Master File.

- Key differences from the time-of-day approach:
  - Uses the same local hub price proxy for all storage resources.
  - Does not include stale-value scaling adjustments or time-of-day multiplier.

The static approach minimizes differences across energy-limited resources and geographies by leveraging a hydro-based framework.

Static Approach Formulation

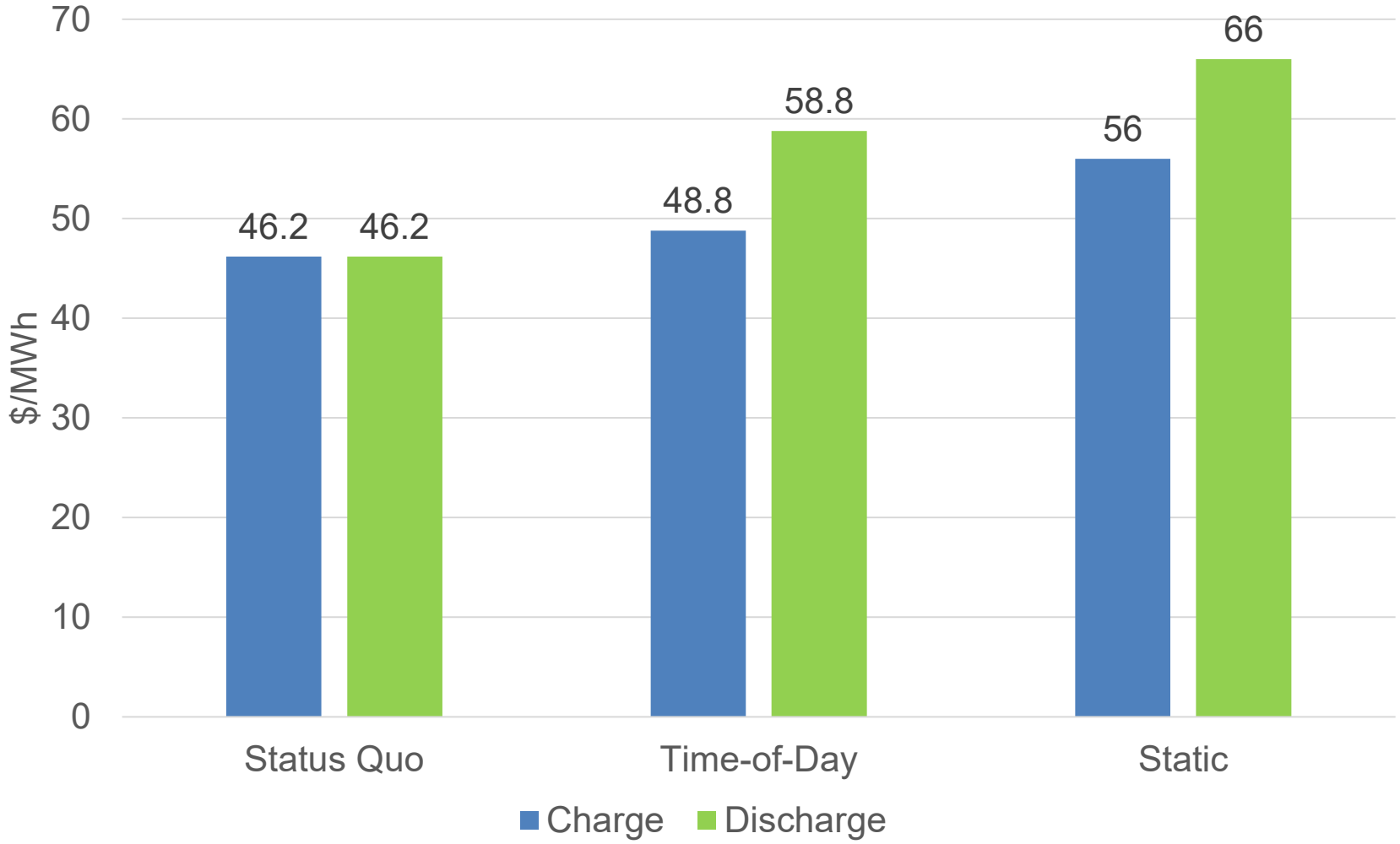
$$Discharge\ Default\ Energy\ Bid = Max(Gas\ Floor * 1.1, STC * 1.4) + Variable\ Operations\ Cost$$

$$Charge\ Default\ Energy\ Bid = (Discharge\ Default\ Energy\ Bid - Variable\ Operations\ Cost)$$

