California ISO

Day-Ahead Market Enhancements: Comparison Matrix

March 20, 2023

	Nodal Approach	Zonal Approach	SCE Approach
Basic description	Procures imbalance reserves within the IFM (co-optimized with energy and ancillary services) and through the use of deployment scenarios to ensure the awards are transmission feasible if deployed as energy.	Procures imbalance reserves within the IFM (co-optimized with energy and ancillary services) using zonal procurement similar to ancillary services.	Procures imbalance reserves within the RUC (co-optimized with reliability capacity) using nodal procurement to respect transmission constraints.
How the uncertainty requirements are calculated – ease and accuracy?	Uncertainty requirements are calculated at the BAA level. The BAA-level uncertainty requirements are distributed into three categories: load, wind, and solar. This reflects the contribution of each category to the BAA uncertainty requirement. Each category requirement is then distributed to respective nodal locations based on load distribution factors (for load) and proportional to VER forecasts (for wind/solar). The BAA-level uncertainty requirements are easy to calculate because there is only one calculation per BAA, and existing methodology/systems already implemented for Flexible Ramping Product can be leveraged. While this proposed mechanism accurately accounts for uncertainty between categories (load, wind, solar), it may not accurately	There are two different approaches discussed. The first approach calculates zonal uncertainty requirements, using similar methodology to the BAA uncertainty requirements but calculated specifically for each zone. This allows for the uncertainty requirements to account for different locational uncertainty within each zone. However, this method would involve increasing the number of uncertainty calculations performed, as well as increasing the quantity of input data collected and stored. It would also result in higher overall uncertainty requirements for the BAA because it does not account for the diversity benefit of pooling forecast errors over a larger footprint. The second approach calculates BAA-level uncertainty requirements and allocates those	This option does not change the distribution of the uncertainty requirement from the ISO's final proposal; it just does so in RUC instead of the IFM.

	account for uncertainty within categories because it assumes similar uncertainty for resources with similar forecasts. In other words, this mechanism does not take into account locational differences in uncertainty within the distribution of the requirement.	requirements to sub-BAA zones. One could do this in two ways: first, a top-down distribution of BAA-level requirements to nodes similar to the nodal approach, followed by a bottom-up aggregation over the nodes within each zone, which allows the BAA to maintain the diversity benefit while distributing the requirements to each zone using the same distribution as in the nodal approach; second, distributing BAA-level requirements to sub-BAA zones in proportion to zonal uncertainty requirements, which would allow the BAA to maintain the diversity benefit but would require an increase in the data collected, stored, and analyzed, as sub-BAA uncertainty calculations are needed to properly allocate the BAA uncertainty.	
Transmission constraints enforced and implications for level of deliverability	This option enforces deployment scenarios in which the IRU/IRD awards are fully deployed as energy, ensuring that transmission constraints are not violated. This improves the reliability and efficiency of the product, as the day-ahead market would not procure imbalance reserves from resources behind constraints. However, the deployment scenarios are a deterministic way to model resource deliverability to	The base design is intended to enforce only inter-zonal transfer constraints. These constraints would essentially allow the zones to trade uncertainty requirements but prevent the imbalance reserve flows from competing with energy on transfer paths. However, this design is incompatible with the current EDAM/WEIM framework where the BAA is used as a fundamental building block. It will require a more granular design where the zone is the fundamental	This approach would incorporate the same nodal delivery test used in RUC and apply the same imbalance reserve deployment scenarios. Imbalance reserve deployment would not compete with energy for internal and transfer transmission capacity because they are not co-optimized, thus losing the opportunity cost in the marginal imbalance reserve price. As a consequence of the 15-min

