Flexible Ramping Product Refinements

Draft Final Proposal

May 8, 2020

Flexible Ramping Product Refinements

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1 Purpose

This paper addresses the flexible ramping product issues identified in the CAISO Energy Markets Price Performance Report[1] published on September 23, 2019. The flexible ramping product[2] was introduced into the real-time market to manage ramp capability to address uncertainty caused by load and variable energy resources that materializes between market runs. Prior to the flexible ramping product implementation, the CAISO observed that the multi-interval market optimization would solve forecasted net load by utilizing the precise amount of ramp needed across the market horizon. However, when system conditions changed in subsequent market runs, the market would lack sufficient ramping capability in the real-time dispatch. The flexible ramping product secures additional ramping capability that can be dispatched in subsequent market runs to cover uncertainty in forecasted net load (i.e., load forecast net of variable energy production). Resources providing this ramping capability are compensated at the marginal opportunity cost (which is related to the cost of energy) for both forecasted movement and uncertainty awards.

2 Changes from Revised Straw Proposal

The table below outlines the issues identified in the CAISO Energy Markets Price Performance Report that need to be addressed and additional issues added to the scope of the initiative after the issue paper. The table also identifies whether the changes being considered require tariff changes or can be implemented through BPM changes.

Issue	BPM or Tariff Change	Targeted Implementation	Change from revised straw proposal
Proxy demand response eligibility	Both	Fall 2021	Changed implementation to Fall 2021
Ramp management between FMM and RTD	BPM only	Fall 2020	None
Minimum FRP requirement	BPM only	Fall 2020	(1) Simplified rule by enforcing a minimum requirement only when a balancing authority area is 60% of the system requirement. (2) A nominal requirement can be used in any balancing authority area in needed.
Deliverability enhancement	Both	Fall 2021	(1) The FRP uncertainty is distributed to load and VERs in the deployment scenarios. Previously distributed to load nodes only. (2) Distributing the demand curve surplus variable as decision

[1] The report is available at http://www.caiso.com/Documents/FinalReport-PricePerformanceAnalysis.pdf
[2] Information on the flexible ramping product design is available at http://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=24AB06E3-B018-4DEC-8F43-28B8A0E90514

			variable at load aggregation points versus balancing authority areas. (3) Since deployment scenarios are not included in the day-ahead market at this time, virtual supply and demand will not be settled for congestion from the deployment scenarios.
FRP demand curve and scarcity pricing	None	Fall 2021	None
Scaling FRP requirement	BPM only	No later than Fall 2021	Additional detail has been provided in Technical Appendix C

3 Stakeholder Comments and Changes from the Revised Straw Proposal

The CAISO appreciates the written stakeholder comments received in response to this initiative's revised straw proposal and the subsequent stakeholder call. The following summarizes these comments and the changes resulting from them.

Proxy Demand Response (PDR) Eligibility

Stakeholders supported the CAISO's intent to modify tariff language to change the default setting from 5-minute dispatchable to 60-minute dispatchable. Based on stakeholder support the CAISO will pursue implementing the enhancements as proposed in its revised straw proposal.

The CAISO has reached out to scheduling coordinators of PDRs to ensure that they selected the correct dispatch option based on the actual operational characteristics of the resources. The vast majority of PDRs have selected either the 15-minute or hourly dispatch option. As a result, the implementation date has been changed to Fall 2021 so that this tariff change can be submitted with the tariff changes needed to support nodal deliverability rather than in a separate filing.

Ramp Management between Fifteen-Minute Market (FMM) and Real-Time Dispatch (RTD)

Stakeholders generally supported the CAISO's proposal to maintain up to 100% of the flexible ramping product awards in the buffer interval that were procured in the prior FMM interval. Some stakeholders suggested the CAISO provide additional analysis on how it plans to address uncertainty that could arise between FMM runs when 100% of the flexible ramping product awards are maintained in the buffer interval. However, the flexible ramping product uncertainty requirement covers uncertainty that arises between FMM and RTD runs, not between FMM runs. The flexible ramping product requirement is included in FMM to ensure unit commitment decisions cover both the net load forecast and flexible ramping product requirement for RTD. No unit commitment decisions can be made in RTD. Thus it is

appropriate to hold 100% of the requirement in the buffer interval so that unit commitment does not change which ensures the ramping capability is available in RTD. Based on stakeholder feedback the CAISO will pursue implementing the enhancements as proposed in its revised straw proposal.

Minimum Flexible Ramping Product Requirement for Balancing Authority Area

Stakeholders generally supported the CAISO's intent to enforce a minimum flexible ramping requirement in a balancing authority area in the EIM footprint.

The Joint EIM entities expressed concern regarding the proposed process for reviewing an EIM entity's minimum requirement, which they contend may not provide an ability to collaborate or provide feedback in a manner that is meaningful. The proposal has clarified that a minimum requirement will be enforced for any BAA in the EIM whose individual requirement is greater than or equal to 60% of the EIM requirement on an hourly basis. When a minimum requirement is needed the CAISO will determine if a nominal amount needs to be procured in each balancing authority area outside the pivotal area. Also, the minimum requirement does not impact the flexible ramping resource sufficiency evaluation.

The CAISO Department of Market Monitoring (DMM) stated they are unsure of the reasoning behind the system requirement adjustments and are concerned that these adjustments could lead to significant over procurement of flexible ramping capacity at the system level. This feature has been removed from the proposal.

