California Independent System Operator Corporation

California ISO

Structural competitiveness of the energy imbalance market:

Arizona Public Service Balancing Area

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Department of Market Monitoring

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1 Overview

In an order dated August 31, 2016, the Federal Energy Regulatory Commission, FERC, declined to grant full market based rate authority to Arizona Public Service (APS) in the Energy Imbalance Market (EIM). The Commission determined that the analysis submitted by APS did not establish a lack of market power or the sufficiency of existing measures to prevent any exercise of market power.

FERC therefore conditioned APS's market based rate authority in the EIM on a bidding restriction that requires all resources be bid into the EIM at or below the default energy bid (DEB). These default energy bids are cost-based bids calculated by the ISO that are designed to be used only when the ISO's automated procedures determine that units may have an opportunity to exercise market power. These cost-based bids are not designed for use during all hours and it can be beneficial to allow greater bidding flexibility during hours when it is determined an entity does not have market power.

The Commission's August 2016 Order specifically noted that APS could re-apply in the future to remove this bidding limitation by submitting analysis based on 12 months of data from EIM. The Commission noted that APS could show evidence that no frequently binding transmission constraints exist that would "…create a relevant geographic submarket that should be studied."[1]

This report provides an analysis of structural market power in the EIM within the APS balancing authority area (BAA) using data from the first 12 months after APS began participating in the EIM in October 2016. The report uses the same method to assess structural market power in the EIM as DMM's June 2017 analysis of the BAAs of the Berkshire Hathaway Entities' (BHE).[2] Results of this analysis show that the APS BAA is structurally competitive, has not been subject to any frequently binding constraints, and should therefore not be considered a submarket of the EIM for purposes of determining whether to grant APS market based rate authority.

The Commission's August 2016 Order also expressed concerns regarding APS's suggestion that any market power by APS would be effectively mitigated by the CAISO's market power mitigation procedures. The Commission specifically pointed to the issues cited in the November 2015 BHE Order as not having been resolved. Since these orders, the CAISO has implemented enhancements to its real-time market power mitigation procedures which address these concerns. This report provides analysis showing significant improvements in the accuracy of congestion prediction in the real time markets, so that these procedures ensure any market power in the EIM would be effectively mitigated.

[1] Order on Market Power Analysis And Market-Based Rate Tariff Changes (August 31, 2016) ER10-2437-004 : https://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=14343700

[2] http://www.caiso.com/Documents/AnalysisofMarketPoweroftheBerkshireHathawayEntities.pdf

2 Background

This section describes a method for measuring imbalance demand and competitive supply in the EIM. The analysis in this report assesses the competitiveness of the APS area based on the amount of competitive supply available to be transferred into the area in the EIM from the broader ISO/EIM footprint compared to the amount of imbalance demand that is served by the EIM in the APS BAA.

2.1 Energy imbalance market

In the California ISO area, the majority of demand is met in the day ahead market. The ISO's real time markets serve primarily to adjust and optimize unit commitments and dispatches in response to changes in system and market conditions and information. In the EIM, almost all system load is served by resources identified in the base schedules of the EIM entities in each BAA. These base schedules are not determined by the automated market systems of the ISO and are not settled by the ISO or paid the EIM prices. The EIM is a real time market which starts from the base schedules for these BAAs just as it starts from the day ahead awards for the ISO, and then adjusts and optimizes to best meet the imbalance needs of the aggregate EIM area.

In the EIM entity areas, only a small portion of energy produced and consumed is settled by the ISO and paid based on EIM prices. Generating resources that receive or pay the EIM price are scheduled by the EIM entity. The only generation settled on EIM prices is the incremental amount scheduled in the EIM relative to each resource's base schedule. If market power is exercised in EIM, it is exercised on those EIM imbalance quantities. Any measure of competition or market power should be centered on those quantities as the measures of supply and demand.

For a seller to have market power in the EIM, some kind of barrier must limit supply from new or outside (third-party) entities. The limited nature of electric transmission can create potential market power in some regions. Any area that can be isolated by limited transmission can be subject to high prices and the effects of uncompetitive behavior if a single seller controls enough generation in the area behind the constraint.

The EIM transfers allow competitively priced sources of power to flow between BAAs, providing access to the BAA for competitive resources from outside areas. The limits of the transfers cap the amount of competitive supply that can be offered in from outside the BAA. If the imbalance demand is greater than the transfer limits, some supply from within the BAA is necessary to meet imbalance demand.

A market is not structurally competitive if a single producer can determine market outcomes. In a structurally competitive market, demand could be met without supply from that single producer. If demand cannot be met without that key producer, that producer is said to be *pivotal*. They can effectively dictate the market price. A *pivotal supplier* test compares demand to competitive supply in order to determine if the key supplier is pivotal. Competitive supply used in the pivotal supplier test consists of supply that can reach the market but is not controlled by the key supplier.

In most areas of the energy imbalance market, this almost always means that the additional imbalance needs that cannot be met by transfers from other areas would have to be met by the EIM entity's generation. In an interval where the imbalance demand is greater than the transfer limits, the EIM entity could theoretically set prices up to the $1,000 bid cap, knowing that they are pivotal and at least one of their resources would need to be dispatched to meet imbalance energy demand. In such

intervals, the EIM entity could determine market outcomes and set market prices at extremely high levels in the absence of any special market power mitigation provisions.