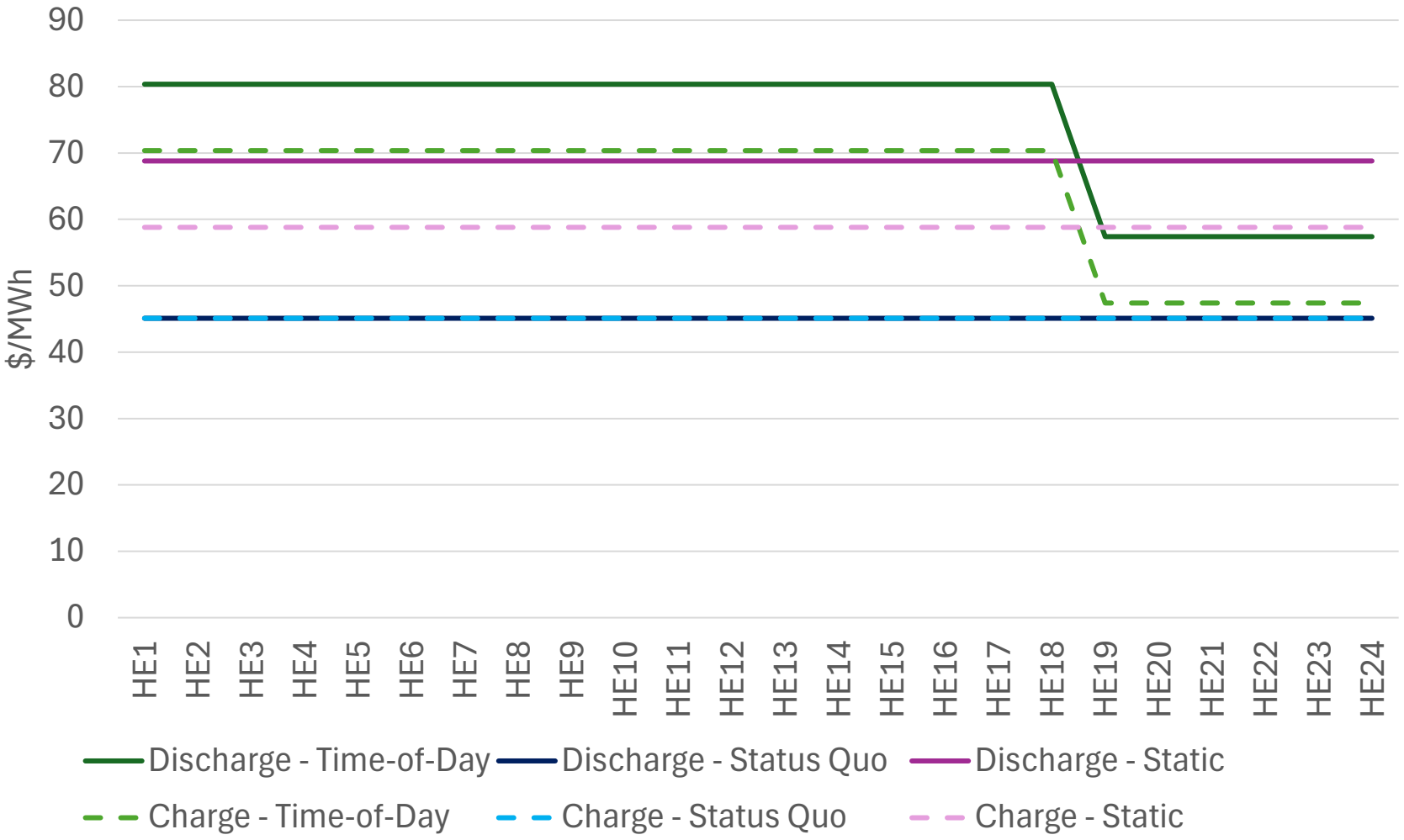
Where:

- $Variable\ Operations\ Cost$: Represents cycling and other operational costs
- $Gas\ Floor$: 11,068 MMBtu/MWh * Fuel region gas price
- STC: Day-ahead power price index at local default electric pricing hub

