Energy Storage and Distributed Energy Resources Phase 4

Final Proposal

August 21, 2020

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1 Introduction

The focus of the California Independent System Operator's (CAISO) energy storage and distributed energy resources (ESDER) initiative is to lower barriers and enhance the ability of these resources to participate in the CAISO's market.[1] The number and diversity of these resources continue to grow and represent an important part of the future grid.

The ESDER initiative is an omnibus initiative covering several related but distinct topics. This paper presents the elements included in the fourth phase of the ESDER initiative. It describes the CAISO's efforts to continuously improve and enhance its interaction and participation models for both storage and distributed energy resources in the CAISO's market.

ESDER 4 final proposal addresses the following topics:

1. State-of-charge biddable parameter for storage resources;
2. Streamlining market participation agreements for non-generator resource participants;
3. Applying market power mitigation to storage resources;
4. Maximum daily run time parameter for demand response; and
5. Vetting qualification and operational processes for variable-output demand response resources

While there have been no changes made to the proposals for the above listed topics 2, 3 and 4, this final proposal includes changes to the end-of-hour state-of-charge biddable parameter proposal included in topic 1 and removal of an end-of-day state-of-charge that was discussed within the initiative but not included in this final proposal paper. Updates includes detail on the market application of the end-of-hour state-of-charge clarifying when it is recognized within the short term unit commitment (STUC) process and clarification of how its use by a resource may have an impact to its resource adequacy valuation. Additionally, another simplified example of the bid-cost-recovery proposed settlement is provided. .

Topic 5, has been included as an informative discussion of a new method in determining a qualifying capacity value for variable-output demand response resources. The material within this section has been updated in referencing results of the study performed by Energy and Environmental Economics, Inc. (E3) in developing an analytical framework for evaluating a resource adequacy value of demand response using an effective load carrying capability (ELCC). These results, including a proposal for allocation of ELCC to different demand response programs, was presented and discussed on the May 27, 2020 stakeholder call. Stakeholders have reviewed the study results and provided feedback that is highlighted and discussed within this topics

[1] DERs are those resources on the distribution system on either the utility side or the customer side of the end-use customer meter, including rooftop solar, energy storage, plug-in electric vehicles, and demand response.

section in order to be transparent as to stakeholder actions taken subsequent to the review of the study results, when taken into consideration in a re-running of the study, might impact those results. The final paper reiterates the intent of the results to be used as a means to inform stakeholders, including Local Regulatory Authorities, on how demand response should be valued with consideration of its variable and energy-limited nature.

2 State-of-Charge Parameters

The CAISO introduced the non-generator resource model in 2012 to enable wholesale market participation of energy storage resources. Although the CAISO believes the non-generator resource model effectively integrates storage resources today, the increasing number of storage devices participating in the wholesale market warrants further investigation of the model to ensure the CAISO is using these unique resources optimally to meet the reliability needs of the grid.

Stakeholders have expressed a desire to more effectively manage their storage resource’s state-of-charge in the real-time market to meet day-ahead schedules or other obligations that may be present outside of the real-time market optimization window later in the day. Stakeholders recognize that while the day-ahead market optimizes the resource across the entire operating day, when participating in the real-time market the resource will receive dispatches based on system supply/demand conditions and prices available in a shorter optimization horizon. This could result in a deviation of the storage resources state-of-charge derived to meet their day-ahead schedules. For instance, based on the resource’s bids, the real-time market may find that it is most economic, over the short-term, to leave a storage resource fully discharged early in the day making it incapable of meeting its obligation to deliver on a day-ahead award later in the day.

Currently, self-schedules can be utilized to help manage the state-of-charge to meet these obligations, however, effective use of them to achieve a desired state-of-charge is difficult due to lag between market execution and bid submission deadlines. Additionally, use of self-schedules limits the CAISO’s ability to flexibly dispatch the resource throughout the operating hour it self-schedules. A more effective means for management of state-of-charge in real-time while allowing for greater flexibility of its use is needed.

2.1 End-Of-Hour State-Of-Charge Bid Parameter

2.1.1 Stakeholder Comments

The comments the CAISO received on the Draft Final Proposal were generally supportive of an optional end-of-hour state-of-charge parameter to help resources manage their state-of-charge in real time. Stakeholders were supportive of designing the parameter to include a minimum and maximum state-of-charge target for the end of the specified operating hour, and that the market optimization would respect the state-of-charge needed to meet an ancillary service award, which we detail below in section

2.1.2. In response to stakeholder comments to the 2nd revised straw proposal, the draft final proposal provided clarification on how this parameter might impact RA resources under the current paradigm and instructed participants to follow the Resource Adequacy Enhancement Initiative to give input on how this parameter might affect resources in the future under the new UCAP paradigm. Boston Energy, CESA, EDF-Renewables, LS Power were unsupportive of this clarification, and felt that this parameter would no longer be useful to the RA fleet of batteries. However, under the RAE initiative, the CAISO is developing additional tools to ensure that RA resources can meet their day ahead awards (although they will still have the freedom to utilize the EOH SOC on top of the minimum charge requirement). The EOH SOC parameter was originally intended to help storage resources manage their state-of-charge to meet other obligations (such as serving as a transmission asset, etc.), and so in the final proposal the CAISO maintains its position that the EOH SOC parameter should not conflict with a storage resource's must offer obligation.

Given the timing discrepancies between when the RTPD and RTD see the end-of-hour constraints, several stakeholders asked for further examples of how this parameter would be used in the optimization, which are provide below. Additionally, in response to questions around how and when STUC would see the EOH SOC target that arouse during the Market Surveillance Committee Meeting on July 30th, we provide details on our proposal to release EOH SOC bid information to STUC once real time bidding closes.

Finally, the CAISO received generally supportive feedback on its Real Time Market Bid-Cost Recovery proposal to exclude revenue shortfalls in the hour and hour prior to the EOH SOC target or self-schedules from the daily BCR settlement. CESA asked for clarity around how this proposal would interact with AS awards and regulation, and the CAISO clarifies below that this proposal only applies to the energy award components of the daily BCR settlement, and AS bid cost recovery would remain unchanged. While CESA and the CPUC expressed concerns that this new approach may lead to under recovery of some bid costs, the CAISO thinks this approach addresses the gaming opportunities brought up in previous comments from the CPUC and DMM. The CAISO will continue to monitor once this policy is implemented and may refine if under-recovery becomes a significant problem in the future.

2.1.2 Proposal

The CAISO proposes to allow scheduling coordinators to submit end-of-hour state-of-charge parameters for storage resources in the real-time market to manage use throughout the day.[2] Scheduling coordinators will be able to submit an end-of-hour state-of-charge MWh value with their bids in the real-time market. In addition, the scheduling coordinator can represent the end-of-hour state-of-charge parameter as a minimum and maximum MWh range.

Scheduling coordinators are able to update their real-time bids at any point after the day-ahead market and up until the relevant real-time market closes. The market will

[2] End-of-hour state-of-charge parameter will not apply to storage resources electing to provide regulation using the regulation energy management (REM) functionality.

use the submitted end-of-hour state-of-charge when the real-time market's optimization horizon reaches the end of the respective hour. The CAISO will not extend the end-of-hour state-of-charge bid into the following day-ahead market. A scheduling coordinator will be responsible for submitting an initial state-of-charge that ensures feasible market scheduling of the resource in that following day-ahead market.[3] The scheduling coordinator will submit an end-of-hour state-of-charge to reflect a minimum and maximum range. If the scheduling coordinator desires a target state-of-charge, then the minimum and maximum state-of-charge values should be set the same.

The end-of-hour state-of-charge bid parameter will work in conjunction with the existing Master File and scheduling infrastructure business rules (SIBR) minimum and maximum energy limits. However, instead of ensuring that resources receive an economic dispatch within the Master File or bid-in energy limits, the proposal will allow the market to dispatch storage resources economically or uneconomically to achieve the scheduling coordinator's preferred hourly end-of-hour state-of-charge when specified to the CAISO. Any end-of-hour state-of-charge will take precedence over economic outcomes in the market optimization.

The real-time market will respect all resource constraints when determining a storage resource's optimal dispatch. The hourly end-of-hour state-of-charge parameter adds additional constraints to the market optimization. The real-time market will respect modeled resource constraints, including the end-of-hour state-of-charge.

<u>Upper and lower state-of-charge constrained</u>

The real-time market will respect a storage resource's upper and lower state-of-charge values stored in Masterfile (or bid in). Consequently, the market optimization will not be able to achieve the hourly end-of-hour state-of-charge values if they fall outside the resource's defined or bid-in upper and lower state-of-charge values.[4] For instance, as shown in

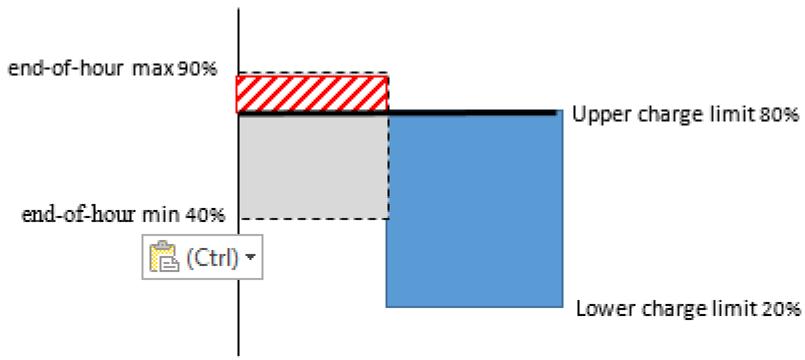
Figure 1, if a scheduling coordinator submits an end-of-hour state-of-charge of 90% for a resource with an upper state-of-charge maximum of 80%, the market will consider the

[3] Day ahead market bids are submitted 14 hours before the start of the day and real-time market bids for the last hour of the day must be submitted 2 hours and 15 minutes before.

[4] The market may also not be able to achieve the submitted end-of-hour state-of-charge targets due to time limits. For instance, if a 4 hour battery submits is at 0% SOC and submits an EOH SOC for 100% 75 minutes prior to the end of the hour, there is not enough time for the market to charge the resource up to this value.

submitted end-of-hour state-of-charge to be 80%, not 90%. A 90% end-of-hour state-of-charge would be infeasible based on the resource's modeled parameter.

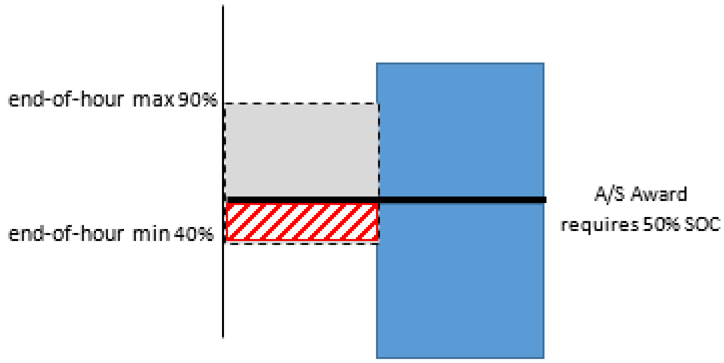
Figure 1: End-of- hour state-of-charge constrained by upper and lower charge limits



<u>Ancillary service award constrained</u>

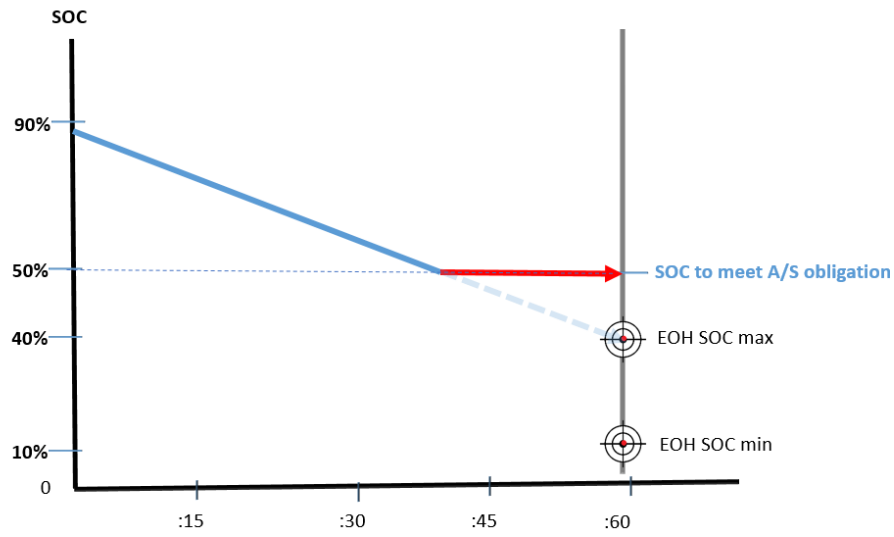
The market will respect ancillary services awards when a scheduling coordinator provides end-of-hour state-of-charge values that are not feasible. The market will maintain a state-of-charge if the resource is providing ancillary services such that the resource can provide the full awarded MW amount over a 30-minute period. As illustrated in Figure 2 below, if a scheduling coordinator were to submit an end-of-hour state-of-charge of maximum of 90% and minimum of 40%, but the resource's ancillary service awards require a 50% state-of-charge, to ensure the ancillary service's award can be met, the market will maintain the 50% state-of-charge.

Figure 2: End-of-hour state-of-charge constrained by ancillary service award



When a storage resource is providing energy simultaneously with ancillary services, the market cannot guarantee meeting a targeted end-of-hour state-of-charge range. For resources providing regulation services, this is due to an independent management of awarded regulation and energy services between the Automatic Generation Control (AGC) system and the real time energy market. This is also true for resources awarded spin and non-spin capacity as, depending on system needs, the capacity could be converted to energy until the end of the hour impacting the resources trajectory to a state-of-charge position. Although the market will attempt to move the resource to the targeted end-of-hour state-of-charge, the actual state of charge could fluctuate above or below targets due to response from ancillary service instructions. Therefore, in hours where the resource receives simultaneous ancillary service and energy awards, there is no guarantee that the resource's end-of-hour state-of-charge will be met. Some stakeholder comments in earlier drafts of this policy suggested that the CAISO prohibit an end-of-day state-of-charge bid in hours the resource has received a day ahead ancillary service award. Since the market will prioritize meeting the ancillary service award over the end-of-hour state-of-charge, the CAISO does not see the need to put a blanket prohibition on use of this parameter when the resource also has an ancillary service award. But rather scheduling coordinators should be aware that the market may not meet the end-of-hour state-of-charge if it conflicts with the ancillary service award. As illustrated in Figure 3 below, to meet an Ancillary Service award requires a 50% state-of-charge. That same hour, the resource also has a minimum 10% to maximum 40% end-of-hour state of charge parameter submitted. While the market may track to the minimum 10% or maximum 40% it would be constrained by what was needed to meet the ancillary service obligation until the end-of-hour.