2.2 Demand for imbalance energy

The relevant demand for each portion of the multi settlement ISO markets involves the sum of *changes* between two market solutions. In the ISO, the 15-minute market demand is equal to (1) the sum of all generation in the 15-minute market *minus* (2) the sum of all generation in the day-ahead market. This represents the incremental energy dispatched by the 15-minute market. Using the changes to generation to quantify imbalance energy demand accurately captures the quantity of imbalance energy dispatched by the market. Using the load forecast in each market can underestimate or overestimate the actual market demand due to possible changes in self schedules, renewable output, resource outages, and other factors.

In the EIM, entities do not participate in the day-ahead market, but instead submit base schedules that are treated very much like day-ahead market schedules in the ISO. For each EIM BAA, the quantity demanded in the 15-minute EIM market is equal to changes made by the market between base schedules and the final 15-minute schedules.

Analyzing market power in the EIM requires measuring supply and demand in the EIM. Exercising market power involves changing prices, so for this analysis we are able to leave out the changes to generation in the EIM BAAs that cannot have any impact on price. Since only changes made by the market software can set price, non-participating resources and self-scheduled resources that have no bids in the market do not need to be counted when measuring demand for market power evaluation.

When a resource has a self-schedule and has economic bids above the self-schedule, any dispatch into the economic bid range will be part of the market demand. Below we present a mathematical representation of this approach, using the following variables:

$E_{15,A}$ 15-minute market demand in BAA A

$E_{5,A}$ 5-minute market demand in BAA A

$Dispatch_{15,A}$ Total 15-minute schedules within BAA A

$Dispatch_{5,A}$ Total 5-minute schedules within BAA A

$schedule_{B,A}$ total base schedule for BAA A

$schedule_{I,A}$ total IFM schedule for BAA A

$gen_{h,p}$ output from economically bid participating resources for market h

For a given EIM BAA A, 15-minute demand is:

$$E_{15,A} = \sum Dispatch_{15,A} - \sum schedule_{B,A}$$

This demand includes changes to generation schedules as well as net energy transfers out of each BAA through the EIM since transfers into and out of each BAA can be adjusted by the EIM dispatch as part of the 15-minute EIM. Mathematically, the two pieces of demand can be broken down to:

$$Dispatch_{15,A} = \sum_{p.np \in A} (gen_{15,p}) + in\ transfers_{15,A} + out\ transfers_{15,A}$$

$$Schedule_{B,A} = \sum_{p.np \in A} (gen_{B,p}) + in\ transfers_{B,A} + out\ transfers_{B,A}$$

The ISO differs from EIM BAAs because we consider the day-ahead schedule instead of the base schedule as the starting point. Because 15-minute intertie transactions into and out of the ISO can be adjusted by the real time market, these transactions area also included in the analysis as imports and exports:

$$E_{15,ISO} = \sum Dispatch_{15,ISO} - \sum schedule_{I,ISO}$$

$$Dispatch_{15,ISO} = \sum_{p \in ISO} (gen_p) + in\ transfers_{15,ISO} + out\ transfers_{15,ISO} + imports_{15,ISO} + exports_{15,ISO}$$

$$Schedule_{I.ISO} = \sum_{p \in ISO} (gen_p) + imports_{I,ISO} + exports_{I,ISO}$$

Total demand for the 15-minute EIM is the sum of the EIM demand in the ISO and in each of the other BAAs participating in EIM:

$$E_{15} = E_{15,ISO} + \sum_{A \in EIM} E_{15,A}$$

In the 5-minute market, imbalance demand is the difference between 5-minute dispatches and 15-minute dispatches. For the 5-minute market, all EIM BAAs and the ISO have the same formulation.

$$E_{5,A} = \sum Dispatch_{5,A} - \sum Dispacth_{15,A}$$

$$Dispatch_{5,A} = \sum_{p.np \in A} \left(gen_{5,p}\right) + in\ transfers_{5,A} + out\ transfers_{5,A}$$

$$E_5 = E_{5,ISO} + \sum_{A \in EIM} E_{5,A}$$

3 Supply and demand in the energy imbalance market

For this report, DMM compiled the data described above for the APS BAA in the period from October 2016 through September 2017. This constitutes a year of data, consistent with the vision for testing set forth in the August 2016 Order.

3.1 Demand for imbalance energy

Figures 1 and 3 show the distribution of the demand for imbalance energy in the 15-minute and 5-minute markets in the APS BAA for this 12 month period (in MW). Figure 2 and Figure 4 highlight the distribution of imbalance energy demand in the 15-minute and 5-mintue markets over this period as a percentage of total load in the APS BAA. Table 1 and Table 2 provide summary statistics for these data.

As seen in Figures 1 and 3, demand for imbalance energy in the APS BAA on a 15-minute and 5-minute basis are roughly normally distributed. Imbalance demand in the 15-minute market averaged 95 MW per interval with a median value of 105MW (see Table 1). The close values for the average and median suggest a symmetric distribution. Base schedules were exceeded by 15-minute schedules (indicating a net positive imbalance demand) on average and in more than half the intervals. Figure 2 shows that imbalance demand in the 5-minute market is slightly more skewed in the positive direction than in the 15-minute market.