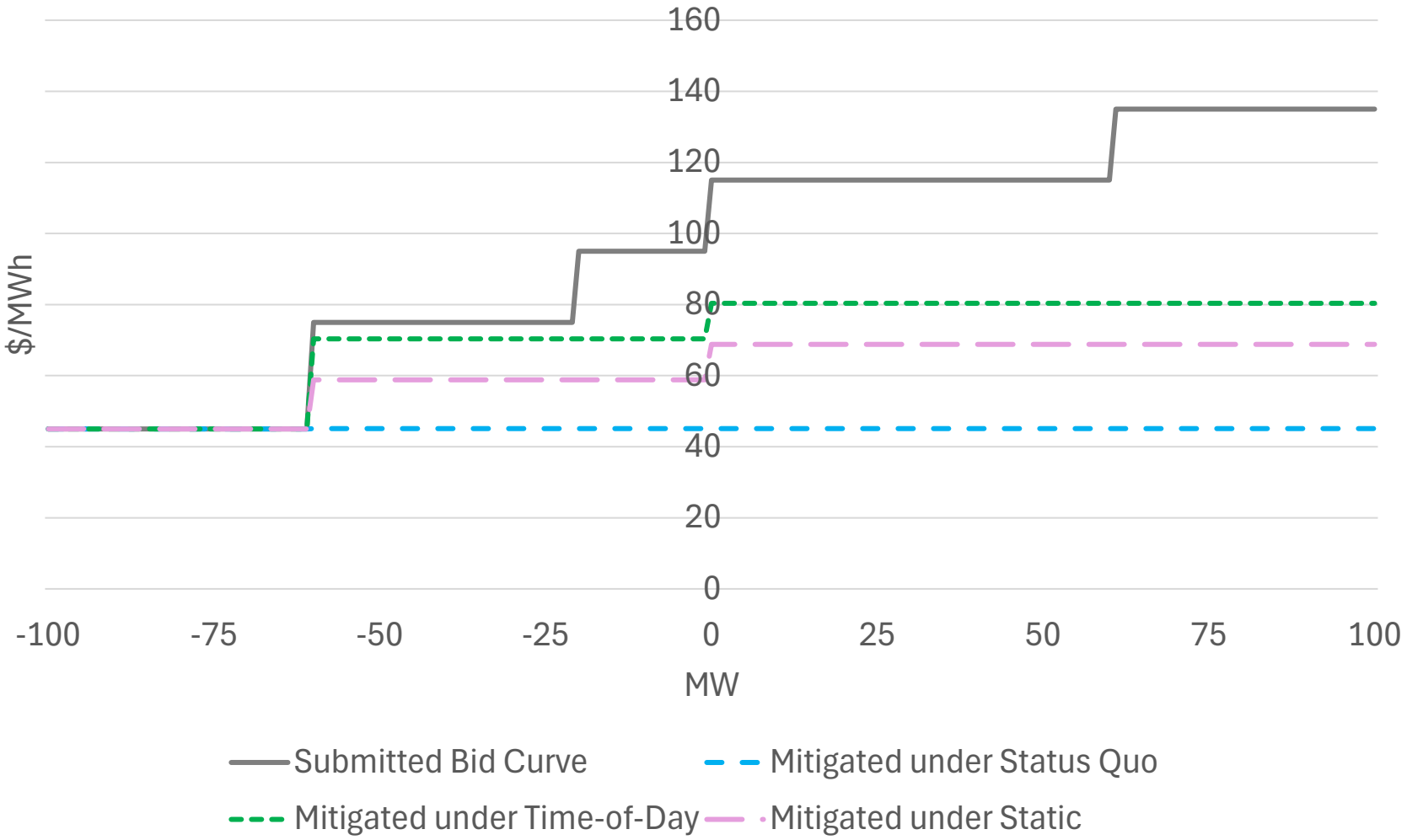
Comparison of Day-Ahead Charge and Discharge Default Energy Bids



Comparison of Real-Time Charge and Discharge Default Energy Bids



Comparison of Approaches Relative to Charging Mitigation



Currently, the ISO sees the time-of-day approach as the alternative that best addresses known default energy bid challenges while remaining practical to implement.