	address a “cloud” of net load uncertainty based on historical levels of uncertainty. The deployment scenarios can be faulted for being imprecise because they will not predict exactly where and how much uncertainty will materialize as they are an estimate based on historical data. This is a tradeoff in incorporating more granular information to inform procuring resources to address uncertainty. A nodal approach leans toward including more granular information as informative, whereas a zonal approach leans more toward discarding information below a certain level of granularity in the name of false precision. Potential design modifications to either framework (see bottom row) represent different ways of balancing that tradeoff. The ISO design is flexible; it can be "tuned" to enforce varying degrees of transmission constraints in the deployment scenarios. This tuning process is occurring today with nodal FRP, allowing lessons learned on the tradeoff between deliverability and optimization performance to be applied to imbalance reserves. Transmission penalty factors in the deployment scenarios can be tuned	building block, with zonal power balance constraints and transfers. Alternatively, the zonal imbalance reserve requirement can be met only by resources residing within the zone leaving the transmission capacity on the zonal interface in the constrained direction (import or export) to be used only for energy schedules in that direction. Deployment scenarios can be used in a limited fashion on EDAM BAA transfer locations to enable co-optimization of transfer capacity between EDAM BAAs. Deliverability is not ensured within zones, as transmission constraints within the zones are not enforced. Furthermore, deliverability is not ensured outside of zones since transmission constraints are also not enforced outside the zones. AS zones may not be suitable to define imbalance reserve zones because internal CAISO constraints tend to be spread out across the system, which would not be reflected by the AS zones.	ramp capability requirement for imbalance reserves, there may be artificial shortage of available 15min ramp-capable capacity in RUC after the optimal energy scheduling in IFM, resulting in scarcity and high imbalance reserve prices in RUC. An alternative approach would be to continue procuring imbalance reserves in IFM, but not model full deployment of the imbalance reserves as energy; instead, only a portion of the imbalance reserve flows would be tested for deliverability.

	such that they would be economically relaxed if the cost of imbalance reserve procurement within a constrained area were too expensive. This can allow transmission constraints to be enforced up to a pre-defined cost and lower the cost impact of transmission constraints in the deployment scenarios.		
Which DAM process procures imbalance reserves?	IFM	IFM	RUC
Need for Market Power Mitigation	Yes. Local market power mitigation measures would be applied to imbalance reserve bids. However, variations of the ISO proposal, where fewer constraints are enforced or lower penalty factors apply, may decrease the frequency with which LMPM would be applied.	Likely. Zonal market power mitigation would likely need to be applied to imbalance reserve bids depending on (1) the granularity of zones, (2) the level of external (inter-zonal) competition enabled by the design, and (3) the level of supplier competition within zones.	Yes. Local market power mitigation measures would be applied to imbalance reserve bids.
Price formation (imbalance reserves)	Imbalance reserve marginal price determined by (1) imbalance reserve bids (2) costs of forgoing opportunity to provide energy or ancillary services and (3) marginal cost of congestion from the upward/downward deployment scenarios in IFM.	Imbalance reserve marginal price determined by (1) imbalance reserve bids and (2) costs of forgoing opportunity to provide energy or ancillary services.	Imbalance reserve marginal price determined by (1) imbalance reserve bids (2) costs of forgoing opportunity to provide reliability capacity but not energy or ancillary services and (3) marginal cost of congestion from the upward/downward deployment scenarios in RUC.
Price formation (energy)	Same as today except includes (1) imbalance reserve opportunity costs and (2) the marginal cost of congestion contributions from the	Same as today except includes imbalance reserve opportunity costs.	Same as today. Imbalance reserves would not be reflected in the energy price and would lose the co-optimized price signal.