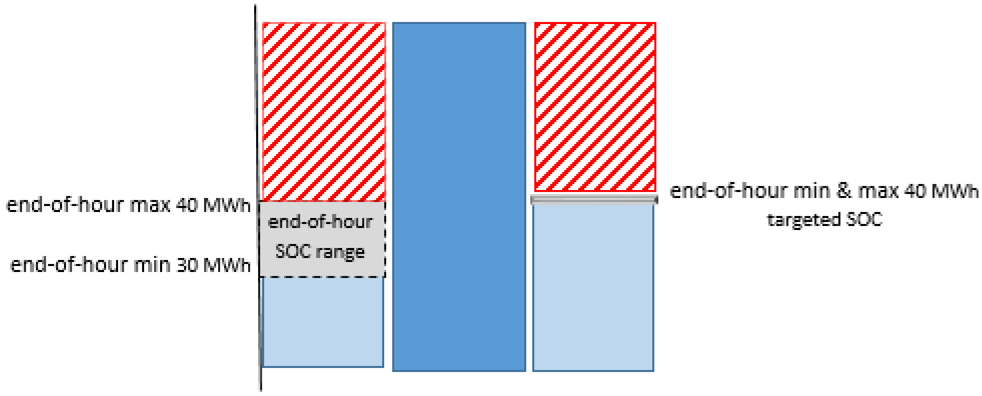
Figure 3: Impact of Ancillary Service award to an end-of-hour state-of-charge



<u>Range in state-of-charge bid</u>

While we have so far discussed the end-of-hour state-of-charge parameter in terms of percentages, the actual parameter will be inputted in terms of MWhs. The scheduling coordinator will submit the end-of-hour state-of-charge parameter as a minimum and maximum MWh range. For example, in Figure 4, if a scheduling coordinator wants to meet a specific state-of-charge of 40 MWh, it will submit a minimum value of 40 MWh and maximum value of 40 MWh. The market will optimize the storage resource to meet the targeted value. If a scheduling coordinator needs a resource to have a minimum state-of-charge of 30 MWh regardless of market prices and a desire to charge up to 40 MWh if it is economic, the bid will represent a range of 30-40 MWh. Dispatches up to the minimum value of 30 MWh may or may not be economic for the resource. If market prices are economic for the resource in the 30-40 MWh range, the market will dispatch the storage resource up to a value within the range of 30-40 MWh. Consistent with Section 6.5.6.1.1 of the CAISO tariff, the CAISO will publish storage resource hourly end-of-hour state-of-charge bid information on OASIS 90 days after the trade day.

Figure 4: End-of-hour state-of-charge bid range



<u>Resource Adequacy</u>

Stakeholders have asked how using this parameter may impact resources with a must-offer obligation. The expectation set out in BPM for Reliability Requirements Section 7.1.1 states that a non-generating resource (non-REM) must submit "economic bids or self-schedules… for any remaining RA Capacity from resources scheduled in IFM or RUC," and "for all RA Capacity not scheduled in IFM".[5] A scheduling coordinator should not submit an end-of-hour state-of-charge parameter that is below the resource's must offer obligation, or use it to withhold additional RA Capacity not scheduled in the IFM or RUC.[6] The Department of Market Monitoring will continue to monitor for such abuse or gaming behavior, and the CAISO may develop additional compliance and incentive mechanisms in future policy initiatives to address these identified issues.

Additionally, the CAISO is proposing significant changes to its Resource Adequacy program in the Resource Adequacy Enhancements Initiative.[7] Under this initiative, the CAISO is moving towards a new unforced capacity valuation methodology (UCAP) which takes into account a resource's derates and forced outages when determining its capacity value. It is likely that as the CAISO moves towards this UCAP paradigm for Resource Adequacy (RA) it may consider treating self-schedules and end-of-hour state-of-charge parameters that fall below the resources contracted value as a reduction in availability of the resource. This may be treated as a derate when UCAP values are calculated, which will decrease the capacity value of that resources. The specifics of this policy will be discussed in the Resource Adequacy Enhancements Initiative, along with any other changes to a resource's must offer obligation, and interested parties should engage with this stakeholder process.

<u>Market application of the end-of-hour state-of-charge bid</u>

The more limited look-out horizon in RTED may impact a resources ability to achieve its target end-of-hour state-of-charge. Below we detail how we are proposing to align visibility between FMM and RTED to help ensure that the end-of-hour state-of-charge

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[5] See page 83 in BPM for Reliability Requirements https://bpmcm.caiso.com/BPM%20Document%20Library/Reliability%20Requirements/BPM%20for%20Reliability%20Requirements%20Version%2048.docx

[6] For additional information on this, see ISO Tariff Sections 40.6.2; 20.6.4; 40.6.5.1

[7] Resource Adequacy Enhancement Initiative http://www.caiso.com/StakeholderProcesses/Resource-adequacy-enhancements

target will be met. Like other hourly real-time bidding parameters, the end-of-hour state-of-charge minimum and maximum parameters are submitted to the market 75 minutes prior to the start of the hour. Once received these values will be used to inform dispatch instructions for resources in the successive STUC runs, 15-minute market (FMM) intervals, and the corresponding 5-minute real time economic dispatch (RTED) intervals.

While the Short-term Unit Commitment (STUC) market runs have no influence on energy storage resources, the EOH SOC bids could still influence the decision to commit (or not) additional medium-start units. Since real-time bids can be submitted and changed from the close of the day ahead market to T-75 minutes prior to the start of the hour, to prevent any potential gaming opportunities, the CAISO will only release the EOH SOC bids from SIBR to STUC once the real-time market closes for that interval. Next, we provide details and examples of how the EOH SOC would be treated in the FMM and RTED.

For example, a 40 MWh resource with a -10 MW Pmin and 10 MW Pmax may submit a minimum end-of-hour state-of-charge parameter of 30 MWh (75%) applicable for hour ending 10.[8] Bids for hour-ending 10 (the period 09:00-10:00) are due at 07:45, or 75 minutes prior to 09:00. At 07:50 one of the market runs for the real-time unit commitment (RTUC) process begins, which generates binding market instructions for the FMM interval, from 08:30-08:45, and advisory instructions for the five successive intervals from 08:45-10:00. Because this is the first RTUC market run to observe the end-of-hour state-of-charge bid submitted, effective for hour-ending 10, the value will be considered in this market run. If the resource has a 10 MWh (25%) initial state-of-charge in this run, the resource will be scheduled to fully charge in all binding and advisory intervals, assuming that all intervals of charging are required based on its resource characteristics to meet the state of charge of at least 75% by hour-ending 10.

The RTED market is different. This market runs 7.5 minutes prior to the start of a specific 5-minute interval and looks out up to 65 minutes, which represents one binding and up to 12 advisory 5-minute intervals. At 08:07:30, one of the market runs for the RTED process begins, which generates binding market instructions for the interval from 08:15-08:20, and advisory instructions for the 12 successive intervals from 08:20-09:20. This is the first RTED market run to receive and optimize bids applicable to hour ending (HE) 10, however the run will not take the end-of-hour state-of-charge parameter into consideration because the last interval of that run does not end at the last interval of HE 10. The first RTED run that will take the end-of-hour state-of-charge parameter into consideration is the run for the binding interval 09:05-09:10, with 10 advisory intervals from 09:10-10:00. Because the RTED runs for binding intervals 08:30-09:05 do not consider the end-of-of hour state-of-charge parameter, there may be a sub-optimal situation where those RTED runs could undo what was planned by the RTUC/FMM, by not dispatching to charge the resource until it is too late to meet the end-of-hour SOC targets.

The CAISO proposes to align visibility of the end-of hour state-of-charge bid parameters to the same binding intervals for both RTED and RTUC/FMM. Specifically, the CAISO

[8] In these examples, the resource also submits a maximum end-of-hour SOC of 35 MWh (87.5%), which does not come into play. Batteries are fast ramping resources; this example assumes an infinite ramp. For simplicity, it is assumed that the charging efficiency of the battery is 1.0.

will apply an implied end-of-hour constraint at the end-of-time horizon for RTED runs for binding intervals starting 08:30 to 09:00. This end-of-horizon constraint will be set to the end-of-hour constraint, adjusted for the resource's charging activity for intervals beyond the RTED time horizon as determined by the latest RTUC advisory instructions for that period.

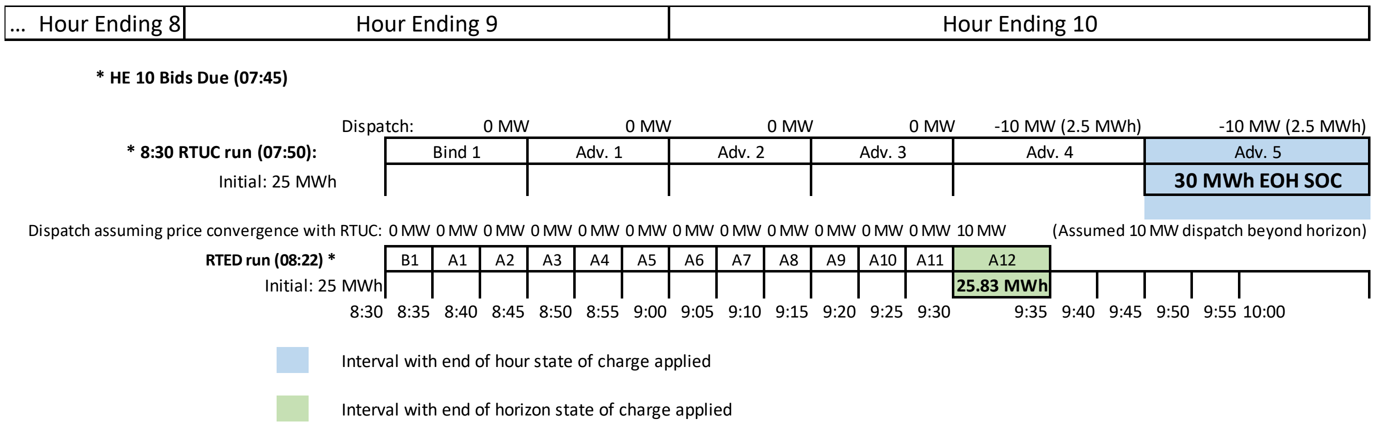
For the purposes of the following two examples, we will modify the previous example slightly. Suppose the 40 MWh resource has a 25 MWh (62.5%) initial SOC for the RTUC 08:30 run, and must get to at least 30 MWh (75%) by the end of hour 10, thus an additional five MWh of charging is required.[9] In this same example, the initial state-of-charge for the RTED 08:30 run is also 25 MWh. Suppose the resource is not economic to charge in the any of the binding or advisory intervals of the RTPD and RTED runs.

<u>RTED end of horizon example 1:</u>

For the RTUC, the most economic prices to meet this target are for the last two intervals of the horizon, 09:30-09:45 and 09:45-10:00, so the resource will be scheduled at -10 MW for the 09:30 and 09:45 advisory intervals. When creating an end of horizon constraint for the RTED 08:30 run for which the horizon ends at 09:35, it is assumed that the RTED results will be following RTUC, thus there will be 4.17 MWh of charging for the intervals 09:35-10:00 that are beyond the optimization time horizon.[10] The end-of-horizon constraint for RTED thus becomes 30 MWh – 4.17 MWh, or 25.83 MWh. Assuming prices between RTUC and RTED are converging, the incremental 0.83 MWh of charging will be dispatched in the interval 09:30-09:35.[11]

Figure 5: RTED end of horizon example 1

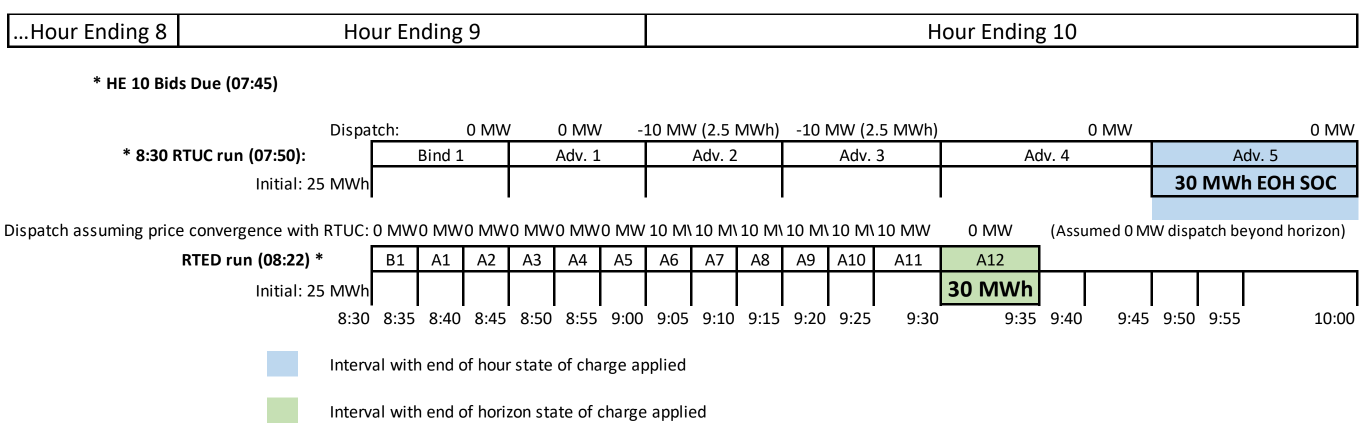
[9] This requires two 15-minute intervals of full charging (-10 MW * ½ hour = five MWh.)
[10] 10 MW * 25 minutes * (1 hour / 60 minutes) = 4.17 MWh.
[11] -10 MW * 5 minutes * (1 hour / 60 minutes) = 0.83 MWh.



RTED end of horizon example 2:

For the RTUC, the most economic prices to meet the target are for the two intervals of the horizon, 09:00-09:15 and 09:15-09:30, so the resource will be scheduled at -10 MW for the 09:00 and 09:15 advisory intervals. When creating an end-of-horizon constraint for the RTED 08:30 run for which the horizon ends at 09:35, it is assumed that the RTED results will follow RTUC, thus there will be no charging for the intervals 09:35-10:00 that are beyond the optimization time horizon. The end of horizon constraint for RTED thus becomes 30 MWh. Assuming prices between RTUC and RTED are converging, the five MWh of charging will be picked up in the intervals 09:00-09:30[12].

Figure 6: RTED end of horizon example 2



Non-generator resource real time market bid-cost recovery rule changes

The CAISO will modify a non-generator resource's real time market bid cost recovery (BCR) settlement in hours when an end-of-hour state-of-charge bid parameter or self-

[12] Although the inputs to both real-time markets are the same, the two markets can lead to different results, and prices may not always converge.

schedule has the potential to create an uneconomic dispatch[13]. If the CAISO must dispatch a resource uneconomically to meet a non-generator resource's optional end-of-hour state-of-charge bid, or to maintain a state-of-charge necessary to meet a self-schedule, it is doing so to meet the scheduling coordinator's strict requirement regardless of market prices. The CAISO believes, and stakeholder comments support, that the resource should bear the associated costs of this movement rather than require the CAISO to uplift the costs to aggregate demand.