- Additional complexity can be minimized through automated implementation.
  - Scaling factors can automatically reflect conditions in the relevant geography using the previous three days of data, as done today in negotiated default energy bids.
  - Time-of-day multipliers can be simplified into two daily values based on the hour used to determine opportunity cost.

- Although the static approach reduces administrative complexity, it does not fully capture dynamic opportunity costs nor does it address the stale-values issue.
  - Lack of a scaling step may create inconsistencies with some existing negotiated default energy bids for WEIM-only storage resources.

Currently, the ISO sees the time-of-day approach as the alternative that best addresses known default energy bid challenges while remaining practical to implement.

- Stakeholder feedback on if and how the static approach or its elements should be considered will continue to inform the proposal.
  - Are there elements of the static approach that should be leveraged in the time-of-day approach?
  - Are there elements of the time-of-day approach that merit modification?

OPEN DISCUSSION

STRAW PROPOSAL ON HYBRID DEFAULT ENERGY BIDS

Stakeholders support development of a dedicated hybrid default energy bid methodology

- During scoping, stakeholders expressed interest in developing a hybrid default energy bid methodology, with near-term interest in leveraging existing storage frameworks

- Stakeholders generally agreed that hybrid default energy bids should reflect the characteristics of the underlying components

- Wellhead proposed setting the hybrid default energy bid as the greater of the default energy bids applicable to the hybrid resource's underlying components (Sept. 2025)
  - Multiple stakeholders supported the Wellhead proposal as a practical and straightforward near-term solution

The Greater-of approach

- The hybrid resource's default energy bid would be equal to the greater of the default energy bid values applicable to each of the components that make up that hybrid resource.

- The ISO believes a minimum share requirement would be needed for this approach
  - A component must constitute at least __% of hybrid resource installed capacity for its default energy bid value to be considered as part of the greater-of approach

  - Ex: 100 MW hybrid resource made up of 99 MW of solar and 1 MW of battery storage would use the solar default energy bid

The Largest Component approach

- The hybrid resource default energy bid would be equal to the default energy bid of its largest component.

- This approach may lead to hybrid components being positioned differently in the bid-stack compared to standalone assets of the same technology, under mitigation

Example for the bid-stack concern:

- Scenario: 100 MW hybrid resource with 60 MW of solar and 40 MW of storage.
- Because the solar component is largest, the solar default energy bid value would be used for the entire hybrid resource
- The hybrid storage component will likely have a lower default energy bid, compared to standalone storage resources
- Hybrid storage components would could be discharged prior to standalone storage resources, under mitigation

The Weighted Average approach

- The default energy bid for the entire hybrid resource would be the weighted average of its components' default energy bids

- Rationale: A hybrid resource's estimated costs is closest to a blend of its underlying components

  – While a hybrid resource's most expensive component may have higher costs in comparison to the weighted default energy bid, the hybrid resource's least expensive component technology will have lower costs in comparison to the resource's default energy bid

The Weighted Average approach

- This approach is viable but has some material drawbacks.
  - Breaks the link between true component-level costs and the default energy bid by introducing a difference relative to the original default energy bid applicable to the components.
  - Different bid-stack positioning for hybrid components in relation to standalone assets with the same costs

Illustrative Approach Comparison

Assumed values for Scenarios:

Storage DEB	$25/MWh
LMP Option	$5/MWh
Variable Cost	$35/MWh

Scenario 1: Solar + Battery

Storage MW	Solar MW	Current	1: Greater of	2: Largest Component	3: Weighted Average
20	80	NA	Storage DEB = 25	LMP Option = 5	0.2*Storage DEB + 0.8 *LMP Option = 9
40	60	NA	Storage DEB = 25	LMP Option = 5	0.4*Storage DEB + 0.6 *LMP Option = 13
80	20	NA	Storage DEB = 25	Storage DEB = 25	0.8*Storage DEB + 0.2 *LMP Option = 21

Illustrative Approach Comparison

Assumed values for Scenarios:

Storage DEB	$25/MWh
LMP Option	$5/MWh
Variable Cost	$35/MWh

Scenario 2: Battery + Thermal

Storage MW	Thermal MW	Current	1: Greater of	2: Largest Component	3: Weighted Average
20	80	NA	Variable Cost = 35	Variable Cost = 35	0.2*Storage DEB + 0.8 *Variable Cost = 33
40	60	NA	Variable Cost = 35	Variable Cost = 35	0.4*Storage DEB + 0.6 *Variable Cost = 31
80	20	NA	Variable Cost = 35	Storage DEB = 25	0.8*Storage DEB + 0.2 *Variable Cost = 27

The ISO proposes a “greater-of” approach, with a minimum share for the hybrid default energy bid

- The hybrid resource’s default energy bid would be equal to the greater of the default energy bid values applicable to each of the components that make up that hybrid resource
  - A component must be at least __% of the hybrid’s installed capacity for its default energy bid value to be considered

- The ISO seeks feedback on the percentage at which the minimum share requirement should be set.