Nodal Procurement

Stakeholders agree with the principles of nodal procurement but are concerned about its complexity and potential impact to the CAISO's market system performance. In its revised straw proposal, the CAISO acknowledged the implementation complexity and significant computational requirements necessary to applying nodal procurement to the flexible ramping product. The Joint EIM entities requested the CAISO to consider implementing zonal procurement of the flexible ramping product if the proposed nodal approach cannot be implemented. Further, stakeholders cautioned the CAISO that moving to nodal procurement seems like a long-term solution because of its design and implementation complexity; however, the CAISO should consider more near-term solutions that can reduce the risk of non-deliverable flexible ramping product and can be implemented more quickly than nodal procurement.

The CAISO is confident that the proposed nodal design can be implemented in both the real-time market for the flexible ramping product and in the day-ahead market for the proposed imbalance reserves in the day-ahead market enhancements. The CAISO believes it is important to focus resources on nodal deliverability of both products and completing these initiatives instead of developing interim solutions.

Other stakeholders requested the CAISO provide additional numerical examples and/or solver scenarios to assist stakeholders. In response, the CAISO has provided an Excel solver[3].

Additionally, PG&E questioned if distributing the uncertainty of the flexible ramping product to load only is sufficiently accurate given that uncertainty is driven by both load and VER variation. The CAISO has provided analysis supporting that the flexible ramping product requirement should also be deployed to VER locations.

Finally, PG&E requested that the CAISO revise its approach to distributing the flexible ramping product "surplus variable." The surplus variable is how the flexible ramping product demand curve is implemented. Spreading the demand curve surplus variable pro-rata to load can cause relaxation needed in one part of the system to occur globally even though ramping capability might be available elsewhere in the system. The CAISO has modified the design and proposes to model the surplus as a decision variable for each major load aggregation point (LAP). This ensures that a shortfall in one LAP does not result in the flexible ramping requirement in another LAP not being met.

Flexible Ramping Product Demand Curve and Scarcity Pricing

Stakeholders supported the CAISO's flexible ramping product design that produces stepped scarcity pricing using a demand curve. Once the nodal procurement of the flexible ramping product is implemented, the flexible ramping product requirement will be fully relaxed prior to the power balance constraint being relaxed. This will produce accurate scarcity pricing signals because the market will no longer award transmission infeasible capacity.

Scaling Flexible Ramping Product Requirements

Stakeholders expressed support for the CAISO's proposal to use a quantile regression approach for calculating the flexible ramping product requirements as a function of the net demand forecast. The CAISO has provided additional detail in Appendix C: Quantile Regression Approach to Enhance the Flexible Ramping Product Requirements[4].

Other items

Powerex requested two additional design considerations to improve the availability and benefit of the flexible ramping product: (1) develop performance metrics to assess if resources should remain eligible for FRP awards; and (2) setting a maximum energy bid price above which the resource would be ineligible to provide the upward flexible ramping product. The CAISO does not believe item 1 is warranted at this time. If after implementation of nodal deliverability, the CAISO observes instances of resources unable to respond to 5-minute dispatches being awarded the flexible ramping product, this may require a design change to consider other approaches similar to the PDR default option reviewed.

[3] The Excel solver will be provided on the initiative webpage. This is available at http://www.caiso.com/StakeholderProcesses/Flexible-ramping-product-refinements

[4] Appendix C will be provided on the initiative webpage. This is available at http://www.caiso.com/StakeholderProcesses/Flexible-ramping-product-refinements

With regards to item 2, the CAISO notes that this same issue exists with the day-ahead market enhancements proposed imbalance reserve product. The CAISO will need to develop a proposal for imbalance reserves and believes that the design decisions made to address this issue in the day-ahead market will need to be aligned with the approach for real-time flexible ramping products.

DMM reiterated their request to increase the uncertainty requirement to cover larger uncertainty that can occur over an hour or longer than the current approach which includes the 15-minute uncertainty in each of the advisory intervals in the real-time market. Since the current flexible ramping product is not fully deliverable, the CAISO is unsure of the incremental benefit of adding an additional time horizon of uncertainty into the optimization at this time since the 15-minute requirement is already included in each advisory interval. The CAISO will include this potential design enhancement in the market initiative catalog.

4 Proxy Demand Response Eligibility

The CAISO can award the flexible ramping product to multiple types of resources, including proxy demand resources (PDR). Recent trends show the market frequently awards flexible ramping product to PDRs because they have energy bids at or close to the bid cap of $1,000/MWh. The market views the PDRs with high priced positive energy bids as economic to provide the upward flexible ramping product because their opportunity cost of providing the flexible ramping product is zero. The market does not view the PDR economic to be dispatched for energy in the binding market interval.

This issue is currently exacerbated because many PDRs cannot respond to the 5-minute dispatch. If PDRs are unable to respond to five-minute real-time dispatches, the procured flexible ramping product cannot be used as energy in a subsequent RTD run.

In the *Energy Storage and Distributed Energy Resources Phase 3A* initiative, additional bidding options were made available to PDRs. These included a 60-minute and 15-minute dispatchable bid option. Unlike the 5-minute dispatch which has a 2.5 minute notification to curtail load, these options provide 22.5 minutes and 52.5 minutes notification prior to the time load needs to be curtailed. Consistent with newly FERC-approved provisions in section 4.13.3 of the CAISO tariff, PDRs will be able to specify in the Master File how the PDR will bid and be dispatched in the real-time market: in (i) hourly blocks, (ii) fifteen minute intervals, or (iii) five minute intervals.

