Maximum Import Bid Price Shaping Factor Analysis

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Executive Summary

This white paper explores the composition and performance of the hourly shaping factor that is used in the Maximum Import Bid Price (MIBP) calculation since its implementation in June 2021 as part of the FERC Order No. 831 - Import Bidding and Market Parameters initiative.

The CAISO has heard feedback from stakeholders regarding the robustness of the current shaping factor calculation. Further, the CAISO is proposing to use MIBP values in its Price Formation Enhancements proposal to screen storage energy bids above the $1,000/MWh soft cap.[1] For these reasons, the CAISO has performed analysis and is starting a stakeholder discussion to explore the current calculation and identify possible enhancements to the existing logic within the scope of the original policy intent.

This white paper does not consider broader changes to the MIBP calculation, but rather explores targeted changes to the logic of the hourly shaping factor component used in the MIBP calculation. Because the shaping factor has been in production for over three years, the CAISO has a robust historical dataset to analyze the shaping factor's effectiveness.

The tariff language which describes the hourly shaping factor formula gives a high-level overview of the intent and points to the BPM for further detail, which captures the currently-implemented formula. However, the current shaping factor formula has opportunities for improvement.

This paper highlights the following findings:

A literal interpretation of the hourly shaping factor formula is more likely to trigger the MIBP above $1,000/MWh than the current formula, due to the sole reference of a historical high-priced day. However, the inclusion of the upcoming day's prices in the current formula may inadvertently depress the MIBP when entering high-priced conditions. Neither formula perfectly captures a projected price shape for the upcoming day, especially under high-priced conditions.

An ideal hourly shaping factor should maintain consistency between the days used in the calculation. Using references to two different days skews the shaped hourly bilateral prices by creating an hourly price that does not average back to the nominal block bilateral price.

Using $200/MWh as the threshold for a high-priced day may overstate the high-priced day when analyzing historical prices. With the exception of prices in 2022, the threshold of $200/MWh is often above the 90th and even the 99th percentile of day-ahead energy prices between 2021 and 2024. A more formalized, programmatic definition of a high-priced day that is updated based on changing historical prices is warranted.

Using day-ahead energy prices for both the day-ahead and real-time shaping factor calculations will not always capture regional price differences across the West. Although the shaping factor

[1] https://www.caiso.com/InitiativeDocuments/Final-Proposal-Price-Formation-Enhancements-May17-2024.pdf

and MIBP need to be a single reference input to the market, the current approach of using only day-ahead prices may not be appropriate for a real-time shaping factor calculation. Alternative shaping factor formulations that account for some level of historical regional price variability can be considered, though the tradeoffs of using a static formula must be assessed.

Maximum Import Bid Price and shaping factor

The MIBP is intended to approximate prevailing bilateral energy prices outside the CAISO's balancing authority area on an hourly basis. The MIBP is used to screen energy bids above \$1,000/MWh from imports, virtual bids, exports, non-participating load, and reliability demand response resources.[2] The MIBP is also used to trigger market penalty prices to the \$2,000/MWh bid cap to appropriately reflect scarcity conditions in the market optimization.[3]

The CAISO's Revised Final Proposal[4] specifies the proposed formula to calculate the MIBP as:

$$MIBP_i = Electric\ Hub\ Price_{TOU} * Hourly\ Shaping\ Factor_i * 1.1 \quad (1)$$

Where

i : hour between 1 and 24

Electric Hub Price : the maximum of Mid-C or Palo Verde bilateral index price

TOU : Time of use, peak or off-peak

With the hourly shaping factor calculated as:

$$Hourly\ Shaping\ Factor = 1 + \frac{Hourly\ DA\ SMEC_{current} - Average\ DA\ SMEC_{high-priced}}{Average\ DA\ SMEC_{high-priced}} \quad (2)$$

This calculation was also detailed in the BPM for Market Instruments Attachment P prior to implementation in 2021.

The MIBP and hourly shaping factor formulas were contemplated by stakeholders and subsequently implemented through the FERC Order No. 831 - Import Bidding and Market

[2] See the BPM for Market Instruments Attachment P for more details

[3] See the BPM for Market Operations section 6.5.5.4 for more details

[4] Pg. 28: https://www.caiso.com/InitiativeDocuments/RevisedFinalProposal-FERCOrder831-ImportBidding-MarketParameters.pdf

Parameters initiative in June 2021. The Revised Final Proposal in section 4.2.2[5] describes the hourly shaping factor as

> *"the ratio of the day-ahead system marginal energy cost to the average system marginal energy cost of a previous high priced day."*

This literal description in the revised final proposal can be written as follows:

$$Hourly\ Shaping\ Factor = \frac{Hourly\ DA\ SMEC_{current}}{Average\ DA\ SMEC_{high-priced}} \qquad (3)$$

When rearranging the terms in equation (2) algebraically, it yields the same as equation (3), which is equivalent to the ratio described verbally in the Revised Final Proposal, although the formula written in the paper uses the initial notation.

$$Hourly\ Shaping\ Factor = \frac{Average\ DA\ SMEC_{high-priced} + Hourly\ DA\ SMEC_{current} - Average\ DA\ SMEC_{high-priced}}{Average\ DA\ SMEC_{high-priced}} \qquad (4)$$

Throughout the FERC Order No. 831 - Import Bidding and Market Parameters initiative, the CAISO contemplated different shaping factor formulas, iterating on previously-proposed formulas in response to stakeholder feedback:

1) Most recent day's hourly and historical average CAISO load forecast[6]
2) Historical hourly and average CAISO day-ahead SMEC from the same month of the previous year[7]
3) Most recent day's hourly and average CAISO day-ahead SMEC[8], and ultimately
4) Most recent day's hourly and high-priced day's average CAISO day-ahead SMEC[9]

The CAISO also considered feedback from the Market Surveillance Committee (MSC) who provided analysis and published their opinion on the initiative.[10] The MSC recommended enhancing the shaping factor formula in the third bullet to include a "representative" high-priced

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[5] *Id*

[6] Revised Straw Proposal: https://www.caiso.com/InitiativeDocuments/RevisedStrawProposal-FERCOrder831-ImportBidding-MarketParameters.pdf

[7] Draft Final Proposal: https://www.caiso.com/InitiativeDocuments/DraftFinalProposal-FERCOrder831-ImportBidding-MarketParameters.pdf

[8] Revised Draft Final Proposal: https://www.caiso.com/InitiativeDocuments/RevisedDraftFinalProposal-FERCOrder831-ImportBidding-MarketParameters.pdf

[9] Revised Final Proposal: https://www.caiso.com/InitiativeDocuments/RevisedFinalProposal-FERCOrder831-ImportBidding-MarketParameters.pdf

[10] MSC opinion: https://www.caiso.com/Documents/MSC-OpiniononFERC831ImportBiddingandMarketParameters-Sep9_2020.pdf

day, *i.e.* when prices exceeded $200/MWh. When entering high price events, relying on the most recent day's day-ahead SMEC may result in lagged or stale prices, particularly for the initial day-ahead calculation which is performed in the morning prior to the actual day-ahead market run. Additionally, the shape of prices during high-priced days can be different than non-high-priced days, so only using the most recent day may yield a price shape that is not representative of the coming conditions. As such, using a historical high-priced day within the calculation, bounded by seasonality, has the benefit of more closely mimicking expected prices at the onset of a high price event.

The hourly shaping factor formula captured in equation (2) was codified in the final policy that was approved and ultimately implemented into CAISO systems, as reflected in the external Business Requirement Specification document and ultimately in BPM language.

However, it has been noted that the CAISO's Tariff transcription of this formula in the language of section 30.7.12.5.3 may actually read as different formula when derived literally. The Tariff states:

> *"As detailed in the CAISO Business Practice Manual, the CAISO calculates the hourly shaping ratio for each hour by dividing the Day-Ahead Market System Marginal Energy Cost for the CAISO Balancing Authority Area in that hour of a previous representative Trading Day by the average Day-Ahead Market System Marginal Energy Cost for the CAISO Balancing Authority Area in all on-peak hours of the same previous representative Trading Day."*

A literal derivation of the Tariff description above results in the following hourly shaping factor formula:

$$Hourly\ Shaping\ Factor = \frac{Hourly\ DA\ SMEC_{high-priced}}{Average\ DA\ SMEC_{high-priced}} \tag{5}$$

It is important to note that the current formula in equation 2 is algebraically similar to equation 3 above, with a numerator representing the hourly day-ahead SMEC of the current day instead of the hourly day-ahead SMEC of the high-priced day. Indeed, when the seasonal high-priced day is equivalent to the current day, the two formulas are identical. However, the two formulas yield different values during most days, which results in final MIBP curves that can have substantive differences. Note that these differences are only material to the market when the resulting MIBP value is above $1,000/MWh.

Performance of current shaping factor

Since the MIBP and underlying hourly shaping factor have been implemented since June 2021, the CAISO has a historical dataset to analyze the historical performance of the current logic to estimate the shaping factors. The analysis in this section will first focus on a comparison between shaping factor values and materialized CAISO prices, then examine the differences between two interpretations of the hourly shaping factor formula. The takeaway from this analysis will illustrate that an ideal shaping factor will maintain consistency between the historical days used in the calculation. The analysis will also examine how the shaping factor can be improved and enhanced in the future.