Therefore, a non-generator resource will be ineligible to receive BCR for an hour with an end-of-hour state-of-charge bid. The CAISO also proposes to extend ineligibility of bid-cost recovery for the hour preceding the hour when a scheduling coordinator submits an end-of-hour state-of-charge. This additional hour of ineligibility addresses comments received on the revised straw proposal from DMM that demonstrated that the impact of the parameter on the market extends beyond the single hour.[14] The CAISO in its development of the optional end-of-hour state-of-charge bid parameter recognized that today non-generator resources can self-schedule and receive BCR even though the market must optimize around the self-schedules. Therefore, a self-scheduled non-generator energy storage resource also will be ineligible for BCR in the hour preceding the self-schedule[15].

Because BCR is a daily settlement, the CPUC and DMM believe there could be scenarios where a resource could be overpaid BCR if both revenue shortfalls and surpluses generated in these hours are excluded. For instance, excluding revenue shortfalls generated during this period could lead to overpaying BCR to resources for dispatches that occurred outside of end-of-hour state-of-charge hours.[16] In response, the CAISO is modifying its proposal so that it will only exclude revenue shortfalls generated in the hour and hour prior to the end-of-hour state-of-charge parameter. It will similarly, only exclude revenue shortfalls generated in the hour prior to a self-schedule.

The CAISO will identify the hour prior to a self-schedule or the two hours in which the end-of-hour state-of-charge parameter is prioritized over economic dispatches in the market. Next it will assess the bid costs vs revenue generated in each 5 minute interval within this two-hour period. For each RTD interval, if energy bid costs are greater than revenue, this interval will be set to 0 in the daily BCR settlement. If energy bid cost are less than revenue, then there will be no change in this interval, and these revenue surpluses will be included in the daily settlement and could be used to cover shortfalls that may have been generated in other periods in the day. The CAISO is not proposing

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[13] Because the EOH SOC parameter only influences real-time market dispatches, this proposal to modify BCR settlement only applies to the real time market settlement, and the CAISO is not proposing any changes to the day ahead market bid cost recovery settlement.

[14] CAISO DMM's comments to ESDER 4 Revised Straw Proposal (page 7) http://www.caiso.com/InitiativeDocuments/DMMComments-EnergyStorage-DistributedEnergyResourcesPhase4-RevisedStrawProposal.pdf

[15] BCR proposal will only apply to NGR resources classified as LESR (energy storage technologies), and will not apply to other resource types who utilize the NGR model.

[16] For example scenario see CPUC comments to ESDER 4 2nd Revised Straw Proposal (page 2) http://www.caiso.com/InitiativeDocuments/CPUCComments-EnergyStorage-DistributedEnergyResourcesPhase4-SecondRevisedStrawProposal.pdf

any changes to the ancillary service award components of the real time market BCR settlement.

Figure 7 below, provides an example of how this calculation would work. Suppose we have a 25 MW four-hour duration battery (100 MWhs), that submits a 50 MWh end-of-hour state-of-charge target for HE14, and a 20 MWh end-of-hour state-of-charge target for HE 20. Its bid range is $0 to charge, and $10 to discharge. The resource will be ineligible to receive BCR in HE13-14 and HE19-20. In RTD intervals 164-168, we can see an example of how the market may dispatch the resource to charge to meet it EOH SOC. In intervals 164 and 168, the market dispatched the resource to charge even though prices were $6 and $5 dollars above its bid price. Because these intervals fall within the BCR ineligibility period, they will be set to 0 in the daily settlement. In RTD intervals 235-240, we can see an example of how the market would dispatch the resource to discharge to meet the 20 MWh end-of-hour state-of-charge. In intervals 235 and 236, the market dispatch the resource to discharge 1 MWh for $5, even though this was below their bid price was $10. The resulting $5 difference in each interval would be set to zero and excluded from the daily BCR settlement. In interval 238-240, the resource was dispatched to discharge 1 MWh for $15. The resulting $5 surplus in each interval would be included in the daily BCR settlement and could be used to cover potential shortfall in other hours without the end-of-hour state-of-charge parameter.

If we assume revenue neutrality in the subsequent intervals not shown in Figure 7, the resource had a Daily Bid Cost of $61 and Daily Revenue of $56.[17] Normally, the resource would have received a payment for $5 to cover this shortfall. However, under this new proposal we would now set intervals 164, 168, 235, and 236 to zero because bids exceeded the market prices, which effectively removes $21 in BCR shortfall from the daily BCR calculation. The new daily settlement would result in Daily Bid Cost $40 and Daily Revenue of $56, thus there would be no BCR shortfall payment issued to this resource. In intervals 165, 166, 238-240, since bids are below market prices, the $16 in excess revenues generated during these intervals would be included in the daily BCR settlement, and would offset shortfalls in other intervals of the day should they occur. Some stakeholders are concerned that this approach may lead to under recovery of bid costs, therefore upon implementation, the CAISO will monitor for its frequency of occurrence reserving the right to refine the approach further if under-recovery emerges as a significant problem.

Figure 7: EOH SOC Bid Cost Recovery sample settlement

[17] This example also assumes that the battery performs as expected, therefore Persistent Deviation and Performance Metrics do not apply.

5M Interval	164	165	166	167	168	~	235	236	237	238	239	240
EOH SOC target					50							20
SOC	46	48	49	49	50	~	25	24	23	22	21	20
Dispatch (MWh)	-1	-1	-1	0	-1	~	1	1	0	1	1	1
Bid (Chg)	0	0	0	0	0	~	-	-	-	-	-	-
Bid (Gen)	-	-	-	-	-	~	10	10	10	10	10	10
Price	6	-1	0	1	5	~	5	5	5	15	15	15
BCR Eligibility	N	N	N	N	N	~	N	N	N	N	N	N
Cost	6	0	0	-	5	~	10	10	-	10	10	10
Revenue	0	1	0	-	0	~	5	5	-	15	15	15
Included in BCR settlement[18]	0	1	0	-	0		0	0	-	5	5	5
BCR Impacted	Y	N	N	N	Y	~	Y	Y	N	N	N	N

Exceptional Dispatch

In earlier comments, DMM asked for clarification on how exceptional dispatches and the end-of-hour state-of-charge parameter would be treated by the market. The market would prioritize meeting the exceptional dispatch instruction and could not ensure that the submitted end-of-hour state-of-charge target would be meet. Additionally, an exceptional dispatch would override the exclusion of this period from the BCR calculation, allowing the resource to be eligible for bid cost recovery, regardless of any submitted state-of-charge target or self-schedule in prior intervals.

2.2 Self-Schedule Enhancement

In reviewing the non-generating model, the CAISO discovered an issue in the real-time market that may prevent a resource from achieving its full self-schedule, and wanted to inform stakeholders of a market enhancement that will be implemented to address this issue. The limited look-ahead horizon in the RTD market may discharge a resource to the point that it cannot meet a self-schedule in the consecutive hour. CAISO has identified the need for a new real-time market constraint to preserve a minimum state-of-charge to meet the submitted self-schedule.

[18]For illustrative purposes, positive signs indicate revenue surplus

To illustrate how this enhancement would operate the CAISO provides the following example. This example demonstrates how the CAISO's new market enhancement will be applied to a hypothetical storage resource that submits a self-schedule to discharge energy during a particular hour.

This example illustrates outcomes in the RTD market if a resource submits a self-schedule to discharge, suppose at 12 MW, during a specific hour of the day, suppose HE 10. For this example, the current construct of the RTD market will not ensure that the resource has a sufficient state of charge to meet the self-schedule, while running for binding intervals during HE 09. When the RTD market runs for the binding 08:25 interval, it will include dispatch instructions to accommodate the self-schedule for each advisory interval between 09:00 and 09:30 for 12 MW, or for a total discharge of 6 MWh during intervals in HE 10. Further, this RTD run will attempt to ensure that 6 MWh of energy is in the storage resource by scheduling the resource to charge, if needed, during the intervals considered in HE 09.

When the RTD market runs for the 08:30 binding interval, it will now observe a need to discharge 7 MWh of energy to meet the self-schedule in HE 10, because the advisory intervals now extends through 09:35. If the previous run of the RTD market only scheduled to have 6 MWh stored in the resource by 09:00, it may be impossible for the 08:30 binding RTD run to ensure that 7 MWh of energy is stored by 09:00. This problem becomes more challenging as the RTD market moves closer to the binding run for 08:55.

The new enhancement to the non-generating resource model applies a constraint on the ending advisory period in RTD market that would preserve the minimum state-of-charge necessary to meet the full self-schedule. In this example, the new enhancement sets a minimum state of charge at 6 MWh for the 09:30 advisory interval, for the 08:25 RTD binding market run. This ensures that the resource is able to meet the full self-schedule in the successive hour. This enhancement places a minimum charge of 5 MWh on the 09:35 advisory interval during the successive 08:30 RTD binding market run. This enhancement would only impact binding RTD market runs during the hour prior to a self-schedule. This enhancement would be applied in a similar way to ensure that storage resources could meet self-schedules to discharge energy.

3 Non-Generator Resource Market Participation Agreements

Non-generator resources currently must execute the participating generator agreement and participating load agreement to participate in the CAISO markets. To reduce administrative burden and improve efficiency, the CAISO is proposing that non-generator resources will participate in the CAISO market solely under the participating generator agreement. Only non-generator resources acting as dispatchable demand response will execute the participating load agreement (and not a participating generator agreement). These modifications will not affect the current treatment of non-generator resource and dispatchable demand response in any CAISO market systems. Non-generator resources that have already executed participating generator agreements and participating load agreements will not be required to execute new agreements or terminate existing agreements.

4 Market Power Mitigation for Storage Resources

To ensure that wholesale prices are just and reasonable, the CAISO and other organized markets have mitigation measures to minimize the exercise of market power and non-competitive outcomes.[19] The CAISO employs a tool called local market power mitigation (LMPM), which replaces market bids with marginal cost based default energy bids (DEBs) when it detects potential market power. The local market power mitigation tool helps to ensure that market prices are economic in uncompetitive situations. With the implementation of this proposal storage resources will be subject to local market power mitigation. They will also have a new option for default energy bids specifically designed for storage resources.

Today, there are about 150 MWs of grid-connected storage resources installed on the system. None are currently subject to market power mitigation. This number does not include behind the meter storage resources installed in households or businesses that participate under state or local tariffs. However, there are over 48,000 MW of storage generation in the CAISO interconnection queue, some of which will be developed and deployed on the system within the next few years.[20] The CAISO believes that it is important to develop mitigation measures to manage potential market power of energy storage resources.

Storage resources can be versatile and have various opportunities to earn potential revenues in the CAISO day-ahead and real-time market. Some of these opportunities include arbitraging energy market prices and potentially moving large amounts of energy from low priced periods to high priced periods in the day to help with renewable integration. These resources are also generally flexible and have fast ramping capabilities to offer ancillary services to the market. Balancing potential revenue streams, in addition to potential fixed payments through the resource adequacy framework, can be challenging for certain storage resource types given their cost structure.

Prices in the day-ahead and the real-time markets generally follow predictable patterns that mirror net load.[21] The net load usually correlates with lower prices in the later morning hours, after solar generation comes online, followed by higher prices in the evening, after solar generation goes offline. In the spring, storage resources have the ability to buy energy when prices are lowest early in the morning, sell during the morning ramp, buy energy again when solar is fully online, and sell during the peak net load hours when prices are highest. Figure 8 below illustrates sample load and net load curves for a day in March. This chart shows that a resource could purchase energy during the lowest net load periods of the day (orange highlight) and sell during the highest net load periods of the day (green highlights). This specific day also shows that there could be an opportunity for this resource to charge prior to the morning peak, during hours ending 3 to 5 (not highlighted).

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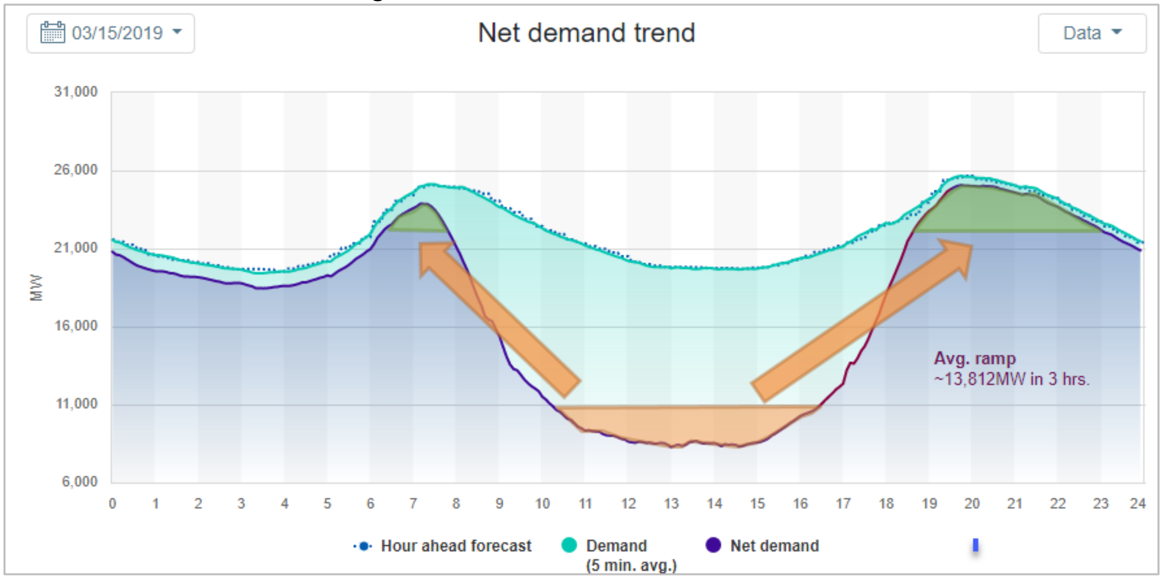
[19] For example, a generator may have the ability to exercise market power when supplying energy within a transmission-constrained area if it is a pivotal supplier.

[20] Currently the CAISO's interconnection queue (up to cluster 12) includes over 230 projects both stand alone and hybrid energy storage totaling up to 48,559 MW.

[21] Net load is gross load less solar and wind generation.

