Flexible Ramping Product Refinements

Revised Straw Proposal

March 16, 2020

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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 caused by load and variable energy resources uncertainty 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 a range of 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 Issue Paper/Straw Proposal

The table below outlines the four issues identified in the CAISO Energy Markets Price Performance Report that need to be addressed. The table also identifies whether the changes being considered require tariff changes or can be implemented through BPM changes. Since the Issue Paper/Straw Proposal[3], there have been a few changes to these issues and two new issues have been added to the scope of this initiative.

Issue	**BPM or Tariff Change**	**Targeted Implementation**	**Change from issue paper/straw proposal**
Proxy demand response eligibility	Both	Fall 2020	Tariff change to set default at 60-minute dispatchable
Ramp management between FMM and RTD	BPM only	Fall 2020	None
Minimum FRP requirement	BPM only	Fall 2020	Describes method to calculate minimum requirement. Applicable to all BAAs in the EIM.
Deliverability enhancement	Both	Fall 2021	Selected nodal procurement
FRP demand curve and scarcity pricing	None	Fall 2021	**New.** Describes how FRP demand curve results in energy prices gradually rising prior to relaxing the power balance constraint.

[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
[3] The CAISO's Flexible Ramping Product Refinements Issue Paper and Straw Proposal is available at http://www.caiso.com/InitiativeDocuments/IssuePaper-StrawProposal-FlexibleRampingProductRefinements.pdf

Scaling FRP requirement	BPM only	TBD	**New**. Describes methodology to incorporate load, wind and solar forecasts into requirement

3. 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 because 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 be 60-minute dispatchable. After implementation of the bid options, very few PDR resources have changed their bid option from 5-minute dispatchable even though the inability to respond to 5-minute dispatch instructions has not changed. The CAISO is considering out-reach to ensure parties are accurately reflecting their master file characteristics. However, by changing the default to 60-minute dispatchable, scheduling coordinators

for PDR resources will need to affirm that their resource can be dispatched in either 15-minute or 5-minute intervals to modify the Master File bid option. This will ensure that the market does not award the flexible ramping product to PDRs that are not five-minute disapatchable.

4. 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 to clear RTD.

The FMM is part of the real-time unit commitment (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 issue binding unit commitment of fast and short start units. The buffer interval also produces advisory schedules and prices that are not financially binding. The remaining intervals in the horizon can also issue binding unit commitments and also produce advisory schedules and prices.

Currently, the flexible ramping product uncertainty requirement is not enforced 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, even worse, the ramping capability may be lost. Ramping capability is lost when projected start-ups of certain units necessary to carry flexible ramping product are re-optimized in subsequent intervals and no longer determined as 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 requirement is not enforced 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 enforced in

the buffer interval, the resource could receive an energy schedule of up to 125 MW because the 75 MW flexible ramping up award is maintained.

5. Minimum Flexible Ramping Product Requirement for BAA

The net import/export capabilities (NIC/NEC) are used as a credit towards 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[4] that credits on imports and exports were beyond levels that a balancing authority area could feasibly support. As a result, in 2018, the CAISO made an enhancement to limit the amount of flexible ramping product that could be awarded in a balancing authority area to that which could be supported given the import/export transfer capability. With this enhancement, the market can schedule flexible ramping product in a balancing authority area up to the amount of the remaining transfer capacity, thereby making use of any remaining import/export capability but not exceed the amount the balancing authority area could feasibly support for the transfer of energy.

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 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[5] given the large import and export capability of the CAISO. However, since the CAISO has such a large share of the 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 proposes to enforce a minimum flexible ramping requirement in the CAISO balancing authority area, which will ensure that a minimum amount of the flexible ramping product will be procured from resources within the CAISO balancing authority area. The minimum amount will need to be higher than the historical procurement that resulted from the system-wide flexible ramping product constraint. Over time, based upon its evaluation of historical flexible ramping product procurement, the

[4] 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

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

CAISO will refine the minimum CAISO requirement and the CAISO will update the CAISO minimum requirement through the business practice manual change process, which includes an opportunity for stakeholder input. The CAISO will also evaluate if similar minimum requirements are needed for other balancing authority areas. CAISO will perform the same historical evaluation and discuss its findings through the regularly held Market Performance and Planning Forum meetings. Any changes to such requirements will be proposed to stakeholders through the business practice manual change management process.

