Opinion on
Day-Ahead Market Enhancements (DAME)

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I. Introduction

The Market Surveillance Committee has been asked to comment on the revised proposal for Day Ahead Market Enhancements (DAME).[2] Elements of this proposal were further revised in an addendum focused on the demand curve for Imbalance Reserves (IR).[3] Our opinion focuses on the aspects of the proposal addressing the definition and pricing of IR; the interaction of IR with other elements of the CAISO market design, including the day-ahead residual unit commitment (RUC), congestion revenue rights, and flexible ramp product (flexiramp, FR); and the need for careful testing and evaluation of the performance of IR and the constraints in the market software that limit when and from whom IR is procured.

In preparation for this Opinion, the MSC has held multiple public meetings on the development and elements of the proposal. Meetings in which DAME where held on March 10, 2023; February 11, May 13, September 26, and December 12, 2022; May 21, August 27, and November 19, 2021; March 13, July 30, and December 11, 2020; January 25, June 17, and August 19, 2019; and April 5, June 7, September 28, and December 7, 2018.

This opinion is structured as follows. In the next section, we summarize our major conclusions. Then in Section 3, we provide detailed comments about the elements of the DAME proposal. In Section 3.1, we address the definition of the imbalance reserve product, including requirements

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[1] The opinions in this document reflect the personal views of the members of the committee and do not necessarily represent or reflect the views of any institutions with which they are affiliated.

[2] California ISO, *Day Ahead Market Enhancements Draft Final Proposal*, April 6, 2023, www.caiso.com/InitiativeDocuments/DraftRevisedFinalProposal-Day-AheadMarketEnhancements.pdf. The CAISO issued a revised version on May 1 (California ISO, *Day Ahead Market Enhancements, Revised Draft Final Proposal*, May 1, 2023, www.caiso.com/InitiativeDocuments/RevisedFinalProposal-Day-AheadMarketEnhancements.pdf). Most page references in this Opinion to the DAME proposal refer to the version of April 6.

[3] California ISO. *Day Ahead Market Enhancements Addendum: Imbalance Reserve Demand Curve*. April 19, 2023, http://www.caiso.com/InitiativeDocuments/Addendum-ImbalanceReserveDemandCurve-Day-AheadMarketEnhancements.pdf.

that a resource has to satisfy to provide IR (Section 3.1.1) and the proposed constraints to ensure nodal deliverability of IR (Section 3.1.2). Four price formation elements are the subject of Section 3.2. These include: definition of the demand curve for IR (Section 3.2.1); market power mitigation (Section 3.2.2, including mitigation of capacity offers and real-time energy costs in Sections 3.2.2.1 and 3.2.2.2, respectively); non-performance penalties (Section 3.2.3, addressing IR and reliability capacity selected in the day-ahead residual unit commitment (RUC) process, in Sections 3.2.3.1 and 3.2.3.2, respectively); and the relationship of IR and RUC prices (Section 3.2.4). The last five subsections of Section 3 address, respectively, the impact of nodal IR flows upon congestion revenue and rights to those revenues (Section 3.4); the need for IR in the downward direction (Section 3.5); constraints upon provision of IR from short-term storage resources (Section 3.6); IR cost allocation (Section 3.7); and our recommendations for testing and evaluating IR design features and parameters prior to and during implementation (Section 3.8).

II. General Conclusions

As we stated in our previous Opinion[4] on the CAISO's Extended Day-Ahead Market (EDAM),[5] we agree with the assessment of many stakeholders that there are significant potential benefits to an expansion of the current west-wide energy-imbalance market into an operationally feasible day-ahead market design. Most power trades well in advance of real-time markets, and commitments often must be made day-ahead to ensure that fuel and resources are available to manage real-time imbalances. There is abundant empirical evidence that day-ahead markets, such as the CAISO IFM and RUC processes, can improve the efficiency of power-system operations and lower the cost of serving customers. These benefits stem from both the ability of such markets to optimize and deploy resources across relatively large footprints and the removal of various trading frictions that increase transaction costs in existing trading hub-based markets.

The proposed day-ahead market enhancements address several key market design issues that we believe must be addressed in order for the EDAM initiative to achieve its goals to enhance efficiency and reliability across the west. Notably, the creation of day-ahead products designed to enable power systems to effectively manage real-time load imbalances that arise from day-ahead net load forecast errors and unexpected net load ramps is, we believe, a prudent feature to add to the ISO administered day-ahead market. This is especially true as the rapid increase in variable renewables increase the likelihood of more extreme forecast errors and ramps.

The issues that the DAME initiative addresses are very important, not just for the success of the Extended Day Ahead Market initiative, but for improving the efficiency and transparency of the CAISO market. The extensive degree to which the current CAISO market relies upon operator

[4] James Bushnell, Scott M. Harvey, and Benjamin F. Hobbs, *Opinion on Extended Day-Ahead Market*, Market Surveillance Committee of the CAISO, Jan. 27, 2023, www.caiso.com/Documents/MSCFinalOpiniononExtendedDay-AheadMarket.pdf.

[5] *Extended Day-Ahead Market, Final Proposal*, CAISO, December 7, 2022, www.caiso.com/InitiativeDocuments/FinalProposal-ExtendedDay-AheadMarket.pdf.

judgement to bias load in various market runs has been a significant and under-appreciated issue for many years.[6] While such operator interventions may be necessary to maintain stable operations, they can have a substantial impact on market outcomes and almost certainly result in a sub-optimal deployment of internal resources and intertie schedules. The chronic longstanding differential between prices in the Hour Ahead Scheduling Process (HASP) and the fifteen minute real-time market is but one example of these impacts. Another is the large amount of additional residual unit commitment (RUC) that operators consistently create through load adjustments during periods of tight conditions. These create hidden costs often recovered through uplift or complicated interactions with resource adequacy and other procurement markets.

Therefore, we agree that integrating as much of this non-market activity as possible into the actual market would increase transparency and allow for operator concerns to be met through market optimization, rather than the ad-hoc tools at operator disposal. The creation of a co-optimized additional imbalance reserve (IR) product, as well as updating the current RUC system into a reliability capacity (RC) process, and improving the modeling of storage state of charge, are sensible concepts that can potentially advance these goals. We therefore support the CAISO proposal, with the testing and monitoring framework laid out in the parameters table.

That said, many significant uncertainties surround the current proposal. Important fundamental elements such as the methods for calculating the amount and location of IR to be acquired and constraints on deliverability and storage provision of IR are untested and may require further development. The degree to which the CAISO is able to accurately estimate locational uncertainty will be an important factor in determining the benefit of procuring IR nodally rather than zonally. Without a fully specified methodology for calculating the quantities demanded from the market, it is impossible to credibly estimate the price and cost impacts of the design.

Other key elements that may need to evolve over time include, but are not limited to, the fact that IR supply will be limited 30 minute rampable capacity, the fact that IR schedules will be locked in at high penalty prices during the sequential RC run, uncertainty about what parameters in the state of charge equations will strike an appropriate balance between risk of storage IR non-performance and the cost of acquiring IR. There are also elements related to interactions with the EDAM design, such as the interaction between IR requirements and the resource sufficiency test, and the BAA level export cap that may need to be adjusted with experience.

Furthermore, many of the benefits of these changes hinge upon their impact on operator behavior. As described above, a high level objective of the initiative is shifting procurement away from ad-hoc load biasing and into more formal optimization objectives. However, if the new

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[6] See, for example, G. Bautista Alderete and K. Zhao, "Day-Ahead Market Enhancements Analysis," CAISO Market Analysis and Forecasting, Jan. 24, 2022, www.caiso.com/InitiativeDocuments/Day-AheadMarketEnhancementsAnalysisReport-Jan24-2022.pdf

products do not satisfy operator concerns, the market could continue to experience substantial load-biasing and RUC commitments.

A core fact is that while some elements of the CAISO DAME proposal draw upon design elements for two settlement systems and real-time optimization of energy and ancillary schedules that have been in operation in MISO and NYISO for more than a decade, there are many elements of DAME for which there is no precedent of successful operational experience in other ISOs to learn from. These include the design of the deployment scenarios, methods for estimating net load uncertainty, procedures for assigning net load uncertainty to locations, and methods for accounting for storage resource state of charge over the day in the IFM and RUC. The CAISO is the innovator in addressing these issues and will need to adapt the design over time based on the results of testing the full software model when it is developed, and then again based on operational experience.

This adaptation will need to move at a more rapid pace than the glacial speed of typical stakeholder processes if it is to enable the CAISO and the WECC to meet the reliability needs of its evolving resource mix and public policy goals. At the same time, the CAISO should not be given permission to make willy-nilly day-to-day changes in parameters or constraints. There needs to be a process for identifying issues and discussing them with stakeholders, proposing then implementing changes, observing outcomes, and then commencing new cycles if needed. We support the stated intention of the CAISO in the Revised Final Proposal to inform and consult carefully with stakeholders in tuning the configurable parameters of the DAME design during testing, implementation, and go-live, and to work with the Department of Market Monitoring to report independently on the performance of alternative parameters and settings before and after implementation.[7]

Given the many new market design concepts, as well as implementation choices, embodied in CAISO proposal, we believe it is reasonable to take a conservative approach to implementation. This would involve both substantial testing before implementation and putting guardrails in place at least through a transition period. One critical element is the "demand curve" for imbalance reserve that will set penalty values for relaxing the IR constraint. These values will influence not just the cost of IR but also energy prices in the IFM. If these penalty values are set too high, they could result in a substantial increase in energy prices. We believe that revisions to the DAME proposal announced in late April to harmonize the IRU demand curve between the ISO and non-ISO BAAs, to base the calculation of the sloped portion of its demand curve on a penalty of $247/MWh, and to cap IRU prices at $55/MWh are consistent with our recommended conservative approach. Should experience show that higher prices are necessary in order to elicit needed IR from the market, the demand curve parameters could then be adjusted.

[7] Op. cit., page 6. See also CAISO, "Flexible Parameter Matrix," May 1, 2023, www.caiso.com/InitiativeDocuments/FlexibleParameterMatrix-Day-AheadMarketEnhancements.pdf.

The many new design elements in the CAISO proposed DAME design, as well as the ambitious scale and scope of the combined EDAM and DAME initiatives, together imply that there are almost certainly "unknown unknowns", as we pointed out in our EDAM opinion. These will become apparent only as the initiative proceeds further toward implementation. A common theme in the EDAM and present opinions is the need for detailed pre-implementation software testing and simulation to assess the impacts of different model specifications and parameters, as well as to evaluate how the pieces fit together and function. We agree that this is an appropriate time to take the first formal steps to creating the IR products and implementing the other proposed DAME elements. As with the Boards' decision to initiate EDAM last January, we believe that enabling the CAISO to proceed with software development based on the proposed DAME design is a necessary next step that will enable stakeholders and policy makers to complete the hard work that needs to be done to successfully implement the vision of a West-wide day-ahead market.