Historical performance

Because the hourly shaping factor is a unique component with a specific usage in CAISO market processes, there is not one good data point to compare its performance. Indeed, the broader assessment of the hourly shaping factor's performance should be how it impacts the final MIBP values and how those values compare to market prices.[11] However, it is informative to counterfactually assess the overall shape of the hourly shaping factor against the shape of CAISO market prices. The shaping factor is intended to provide a pre-market estimation of market prices to decompose the block bilateral prices into an hourly curve, so a comparison to realized market prices can signal its effectiveness in estimating that shape.

Figure 1 shows normalized day-ahead hourly shaping factor values for both the current and literal formulations in yellow and blue plotted against normalized day-ahead SMEC prices in green for the January 2024 cold snap period. A min-max normalization formula was applied to the data to convert values into a readable range between 0 and 1.[12] This normalization allows data with different ranges to be compared on the same basis.

The three curves appear well-correlated during mid-day and afternoon ramping hours, with the greatest divergence during early morning and later evening hours. At times, the literal shaping factor tracks more closely to normalized prices but at other times, the current shaping factor tracks more closely to normalized prices. At other times, the two shaping factors track each other closely but not normalized prices. Note that the two shaping factor methodologies overlap completely for the second row of January chart and overlap for all days in the September chart; this phenomenon is explained in more detail in the subsequent section.

[11] The CAISO presented this analysis for real-time SMEC and MIBPs during the April 24, 2024 Market Surveillance Committee meeting on slides 32-34: https://www.caiso.com/Documents/PFE-rules-for-bidding-above-the-soft-offer-cap-straw-proposal-presentation-apr24_2024.pdf

[12] Min-max normalization for data-point x calculated as (x-x_min)/(x_max – x_min)

Figure 2 shows the same trends for the September 2022 heat wave. The curves are similarly well-correlated during mid-day and afternoon hours with larger differences during morning and evening off-peak hours, indicating poorer performance of the shaping factor during off-peak hours.

Figure 3 and Figure 4 show a similar comparison for fifteen-minute real-time pre-dispatch (RTPD) SMEC and the real-time hourly shaping factor for January 2024 and September 2022. The normalized RTPD prices are more susceptible to the presence of outliers in the min-max normalization process, thus the trends are harder to examine, however some correlation is observed during the September 2022 days and in some hours of the January 2024 days. The normalized real-time prices in January 2024 are also influenced by the pricing conditions from the Pacific Northwest and Central/Mountain regions, which had a discernably different shape than California or Southwest prices, as compared to the real-time shaping factor which only utilized day-ahead SMEC prices. See the section titled Regional considerations for further discussion on regional prices.

These four figures suggest that while the hourly shaping factor performs somewhat well in shaping prices to mimic the shape of materialized market prices, it is not able to track the precise shape pre-market, thus some margin of error is expected of any formulation.

Figure 1. Normalized hourly shaping factor values vs. normalized SMEC, day-ahead, January 2024

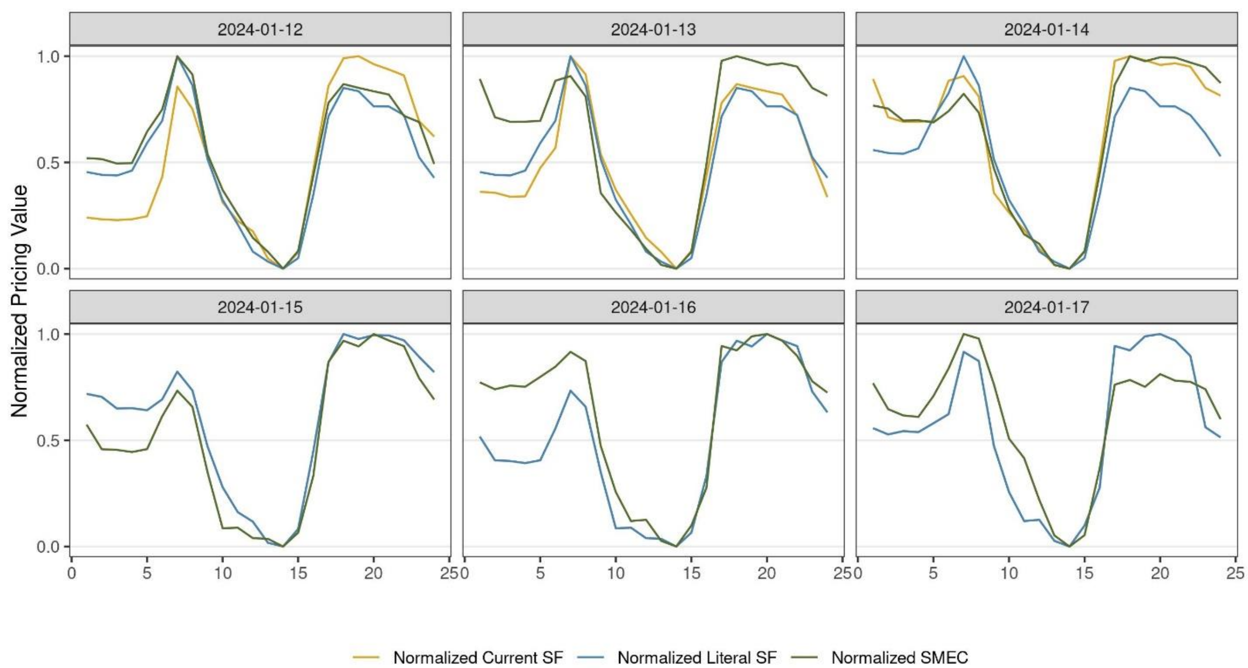


Figure 2. Normalized hourly shaping factor values vs. normalized SMEC, day-ahead, September 2022

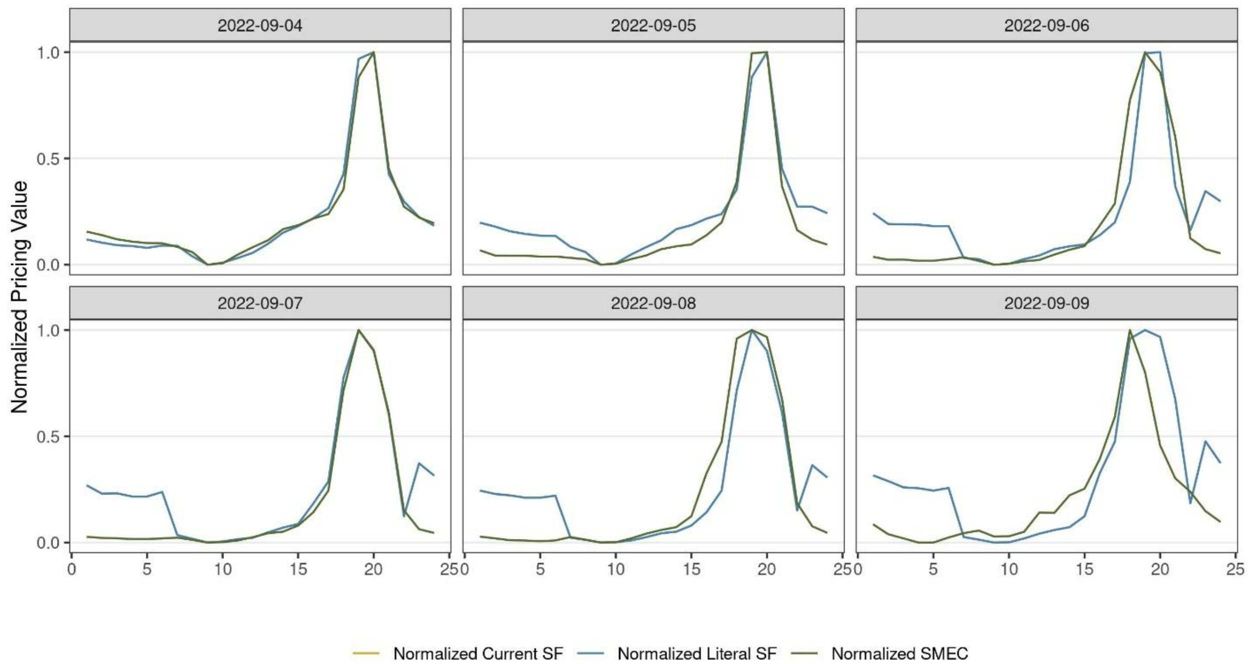


Figure 3. Normalized hourly shaping factor values vs. normalized SMEC, real-time, January 2024