- If all components fail the minimum share requirement, the largest component’s default energy bid would be leveraged for the hybrid resource

OPEN DISCUSSION

BREAK

OVERVIEW OF THE NGR BIDDING CONCEPT PUT FORTH BY THE MARKET SURVEILLANCE COMMITTEE

The ISO is exploring whether storage bidding could be reframed around the value of ending a market horizon with more or less energy than a reference state of charge.

- This concept builds on:
  - The ISO's end-of-hour state-of-charge framework and the 2020 Market Surveillance Committee (MSC) opinion on it.
  - Recent work by MSC member Ross Baldick.

- Objective of today's discussion
  - Explain the limitations of today's bidding framework.
  - Describe the reframed bidding paradigm for discussion.
  - Review stakeholder feedback and discuss key questions.

Why is Storage Bidding Different?

- Unlike conventional resources:
  - Energy can be stored and used later.
  - Dispatch decisions depend on current and future opportunities.
  - State-of-charge decisions create intertemporal tradeoffs.
  - The value of energy changes depending on expected future market conditions.

- As a result, storage bids must communicate not only short-term operating preferences but also the future value of stored energy.

- **Key Question** How can markets most efficiently incorporate that future value into dispatch?

How Storage Bidding Works Today

- Under the current framework, storage submits:
  - Monotonically non-decreasing bid curves.
  - Up to ten MW and $/MWh price pairs.
  - Separate charging and discharging ranges.

- The market optimizes storage based on:
  - Submitted bid curves.
  - State-of-charge constraints.
  - Efficiency assumptions.
  - Market prices within the optimization horizon.

- The bid curve communicates willingness to charge or discharge at different prices.

The Role of Bid Spreads

- When state-of-charge constraints bind, storage scheduling in the optimization horizon is often driven by the difference between the highest charging offer and the lowest discharging bid, also known as the bid spread.

- The market effectively interprets the spread as the minimum arbitrage value required for the resource to charge now and discharge later.

- The optimization seeks to:
  - Charge during lower-price intervals.
  - Discharge during higher-price intervals.
  - Preserve profitability implied by the submitted spread.

Challenges Under the Current Framework

Challenge 1: Forecasting Burden

- Storage operators must:
  - Forecast prices within the optimization horizon.
  - Predict future state-of-charge needs.
  - Construct hourly bid curves accordingly and submit them 75 minutes prior to the trade hour.

Challenge 2: Endogeneity

- Storage operators are attempting to forecast prices that are themselves influenced by the actions of other storage resources.
- This creates a circular forecasting challenge.

Challenges Under the Current Framework

Challenge 3: Variable Cost Representation

- The current framework assumes the bid spread reflects efficiency losses and cycling and variable operations costs
- However, participants may submit spreads that do not accurately represent these costs.

Challenge 4: Disconnect Between DA and RT

- The real-time bidding framework is largely independent of day-ahead energy positions.
- Storage must continually rebid throughout the day to maintain consistency between DA plans and RT operations.

The End-of-Hour SOC Parameter

- To address some of these challenges, the ISO implemented the optional End-of-Hour State-of-Charge parameter, which allows for a resource to specify a target state-of-charge range to be achieved by the end of a given real-time trade hour.
  - Market optimization attempts to achieve the specified SOC.
  - The SOC target may supersede economic outcomes.

- Advantages:
  - Direct communication of inventory preferences.
  - Reduced need for indirect bidding strategies.

- Disadvantages:
  - Bid cost recovery consequences.
  - Limited market use.

The 2020 Market Surveillance Committee Opinion

- In their 2020 opinion, the Market Surveillance Committee characterized the end-of-hour SOC framework as a **primal solution**.
  - The resource specifies a desired SOC outcome.
  - The optimization seeks to achieve it.

