Comments of Powerex Corp. on
Day-Ahead Market Enhancements Technical Workshop

Submitted by	Company	Date Submitted
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Please provide comments on the proposed formulation options described below. In your comments, please explain your rationale and include examples if applicable. Also, recommend any analysis and data that your organization believes would be helpful to review on these options. Include details and explain your reasoning for the type of analysis and data that you suggest.

1. **At this time, does your organization support moving forward with Option 1: Sequential Integrated Forward Market followed by an after-market Reliability and Deliverability Assessment (Sequential IFM-RDA), Option 2: Integrated IFM and Residual Unit Commitment (Integrated IFM-RUC), or undecided. Provide supportive comments (in favor of, or in opposition to) below.**

Option 1:	**Option 2:**
☐ Support	☐ Support
☐ Support with caveats	☒ Support with caveats
☒ Oppose	☐ Oppose
☐ Undecided	☐ Undecided

Option 1: Sequential IFM-RDA

Powerex opposes a day-ahead market design that involves the sequential procurement of capacity, flexibility or energy outside of a single day-ahead co-optimization market process. Sequential procurement processes, and any processes founded upon the separate procurement of energy, capacity or flexibility more generally, are highly inefficient in several respects. In particular, separate procurement processes:

1. result in higher overall production costs by failing to award required capacity, flexibility and energy products to the supply resources that are most cost effective at providing each particular product; and
2. result in some resources being compensated for capacity and/or flexibility through side payments in the sequential procurement process (such as residual unit capacity

commitments), whereas other resources dispatched in the primary energy market optimization processes—that are also providing capacity bundled with their physical energy offer—are not, even where both resources contribute, and are relied upon, similarly to meet the day-ahead capacity needs of the grid.

Moreover, a sequential day-ahead market design would be unworkable for a regional market in the west, such as an extended day-ahead market ("EDAM"). Of particular concern, firm energy resources, such as Pacific Northwest hydro resources, would be treated as "energy only" in the primary optimization step of a sequential market design, effectively erasing any distinction between these firm resources and virtual supply, speculative supply, non-firm energy and variable energy resources. This outcome would be highly inappropriate since firm supply sources provide additional capacity and flexibility attributes that are relied upon to serve demand.

Option 2: Integrated IFM-RUC

Powerex strongly supports pursuing the development of a single integrated day-ahead market design that simultaneously dispatches physical energy resources to meet (1) bid-in energy demand; and (2) the CAISO's need for capacity and flexibility to reliably operate the grid under a range of uncertain real-time conditions. An integrated market is needed to ensure that each resource is used in the manner that is of greatest benefit to the grid—thus minimizing total production costs—and to ensure that all resources receive efficient, non-discriminatory market clearing prices for the capacity, flexibility and energy attributes they provide and that are relied upon to meet the needs of the grid.

While Powerex believes that a fully integrated day-ahead market design is necessary to achieve efficient outcomes, Powerex has concerns about some of the specific aspects of the proposal discussed at the June 20 workshop. These concerns are summarized in Section 3, below.

2. **Please identify any specific data analysis that your organization recommends. Indicate the data request(s), the purpose of the request(s), and how the request(s) will advise the determination of the day-ahead market formulation, or will assist with determining the procurement target for the new day-ahead product.**

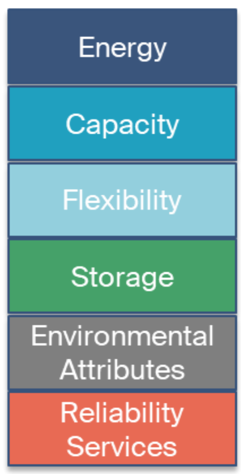
No comments at this time

3. **Please offer any other feedback your organization would like to provide on presentation materials and discussion for the June 20, 2019 Day-Ahead Market Enhancements stakeholder workshop.**

Powerex supports CAISO continuing to work with stakeholders to develop a fully integrated day-ahead market that procures energy, capacity and flexibility in a single market optimization. The transition of the grid—including the addition of large amounts of variable energy resources and the retirement of substantial portions of the conventional fossil fleet—requires a modern market design that efficiently commits, schedules, and compensates resources for the specific attributes they can provide.

CAISO's initial IFM-RUC integrated proposal, while promising, does not appear to fully satisfy this objective, as it results in identical "capacity" compensation for baseload resources, dispatchable resources, different types of variable energy resources, firm imports, and non-firm imports. Each of these resources makes a different contribution to meeting the capacity needs of the grid, and it is critical that any regional day-ahead market design recognize and compensate these different attributes accordingly.

A market design that does not meaningfully recognize differences in capacity attributes is particularly problematic for the selection of import offers into the CAISO BAA. The participation of resources located outside of the CAISO BAA is a vital element of reliably serving CAISO load. Such external resources vary across different regions of the west, and include flexible storage hydro resources, dispatchable but less flexible fossil fuel fired resources, and renewable variable energy resources. Each of these types of resources can play a valuable role in meeting the needs of the CAISO BAA, but securing the *right* resources at the *right* time requires accurate price signals to reflect the value of energy, capacity, and flexibility and encourage the voluntary participation of resources with these attributes, both generally, and in the specific hours each attribute is most needed.



The initial CAISO proposal, which treats all "physical" resources as identical for purposes of evaluating capacity needs, can logically be expected to result in imports from non-firm resources displacing imports from firm supply, particularly during hours in which the value of firm supply is greatest.

A design that does not distinguish between the specific attributes of resources is also likely to be unworkable as a starting point for exploring a regional day-ahead organized market. Under a design in which supply is undifferentiated, the cost of carrying sufficient capacity and flexibility reserves to backstop resources that lack such attributes, and ensure reliability, is broadly socialized to all customers in the footprint. This will raise major equity concerns between the differently-situated entities that might participate in a day-ahead organized market. Additional concerns are likely to arise for entities with substantial unaffiliated renewable resources, as the cost of balancing these resources will be borne by all customers, while the benefits of undifferentiated compensation will accrue to the individual owners of these facilities.

Powerex urges CAISO to explore refinements to the integrated market design proposal to ensure that:

- All resources that contribute to addressing the energy, capacity, and/or flexibility needs of the grid are compensated for their contributions; and
- Meaningful distinctions are made based on different resources' specific energy, capacity, and flexibility attributes.

By pursuing improvements to the CAISO's integrated market design proposal, Powerex believes significant progress can be made toward implementation of a highly efficient, day-ahead market design in the west. Such a design could provide a foundation for an EDAM that is workable for differently situated entities and regions across the west, and could also position the CAISO's day-ahead market design as an industry leader.