Given the large potential benefits at stake, and the reality that the evolution of the WECC resource mix will not wait for further improvements to the proposed design, progress on the DAME and EDAM initiatives is crucial. However, as we note in our EDAM opinion, approval at this time should be viewed as an important intermediate, but no means final, step in the design and implementation process. As we noted in the EDAM opinion, the DAME and EDAM designs contain a number of design elements that have not been tested in other ISOs but are important elements of the proposed design. The proposed DAME design will benefit from adjustments based on experience from pre-implementation software testing and subsequent operations. The likelihood that EDAM will begin operation with a small set of balancing areas that will expand over time will help the CAISO and other EDAM participants improve the design with accumulating experience. The proposal that the CAISO would exercise the flexibility it proposes to build into the software will, we believe, contribute to allowing parameters to be adjusted with needed stakeholder input without undue delay.

III. Comments on DAME Elements

In Section 3.1, we comment on two aspects of the imbalance reserve (IR) product definition: the restriction that only 30-minute rampable capacity would be acquired, that a nodal model would be used to constrain where it would be acquired, and the effects of state-of-charge constraints upon storage participation in the IR and RUC markets. Section 3.2 addresses price formation issues, including the IR demand curve, market power mitigation, non-performance penalties, interactions between IR and RUC pricing, and IR settlement issues posed by energy exports. Finally, in Sections 3.3 through 3.8, we turn to issues associated with congestion revenue rights and revenue shortfalls; IR down; procurement of IR from storage; IR cost allocation; and testing and evaluation, respectively.

3.1 IR Market Design: Product Definition

3.1.1 *Requirements for Capacity Providing IR*

The supply, storage, and demand-side resources that are eligible to provide imbalance reserves must be dispatchable in the fifteen-minute market. Their imbalance reserve awards would be limited to their 30-minute ramping capability.[8] The requirement for such resources in the upward direction is the 97.5th percentile error for day-ahead forecasts of net load, while the amount in the downward direction must be enough to cover the 2.5th percentile.

We believe that the originally proposed requirement that <u>all</u> imbalance reserves can be deployed in 15 minutes was overly conservative, and would likely increase the cost of meeting the requirement (or, alternatively, result in procurement of less than the requirement, with the demand curve setting the price). The reason is that net load forecast errors tend to be highly (and positively) autocorrelated, with errors in hour h+1 tending to be the same sign as errors in hour h. Error signs and magnitudes tend to persist over time. Figure 1 below shows an example of day-ahead and real-time (15 minute) load forecasts for the CAISO for one day— in this case day-ahead forecasts tended to be too low from 8 am to 5 pm, and too high from 7 pm to 10 pm. Figure 2 shows similar data for a 9 day period in March 2023. Examples of periods over which error signs and even magnitudes persisted for multiple hours are hours 24-72 (day-ahead overforecasts) and 72-96 (day-ahead underforecasts).

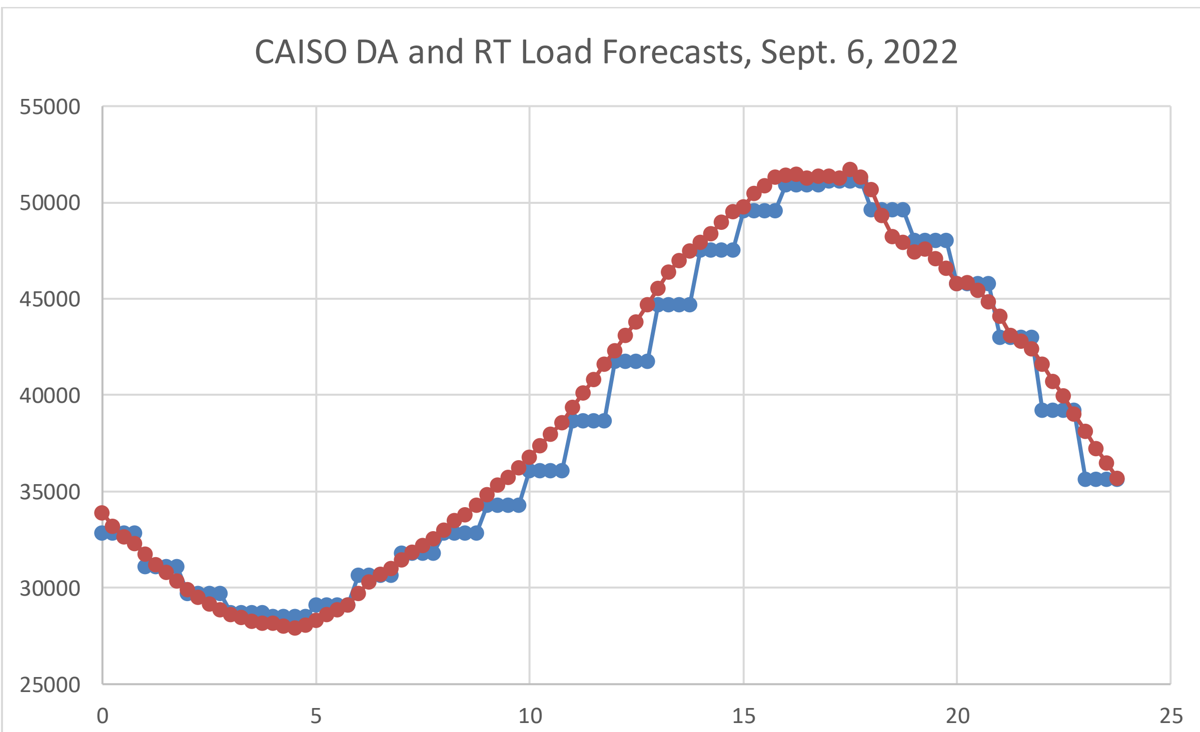

Fig. 1. Comparison of one day's net load forecasts (day-ahead in blue, RTPD 15 minute forecasts in red) illustrating persistence of over- and under-forecasts

[8] However, imbalance reserves provided by off-line resources would continue to be limited to those that can come on-line within 15 minutes.

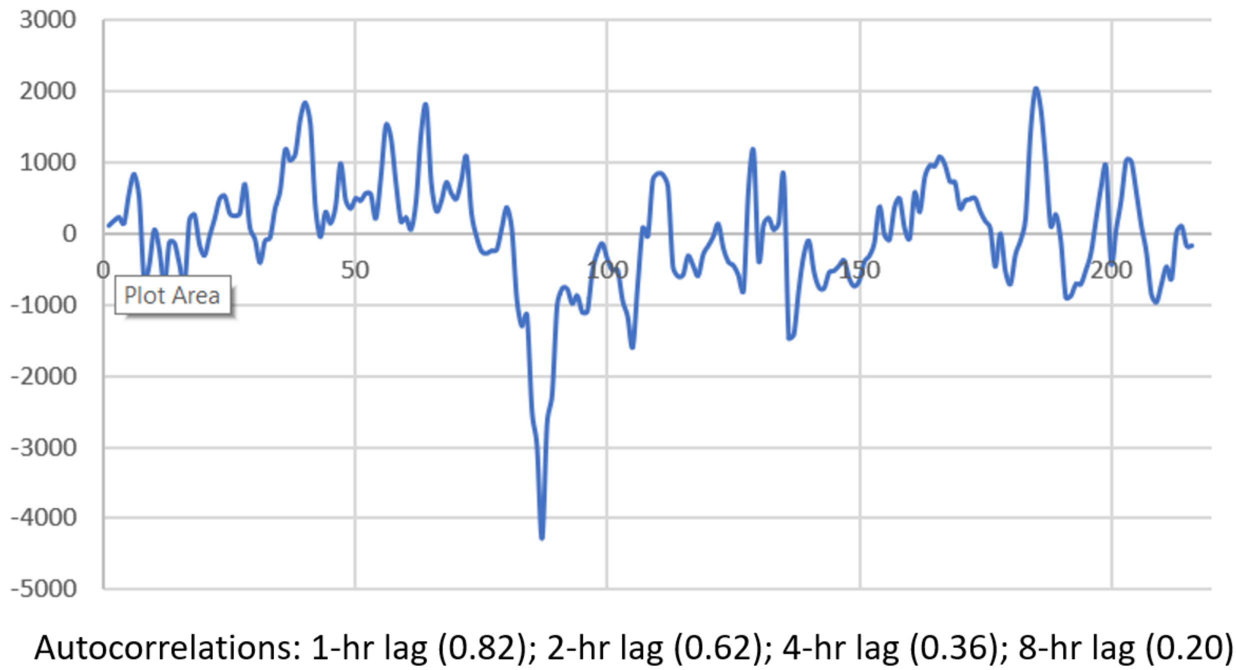

Fig. 2. Normalized net load forecast errors: March 1-9, 2023, illustrating the tendency for error signs to persist. (Errors calculated as difference between day-ahead and RTPD forecasted load minus wind + solar. Errors normalized so each hour (1,2,..,24) has zero mean error over this 9 day period. Note: actual loads are not used due to inclusion of storage charging in actual load data.)

Figure 2 shows that errors in different hours are highly autocorrelated, meaning that if that if an error is, say, positive in one hour, it is likely to be positive in several subsequent hours. The prevalence of such autocorrelations in forecast errors means that it is relatively rare to see large swings in the magnitude and signs of errors from fifteen minute to fifteen minute interval. To require that all IR capacity be able to respond in 15 minutes in a sense presumes that forecast errors do not reduce as you move from day-ahead to, say, 6 hours ahead, to 3 hours ahead, and to real time. In a sense it is as if the system has to be ready to deploy all its IR with only 15 minute notice. In reality, the slow movement in forecast errors and their reduction as the forecasting horizon shrinks from a day to a few hours to a few minutes means that operators will usually have a lot of warning if forecast errors are tending towards being, say, large and positive. Procuring some of the imbalance reserve capacity allowing, for instance, 1 hour to ramp across its full range, while requiring only a fraction of the IR to be able to ramp in 15 minutes could provide operators all the flexibility that is needed to manage day-ahead net load forecast errors.

Since there will usually be a lot more 1 hour ramping capability available than 15 minute capability, there is less likely to be scarcity of IR if IR requirements were to be met at least in part with the slower capacity. If our hypothesis is true, little degradation in the ability to manage net load errors would result from doing so. We are therefore supportive of the ISO's revised draft proposal, which changed the 15-minute ramp requirement to a 30-minute ramp requirement. We recommend that the ISO conduct analyses of the performance of deployed IR under realistic conditions to assess whether an additional relaxation to a 60-minute requirement would still provide sufficient 15 minute ramp capability for balancing variations in net load in real-time.[9]

One way to satisfy the need for some, but not all, of the IR to be 15-minute dispatchable would be to define two (or more) types of both IR-up (IRU) and IR-down (IRD), differentiated by their speed of response and each having their own level of requirement. The intent would be that capacity that is dispatchable within 15 minutes would be available for balancing variations in net load within the FMM timeframe while using capacity that would be available over a longer timeframe for balancing day-ahead to real-time forecast error. For instance, there would be a requirement for the amount of 1 hr capacity (to meet the full 2.5% and 97.5% rage of errors), and a smaller requirement for faster capacity. A 500 MW generator that could ramp 5 MW per minute could then provide 75 MW of 15 minute IR, and 300 MW of 1 hour reserve, and could receive payments for both products. We appreciate that the desire for simplicity or to avoid the need for additional near-term software changes may have motivated the ISO's proposal to have just a single 30 minute ramping requirement, but these constraints would be reduced in the long-run.