- The MSC suggested complementing this with a **dual approach**.

- Under the dual approach:
  - The resource specifies an economic value for stored energy.
  - The market understands the opportunity cost associated with preserving energy beyond the optimization horizon.

Ross Baldick's Ongoing Work

- MSC member Ross Baldick has developed a formulation centered on state-of-charge value.

- Rather than continuously bidding charge and discharge quantities, storage would:
  - Submit a willingness-to-pay for ending with more energy.
  - Submit a willingness-to-accept compensation for ending with less energy.

How should storage charge and discharge?

What is the value of energy remaining in storage at the end of the horizon?

Core Concept of the Reframed Bid

- The proposed framework would replace interval-by-interval bids with a terminal value bid that represents the asset's willingness to:
  - Pay for a higher end-of-horizon state of charge, or
  - Accept compensation for a lower end-of-horizon state of charge.

- The bid represents:
  - Future opportunity costs.
  - Expected value of energy beyond the optimization horizon.
  - Operator preferences regarding energy inventory.

- The market would determine the optimal charging and discharging pattern within the optimization horizon.

How Optimization Would Change

Today's Framework

- The optimization largely propagates bid spreads forward through time.
- The market asks: "What charging and discharging opportunities satisfy the submitted spread?"

Reframed Framework

- The optimization propagates terminal energy value backward through time.
- The market asks: "How valuable is energy at the end of the horizon?"
- Dispatch decisions emerge from the future energy value while respecting the asset's variable operating costs, efficiency constraints, and state-of-charge limits.

How Optimization Would Work in Different Markets

Day-Ahead Market

- Storage scheduling coordinators submit a bid/offer that represents the willingness-to-pay (or be paid) for deviating end-of-day state-of-charge from initial state-of-charge.
- This bid reflects the expectations about prices in the next trade date.
- Allows scheduling coordinators to represent their long-term operational strategy on wear, fuel substitution, and risk appetite via their bids.

Real-Time Market

- Due to the short look-ahead horizon, the real-time end-of-horizon state-of-charge is defined relative to the day-ahead state-of-charge trajectory.
- Across the real-time market, the storage resource would submit one real-time deviation bid per hour to capture its willingness-to-pay or its willingness-to-be-paid for deviating its real-time end-of-horizon state-of-charge from the day-ahead-implied state-of-charge.

Stakeholder Feedback

- Stakeholders generally recognized value in:
  - Better representation of opportunity costs.
  - Improved state-of-charge management.
  - Reduced reliance on short-term forecasting.
  - Stronger integration of DA and RT outcomes.

- There was a recognition of the value of additional discussions on this concept ahead of further development.

- Several stakeholders were interested in further discussion but expressed caution around fundamental changes.

Discussion Questions

Questions related to the reflection of storage economics

- Does a terminal-value bidding framework better communicate storage economics than the current interval-by-interval bidding paradigm?
- Does a terminal-value bid more accurately represent storage opportunity costs?
- Is this a simpler and more intuitive expression of storage economics?
- Would participants be able to estimate terminal value more effectively than hourly bid curves?

Discussion Questions

Questions related to price forecasting burden

- Would this framework meaningfully reduce the need for near-term price forecasts?
- Would it improve state-of-charge management in real-time?
- Would participants still need to implicitly forecast prices when determining the terminal value bid?

Discussion Questions

Questions related to bidding flexibility and price formation

- Are additional bid parameters necessary to preserve operational flexibility?
- Would the framework improve price signals by better reflecting opportunity costs?
- Are there circumstances where price formation could become less transparent?

Discussion Questions

Questions related to the reference state-of-charge

- Is the day-ahead SOC trajectory the appropriate real-time reference point?
- How should resources without day-ahead schedules participate?

OPEN DISCUSSION

NEXT STEPS

Next Steps and Key Dates

- **August 5th:** Comments due
- **September 2nd:** Revised Straw Proposal on Uplift & DEB and SOC Management
- **September 16th:** Hybrid meeting on Revised Straw Proposal
- Contact us at Stakeholder Affairs at ISOStakeholderaffairs@caiso.com or bmarquez@caiso.com

Please note that the dates above are tentative until the CAISO publishes a notice formally confirming them

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