Powerex understands some stakeholders have raised concerns during this stakeholder process regarding the concept of an integrated market design approach. As proposed at the recent workshop, Powerex strongly supports CAISO convening an additional workshop prior to the next meeting of the Market Surveillance Committee to allow for further dialogue between CAISO and stakeholders on these important topics. While Powerex understands the need for continued dialogue in order to ensure stakeholders have an opportunity to thoroughly consider the concept, Powerex disagrees with many of the initial concerns raised by some stakeholders as further explained below.

1. <u>Financial vs Physical Markets:</u>

Some stakeholders have referred to the day-ahead market as a financial market and raise concerns that Option 2 is an unwarranted shift towards a "physical" market. This bright-line characterization of the current market design as "financial" and an integrated approach as "physical" is misguided.

As is well documented by CAISO, there are numerous physical components of the existing day-ahead market, including the procurement of contingency reserves and regulation in IFM, and the increasing use of the RUC process and exceptional dispatch ahead of real-time to ensure access to sufficient physical supply to meet the CAISO's load forecast with a high degree of certainty. The question, then, is not whether the CAISO should secure physical capacity and flexibility in the day-ahead time frame, but rather how to do so in an efficient and transparent manner.

Furthermore, it is well-established and uncontroversial that an efficient market should co-optimize energy with the traditional reliability-based physical products such as contingency reserves and regulation. The integrated IFM/RUC is simply extending this approach to include the additional capacity and flexibility products that are now clearly needed (and often being procured out-of-market) to operate an increasingly unpredictable grid.

2. <u>Price Formation</u>

Some stakeholders have questioned whether LMPs should include an additional capacity component that would compensate physical resources for the capacity attributes they provide, and have raised concerns that such an approach would have negative implications for the transparency of the nodal LMPs provided by the market solution.

Powerex does not share this concern for two reasons. First, the concept of including an additional component to the LMP is not new: the CAISO itself has included a GHG component in the calculation of its real-time LMPs in the EIM, which allows CAISO to exclude GHG costs from the LMPs outside of California, while compensating those resources that are deemed delivered to California. Notably, the GHG component is a single regional price – one that does not in any way obscure the transparency of nodal energy prices at different locations within the EIM.

Second, the purpose of the integrated design is to properly distinguish between resources based on the specific capacity, flexibility and energy contributions they are capable of providing. Rather than obscure prices, the LMPs created by an integrated approach will serve to increase the accuracy and transparency of nodal prices by providing a proper measure of the marginal value of the capacity and energy attributes at a given location.

3. Virtual Bids

Powerex believes that an integrated design has the potential to allow virtual bids to play an important and efficient role in improving the day-ahead solution and converging day-ahead and real time energy prices.

Under today's sequential market design, virtual bids often lead to inefficient market outcomes, raising total production costs. For example, virtual supply can displace physical supply in the IFM, even if selecting the virtual supply means that total production costs are higher after considering the out-of-market costs of securing *additional back-stop capacity to supplement the virtual supply* through RUC or exceptional dispatch. While inefficient for the market as a whole, this outcome is also problematic for the virtual supply receiving such an award because it can result in additional out-of-market uplift charges allocated to the virtual supply that add uncertainty regarding whether the virtual transaction was profitable in the first place.

Under the integrated design, in contrast, virtual supply will be dispatched based on evaluating the total production costs savings (including the potential cost of securing additional capacity from physical resources) of selecting the virtual supply bid relative to physical supply offers. Not only will this result in a more efficient dispatch outcome, it will result in a more transparent settlement outcome for the virtual supply based on the energy component of the LMP, and will avoid resulting in unpredictable and after-the-fact uplift charges for additional capacity secured out-of-market.

4. Friction

Some stakeholders have raised questions about the potential for friction between CAISO day-ahead market design changes and the Resource Adequacy program. Powerex agrees that market rules and RA requirements should be carefully considered to ensure an appropriate transition from securing long-term capacity through the RA program and efficiently deploying capacity and energy to meet load through the short-term energy markets. Powerex does not believe, however, that the need to consider such co-ordination is insurmountable, that it will result in any "double compensation” nor that it forms a credible argument against pursuing an efficient day-market market framework.

Stakeholders have raised similar concerns that market design changes may impact existing bilateral contracts. Powerex agrees that this may be the case, but believes that tolerating some short-term administrative burden is acceptable when pursuing long-term market design choices that have the potential to improve the market significantly going forward.

In the attached Appendix, Powerex more fully explains the need for a co-optimized day-ahead market design and outlines a potential conceptual and preliminary technical framework for achieving such a design. Powerex believes identifying a workable and feasible day-ahead market design will require multiple iterations between CAISO and stakeholders.

Appendix A

DAM Enhancements Are Needed To Efficiently Meet New Needs Of Transformed Grid

Reliably operating the grid in real-time increasingly requires not only the dispatch of resources to produce energy, but committing resources and positioning them ahead of real-time energy dispatch in order to maintain the CAISO's ability to meet rapidly-changing and unpredictable conditions. The current design of CAISO's organized markets only partially addresses this need, requiring frequent and growing manual interventions by CAISO operators in order to maintain reliability. These out-of-market actions come at a higher total production cost than if the same services were procured through a competitive co-optimized market-clearing process. Manual actions are also imprecise, potentially resulting in over-procurement (inefficiently increasing costs) or under-procurement (reducing reliability). And because these actions occur outside of the co-optimized market process, they negatively impact accurate price formation and undermine the important price signals that encourage resources to be available and responsive during times of greatest value to the grid.

This appendix sets out Powerex's current understanding of the need for and important design elements of day-ahead market enhancements to efficiently procure energy, capacity and flexibility. The ideas expressed in the appendix are necessarily preliminary, and are expected to evolve as stakeholder dialogue progresses. In particular, many of the technical details associated with each concept are likely to require multiple iterations before being properly formulated and defined. Powerex offers this appendix for the purposes of facilitating discussions with other stakeholders and with CAISO.

The appendix is organized as follows:

- Section 1 discusses the need for the co-optimized day-ahead procurement of physical products needed by CAISO operators to reliably operate the grid;
- Section 2 presents the key concepts underpinning a co-optimized day-ahead market design, including defining the necessary attributes and the additional products to be procured; and
- Section 3 outlines the technical formulation for the day-ahead co-optimization of financially binding energy awards with physical capacity and flexibility products, in addition to the ancillary service products currently procured.