These provisions became effective as of November 13, 2019. Consistent with existing section 4.6.4, the Master File must be an accurate reflection of the design capabilities of the resources. Therefore, scheduling coordinators will be required to ensure their Master File designation appropriately reflects their PDR capabilities and if they do not have the ability to respond to five minute dispatch, the scheduling coordinator should designate their resource as hourly blocks or 15-minute dispatchable. Consistent with section 44.2.3.1, the 15-minute and 60-minute options will not be eligible to be awarded the flexible ramping products.

Although this was not an integral element of the ESDER policy as approved by the board, in developing implementation details for this initiative, expecting that PDRs would accurately reflect the resource's characteristics in the Master File, the CAISO decided to set the default Master File entry to "5-minute dispatchable" should the scheduling coordinator fail to make an election. The CAISO also included the default detail in the tariff. The CAISO proposes to modify the default setting to be 60-minute dispatchable.

After implementation of the bid options, very few PDR resources changed their bid option from 5-minute dispatchable even though the inability to respond to 5-minute dispatch instructions has not changed. The CAISO has reached out to scheduling coordinators of PDRs to ensure that they selected the correct dispatch setting consistent with their actual operational characteristics. The vast majority of PDRs have selected either the 15-minute or hourly dispatch option. As a result, the implementation date has been changed to Fall 2021 so that this tariff change can be submitted with the tariff changes needed to support nodal deliverability rather than in a separate filing.

5 Ramp Management between FMM and RTD

The CAISO procures the flexible ramping product in both the 15-minute market (FMM) and the 5-minute real-time dispatch (RTD). In the FMM, the flexible ramping product covers the uncertainty between the advisory FMM interval and the highest/lowest binding RTD interval for the same 15-minute time interval. This ensures that there is sufficient ramp capability committed in the real-time unit commitment process (RTUC) to cover uncertainty materializing in RTD. The flexible ramping product requirement does not cover uncertainty between FMM runs.

The FMM is part of the RTUC process. The RTUC runs every fifteen minutes to determine binding unit commitment decisions for fast and short start units within the RTUC horizon. The RTUC horizon is the next four to seven fifteen-minute intervals, depending on when during the hour the run occurs. The second interval of each RTUC run horizon is designated as the FMM and is the financially binding interval for energy prices and schedules used for settlements. The first interval in an RTUC run horizon, or the interval preceding FMM, is referred to as the buffer interval. The logic of the buffer interval was introduced in the market with the implementation of the FERC Order No. 764 in order to provide sufficient time for tagging purposes once fifteen-minute interties could economically participate in the real-time market. The buffer interval can be used to issue binding unit commitment of fast and short start units. The schedules and prices in the buffer interval are not financially binding. The remaining intervals in the horizon can also have binding unit commitments and advisory schedules and prices.

Currently, the flexible ramping product awards are not reserved in the buffer interval. As a result, the ramping capability procured in the prior RTUC run, when the time interval was financially binding (FMM), may be used to meet the ramping needs of the current market run. When system conditions change between FMM runs there may no longer be any ramping capability available for the RTD intervals within that timeframe, or the ramping capability may be lost. Ramping capability is lost when projected start-ups of units with flexible ramping product awards are not started in the next run when

they are no longer needed because of additional ramping capability resulting from the release of the flexible ramping product from the buffer interval to the binding interval.

The CAISO proposes to maintain a portion, up to 100%, of the FRP awards in the buffer interval that were procured in the prior FMM. This will ensure that ramping capability will be preserved for RTD. This can result in a resource not being scheduled in the FMM interval because its ramping capability was secured through a flexible ramping product award in the previous market run. For example, assume a resource with the following characteristics: Pmin = 100 MW, Pmax = 200 MW, and a ramp rate of 5 MW/Minute. In market run #1, the resource receives a binding commitment in FMM and is scheduled for energy at 100 MW and awarded flexible ramping up of 75 MW. In market run #2, if the flexible ramping product awards are not reserved in the buffer interval, the resource could receive an energy schedule of up to 175 MW in the FMM. However, if the flexible ramping product is reserved in the buffer interval for potential deployment in RTD, the resource could receive an energy schedule of up to 125 MW because the 75 MW flexible ramping up award is maintained.

6 Minimum Flexible Ramping Product Requirement for BAA

The net import/export capabilities (NIC/NEC) are used to reduce a balancing authority area's requirement. The basic idea is that flexible ramping awards can be supplied from other balancing authority areas through the import or export transfer capability. The CAISO has previously found[5] that requirement reductions counting on imports and exports were beyond levels that a balancing authority area could feasibly support. If the import capability is higher than the balancing authority area's flexible ramping product up requirement, then the balancing authority area's flexible ramping product requirement is effectively 0 MW. That is, none of the balancing authority area's upward flexible ramping product needs to be awarded to internal resources. Under typical conditions, all balancing authority areas generally have larger import or export limits than their flexible ramping up or flexible ramping down requirement. Within an interconnected system with multiple areas, a flexible ramping product can be counted towards other areas by wheeling through other balancing authority areas. However, only the transfer capability with adjacent balancing authority areas is considered when calculating the net import/export capability. This is true for all balancing authority areas in the EIM footprint.