Figure 8: Net load on March 15, 2019



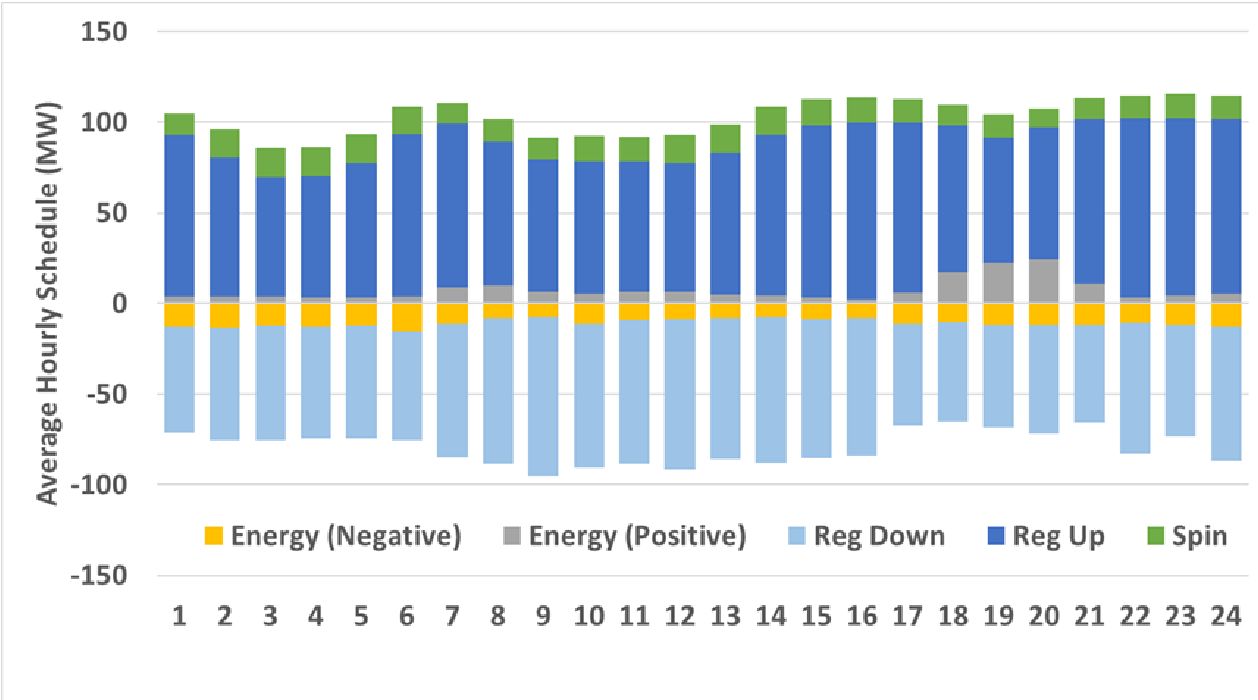
In the real-time market, storage resources also may have the opportunity to respond to short-term price spikes in low supply or oversupply conditions. In low supply conditions, the market often conveys high system marginal costs, which can be up to a $1,000/MWh penalty price for the power balance constraint. Conversely, in oversupply conditions, market prices can drop as low as -$150/MWh as a penalty price for the power balance constraint. Because storage resources have the ability to ramp quickly, they are well suited to take advantage of these prices in the real-time market.

Resources are able to collect revenue for providing ancillary services, such as regulation, by responding to automatic generation control signals in the market. Revenues from providing ancillary services to the market may be lower than revenues earned in the energy market, but generally come with awards that require the resource to provide less energy overall. This is advantageous for storage resources that have to purchase energy from the grid, encounter efficiency losses on energy purchased, and will eventually require maintenance because of charging and discharging.

As stated earlier, the CAISO operates about 150 MWs of storage resources today. Nearly all participate as resource adequacy capacity. These resources receive compensation for their capacity, which make up a large component of the resource's total revenues. Although energy storage participates in the day-ahead and real-time markets, a majority of the 150 MWs sell very little energy into the system.

Figure 9 illustrates that most of the capacity for energy storage clears in the ancillary service market to provide regulation.

Figure 9: Average hourly schedules for storage resources (July-Dec 2019)



The data shown in Figure 9 supports the CAISO's assertion that energy storage resources are incentivized to reduce cycling through regulation services and only provide energy in the day-ahead or real-time market when prices are high. Several factors lead to this behavior. Storage resources on the system today degrade as they charge and discharge (cycle) energy. Second, storage resources receive a capacity payment from resource adequacy to reflect fixed costs. The majority of the fixed cost represent warranty contracts that specify an amount of cycling the resource can achieve over a pre-defined time horizon.[22] A typical warranty for a four-hour storage device may allow for one cycle, a full discharge and charge, per day over ten years of operation. If the resource exceeds the limit, it could void its warranty, or reduce the "guaranteed" calendar life of the battery.

The CAISO believes the current warranty constructs and capacity payments for battery storage resources may not reflect the true costs of owning and operating these devices. These physical and contractual constraints may impede these resources from wanting to shift large tranches of energy from the afternoon to evening in the energy market to help integrate renewable resources like solar PV. Further, it is unclear if actual price spreads in the electricity market are sufficient to clear any hurdle that would make it economic for these resources to shift large quantities of energy. This is in part due to data showing that the average maximum possible spreads to move 4 hours of energy during the day are just over $40/MWh, and the spreads in the morning hours — when present — are less than $20/MWh on average. The CAISO's objective is to build a

[22] CAISO staff learned this from discussions with multiple parties that operate storage resources in the market.

construct for storage resources that will accurately reflect true costs, and may be used to mitigate resources when true costs are below observed market prices.

4.1 Default Energy Bid Proposal

The CAISO proposes a default energy bid applicable to all storage resources on the system.[23] This default energy bid will be representative of marginal costs for storage resources, calculated from a methodology outlined in this policy initiative. Furthermore, each energy storage resource will submit parameters to the CAISO that are verified, stored in master file, and are subject to review to inform calculations for approximating actual marginal costs.

In the CAISO's initial straw proposal, several possible methodologies to model storage resource costs were introduced. These included additional adders on existing variable cost default energy bids, an estimated cost methodology to allow storage resources to discharge during certain high price hours, and a methodology to model true costs for a resource.

In the revised straw proposal, the CAISO proposed a more complex default energy bid that more closely reflected actual marginal costs for energy storage operations. This default energy bid set up a four part default energy bid framework that included cost categories for energy purchased, efficiency losses, cycling costs and opportunity costs.

The revised straw proposal included a significant amount of detail about the cycling costs incurred when storage resources are operating. These costs are particularly relevant to lithium-ion storage resources and are incurred as batteries charge and discharge, which causes the cells to degrade. In turn, this causes the cells to be less effective in total charging capability, and eventually requires cell replacement. Because this degradation cost is strictly associated with the operation of the resource, it is a marginal cost and should be included in the default energy bid. However, this cost is difficult to model because it is non-linear in nature, may increase with the total depth of discharge of the resource, and may be technology or chemistry dependent.

The details outlined in the revised straw proposal included a dynamically calculated default energy bid that could change on an interval-by-interval basis directly with depth of discharge or specific dispatch for storage resources. Currently, the CAISO does not update default energy bids at any time during the day, and this would be a large departure from that paradigm.[24] The paradigm previously proposed would allow for default energy bids to change throughout the day.

The draft final proposal included the four cost categories outlined in initial versions of the paper, however it greatly simplifies the approach for estimating cycling costs for these resources and eliminates the dynamic nature that was proposed previously. This simpler calculation will reduce implementation burden and should be more

[23] This proposal and the storage terminology refers to battery storage resources, and is not meant to accommodate pumped storage resources.

[24] The ISO will provide the ability for market participants to update their default energy bid and commitments costs during the day when there is gas price increase within specified parameters.

straightforward for market participants. This final proposal maintains the default energy bid methodology represented in the draft final proposal.

4.1.1 Stakeholder Comments

The CAISO summarizes the stakeholder comments received on the Draft Final Proposals application of a default energy bid for storage resources and the proposed four part default energy bid framework used in its formulation. CAISO continues to thank participants for active engagement in this stakeholder process.

Overall comments were generally supportive of the draft final proposal. Some of the questions from stakeholder comments are discussed in this section. Some stakeholders also asked for clarification of details in the policy. CAISO included some very small changes to language in this section. These changes were meant to clarify but not to change the intent of the policy.

A number of stakeholders commented on ways that the CAISO could improve the accuracy of the default energy bid. CAISO developed this default energy bid with a concern for balancing ease of understanding and implementation with the accuracy of the calculation. CAISO is proceeding with this default energy bid with the understanding that it is not an accurate representation of costs for a resource during all intervals, but rather a more general upper bound of costs for storage. CAISO believes that this default energy bid is prudent, as is it is not an overly prescriptive first step for implementing market power mitigation on storage resources. As CAISO gains more experience from actual storage resources bidding and operating in the market, this methodology can be refined in future stakeholder initiatives.

In previous versions of this proposal CAISO included more complex versions of the default energy bid than what is currently proposed. CAISO also noted challenges with implementing more elaborate, and potentially more accurate default energy bids in previous proposals. This proposal is relatively straightforward and is an appropriate first attempt at applying market power mitigation to storage resources.

Some stakeholders commented that this default energy bid proposal is incomplete, and that spread bids and the negative portion of a bid curve need to be mitigated in addition to the positive portion of the bid curve. CAISO agrees with this and will plan to address these issues in the future. Although this default energy bid may not be complete, it is the first phase at implementing market power in the real-time and day-ahead markets for storage resources. CAISO will work to develop a more robust default energy bid in future stakeholder initiatives. CESA includes a concern that storage resources may be optimizing bids over multiple products, including energy, and as a result storage resources may not always be charging at the periods of the day when prices are lowest. This implies that the lowest prices of the day may not be appropriate to include in the default energy bid for resources. CAISO agrees that there could be situations where storage resources need to increase state of charge to ensure that they can provide energy or another service to the market. However, the energy market makes up the bulk of revenue for resources participating in the CAISO markets, and we believe that this is likely to be true for storage resources as well, particularly as we get deeper penetrations of these resources on the system. Thus, profit maximizing storage resource operators, will likely find that a majority of charging will be done during the lowest priced hours. CAISO plans to monitor storage resources as they integrate into the market and will report on actual observed behavior.

CESA asks that the default energy bid include costs for exceeding the first cycles on a resource. This cost is already included in the proposed default energy bid, as the resource is to provide documentation of costs to the CAISO, inclusive of the upper bound of the variable cost to operate the storage resource.

LS Power suggested that the analysis performed on the default energy bid, discussed in Section 4.3, may result in default energy bids that are too low for storage resources. LS Power notes that on many days they observe opportunity costs that would exceed $100/MWh for some of the resources that they actually operate on the system. First, CAISO notes that the data provided in the analysis is only for a resource that would be exposed to SP-15 prices, and is not specific to resources at other locations. Resources at alternative locations with higher prices, implies higher opportunity costs and higher default energy bids. Second, if the hypothetical storage resources was bidding at their default energy bids, for discharge energy, these resources would be dispatched significantly less than 4-hours per day in the real-time market, which is the assumed duration of the battery. Thus, storage resources would generally be able and available to discharge energy when prices were high, with opportunity to recharge during the day. Finally, that the numbers reported in the table are averages, and on many of the days with the highest prices opportunity costs did exceed $100/MWh.

4.2 Default Energy Bid Formulation

To apply local market power mitigation, the CAISO determines cost components to include in the default energy bid for storage resources. Costs for energy storage resources fall into specific components and are described in detail below:

1. Energy Costs
2. Variable Operations Costs, including Cycling and Cell Degradation Costs
3. Opportunity Costs

Each of these components are included in a default energy bid calculation outlined in Equation 1. This formula has two components, the first of which includes an estimate of the cost that the resource would have to pay to purchase energy and the cost for the resource to cycle. The second component contains the opportunity cost a resource would incur from selling energy prior to the highest priced hours of the day. These components are described in greater detail in the text below.

Equation 1: Storage Default Energy Bid

$$Storage\ DEB = Max\left[\left(En_{\delta/\eta} + \rho\right), OC_{\delta}\right] * 1.1$$

Where:

En: Estimated cost for resource to buy energy
δ: Energy duration
η: Round-trip efficiency
ρ: Variable cost
OC: Opportunity Cost

The ISO proposes to mitigate the entire bid curve for a storage resource. Because a +/- 200 MW storage resource could back generation down from 200 MW to 100 MW or charge at -200 MW instead of -100 MW in an effort to increase prices in local areas, the CAISO proposes that the default energy bid be applied to the entire output of a storage resource, not to only the discharging portion of the resource bid. Mitigation will be applied to the full range of output, including the entire charging and discharging range for storage resources.

The formulation for the default energy bid outlined in Equation 1 above includes a variable 'ρ' to account for the variable costs that the resource incurs while producing energy. CAISO believes that for most storage resources, the bulk of these costs will include cell degradation costs, or the wear and tear the cells of the battery experience as the resources charges and discharges. However, other costs related to the storage resource charging or discharging may be included in this component. This value will be assumed to be zero for the entire charging portion of the bid, when computing the default energy bid curve for the entire operating range of the resource. Therefore, for any market interval the default energy bid will always be a constant value for the entire charging portion of the resource's operating range. These assumptions will always ensure that the default energy bid is monotonically increasing with output, consistent with the current framework for our market solution.

4.2.1 Energy Costs

Storage resources are different from traditional resources on the CAISO system. For example, gas fired generators have an available fuel supply that is converted to energy, and the heat rate, which describes the efficiency of the resource, informs the resource's marginal cost. Storage resources "buy" energy from the grid and sell that energy back to the grid by discharging at a later point in time. Nevertheless, when a storage resource discharges, the impacts to the grid are identical to a traditional generator running.

It is critical that a value approximating the costs of energy purchased through the wholesale market be included in the default energy bid for storage resources. For example, if a storage resource buys energy at the lowest prices of the day at $10/MWh, it will have significantly lower costs than if it was buying energy at $50/MWh. Energy purchased at higher costs implies that sales need to be made at higher prices to maintain the same price spread.

In this proposal the CAISO proposes an updated methodology to what was included in the revised straw proposal. This updated proposal includes using the actual results from the day-ahead market process to compute expected costs for a resource to purchase energy. Today, the day-ahead market process initially performs a market power mitigation (MPM) run, with unmitigated bids, then it performs a test to determine specific resource/hours that fail a dynamic competitive test assessment (DCPA), finally it performs the integrated forward market (IFM) run that includes mitigated bids for all resource/hours that fail dynamic competitive test assessment. The premise of this default energy bid is that storage resources will include energy prices from the market power mitigation run, which will inform the energy cost component of any default energy bid that may be applied in the successive integrated forward market run.[25]

Expected costs will be calculated for resources, as if they were performing one cycle per day, and charging during the least expensive continuous block of time during the day. The CAISO anticipates that most resources will have a 4-hours of storage duration, which implies that the amount of energy necessary to charge the resource will be just longer than 4-hours to include round trip efficiencies. This value should represent a conservative estimate of cost (on a $/MWh basis, for the duration of the discharge period) to charge a specific resource, particularly if the resource is performing less than one cycle per day. If a sub-set of storage resources routinely perform more than one cycle per day and require adjustment to the default energy bid, this update may be accommodated by a consultation with the CAISO.

This process will hold true for all storage resources in the day-ahead market. The real-time market will perform differently. Here actual locational marginal pricing (LMP) results from the integrated forward market run for a specific day will be used to determine energy costs for storage resource default energy bids in the real-time market.

4.2.2 Variable Costs (Including Cycling Costs)

The revised straw proposal included a complex modelling approach for cycling costs for storage resources. The second revised straw proposal outlined a significantly simplified approach to model cycling cost in a more general way, which is maintained in this final proposal. This proposal aligns with expectations for operating costs anticipated by battery developers with resources coming online in response to requests for offers (RFOs) to meet energy capacity needs on the California system in the next few years and in response to CPUC procurement.