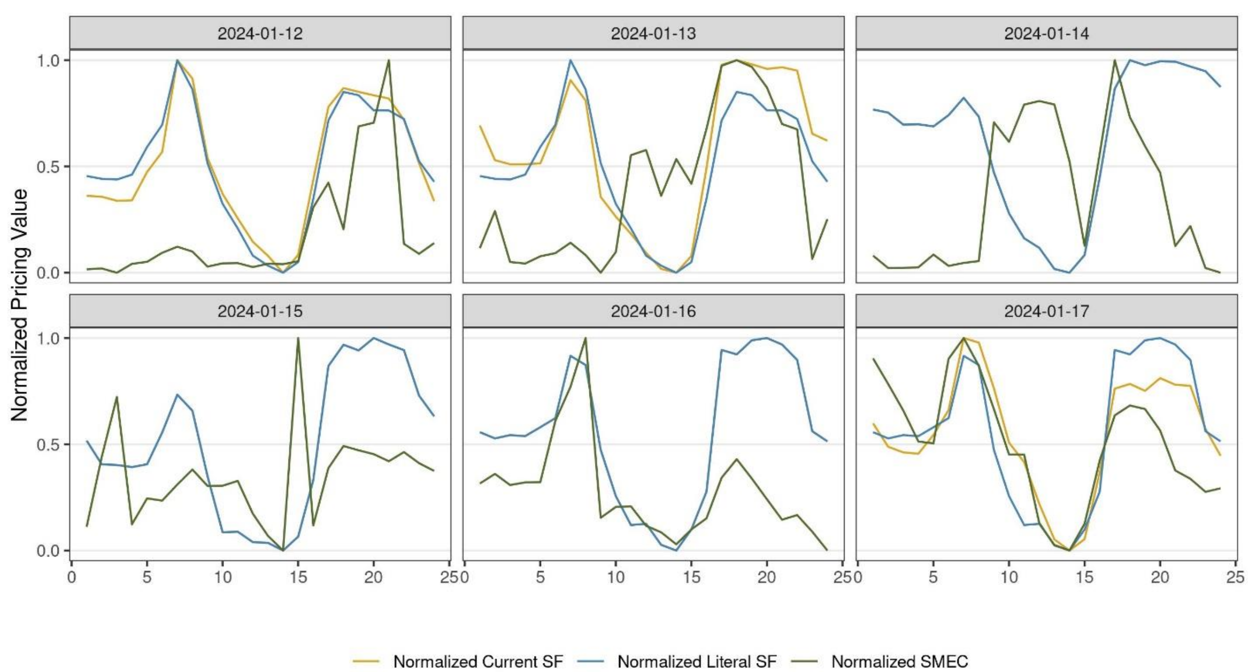
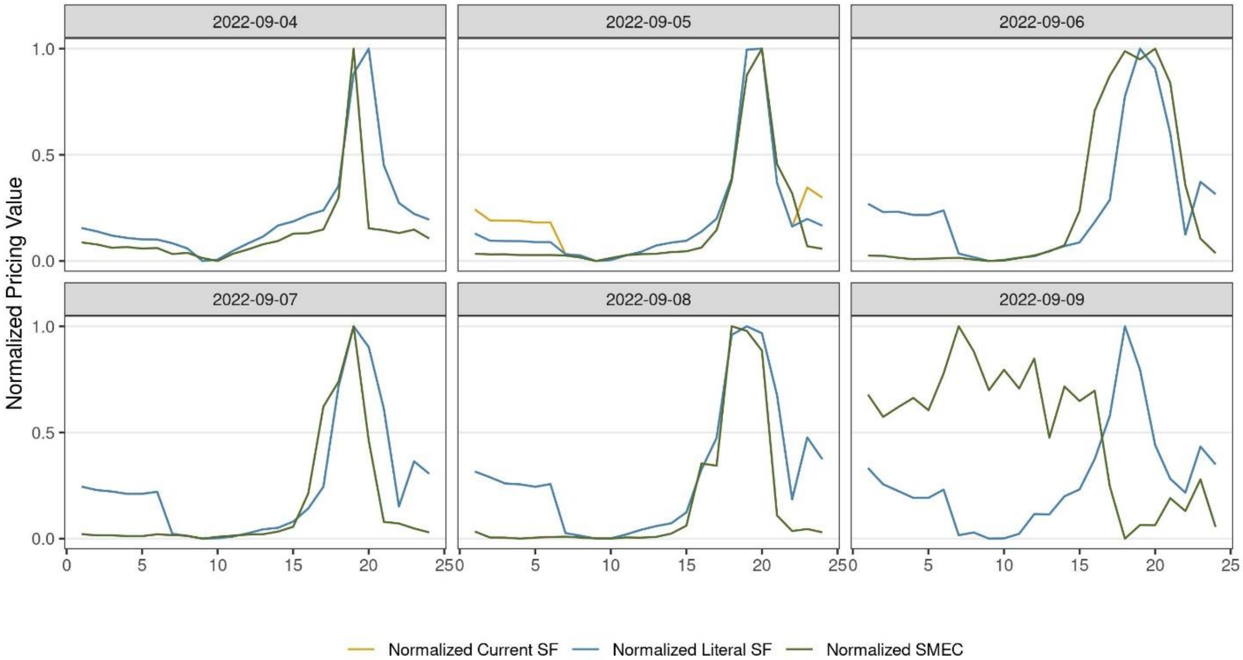


Figure 4. Normalized hourly shaping factor values vs. normalized SMEC, real-time, September 2022



Impacts on the MIBP

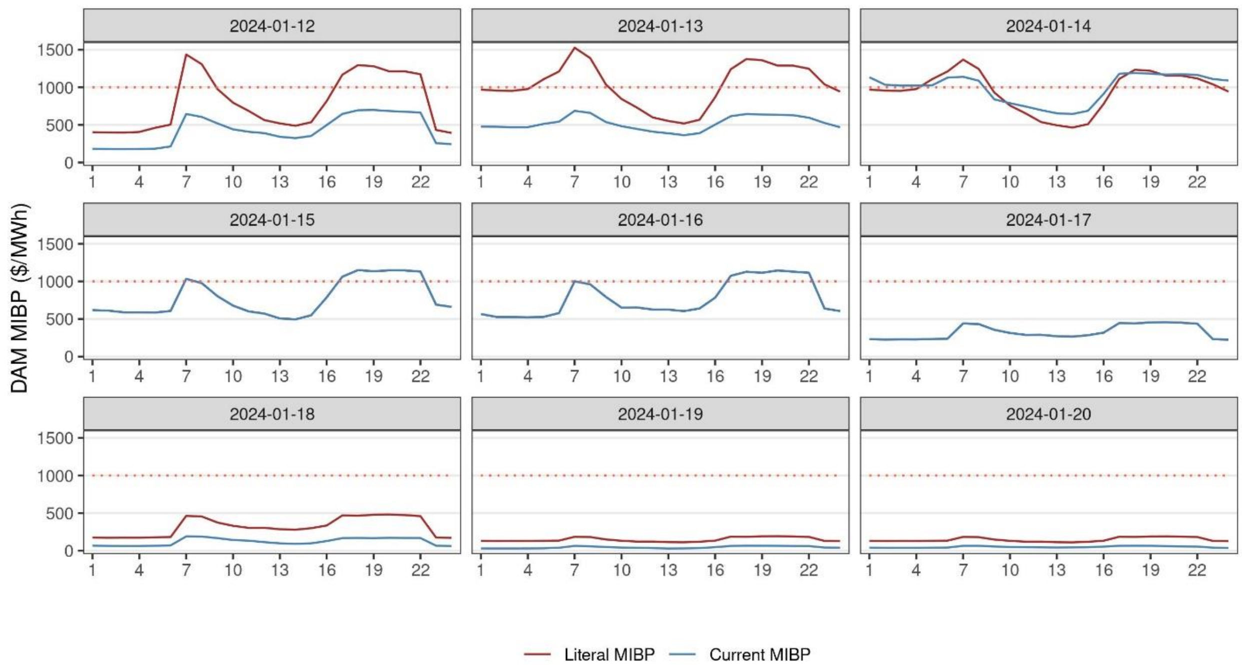
As illustrated in the prior section, different interpretations of the shaping factor formula can yield divergent MIBP curves. The MIBP curve is ultimately used for energy bid screening and penalty price scaling, however the actual MIBP value is only material once it exceeds $1,000/MWh. When it is under the $1,000/MWh threshold, the MIBP is not used elsewhere in the market.

Figure 5 shows one example from the January 2024 MLK weekend cold snap. The literally-interpreted shaping factor formula from the Tariff (see equation 3) was used in a counterfactual recalculation of the MIBP, in red, and compared to the currently-implemented shaping factor, in blue, for the period surrounding the cold snap. A red dashed line at $1,000/MWh is plotted for reference.

Entering the long weekend, the two calculations diverged significantly with the current MIBP suppressed below the literal MIBP, failing to break the $1,000/MWh threshold. Accordingly, the bid ceiling was set to $1,000/MWh for import and virtual bids on these trading days. The two calculations aligned with each other starting on January 14 and yielded the same values for January 15 through 17, so the trends overlap completely. This is because, as explained above, the historical high-priced day was the same as the most recent day which makes the two calculations identical. Towards the tail end of the event, the literal MIBP remained higher than the current

MIBP, though both fell well below the $1,000/MWh threshold and were thus immaterial for purposes of import bid screening and penalty price scaling.

Figure 5. Comparison of day-ahead MIBP using current and literal shaping factor formulas, January 2024



The results from January 2024 show that the current shaping factor formula biases down the calculated MIBP as compared to a literal interpretation of the shaping factor formula, especially during the onset of high price events. However, the literal formula's results could also be interpreted as yielding a higher MIBP during the same timeframe leading up to high price events.

At the onset of the event, the literal MIBP would have reached its highest values of around $1,500/MWh on January 12 and 13 in morning and evening hours, however the corresponding on-peak bilateral prices hovered around $900/MWh. The day-ahead energy prices that ultimately materialized for these hours were still under $200/MWh. The literal MIBP would therefore have been set higher by only relying on the last high-priced day to set the shaping factor when prices were still low. So, while a literal shaping factor formula can better capture price levels entering a high price event, it may have the unintended outcome of overinflating the shaped prices for certain days or hours when compared to the day-ahead SMEC prices. This indicates the natural consequence of using historical data to project future outcomes. In other words, no simple formulation can precisely capture every nuance contained within high priced events in order to perfectly project this scaled quantity, when each high priced event has their own unique drivers and impacts to the market.