Currently, the CAISO is the largest driver of the system-wide flexible ramping product requirement because it has the largest load and penetration of variable energy resources. The CAISO requirement for the flexible ramping product that must be procured from internal resources is effectively zero[6] given the large import and export capability of the CAISO. However, since the CAISO has such a large share of the

[5] This was discussed at the February 2, 2018 Market Surveillance Committee meeting. The presentation is available at http://www.caiso.com/Documents/Presentation-FlexibleRampingProductPerformanceDiscussionFeb22018.pdf

[6] See figure 73 from the Price Performance Report available at http://www.caiso.com/Documents/FinalReport-PricePerformanceAnalysis.pdf

requirement, a portion needs to be procured within the balancing authority area in order to be available for uncertainty that materializes in the CAISO balancing authority area.

The CAISO and other large EIM balancing authority areas have been seen to be driving a large share of the total EIM requirement. Therefore, the proposal is to set a minimum requirement for an EIM balancing authority area that is a pivotal share (greater than 60%) of the entire system requirement in a given hour.

The CAISO will calculate the minimum requirement based on the existing flexible ramping product requirements. The existing requirement calculates the uncertainty for the individual balancing authority area along with the EIM footprint. The CAISO can estimate the requirement for the pivotal areas based on these uncertainty calculations, historical percentages, comparison of the area to the EIM footprint, and diversity benefit factors for the pivotal areas. Requirement data from the flexible ramping product procured in 2019 was used to determine the minimum requirement and when it should be enforced. In Table 1 the percentage of the balancing authority area requirement is shown in comparison to the EIM footprint requirement. This comparison is important because in applying the NIC/NEC credit to the individual area leads to the EIM footprint requirement being the only requirement for the flexible ramping product. The data summarized in Table 1 shows that in 2019 CAISO was the pivotal, with the next five largest areas' total percentage of the requirement still less than the CAISO percentage of the total EIM area requirement. It is important to note that both upward and downward flexible ramping product for the 4th largest area is around 67% to 68%, as noted in Table 2.

Table 1: Average percentage of EIM footprint requirement

Balancing Authority Area	2019-Flex Up	Rank-Flex Up	2019-Flex Down	Rank-Flex Down
CAISO	80.56%	1	83.54%	1
APS	15.24%	4	13.09%	6
BANC SMUD	1.93%	10	2.48%	10
PWRX	16.80%	3	16.36%	3
IPC	12.76%	5	14.27%	5
NVP	11.38%	7	10.91%	8
PACE	21.54%	2	22.69%	2
PACW	11.33%	8	9.18%	9
PGE	12.48%	6	14.31%	4
PSE	9.59%	9	11.43%	7

Table 2

Next largest areas	Total Flex Up	Total Flex Down
Top 3	53.59%	53.37%
Top 4	66.35%	67.64%
Top 5	78.83%	80.73%

Top 6	90.21%	92.16%

The CAISO's share of the EIM area's uncertainty requirement in 2019 was between 80% to 84%. Therefore those percentages can be set as the higher bound for the requirement. The lower bound can be established by looking at the procurement CAISO had in comparison to the EIM area. Table 3 shows these percentages and the lower bound can be establish between 45% and 52% of the EIM area requirement.

Table 3: Procurement of Area Requirement

Balancing Authority Area	Flex Up	Flex Down
CAISO	45.67%	51.76%
APS	2.34%	2.09%
BANC SMUD	8.99%	5.13%
PWRX	20.46%	5.13%
IPC	4.27%	3.88%
NVP	1.24%	3.96%
PACE	7.10%	14.42%
PACW	4.61%	6.76%
PGE	4.52%	4.68%
PSE	5.68%	5.71%

Although this average procurement is not an established minimum because this is the average for the year and there are several data points where the procurement is well below 52%, this data shows that the minimum for the pivotal area should be greater than the current procurement.

The diversity benefit is an important factor to consider for the minimum requirement. The diversity benefit factor is the ratio of the EIM area uncertainty requirement to the sum of all the uncertainty requirements over all balancing authority areas in the EIM area. The average requirements and diversity benefits per hour for 2019 have been calculated in Table 4 and Table 5.

Table 4: Flexible Ramping Up Requirement Amounts

HE-Flex Up	Avg of CAISO REQ	Avg of EIM REQ	Avg of EIM TOT	Avg of DB Factor	Avg of MW CAISO DB	Avg of Min Req CAISO	Avg of Min Req Percent of CAISO REQ
1	531.98	769.46	1488.17	51.46%	280.16	294.76	55.21%
2	509.27	605.64	1297.21	45.78%	240.59	287.78	57.41%
3	479.58	601.10	1186.34	50.50%	246.54	267.08	55.56%
4	469.76	601.11	1151.45	51.62%	250.51	262.35	55.67%
5	503.38	690.56	1208.16	56.68%	290.91	296.39	58.31%