But if experience shows that the costs of procuring IR are high in part because of scarcity of inexpensive 30 minute rampable capacity, while also showing that the design provides more than the required about of 15 minute dispatch capability in FMM, we would encourage the ISO to consider this more nuanced approach and assess its potential cost savings and effects, if any, on the system's ability to meet net load ramps. Such a bifurcation would also allow the CAISO to utilize off-line resources and demand response with start-up and notification times longer than 15 minutes to meet day-ahead to real-time net load forecast error.[10] Alternatively, experience might show that this approach is desirable to cap the amount of ramp provided in the form of 30 minute capacity, if it turns out that the price of IR is very low because of ample supplies of 30 minute ramp, while at the same time scarcity of 15 minute rampable capacity frequently results in shortages of flexiramp in real-time, accompanied by energy and flexiramp price spikes.

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[9] Our understanding is that one of the original motivations for a sub-hourly IR ramping requirement is that such a requirement would eliminate the possibility of inflexible hourly intertie transactions providing the reserve service. However, with the proposed change to 30 minute ramping capability, the IR framework has now separated the concepts of ramping capacity from that of 15 minute dispatchability. Therefore, even a 60 minute ramp capacity requirement, combined with the proposed requirement for 15 minute dispatchability, would also ensure that only 15 minute dispatchable resources who are eligible to participate in the FMM could supply IR, although the amount of IR they could provide would be their 30 minute rampability.

[10] The current CAISO proposal restricts the supply of IRU to offline resources able to start and ramp up in 15 minutes. It appears to us that resources with longer start up and notification times could be used to cover day-ahead to real-time load forecast uncertainty as these increases in net load materialize with much more notice than 15 minutes. An eventual implementation of a distinct product with a 30 minute or one hour start-up and notification time would enable additional types of resources to meet these balancing needs.

3.1.2 *IR Nodal Procurement*

Nodal and Zonal Procurement Proposals. The CAISO has encountered a continuing series of major issues with the deliverability of flexi-ramp due to within-BAA network constraints, and these issues have had significant market impacts over the past 6 years. It is important to address these deliverability issues more effectively than they have been to date.[11]

The need for an effective delivery test for flexiramp-up (FRU) has been documented in numerous past studies, some of which are identified by the CAISO in section 2.3 of the April 6, 2023 Draft Revised Final Proposal. Moreover, as recently as during the September 2022 heatwave zero prices for flexiramp prevailed in FMM in the BAAs around the CAISO, despite little or no unloaded capacity being available within the region around the CAISO. These zero prices for flexiramp during shortage conditions were a result of the lack of a delivery test, which allowed the flexiramp requirement for these regions to be met with capacity that was bottled within the Pacific Northwest.[12]

The requirement that a minimum amount of flexiramp be located within the CAISO BAA that was in effect from November 2020 to February 1, 2023 had the intended result that resources were dispatched across the Western EIM to unload capacity within the CAISO to create flexiramp within the CAISO BAA. However, this zonal requirement was less efficient than the proposed nodal dispatch with deployment scenarios. This is because the prior minimum locational requirement can result in high cost resources being dispatched to unload lower cost resources in the CAISO to meet the CAISO locational ramp requirement, rather than simply relying on the higher cost external resources to provide flexiramp when the system is not transmission constrained. Extending this design to more balancing areas would result in even greater inefficiency.

Nodal scheduling is the CAISO's proposed design for addressing these deliverability issues in both the WEIM and in DAME/EDAM, for flexiramp and IR procurement, respectively. Flexiramp and IR procurement would be constrained to result in feasible network flows in two net load scenarios (upward and downward). There are a number of conceptual issues as well as implementation challenges in implementing the nodal design. The proposed design for evaluating deliverability will almost certainly need to be refined in the future as a result of experience with the flexiramp and IR nodal dispatch implementations. In the meantime, it is reasonable to take a cautious approach to defining penalties for violations of deployment constraints (discussed below) while experience is accumulated in order to avoid risks of extreme unanticipated consequences.

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[11] Other ISOs are beginning to recognize deliverability issues for reserves and are assessing the desirability and practicality of nodal models with full network representations, such as MISO (F. Wang and Y. Chen, Market Implications of Short-Term Reserve Deliverability Enhancement, *IEEE Trans. Power Systems,* 36(2), 2021, 1504-1514).

[12] See Real-Time Daily Market Watch - Sep 06, 2022 (caiso.com) www.caiso.com/Documents/Real-TimeDailyMarketWatchSep06-2022.html

There has also been stakeholder discussion of the potential to implement a zonal IR design instead of a nodal design. As discussed at length at the March 10, 2023 MSC meeting, there are a number of variations on zonal designs, some types of zonal designs would simplify some elements of the IR implementation but create new issues. Other types of zonal designs would be so similar to the nodal design that they are just variations in how some elements of the nodal design would be implemented. As discussed extensively at the March 10, 2023 MSC meeting,[13] the various choices have the potential to simplify the resolution of some issues, while complicating others and potentially creating new ones.

For example, specifying a minimum procurement target for a series of zones would avoid the need to apply a nodal delivery test but would give rise to other serious issues. First, such a design would exacerbate market power concerns because resources outside a zone could not provide IR even when there is no congestion on transfers into the zone. Second, for the same reason, such a design would greatly reduce the potential benefits to the EDAM, because each zone's requirement would have to be met with resources within the zone, even if cheaper IR supply was available outside the zone. Third, this design would have the potential to schedule imbalance reserves on resources located behind binding transmission constraints within individual zones.

An alternative approach would be to define zonal requirements, but enable the zonal requirement to be met with imported imbalance reserves. This approach would intrinsically require a delivery test, or else it would simply expand the current dysfunctional FRP design. Such a design could utilize a simplified zonal model in the deployment tests, which might improve solution times. As discussed on March 10, this kind of simplification in the application of the deployment test is an option that has been built into the CAISO nodal design, with the CAISO having the ability to select which constraints are enforced in the deployment test. If only inter-zonal constraints were tested in the deployment scenarios, this design would also have the potential to chronically schedule imbalance reserves on resources behind constraints within individual zones. However, we understand that the CAISO software implementation will have the functionally to selectively enforce constraints so as to reduce the scheduling of bottled IR , while also managing solution time and potentially other issues related to the number of constraints enforced in the deployment scenarios.

Some stakeholders have suggested that the CAISO's nodal dispatch design is inconsistent with the approach other ISOs are taking to manage deliverability, and that other ISOs have been able to avoid deliverability problems without moving to a nodal dispatch type design. Our view is that this is not the case. Both MISO and SPP are having deliverability issues under their current

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[13] Scott Harvey, "Zonal and Nodal Delivery Tests for Imbalance Reserves and Flexiramp", Presentation, CAISO MSC Meeting, March 10, 2023, www.caiso.com/Documents/Day-AheadMarketEnhancementsZonalIBRDesign-Presentation-Mar10_2023.pdf.

designs. Moreover, rather than moving in a different direction, the NYISO's dynamic reserve design is moving towards a CAISO type design to manage its transmission system, which will have to deliver much higher projected levels of intermittent resource output in New York state over the next decade without undue consumer costs. We discuss these observations in greater detail below.

Some stakeholders suggested that the design and performance of SPP's ramping product provides an alternative to the proposed CAISO nodal dispatch design. On the contrary, our review of the performance of the SPP ramp product design finds that it provides strong support for the CAISO DAME and nodal dispatch design. First, as proposed in DAME, the SPP product is scheduled both in the day-ahead market and in real-time. Second, the SPP market monitor has found that the SPP product has problems with deliverability due to the lack of a deployment test, with a considerable amount of the ramp capacity stranded behind transmission constraints.[14] Third, the market monitor expresses a concern that the lack of offer prices is limiting participation in the market.[15]

Like the CAISO, the MISO has had issues with the deliverability of resources scheduled to provide the ramp capability product. MISO's recent filing in docket ER23-1195 to disqualify VERs from providing ramp was largely motivated by a need to reduce procurement of undeliverable ramp product.[16]

While the MISO ramp capability product originally had a demand curve with the uniform $5 price, the MISO has since shifted to a ramp capability product with shortage prices ranging up to $31/MWh.[17] In addition, the MISO demand curve for spinning reserves has a step with a $65 shortage price.[18] Hence the MISO demand curve with penalty prices gradually rising up to $31,

[14] SPP Market Monitoring Unit, State of the Market, Summer 2022, Oct 31, 2022, pp. 69-70, see finding 2) that "much of the ramp capability is procured behind congestion, which is thus unable to be dispatched to meet ramping needs."

[15] SPP Market Monitoring Unit, State of the Market Summer 2022, Oct 31, 2022 p. 70, see recommendations 3) and 4) that "the market clearing price is too low, thus not providing meaningful incentives to provide more ramp, especially given the increase in natural gas prices over the past several month," and "if the market clearing price was set by the resources and not opportunity costs, the price would be higher and would likely encourage more participation in this product."

[16] See MISO filing letter in Docket ER23-1195-000, p. 2: "MISO's market engine is currently incapable of automatically screening out undeliverable capacity from both DIRs and non-DIRs… the proposed disqualification of DIRS from providing the Ramp Capability Products is a necessary temporary solution until appropriate market design and system changes can be developed and implemented by MISO in the next several years." See also the affidavit of David Patton, paragraphs 7 and 8.

[17] MISO Tariff Schedule 28 Section VI.

[18] MISO Tariff Schedule 28 Section V.

then to $65 is generally consistent with the revised CAISO proposal. The MISO also has a 30 minute reserve product (short-term reserves) with steps ranging from $100 to $500.[19]

Finally, some stakeholders have suggested that the NYISO's proposed dynamic reserves design is based on a zonal formulation of reserve requirements that would provide an alternative to the CAISO proposed nodal design. In fact, the NYISO's dynamic reserves project is focused on moving away from static zonal reserve requirements and instead allowing reserves to be provided from resources located outside the reserve region. The NYISO design is therefore completely consistent with the CAISO nodal dispatch design and the use of unloaded transmission to deliver reserves.[20]

Overall, the CAISO's nodal software implementation has the ability to apply deliverability tests to reduce the extent to which IR cannot be dispatched to balance net load uncertainty in real-time as a result of transmission constraints, while also having the functionality to be adjusted to manage solution time or other issues.