As shown in Table 1, the demand for imbalance energy was positive during about 68 percent of 15-minute intervals. During intervals with positive imbalance demand, the average demand was about 196 MW. [3] Table 2 shows that the median imbalance demand in the 15 minute market was lower, about 5.4 percent in absolute value of total demand. Median imbalance demand as a share of total load was about 6.4 percent in the 5-minute market.

Table 1. Imbalance demand (MW)

Market	average	median	Intervals demand positive	Average positive demand	Percentiles 90th	95th	97th
15 minute	95	105	67.9%	196	393	488	549
5 minute	17	5	50.7%	278	437	612	739

Table 2: Imbalance demand as share of total load (absolute value)

Market	Median	90th	95th	97th
15 minute	5.4%	12.4%	14.5%	15.9%
5 minute	6.4%	16.7%	20.6%	23.3%

[3] In a few intervals, imbalance demand in the 15-minute market was much larger than average, and even approached as much as 25 percent of total load. DMM's review of these extreme values indicate we have calculated this correctly according to ISO data. In some cases, systems issues may have prevented the ISO from receiving accurate data from the EIM entities. Whatever the cause, it is clear that even with these intervals in the dataset the instances of high levels of imbalance demand are extremely rare.

Figure 1. Demand for imbalance energy for the APS BAA (15-minute market, October 2016 to September 2017)

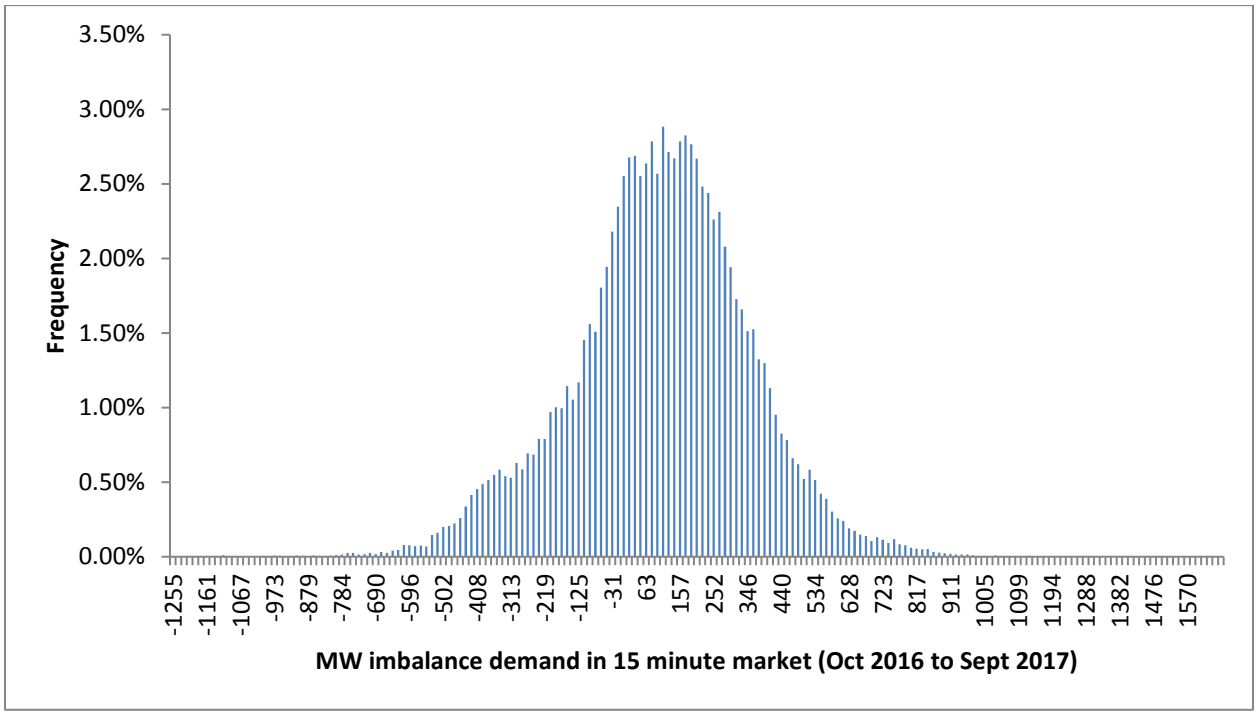


Figure 2. Imbalance energy demand compared to total load for the APS BAA (15-minute market, October 2016 to September 2017)