6	561.43	734.10	1344.99	53.41%	312.49	325.71	57.62%
7	748.01	931.33	1689.99	54.28%	418.93	435.50	57.66%
8	1295.05	1509.77	2355.19	63.84%	831.34	832.08	63.92%
9	1055.74	1340.93	3353.36	43.02%	504.94	697.83	66.68%
10	966.70	1073.12	2009.24	51.85%	526.26	563.05	57.69%
11	785.73	861.03	1797.80	47.63%	382.47	433.47	55.67%
12	760.76	835.88	1742.73	47.76%	368.11	423.19	55.66%
13	838.64	924.65	1848.60	49.06%	430.79	479.70	57.29%
14	964.74	1038.01	1938.98	51.67%	531.51	572.65	59.04%
15	1114.30	1219.24	2134.50	55.36%	649.59	683.00	60.52%
16	1071.11	1183.33	2141.65	54.18%	600.28	633.79	59.10%
17	979.74	1160.73	2059.01	55.71%	560.89	570.51	57.71%
18	991.28	1203.19	2102.63	56.61%	569.89	584.51	58.62%
19	732.39	936.16	1816.00	50.61%	383.55	412.17	56.40%
20	643.57	813.16	1656.54	48.20%	324.01	363.99	56.66%
21	469.28	691.24	1416.12	48.80%	231.79	264.19	56.46%
22	582.82	852.51	1580.79	52.15%	328.12	354.25	60.33%
23	664.36	961.99	1647.63	57.79%	393.48	398.54	58.86%
24	565.63	817.14	1470.94	54.82%	319.59	328.89	58.07%
Grand Total	**777.94**	**953.99**	**1855.84**	**51.69%**	**420.51**	**462.24**	**58.64%**

Table 5: Flexible Ramping Down Requirement Amounts

HE-Flex Down	Avg of CAISO REQ	Avg of EIM REQ	Avg of EIM TOT	Avg of DB Factor	Avg of CAISO DB	Avg of Min Req CAISO	Avg of Min Req Percent of CAISO REQ
1	484.19	573.08	1269.81	44.65%	225.90	275.74	58.08%
2	462.32	535.01	1191.67	44.70%	211.64	266.66	58.04%
3	447.90	495.22	1123.23	43.60%	202.57	266.80	60.58%
4	412.18	472.65	1057.56	43.71%	192.39	242.60	59.91%
5	443.18	586.37	1124.13	51.70%	235.67	253.70	56.84%
6	520.10	711.63	1280.36	52.98%	303.71	325.67	59.92%
7	526.17	694.07	1369.73	48.85%	275.84	321.50	61.33%
8	751.28	863.45	1748.35	48.16%	380.90	424.35	57.13%
9	971.03	1117.24	3156.15	38.80%	402.06	643.87	67.21%
10	1087.27	1245.23	2236.45	55.19%	610.06	620.24	56.64%
11	985.41	1135.39	2097.09	53.78%	537.73	548.39	55.14%
12	978.26	1096.81	2029.58	53.49%	537.31	560.00	56.65%
13	943.04	1096.64	2002.52	54.63%	518.79	526.05	55.61%
14	963.63	1121.13	2007.17	55.75%	541.61	543.98	56.06%
15	1075.91	1238.62	2212.33	55.94%	603.48	606.71	56.38%

16	1109.53	1320.89	2295.54	57.77%	643.42	649.98	58.49%
17	1208.23	1423.05	2408.23	59.04%	716.16	717.93	59.25%
18	1044.67	1265.72	2273.67	55.72%	587.16	603.85	57.47%
19	913.84	1071.38	1988.03	54.10%	494.10	518.33	56.97%
20	727.47	874.48	1726.42	50.43%	374.20	420.11	58.12%
21	770.86	965.13	1787.59	53.73%	417.03	428.22	55.42%
22	748.51	967.58	1744.26	55.29%	416.87	430.78	57.29%
23	610.00	841.92	1517.44	54.95%	348.81	360.94	58.23%
24	534.60	671.86	1388.38	47.58%	267.47	296.84	56.19%
Grand Total	**790.34**	**942.65**	**1868.41**	**50.73%**	**417.46**	**462.71**	**58.55%**

A flat 60 percent requirement is chosen to test whether a minimum requirement is to be enforced or stated differently, the balancing authority area is pivotal. This is based on the finding that the pivotal areas of Top 4 is around 68%, current procurement for CAISO is approximately 50%, and considering diversity benefit averages around 58%. The enforcement will be for situations where the uncertainty requirement or flexible ramping product requirement is greater than or equal to 60% of the EIM requirement on an hourly basis. Because this rule does have the possibility to apply to other EIM areas for specific hours, this will not be limited just to the CAISO.

An example is provided in Table 6. Assume that the sum of the individual balancing authority area requirements is 1000 MW. The EIM area system requirement is 450 MW. This results in a diversity benefit factor of 45%. A pivotal balancing authority area (BAA 1) is identified because its requirement with its share of the diversity benefit is 292.5 MW. This is greater than 60% of the 450 MW which means the balancing authority area is pivotal. The sum of the remaining balancing authority areas requirement is 157.5 MW. In order to ensure a portion of the remaining requirement is procured locally, a nominal portion of the non-pivotal balancing authority area may be allocated to support a minimum requirement in each of the non-pivotal balancing authority areas. The 10% is for illustrative purposes only. By only using a nominal portion the remaining requirement can ensure the flexible ramping awards are distributed and continue to allow the requirement met by the least cost resources in other balancing authority areas.

Table 6: Example of minimum requirement being enforced

	BAA1	BAA2	BAA3	Total	System
Independent FRU requirement	650	150	200	1000	
Diversity Benefit Factor					45%
EIM System Requirement	292.5	67.5	90	450	
Pivotal BAA Threshold %					60%
Pivotal BAA	Yes	No	No		
Minimum BAA Requirement	292.5	0	0	292.5	
Remaining EIM System Requirement				157.5	
Nominal % to be Held Local for Remaining					10%
Minimum BAA Requirement all BAAs	292.5	6.75	9		

With the implementation of nodal deliverability of the flexible ramping product, the need to enforce a minimum requirement in a balancing authority area will no longer be needed. In the event the implementation of nodal deliverability is delay the CAISO will maintain the minimum BAA requirement, which is in effect a zonal requirement at the balancing authority area level and will consider if sub-BAAs are warranted as well.