Other Issues. Four other sets of issues related to the design of the nodal dispatch have been raised by stakeholders and the MSC.

First, the assignment of up and down BAA level uncertainty to particular nodes in the up and down deployment scenarios models are just two possible realizations of net load uncertainty. However, there will actually be a dispersion of net load uncertainty outcomes in the FMM. Testing deliverability against a single upward realization in a single deployment scenario can overstate the need for upward imbalance reserves at a particular location. This could result in procurement of imbalances reserves located inside a load pocket at an undue cost. A more likely outcome if the demand curve is set at moderate levels is that the imbalance reserves would not be procured inside the load pocket and also would not be procured elsewhere, resulting in a reduction in the overall imbalance reserves that would be scheduled.

One element of the proposed deployment scenario design is that the deployment scenarios are envisioned to use the same transmission penalty violation factors that are used for transmission constraints in the IFM solution. However, the amount of (upward) net load uncertainty modeled within a load pocket is a single representation of many possible outcomes with more or less net load uncertainty realized within or outside the load pocket. The outcome in which imbalance reserves are not procured anywhere in the balancing area, or the EDAM, when they are expen-

[19] MISO Tariff Schedule 28 Section VIII.

[20] See Ashley Ferrer, NYISO, Dynamic Reserves, MIWG October 19, 2022, particularly slide 32 describing the goals of the design (www.nyiso.com/documents/20142/33857891/05_20221019%20Dynamic%20Reserves%20MIWG.pdf). See also Scott Harvey, "Dynamic Reserves Examples," September 28, 2022 presented for NYISO, Oct. 4, 2022 MIWG. www.nyiso.com/documents/20142/33562316/20220928%20Dynamic%20Reserves%20Examples%20MIWG%20draft%20revised%20v2%20(002).pdf .

sive within a particular load pocket will tend to underprocure imbalance reserves for realizations of uncertainty in which the increase in net load is mostly outside the constrained region, including when much of the realized net load uncertainty is in other balancing areas that need to draw upon the EDAM diversity benefit.

A fundamental approach to addressing these issues would be for the CAISO to define a larger and diverse set of deployment scenarios, although this poses obvious computational challenges at this time. A more cautious, *ad hoc*, and practical approach at this time would be to use lower transmission penalty factors in the deployment scenarios, for at least some constraints, so that imbalance reserves not procured within a constrained areas because they are too expensive or entirely unavailable would instead be procured outside the load pocket, making them available to meet realizations of net load uncertainty that are not concentrated within the load pocket. We understand that the CAISO has the ability to set different transmission penalty factors in the deployment scenarios than in the base case dispatch But this design option was not discussed in the draft revised final proposal. We urge the CAISO to verify that it has the ability in its software to utilize this functionality and that this functionality is included in pre go-live testing.[21] We believe that this option has advantages over the "tunable parameter" approach in the final proposal discussed below.

As an alternative to utilizing reduced transmission penalty factors in the deployment scenarios, the CAISO has proposed another cautious and ad hoc option that would only include a portion of the incremental deployment scenario output in the transmission flows. While this would at times reduce the impact of constraints in the deployment scenario, the design has a few limitations. First, because there is no penalty price applied for dispatching only a portion of the imbalance reserves in the deployment scenarios, the CAISO alternative would schedule imbalances reserves behind constraints that could bind, even if the cost savings are small. Second, the amount of imbalance reserves flows that could be dispatched in this manner would be 0 for constraints that are binding in the energy dispatch, resulting in the outcome that the imbalance reserves would not be scheduled anywhere if they could not be dispatched to meet net load uncertainty modeled at a particular location.

A second related issue is that the CAISO design estimates net load uncertainty for load, wind output and solar output for the balancing area as a whole, which is then allocated to nodes based on the location of forecast load, wind and solar output. Stakeholders have pointed out that this methodology may not be the best way to model the location of net load uncertainty and may result in too much or too little imbalance reserves being procured within particular areas. For ex-

[21] In recommending that the CAISO develop this functionality, we are not recommending that the CAISO would vary these transmission penalty prices up and down from day to day. Rather, we envision that after the imbalance reserve market has been in operation for a period of time, the CAISO might adjust the transmission penalty prices used in the deployment scenarios, with notice to stakeholders and an explanation of the reasons for the changes. The CAISO would then observe the operation of these parameter changes for a period of time before making further changes. The CAISO has proposed such a process in its May 2, 2023 Revised Final Proposal, as we note at the end of Section II, above.

ample, there may be relatively little net load uncertainty associated with the output of some solar resources on particular days and hours, while there is considerable net load uncertainty associated with the output of resources elsewhere on those day and hours.

We agree with stakeholders that there is a potential to improve the methods the CAISO uses to allocate the MOSAIC estimates of net load uncertainty to balancing areas and to locations within balancing areas. It would be possible for the CAISO to develop and implement a variety of more complex methods of allocating estimated net load uncertainty to particular locations. However, there would be significant complexity to implementing any such alternative design. Moreover, it does not appear to us that it is possible to assess in the abstract which potential enhancements would in practice materially improve the performance of the nodal dispatch as a deliverability test. Rather, the potential to develop better methods for allocating net load uncertainty across the EDAM is something the CAISO and stakeholders will need to work on over time as they observe the operation of the market, and the evolution of the WECC resource mix.

Rather than delaying DAME now in hopes of eventually developing an improved allocation design for modeling the location of net load uncertainty, it appears to us that, first, the CAISO should build some flexibility into the imbalance reserve software to allow the CAISO to make some adjustments to the assignment of net load uncertainty over time as it gains operational experience. Second, the CAISO needs to track whether there are material issues with the assignment of net load uncertainty in FRU over the next two years. Metrics for this would include tracking the net load uncertainty allocated to sub-zonal regions and the FMM realizations on an ongoing basis; monitoring these would provide a growing empirical database to support improvements to the design.[22] Third, the CAISO also needs flexibility to implement adjustments to the formulas used to assign uncertainty to locations with appropriate notice to stakeholders. By this we do not mean that the CAISO should have the flexibility to change parameter values up and down daily with little or no notice to stakeholders. Rather, we recommend that the CAISO should track performance, identify performance issues and discuss the problems and potential resolutions with stakeholders in existing forums. We also do not believe that implementation of needed changes should be delayed for years by requirements to conduct full stakeholder processes. We anticipate that WECC reliability challenges will be growing too rapidly for such a glacial pace of evolving the IRU product to be responsive to the system's changing needs.

A third issue with the CAISO imbalance reserve design is that net load uncertainty is calculated for the model by comparing day-ahead forecasts for load, wind output and solar output to FMM forecasts for load, wind output and solar output. This approach will potentially overstate net load uncertainty to the extent that market participants reflect that net load uncertainty in their bids and offers. That is, if LSEs increase their load bids above the expected load forecast to reflect net load uncertainty, the difference between cleared load and FMM load will be smaller than the difference between the mean load forecast and the FMM forecast. Similarly, if solar resources conservatively offer less than their expected output into the market on days with high

[22] This ongoing evaluation would also enable stakeholders and the CAISO to assess whether some type of regional constraint on IRU and FRU procurement would be beneficial.

output uncertainty, the difference between cleared output and the FMM forecast will be smaller. This might or might not be a significant issue. There are many methodological choices and compromises in the CAISO design that will need to be evaluated over time. Tracking the modeled and actual location of net load uncertainty, tracking constraint shadow prices in the IFM and deployment scenarios and comparing them to constraint shadow prices in the FMM, and tracking the frequency that imbalance reserves in particular regions are constrained down, would over time provide insight into potential improvements, and into whether some of the methodological choices or compromises in forecasting methods are leading to inefficient outcomes.

A fourth issue is that the CAISO deployment scenarios do not test the deliverability of the diversity benefit. The CAISO methodology reduces individual BAA imbalance reserve requirements by the estimated diversity benefit. The deployment scenarios do not test whether this diversity benefit can in fact be realized. Our assessment is that it would be complex to correct this (for instance, with a larger and more diverse set of scenarios), and that the alternatives are likely to have material solution time impacts. Hence, we do not recommend any changes to the CAISO design to better model deliverability of the diversity benefit. However, we think that the CAISO and stakeholders need to keep in mind the need to assess the degree of assurance provided by the current nodal design that the estimated net load uncertainty balancing requirement will be deliverable.

Another important element of the DAME design that is shared with the WEIM flexiramp design is the development of the MOSAIC model for calculating flexiramp and imbalance reserve requirements.[23] This is also a complex model with many implementation challenges, and resting on a number of statistical and modeling compromises. As we recommended for the nodal dispatch design, we suggest that the CAISO assess the performance of the current FRU uncertainty estimates on an ongoing basis and review the performance of the DAME methodology prior to DAME go-live, and track performance after go-live. The CAISO methodology for estimating net load uncertainty addresses very complex estimation issues and there should be no illusions that the initial model will be perfect, as it will inevitably need to be improved over time.

3.2 IR Market Design: Price Formation Elements

3.2.1 *IR Demand Curve*

The demand curve for IR procurement will determine the prices at which the CAISO will reduce its IR procurement quantities. This element of the proposal has evolved substantially in recent months, with the most recent changes summarized in an addendum to the Draft Final Proposal.[24]

[23] H. Zhou, Flexible Ramping Uncertainty Calculation in the Western Energy Imbalance Market (WEIM), California ISO, March 25, 2022, www.caiso.com/InitiativeDocuments/Analysis-FlexibleRampingUncertaintyCalculationintheWesternEnergyImbalanceMarket.pdf

[24] California ISO. "Day Ahead Market Enhancements Addendum: Imbalance Reserve Demand Curve," www.caiso.com/InitiativeDocuments/Addendum-ImbalanceReserveDemandCurve-Day-AheadMarketEnhancements.pdf.

In general, the ISO should acquire more reserves than is presently the case. Today, the relatively small amount of reserves required to meet mandatory WECC requirements is procured in the IFM at very high penalty prices in the scheduling pass, and additional reserves in excess of the mandatory WECC requirement are *de facto* acquired in RUC. The proposed imbalance reserves is a reasonable vehicle for procuring reserves in excess of the mandatory WECC requirement in the IFM. Markets in other ISOs procure IR-like reserves with graduated penalty prices (e.g., 30 minute reserves in the eastern markets). Such reserves serve a valuable role in lowering the risk of supply shortage and high prices in real time as a result of changes in system conditions, including generation and transmission outages. A demand curve reflecting a declining but positive value of IR as procurement increases is reasonable, while a high penalty for any shortfall below the full IR target is not.