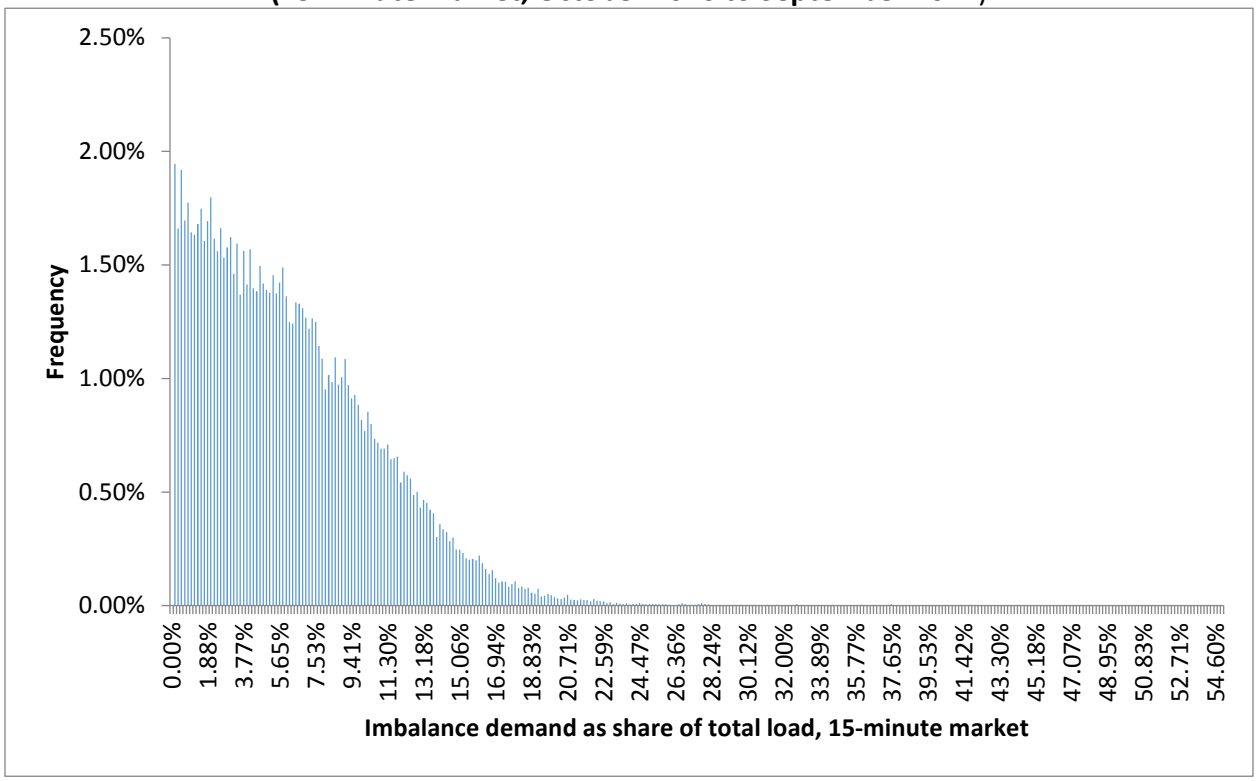


Figure 3. Demand for imbalance energy for the APS BAA (5-minute market, October 2016 to September 2017)