From the workshop hosted in December, the CAISO learned that the actual operating costs for many of the resources that will or could potentially be built and interconnected to the system, are designed specifically to optimally accomplish a particular operating behavior on a daily basis. This behavior may be configurable, however, it generally must be specified prior to the battery being developed. Many of the batteries are being built to optimally perform one cycle per day, which includes charging the battery once for four hours and discharging the battery for four hours later in the day.[26] Procurement of resources with these capabilities is a direct result of the CPUC RA counting rules that state that resources are only able to count for resource adequacy for the amount of energy they are able to provide consistently during a minimum four hour period.

[25] Additional information about the day-ahead market process is available in the market operations business practice manual here:
https://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Market%20Operations.

[26] Some resources may be designed with the purpose of delivering just over 1 cycle per day to allow for some additional flexibility. These resources may be designed to deliver 1.1 or 1.25 cycles per day.

Because most storage resources are designed to these minimum specifications, they generally experience a relatively consistent cost while operating within their design criteria, say 1 cycle per day, and significantly higher costs when operating at higher levels, say while operating beyond 1 cycle per day. Although these costs are impacted by the factors described in earlier versions of this proposal, which may include cycle depth, ambient temperature, current rate, and average state-of-charge, the impact may only be appreciable when the resource is operating within the bounds of where it was designed to operate. Specifically, the impact of each of these factors may be relatively small compared to the cost to operate a typical storage resource that may be built on the CAISO system beyond one cycle per day.

Many of these factors and how they impact cycling costs were explored in great detail in earlier versions of the paper. Although this work was useful, the approaches to model the specifics of these costs can be very complicated and may exceed the CAISO's current computational capabilities.

In this proposal, the ISO updates the proposed calculation for variable costs, including cycling costs, to correspond to a value that represents operating a storage resource beyond the specified range of performance that the resource was designed for. This value will be submitted by market participants to the CAISO and vetted. For example, this might be the cost to operate a resource beyond one cycle for most of the new storage resources that may likely be built on the system over the next few years.

There will be significantly more storage resources developed and integrated onto the CAISO system in the next few years. In discussions with battery manufacturers and experts in developing batteries, the CAISO learned that many anticipate costs related to cycling and operating, to generally be less than $30/MWh for most new lithium-ion resources. The ISO notes that several developers have declared large differences between marginal cycling costs for different storage projects with different chemistries, even within the lithium-ion technology. This number may be applicable while the battery operates within its design specification, i.e. the first cycle per day. Conversations with a variety of battery manufacturers have been informative as to the costs of storage resources operating beyond their design specification, which may be between 2 to 3 times larger than those costs when operating within them.

Although CAISO plans to allow the higher of these values to be included in the default energy bid for the storage resource, all values will need to be validated by CAISO staff before they may be used in default energy bids. Validation, in the form of estimates from storage manufactures may suffice for CAISO review. In the future, as more storage resources are connected to the grid, CAISO may develop guidelines for acceptable values, similar to guidelines for other values currently reviewed by the CAISO.[27] CAISO envisions that these values will be submitted once and will likely be set for longer periods of time, but will always have the potential of being updated when needed. CAISO does not expect that the costs associated with cycling cost will change much on a day-to-day basis. CAISO also acknowledges that these costs capture operations and maintenance costs for storage resources, which may adjust seasonally

[27] These may include other values collected and verified by the ISO, such as major maintenance costs for specific resources.

and may be changed to account for costs when resources are operating during hot weather in the summer or cooler weather during the remainder of the year.

4.2.3 Opportunity Costs

The market power mitigation tool can replace submitted bids with CAISO calculated default energy bids in the day-ahead and real-time market process. In the event that these bids are lower than the true cost to operate a resource, the tool may force an inefficient dispatch. Storage resources can only generate until stored energy is depleted before needing to be recharged. To avoid being discharged before the optimal time, a resource with limited availability should have an opportunity cost included in its default energy bid. These opportunity costs include the value to the resource owner from not running during a particular interval and saving stored energy until a later time when prices are higher.

If the resource is fully charged and has a default energy bid of $60/MWh, and the current market price is $75/MWh, it would be profitable for the resource to discharge and receive this revenue. However, this may be sub-optimal as prices in the successive four hours rise to $100/MWh. In this example, the resource would optimally wait to discharge stored energy, until the later hours when prices are higher.

This example is highly simplified, but illustrates the need for inclusion of an opportunity cost component in the default energy bid for storage resources. In this simple example, an opportunity cost increasing the total default energy bid to $100/MWh is appropriate for this resource. The inclusion of opportunity costs in the default energy bid is further complicated when a resource is capable of buying and selling energy for multiple hours, and buys or sells energy in the real-time market and experiences economic losses.

CAISO proposes including the highest price, corresponding to the storage duration of the resource in the default energy bids for storage resources. For example, if a specific storage resource is capable of storing 4 hours of energy, the opportunity cost included in the default energy bid will be equal to estimated prices in the 4th highest hours of the day.[28] The process used to estimate these costs in the day-ahead market will use previous day prices from the day-ahead market scaled by a bilateral index prices. The methodology is outlined in the Equation 2.

Equation 2: Opportunity Costs

$$OC_{\delta,t} = OC_{\delta,t-1} * Max\left(\frac{DAB_t}{DAB_{t-1}}, 1\right)$$

where:

OC: Opportunity cost
DAB: Day-ahead bilateral hub
t: Interval (day)
δ: Storage duration for the resource (i.e. 4 hours)

[28] For example, if prices are $45, $35, $32, $30, $27, $31, $40; the fourth highest hour would be $32.

The opportunity cost component will be computed differently in the real-time market than the day-ahead market. The CAISO is unable to use the prices in the market power mitigation run in a similar way to the energy cost component of the default energy bid because integrated forward market prices could be influenced by resources with market power. The real-time market will, however, use actual integrated forward market prices from the day-ahead market process to inform the opportunity cost component of the default energy bid for each storage resource.

4.3 Analysis

With this formulation the CAISO is able to calculate values for the default energy bid for historic data. The CAISO performed such analysis for actual pricing data for all days in 2019, for a node priced at north of path 15 and another priced at south of path 15. For these examples, the CAISO assumes that a four hour lithium-ion battery with an 80% round trip efficiency, and a $20/MWh assumed degradation on the storage resource while operating.[29] These assumptions are based on based on general observations for storage resources currently participating in the CAISO market, from industry literature and discussions with industry experts. As noted above, the CAISO expects that these values may be representative of some resources, but are certainly not representative of costs for all potential storage resources in operation or that could be in operation. Further, the CAISO will be collecting this information for each individual resource, as storage integrates into the market.

To perform this analysis the CAISO followed the following steps:

1. Calculate the bilateral hub ratio from the previous day
2. Calculate the expected price that the resource would pay to buy energy
3. Calculate the expected opportunity cost for the resource to sell energy
4. Assemble the components to generate a daily default energy bid
5. Compare real-time prices to default energy bids to determine potential discharge

[29] The ISO performed calculations for storage resources with 80% and 100% efficiencies. Aggregate outcomes for both resources were similar.

Table 1 Storage DEB results for a resource located at SP-15

Month	Energy & Var. Cost Comp.	OC Comp.	DEB	Run Hrs./Day
Jan	$ 47.71	$ 49.93	$ 56.98	1.4
Feb	$ 59.54	$ 98.27	$ 108.64	1.7
March	$ 32.05	$ 54.74	$ 60.21	2.0
April	$ 26.76	$ 36.98	$ 40.91	1.6
May	$ 25.36	$ 29.09	$ 32.03	1.9
June	$ 31.98	$ 33.18	$ 38.29	1.6
July	$ 41.41	$ 42.88	$ 48.86	0.7
Aug	$ 42.35	$ 43.68	$ 49.53	1.5
Sept	$ 42.32	$ 45.43	$ 51.35	1.0
Oct	$ 39.36	$ 44.29	$ 49.04	0.7
Nov	$ 47.80	$ 54.12	$ 60.29	1.2
Dec	$ 50.49	$ 49.23	$ 56.66	1.1

Table 1 shows the average energy and variable cost component, opportunity cost component and total default energy bid for each month of the year for this hypothetical resource located in south of path 15. Finally, the table shows how frequently a hypothetical storage resource would run if charged and bidding at the default energy bid during all hours of the day. During some months the energy and variable components of the default energy bid tends to be highest, and during other months the opportunity cost component is highest. Across the entire year, for this hypothetical resource, variable cost component is larger during about 70 percent of intervals. These values help to describe the underlying mechanics of how the default energy bid is set. Larger spreads between the lowest and highest priced intervals of the day generally imply that opportunity costs should outweigh variable costs. This is the case during the winter months, when peak prices tend to be lower overall. When prices are generally higher, during the summer, the default energy bid tends to be based on the cost to buy energy included in the variable component of the default energy bid.

The monthly average default energy bids range from as low as $34/MWh, up to more than $110/MWh. This is logical and expected. As underlying market prices change, the default energy bids for the resources changes as well. Default energy bid prices are driven by the underlying market prices, which result in higher default energy bids when prices are market prices highest, and lower default energy bids when prices are lowest.

CAISO also computed the total number of hours the resource would run each day, in the real-time market, with the simplifying assumption that the resources was bidding only to discharge energy at the default energy bid. CAISO further assumed that the resource had no state-of charge to maintain. The results of this analysis are also shown in

Table 1. They show that during most months, the hypothetical resource was typically dispatched to provide energy during two hours of the day or less.

Finally, CAISO picked two specific days during the prior year, one day in in August, when loads were relatively high and one day in February when day-ahead prices were high and real-time prices were also high and volatile. These examples illustrate what actual values for the default energy bids may look like, and how a resource may get dispatched in the real-time market, if bidding at the default energy bids. CAISO also notes that the date in February is particularly unusual, and is an exception to typical market performance.

Figure 10 shows real-time and day-ahead prices for August 18, 2019 as well as the default energy bid that CAISO would calculate for a resource located at SP-15. In this example, expected prices to buy energy is greater than the expected opportunity cost, and the resulting default energy bid is set at about $40/MWh. In the real-time market there were 28 intervals (2.7 hours) where prices exceed the default energy bid, some of which approached $1,000/MWh. This graph shows that if the resource were charged and bidding at the default energy bid during the evening hours, it would run just over one half cycle on this day in the real-time market.

Figure 10: Real-time operations on August 18, 2019

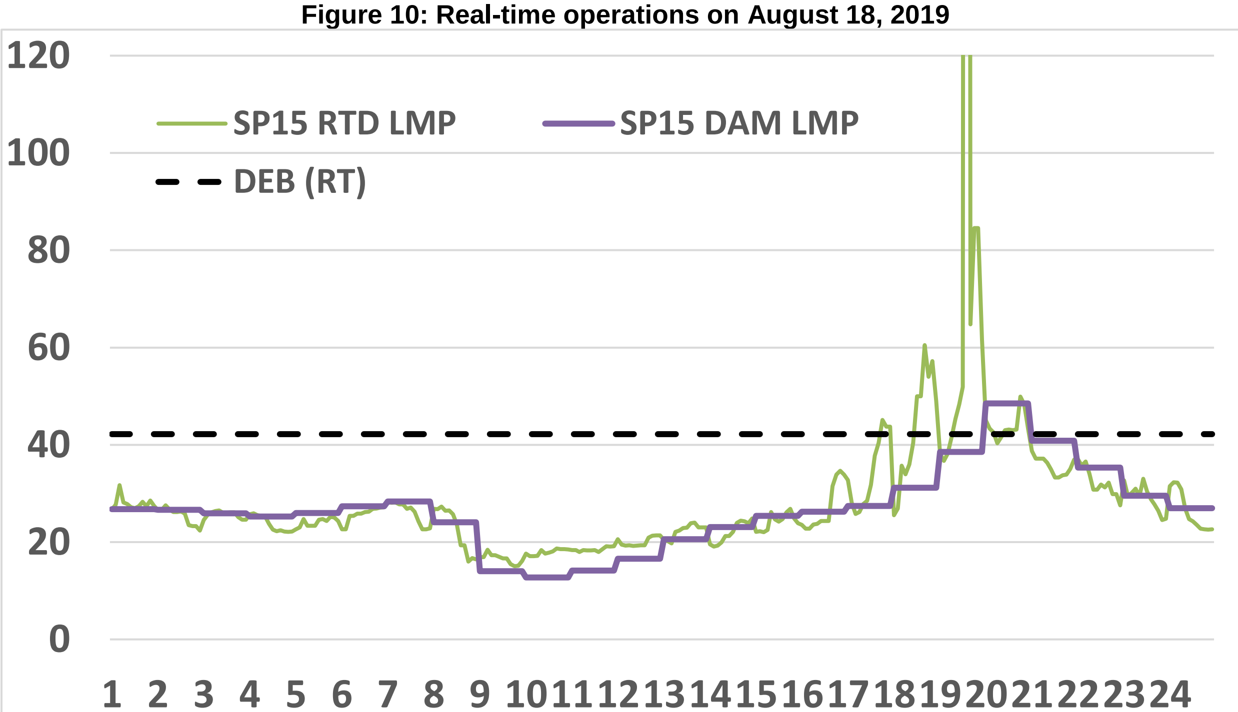


Figure 11: Real-time market volatility on Feb 21, 2019

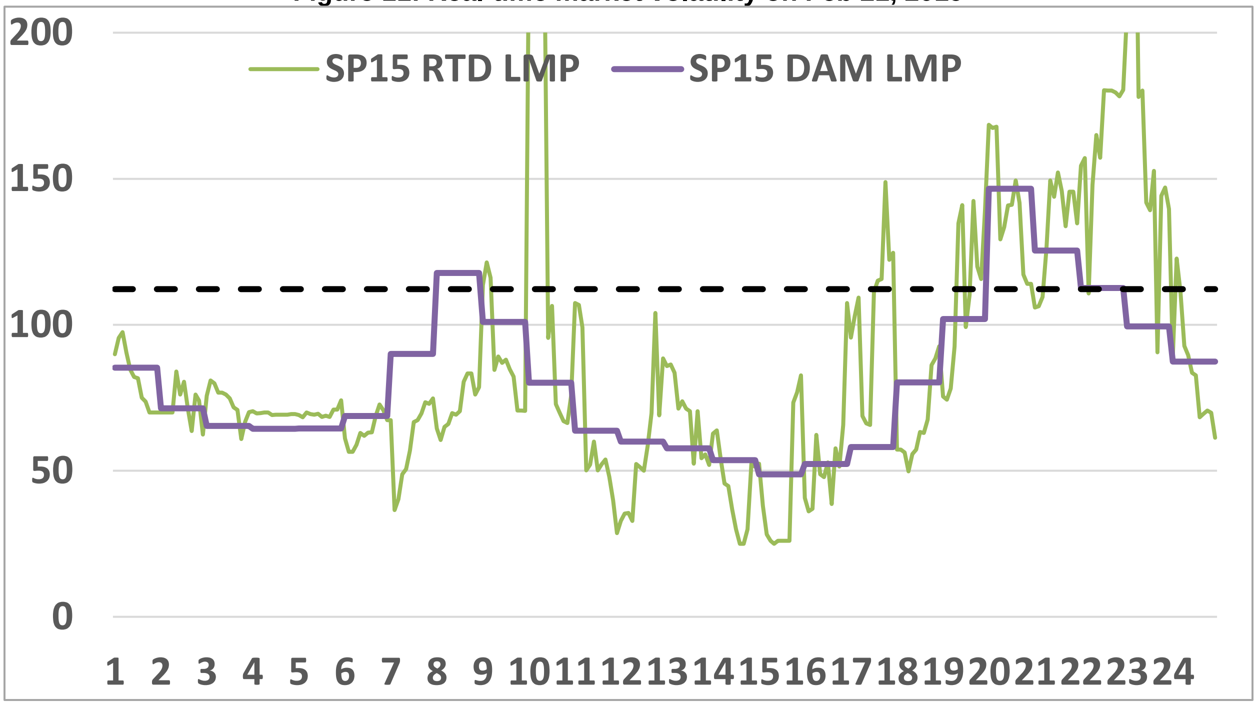


Figure 11 shows real-time and day-ahead prices for February 21, 2019 as well as the real-time default energy bid that CAISO would calculate for a resource located at SP-15. The market results on this day are not typical, and are meant to illustrate a day where real-time prices are highly variable. In this example, expected prices to buy energy is less than the expected opportunity cost, and the resulting default energy bid is set at about $112/MWh, to reflect the potential value a resource may have to give up if it discharges energy too early. In the real-time market there were 63 intervals (5.3 hours) when prices were above the default energy bid, with many intervals where prices approached $1,000/MWh. This graph shows that if the resource were charged and bidding at the default energy bid during the evening hours on this particular day, it would run more than one cycle. However, it may not be appropriate to assume that storage will be charged at the end of the day, when prices have been particularly high for many consecutive intervals.