The CAISO and other large EIM areas have been seen to be driving a large share of the total EIM requirement. Therefore, the revised straw proposal recommends setting the EIM procurement targets in two tiers. The first tier will be to set a minimum requirement for EIM areas that demonstrate its area's requirement is a pivotal share of the entire system or EIM area requirement. The second tier is to ensure that when a minimum requirement is imposed or when an area is separated due to lack of transfer capability or failed sufficiency test, the EIM level requirement is properly balanced due to the increased procurement in that area.

The CAISO will calculate the first tier based on the existing flexible ramping product requirements to determine first when there is a need for a minimum requirement and then what that requirement will be. 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 the pivotal areas. Requirement data from the flexible ramping product procured in 2019 was used to determine the minimum requirement and when it will be determined to be enforced. This is because 2019 procurement data includes the most recent enhancements to the procurement and credit calculations. In Table 1,Table 6 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 requirement, with the next five largest areas' total percentage of the requirement is 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 this 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 proportionality of the EIM balancing authority area uncertainty to the total of all EIM entities uncertainty. It illustrates where a higher minimum requirement is needed versus when the EIM uncertainty may do a better job covering the pivotal area and the individual EIM area's

requirement. When that proportionality is high it means that the EIM footprint requirement is higher as compared to the rest of the individual areas. At this point a minimum requirement may not need to be as high as when that ratio is low. Based on this, in order to balance the diversity benefits along with making sure that the diversity benefit is always considered, the proposed minimum for a pivotal area would be the maximum value of the diversity benefit of that area or the difference between the uncertainty requirement and the diversity benefit. These amounts have been calculated in **Error! Reference source not found.** and Table 5 average per hour for 2019.

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 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. 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.

With a baseline percentage of 60% as the test, the minimum requirement needs to consider the diversity benefit of the area that is now required to have a minimum. Because of that, the proposal for the minimum requirement would be the maximum value of 60% of the uncertainty of the area or the

difference between the uncertainty of that area and the diversity benefit of that area. This helps guarantee that when the requirement for uncertainty is greater than 60% of the total requirement either that amount is procured for that pivotal area, or the uncertainty required within that area not considering the overall system requirements.

With the addition of a minimum requirement and based on that new requirement comparison to the EIM footprint procurement, this could leave other EIM areas without enough flexible ramping product awards to cover their need because the minimum is now the majority share of what will be procured. Therefore, the EIM footprint requirement must be increased based the amount by which the area with a minimum requirement left the others short. This would be the total of the remaining areas total requirement multiplied by the diversity factor minus, the minimum requirement shortfall or the EIM footprint requirement minus the minimum requirement.

Similar to the minimum requirement, when a balancing authority area has a shortage of transfer capability or has failed a sufficiency test limiting the transfer capability, other areas can suffer based upon the proportionality of the limited area now procuring higher MW quantities outside the other area's needs. Based on this, along with that individual area now being solely responsible for its own requirements, the EIM footprint should have an additional increased requirement when an area is limited by transfer capability or resource sufficiency evaluation failures. Therefore, the EIM footprint uncertainty requirement will be increased by the remaining areas total requirement times the diversity factor minus the minimum requirement shortfall or the calculated EIM footprint requirement minus the transfer limited effective uncertainty requirement as laid out in the EIM operations BPM section 11.3.2.

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.

6. 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 under-utilization or under-deployment of the flexible ramping product.

The complication relates to congestion from internal constraints within a balancing authority area. The market enforces transmission constraints within each balancing authority area, which allows the market to economically manage congestion. As part of the congestion management process, resources can 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 to manage congestion. This interplay between congestion and flexible ramping product procurement can be further complicated 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. However, 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 market formulation is included in Appendix B.

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.

However, the implementation complexity and computational requirements necessary to move to locational flexible ramping product are significant. In addition, because system conditions may change congestion patterns from the time the flexible ramping product was awarded, the nodal approach does not ensure 100% deliverability. The nodal approach only can ensure that the market does not award resources that it knows at the time of the applicable market run would not be deliverable.

7. 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, 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. 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 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 curve applies to both the upward and downward flexible ramping product. The demand 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. But 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.