The CAISO is proposing to use a conceptual framework to define IR demand curves similar to the approach used to define flexiramp demand curves. This involves calculating the probability that the procured reserves will be sufficient to cover the net load error (in the case of IR) or net load ramp (in the case of flexiramp), and if not, the probability of various possible MW levels of shortfall. Multiplying the possible shortfalls, their probabilities, and an assumed $/MWh penalty for violation, and then summing over all possible shortfalls, results in an expected loss in $/hr, given the level of reserves procured. The demand curve is then calculated by noting the rate (in $/MW/hr) at which this expected loss decreases if more reserves are acquired, and capping that value at an assumed maximum $/MWh penalty value.

This general approach is a logical way to integrate the likelihood and severity of consequences of reserve shortages into a coherent framework for valuing reserves. However, the particular value of the penalty can greatly impact the height of the curve if the curve is uncapped, as well as its shape.

The initially proposed use of a $1000/MWh penalty value in the demand curve calculations assumed that any time the realized net-load shock is greater than the IR capacity procured, there would be a near-certainty of real-time scarcity. In fact, there are several reasons to expect that the real-time market would have sufficient energy supply, even when there was insufficient IR procured. First, as discussed above, the IR requires 30 minute rampable capacity and a significant net-load shock would likely be anticipated well before real-time. Thus, IR resources would have additional upward capacity that would have been dispatched, as well as resources that had not been procured for IR. Second, there may be less-costly ways for operators to manage the shortfall, including imported power, but also, e.g., public appeals and temporary overloading of generators or transmission.

Although we can accept the conceptual framework for the demand curve that the CAISO proposes as a starting point, we support the latest proposed revisions to the demand curve, which substantially reduces the risk of large-scale unintended price impacts from anomalous outcomes produced by untested elements of the IR design or its interaction with the overall DAME/EDAM design. These changes include replacing the originally proposed $1000/MWh penalty value used to derive the IR demand curve with a $247 penalty value based upon the maximum price of FRP. Since FRP has been positioned as the real-time analog to IR, and the settlement process would, at least partially, require non-performing resources to replace their capacity with FRP, the FRP maximum price is a logical basis for anchoring the "top" of the demand curve.

In addition, the addendum to the draft final proposal would truncate the top of the IRU demand curve at $55/MWh, effectively making demand for IR perfectly elastic once the IR price rises to $55.[25] This cap in the demand curve would have the effect that any IR with a combined offer price and opportunity cost in excess of $55 would not be scheduled to provide IR. While this level is considerably below the maximum FRP price, the above arguments about the relative severity of a day-ahead shortfall compared to a real-time one still apply. It is reasonable to assume that the consequences of a day-ahead shortfall of IR is less costly than a near real-time shortfall of ramping capacity.

Beyond these points, the many layers of uncertainty with respect to the design and performance of the IR market, including the method for estimating net load uncertainty, as well as its interaction with the overall DAME and EDAM designs, combined with the fact that IR prices will influence prices in the much larger day-ahead energy market argue for a conservative approach to IR pricing. The proposed $55 maximum price is higher than the maximum price for the aforementioned ramp capability product in MISO, around the same level at which MISO relaxes its spinning reserve requirement, and lower than the steps for the 30 minute reserve product in MISO.

We see the logic in trying to bound the cost of worst-case scenarios of a flawed initial IRU implementation or unintended and unexpected market design interactions, and the $55 maximum IRU price would substantially reduce those costs. This cap should be evaluated and reassessed once data on the actual performance of the IRU and broader DAME package become available and the CAISO and stakeholders have experience with the performance of the design for estimating net load forecast uncertainty. Such an evaluation would have to consider not just the price levels but also the underlying implications of the IRU pricing outcomes.

It is our expectation that the IRU price would rarely reach $55/MWh, and generally settle at most locations at a fraction of that level. If the $55 cap turns out to frequently bind, especially in cases other than the expected circumstances of RSE failures, regional supply shortages, high gas prices, or perhaps west wide low hydro conditions, that would tend to indicate that some element of the overall IR, DAME. EDAM and MOSAIC designs was not operating as intended and expected. In the situation in which some element of the design or implementation produces anomalous outcomes, the demand curve would limit the resulting inefficiencies and cost shifts during the period of time that the CAISO would take to modify the market design or software implementations. Conversely, we may observe following DAME go-live that the overall design is operating as intended with imbalance reserve prices rarely reaching $/55MWh but that too little

[25] Ibid. page 2.

imbalance reserves are being procured in some locations when imbalance reserve costs are high at those locations. In that case, adjustments to some element of the demand curve or other elements of the IR design would need to be considered,

For example, if the market frequently clears at $55 dollars *and* operators compensate for potentially lower IRU quantities with continued heavy reliance on load conformance in RUC, that would be a signal that an increase in the maximum price should be considered. On the other hand, if prices in some locations frequently reach the maximum levels largely because of assumptions about the deployment scenarios and/or the implications for local market power, then this would be a signal that the price cap is serving an important function.

One argument for maintaining a higher IRU maximum price was to prevent day-ahead low-priority exports of energy during periods of energy scarcity. This was the basis for the "inelastic" IRU demand portion for CAISO put forward in the previous draft proposal.[26] We did not agree with this logic since a natural consequence would be CAISO paying high prices for IRU that might be physically located in other control areas. Such IRU could even provide counter-flow in the IFM and potentially allow even more day-ahead energy exports, while reserving real-time capacity that would benefit neighboring balancing areas as well the balancing area procuring the IRU.

Beyond the efficacy of such a policy, it is better to not conflate the issues surrounding somewhat predictable scarcity conditions and those related to better coping with large unexpected net-load shocks. The IRU product is designed to deal with the latter by better positioning existing resources to provide the services (e.g., energy, ramp) that they are best capable of supplying to balance net load when these unexpected shocks occur. The problem of predictable scarcity, and the concern that neighboring areas may purchase scarce energy at prices below their value to CAISO load is best dealt with through higher and better rationalized scarcity prices for energy. Moreover, appropriate deviation settlements for imbalance reserves converted to energy in real-time would ensure that IR that is procured by the rate payers of EDAM BAAs, and subsequently converted to energy to meet the energy needs of a particular BAA in real-time, would produce net real-time imbalances revenues that would benefit the rate payers of the other EDAM BAAs.

3.2.2 *IR Market Power Mitigation*

3.2.2.1 *Mitigation of IR Capacity Offers*. Another challenging element of the design of IR has been whether and how to mitigate potential market power in the supply of this new product.

There are two reasons to expect less potential for the exercise of material market power in the IR market than in the energy market. First, we expect IR procurement to be based on a demand curve. Thus, as the cost of IR rises less will be procured. This will make the residual demand curve more elastic and reduce the profitability of exercising market power even for suppliers fac-

[26] *Draft Final Proposal*, page 9.

ing little competition in the supply of IR at their location. The revisions to the demand curve proposed in late April 2023 effectively place a hard cap on the price of $55/MWh on IR, which will result in a large perfectly elastic portion of the demand curve at this price, as summarized in the previous subsection. Furthermore, the residual demand curve will be particularly elastic for attempts to exercise market power in local areas because the demand curve is defined for the balancing area as a whole.[27]

Second, because energy offers are subject to local market power mitigation, resources that unduly raise their IR offer can be dispatched up for energy, either freeing up capacity on other resources at the same location that are able to provide imbalance reserves with an opportunity cost or reducing import energy flows and making that unloaded transmission capacity available for IR imports. This substitution of energy for IR will be less effective to the extent that resources able to provide IR have default energy bids that materially exceed the market price of energy when there is congestion. Hence, even if some resources offering imbalance reserves have high default energy bids, it is not clear that this would be a material set of resources that would have the potential to exercise significant market power in the imbalance reserve market.

In light of the CAISO's determination to at least initially cap the price of IRU at $55/MWh, we do not see any need to implement any market power mitigation design for imbalance reserves at DAM start-up, consistent with the CAISO proposal. We also support the CAISO's determination to build the functionality to apply market power mitigation into the DAME software so that it could be applied without a lengthy delay for software development were market experience to lead to changes in the demand curve for imbalance reserves.[28]

Three considerations underlie our support for the CAISO to develop software having the capability to apply market power mitigation in the future, should changes be made to imbalance reserve demand curve. First, since the nodal dispatch design for flexiramp and IR is still under development, we do not know what changes or compromises in the design may be made in the implementation between now and the point in time at which changes are made to the demand curve. Also there are no test results to assess how it might be impacted by high offer prices at particular locations, or even how much IR procurement might be allocated to constrained regions within a balancing area.[29] Second, the market power mitigation design must be adequate not only for the

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[27]Hence, a localized price increase could result in a 100% reduction in the quantity of imbalance reserves scheduled within the local area, but only a small percentage reduction in the amount of imbalance reserves scheduled for the balancing area as a whole.

[28] California ISO, Day-Ahead Market Enhancements: Addendum: Imbalance Reserve Demand Curve, April 19, 2023 p. 3.

[29]Analysis of the location of flexiramp schedules under the nodal dispatch design will provide some insight into these patterns but 1) this will not be the case until the CAISO is enforcing a set of constraints in the FMM deployment scenarios that is consistent with those that would be enforced in IFM deployment scenarios and 2) even then the amount of FRU procured in the FMM is much smaller than the amount of IRU that would be procured in the IFM.

CAISO BAA but also for other BAAs participating in EDAM that may have less diversity of resource ownership within the BAA than is the case for the CAISO.[30] Similarly, the market power mitigation design also must be adequate during a transitional period when a limited number of BAAs participate in the EDAM. Third, the procurement of large amounts of 30 minute ramp capacity on top of requirements for 10 minute spinning and non-spinning reserves could reduce competition relative to that currently observed in the spinning reserve market.[31]

We therefore cannot at this point in time provide complete assurance that no elements of this design will create the potential for the exercise of market power. Some of these uncertainties may be resolved by the time of EDAM go-live in a way that reduces the need for market power mitigation but we cannot be assured of that at this point in time. Providing some reassurance is the fact that the $55 cap on IR prices will also serve to limit the effects of exercising market power.

That said, it is not at all clear exactly how mitigation should be implemented. One issue is that, unlike energy, there is no obvious "right" way to set a default bid that approximates the marginal cost of supplying IR capacity. Given the lack of even a theoretical framework for setting unit-specific mitigated bids, we support the CAISOs proposal to utilize a uniform default availability bid (DAB) that would apply to all mitigated units. The Final Proposal sets this DAB value at $55 based upon a review of spinning reserve offer data, which is now redundant, given the hard price cap resulting from the proposed demand curve. While this general approach seems reasonable, we have previously requested that the CAISO carry out a more thorough analysis of offers and market clearing prices in the spin and non-spin market to better understand the relationships between market prices and other factors, such as the natural gas price, before finalizing the DAB.