7 Nodal Procurement

Procurement of the flexible ramping product is based on opportunity costs, which arise from the trade-offs between the need for energy and the need for ramping capability. The current market does not consider locational constraints when procuring the flexible ramping product. This results in procuring flexible ramp awards that may not be fully deliverable.

The complication relates to congestion from internal constraints within a balancing authority area and from scheduling limits on transfers between balancing authority areas. The market enforces transmission constraints within each balancing authority area to economically manage congestion while resources are optimally dispatched to meet the demand forecast. As part of the congestion management process, resources move up if they help to mitigate the congestion, or down if they exacerbate congestion. Since flexible ramping product is not locational-based, this part of congestion management does not explicitly account for the flexible ramping product procurement. As a result, the market can procure upward flexible ramping capacity from resources that are dispatched down for congestion management, which in the next market run when uncertainty materializes cannot be deployed due to congestion. This interplay between congestion and flexible ramping product procurement can be further exacerbated because the market may find it optimal to allocate upward flexible ramping product capacity precisely to resources dispatched down for congestion management. A similar dynamic exists for downward flexible ramping capacity and resources dispatched higher for energy to provide counter flow to mitigate congestion. In its current implementation, the market has no mechanism to avoid this outcome.

Nodal procurement ensures that both energy and flexible ramping product awards are transmission feasible. This requires the introduction of deployment scenarios to ensure that energy plus upward flexible ramping product awards and energy less downward flexible ramping product awards are transmission feasible. This ensures that upward flexible ramping product awards are not given to resources located behind a transmission constraint and downward flexible ramping product awards are not given to resources providing counter flow to resolve a transmission constraint. The updated market formulation is included in Appendix B: Procurement and Deployment Scenarios Draft Technical Description.

The nodal approach addresses operational concerns that flexible ramping capacity may not be dispatchable and more accurately prices individual resource's flexible ramping capacity. The flexible ramping product awards will result in a locational value of flexible ramping product similar to energy. As more solar, wind and other zero marginal energy cost resources make up a larger portion of the generation fleet, the marginal cost of energy will be lowered. As a result, in the future the compensation of flexible generation will come more from flexible ramping product payments than energy payments.

The goal of the nodal approach is to not eliminate stranded ramping capability when system conditions change. The goal is to not knowingly strand capacity because the optimization awards resources with zero opportunity cost due to congestion. In response to stakeholder comments, the CAISO is proposing two changes to the deployment scenarios to improve deliverability and availability.

1. Distributing the uncertainty requirement to load and VER locations versus just load.
2. Distributing the demand curve surplus variable as a decision variable at load aggregation points versus balancing authority areas.

The CAISO proposes to distribute the requirement to both load and VER supply nodes based upon historically how uncertainty has materialized. Table 6 below shows the average P97.5 uncertainty for load, wind and solar individually by operating hour for 2019. Table 7 below shows the average P2.5 uncertainty for load, wind and solar individually by operating hour for 2019. As the data shows in the middle of the day, uncertainty in VER forecast is the predominant driver of uncertainty. Therefore, the deployment scenario will more accurately reflect the dispatch of the flexible ramping product by distributing a larger portion of the requirement to VER nodes.

Table 7: P97.5 Uncertainty by Load, Wind and Solar

Hour	Load	Wind	Solar	Load	Wind	Solar	Load	VER
1	188	272	1	41%	59%	0%	41%	59%
2	143	322	1	31%	69%	0%	31%	69%
3	97	302	1	24%	76%	0%	24%	76%
4	81	285	1	22%	78%	0%	22%	78%
5	140	293	1	32%	68%	0%	32%	68%
6	209	322	10	39%	59%	2%	39%	61%
7	239	278	214	33%	38%	29%	33%	67%
8	205	270	697	18%	23%	59%	18%	82%
9	253	277	678	21%	23%	56%	21%	79%
10	214	246	475	23%	26%	51%	23%	77%
11	228	232	480	24%	25%	51%	24%	76%
12	258	227	483	27%	23%	50%	27%	73%
13	228	201	501	25%	22%	54%	25%	75%
14	243	204	638	22%	19%	59%	22%	78%
15	277	215	635	25%	19%	56%	25%	75%
16	390	255	680	29%	19%	51%	29%	71%
17	384	262	572	32%	22%	47%	32%	68%
18	353	303	465	32%	27%	41%	32%	68%
19	311	303	269	35%	34%	30%	35%	65%
20	284	343	62	41%	50%	9%	41%	59%
21	190	320	5	37%	62%	1%	37%	63%
22	253	306	1	45%	55%	0%	45%	55%
23	276	325	1	46%	54%	0%	46%	54%
24	228	306	1	43%	57%	0%	43%	57%