8. Scaling Flexible Ramping Product Requirements

8.1 Background and Current Methodology

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 forecast error between RTPD and RTD for the determination of the fifteen-minute market requirements, and the net forecast error between advisory and binding intervals for the RTD requirement. The net 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 RTPD 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 approach, similar to what it has proposed in the day-ahead market enhancements initiative to determine imbalance reserves.[6]

8.2 Quantile Regression Approach for setting the Flexible Ramping Product Requirements

Based on an assessment of a statistical regression model, the forecasted amount of load, wind, and solar are found to be statistically significant predictors of the flexible ramping product requirement. Thus, forecast information can be used as independent variables in a regression model to refine the flexible ramping product requirement. Statistical regression has an added benefit of providing more informed requirements compared to a histogram approach due to its ability to inform the relationship based on multiple sets of predictors.

The type of regression model proposed by the CAISO to determine the flexible ramping product requirements is known as "quantile regression." Quantile regression estimates relationships between the predictor(s) and result, using multiple points to come up with the distribution. Quantile regression allows for the possibility that how important predictors are may be different depending on the quantile (a term that closely corresponds to percentile) of the outcome variable; (i.e., whether they are low, average, or high on the outcome; Koenker & Bassett, 1978). A quantile regression is superior to standard linear regression in this case because the current flexible ramping product requirement is based on a relatively extreme high and low (*i.e* 2.5th and 97.5th percentile) observations of net load imbalances, as opposed to the average net load imbalance. The regressors (independent predictors) include forecasted values for load, solar, and wind for the applicable operating hour and month. The specific results and formulation of the regression model used to set the flexible ramping product requirement, including a full list of predictors, will be described in the business practice manual.[7]

[6] Additional information is available in Section 7.1.3.1.3 of the Business Practice Manual for Market Operations available at https://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Market Operations.

[7] Section 44.2.4.2 describes how the CAISO is to procure flexible ramping product. It states that the uncertainty requirement procured must be "[b]ased on statistical analysis of the Uncertainty Requirement" and that "the CAISO will calculate constraint relaxation parameters to ensure the total cost of the Uncertainty Awards will not exceed the cost of expected power balance violations in absence of the Uncertainty Award, by each Balancing Authority Area and for the EIM Area overall, as set forth in the Business Practice Manual." The tariff also requires that the "CAISO will establish in the Business Practice Manual a limit on the procurement curve – (1) at an amount less than the contingency relaxation penalty pricing parameter specified in the Business Practice Manual for

9. 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.

9.1 Schedule

Table 6 lists the planned schedule for the *Flexible Ramping Product Refinements* stakeholder process.

Table 6 : Proposed schedule for the Flexible Ramping Product Refinements stakeholder process

Item	Date
Revised Straw Proposal	March 16, 2020
Stakeholder Conference Call	March 23, 2020
Stakeholder Comments Due	April 6, 2020
Draft Final Proposal	May 5, 2020
Stakeholder Conference Call	May 12, 2020
Stakeholder Comments Due	May 28, 2020
BPM Language within a Proposed Revision Request – Buffer, Minimum, Requirement	Aligned with Fall 2020 release
Complete Business Requirement Specifications	October, 2020
Complete Tariff Development	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 March 23, 2020. The CAISO requests that stakeholders submit written comments by April 6, 2020 to InitiativeComments@caiso.com.

market operations, in the case of an upward demand curve; and (2) at an amount more than the regulation down relaxation penalty pricing parameter specified in the Business Practice Manual for market operations, in the case of a downward demand curve." The proposal to use the quantile regression approach is consistent with these requirements.

9.2 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 ISO 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

10. Appendix A – Other ISO/RTO Demand Curve Summaries

Below are summaries of how other ISO/RTOs employ demand curves to relax reserve constraints and produce stepped price signals during scarcity conditions.

Midcontinent Independent System Operator (MISO):

The MISO utilizes demand curves to relax reserve constraints and ensure the market produces scarcity price signals. The three market-wide demand curves the MISO employs are for operative reserves, the sum of regulating and spinning reserves, and regulating reserves. Each of these demand curves are designed to communicate shortages in capacity, regulating, and spinning reserves and the prices produced from these reflect deficiencies in each product in the entire market. These demand curves and rationale behind their designs are detailed in the Energy and Operating Reserve Markets Business Practices Manual Section 5.2.1.[8]

[8] See pages 172 – 182 for information on MISO's demand curves from the Energy and Operating Reserve Markets Business Practices Manual available at https://cdn.misoenergy.org//BPM%20002%20-%20Energy%20and%20Operating%20Reserve%20Markets49546.zip

The MISO fully co-optimizes energy, regulating reserve and contingency reserve requirements in both their day-ahead and real-time energy markets. This differs from the CAISO's design in which energy and ancillary services are only fully co-optimized in the day-ahead market. In the real-time market the CAISO only procures additional ancillary services if needed.