I. Co-Optimized Day Ahead Procurement Of Capacity And Flexibility Is Necessary To Meet Demands Of Transformed CAISO Grid

The current conventional organized market design typically consists of a real-time market and a day-ahead market. In the past, the real-time market has generally been regarded as the "physical" market. Physical resources are dispatched to meet the market operator's forecast of load in each interval; the market does not clear against purchasers' bid-in quantities of demand, and virtual load and virtual supply do not participate in the real-time market. In real-time, the physical supply of energy must equal the market operator's forecast of the physical demand for energy, plus losses:

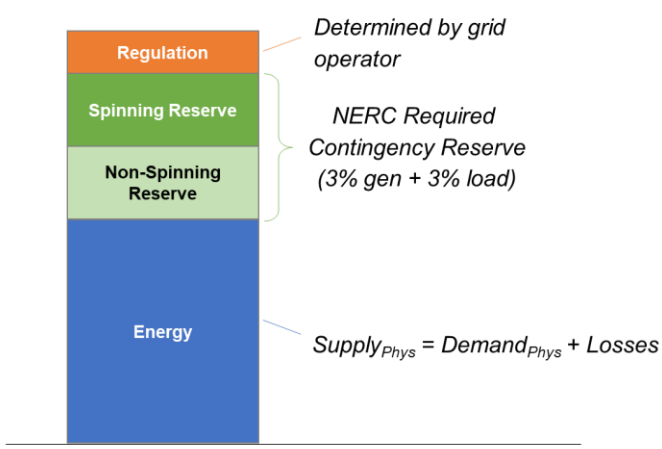
$$Supply_{Phys} = Demand_{Phys} + Losses$$

The day-ahead market, in contrast, has historically generally been regarded as a financial market, including both physical and virtual supply, and clearing against purchasers' bid-in quantity of physical and virtual demand, rather than against the market operator's forecast of load. In the day-ahead market, the physical *and* virtual supply of energy must equal the bid-in physical *and* virtual demand for energy, plus losses:

$$Supply_{Phys} + Supply_{Virtual} = Demand_{Bid\text{-}In} + Demand_{Virtual} + Losses$$

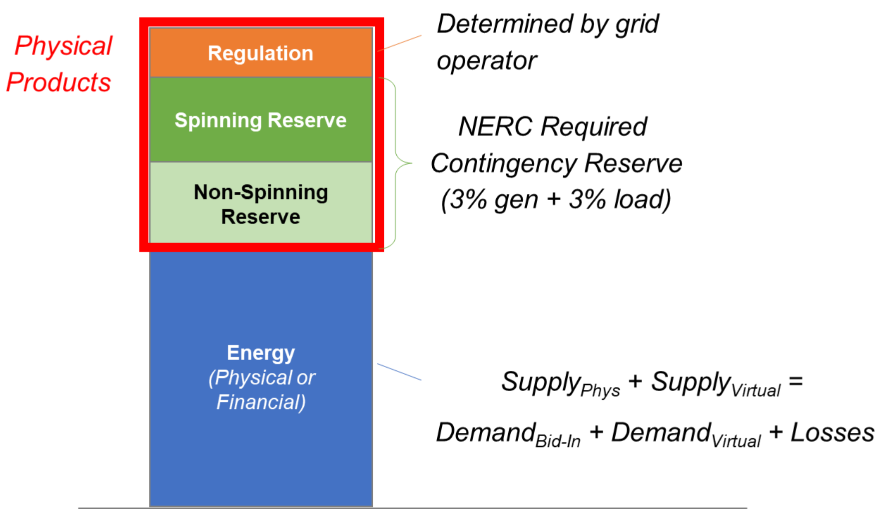
It has also long been recognized, however, that the reliable operation of the grid requires more than simply satisfying the need for energy in each interval. In particular, the market operator must maintain contingency reserves as required by NERC standards (*i.e.,* spinning and non-spinning reserve that can be activated within 10 minutes to respond to a defined contingency event, such as a unit tripping offline). The market operator must also maintain load-following or balancing reserves to continually meet load *within* each dispatch interval (*i.e.,* regulation up and regulation down). The real-time needs can therefore be represented as shown below:

Real-Time Market Needs



Importantly, contingency reserve and regulation are strictly physical products, and can only be provided by resources that satisfy clear technical requirements, which may include demonstration of the required characteristics. But even though these are physical products, their procurement is not deferred to only the "physical" real-time market. Instead, the procurement of these physical products is incorporated into the otherwise "financial" day-ahead market. In the CAISO day-ahead market design, the market solution co-optimizes the procurement of Spinning Reserve, Non-Spinning Reserve, Regulation Up and Regulation Down physical capacity products together with clearing physical and virtual energy awards to meet bid-in demand plus virtual demand, as shown below:

Day-Ahead Market Products



The co-optimized day-ahead procurement of physical capacity products and financially-binding energy schedules promotes the most efficient commitment of resources. While virtual supply can *only* be used to satisfy the day-ahead demand for financial energy schedules, physical supply resources can be used either to support a financial energy schedule *or* to provide a physical capacity product; co-optimization ensures each resource is used for the purpose that is most beneficial to the grid (*i.e.,* minimizes the bid-in cost of reliably serving load).

For many years, this framework was generally sufficient to enable the CAISO to reliably operate the grid in real time. The day-ahead energy schedules generally left both upward and downward headroom on physical resources, and this headroom was typically sufficient and made available in real-time to enable the CAISO to manage real-time conditions. If real-time load was higher than the day-ahead cleared energy quantity, there would generally be sufficient on-line resources scheduled below their maximum output, which could then be dispatched in the real-time market to increase output. Similarly, if real-time load was less than the day-ahead cleared energy quantity, there would generally be sufficient on-line resources scheduled above their minimum output, and which could then be dispatched down in the real-time market to reduce output. In other words, the market solution typically resulted in sufficient natural headroom "just sitting there" relative to the range of potential real-time needs, even though the market optimization did not explicitly reserve headroom in the day-ahead market for this purpose. From time to time, circumstances would arise in which the headroom resulting from the day-ahead market solution was less than what CAISO operators felt was necessary to maintain reliability, requiring out-of-market actions to commit additional capacity, but both the frequency and magnitude of these events were limited.

As the grid has transformed, however, the CAISO has experienced challenges as the natural upward and downward physical headroom resulting from the day-ahead energy market solution has not been sufficient to manage the potential range of real-time conditions. The growth of renewable resources, particularly solar and wind, has significantly increased the potential divergence between the net energy needs forecasted on a day-ahead basis and the real-time needs of the grid. In addition to greater uncertainty about the overall level of energy needs, the variable nature of renewable resources has also increased the variability of energy needs across hours and within each hour. At the same time as the CAISO BAA has experienced a significant increase in uncertainty and variability of real-time conditions, the retirement of substantial portions of its conventional fossil fueled generation fleet has diminished the natural headroom of resources available to be dispatched in real-time to meet these needs. Furthermore, the increase in renewable resources with minimal variable costs may often displace the dispatch of conventional resources that remain on the grid, further depriving the CAISO operators of the resources that would have previously been online and available to provide flexibility to respond to changing real-time conditions. Whereas the natural upward and downward headroom "just sitting there" after the day-ahead market solution may have previously been large relative to potential real-time changes in energy needs, this is no longer the case, and indeed precisely the opposite may now be said to occur.