The CAISO reported on an initial analysis of the relationship between gas prices and spinning reserve offers at the market performance and planning forum on March 16, 2023.[32] We focus on the analysis of the relationship between the spin offers of gas-fired generation and the spot gas price on the gas pipeline serving them. The CAISO's analysis generally found little overall relationship between spin offers and gas prices over the year. However, the CAISO analysis did find material correlations between gas prices and spinning reserve offers for resources supplied by the Socal Gas and PG&E pipeline systems during the winter months. This finding would be consistent with an expectation that gas prices would only impact spin offers when gas pipeline bal-

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[30] Since IRU procurement costs will be aggregated and then allocated across balancing areas, the exercise of market power with a particular balancing area could result in cost shifts across balancing areas. In addition, while it is our understanding that imbalance reserve procurement costs will be allocated to the balancing area , these costs may be allocated among multiple entities within the balancing area pursuant to OATT provisions and it is therefore important that all imbalance reserve prices reflect competitive market outcomes.

[31] The CAISO's decision to shift to procuring 30 minutes of ramp on resources to meet the IR requirement, rather than only 15 minutes of ramp, should also serve to reduce the potential for the exercise of market power.

[32] www.caiso.com/Documents/Presentation-MarketPerformancePlanningForum-Mar16-2023.pdf

ancing requirements would require the spinning reserve supplier to buy and schedule gas in order to be assured of being able to respond to a spinning reserve activation. A core reason for having offer prices for resources in the day-ahead market is to allow the optimization to schedule imbalance reserves on resources with low cost of providing reserves, which would include gas-fired generation served by gas pipelines whose supply is unconstrained and that have lower gas prices.

The performance of the market power mitigation design, and the competitiveness of IR offers are two of many elements of the IR implementation that will have to be monitored following DAME implementation. The software implementation should retain the capability for the CAISO to adjust the IR DEB and to implement unit-specific DEBs if serious market power problems are detected. Conversely, it may be that after a year or two of operation it will become apparent that there is no problem with market power and that the mitigation design never binds.]

3.2.2.2 *Caps on Energy Offers.* Another important consideration in the IR design is the consideration of the energy bids of the units competing to provide IR capacity. Typically, only the capacity prices are considered when evaluating the offers of resources bidding to supply traditional ancillary services such as spinning reserve. However, those reserves are almost exclusively "contingency only" meaning that they would be expected to generate energy only if a contingency arises. By contrast IR is meant to provide extra capacity to cover somewhat predictable uncertainty in net-load as well as provide additional flexibility in real time. In other words, it is expected that at least some of the resources providing IR will be called upon to provide energy in real time. Given this fact, it might be desirable to consider the energy bids of resources when considering their value as an IR resource. It is intuitive that a unit with a lower energy price would be more appealing that one with a high energy offer price if they both submit comparable IR capacity offers.

However, it has turned out to be quite difficult to turn this intuitive value into a workable market clearing criterion. The CAISO has spent several years on different options, most recently with a formula that would simply exclude any resources whose energy offer prices were above a certain threshold. We, as well as many stakeholders, have been concerned that simply throwing out part of the IR supply curve would result in unnecessarily high IR capacity prices. Therefore, we support the option of basing all IR awards exclusively on the IR capacity offer price.

Moreover, the proposed CAISO design would procure IRU both for balancing--which would be dispatched often and for which the level of energy offer price is important--and for covering large, low probability net load forecast errors--for which the level of the energy offer matters much less. We recognize that having no cap on energy offers risks the procurement of too many "stand-by" resources that could be very expensive to actually utilize, but this risk is more hypothetical than the clear impact that truncating the supply curve for IR would have on IR prices. This is an aspect of the market design that would be better for the CAISO to consider with a few years' experience, perhaps in conjunction with other changes.

3.2.3 *Non-Performance Penalties*

We support the element of the non-performance penalty design which will relate the non-performance charge for IRU to the price of flexiramp. Moreover, we support the application of a "no pay" of the type proposed in the Draft Revised Final Proposal to capacity segments scheduled to provide imbalance reserves that are not available in the FMM, due to outage, derating, or lack of energy in storage. The CAISO proposes to apply imbalance settlements for imbalance reserves for 5 minutes (one RTD interval) of ramp for flexiramp in each 15 minute interval in the FMM, while up to 30 minutes of ramp may be purchased in DAME.

Conversely, we understand that the non-performance penalty for RCU capacity segments that are not available in real-time would apparently just be a claw-back of the day-ahead RCU payment, with no penalty if system conditions are tight in real-time and the RCU capacity is needed.[33] Similarly, there would be no imbalance settlement for capacity scheduled to provide RCU in the day-ahead market that are scheduled to provide energy or imbalance reserves in the FMM.

These design elements are discussed further below.

3.2.3.1 ***Imbalance Reserves*****.** Our understanding of the proposed settlement design for capacity segments that are scheduled to provide imbalance reserves in the day-ahead market but are not available to be dispatched for energy or to provide imbalance reserves in the FMM, is that the deviation from the DAME schedule will be settled with a "no pay" that is an imbalance charge set at the higher of the DAME imbalance reserve price or the FMM FRU price.[34]

For example, consider a resource with a 90 MW energy schedule and 30 MW imbalance reserve schedule in the IFM, with a 5 minute ramp rate of 5 MW. Further suppose that the price of imbalance reserves in the IFM was $2, the resource's energy offer price is $30, and the price of energy in the FMM is $45, set by a $35 incremental energy offer and a $10 opportunity cost tradeoff between energy and FRU in FMM and RTD. If this resource were derated to 90 MW in the FMM, it would have to buy back its 30 MW IFM imbalance schedule at the $10 FMM FRU price. This settlement design is appropriate because although the resource fails to provide just 5 MW of flexiramp, it also fails to provide 25 MW of capacity that could have been dispatched for energy to back down other resources to enable them to provide additional flexiramp. The $10 charge thus reflects the incremental cost of flexiramp in FMM.

Conversely, capacity segments scheduled to provide imbalance reserves in the day-ahead market that are either fully dispatched for energy, and therefore unable to provide FRU in the binding 15 minute interval in each FMM interval, would be subject to an imbalance charge (based on the FMM FRU price) just on the five-minute ramp quantity of flexiramp that is not available in

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[33] Draft Revised Final Proposal, p. 50-51.

[34] Draft Revised Final Proposal, p. 38, 50. The Revised Final Proposal refers to the higher of the FMM or RTD price but we understand from the CAISO this was intended to refer just to the FMM –price.

FMM because the resource has been dispatched for energy.[35] Thus, in the example above, if the resource with a 90 MW energy schedule and 30 MW imbalance reserve schedule in the DAME was dispatched for 120 MW of energy in the FMM, it would be paid for the 30 MW of imbalance reserves in the DAME, buy back 5 MW of flexiramp at the $10 real-time price, but would sell 30 MW of energy at the $45 real-time energy price. In the example, this FMM energy price is assumed to include a $10 flexiramp opportunity cost. Hence, the resource would be paid $2 in the DAME for 25 MW of imbalance reserves and then paid an energy price in the FMM that would in some situations reflect a $10 FRU opportunity cost, while only buying back its IR schedule on 5 MW of capacity scheduled for flexiramp.

This settlement design could create inefficient incentives in some circumstances. For example, a resource with a 30 MW IFM imbalance reserve schedule and a $34 cost-based offer price in FMM would be dispatched for energy in FMM, being paid $45 for the energy while incurring $34 in energy costs, netting $11. However, if the same resource had an energy market offer price of $36, it would be dispatched for energy on 25 MW of its imbalance reserve schedule in FMM but would be scheduled to provide FRU with the other 5 MW, earning no incremental revenues. If the resource reduced its offer price of $34, less than its costs, it would be dispatched for energy in FMM and be paid $45 for the energy, while incurring $36 of costs, for a net margin of $9 on the incremental 5 MW. While these inefficient incentives would be small for slow ramping resources that would not receive large flexiramp megawatt awards in FMM, they could be material for fast ramping resources.

However, under the proposed DAME/FMM IR/FRU design, the FRU price will not always be reflected as an opportunity cost in the FMM energy prices when only a portion of the IR schedule is converted to energy in the FMM. However, a resource will not be dispatched for energy rather than FRU in the FMM unless the energy price reflects the opportunity cost of providing FRU and the resource is therefore better off, or at least indifferent, from providing energy rather than FRU. Hence, in other circumstances the energy price could be $35 in FMM accompanied by an $10 FRU price with no FRU opportunity cost reflected in the energy price, in the situation where a resource is able to provide FRU in FMM in combination with its energy schedule such that there is no tradeoff between energy and FRU in FMM. In this alternative outcome, an imbalance settlement based on the full IFM IR schedule could at times impose losses on resources with IFM IR schedules that are dispatched for energy in the FMM.

In sum, there is no settlement rule that provides efficient incentives over all FMM outcomes. These settlement complexities arise largely from the different IFM and FMM requirements for IR and FR, respectively, and may be addressed over time as the CAISO IR design evolves with experience. Overall, therefore, the CAISO's proposed settlement design which settles the por-

[35] Draft Revised Final Proposal, p. 50. This type of settlement rule between day-ahead and real-time is consistent with the settlement rules in other ISO markets that clear AS schedules in their day-ahead markets and re-optimize the AS schedules in the real-time dispatch, such as MISO and NYISO. The MISO settlement rules have been in operation since 2009 and the NYISO's since 2005, so are well tested in operation.

tion of the IR schedule that corresponds to the FMM FRU capability is reasonable, but will at times produce outcomes that might create somewhat inefficient incentives when a resource scheduled for IR in the IFM can alter its bids to affect the choice between providing energy or FRP in real time.

3.2.3.2. *Reliability Capacity*. The section of the draft revised final proposal addressing this aspect of the design starts with a statement that "*a stronger incentive than a no-pay mechanism is needed*."[36] But this does not appear to be what is proposed for RCU. Instead, the CAISO appears to propose a no-pay in which resources called upon to provide RCU capacity that they cannot provide simply return the DAME payment.

The lack of an imbalance payment related to real-time market conditions largely eliminates the beneficial performance incentives created by a design with financially binding RUC schedules. While reliability capacity up cannot be dispatched on a 15 minute basis, it can be dispatched on an hourly or other basis to maintain imbalance reserves, and thereby reduce the price set by the FRU demand curve. Hence, we recommend that resources with an upper limit that does not support their day-ahead energy + RCU award be charged the real-time FRU price for the capacity not provided to the RT market. This charge could be based on the HASP FRU price for resources not offered in HASP, and the FMM or RTD FRU price for resources not offered in FMM or RTD, or the FMM and RTD FRU prices could be used to settle all shortfalls.

3.2.4 *Sequential vs Simultaneous IFM and RUC design: Interaction of IR and RUC Prices*

Although the proposed sequential IFM and RUC design eliminates some difficult implementation challenges that were identified early in the DAME proposal development process, stakeholders should recognize that this design has the potential to result in disconnects between IR prices and RCU prices, particularly on tight supply days. The CAISO design has several elements that reduce the potential for large disconnects but it should be recognized that there will be occasional pricing disconnects.