	upward and downward deployment scenarios.		
Confidence in EDAM transfers	High. Both internal and transfer constraints are modeled, leading to confidence that the awards from the day-ahead market solution can be delivered if needed.	Ranges depending on the design assumptions. Generally, fewer transmission constraints considered will lower the likelihood of deliverability, and thus confidence in EDAM transfers. If zones are set at the BAA level, confidence in transfers will be higher from BAAs with fewer locational constraints and lower from BAAs with numerous locational constraints.	High. Both internal and transfer constraints are modeled, leading to confidence that the awards from the day-ahead market solution can be delivered if needed.
Connection to EDAM RSE proposal likelihood of EDAM RSE failure	No changes to the EDAM RSE proposal or likelihood of RSE failure.	Potential changes to EDAM RSE proposal. If the BAA has zonal uncertainty requirements, CAISO and stakeholders may have to amend the EDAM RSE design to test for supply sufficiency in each zone. Additionally, zonal uncertainty requirements would lead to higher overall BAA requirements, and thus a higher likelihood of RSE failure. If the zonal design continues with BAA-level requirements, then no changes to the EDAM RSE proposal or likelihood of RSE failure are expected.	No changes to the EDAM RSE proposal are expected; however, because energy schedules are not co-optimized with uncertainty needs, there is a chance of creating artificial scarcity for 15-minute rampable capacity in RUC, which may increase the likelihood of EDAM RSE failure, especially in tight supply conditions.
Co-optimization benefit	Imbalance reserves would be procured in a fully co-optimized fashion with energy and ancillary services. The market would fully optimize resource capacity between these products and	Reduced co-optimization benefits as the nodal approach due to zonal procurement of imbalance reserves that foregoes the co-optimization of energy and imbalance reserve transfers	Imbalance reserves would not be co-optimized with energy and ancillary services. There would be no co-optimization benefit, and would reduce efficiencies in unit

	produce prices that reflect opportunity costs of not selling energy and other products in that interval. Co-optimization also allows for more efficient unit commitment by minimizing the set of resources committed to meet the energy, AS, and imbalance reserve demand. Overall this reduces the total dispatch cost of meeting demand.	across zonal boundaries. Imbalance reserves would still be procured in a co-optimized fashion with energy and ancillary services within and outside of zones. The market would optimize resource capacity between these products and produce prices that reflect opportunity costs of not selling energy and other products in that interval. Co-optimization also allows for an efficient unit commitment by minimizing the set of resources committed to meet the energy, AS, and imbalance reserve demand. Overall, this reduces the total dispatch cost of meeting demand, albeit not at the level of the nodal approach.	commitment, scheduling, and prices. Imbalance reserves would be co-optimized with reliability capacity to optimize the residual capacity left over from the IFM run between these two products.
Consistency with Flexible Ramping Product	Consistent price formation and modeling with Flexible Ramping Product.	Inconsistent price formation and modeling with Flexible Ramping Product. Potential implications for settlements and convergence bidding.	Inconsistent price formation and modeling with Flexible Ramping Product. Potential implications for settlements and convergence bidding.
Enables diversity benefit	Yes.	Yes, depending on whether the uncertainty requirements are calculated by BAA and distributed to zones (diversity benefit) or calculated by zone (no diversity benefit).	Yes.
Enables transfers between EDAM areas	Yes.	Varying degrees of transfers based on design assumptions. On one end of the spectrum, deployment scenarios between BAAs gives high confidence in transfers of both energy and imbalance awards, assuming	Yes. However, imbalance reserves transfers would not compete with energy for use of transfer capacity.

		resources with imbalance awards are not located behind local constraints. On the other end, a zonal design with requirements that must be met by resources within a zone will not enable transfers of imbalance awards.	
Operator confidence and intervention	High operator confidence with minimal operator intervention. Expected to greatly reduce the practice of RUC operator biasing. For CAISO BAA, it is possible that deliverable imbalance reserves could displace deliverable capacity for other AS products, increasing the frequency of CAISO operator intervention of undeliverable AS products. This would be limited to the CAISO BAA in EDAM and CAISO BAA operators are already well-trained in this function.	Lower operator confidence, with likely increased levels of operator intervention, especially for EDAM BAAs. Lower confidence in deliverability of reserves could result in BAA operators reverting back to use of out-of-market actions like RUC biasing. EDAM BAA operators would need to monitor and take action against undeliverable reserves. Ad hoc actions and tools may be required for operators to define zones. For CAISO BAA, may reduce frequency of CAISO operator intervention for undeliverable AS products compared to nodal approach.	High operator confidence with minimal operator intervention. Expected to reduce the practice of RUC operator biasing. That said, there is less to distinguish the impact of RUC operator biasing from the market solution. Operator biasing may persist if the IFM solution produces scarcity of 15-min ramping capacity in RUC. No concern about displacement of deliverable capacity for AS because the products are not co-optimized.
Virtual bidding impact	Concern that virtual bidders may undermine the day-ahead market solution by arbitraging the deployment scenario congestion that may not materialize in real time. The MSC indicated this is not probable because clearing virtual supply in constrained areas is risky and several market functions (EDAM diversity benefit, imbalance reserve demand curve) may lower	No similar concern; but inconsistency in price formation between markets may introduce other virtual arbitrage issues.	No similar concern; but inconsistency in price formation between markets (the FMM will co-optimize energy with FRP through deployment scenarios but under this proposal there would be no parallel in IFM) may introduce other virtual arbitrage issues.