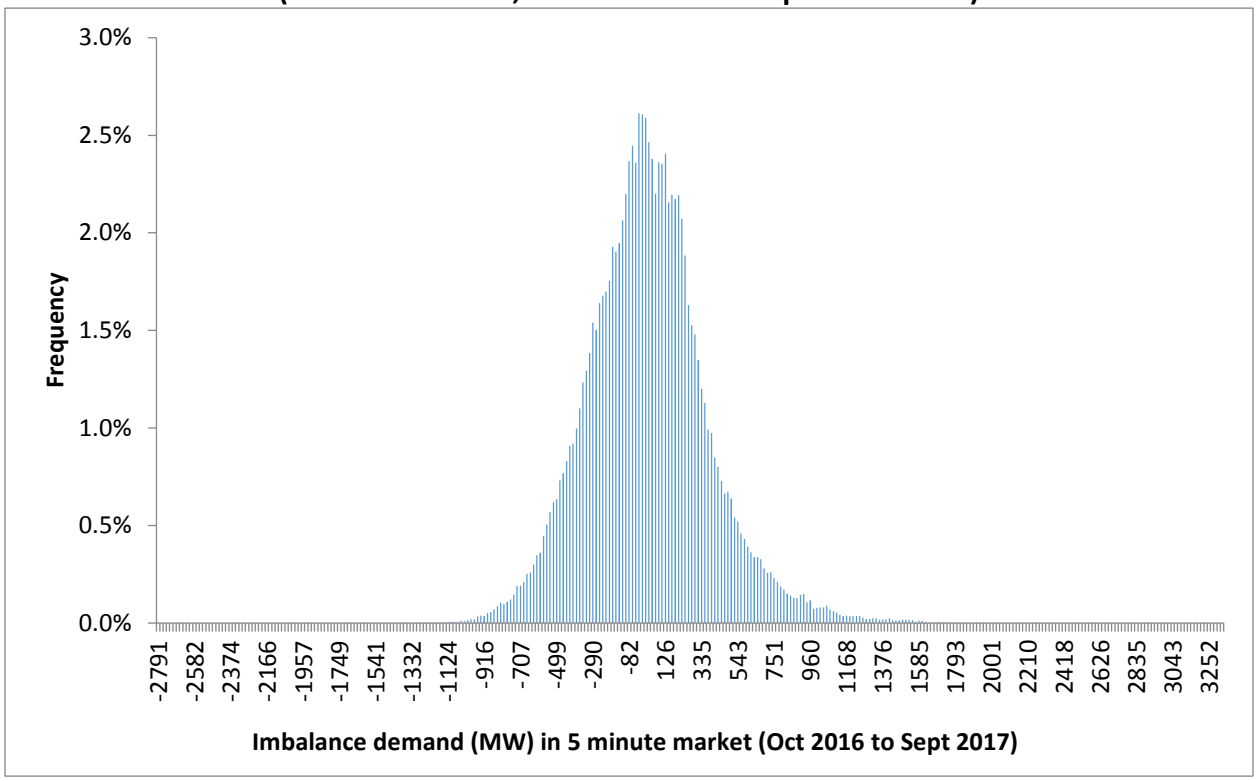
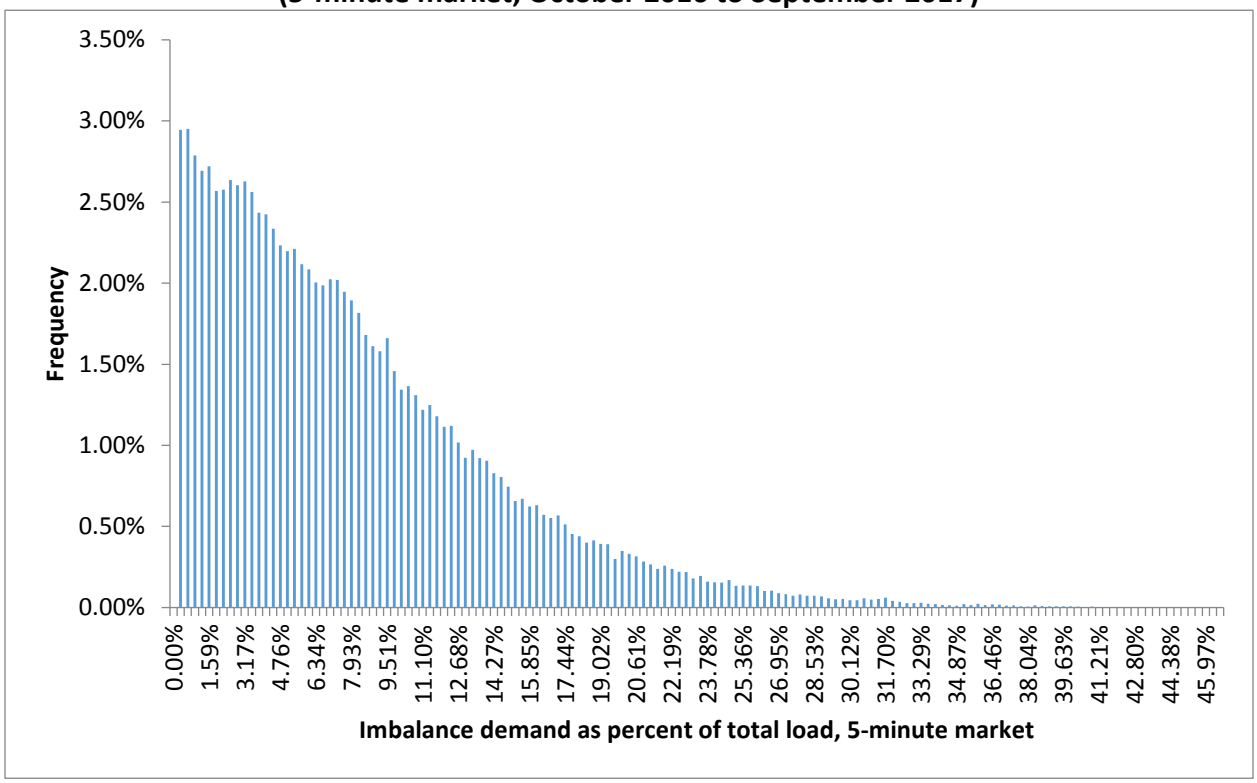


Figure 4. Imbalance energy demand compared to total load for the APS BAA (5-minute market, October 2016 to September 2017)



3.2 Competitive supply of imbalance energy

The competitive supply available to meet EIM internal demand consists of supply that is not controlled by the generation arm of the EIM BAA or one of its affiliates. In EIM areas, all or most of the available competitive supply is from outside the EIM BAA. In the case of the APS BAA, competitive supply comes in the form of EIM transfers

In both the 15-minute and 5-minute markets, a significant amount of competitive supply from the ISO was available to be transferred into the APS BAA during the period of this analysis. As shown in Table 3, during 90 percent of 15-minute market intervals, the potential supply that could be transferred from the ISO into the APS BAA exceeded 1,000 MW.

Significant amounts of transfers are also available from PACE and NEVP, with total transfer capacity exceeding 1,300 MW in more than 95 percent of intervals. This amount easily exceeds the 99th percentile of imbalance demand in the 15 minute market in each month of this study, which peaked at about 850 MW in June (see Figure 1). These numbers demonstrate that considerable amounts of transfers have been available, and that no single EIM entity has the ability to slash that capacity below needed levels.

Transfer capacity available in the 5-minute market was very similar to that available in the 15 minute market. In 90 percent of all 5-minute market intervals, significant headroom was available above the worst month's 99th percentile of demand.