4.4 Input parameters

There are several equations in this section of the proposal outlining the calculation for a default energy bid for storage resources. Some of these equations include variables that characterize costs that are specific to individual resources. CAISO contends that these values are relatively stable over time, but also are generally unknown to the CAISO. Similar to existing gas resources today, CAISO plans to collect this data for all storage resources in the future. This data will be collected via CAISO master file process that is already in place to capture resource specific data.

Master File variables that will be collected for storage resources:

- η: Round-trip efficiency
- δ: Storage duration for the resource (i.e. 4 hours)
- ρ: Cell degradation cost

Like other variables that are collected and stored in master file, scheduling coordinators for these resources will have requirements for submitting these variables to CAISO. As with other master file data, CAISO will have descriptions of what this data should represent, how the data should be submitted and what, if any, documentation should accompany this data when it is submitted to master file. Finally, as with all data submitted to CAISO, there will be an obligation for scheduling coordinators to ensure that this data is up to date and accurate for all resources.

CAISO collects round trip efficiency values today through the master file for each storage resource on the system. CAISO does not envision any changes to this process in the future. The ISO also collects the maximum amount of storage capability (in MWh) for each storage resource, this value combined with the resource Pmax value, will inform the storage duration parameter above.

4.5 Alternative Default Energy Bids

Although CAISO is striving to develop a functional default energy bid that will reasonably approximate costs for most storage resources, it may not be feasible to develop a methodology that will work for all storage resources and technology types. Therefore, resources always have the ability to apply for a negotiated default energy bid if the proposed methodology outlined is insufficient. Although the CAISO started a stakeholder initiative to update allowable operations and maintenance values because there are so few of these resources operating today, there is little reliable data for what these values will be for participating storage resources.[30] In the future, the ISO may update the default values allowable for all storage resources. These values will apply to variable cost default energy bids and may also be sufficient for some storage resources. Further, the operations and maintenance adders can be negotiated with the CAISO at a resource specific level, at a justifiable cost.

5 Reflecting Demand Response Operational Characteristics

Certain demand response resources may not have a minimum operating level similar or analogous to conventional resources and, therefore, registers a Pmin value of 0 MW in the CAISO Master File representing its minimum load curtailment capability. Experience has shown that a Pmin of 0 MW presents operational challenges for certain demand response resources. Today, long-start resources (equivalent of day-ahead only DR) committed in the residual unit commitment (RUC) process are started and instructed to their Pmin so that they are available for dispatch and can ramp in real-time when needed. For demand response, the market instructs the demand response

[30] Variable operations and maintenance cost review initiative: http://www.caiso.com/StakeholderProcesses/Variable-operations-maintenance-cost-review.

resource to its Pmin (respecting its minimum run time) and assumes the resource is ready to be dispatched and reduce load when instructed.[31]

The scenario above can result in a rational and economic dispatch where a demand response resource receives multiple and subsequent instructions to curtail load in one interval and return to Pmin of 0 MW in another interval. While the CAISO market systems are acting appropriately and see the demand response resource as economic and capable of moving between its Pmin and Pmax in any interval, certain demand response resources are inflexible and can only provide a limited number of sustained responses from their Pmin.

The CAISO continues to believe that a combination of market parameters and bidding options can best address demand response resources' operational limitations. The CAISO has received positive feedback on these options. However, stakeholders have identified specific demand response program designs that may not be effectively characterized utilizing these available and emerging options. Program designs are constrained with a limited number of starts and a set number of hours available for dispatch within a day. To optimize demand response resources with these programmatic constraints, the CAISO proposes a maximum daily run time parameter so that the market can optimize demand response resources with daily hourly limitations that may not be manageable utilizing the current maximum daily energy limitation parameter.

5.1 Scenarios utilizing current market parameters

Option 1: Pmin = 0 MW and resource registers startup costs

In ESDER 3, the CAISO designed the hourly and 15-minute bidding options for proxy demand resources to extend notification times and longer duration dispatches. This allows for effective real time dispatching of PDRs with a Pmin = 0 MW. Additionally, with the implementation of the Commitment Cost and Default Energy Bid Enhancements[32] and Commitment Cost Enhancements[33] initiatives, non-gas resources have the ability to submit a minimum load cost and enhanced capability to have their start-up cost be independent of Pmin, allowing for non-zero start-up with Pmin = 0MW.

If a proxy demand resource (PDR) were to elect an hourly bid option and define a non-zero dollar commitment cost at a Pmin of 0 MW, the resource would no longer be a zero cost option in the CAISO's residual unit commitment optimization. Additionally, once committed in the residual unit commitment process, the proxy demand resource would only be dispatched off its Pmin in hourly blocks per its elected bidding option.

Even with these additional PDR resource parameter options, the CAISO recognizes that some challenges remain. For example, demand response resources are unable to

[31] Definition of minimum run time http://www.caiso.com/Documents/Section34_RealTimeMarket_asof_May2_2017.pdf.

[32] Commitment costs and default energy bid enhancements (CCDEBE) policy page http://www.caiso.com/informed/Pages/StakeholderProcesses/CommitmentCosts_DefaultEnergyBidEnhancements.aspx

[33] Commitment cost enhancements (CCE3) reference material http://www.caiso.com/informed/Pages/StakeholderProcesses/CommitmentCostEnhancements.aspx

respond to multiple and variable dispatches from Pmin based on program limitations on the number of curtailments available within a day. Additionally, scheduling coordinators for demand response resources have hesitated to submit commitment costs and have asked the CAISO to provide guidance.

Nevertheless, the CAISO believes that these challenges are inherit to some demand response resources. The benefit of the options proposed here is the ability for a demand response resource to implement these changes when the policy proposals (ESDER 3B, CCDEBE, CCE3) are approved by FERC and implemented.[34]

Option 2: Non-zero Pmin with minimum load costs (minimum load cost)

During the March 18, 2019 working group meeting, the CAISO presented a scenario in which demand response resources could register a Pmin close to its Pmax and assign a minimum load cost.[35] The optimization will consider the non-zero Pmin and associated minimum load cost to determine if it is economic to dispatch a resource to its Pmin (close to Pmax). Additionally, the resource could utilize the maximum daily energy limit to identify a MWh quantity it can only be awarded to account for the limited run time of a demand response resource.

This proposed option requires the scheduling coordinators to determine and provide a minimum load cost.

The benefit of option two is the ability of scheduling coordinators to use parameters that exist today without any dependency on current or future implementation timelines.

In response to Southern California Edison's comments of the limitations of the maximum daily energy limit, if the resource identifies its Pmin at .01 MW below its Pmax, the CAISO will consider the minimum load cost and non-zero Pmin in the residual unit commitment process. If the resource is committed, it will be dispatched to its Pmin, and the CAISO will respect the maximum daily energy limit. Additionally, inflexible demand response resources that are not able to respond to varying dispatches will receive a consistent award at the non-zero Pmin value.

5.2 Maximum Daily Run Time Parameter

5.2.1 Stakeholder Comments

The CAISO continued to receive stakeholder comments strongly supporting the inclusion of a maximum daily run time parameter proposal. As a result, there have been no changes in the Final Proposal from the draft final proposal.

[34] CCE3 and ESDER3 Phase A has been approved by FERC and implemented. ESDER 3 Phase B and CCDEBE have not been filed with FERC, as both await technology development.

[35] Tariff Appendix A "Minimum Load Costs – The costs a Generating Unit, Participating Load, Reliability Demand Response Resource, or Proxy Demand Resource incurs operating at Minimum Load, which in the case of Participating Load, Reliability Demand Response Resource, or Proxy Demand Resource may not be negative. Minimum Load Costs may be adjusted pursuant to Section 30.7.10.2, if applicable."

5.2.2 Proposal

The CAISO is proposing a maximum daily run time parameter to optimally resolve the issue of demand response resources being dispatched beyond program limitations. This proposal will resolve the issue occurring when the market observes a Pmin of zero as an “on” state and moves dispatches between its Pmin of zero and a non-zero value. Introducing a maximum daily run time parameter allows a demand response resource to identify the maximum number of hours the resource could be “on” over the course of a day. This parameter, in combination with the currently available start-up constraint, provides for ability to characterize program constraints along with flexibilities that can be considered in their optimization.

The parameter will be captured in master file and represent the maximum number of hours a demand response resource can be committed and/or dispatched on a daily basis. The parameter components and requirements are summarized below:

- Master file parameter representing a daily maximum number of hours the resource can be committed and/or dispatched.
- Parameter is an option under master file and not a requirement.
- Applicable for both proxy demand response and reliability demand response resources.
- Resources must have a minimum 1 MW curtailment capability and register a Pmax value that is equal to or greater than 1 MW.

The CAISO is establishing the 1 MW threshold due to concerns with degradation of market system performance with the utilization of an additional constraint by a significant number of resources with fractional MW offerings. As the number of participants in the market has expanded, the CAISO is concerned with maintaining the performance of its market systems. In general, implementing discrete constraints in addition to binary variables, have a large impact on market performance. On most days, the day-ahead market is evaluating bids for over 800 proxy demand resources. If the CAISO allowed a maximum daily run time parameter for all demand response resources regardless of size, the resulting impact on performance could put the 1 PM day-ahead market publishing deadline in jeopardy. The CAISO has developed these requirement restrictions to minimize the known risk to market performance.

The examples below illustrate how the proposed parameter will be utilized in the market’s optimization of demand response resources.

Example 1: Maximum Daily Run Time Constraint with Day Ahead Commitments

Figure 12 and Figure 13 represent a demand response resource with a Pmin of 0 MW, start-up >= 1, a minimum run time of 1 hour, and a maximum daily run time of 5 hours.

Figure 12 illustrates the resources commitment in the day-ahead market to a Pmin= 0 MW to its maximum daily run time limitation and receiving contiguous dispatches in real-time.

In this example, the resource is committed for its maximum daily run time of 5 hours with its initial start-up to Pmin.

In real time the resource is dispatched contiguously in the hours in which it was committed, from HE17 to HE 21. This example illustrates how a resource with a start-up = 1 would receive a contiguous real time dispatch at its maximum daily run time. The characteristics of this resource will always result in a contiguous real time dispatch of the resource for a number of hours up to its maximum daily run time.

Figure 12: Contiguous dispatch in real-time market

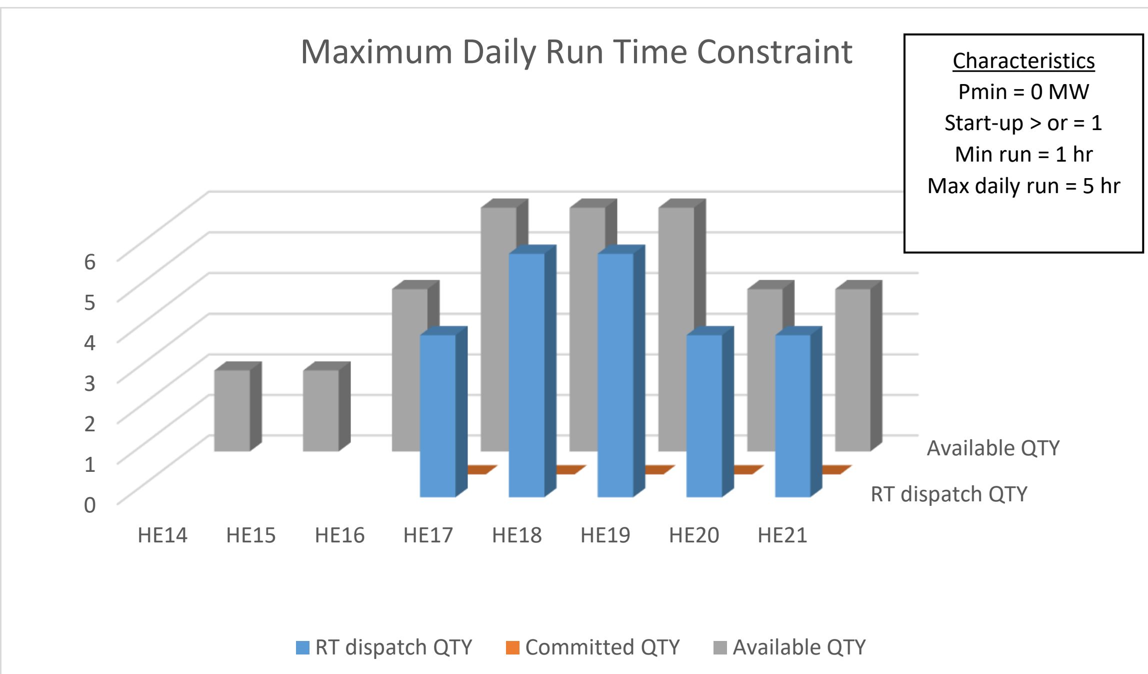
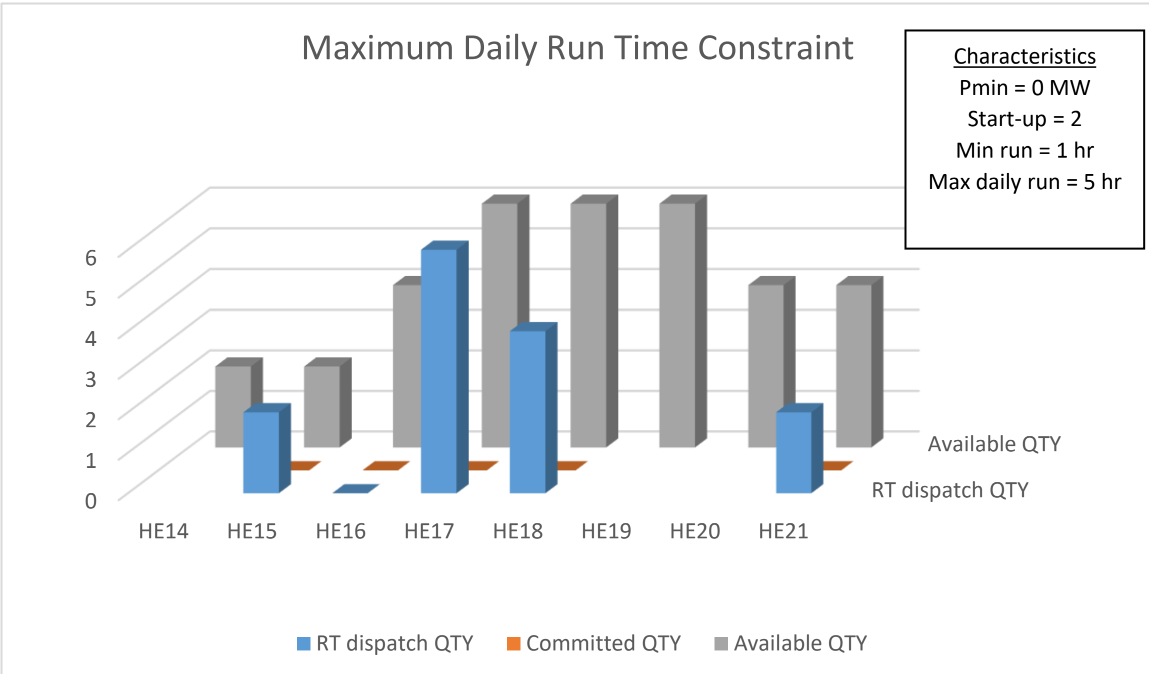


Figure 13 illustrates the resources commitment in the day-ahead market to a Pmin= 0 MW to its maximum daily run time limitation while receiving non-contiguous dispatches in real-time.