	the imbalance reserve requirement significantly below the 97.5 percentile. The MSC also foresees a low probability for imbalance reserves outcompeting energy for use of congested transmission, especially if combined with adjustments to demand curves for the product as well as adjustments to transmission penalties in the deployment scenarios.		
Cost allocation and settlement impact	Allows for a deviation settlement with FRP.	May not allow for a deviation settlement with FRP. Cost allocation would have to be re-visited.	May not allow for a deviation settlement with FRP Cost allocation would have to be re-visited.
Congestion revenue impact	Imbalance reserve flows that result in binding transmission constraints can “displace” energy congestion revenue collected. The CAISO has a proposal to resolve this issue.	No congestion revenue impact because the flows of imbalance reserves are not modeled.	No congestion revenue impact because the imbalance reserve “flows” are not part of the IFM solution.
Market performance impact	Higher impact to market performance and computational requirements. Quantity of constraints enforced would require identifying the right balance in market performance and optimization/software performance.	Lower market performance impact and computational requirements if there is no co-optimization of energy and imbalance reserve transfers on zonal boundaries. Otherwise, the redesign of the market and the computational requirements for solving and settling are high.	Lower market performance impact and computational requirements.
Implementation risk	CAISO’s experience implementing nodal FRP will reduce implementation challenges for nodal imbalance reserves because CAISO can leverage understanding of impact to market/system/applications and	May involve additional implementation risk by adding more components (data collection/storage/calculation of sub-BAA requirements, process of defining/managing zones). Process of defining and managing	Perceived to be slightly lower than nodal approach.

	leverage past work on the uncertainty requirement calculation and new application to host the calculation. Higher computational requirements and other complexities may result in more anomalies/issues in market testing that would need to be addressed.	zones would be complicated and subject to constant re-evaluation. Lower computational requirements may also reduce likelihood of certain implementation issues if there is no co-optimization of energy and imbalance reserve transfers on zonal boundaries.	
Timeline risk	The policy, business requirements, and tariff changes are nearly complete. Maintains current implementation target schedule of Fall 2024 coincident with EDAM.	Depending on degree of variances from current market architecture and design, would require re-visiting the day-ahead and EDAM design elements in consideration of a zonal design. Could delay implementation past Fall 2024.	Would require some additional policy, business requirement, and tariff changes. May have some schedule impacts, but not as significant as moving to a zonal design.
Potential design modifications to address concerns with approach	Model fewer constraints in deployment scenarios to address computational risk and limit congestion impacts of IR deployment scenarios. Transmission penalty factors in the deployment scenarios can be tuned such that they would be economically relaxed if the cost of imbalance reserve procurement within a constrained area were too expensive. This can allow transmission constraints to be enforced up to a pre-defined cost and lower the cost impact of transmission constraints in the deployment scenarios.	Varying degrees of granularity of zones to balance deliverability issues, costs, and congestion impacts. Deployment scenarios can be used in a limited fashion on EDAM BAA transfer locations to enable co-optimization of transfer capacity between EDAM BAAs, which would create more confidence in transfers.	

	Add a parameter to reduce the quantity of imbalance reserves that is tested for deliverability, to address concerns about virtual bidding behavior and the pricing impacts from congestion in the deployment scenarios. For instance, the deployment scenarios could test 0.5 MW for every 1 MW of imbalance procured.		