The underlying day-ahead SMEC prices in each of these formulations can further contextualize the divergent results. Table 1 compares the hourly day-ahead SMEC prices used in the DAM

January 12, 2024 would-be literal and current shaping factor calculations.[13] Note that due to calculation timelines, the most recent day-ahead SMEC available for the DAM January 12 calculation was day-ahead SMEC for January 11. At the beginning of the cold snap, day-ahead CAISO SMEC prices were still relatively low and the latest high-priced day with at least one day-ahead SMEC price above $200 within the same winter season was January 25, 2023. Mid-C bilateral hub prices had already climbed to $879/MWh and $386/MWh for on-peak and off-peak periods respectively.

Thus, day-ahead CAISO SMEC prices did not yet mirror the pricing levels at the bilateral hubs, though regional price separation may have played a role in this initial divergence. The current hourly shaping factor values were accordingly tempered by the inclusion of both the lower January 11, 2024 hourly prices and higher January 25, 2023 average prices. The literal hourly shaping factor values were higher because they were only based on the January 25, 2023 hourly and average prices. A singular reference to the January 25, 2023 prices would have pushed the shaping factor higher than the reference of where day-ahead prices were at the onset of the cold snap, however that may be deemed a more accurate reference to shape the prices for the upcoming high-priced event.

[13] Values are rounded for readability, however actual calculations consider data to a higher decimal precision

Table 1. DAM January 12, 2024 current vs. literal shaping factor formulas

Hour-ending	Time of use	Jan. 11, 2024 DA SMEC (latest day)	Jan. 25, 2023 DA SMEC (high-priced day)	Current hourly shaping factor	Literal hourly shaping factor
1	OFF	72.57	161.07	0.43	0.95
2	OFF	72.02	158.90	0.43	0.94
3	OFF	71.79	158.34	0.42	0.94
4	OFF	72.04	162.20	0.43	0.96
5	OFF	72.97	183.78	0.43	1.09
6	OFF	85.08	201.16	0.50	1.19
7	ON	102.04	227.28	0.67	1.49
8	ON	95.81	206.64	0.63	1.35
9	ON	82.29	154.49	0.54	1.01
10	ON	69.76	125.82	0.46	0.82
11	ON	64.59	108.48	0.42	0.71
12	ON	61.72	89.25	0.40	0.58
13	ON	54.08	82.19	0.35	0.54
14	ON	51.29	77.21	0.34	0.50
15	ON	55.83	84.72	0.37	0.55
16	ON	78.83	129.38	0.52	0.85
17	ON	102.17	184.76	0.67	1.21
18	ON	109.93	204.89	0.72	1.34
19	ON	110.50	202.54	0.72	1.32
20	ON	108.28	191.83	0.71	1.25
21	ON	106.79	191.76	0.70	1.25
22	ON	105.14	185.70	0.69	1.21
23	OFF	102.32	172.63	0.60	1.02
24	OFF	97.56	156.58	0.58	0.92

The counterfactual analysis described above was performed for June 2021[14] through April 2024. Table 2 shows the results of the counterfactual analysis for two scenarios: first, the number of hours when the current MIBP was below $1,000/MWh but the literal MIBP was above $1,000/MWh and second, the number of hours when the current MIBP was above $1,000/MWh but the literal MIBP was below $1,000/MWh. The table also shows the relative percentage of these impacted hours to the total number of hours in the study period and to the total number of hours where the corresponding scenario's MIBP was above $1,000/MWh.

[14] The MIBP was implemented on June 13, 2021 so the comparison becomes effective for June 13, 2021 onward.

Table 2. Full counterfactual analysis results, June 2021 through April 2024

Scenario	DAM impacted hours	Percentage of total hours	Percentage of DAM hours above $1,000/MWh	RTM impacted hours	Percentage of total hours	Percentage of RTM hours above $1,000/MWh
1: Current MIBP < $1,000/MWh, literal MIBP ≥ $1,000/MWh	32	0.13%	30%	19	0.08%	17%
2: Current MIBP ≥ $1,000/MWh, literal MIBP < $1,000/MWh	5	0.02%	6.4%	6	0.02%	6.2%

The following figures show the full results of the counterfactual analysis for all trade dates captured within the impacted hours table above. In Figure 6 and Figure 7, the literal shaping factor formula pushes the recalculated MIBP above $1,000/MWh much sooner than the current MIBP at the onset of high-priced periods. It takes more days for the current shaping factor formulation used in the MIBP to equalize to the higher prices, largely because day-ahead SMEC prices for the recent day are typically not yet at high levels mirroring the bilateral prices, as discussed above for the January 2024 period. There are far fewer instances of the current MIBP undershooting the literal MIBP in both day-ahead and real-time, as shown in Figure 8 and Figure 9, with only one total trade date impacted for each market.