Table 8: P92.5 Uncertainty by Load, Wind and Solar

Hour	Load	Wind	Solar	Load	Wind	Solar	Load	VER
1	-171	-255	-1	40%	60%	0%	40%	60%
2	-153	-248	-1	38%	62%	0%	38%	62%
3	-120	-240	-1	33%	67%	0%	33%	67%
4	-94	-237	-1	28%	72%	0%	28%	72%
5	-122	-213	-1	36%	63%	0%	36%	64%
6	-206	-212	-7	48%	50%	2%	48%	52%
7	-244	-201	-113	44%	36%	20%	44%	56%
8	-243	-202	-492	26%	22%	53%	26%	74%
9	-316	-228	-709	25%	18%	57%	25%	75%
10	-319	-256	-613	27%	22%	52%	27%	73%
11	-346	-276	-469	32%	25%	43%	32%	68%
12	-243	-283	-423	26%	30%	45%	26%	74%
13	-237	-232	-342	29%	29%	42%	29%	71%
14	-238	-321	-340	26%	36%	38%	26%	74%
15	-238	-286	-393	26%	31%	43%	26%	74%
16	-272	-332	-505	24%	30%	46%	24%	76%
17	-326	-364	-529	27%	30%	43%	27%	73%
18	-296	-287	-488	28%	27%	46%	28%	72%
19	-260	-264	-301	32%	32%	36%	32%	68%
20	-265	-260	-122	41%	40%	19%	41%	59%
21	-272	-257	-10	50%	48%	2%	50%	50%
22	-288	-248	-2	54%	46%	0%	54%	46%
23	-286	-250	-1	53%	47%	0%	53%	47%
24	-224	-254	-1	47%	53%	0%	47%	53%

The flexible ramping product requirement is relaxed by a demand price curve that reflects the expected cost of foregoing the procurement of the flexible ramping product, so that it is not procured when it is more expensive than the benefit it provides. In order to implement the demand curve, the market uses a flexible ramping product surplus variable to add "supply," and procure less flexible ramping product, if the opportunity cost of providing the flexible ramping product exceeds a given segment of the demand price curve. In the previous straw proposal, there was a ramping product surplus variable for each BAA that fails the flexible ramping sufficiency test, and one for the group of balancing authority areas that pass it. In the revised straw proposal, the CAISO proposes a more granular flexible ramping product surplus variable for each major load aggregation point (LAP) in each balancing authority area. As a result, the ramping product surplus variables will be independent decision variables to relax the flexible ramping requirements separately for each major LAP as needed. This may limit the shortfall to an individual LAP while allowing the requirement in other LAPs to be fully met.

In the day-ahead market, virtual supply and virtual demand are exposed to congestion in the integrated forward market. The current day-ahead market does not include deployment scenarios to cover uncertainty between the day-ahead and real-time market. Therefore, energy in the day-ahead market

will only be exposed to congestion when cleared against bid in demand. However in the real-time market energy will be exposed to congestion when clearing against the ISO load forecast, the upward flexible ramping deployment scenario and the downward flexible ramping deployment scenario. This could lead to systematic differences between the day-ahead LMP and real-time LMP which virtual bids will have no impact in driving convergence. As a result, the CAISO proposes not to settle virtual and physical supply for congestion resulting from the deployment scenarios. This congestion from the deployment scenarios will be included in the real-time congestion offset.

The inclusion of deployment scenarios and their structure in the day-ahead market is being considered as part of the day-ahead market enhancements initiative. Depending upon the final market design to implement imbalance reserves, the settlement rules for virtuals will be re-evaluated.

Additional detail on the market formulation for nodal deliverability of the flexible ramping produce is included in Appendix B: Procurement and Deployment Scenarios Draft Technical Description[7].

8 Flexible Ramping Product Demand Curve and Scarcity Pricing

Various stakeholders have recently commented as part of several other CAISO market design initiatives that the CAISO market should have improved scarcity pricing provisions. Scarcity pricing is typically intended to set market pricing at higher levels than submitted energy bids when there is not enough bid-in supply to meet demand. Stakeholders have suggested that the market should produce scarcity pricing that increases in steps, similar to other ISO/RTOs[8], based on the amount that supply is short, before setting prices at $1,000/MWh. The market currently sets prices at $1,000/MWh when it relaxes its power balance constraint.[9] The flexible ramping product will produce this stepped scarcity pricing if the CAISO implements the nodal flexible ramping product procurement described in the preceding section. Appendix A provides an outline of how other ISO/RTOs employ demand curves to relax reserve constraints and produce stepped price signals during scarcity conditions.

The flexible ramping product design includes a procurement demand price curve that is calculated based on the probability of a power balance constraint occurring if the flexible ramping product was not procured. For example, assume there is a 10% chance of an upward power balance constraint violation, then the market optimization would not procure additional upward flexible ramping product if the cost exceeded $100/MWh. This is because when the power balance constraint is relaxed prices are administratively set at the $1000/MWh bid cap. If there is a 10% chance of a power balance constraint can be avoided, then the expected value of the upward flexible ramping product is $100/MWh. The demand price curve applies to both the upward and downward flexible ramping product. The demand

[7] Appendix B will be provided on the initiative webpage. This is available at http://www.caiso.com/StakeholderProcesses/Flexible-ramping-product-refinements

[8] The CAISO's documented the scarcity pricing in Appendix A: Other ISO/RTO Demand Curve Summaries available on this initiatives webpage at http://www.caiso.com/StakeholderProcesses/Flexible-ramping-product-refinements.

[9] As part of its effort to comply with FERC Order No. 831, the CAISO this methodology. http://www.caiso.com/StakeholderProcesses/FERC-Order-831-Import-bidding-and-market-parameters.

price curve is capped to ensure that the flexible ramping products are fully relaxed prior to deploying ancillary services.

The procurement demand curve was intended to provide improved scarcity pricing signals in the real-time market. If the upward flexible ramping product requirement was relaxed, the demand curve value would increase the energy price above last economic energy bid. Using the previous example, if the upward flexible ramping product requirement was relaxed at $100/MWh and the last economic bid was $200MWh, then energy price would be $300/MWh. If the downward flexible ramping product requirement was relaxed, the demand curve value would decrease the energy price below last economic energy bid. Only if the full flexible ramping product requirement was not procured would prices increase to the administrative rate.