In this example, the first start up committed the resource for 4 hours with a subsequent start-up to Pmin for 1 hour, honoring both the start-up and maximum daily run time constraints.

In real time the resource is dispatched in HE15 and again in HE17-18 after being instructed back to its Pmin of 0 MW. The resource is again called in HE 21. This example illustrates how a real time dispatch respecting the resources start-up and maximum daily run time is respected for a resource with Pmin = 0 MW. Market participants must take into account this potential dispatch outcome for a demand response resource choosing to register with a Pmin of 0 MW and start-up > 1 when utilizing a maximum daily run time.

Figure 13: Noncontiguous dispatch in real-time market



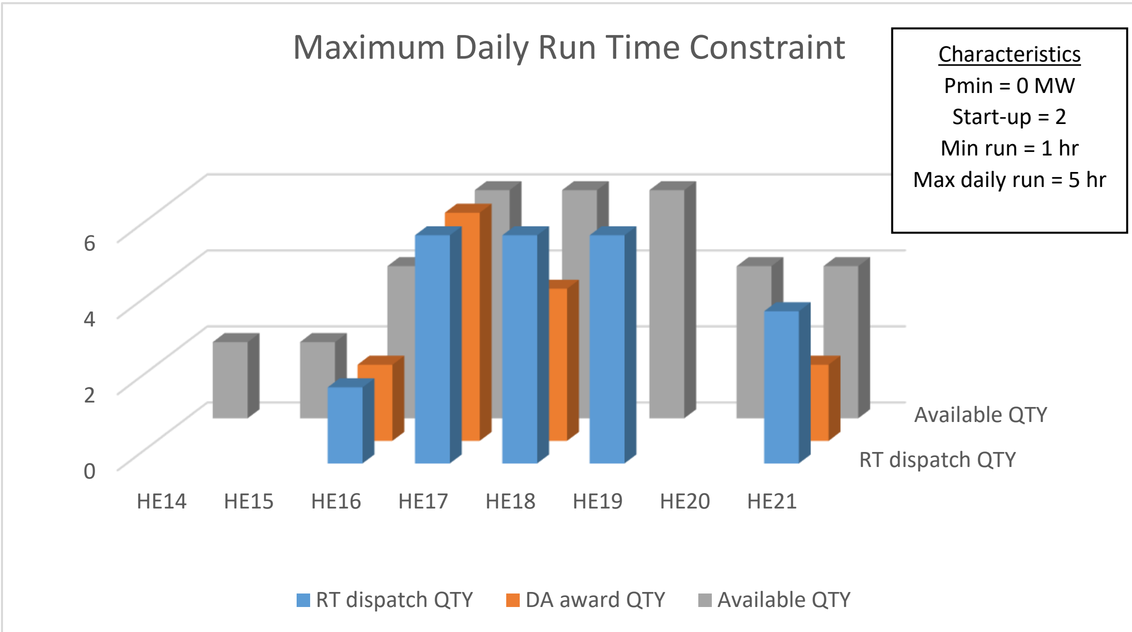
Example 2: Interaction between day-ahead and real-time market awards

Figure 14 represent a demand response resource with a Pmin of 0 MW, start-up = 2, a minimum run time of 1 hour, and a maximum daily run time of 5 hours and demonstrates how the CAISO optimization will consider the maximum daily run time constraint across both the day-ahead and real-time markets.

In this example, the resource is awarded in the day-ahead market for 3 hours with its first start up with a subsequent award for 1 hour with its second start-up, honoring both the start-up and maximum daily run time constraints.

Figure 14 illustrates the resource day-ahead market awards in for HE16-18 and HE21. In real time, the resource is not only dispatched for hours awarded in the day ahead but also for an additional hour contiguous to its day ahead award in HE19. In real-time, the optimization has feasibly dispatched the resource considering and respecting both start up and maximum daily run time constraints.

Figure 14: Resource receives awards in day-ahead and real-time market



6 Valuation and Operational Processes for Variable-Output Demand Response

The CAISO defines variable-output demand response resources as those demand response resources whose maximum output can vary over the course of a day, month, or season due to production schedules, duty cycles, availability, seasonality, temperature, occupancy, etc. For instance, certain demand response resources' output may vary with weather, like an AC cycling demand response program that can reduce more load on a hot day when air-conditioner use is high versus on a moderate day when air conditioner use is low. When a variable-output demand response resource provides resource adequacy capacity in the year-ahead or month-ahead timeframe, depending on conditions, the resource may be unable to deliver its full stated resource adequacy capacity in the day-ahead or real-time given its variable nature.

Many demand response resources also have energy limitations that affect a resource's ability to provide the energy associated with the resource adequacy capacity they provide. These limitations include hours of operability, duration, or number of event calls. As California transitions to a decarbonized grid, the CAISO will likely rely more heavily on both variable and energy limited resources. As such, it is critical to assess the ability of the new resource fleet, including preferred resources, to displace carbon-emitting generation while maintaining system reliability and serving energy needs every hour of the year.

The central tenet of the resource adequacy program is to ensure sufficient energy is available and deliverable when and where needed. As California Public Utilities Commission (CPUC) Commissioner Randolph stated, "*A successful Resource Adequacy program ensures that every part of California has instantaneous power to serve their customers every hour of the year. It is invisible to the public when it is* *functioning as it should, because power flows without curtailment or outages even when the grid is stressed*."[36] Thus, the inability to deliver energy associated with resource adequacy capacity because of certain known dependencies is a "visibly" significant issue. If a resource cannot bid its full shown qualifying capacity and deliver it under its must offer obligation, it jeopardizes the central tenet of the resource adequacy program. Additionally, resources incapable of meeting their shown net qualifying capacity value during the availability assessment hours will be assessed charges through the Resource Adequacy Availability Incentive Mechanism (RAAIM).[37]

A majority of demand response resources have dependencies that result in having a variable output (curtailment capability) even though they are treated under CPUC resource adequacy rules as capable of delivering their full qualifying capacity value whenever dispatched. This potentially overstates their resource adequacy qualifying capacity value and jeopardizes the CPUC's resource adequacy program and reliability.

To address this issue, the CAISO, the CPUC, and local regulatory authorities must modify demand response resource adequacy and market participation rules to align with the following two principles:

1. The qualifying capacity valuation methodology for demand response resources must consider variable-output demand response resources' reliability contribution to system resource adequacy needs, and
2. Market participation and must offer obligations must align with demand response resource capabilities.

Operational capabilities of variable-output demand response resources change over the course of the day, month or season because maximum output is dependent on some variable condition like weather, availability, temperature, product production, etc. Increasing penetrations of variable resources, including certain types of demand response, make it important to quantify the contribution of these resources and their ability to serve system load when they are needed. For wind and solar resources, this assessment is done by determining the resources' Effective Load Carrying Capability (ELCC).[38] Once an appropriate qualifying capacity value is determined for wind and solar by applying the ELCC, the resource can fulfill its must offer obligation by bidding the amount it is physically capable of providing per its forecast. In this paper, the CAISO proposes to demonstrate how a similar methodology should be applied to variable-output demand response and those with energy limitations.[39]

This issue will need further vetting and decision-making at the CPUC and with other local regulatory authorities since local regulatory authorities have jurisdiction over

[36] CPUC News Blog; Commissioner Blog: Keeping the Lights On, by Commissioner Randolph, 2/22/2019, found here: https://www.cpuc.ca.gov/cpucblog.aspx?id=6442460494&blogid=1551
[37] The broader application of RAAIM is currently being reviewed in the RA Enhancements initiative: http://www.caiso.com/informed/Pages/StakeholderProcesses/ResourceAdequacyEnhancements.aspx
[38] ELCC is explained in detail below.
[39] It may not be necessary to apply an ELCC value or provide alternative market participation options for demand response resources that are neither variable nor energy limited if they can provide a fixed load reduction value over the course of the RA month.

establishing resource adequacy qualifying capacity values. To encourage and advance this issue, the CAISO contracted with Energy and Environmental Economics, Inc. (E3) to perform an ELCC study on demand response resources and has solicited stakeholder input for its recommendations to the CPUC and other local regulatory authorities regarding the appropriate methodology for establishing qualifying capacity values for variable-output demand response. The CAISO also developed a methodology to operationalize and accommodate variable-output demand response as a resource adequacy resource in the CAISO market once the CPUC and local regulatory authorities have adopted such a methodology.

In this ESDER process, the CAISO's goal was to demonstrate the importance of modifying demand response capacity valuation to consider resources' variability and energy-limitations, as well as demonstrate how such an approach could be performed. This Final Proposal maintains the variable output demand response proposal represented in the draft final proposal. Following the publication of this final proposal, the CAISO will continue working with stakeholders in regulatory proceedings to refine this methodology for future approval and implementation by local regulatory authorities and the CAISO.

6.1 Stakeholder Comments

The CAISO summarizes the stakeholder comments received on the Draft Final Proposal and ELCC study results shared at the May 27th working group meeting to aid stakeholders in interpreting the study results.

Following the presentation of the ELCC study results at the May 27, 2020 stakeholder call, Southern California Edison identified a limitation when using discrete dispatch that limited their bid volume below the full capability of a portion of their resources. Since then, Southern California Edison refined their resource bid volumes to reflect the full capability of the resources. While it was not possible to incorporate these modified bids into the ELCC study within the ESDER process, the CAISO appreciates the work done by Southern California Edison related to this effort and believes these modified bid volumes should be considered in any future studies performed to establish ELCC values. Saying this, modifications to DR bids since the study should not inhibit consideration of the methodology used in the ESDER 4 study.

SCE and PG&E also informed the CAISO that demand response resource bids do not include the 15% PRM and line loss adder that is included in the qualifying capacity value of demand response.

6.2 Qualifying Capacity using ELCC for variable-output demand response

Local regulatory authorities are responsible for determining the qualifying capacity values for resource adequacy resources. To set the qualifying capacity for demand response resources, the CPUC adopted load impact protocols as a defined set of guidelines to estimate the load impacts of Investor Owned Utility and third party demand response program. Load impact protocols are a combination of ex-post and ex-ante assessments of load impacts used to determine the load reduction capability of each demand response program. Ex-post impacts consider historical demand reductions during actual demand response events. Ex-ante load impacts estimate load reduction capability for each month using 1-in-2 system peak conditions. Ex-ante impacts are forward looking and based on historical load impact performance. Load impact protocols rely on regression analysis to predict average customer load and estimate demand response program load impacts using independent variables including weather conditions, month, time of day, and day of the week. The qualifying capacity value is established using the average load impacts from the system monthly peak day during the resource adequacy measurement hours. For demand response auction mechanism resources effective with the 2019 solicitation, the qualifying capacity is estimated based on historical performance data supplemented with disclosure of load aggregation data with reference to past test events or market dispatches of similar resources.

It is important to develop appropriate and comparable qualifying capacity methodologies for utility, demand response auction mechanism, and third party demand response resources reflective of their contribution to reliability. Through this initiative, the CAISO, with the input of stakeholders, explored how ELCC values can be established for demand response. The CAISO intends to use the outcome of this initiative to inform the CPUC and other local regulatory authorities on how demand response could be valued considering its variable and energy-limited nature. The CAISO will to continue to engage with the CPUC in future proceedings to further develop and implement an ELCC methodology, and depending on local regulatory authority adoption will consider establishing in the CAISO tariff default qualifying capacity provisions for local regulatory authorities who do not adopt their own qualifying capacity counting methodology in the future.

ELCC background

ELCC is a probabilistic approach used to quantify the reliability contribution of a resources or class of resources. The CPUC currently uses this approach to determine the qualifying capacity of wind and solar resources. As a first step to determining the ELCC, the CPUC performs a loss of load expectation study to determine the expected average number of events during which system capacity is unable to meet CAISO system load. A commonly accepted reliability target is 0.1 days per year.

The ELCC quantifies the contribution of the resources or group of resources to resource adequacy by assessing the resource’s ability to avoid a loss of load event considering inputs such as expected load, forced outage rates, transmission constraints, etc. When calculating the ELCC for wind and solar, a ratio of the ability of a resource to avoid loss of load compared to a perfect generator is used and a monthly, system-wide ELCC value to wind and solar resources to determine the qualifying capacity is assigned.