Figure 6. Scenario 1, current MIBP < $1,000/MWh, literal MIBP ⩾ $1,000/MWh, DAM

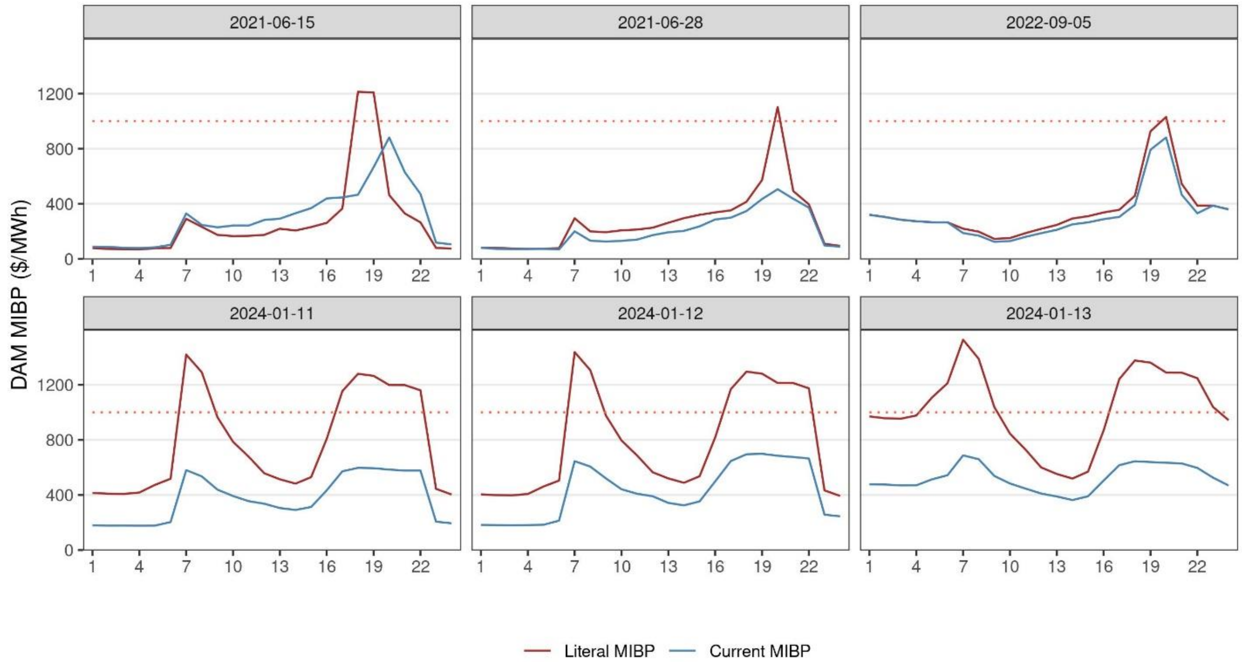


Figure 7. Scenario 1, current MIBP < $1,000/MWh, literal MIBP ⩾ $1,000/MWh, RTM

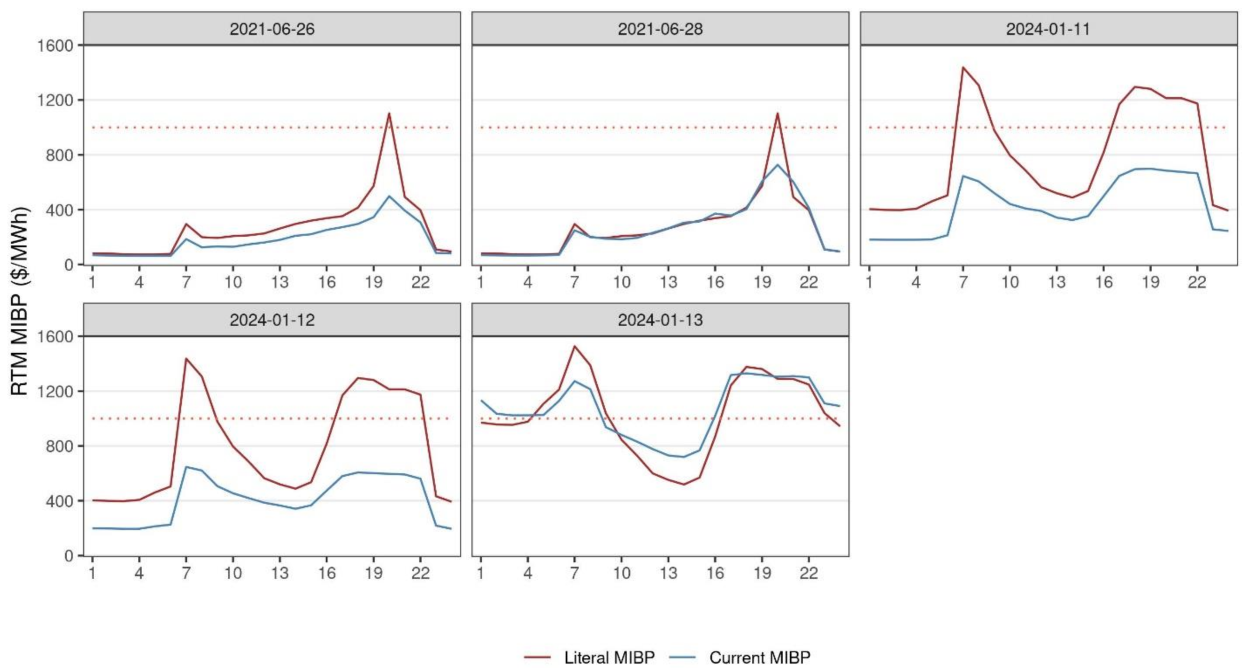


Figure 8. Scenario 2, current MIBP ⩾ $1,000/MWh, literal MIBP < $1,000/MWh, DAM

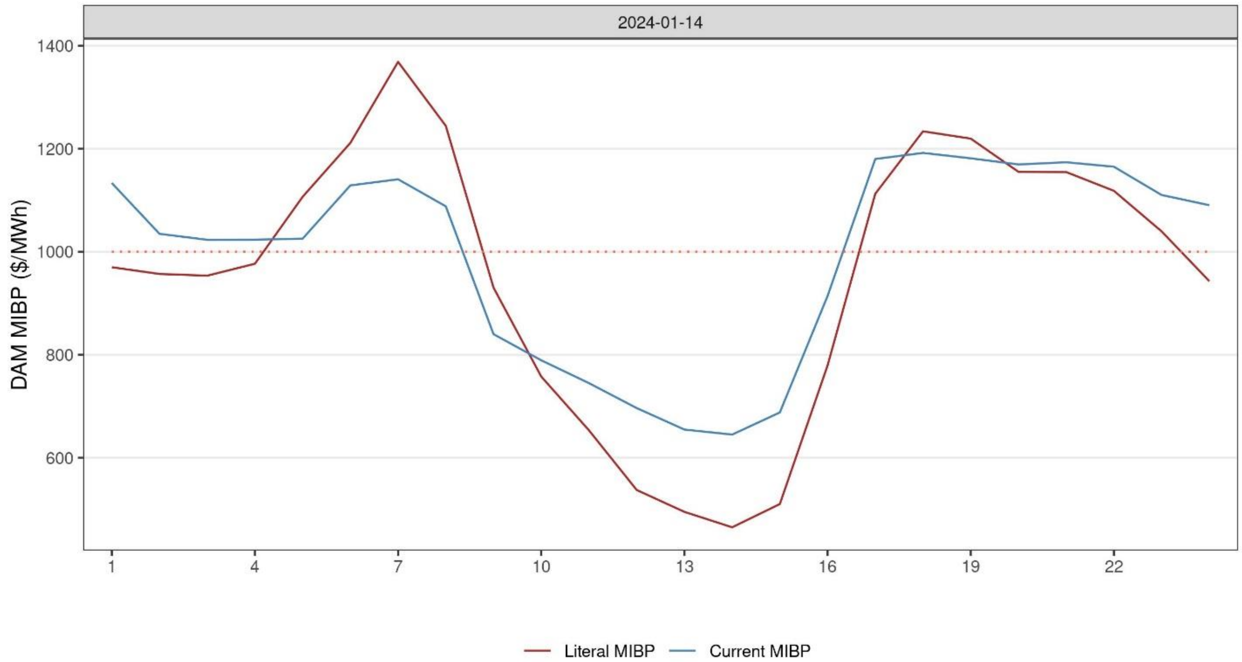
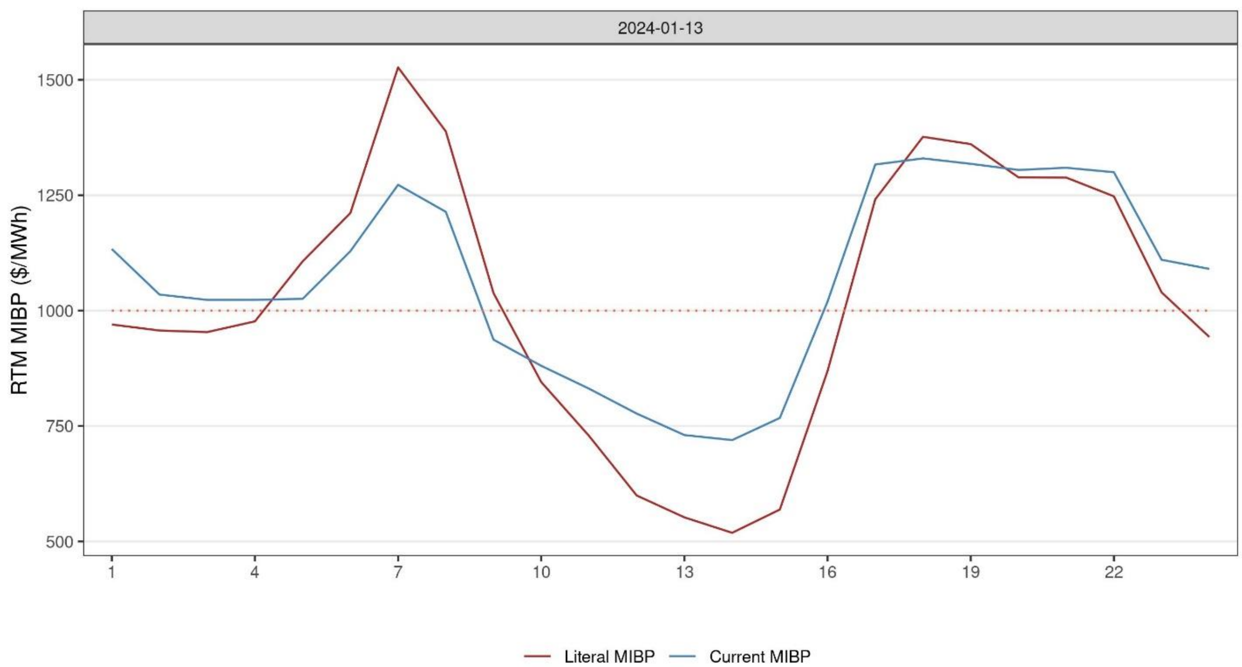


Figure 9. Scenario 2, current MIBP ⩾ $1,000/MWh, literal MIBP < $1,000/MWh, RTM



Implications of the current logic

To assess the implication of the current shaping factor formula, notate the equation (2) as follows:

$$SF_t = 1 + \frac{P_t^c - \sum_{t \in T} \frac{P_t^h}{|T|}}{\sum_{t \in T} \frac{P_t^h}{|T|}} \quad \forall t \in T \tag{6}$$

where

$t, T\ and\ |T|$ stand for hour ,the set of hours and the number of hours in the block period

SF_t is the shaping factor calculated for hour t

P_t^c is the price for the current day in hour t

P_t^c is the price for the high-price day in hour t

The equation can be reorganized by getting a common denominator of the two terms

$$SF_t = \frac{\sum_{t \in T} \frac{P_t^h}{|T|} + P_t^c - \sum_{t \in T} \frac{P_t^h}{|T|}}{\sum_{t \in T} \frac{P_t^h}{|T|}} \quad \forall t \in T \tag{7}$$

The averages of the numerator cancel each other out, yielding the formula for the shaping factors described in the proposal

$$SF_t = \frac{P_t^c}{\sum_{t \in T} \frac{P_t^h}{|T|}} = \frac{|T| P_t^c}{\sum_{t \in T} P_t^h} \quad \forall t \in T \tag{8}$$

The average of the shaping factors for the block of $|T|$ hours comprising the applicable TOU can be derived as

$$\widetilde{SF} = \sum_{t \in T} \frac{\frac{|T| P_t^c}{\sum_{t \in T} P_t^h}}{|T|} = \sum_{t \in T} \frac{P_t^c}{P_t^h} \tag{9}$$

The average of the shaping factors reduces simply to a ratio of the prices of the current day against the prices of the high-price day. In general, that ratio will be any positive value depending on the specific prices of the current and high-price day's selection. The average of the shaping ratios will be less than 1 per unit if the prices of the current day are lower than the prices of the high-price day, and vice versa. The special case is when the average of the shaping factors equals 1 per unit. This happens as long as the summation of all prices for current day equals the summation of all prices of the high-price day. Mathematically, this does not require that the current price of each hour exactly matches the corresponding price of the high-price day, it only requires the summations are the same. However, practically the shaping factors will average to 1 per unit only when the current day and the high price day are the same.