Generally speaking, the CAISO needs access to resources to be able to respond to several identifiable categories of changes between day-ahead and real-time, resulting from changes in information or resulting from changes in the granularity of the market solution:

Type of Change	Uncertainty?	Variability?	Currently Addressed by:
1.DAM ➔ HASP	**Yes** *Forecast from day-ahead* ➔ *T-60 min.*	**No** *Granularity remains at hourly level*	N/A
2.HASP ➔ FMM	**Yes** *Forecast from T-60 min.* ➔ *T-37.5 min.*	**Yes** *Granularity from 1 hour* ➔ *15 minutes*	N/A
3.FMM ➔ RTD	**Yes** *Forecast from T-37.5 min* ➔ *T-7.5 min.*	**Yes** *Granularity from 15 minutes* ➔ *5 minutes*	DAM: N/A RTM: FRP
4.RTD ➔ Actual	**Yes** *RTD forecast* ➔ *actual*	**Yes** *Granularity from 5 minutes* ➔ *4 seconds*	DAM and RTM: Regulation Up Regulation Down

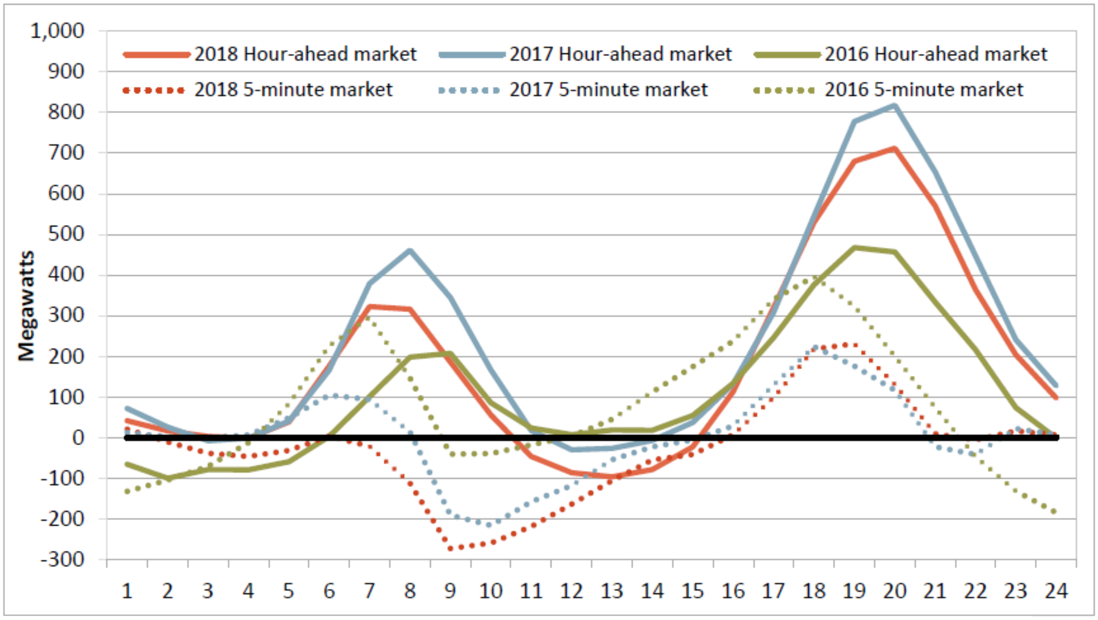
The current day-ahead market procures physical capacity and flexibility only to meet the fourth category listed above; that is, it procures Regulation Up and Regulation Down capacity and flexibility to balance actual demand within each 5-minute RTD interval. The current day-ahead market does not procure capacity and flexibility to address any of the first three sources of uncertainty and variability. The introduction of the Flexible Ramping Product in the real-time market arguably addresses only the third category.[1]

In order to ensure that CAISO operators have access to sufficient resources to enable managing all of the above types of uncertainty and variability, CAISO operators have had to take steps to create additional upward and downward headroom on physical units. These actions include upward adjustments to the load forecast used in the day-ahead RUC process; exceptional dispatch; and load biasing in the real-time market. Each of these types of actions results in the commitment of additional supply, and hence an increase in the upward headroom available on online resources. But these actions are inherently imprecise, and may overstate needs in some cases and understate them in others. Additionally, these actions occur after the day-ahead energy awards are already fixed, leaving CAISO operators with only a limited subset of resources to utilize for this purpose. And because several of these actions do not create additional headroom directly, but do so only indirectly by committing additional energy, the resulting headroom is not necessarily created on the specific units where that headroom would be most beneficial to the grid. In addition to being an imprecise and inefficient way to create additional headroom on physical resources, out-of-market actions can significantly distort price formation in CAISO's organized market and increase the need to recover costs through uplift, the detrimental impacts of which are well established.

The evolution of the CAISO grid and services needed to ensure reliable operations has simply outpaced the evolution of the organized market. The gap between the market solution and what CAISO operators feel is necessary to maintain reliability has grown, such that out-of-market actions are no longer rare and limited, but frequent and substantial each and every day.

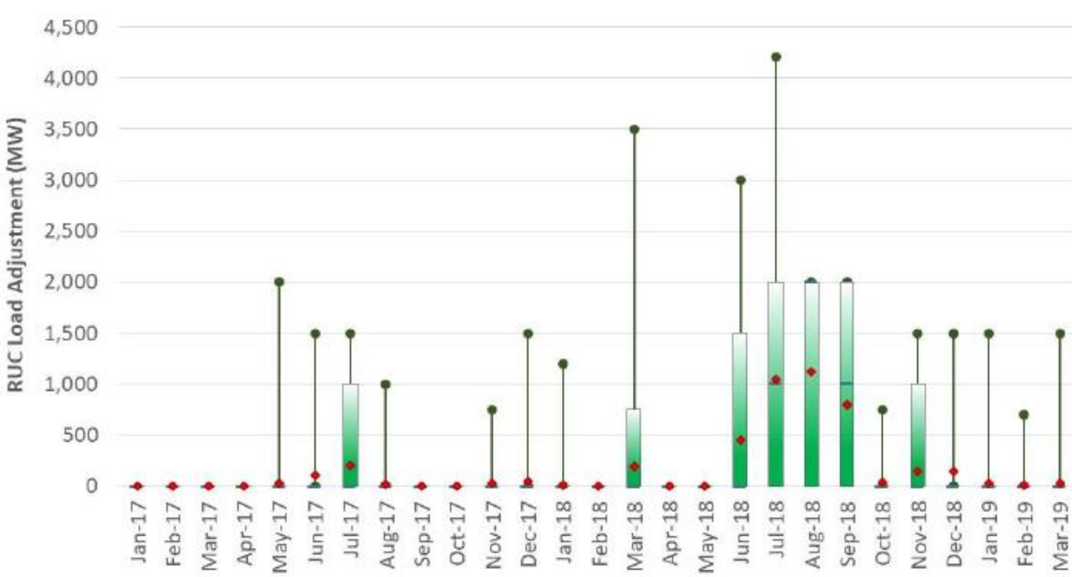
[1] It is unclear at this time whether a day-ahead market solution that addressed the first two categories of uncertainty and variability would still have material uncertainty in the third category. That is, it is conceivable that a day-ahead solution that ensured sufficient capacity and flexibility to enable the FMM to reach a feasible solution under a wide range of potential conditions may also largely (or entirely) ensure that the RTD solution is also feasible under a wide range of potential conditions.