On the one hand, the RCU prices could clear higher than the IR price in the IFM, if there is adequate supply in the IFM, but large amounts of underbidding that then cause RUC to clear RCU at a higher price. The potential for such disconnects would be somewhat increased by the apparent lack of a demand curve for IR capacity in RUC.[37] On the other hand, the $250 RUC penalty price cap, the availability of additional capacity in RUC that cannot be dispatched on a 15 minute basis, and the availability of the full 60 minutes of ramp on dispatchable resources in RUC could result in RUC prices that are less than the imbalance reserve prices set by the demand curve. Hence, resources may tend to offer IR at relatively high prices in the IFM on days when RUC shortfalls are anticipated. The risk of this happening has been significantly reduced by the imposition of a hard $55 cap on IR prices through the most recent demand curve proposal.

[36] Revised Final Proposal, op. cit., p. 46.

[37] It is our understanding that the amount of imbalance resources cleared in the market pass would be locked in a high penalty price in the RUC pass.

All of these potential price inconsistencies will be small if there is relatively little underbidding in the day-ahead market, and the market-based settlement of RUC capacity will tend to deter underbidding except on days with high expected IFM prices that are close to the real-time price cap. These issues could be addressed with changes in CAISO price formation to better reflect scarcity.

3.3 Congestion Revenue Rights and Revenue Shortfalls

In the prior versions of the DAME proposal, the CAISO has recognized that the way it originally proposed to calculate and allocate IR costs to load created the potential for congestion rent shortfalls, but that these shortfalls were expected to be small. Hence, as the CAISO noted in the Draft Revised Final Proposal:

> "*The CAISO expects that the differences between imbalance reserve bid prices for the constrained vs unconstrained areas generally will be much lower than the difference in energy bid prices for the constrained vs unconstrained areas. This expectation is based on the lower cost of providing imbalance reserves compared to providing energy. As a result the CAISO expects the constrained transmission to be mostly consumed by energy. Thus the CAISO does not expect this to be a major issue*."[38]

We agree that this relationship between energy and reserve offer prices within and outside constrained areas will generally prevail. However, it will not necessarily prevail at all locations. There may be particular locations at which this will not be the case, producing chronic congestion rent shortfalls. We also note that market power mitigation design has the potential to mitigate high energy prices more effectively than high imbalance reserve offers, with the result that it is possible that energy price differences across nodes could at times be smaller than the differences marginal imbalance reserve prices.

We also note that the original design for calculating IR costs would not only potentially lead to congestion rent shortfalls in the CAISO CRR settlements could lead to shortfalls in transfer revenue allocation in other BAAs as well as shortfalls in the funding of CAISO CRRS. Moreover, there would have been a potential for the economics that cause IR to be imported over binding transmission constraints to not be random, but to frequently recur in the same locations, due to the repeating offer price patterns, so that there could occur shortfalls day-to-day on the same constraints, with shortfalls regularly impacting the same LSEs or balancing areas.

We therefore support the CAISO's revised proposal to calculate the congestion costs (opportunity costs) of using transmission to support flows of imbalance reserves across constrained interfaces and recover these costs in charges for imbalance reserves. This design will avoid the potential for unintended cost shifts involving both CRR holders and EDAM balancing areas. If, as expected, transmission on constrained interfaces is rarely used to support flows of imbalance re-

[38] DAME Draft Revised Final Proposal, April 6, 2023, p. 52.

serves, then these charges will be small. If, however, there are situations in which the congestion opportunity costs of IR schedules are not small, the revised settlement design will avoid the potential for material unintended cost shifts.

3.4 IR and Flexiramp Down

A number of stakeholders have recommended eliminating the IR and flexiramp down products. The MISO has recently filed with FERC to eliminate its ramp down product, finding it almost never bound in recent years.[39] On the other hand, some stakeholders in the Pacific Northwest suggested the desirability of retaining a ramp down product. MISO does not have the same level of inflexible hydro generation that some WEIM balancing areas may need to manage during the spring runoff season, so its experience may not be completely relevant to WECC conditions.[40]

As renewable penetration increases in the West, swelling the belly of the duck curve and increasing variability of net load, we anticipate that the need to manage overgeneration situations, such as the conflict between northwest wind and Pacific Northwest hydro resources,[41] could grow. For this reason, while some stakeholders have favored deleting the downward IR product from the DAME proposal in the name of simplifying the market software and reducing computing times, several stakeholders in the Pacific Northwest have favored its retention, while others have not commented on this issue.

We foresee that such a product may be needed and useful for managing overgeneration and over forecasts of net load, at least during some times of the year and over portions of the day. Hence, we recommend that the capability to schedule imbalance reserves down be developed in the DAME software. If none of the balancing areas that initially participate in EDAM see a need for an IR-down product, the procurement target could be set to zero, which would improve DAME solution time. At the same time, the CAISO would have the ability to utilize the product when EDAM expands to include balancing areas that may see a need for such a product, perhaps during particular times of year, reducing the overall costs of managing the EDAM transmission sys-

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[39] See MISO filing letter in docket ER23-1195-000.

[40] Vistra provided an historical analysis of downward power balance violations in the FMM and RTD at the WEIM distributed load reference bus, finding a lack apparent need for a downward ramp product. While informative, this analysis only measures prices at the distributed load reference bus,. Therefore the analysis does not inform us of the extent to which downward power balance violations may occur at other locations on the WEIM grid, in particular in balancing areas in the Pacific Northwest. It also does not address whether balancing areas in the Pacific Northwest or elsewhere currently avoid real-time power balance violations by taking account of downward ramp needs in their unit commitment and scheduling decisions. See Vistra Corp. Comments on Day-Ahead Market Enhancements, Fourth Revised Straw Proposal

[41] Z. Ferkin, "Water on, wind off? Generator curtailment in the Pacific Northwest," *Trends*, American Bar Association, Section of Environment, Energy, and Resources, November/December 2013, www.americanbar.org/groups/environment_energy_resources/publications/trends/2013-14/november-december-2013/water_wind_generator_curtailment_the_pacific_northwest/.

tem. It might not be needed in most months, at least in the near term, but we anticipate that as EDAM expands to include more balancing areas in the Pacific Northwest its occasional use might be necessary, and if so, will give valuable experience in dealing with transient oversupplies of inflexible resources, which may increase in frequency.

Because the CAISO experience with the need for downward ramp capability may not generalize across other potential EDAM balancing area participants, any decision to completely eliminate the downward product should include discussions with other balancing areas of what actions they may take in advance of real-time to ensure their ability to maintain downward ramp capability. We also agree with Tacoma Power than a decision to eliminate the downward ramp product from the DAME/EDAM should be accompanied by the elimination of the downward RSE in real-time so that balancing areas will not fail the downward RSE because of requirements not modeled in DAME.[42]

3.5 IR and Storage Resources

Ideally, one goal in scheduling storage in the day-ahead market is to limit the risk of storage being unable to deliver the service (energy, IRU, IRD, RUC, spin, regulation) that it is scheduled day-ahead to deliver, and to have those contracted to deliver the service bear the full costs of failure to deliver. On one hand, if the consequences of being unable to deliver was to pay the full cost of replacement (real-time price for energy, replacement costs or constraint penalty for other services), the resource operator would have efficient incentives to submit bids and offers that limit the costs of failure to deliver these services. However, given the inadequate state of scarcity signals in the CAISO markets, and the use of claw-backs rather than replacement costs for services, the incentive to deliver on day-ahead commitments is weakened, and the system bears some or even most of the cost of a failure to deliver.

Moreover, even efficient performance incentives would not necessarily produce efficient market outcomes, if the CAISO market engine inherently produces infeasible day-ahead market schedules without regard to storage resource bids and offers.

Given this situation, it is necessary that the ISO day-ahead market engine set constraints designed to limit the probability of clearing storage schedules that would not be deliverable in real-time. Designing such constraints in the context of the considerable uncertainty regarding real-time schedules involves a balance between minimizing that risk, and minimizing the cost of being over conservative (increasing the cost of services by precluding storage from providing them when it is efficient to do so).

The CAISO proposes to achieve this balance with the following three sets of constraints:

a) A single equation that governs SOC in both IFM and RUC for each storage resource that accounts for expected energy charge/discharge from energy and regulation schedules, placing upper and lower limits on the expected SOC over the day based on storage capac-

[42] Tacoma Power Comments in February 27 and March 7-8, 2023 workshops.

ity. Regulation-up and -down schedules are to be discounted by tunable parameters reflecting anticipated changes in charge. Regulation-up and -down can offset each other. RUC awards of course do not appear in those constraints. *This constraint is intended to reflect typical usage in the determination of IFM energy schedules for storage, while reflecting typical regulation effects on depletion or accretion of SOC.*

b) A set of ancillary service SOC constraints in RUC (also in IFM, omitting RC), two constraints per period, that limit ancillary service schedules for each hour by ensuring the starting SOC in the hour is sufficient to (i) provide all the scheduled upward service if deployed for the full hour, without the ending SOC violating its lower bound from equation a) and (ii) provide all the scheduled downward service if fully deployed for the hour, without the ending SOC violating its lower bound from equation a). (We note that this is more restrictive than the 15 minute limit for regulation provided by certain technologies such as flywheels/capacitors;[43] however, such exceptions could be accommodated in a very general version of this constraint). A/S capacity is not discounted in the calculation, and is assumed to be charged or discharged at the maximum rate as a boundary case. *These constraints are intended to ensure that all the scheduled A/S-up capacity can perform in that direction for at least one hour, and separately check that all the scheduled A/S-down capacity can perform in the down direction, also for an hour.*

c) Two sets of envelope constraints in the IFM and RUC that limit use of storage to provide imbalance reserves (IFM) and RUC and imbalance reserves (reliability capacity RC) in RUC, given the IFM energy schedule and imbalance reserve schedule, under two sets of assumptions: (i) RC-up scheduled from storage is deployed (discharged in each hour scheduled) to a degree expressed by a multiplier, which results in a possible SOC(-) trajectory in the downward direction and (ii) RC-down scheduled from storage is deployed (charged in each hour scheduled) to a degree expressed in a multiplier, resulting in a possible SOC(+) in the upward direction. SOC(-) and SOC(+) are traced out over the entire day, and are constrained to be within the SOC lower and upper bounds in every hour. These trajectories are not the extreme possibilities, which would result from full deployment, but are meant to represent possibilities that could occur if net load forecast errors in one direction persist somewhat over the day. An important element of the CAISO RUC design is that storage could be awarded RC-up and RC-down schedules but would not be charged or discharged to make those RC awards feasible.

One element of this design that we do not understand is why regulation up and down energy use is not included in these envelope equations, particularly given the CAISO's recent experience with storage state of charge depletion due to regulation schedules not accounted for in the IFM.