The MIBP[15] for hour t is derived from both the shaping factors and the bilateral power price per time-of-use (TOU), or Q^{TOU}

$$MIBP_t = Q^{TOU} \frac{|T| P_t^c}{\sum_{t \in T} P_t^h} \quad \forall t \in T \tag{10}$$

Since the bilateral price is a block price for the set of hours composing the applicable TOU, the cost of the block per MW can simply be stated as

$$Q_{cost} = |T| \, Q^{TOU} \tag{11}$$

The associated cost of the MIBP for the same TOU is no more than the summation of all MIBP prices of the block

$$MIBP_{cost} = \sum_{t \in T} MIBP_t \tag{12}$$

Inserting (10) into (12) yields

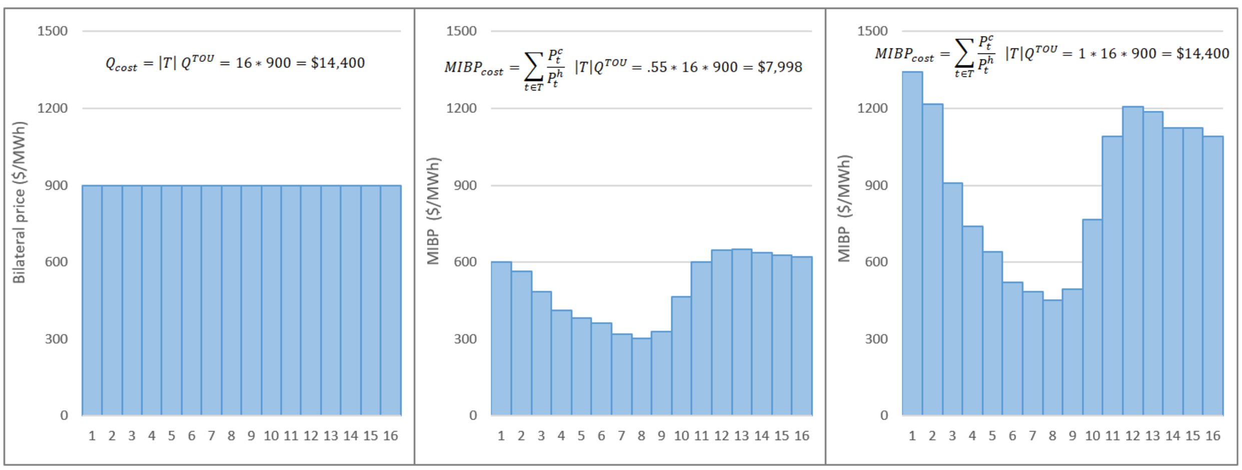
$$MIBP_{cost} = \sum_{t \in T} H^{TOU} \frac{|T| P_t^c}{\sum_{t \in T} P_t^h} = \sum_{t \in T} \frac{P_t^c}{P_t^h} \; |T| Q^{TOU} \tag{13}$$

In order for the cost derived using the shaping factors to match the cost of the nominal bilateral price expressed in equation (11), the factor $\sum_{t \in T} \frac{P_t^c}{P_t^h}$ has to be equal to 1. Although numerically this can happen with any combination of prices over the block period, practically this will only happen when the reference price used in the numerator is the same used for the denominator, which is when the current price is the same as the high-price day. The ratio from the term $\sum_{t \in T} \frac{P_t^c}{P_t^h}$

[15] The MIBP also includes a scalar of 110% which can be set aside in this description for simplicity as it does not impact the underlying discussion of the shaping factors

simply reflects the proportion between the current day and the high-price day over the TOU period. When the block cost of the current day is lower than the block cost of the high-price day, the current logic will result in overall lower prices and lower cost. When the current prices are higher than the high-price day, the overall prices will be higher and result in a higher cost than the nominal bilateral cost. Figure 10 illustrates this relationship. The first panel illustrates the nominal cost of the bilateral 16-hour block price. The cost associated with this block is simply the price per MW for 16 hours, which amounts to $14,400. Under the current logic the ratio of current price to high-price day is about 55%, which will result in shaping the cost of only $7,998 out of the total $14,400; this is illustrated in the second panel. Under the literal definition of the shaping factors that ratio remains to be 1 per unit and thus the total cost shaped is still $14,400, which is illustrated in the third panel.

Figure 10. Implications of different shaping factors on nominal bilateral cost



Based on this, the current logic of using a reference day for the numerator and a different one for the denominator introduces inconsistency that can result in either higher or lower prices and cost spread depending on the resulting combination of the two (current and high-day) reference points. Consequently, it is important to adjust the current shaping factor logic to have a consistent reference of prices used in both numerator and denominator.

Shaping factor improvements

This section explores other potential areas for improvement in the hourly shaping factor calculation: how to determine a high-priced day, robustness of a static versus dynamic shaping factor, and how to account for regional price variation.

High-priced day logic

The current formulation's high-priced day is defined as any day with at least one hour of day-ahead SMEC above $200/MWh. Depending on pricing conditions, a threshold of $200/MWh may be more or less conservative to set the high-priced day used in the shaping factor calculation.

Figure 11 and Figure 12 show the distribution of day-ahead SMEC between June 2021 and April 2024, separated by seasons.[16] Density plots are used to visually represent the distribution of data with price plotted on the x-axis and the probability density of values along the y-axis. The density plots show the current high-priced threshold of $200/MWh plotted in red with the 90th, 99th and 100th (maximum) percentiles plotted in blue, green and yellow. With the exception of 2022, the 90th percentile of day-ahead SMEC was always less than the current $200/MWh threshold and the 99th percentile was approximately equal to the current threshold. The $200/MWh threshold is still below the maximum day-ahead SMEC value. The CAISO did not propose a definition of what a high-priced threshold should be in previous policy papers, however values above the 90th percentile are typically accepted as being high percentile in other analytical contexts. Taking the 90th percentile as the high price reference signals that the current $200/MWh threshold was too high for most years and seasons, but was too low for 2022 pricing conditions.

Using a threshold that is too high will bias up an hourly shaping factor that is calculated using the literal tariff definition, because the shaping factor will only be shaping bilateral prices using a ratio from a day that may be higher than the 90th or even 99th percentile of observed prices. In other words, there is no opportunity to temper the ratio with some projection of expected hourly prices for the upcoming trading day, like what the current formula attempts to do.

[16] Seasons are defined in alignment with the shaping factor's seasonal definition, where summer is defined as April – October 31 and winter is defined as November 1 – March 31.