Figure E.7 Average hourly load adjustment (2016 - 2018)



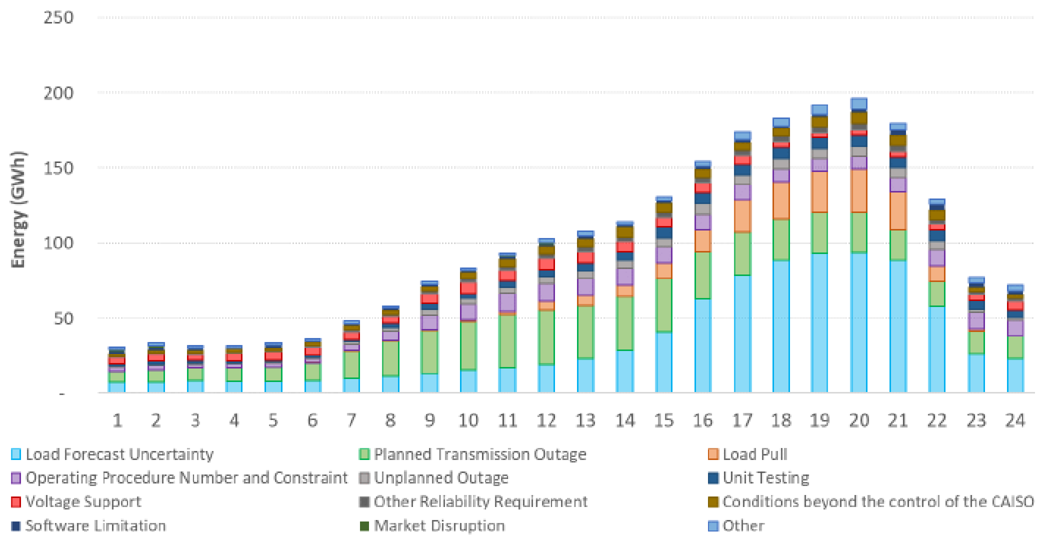
Source: CAISO 2018 Annual Report On Market Issues and Performance

Figure 23: Monthly profile of RUC load adjustments



Source: Price Performance in the CAISO's Energy Markets, June 18 2019

Figure 53: 2018 Volume of exceptional dispatches in the CAISO market



Source: Price Performance in the CAISO's Energy Markets, June 18 2019

In Powerex's view, the systemic and growing use by CAISO operators of out-of-market actions, particularly during times of tight system conditions, is the clearest indication of the need to enhance the day-ahead market design to procure additional physical products, just as it already procures physical Spinning Reserve, Non-Spinning Reserve, Regulation Up and Regulation Down. Explicitly procuring new physical Reliability Capacity and Flexible Ramping Up and Down products (discussed further below) will enable more precise and efficient procurement of the physical attributes currently procured by CAISO operators through out-of-market actions. Procuring these products through a co-optimized market process also ensures they are obtained in the least-cost manner, without inadvertently scheduling a flexible resource for energy when it can more beneficially be used to provide upward Flexible Ramping, for instance. ***Just as it would be an obvious step backward - from both a reliability and efficiency perspective - to fragment the procurement of energy from the procurement of Spinning and Non-Spinning Reserve, it would be equally problematic to continue to fragment the procurement of capacity and flexibility from the market optimization***.

Powerex believes that the Day Ahead Market Enhancements stakeholder process should be used to develop a fully co-optimized day-ahead market that simultaneously clears financially binding energy schedules and procures the physical products that CAISO operators regularly require to reliably operate the grid in real-time. Such a day-ahead market would represent a major step in the evolution of organized market design.

II. Conceptual Framework For A Co-Optimized Day-Ahead Market

The financially binding energy schedules from the day-ahead market are designed to also represent *physically feasible* energy production schedules. That is, resources should be able to physically produce according to their day-ahead schedules without violating limitations on resources output levels or ramp rates, and without violating transmission limits or other security constraints. The real-time market processes—including the HASP, FMM and RTD—must therefore bridge the gap between real-time system needs and the system needs satisfied by the day-ahead market solution.

The day-ahead market solution has an inherent degree of adjustability, but only up to a point. For example, a day-ahead solution with aggregate energy schedules of 30,000 MW may be increased in real-time to produce 30,100 MW, but it may not be capable of being adjusted to 40,000 MW absent additional measures being taken. The goal of a co-optimized day-ahead market must therefore be to produce a solution that not only ensures the day-ahead energy schedules are physically feasible (as it does today), but that also ensures that the real-time market is able to meet the full range of potential grid conditions with a high degree of confidence.

A critical starting point must therefore be to define the degree of confidence that the day-ahead market solution is intended to achieve. The goal cannot realistically be to ensure the real-time market can accommodate every conceivable outcome, including extreme outlier cases. For purposes of this discussion, it is assumed that the day-ahead optimization seeks to ensure reliability with a confidence level of 95%. That is, the day-ahead solution should enable the real-time market to fully meet the real-time needs of the grid in all but 5% of cases.[2] This confidence level will govern the range of potential real-time grid conditions that must be capable of being met with the resources committed in the day-ahead solution. To ensure such an outcome, it will be necessary to more precisely define the requirements that the day-ahead solution must satisfy. Powerex believes that a day-ahead solution that satisfies the following four core requirements, at least cost, will enable real-time needs to be met with the requisite level of confidence. Each of these four requirements is discussed below.

Requirement 1: Energy awards satisfy bid-in demand each operating hour

The first requirement of the day-ahead solution is that aggregate supply awards must equal aggregate demand awards, plus losses. Virtual and physical supply is cleared against virtual and physical bid-in demand, just as under the current market design. The day-ahead market optimizes across a 24-hour horizon, and will therefore enforce inter-temporal constraints of physical resources including ramp constraints, minimum run-time constraints, or daily energy limits. This aspect of the day-ahead market, which already exists, will continue to enable all

[2] This still implies that the real-time market will rely on additional resources beyond what was committed in the day-ahead solution in approximately 36 hours per month, of which approximately half would be expected to reflect upward insufficiency while approximately half would be expected to reflect downward insufficiency. Whether this standard is sufficiently stringent should be more fully discussed in the stakeholder process.

participants to hedge their exposure to real-time prices by entering into financially-binding purchases and sales transactions.