Table 3. Competitive supply from EIM into APS (MW)

	Percentiles: 15 minute market				
Source	5th	10th	25th	median	90th
Total	1,384	1,750	2,169	2,551	3,714
PACE	0	65	600	600	625
NEVP	0	0	0	323	349
ISO	739	1,006	1,397	1,817	2,850
	Percentiles: 5 minute market				
Source	5th	10th	25th	median	90th
Total	1,330	1,672	2,107	2,488	3,696
PACE	0	100	466	474	625
NEVP	0	0	0	324	349
ISO	721	968	1,368	1,801	2,847

4 Structural market competitiveness

4.1 Pivotal supplier test

The pivotal supplier test for structural market power in EIM asks this question: could imbalance demand within the EIM BAA have been met by transfers from other unaffiliated BAAs, without using generation controlled by the EIM entity or its affiliates? If so, then the EIM entity was not pivotal in that interval and could not have successfully raised prices at that time. In a structurally competitive market the exercise of market power would be difficult and opportunities to do so would be rare.

To perform this test, the imbalance demand in APS is compared to possible supply that could be transferred into the APS BAA from the ISO BAA and other EIM BAAs that are not affiliated with APS.

The pivotal supplier test can be performed for individual intervals using historical data by calculating how often competitive supply was able to meet imbalance demand in the APS BAA. When the level of competitive supply exceeds imbalance demand, APS would be pivotal. Table 4 shows results of this analysis for each of the 12 months examined in this report.

Results are different in March of 2017, with a notable increase the number of intervals exhibiting imbalance demand greater than potential transfers. Many of these intervals appear to be related to computer system problems that hampered communication between ISO and APS systems during this period. In the months that did not experience these significant disruptions, the frequency of intervals where imbalance demand is greater than supply is usually less than 1 percent.

Table 4. Frequency that APS is pivotal in APS EIM BAA

	Share of intervals with imbalance demand greater than transfer capacity	
Month	15-minute market	5-minute market
Oct-16	0.4%	0.8%
Nov-16	0.0%	0.4%
Dec-16	0.0%	0.1%
Jan-17	0.0%	0.3%
Feb-17	1.7%	0.8%
Mar-17	5.8%	2.3%
Apr-17	0.8%	1.3%
May-17	0.7%	1.0%
Jun-17	0.5%	0.4%
Jul-17	0.3%	0.6%
Aug-17	0.0%	0.3%
Sep-17	0.2%	0.4%

We can also summarize the structural competitiveness of the APS BAA in the EIM based on statistical values of supply and demand. Figure 5 and Figure 6 provide a comparison between average transfer capacity, representing competitive supply, and the 95th percentile of imbalance demand.[4]

Figure 5 shows a comparison of average available supply to the 95th percentile and the 99th percentile of demand for the 15-minute market. In the 15-minute market, average competitive supply exceeded both the 95th and 99th percentile of imbalance demand during each month of the study period. In most months, average competitive supply is about four times as large as the 95th percentile of imbalance demand or larger. In the closest months, average available supply is about three times the volume of the 99th percentile of imbalance demand.

These results show that supply and demand conditions in the 15-minute market were competitive during more than 99 percent of the study period. Transfer capacity allowed resources from other parts of EIM to compete with resources controlled by APS in almost all intervals of the 15-minute market.

Fundamental supply and demand conditions in the 5-minute market are also competitive. Figure 6 shows that these conditions are tighter than in the 15-minute market, but that average competitive supply still meets the 95th and 99th percentile of demand in all months of the study period. Competitive supply exceeded imbalance demand in the vast majority of 5-minute intervals. In more than 97 percent of intervals in each month, the amount of EIM transfer capacity from the EIM exceeded total imbalance demand in the APS area.

[4] If we use the average demand over some period of time to compare to average transfer capacity, we will include the negative intervals and may provide an underestimate of the size of the market. Therefore, instead of comparing average competitive supply to average demand, we compare average competitive supply to imbalance demand during intervals with particularly tight supply conditions.

Figure 5: APS imbalance demand and competitive supply (15-minute market)