Figure 11. Distribution of day-ahead SMEC, winter period, June 2021 – April 2024

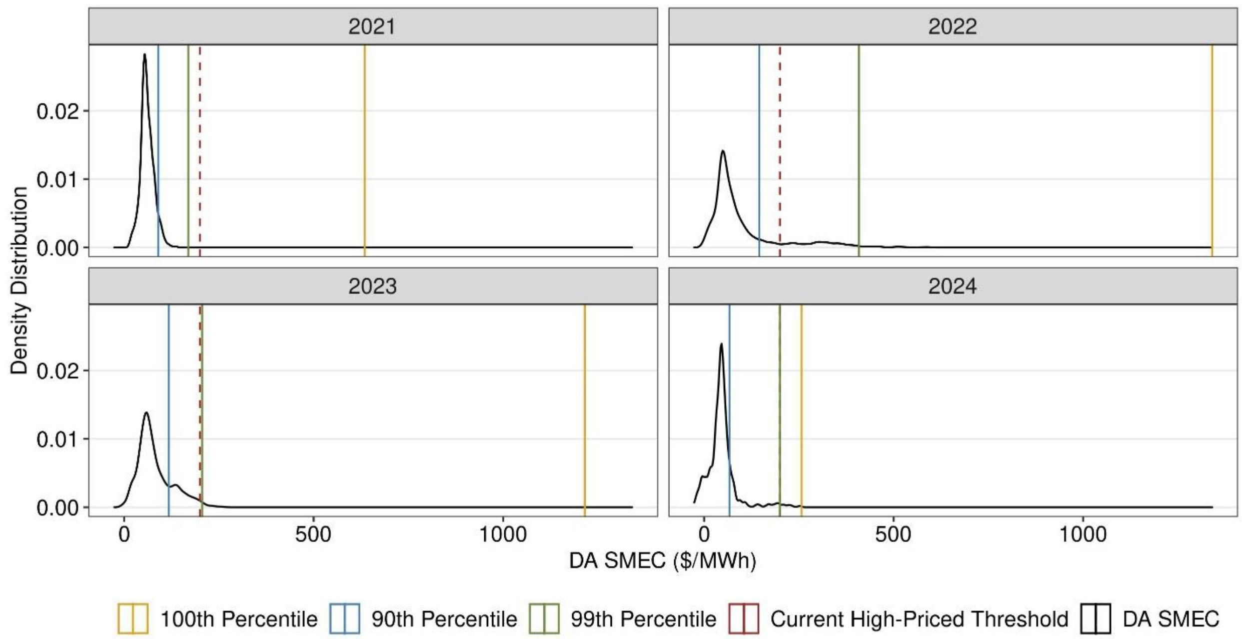


Figure 12. Distribution of day-ahead SMEC, summer period, June 2021 – April 2024

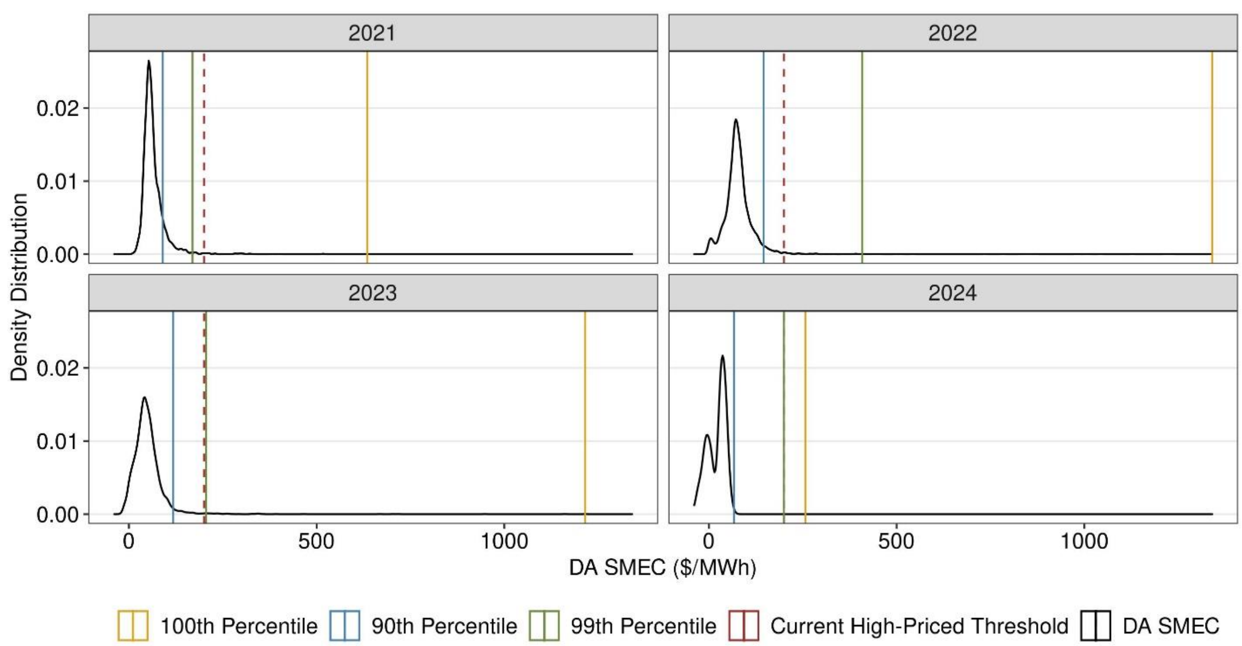


Table 3 lists out different statistical metrics on historical day-ahead SMEC per year, further broken out by on- or off-peak period. Although a $200/MWh threshold has often aligned with some very high percentile of prices over the past four years, it is not always representative of high prices for that particular year. The challenge of needing to rely on historical data to inform a future projection will always exist, however the selection of the high-priced day could be tuned more precisely. For example, the high-priced threshold could be set at the 95th percentile of historical prices, chosen on a static (e.g. annual, quarterly) basis or chosen dynamically with a rolling look-back period for each trade date.

Table 3. CAISO day-ahead SMEC statistical metrics, 2021 through 2024

Year	2021		2022		2023		2024	
Time of use	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Mean	55.93	69.77	83.49	94.34	59.82	64.10	43.51	36.44
80th Percentile	64.13	85.28	92.04	115.30	76.99	90.66	50.53	57.21
90th Percentile	70.47	100.00	122.03	159.66	104.55	125.77	64.91	67.31
95th Percentile	78.64	119.81	234.85	259.40	138.48	166.02	79.32	86.72
99th Percentile	101.37	211.40	364.82	448.37	172.25	227.38	200.19	197.11

Regional considerations

Regional price divergence is relevant when examining potential improvements to the hourly shaping factor. The current shaping factor formula only uses CAISO day-ahead energy prices, which informs the market-wide MIBP curve. The CAISO has heard from stakeholders, including the Market Surveillance Committee, that it may be inappropriate to shape bilateral prices using only day-ahead CAISO prices without consideration to regional real-time WEIM prices. Although the MIBP is impactful for screening RA imports into the CAISO balancing area, the MIBP also affects the entire market through its use in scaling penalty prices and under the recent Price Formation Enhancements proposal, setting energy storage bid cap values for storage resources across the market. In addition, market prices as a result of higher penalty prices may also influence the opportunity costs for storage resources and other resources with intra-day opportunity costs.

As illustrated in Figure 13, between January 5 and 19, 2024, daily average fifteen-minute RTPD and five-minute RTD prices[17] diverged across regions depending on which region was most impacted by the operational conditions. Average real-time prices in the Pacific Northwest Western Energy Imbalance Market (WEIM) balancing areas reached over $750/MWh on average during the long weekend while average real-time prices in California and Southwest WEIM balancing areas remained below $250/MWh.[18]

Figure 14 shows a distribution of RTPD ELAPs over the same timeframe, with different high-percentile references plotted for comparison. In the Pacific Northwest and Central/Mountain

[17] Note that this chart shows EIM Load Aggregation Point (ELAP) nodal prices which include energy, loss, congestion and GHG components as applicable.
[18] Winter Market Performance Report for January 2024, pg. 31

regions the 95th percentile of prices was around $1,000/MWh, compared to the California and Southwest regions where the 95th percentile of prices was closer to $200/MWh.

As discussed in the section above on shaping factor historical performance, one key factor that influenced the calculated shaping factor at the onset of the January 2024 event was price divergence between lower day-ahead SMEC of the current day and higher average SMEC of the high-priced day. Compounding to this logic, prices were already high for the Pacific Northwest and Central/Mountain regions, in alignment with the higher bilateral prices at Mid-C, while the shaping factor logic relied only on day-ahead CAISO prices that were still lower at the onset of the event, resulting in a lower MIBP.

Conversely, the price distributions in Figure 15 for the period surrounding the September 2022 heat wave, specifically August 29 through September 12, show extremely high prices at the 95th percentile for California and Southwest regions while Pacific Northwest and Central/Mountain remained lower. In this instance, using day-ahead SMEC in a shaping factor could be accurate for California and Southwest regions but overstate the values for other regions.