Requirement 2: Day-ahead solution includes sufficient capacity to meet peak 15-minute demand each operating hour with 95% confidence

The aggregate quantity of cleared energy awards may be greater or less than the CAISO's forecast of demand. This difference will need to be made up in the real-time market, which requires that CAISO have access to additional physical resources that it can deploy. But the need for additional capacity is not limited to the difference between the aggregate energy schedules in the day-ahead solution and CAISO's forecast of demand. Capacity is also needed as a result of the fact that not all day-ahead energy awards represent physical supply. CAISO's Workshop Proposal expressly recognizes that virtual supply does not contribute to meeting real-time demand. In addition, different sources of physical supply will vary in the degree of certainty of being able to produce a given level of output.

A capacity constraint is therefore introduced to the day-ahead optimization to ensure that the day-ahead solution includes sufficient physical supply to be able to meet real-time demand with the target confidence level (*i.e.,* 95% confidence in this discussion).

Achieving the target confidence level requires defining the capacity requirement, and also defining how the capacity contribution of each resource is determined. Powerex proposes that the target day-ahead capacity requirement be based on the 95% confidence interval of the peak demand forecast for any of the four 15-minute intervals of a given operating hour. This ensures that CAISO will be highly likely to be able to meet its 15-minute demand forecast in each FMM interval.

The amount of capacity that a physical resource is eligible to contribute must also be accurately determined. The reliability benefits of establishing an appropriate capacity requirement can be entirely undermined if the capacity contribution of resources is overstated. Powerex suggests that the capacity contribution of a resource should represent the amount of physical supply that the resource is expected to be able to produce in real-time, at a confidence level of 95%.[3] This largely depends on whether or not a resource's output can be directly controlled. Conventional thermal resources as well as storage hydro resources would generally be qualified to provide capacity up to their nameplate capacity, as this likely reflects the upward level of they can produce in 97.5% of cases. VERs, whose output is subject to uncertainty associated with natural phenomena, would generally be qualified to provide capacity up to the level of output that is likely to be equal or exceeded in 97.5% of cases. The capacity contribution is expected to vary across different types of VERs, and across different hours of the day. Powerex notes that the eligibility of VERs to contribute capacity should also incorporate a recognition of diversity credit, both among individual VER resources but also between VERs and demand. Powerex believes a workable approach would be for the CAISO to calculate and publish a "capacity factor" for each type of VER for each operating hour, representing the percentage of the forecast output that is

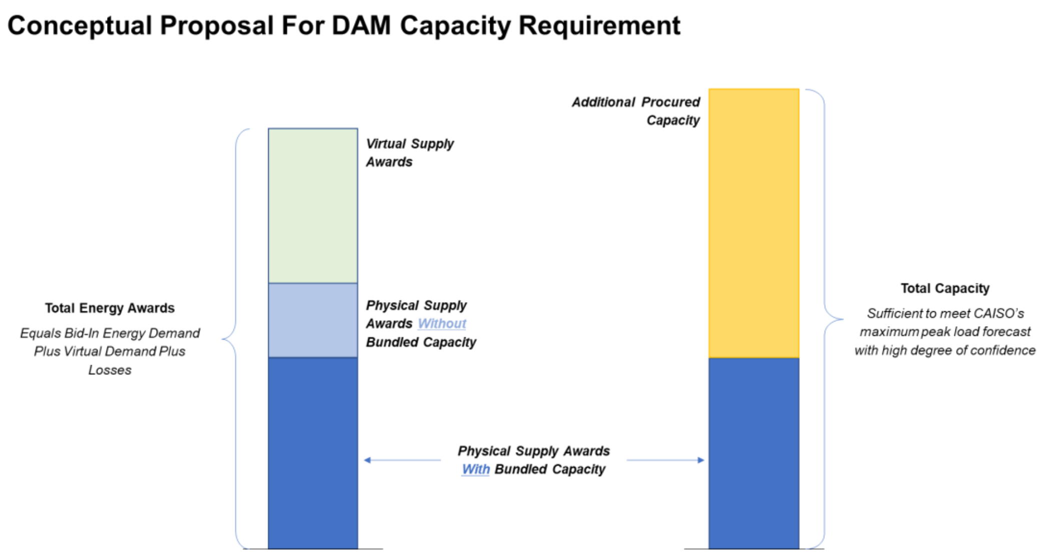
[3] As used in this appendix, a 95% confidence level refers to the range values that are expected in 95% of potential outcomes. This range is defined by a minimum value, which is expected to be exceeded in 97.5% of outcomes, and a maximum value, which is expected to be exceeded in 2.5% of outcomes.

qualified to contribute to the capacity requirement. Finally, imports can contribute capacity to the extent the source BA carries operating reserves—including both contingency reserve and balancing reserves—necessary to ensure delivery of the imports with a high degree of confidence. Imports that are declared to be non-firm would not contribute toward the day-ahead capacity requirement.[4]

It is critical to note that the energy awards resulting from Requirement 1, above, will already provide a substantial contribution of capacity from physical resources. In other words, the capacity requirement is *not* a requirement to separately procure all of the required capacity on a stand-alone basis. Rather, stand-alone capacity would be procured *only* to the extent it is needed to supplement the capacity already "bundled" with the energy awards of physical resources.

To the extent the "bundled" capacity is insufficient to meet or exceed the capacity requirement, the market solution will need to procure additional Reliable Capacity Up ("RCU") and/or Flexible Ramping Capacity Up ("FRU"), discussed more fully below. Both of these products represent commitments by resources, up to their eligible capacity amounts, to be available to the CAISO in the real-time market. As a result, the capacity bundled in the energy awards of physical resources *plus* the additional stand-alone capacity procured as RCU and/or FRU will equal or exceed the peak 15-minute demand forecast in all but 2.5% of cases.

The relationship between energy awards, resources' eligible capacity contribution, and the procurement of stand-alone capacity is illustrated below:



[4] Powerex believes it would be efficient to enable both firm and non-firm imports, provided these are clearly defined and identified at the time they are offered. Firm imports will be cost-minimizing where reserves can be more efficiently carried by the source BA, whereas non-firm imports will be cost-minimizing where reserves can be more efficiently carried by the CAISO. A further possibility is for unit-contingent imports, whose delivery is tied to the performance of a specific external resource (e.g., out of state wind facilities), which can contribute capacity on the same basis as internal resources of the same type.

Requirement 3: The day-ahead solution should include sufficient flexibility to ensure ramp-feasible real-time market solutions with 95% confidence

The capacity requirement discussed above ensures that the total physical capacity of resources available in the FMM will be equal to or greater than the real-time load forecast for any 15-minute interval of that operating hour, with a high degree of confidence. However, the capacity requirement, without more, does not directly ensure that the available resources can move to that peak level within a defined amount of time. For example, there may be sufficient capacity to meet a 15-minute load forecast of 40,000 MW, but that capacity may lack the flexibility to reach that level if the load forecast for the prior interval was, say, 38,000 MW or less.