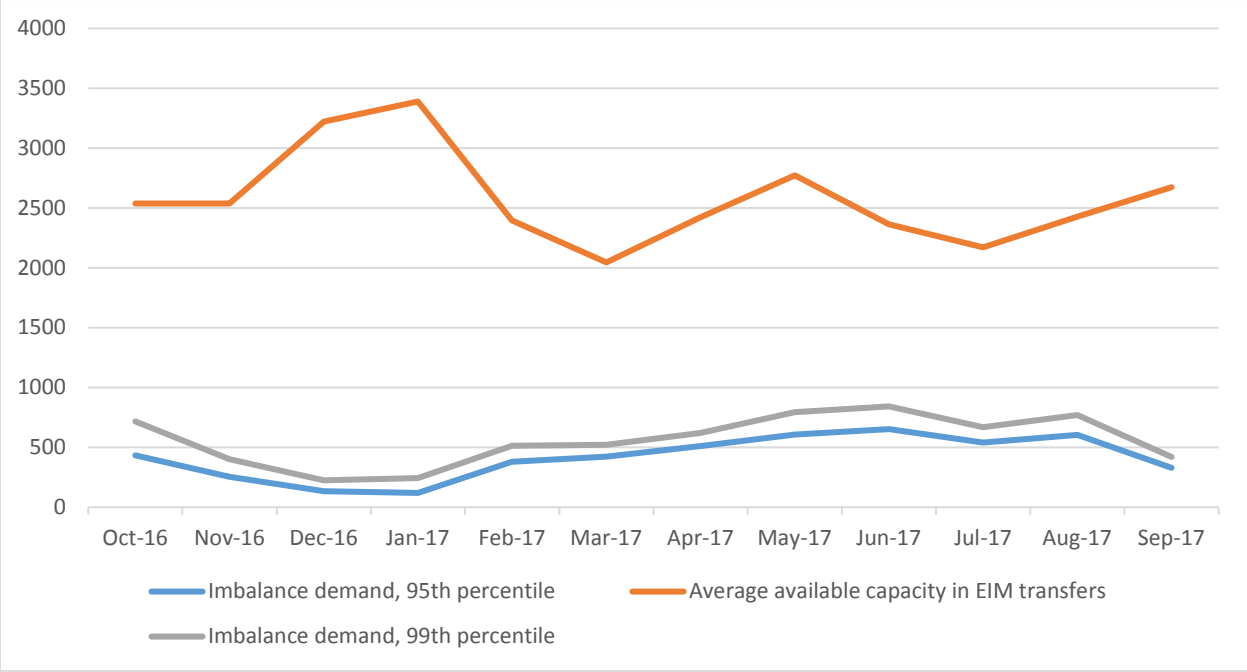
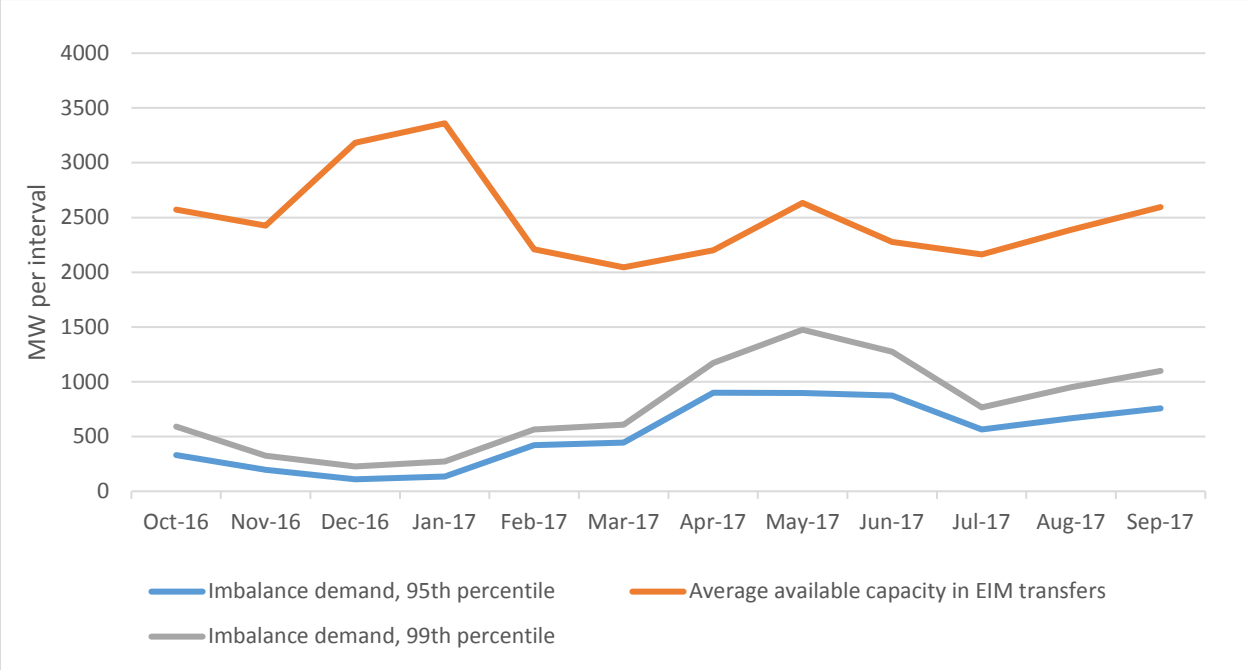


Figure 6: APS imbalance demand and competitive supply (5-minute market)



4.2 Market separation due to congestion

Another indicator that is often used to assess the structural competitiveness of a market (or a potential sub-market within a larger market) is the frequency with which an area is separated by congestion from other markets or a larger market. In an LMP market, such congestion results in *price separation,* which reflects higher LMPs within a congested area due to the positive congestion component of LMPs in that area.

Table 5 shows the portion of intervals that the APS BAA was separated by congestion from the rest of the EIM, such that prices within the APS BAA were higher due to congestion on EIM transfer constraints between the APS BAA and other EIM areas. [5] As shown in Figure 5, the frequency of price separation due to congestion limiting transfers into the APS BAAs is extremely low.