In calculating SOC(-) and SOC(+) trajectories, RC-up and RC-down (and imbalance reserves) (respectively) are to be discounted by tunable parameters that would be set at values less than 1 in acknowledgment that the worst case (maximum rate of RC discharge/charge, respectively) is unlikely to occur for many consecutive RT intervals. The

[43] www.caiso.com/Documents/RevisedDraftFinalProposal-RegulationEnergyManagement-Jan13_2011.pdf

CAISO has showed useful results of simulations with three years of data to assess the probability that the envelope constraints would prevent scheduling of infeasible amounts of RC-up and RC-down.[44] These data could be examined for evidence of systematically higher probabilities for stressed conditions when reliability capacity is most needed.

These constraints are intended to increase the probability of sufficient SOC to provide energy when storage RC is called on, recognizing that net load forecast errors are correlated, and storage may be called upon for several RT intervals in a day.

We make several observations about these constraints upon use of storage to provide IR and RC.

1. The three types of constraints are generally reasonable formulations, given present time constraints and that the IFM and RUC calculations are deterministic, not stochastic. The envelope constraints should be retained (contrary to some stakeholder recommendations that they be omitted) to increase assurance that RC can deliver on days with persistent net load forecast errors in one direction or the other. Removing the envelope constraints might increase storage profits from more IR sales in the IFM, but if as a result IR cannot be used for energy or FRU in real time due to lack of charge (resulting only in clawback of DA payments), then this doesn't help the system.

2. The tunable parameters in constraints types (a) and (c) should be tested and updated regularly, with a focus on performance during days of system stress (both high net load or overgen situations).[45] Consideration should be given to how deployment of storage for IR, RC, and A/S may be quite different on such days and would affect that SOC constraint if IR and A/S were included. Sample error is likely to be a significant problem, however, so consideration should be given to methods to estimate the parameters that take advantage of data over long periods, perhaps with appropriate adjustments/rescaling. The performance of the constraints in periods of stress should be carefully tested to ensure that the system doesn't run out of A/S, IR, and RC during the days in which they are most needed.

3. "Misalignment" of the constraints (use of different parameters between (a) and (c) for regulation or RC), which some stakeholders are concerned about, is not inherently a problem, as the constraints are meant to represent the way different types of types of IFM schedules would impact storage use. The omission of spin and non-spin from expected SOC movement (a) and from envelope constraints (c) appears to us to be a reasonable starting point but should be tested against data when enough is accumulated. It is an em-

[44] "Day-Ahead Market Enhancements, Impacts to Storage," ISO presentation, April 17, 2023, www.caiso.com/InitiativeDocuments/Presentation-Day-AheadMarketEnhancements-Apr17-2023.pdf .

[45] By "updated regularly" we do not mean they should be changing every day or week. Rather we mean that they should be updated over time as the CAISO and stakeholders accumulate historical data on the performance of the initial parameter values. This updating should not require a stakeholder process that could easily take a year or more to complete. However, stakeholders should be provided with advance notice of the changes. In addition, the data suggesting the need for the changes should have been discussed beforehand in stakeholder forums, such as the Market Performance and Planning Forum, so that stakeholders understand the reasons for the changes.

pirical issue whether spinning reserve and non-spin schedules typically have a significant impact on SOC, especially on high stress days. We share market participant concerns with the omission of regulation schedules from the envelope constraints, particularly given the experience with infeasible IFM regulation awards due to a failure to model regulation use in the IFM.

4. It is essential that resources providing contingency reserves have sufficient energy to respond to a contingency over the hour of their reserve schedule. Hence, the one hour energy requirement enforced by (b) is appropriate in our view. However, requiring resources providing contingency reserves over multiple hours to have sufficient energy to respond to a reserve activation in every hour appears likely to be excessive with the current resource mix across the west. During most system conditions there would be an opportunity to re-optimize supply within an hour following a contingency to maintain reserve availability over the balance of the day. However, we can foresee the possibility for the WECC resource mix to evolve over the next five years in a way that makes energy limits much more restrictive and could limit the ability of balancing areas to compensate for storage resources providing contingency reserves having insufficient SOC to support day-ahead market schedules to provide reserves over a series of hours following a contingency. This evolution will be something the CAISO and EDAM balancing areas will need to assess over time. Because the evolution of WECC daily energy limitations over time is a foreseeable possibility, we suggest that the CAISO include contingency reserve requirements in (a) and (c) but initially set the tunable parameter to zero. Having the reserve requirement built into the envelope requirements will enable the CAISO and EDAM balancing areas generally to respond more quickly to changing system conditions, while the ability to set the tunable parameters to zero initially will avoid unduly restricting the role of storage.

5. Regarding stakeholder suggestions that the parameters be tuned on a nodal or plant-by-plant basis, this has the distinct disadvantage of requiring a great deal of staff time, and being even more subject to sampling error. It is possible, and perhaps likely, that limited sample sizes will cause plant-by-plant variations in estimates to be somewhat or largely an artifact of sampling error, leading to anomalous parameter variables that would be constantly changing over time. The ISO could perform analyses of the feasibility of this after sufficient experience is gained, including an assessment of the reasons for variations among plants, and whether enshrining these variations in the market software might provide competitive advantages for some facilities that are not justified by their costs and other characteristics.

6. An alternative approach to setting tunable parameters that could be implemented in combination with efficient settlement rules for real-time imbalances would be to allow storage resource operators to use to submit hourly values of the tunable parameter for imbalance reserves for each resource in the day-ahead market, with resource operators retaining the option to allow the CAISO to set the tunable parameter. Allowing this flexibility, however, would require efficient imbalance settlement rules for spinning reserves, regulation and RC-up, as well as imbalance reserves.

7. As computational capabilities improve, the ISO could consider feasibility checks (endogenous calculations in the model) for multiple deployment scenarios for storage (analogous to the nodal FRP deployment scenarios, the contingency modeling enhancements,[46] and the proposed IR nodal deployment). This would require significant development effort and testing and is not recommended immediately, but should be considered eventually if it turns out that constraints (a) and (c) are difficult to tune for conditions of system stress. The advantage of multiple scenarios is that they lessen eliminate the need for tunable parameters with unclear relationships to system conditions;[47] the disadvantage, of course, is that more scenarios requires more computational effort and therefore might not be practical anytime in the near future.

8. Battery degradation costs, which motivate storage owners to limit SOC within more conservative ranges under typical conditions (e.g., 25%-75% rather than 0% to 100%), continue to be treated very simplistically in the ISO market software. Tests at ISO-New England have shown that better representations of impacts of deep drawdowns on lithium-ion battery lifetime and costs implies significantly different optimal schedules for storage.[48] The envelope constraints (c) are meant to prevent deployment problems during stressed conditions, so using the full range of SOC in that case seems reasonable, however. Implementation of the long deferred SOC-dependent charge and discharge bids could address this issue and/or more sophisticated degradation models, but market power mitigation of such offers/bids has fundamental conceptual challenges.

3.6 Imbalance Reserve Cost Allocation

We understand that the cost of procuring imbalance reserve in the day-ahead market will be aggregated across the balancing areas participating in EDAM and then allocated to the balancing areas based on the allocation factors described in Section 3.3 of the revised draft final proposal (p. 37). This socialization of costs is important for understanding incentives.

We believe this socialization is appropriate and inevitable for three reasons. First, while imbalance reserve procurement and deployment is tested to particular balancing areas, imbalance reserves will be used to balance net load uncertainty across the EDAM footprint. Indeed, this fact is the basis for the diversity benefit. Second, while imbalance reserves procurement costs could be assigned to balancing areas based on deployment scenario prices and quantities, this methodology could not be used to allocate imbalance settlements to particular balancing areas because there will be no unique mapping of resources to imbalance reserve deployments. Third, a de-

[46] CAISO, "Draft Final Proposal, Contingency Modelling Enhancements," Aug. 11, 2017, https://stakeholdercenter.caiso.com/RecurringStakeholderProcesses/Contingency-modeling-enhancements

[47] We agree with stakeholder observations that, generally speaking, using multipliers and constraints in the IFM to estimate state-of-charge impacts of IR awards are heuristics that may improve, but cannot guarantee, that day-ahead storage awards of IR or other products are deliverable in real-time.

[48] Xu, B., Zhao, J., Zheng, T., Litvinov, E. and Kirschen, D.S., 2017. Factoring the cycle aging cost of batteries participating in electricity markets. *IEEE Transactions on Power Systems*, *33*(2), pp.2248-2259.

ployment-based cost allocation might allocate few imbalance reserve costs to balancing areas in which significant imbalance reserve procurement costs were incurred as a result of the operation of the demand curve. Costs result from both procurement and deployment, and basing allocation just on the latter could result in what would be viewed as inequitable allocations.

3.7 Testing and Evaluation

It will be important for the CAISO to carry out effective pre-implementation software testing to identify anomalous outcomes and verify that the software implementation is consistent with the market design. It will also be important for the CAISO to carry out effective post-implementation price validation and to review the performance of several elements of the DAME design after go-live. There do not appear to have been any public reports on the methodology for, and results of, software testing for the flexiramp enhancements (especially nodal delivery tests) that are now in early stages of implementation. A presentation covering testing methodology and results prior to DAME/EDAM go-live would be useful and likely welcomed by stakeholders.

Some of the metrics that the CAISO should consider compiling and reviewing on an on-going basis after go-live are the following:

1. Impact of the IR implementation on the level and price impacts of load-biasing. One of the goals of this initiative is to reduce load-biasing, particularly in RUC. If operators conclude that the level and location of IR procured is insufficient, they may continue to resort to load-biasing in order to compensate;

2. average constraint shadow prices in the IFM and deployment scenarios compared to FMM shadow prices and RTD shadow prices;

3. differences between modeled and actually realized distributions of the amount and location of net load forecast uncertainty between the DAM and the RT FMM and RTD;

4. proportions of imbalance reserves scheduled at particular locations that is constrained down in FMM and in RTD;

5. calculations of the proportion of imbalance reserve scheduled on VERS in the DAME that cannot be dispatched because the real-time upper limit/output is too low;

6. calculations of the amount of capacity scheduled to provide imbalance reserves whose real-time offer price is well above (e.g., by $200/MW or more) the day-ahead market price at their location;

7. changes in battery state-of-charge relative to DA and RUC schedules due to activation of IR and RC scheduled on storage resources, and due to activation of ancillary services (spin, non-pin, and regulation reserves); and

8. frequencies with which envelope constraints for state-of-charge are binding in RUC, and actually are predictive of active state-of-charge constraints in the RT markets.

It is also important that the CAISO have reasonable discretion to adjust the set of constraints enforced in the deployment scenarios, to adjust the modeling of the amount of net load uncertainty, to adjust the locational modeling of net load uncertainty,