It is therefore necessary to supplement the above *capacity* requirement with a *flexibility* requirement. Defining the flexibility needs of the grid can be challenging, as changes can be measured over multiple different timeframes. The current Flexible Resource Adequacy program, for instance, seeks to meet a requirement based on a maximum net demand change over 3 hours. Moreover, satisfying a ramping need over one timeframe (such as 3 hours) does not guarantee that ramping needs over different timeframes (such as 1 hour) will also be satisfied.

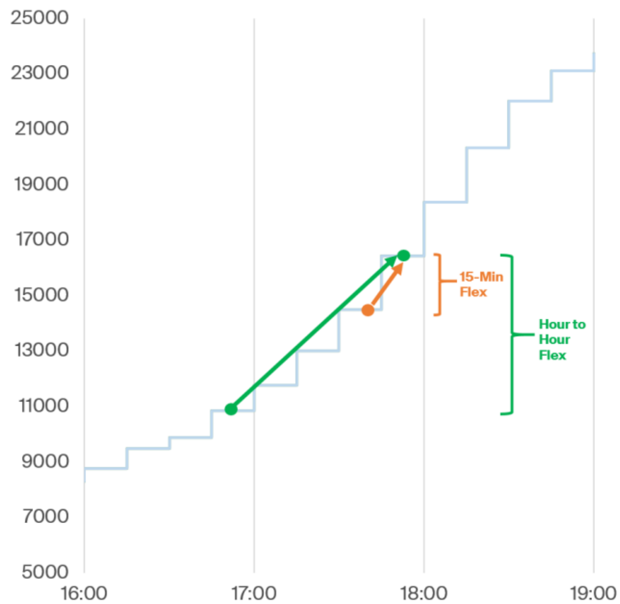
In addition, the need for flexibility is driven not only by the change in output that may be required over a given amount of time, but also by how far in advance the need for that change can be anticipated by CAISO operators. Broadly speaking, it is the potential need to make large changes in resource output with little notice that drives the need to procure flexibility. This means that the flexibility products can be provided only by resources that meet specific technical requirements related to ramp rate and lead time.

Defining the appropriate metric for the amount of flexibility that needs to be procured will require extensive discussion and analysis, as the need for flexibility may be challenging to observe directly. For example, it is not the *average* change in net demand that is likely of interest, as some or all of this expected change will typically be embedded in the energy solution, which will already be required to be ramp-feasible. Rather, what is more likely to be relevant is the potential for the actual changes in net demand to be "steeper" (or "flatter") than the movement accommodated by hourly energy schedules (and, potentially, by RCU awards). This will require a methodology to estimate, from historical data, the distribution of the portion of changes in net demand that are not otherwise met by the energy and capacity requirements, and hence that can only be met by the real-time market deployment of resources capable of fast changes in output with little lead time.

For purposes of this preliminary discussion, Powerex believes it may be beneficial to consider flexibility requirements over two timeframes:

- Flexibility for potential movement from one hour to the next; and
- Flexibility for potential movement from one 15-minute interval to the next.

These two requirements are complementary but distinct. If the day-ahead solution considered only the change in net demand across a single 15-minute interval, it may have insufficient flexibility to "move" or ramp the total quantity needed over multiple intervals in the same hour. Conversely, if the day-ahead solution considered only the hour-to-hour change in net demand, it may be unable to meet the need for shorter but steeper ramps within that period, such as from one 15-minute interval to the next. "Flexibility" must be recognized as being defined both by total quantity of movement as well as the maximum speed at which it can be deployed. Both attributes are important, as illustrated below:



Powerex believes additional analysis and stakeholder engagement can help clarify whether these two preliminary requirements represent the most appropriate way to define the flexibility that should be procured in the day-ahead market. It is possible that alternative timeframes may more effectively characterize the needs of the grid, or that additional metrics are needed. For instance, this preliminary discussion assumes that if the CAISO day-ahead market design ensures sufficient flexibility is available to enable the FMM to reach a ramp-feasible solution with a high degree of certainty, then a ramp-feasible solution will also be possible within each 15-minute interval in RTD with a high degree of certainty. None of this can be predetermined at this stage, however, but by outlining an initial conceptual approach, Powerex believes CAISO and stakeholders can identify the empirical analysis needed to test the robustness of different approaches.

Requirement 3a: Day-ahead solution includes sufficient flexibility to meet hour-to-hour needs

The first of the two preliminary flexibility requirements defines how much additional, unanticipated upward or downward change in output the fleet must be capable of achieving across a particular operating hour, with a 95% level of confidence. This requirement captures the cumulative potential movement that can be achieved by the resources offered into the real-time market. Resources submit real-time offers for one operating hour at a time (and not separately for each 15- or 5-minute market interval), and these offers must therefore suffice to meet the cumulative changes across multiple successive intervals.

Calculating this "hourly flexibility" requirement will entail analysis of historical data for the particular hour of day, and further characterized for the type of day (*i.e.,* weekday vs. weekend) and season, among other potential factors. More specifically, the historical data can be used to estimate the 95% confidence interval of the unanticipated potential change in net demand between the prior operating hour and the current operating hour.[5] The day-ahead market will optimize procuring this requirement through FRU and FRD awards.

It is important to note that the flexibility requirement is expressed as the need for total flexibility *range*, but is not prescriptive in terms of whether that is achieved only from Flexible Ramping Up, only from Flexible Ramping Down, or a combination of both. This is based on Powerex's understanding that, from an operational perspective, there is no difference between ramping down from a higher starting value or ramping up from a lower starting value. In this manner, the optimization will have the ability to shift the allocation of the flexibility range between FRU and FRD in a manner that minimizes total costs.

Requirement 3b: Day-ahead solution includes sufficient flexibility to meet maximum 15-minute change

The second preliminary flexibility requirement is based on the potential for CAISO's real-time need for energy to change more rapidly from one 15-minute interval to the next than the average rate of change over the entire hour. For example, if the hourly flexibility requirement is 1,000 MW for the full hour, the FMM may not be able to reach a feasible solution for an interval with an interval-to-interval change of more than 250 MW *(*1,000 MW / 4) over any 15-minute period. The potential for the grid to encounter a "short but steep" ramp need within the hour must therefore be considered and planned for. In this example, the potential for a "short but steep" single-interval ramp of 300 MW in a single 15-minute interval would require procuring additional flexibility that could deploy an additional 50 MW in 15 minutes.