ISO-New England (ISO-NE):

ISO-NE relaxes real-time reserve constraints depending on the specific reserve requirement. The following reserve constraint penalty factors (RCPFs) are the prices beyond which ISO-NE's real-time dispatch software will no longer re-dispatch the system to maintain reserve requirements[9]:

Constraint	RCPF ($/MWh)
Ten Minute Spinning Reserves	$50
Total Ten Minute Reserves	$1,500
Total Thirty Minute Reserves	$1,000

During 5-minute scarcity conditions in which the Total Ten Minute Reserve or Total Thirty Minute Reserve requirements are deficient, the RCPFs will set the real-time reserve price and serve as an adder to the real-time LMP. Assuming all reserve requirements are deficient, the maximum LMP adder that could be applied would equal:

$2,550/MWh (all RCPFs) + $1,000/MWh (energy offer cap) = $3,500/MWh

Additionally, ISO-NE fully co-optimizes reserve requirements in their real-time market for every interval.

New York ISO (NYISO):

The NYISO relaxes reserve constraints using 15 Operating Reserve Demand Curves based on reserve regions. The following table outlines the various demand curves that apply to both the Day-Ahead Market and Real-Time Market[10]:

New York Region	Operating Reserve Demand Curve Type	Demand Curve Amount (MW)	Demand Curve ($)
NYCA	Spinning Reserves	All	$775
NYCA	10-Minute Reserves	All	$750
NYCA	30-Minute Reserves	300 655 955	$25 $100 $200

[9] See Section III.2.7A for information on ISO-NE Calculation of Real-Time Reserve Clearing Prices available at https://www.iso-ne.com/static-assets/documents/2014/12/mr1_sec_1_12.pdf

[10] See Section 6.8 for information on NYISO's Operating Reserve Demand Curves available at https://www.nyiso.com/documents/20142/2923301/ancserv.pdf/df83ac75-c616-8c89-c664-99dfea06fe2f

		Remainder	$750
Eastern New York (EAST)	Spinning Reserve	All	$25
	10-Minute Reserves	All	$775
	30-Minute Reserves	All	$25
Southeastern New York (SENY)	Spinning Reserve	All	$25
	10-Minute Reserves	All	$25
	30-Minute Reserves	All	$500
New York City (N.Y.C.)	Spinning Reserve	All	$25
	10-Minute Reserves	All	$25
	30-Minute Reserves	All	$25
Long Island (LI)	Spinning Reserve	All	$25
	10-Minute Reserves	All	$25
	30-Minute Reserves	All	$25

The NYISO fully co-optimizes energy, reserve, and regulation requirements in their real-time market.

PJM:

PJM utilizes a two-step Operative Reserve Demand Curve (ORDC) to relax reserve constraints in which the first step is set at the Reserve Penalty Factor of $850/MWh and the second is at $300/MWh for 190MW of added reserves.[11] The first step at the Reserve Penalty Factor was designed to prevent the reserve market clearing price from reflecting the incremental costs of resources needed to meet reserve requirements in the shortage or near-shortage conditions. The second step provides protection against price swings associated with scarcity conditions by signaling to market participants if the market is approaching scarcity/shortage conditions.

PJM fully co-optimizes energy and reserves in their day-ahead and real-time markets. When constraints are relaxed and the ORDC is used, the determined penalty factor is included in the calculation of the energy price. This increases the energy price to reflect scarcity/shortage conditions.

Southwest Power Pool (SPP):

SPP uses three demand curves, Contingency Reserve, Regulation-Up Service, and Regulation-Down Service, to set LMPs and market clearing prices during scarcity conditions on either a Reserve Zone or system-wide basis. The prices determined from these demand curves are calculated based on the MW

[11] See Section 4.2.2.1 for information on PJM's Reserve Demand Curves and Penalty Factors in the Energy & Ancillary Services Market Operations Manual available at https://www.pjm.com/-/media/documents/manuals/m11.ashx?la=en

amounts of shortages per product and are outlined in detail within the Market Protocols for SPP Integrated Marketplace Section 4.1.5.[12]

SPP fully co-optimizes energy and reserves in their day-ahead and real-time markets.

[12] See Section 4.1.5 for information on SPP's demand curves available at https://spp.org/Documents/61445/Integrated%20Marketplace%20Protocols%2075.zip