Figure 13. Trend of RTPD and RTD ELAPs by WEIM region, January 2024 cold snap

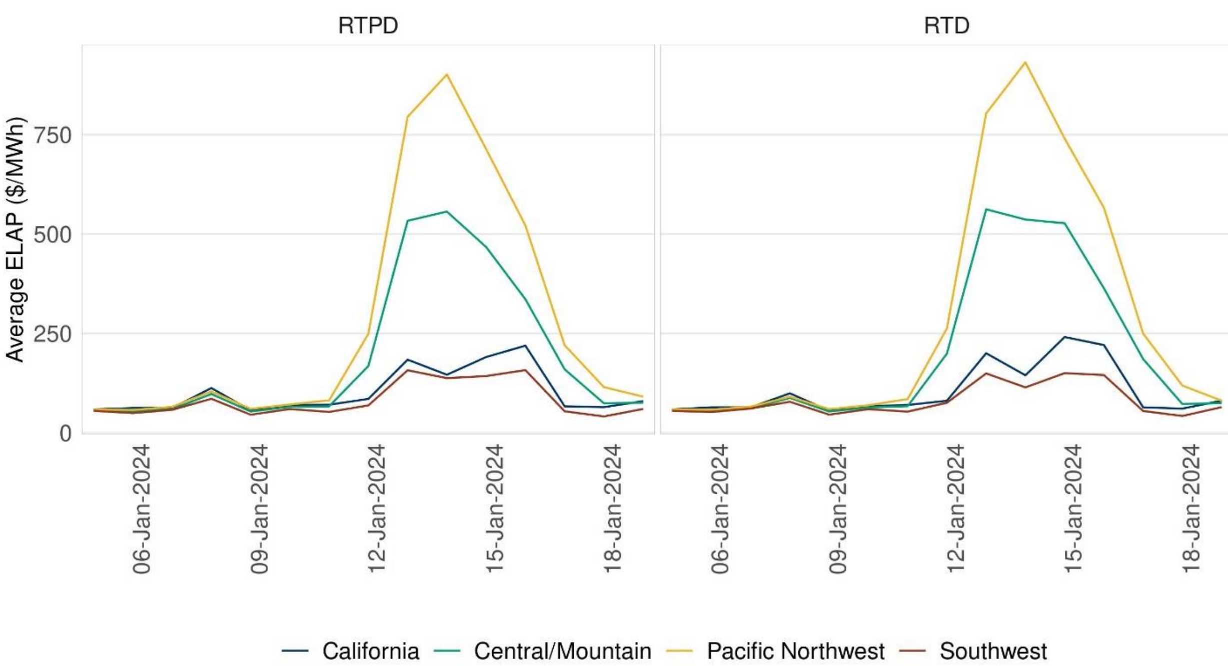


Figure 14. Distribution of RTPD ELAPs by WEIM region, January 2024 cold snap

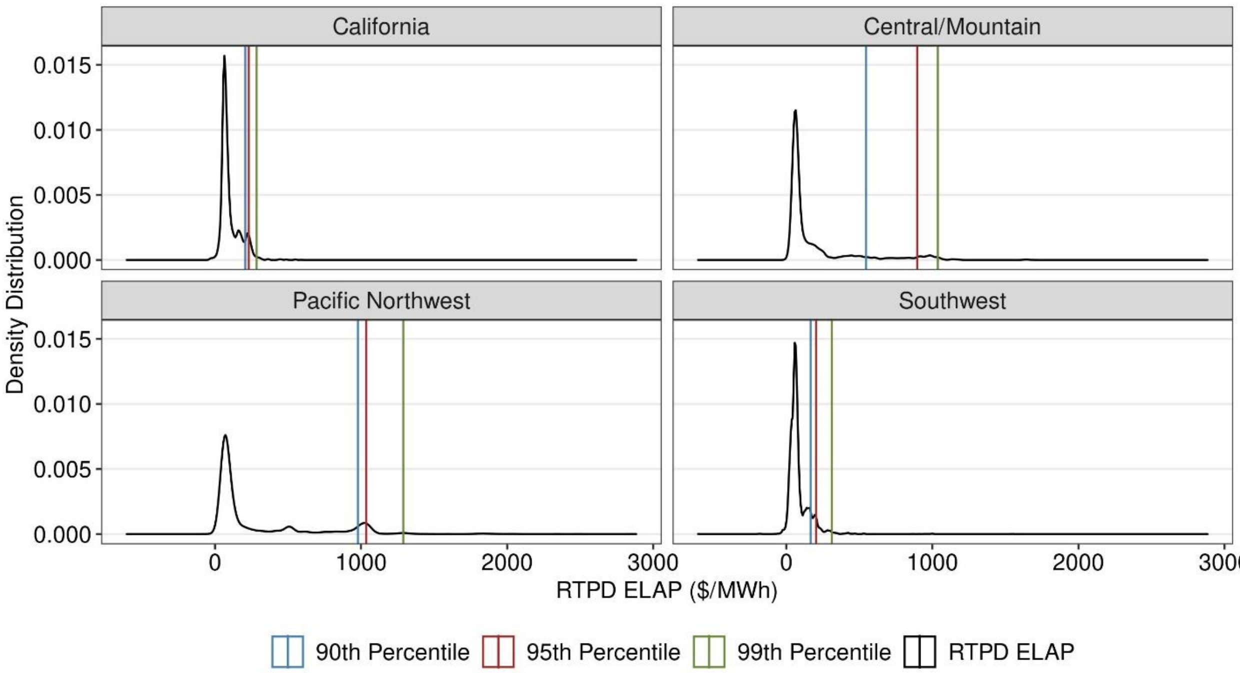


Figure 15. Trend of RTPD and RTD ELAPs by WEIM region, September 2022 heat wave

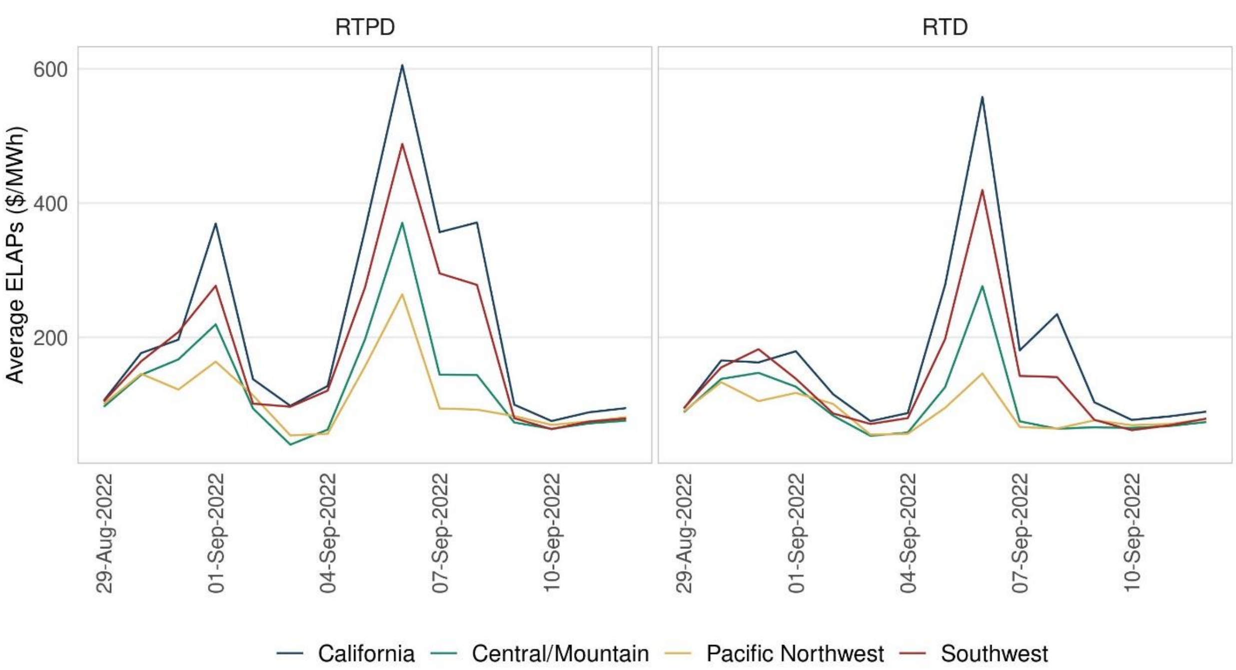
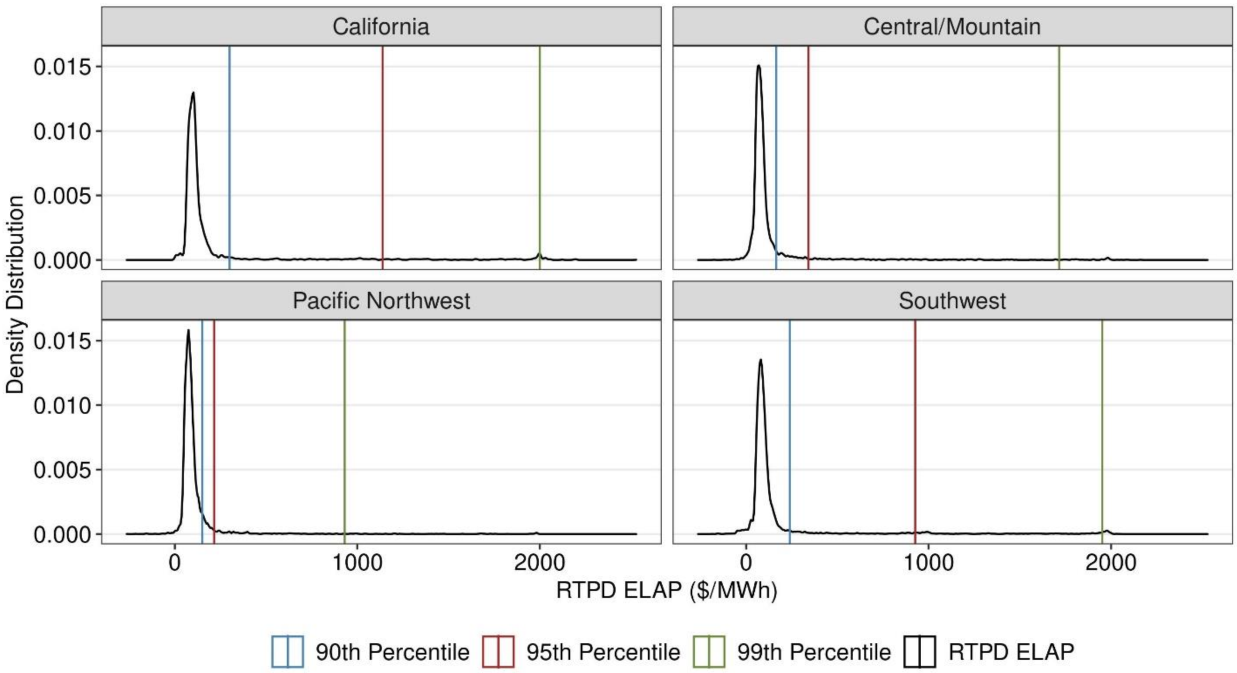


Figure 16. Distribution of RTPD ELAPs by WEIM region, September 2022 heat wave



The use of day-ahead SMEC in the shaping factor was originally proposed because it was a better indicator of expected hourly price variation than the static values proposed in previous iterations of the formula. The CAISO had considered static shaping factor formulations in previous 831 policy[19] but moved away from the approach given stakeholder feedback that a historical price from the previous year would not be representative enough of current day's conditions to accurately shape the bilateral price. Despite the fact that day-ahead SMEC provides a better dynamic reference of expected hourly prices, some drawbacks remain:

- The day-ahead shaping factor calculation will always need to use stale day-ahead SMEC because the calculation is performed prior to the close of the day-ahead market when SMEC is not yet available
- Does not provide as accurate of a real-time pricing projection when used in the real-time MIBP calculation
- Does not account for diversity of real-time prices within WEIM footprint

Challenges exist with calculating a regional hourly shaping factor and by virtue, a regional MIBP. The MIBP controls penalty price scaling and raises the energy bid ceiling for imports and other non-generator bids across the entire market and needs to send one cohesive price signal to the market. While it may not be feasible to calculate different regional shaping factors, the shaping

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[19] https://www.caiso.com/InitiativeDocuments/DraftFinalProposal-FERCOrder831-ImportBidding-MarketParameters.pdf p. 22

factor could still be designed to consider different WEIM regional prices in a static, historical calculation.

A static hourly shaping factor would have the limitation of not reflecting expected hourly price variation but could be designed to incorporate real-time and regional pricing differences. For example, the day-ahead shaping factor could be calculated using some high percentile or average of historical day-ahead prices, either day-ahead SMEC or EDAM MEC once available, and updated on some recurring frequency (e.g. quarterly, annually). A real-time shaping factor could be calculated in a similar manner, taking real-time SMEC with consideration to ELAP price differences. The final MIBP calculation would still have a reference to the upcoming day's projected prices via the inclusion of next-day bilateral hub price, which would incorporate that element of expected hourly price variation. Further analysis is needed to examine how a potential static solution would perform under counterfactual scenarios.