ELCC % = (MW of Perfect Generator) / (MW of resource being studied)

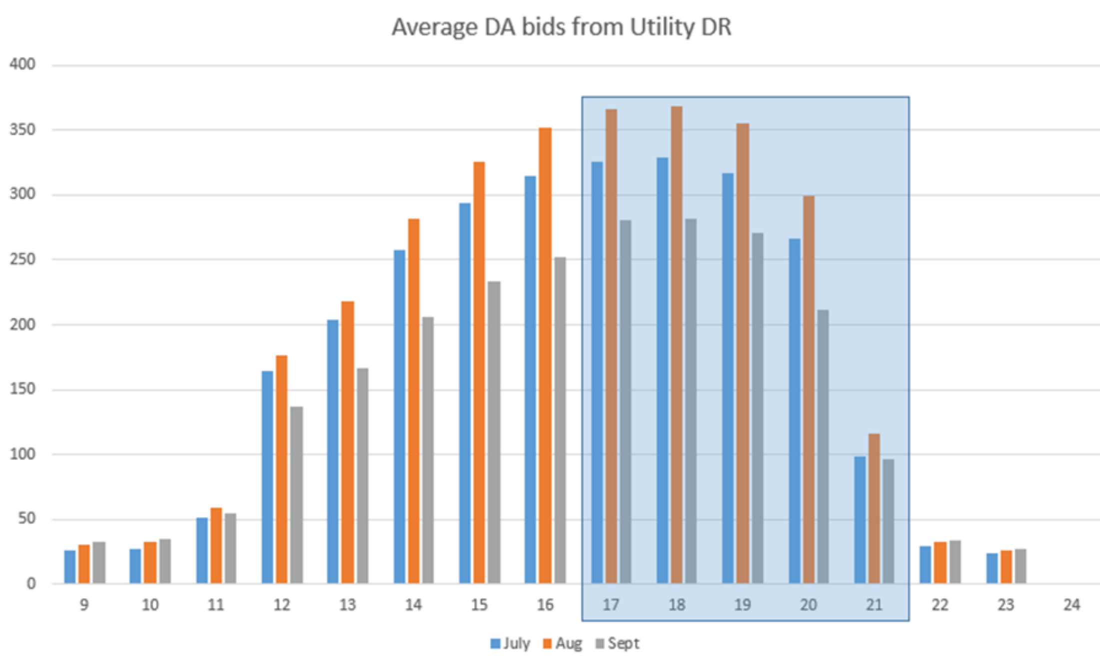
The ELCC value is a percentage applied to the nameplate capacity of a resource to determine the qualifying capacity. For example, a perfect generator would have an ELCC equal to 100%. A resource with an ELCC of 50% would be half as effective at reducing loss of load expectation as a perfect generator. If a solar resource had a nameplate capacity of 100 MW and a 50% ELCC, the resource adequacy qualifying capacity would equal 50 MW. As discussed below, because demand response does not have a nameplate value like wind, solar, or other generators, an alternative method for determining the maximum capability of a demand response resource should be defined.

Using ELCC to assess the capacity value of variable-output demand response

The CAISO believes the ELCC method can and should be applied to variable-output and use- or availability-limited demand response resources. This type of assessment is appropriately applied to resources whose output is variable or potentially limited based on its use. Its application to variable-output and use- or availability-limited demand response will provide a more accurate assessment of the actual load impact and load-sustaining capability variable-output demand response resource can provide the system.

The CAISO has observed bidding by demand response resources that suggests variability in the underlying load profiles of the resource. Figure 15 below shows average day-ahead bids on non-holiday weekdays from utility-operated demand response programs in July, August, and September of 2019. These programs are not shown on monthly resource adequacy supply plans and instead are credited toward the LSE's resource adequacy requirements by the CPUC. Because these resources are not listed on supply plans, they are not subject to the must offer obligation and associated RAAIM charges for not bidding in the availability assessment hours. The 2019 availability assessment hours (HE17 to HE21) are highlighted by the blue box. As the bid data reflects, utility demand response available to the CAISO through bids varies over the course of the day.

Figure 15: Average Day-Ahead Bids from Utility DR (2019)



The shaped availability of utility-operated demand response resources shows these resources do not provide a fixed load reduction in all hours of the resource adequacy month. As such, their capacity value is more appropriately assessed on the resources availability and capability when it is needed considering load levels and the contribution from the rest of the resource adequacy resource fleet. It is not appropriate to treat variable demand response resources as if they are fixed resource adequacy resources that are capable of delivering a fixed resource adequacy capacity quantity in all hours under their must offer obligation.

The current load impact protocols are too limiting and only considers a resource’s own load reduction capability in the resource adequacy measurement hours of the monthly peak day. This does not necessarily align with when resources are needed to avoid a loss of load event when considering the availability of other resources on the system, especially as the system grows more dependent on variable energy resources and retires fuel-backed resources. The load impact protocols assess the load impact of an individual program rather than the reliability contribution of a resource given its limited availability and the availability of the rest of the resource fleet. The ELCC considers the ability of a portfolio of resources to avoid loss of load at a system level. It is important to consider the portfolio of resources because the reliability contribution of a resource or class of resources can vary depending on the makeup of the other resources in the portfolio used to meet the resource adequacy need.

Variable-output and use- and availability-limited demand responses should be considered under an ELCC methodology to determine their qualifying capacity values since the ELCC can capture the incremental benefit of a demand response resource to system reliability across multiple hours while considering the impact of the entire demand response and variable energy resource portfolio.

Once an ELCC methodology is adopted for demand response, the CAISO believes resource bids could inform the ELCC calculation to reflect resource availability. As outlined in the section below, the CAISO proposes to allow variable-output demand response resources to bid their expected capability to meet their must offer obligation. Once demand response resources bid the amount they are physically capable of providing, the bids should accurately reflect the capability of the resource. This bidding profile could then be used as an input into the ELCC to evaluate variable-output demand response’s reliability contribution.

Some stakeholders asked the CAISO how to determine a “nameplate” value for demand response to apply an ELCC percentage to. The CAISO agrees with stakeholders that demand response does not have a precise “nameplate”, like a wind, solar, or other generating units. However, the maximum capability of a demand response program can and should be estimated using an established set of guidelines to determine the maximum MWs of load reduction a demand response program can provide under 1 in 2 peak load weather conditions based on historical capabilities. While the precise methodology for determining nameplate could be further refined, the load impact protocols are a reasonable approach to establish this value. Analysis performed as part of this stakeholder process was performed by calculating ELCC values on profiles of demand response availability (forecasted capability used for submitting bids) and comparing those values to existing net qualifying capacity values as an initial starting point and point of comparison.

ELCC Study

In parallel with this initiative, the CAISO contracted with E3 to develop an analytical framework to evaluate the resource adequacy value of demand response using an ELCC. Through this effort, E3 has simulated the capacity contribution of demand response in their Renewable Energy Capacity Planning (RECAP) model. Results of this work have been presented to stakeholders throughout the ESDER 4 stakeholder process for stakeholder consideration, including allocation of ELCC to different demand response programs.[40]

6.3 Market participation and must offer obligations for variable-output demand response

Resource adequacy resources have must offer obligations to bid into the CAISO market the amount of net qualifying capacity the resource has shown in their supply plan. Demand response resources on supply plans are required to bid into the CAISO markets according to tariff sections 40.6.1 and 40.6.2. In general, resource adequacy resources are required to bid into the day-ahead market its shown capacity all hours of the day the resource is not on outage. The CAISO allows demand response to bid in the hours specified within their program established by the local regulatory authority. If the resource does not bid its shown resource adequacy in the availability assessment hours, it could be assessed a non-availability charge through RAAIM. Because most if not all demand response programs exhibit variability, and the QC valuation process gives DR a single value for the purposes of RA counting, resources risk being assessed RAAIM penalties in hours they cannot bid all of their shown resource adequacy capacity.

In the event local regulatory authorities adopt the ELCC methodology for determining the qualifying capacity for demand response, the CAISO proposes to address this issue by allowing variable-output demand response resources to bid the amount they are physically capable of providing, rather than the shown amount of net qualifying capacity, in order to meet their must offer obligation. Today, variable energy resources receive similar treatment. Scheduling coordinators for variable energy resources must either use a forecast provided by the CAISO or submit their own CAISO-approved forecast. Bids are submitted every hour, and the forecast is used to set the upper economic limit on these bids, such that the resource is not dispatched above its forecasted capability in any interval. Therefore, the maximum MWs dispatched by the CAISO for a variable energy resource could be at, above, or below the net qualifying capacity value depending on the resource’s forecasted output. Wind and solar resources are exempt from RAAIM penalties for local and system resource adequacy. CAISO proposes to adopt similar must offer obligation rules upon adoption of an ELCC methodology by the local regulatory authority.

The CAISO considered two options for the type of real-time data submission required to enable these resources to bid to their capability. The first option would require resources to submit their forecasted capability in real-time on a 15- or 5-minute basis to

[40] http://www.caiso.com/InitiativeDocuments/E3Presentation-EnergyStorage-DistributedEnergyResourcesPhase4-May27-2020.pdf

reflect any updates to real-time capability after bid submission. This way, resources could still submit bids 75-minutes prior to the operating interval, as is done today. Then, if their capability changes between when they submit their bids and the operating interval, the most recent forecast would set the upper economic limit on the resource's bids and the amount the resource could be dispatched. This option would be required to ensure feasible dispatches that do not exceed the resource's capability if the resource's capability regularly changes between bid submission and the operating interval. Because demand response resource performance is largely dependent on consumer behavior, the CAISO does not have the appropriate visibility into individual resource capabilities to forecast load reduction for these resources. Therefore, the resource scheduling coordinator would need to submit this capability.

The second option would allow resources to reflect their capability through their bids into the day-ahead and real-time markets. Bids are submitted in hourly granularity. The CAISO has received feedback from stakeholders that many demand response resources do not have intra-hour variability that would require more granular submission of resource capability to ensure feasible dispatches. In this case, it seems unnecessary for resources to provide real-time data after T-75 to reflect their capability. Instead, resources should reflect their capability through their bids, which are submitted on an hourly basis 75 minutes prior to the operating interval for the real-time market.

The CAISO received stakeholder feedback on these two options and based on this input, the CAISO believes it is appropriate to allow variable output demand response to reflect variability through their bids, which are submitted every hour, rather than more frequent data submission of resource availability, such as every 15 or 5 minutes. Several stakeholders have indicated to the CAISO that more frequently updated availability is likely not needed for the current demand response programs participating in the CAISO market, and that their availability can be reflected under the existing timeline for bid submission (hourly at T-75). Additionally, some stakeholders indicated that requiring resources to have more stringent data submission requirements would likely be cost prohibitive, without providing additional benefits. Given this, the CAISO proposes resources bid their availability, considering resource availability will generally not change throughout the course of the operating hour. If capabilities of demand response programs or grid needs shift in the future, the CAISO could revisit this requirement.

Additionally, the CAISO proposes the scheduling coordinator for the resource submit bids reflective of the resource's capability, as determined by the demand response provider, to fulfill its must offer obligation. The capability of the resource could be at, above, or below the shown capacity value specified in the supply plan. Under this proposal, the CAISO would exempt variable-output demand response that bids its availability from RAAIM, similar to wind and solar. If a resource does not have variable-output and can provide consistent load reduction throughout the RA month and year, the CAISO proposes the resource bid its full shown resource adequacy value, consistent with the standard 24/7 must offer obligation.

Variable output demand response will be required to bid full capability into both day-ahead and real-time markets, until the proposed revisions to the real-time resource adequacy must offer obligation is implemented in Day-Ahead Market Enhancements and Resource Adequacy Enhancements.[41, 42] In those initiatives, the CAISO is proposing day-ahead must offer obligations for all resource adequacy resources and real-time must offer obligations for all resources with day-ahead awards. Upon implementation of those initiatives, variable-output proxy demand resources will be required to bid their full capability in the day-ahead market in all hours it is available and for all products it is eligible for and required to provide. Like other resources, its real-time must offer obligation will be based on day-ahead market awards.

Given the CAISO proposes to exempt variable output demand response resources from RAAIM in this initiative, it is important to ensure resources are still incentivized to bid the resources' true capability. In the event the adopted ELCC methodology does not result in these resources bidding their full capability, the CAISO could consider additional means to incentivize availability in other initiatives such as Resource Adequacy Enhancements.

7 Next Steps

The CAISO will hold its final stakeholder call on August 27, 2020 to review the Final Proposal with stakeholders, highlighting the changes from the Draft Final Proposal and solicit final proposal comments requested for submission by September 10, 2020.

8 Stakeholder Process

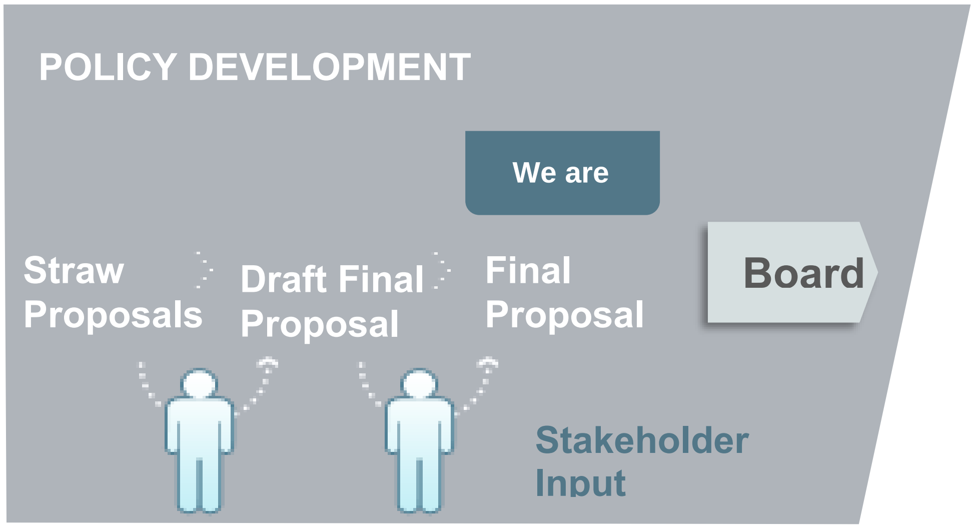
The CAISO is at the "Final Proposal" stage in the ESDER 4 stakeholder process. Figure 16 below shows the positioning of the Draft Final Proposal within the overall ESDER 4 stakeholder initiative.

The purpose of the final proposal process is to present the final CAISO proposals which, having been vetted with external stakeholder throughout the process and reviewed with internal stakeholder for implementation impact, presents the final proposed solutions of identified issues related to the integration, modeling, and participation of energy storage and DERs in the CAISO's market. The CAISO incorporated stakeholder feedback received through comments and working group meetings to develop, enhance, and update final proposals for this initiative. After publication of the Final Proposal, the CAISO will hold one last conference call to review updates and clarifications to the proposals detailed in the draft final proposal and highlighted in this paper finalizing them for presentation to the CAISO Board for their approval.

[41] For a detailed description of must offer obligations for RA resources, see the RA Enhancements stakeholder initiative webpage: http://www.caiso.com/StakeholderProcesses/Resource-Adequacy-Enhancements

[42] For a detailed description of proposed new products and eligibility requirements and the real-time must offer obligation, see the Day-Ahead Market Enhancements stakeholder initiative webpage: http://www.caiso.com/StakeholderProcesses/Day-ahead-market-enhancements

Figure 16: Stakeholder Process for ESDER 4 Stakeholder Initiative



9 Energy Imbalance Market Classification

CAISO staff believes that ESDER 4 involves the Energy Imbalance Market (EIM) Governing Body's advisory role to the Board of Governors (Governing Body – E2 classification). This initiative proposes changes to the non-generator resource and proxy demand resource model, with the aim of reducing barriers to participation and enhancing the ability to provide services in the day-ahead and real-time markets. While proposed enhancements will be applicable to EIM participants, there are no changes specific to EIM balancing authority areas.

All of the new proposed features would apply generally throughout the CAISO market, and thus be advisory for the EIM Governing Body.