Similar to the calculation of the hourly flexibility requirement, historical data can be used to develop a distribution of the potential "excess" change in net demand between successive 15-minute intervals. As discussed above, further analysis and discussion is likely necessary to develop an appropriate methodology to quantify the need for flexibility to meet the steepest single 15-minute interval with a high degree of certainty.

Both the hourly flexibility requirement and the 15-minute flexibility requirement represent the quantity of fast-ramping, short-lead time resources that must be available to be deployed in the FMM. The 15-minute flexibility requirement is intended to represent the maximum single-interval need, whereas the hourly flexibility requirement is intended to represent the cumulate need for such flexibility over the course of all four FMM intervals in a given operating hour. That is, the hourly flexibility requirement does not necessarily represent a "less stringent" need in terms of ramping speed or lead time than the 15-minute flexibility requirement. For this reason, both of the flexibility requirements must be met through the same products: FRU and FRD.

[5] There are multiple potential ways to define this hour to hour change. As just two examples, it might be defined from the *last* FMM interval of the prior hour to the maximum or minimum FMM interval of the current hour; or between the *same* interval in each of the two hours. These details, as with many others, will require careful consideration and dialogue between CAISO and stakeholders.

Interaction among requirements

The four requirements discussed above would be enforced simultaneously, enabling the co-optimization process to find the least-cost combination of energy schedules and stand-alone RCU, FRU and FRD that meets all of the requirements. For instance, the co-optimization would enable the solution to recognize that accepting lower-priced virtual supply offers may result in higher total costs, since the lack of capacity contribution may require procurement of greater quantities of stand-alone RCU compared to accepting supply offers physical resources with high eligible capacity contributions, but at higher offer prices.

In this manner, the co-optimization process can find the least cost solution that:

- Clears physical and virtual energy offers against bid-in demand and virtual demand;
- Ensures, with a high degree of confidence, that CAISO operators will have sufficient physical supply in real-time to:
    - Meet peak demand;
    - Meet the highest potential change in energy required between one 15-minute interval and the next within an hour; and
    - Meet the highest potential cumulative change in the energy required across all 15-minute intervals over the entire operating hour.

Powerex reiterates that the above is intended to provide a discussion of key concepts underlying a co-optimized day-ahead market, while recognizing that many of the specific technical details will evolve in the course of further stakeholder discussion.

III. Technical Formulation Of Proposed Co-Optimization

This section provides a more technical specification of the conceptual proposal outlined above, both to more formally specify the optimization constraints that ensure procurement of sufficient capacity and flexibility, but also to identify some of the areas requiring further development through this stakeholder process. In particular, this section formulates the constraints for energy, capacity, and flexibility discussed in Section 2.

For convenience, the formulation employs many of the same elements as the CAISO's Workshop Proposal. In particular, the notation from the CAISO's June 20 Workshop Proposal is used wherever possible, limiting the explanation to new notation introduced here. In addition, the new stand-alone products contemplated in this preliminary framework are largely the same as in the Workshop Proposal:

- **RCU** represents physical capacity that is expected to be available in real-time with a high degree of certainty. Resources receiving a stand-alone RCU award are required to submit offers into the real-time market for at least the awarded quantity. While stand-alone RCU is a capacity product, and not a flexibility product, it may nevertheless be necessary to define minimum technical requirements to ensure the capacity can be deployed through the CAISO's market processes.

- **FRU and FRD** represent upward and downward flexibility, respectively, that can be deployed on a 15-minute basis and that is expected to be available in real-time with a high degree of certainty. Resources receiving an FRU or FRD award are required to submit offers into the real-time market for at least the awarded quantity. FRU and FRD awards are flexibility products, and resources are therefore limited in the quantity of FRU and FRD awards they may receive based on the capability of the underlying physical resource.

The energy schedules and stand-alone awards for RCU, FRU and FRD must be consistent with the physical capabilities of the associated resource. That is, the sum of energy schedules, FRU awards and RCU awards is limited based on the maximum output of the resource, while FRD awards are limited based on the energy schedule and the minimum output of the resource.

The objective function, security constraints, and the constraints associated with procuring Spinning Reserve, Non-Spinning Reserve, Regulation Up and Regulation Down are unchanged from the current day-ahead market formulation.

Energy power balance constraint:

$$\sum_i EN_{i,t} + \sum_j EN_{j,t} = \sum_i L_{i,t} + \sum_j L_{j,t} + Loss_t$$

This formulation is the same as in the CAISO Workshop Proposal, in which the subscript *i* refers to physical supply or load resources and the subscript *j* refers to virtual supply or load resources. Importantly, this retains the financial aspect of the day-ahead market for *energy*, including (1) the fungibility of physical and virtual energy offers towards meeting this constraint; and (2) allowing the market to decided how much energy demand is served on a day-ahead basis.

Capacity constraint

$$\sum_i EN_{i,t} * CCF_{i,t} + \sum_i RCU_{i,t} + \sum_i FRU_{i,t} = D(15)_t^{97.5}$$

Where:

$CCF_{i,t}$ denotes the Capacity Contribution Factor of physical resource, *i,* for operating hour, *t*. As discussed in Section 2, a workable approach may be for Capacity Contribution Factors to be established for each *category* of resources. For VERs, whose output depends on changing natural phenomena, it may be workable for CAISO to calculate and publish, on a day-ahead basis, the Capacity Contribution Factor for each type of VER and for each operating hour.

$D(15)_t^{97.5}$ denotes the 97.5 percentile value of the load forecast, at 15-minute granularity, during operating hour, *t*.

Powerex notes that this formulation describes only an upward capacity requirement. This formulation could be readily extended to define a symmetric downward capacity requirement if CAISO believes doing so would address a recurring operational challenge.

<u>Hourly flexibility constraint</u>

$$\sum_i FRU_{i,t} + \sum_i FRD_{i,t} = FR(60)_t^{95}$$

Where:

$FR(60)_t^{95}$ is the maximum potential cumulative requirement for flexibility across the entire operating hour, *t*, at a 95 percent confidence level. This requirement is based on analysis of historical data for similar hours, and is intended to exclude movement that is already accommodated prior to real-time (*e.g.,* through ramp-constrained physical energy schedule changes resulting from the hourly energy market solution).

<u>15-minute flexibility constraint</u>

$$\sum_i FRU_{i,t} + \sum_i FRD_{i,t} = FR(15)_t^{95}$$

Where:

$FR(15)_t^{95}$ is the maximum potential requirement for flexibility from a single 15-minute interval to the next during the operating hour, *t*, at a 95 percent confidence level. This requirement is based on analysis of historical data for similar hours, and is intended to exclude movement that is already accommodated prior to real-time (*e.g.,* through ramp-constrained physical energy schedule changes resulting from the hourly energy market solution.) Since this requirement is enforced simultaneously with the hourly flexibility requirement, the addition of this constraint will result in additional procurement only for the potential "additional steepness" within an hour.