However, the flexible ramping product is not providing the intended scarcity pricing signals because the flexible ramping product requirement is not always relaxed prior to the power balance constraint due to congestion. As discussed in the previous section, the market optimization can award the upward flexible ramping product to resources that are located behind a transmission constraint. No additional energy can be dispatched from this resource, so the resource cannot be used to meet power balance constraint. However, since it can be awarded the upward flexible ramping product at no opportunity cost, the upward flexible ramping product requirement is not relaxed based upon the demand curve because the market can make capacity awards to resources that cannot be awarded additional energy. Moving to nodal procurement of the flexible ramping product will ensure that the flexible ramping product requirement is fully relaxed prior to the power balance constraint being relaxed because the market will no longer make awards to transmission infeasible capacity.

9 Calculating Flexible Ramping Product Requirements

This section describes a high level overview of how the CAISO plans to evolve the current methodology for setting real-time flexible ramping product requirements to incorporate forecasts for load, wind, and solar into the formulation. The currently implemented approach uses a histogram method to set the flexible ramping product requirements. Historical data is used to calculate the net load forecast error between FMM and RTD for the determination of the fifteen-minute market requirements, and the net load forecast error between advisory and binding intervals for the RTD requirement. The net load forecast error data is then used to determine the upward and downward uncertainty requirements for each hour of the day that are posted the day prior.

For example, the upward requirement would be set using values measuring the difference between the hourly RTD net load maximum and the FMM net load forecast. As we have seen, the histogram approach yields uncertainty up and down requirements that vary seasonally and by time of the day. The histogram methodology also has the benefit of being relatively simple to calculate. However, the main drawback of this approach is it is only looking using historical data and not taking into consideration the variability that is forecasted to exist in a given point on time due to differing weather conditions.

Following the implementation of the flexible ramping product, the CAISO intended to enhance the current logic towards a methodology that takes into consideration the forecasted conditions that will be occurring on the system throughout the day. Consistent with this goal, the CAISO proposes to enhance the current approach by adopting a quantile regression method to adjust the current system up and down requirement similar to what it has proposed in the day-ahead market enhancements initiative to determine imbalance reserves.

A quantile regression estimates quantiles of a dependent variable conditional on the values of a set of independent variables. A quantile regression is preferred to standard linear regression in this case because the requirement is based on relatively extreme high and low (i.e., 2.5 and 97.5 percentile) observations of net load imbalances, as opposed to the average net load imbalance. The regressors (independent variables) include forecasted load, solar, and wind values, as well as the operating hour and month.

Additional details outlining the proposed quantile regression methodology, as well as results observed simulating the new methodology in comparison to the current histogram approach can be found in Appendix C: Quantile Regression Approach to Enhance the Flexible Ramping Product Requirements. The formulation of the regression model used to set the flexible ramping product requirement, including all the models with full list of predictors, will be described in the business practice manual.

10 Stakeholder Engagement and Next Steps

Stakeholder input is critical for developing market design policy. The schedule proposed below allows several opportunities for stakeholder's involvement and feedback.

10.1 Schedule

Table 9 lists the planned schedule for the *Flexible Ramping Product Refinements* stakeholder process.

Table 9 : Proposed schedule for the Flexible Ramping Product Refinements stakeholder process

Item	Date
Draft Final Proposal	May 8, 2020
Stakeholder Conference Call	May 18, 2020
Stakeholder Comments Due	June 2, 2020
BPM Language within a Proposed Revision Request – Buffer, Minimum, Requirement	Aligned with Fall 2020 release
Complete Business Requirement Specifications for nodal deliverability	October, 2020
Complete Tariff Development for nodal deliverability and PDR rules	October, 2020

EIM Governing Body Briefing	November 4, 2020
ISO Board of Governors Decision	November 18-19, 2020

The CAISO will discuss this revised straw proposal during a stakeholder conference call on May 18, 2020. The CAISO requests that stakeholders submit written comments by June 2, 2020 to InitiativeComments@caiso.com.

10.2 EIM Governing Body Role

The rules that govern decisional classification were amended in March 2019 when the Board adopted changes to the Charter for EIM Governance and the Guidance Document. An initiative proposing to change rules of the real-time market now falls within the primary authority of the EIM Governing Body either if the proposed new rule is EIM-specific in the sense that it applies uniquely or differently in the balancing authority areas of EIM Entities, as opposed to a generally applicable rule, or for proposed market rules that are generally applicable, if "an issue that is specific to the EIM balancing authority areas is the primary driver for the proposed change."

This initiative does not satisfy the first test, because any proposed rules would be generally applicable to the entire CAISO market footprint, rather than EIM-specific. Moreover, primary driver for pursuing these objectives is not an issue that is specific to the EIM balancing authority areas. The improvements to FRP deliverability will seek to minimize instances where ramping capability is stranded behind all kinds of transmission constraints. While EIM transfer limits are one type of constraint, they are only one of several types. Moreover, the CAISO identified the need for this initiative based on a study of pricing in the CAISO's balancing authority area. Accordingly, this initiative would fall entirely within the advisory role of the EIM Governing Body.

Stakeholders are encouraged to submit a response to the EIM categorization in their written comments following the conference call for the Revised Straw Proposal, particularly if they have concerns or questions