Table 5. Frequency of price separation (October 2016 to September 2017)

	Share of intervals exhibiting price separation	
	15-minute market	5-minute market
AZPS	3.0%	2.0%

Price separation is the result of both physical and behavioral outcomes in electricity markets. Thus far, APS' participation in the EIM has been subject to behavioral limitations that force the bids to be at or below the DEB. This restriction may be part of the reason that congestion has been so infrequent. While our analysis shows that we can expect competitive outcomes if that restriction is lifted, we may also see changes to congestion patterns if that restriction is lifted.

4.3 Energy bid mitigation

During the relatively small number of intervals when APS may be pivotal and competitive supply from the ISO and broader EIM into the APS BAAs may be limited by congestion, this potential structural market power is mitigated by the ISO's real-time bid mitigation procedures. When these procedures are triggered by congestion in the real-time market, bids of all supply within a BAA that is separated from the ISO are automatically subject to cost-based bid limits.

The ISO implemented enhancements to its real-time bid mitigation procedures in the 15-minute market in Q3 2016 and in the 5-minute market in Q2 2017. [6] DMM analysis shows that these enhancements have significantly improved the accuracy of congestion estimation for EIM transfer constraints.[7] This reduces the possibilities of missed mitigation to a very low level.

[5] In the EIM, price separation can also occur due to the greenhouse gas (GHG) component of LMPs and congestion on constraints within each EIM BAA. Therefore, this analysis is based only on price separation due to congestion on transfer constraints between EIM areas.

[6] *2016 Annual Report on Market Issue and Performance*, Department of Market Monitoring, May 2017. pp. 20, 253-255, http://www.caiso.com/Documents/2016AnnualReportonMarketIssuesandPerformance.pdf

[7] http://www.caiso.com/Documents/ImpactofReal-timeMarketPowerMitigationEnhancementsinEIMAreas.pdf

Results for 15-minute market

Improvements to the 15-minute market tools were made in August of 2016, and are summarized in Table 6 and Table 7. Under predicted congestion on both EIM transfers and flow based constraints dropped into the low single digits as a share of congested constraint intervals. The frequency of 15-minute intervals with potential under mitigation dropped form 26 percent to 3 percent on EIM transfer constraints, and from 10 percent to 4 percent on flow based constraints.

Table 6: Accuracy of congestion prediction on EIM transfers, 15-minute market

	Accurately predicted	Over predicted	Under predicted
January - August 14 2016	50%	24%	26%
January - September 2017	93%	4%	3%

Table 7: Accuracy of congestion prediction on flow based constraints, 15-minute market

	Accurately predicted	Over predicted	Under predicted
January - August 14 2016	64%	26%	10%
January - September 2017	77%	20%	4%

Results for 5-minute market

The accuracy of predicted congestion in the 5-minute market also improved significantly after changes implemented in the 5-minute market on May 2, 2017. As shown in Table 8 and Table 9 the improvements dropped under predicted congestion from 41 percent to 13 percent on EIM transfers, and from 14 percent to 2 percent on flow based constraints. The period *before changes* reflected in these tables spans from June 2016 through May 1, 2017. The period *after changes* starts on May 2, 2017 and ends on February 28, 2018.

Table 8: Accuracy of congestion prediction on EIM transfer constraints, 5-minute market

	Accurately predicted	Predicted but resolved	Under predicted
Before changes	29%	30%	41%
After changes	62%	26%	13%

Table 9: Accuracy of congestion prediction on flow based constraints, 5-minute market

	Accurately predicted	Predicted but resolved	Under predicted
Before changes	72%	73%	14%
After changes	83%	15%	2%

The changes to mitigation in the 5-minute market made drastic improvements to accuracy of mitigation for EIM transfers. However, the frequency of potential under mitigation in the 5-minute market on all EIM transfers constraints (13 percent) is still relatively high compared to expected performance s under the new mitigation procedures. DMM has investigated this inaccuracy and has asked the ISO to do the same.

Preliminary analysis shows that the relatively high frequency of under mitigation on EIM transfer constraints in the 5-minute market is driven by results in the Pacific Northwest. Table 10 shows the accuracy broken down by BAA. Results for AZPS (4 percent) are much better than the average in terms of avoiding under mitigation. Because of those better results in AZPS and because the ISO plans to implement some changes that may improve RTD mitigation accuracy for EIM transfers in the near future, DMM believes that it is reasonable to expect mitigation in APS to perform at a similar level to current performance.

Table 10: Accuracy of congestion prediction by region on EIM transfers, 5-minute market

REGION_ID	Accruately predicted	Predicted but resolved	Under predicted
PACE	40%	56%	4%
PACW	67%	18%	15%
PGE	66%	17%	18%
PSE	66%	20%	14%
NEVP	39%	58%	3%
AZPS	54%	42%	4%

With these enhancements in place, the CAISO's real-time market procedures for market power mitigation are robust and accurate, and effectively mitigate the potential for market power in the EIM.

5 Conclusion

This paper describes analysis by DMM to evaluate the potential for market power in existing EIM areas. Results of this analysis show that the APS BAA is structurally competitive during almost all intervals in the EIM due to the amount of competitive supply that could be transferred into APS from the rest of the EIM. Recent enhancements to the CAISO's real-time market power mitigation procedures also provide assurance that any potential market power on the APS BAA is sufficiently mitigated.