Memorandum

To: ISO Board of Governors

From: Eric Hildebrandt, Director, Market Monitoring

Date: March 8, 2017

Re: **Department of Market Monitoring update**

This memorandum does not require Board action.

EXECUTIVE SUMMARY

This memo provides a summary of the growth of renewable generation in 2016 and its effects on the ISO market. The Department of Market Monitoring (DMM) will include this analysis in its 2016 annual report, which DMM plans to publish in April.

Growth in renewable generation

Non-hydro renewable generation directly connected to the ISO system accounted for about 20 percent of total supply in 2016.[1] This represents an increase from about 18 percent in 2015, and was driven primarily by growth in generation from solar resources. The increase in solar generation primarily displaced natural gas generation, which was down about 8 percent in 2016 compared to 2015 as a result of the increase in renewable and hydro-electric generation.

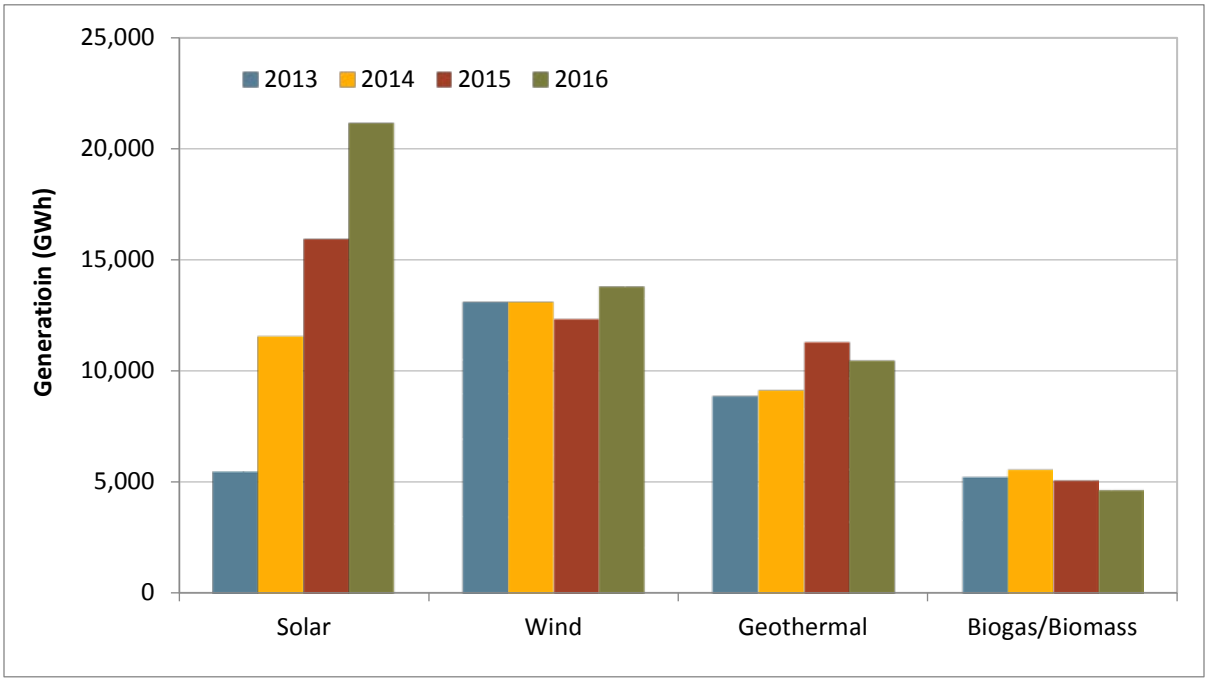
Solar generation became the largest source of renewable energy within the ISO for the first time in 2015 and this trend continued in 2016 (see Figure 1). Overall output from solar generation increased by about 32 percent compared to 2015 and accounted for around 9 percent of total supply in 2016. The increase was primarily driven by the addition of new solar resources.

Other renewable generation highlights include:

- Generation from wind resources increased by around 12 percent and contributed about 6 percent of total system energy in 2016. This was up from 5 percent in 2015.

[1] In this analysis, non-hydro renewables do not include imports or behind the meter generation such as rooftop solar. DMM has very limited access to this information. Thus, this analysis may differ from other reports of total renewable generation.

Figure 1. Total renewable generation by type (2013-2016)



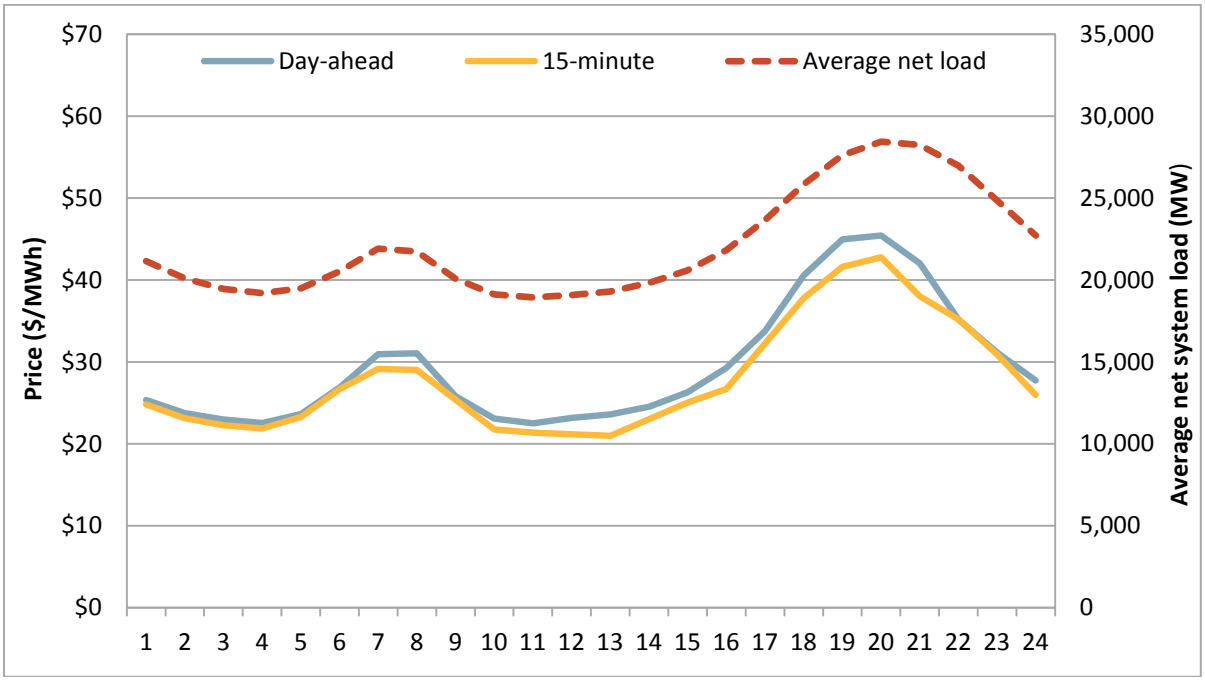
- The overall output from geothermal generation decreased by about 8 percent in 2016 and provided almost 5 percent of system energy, about the same overall percentage as last year.
- Biogas, biomass, and waste generation accounted for about 2 percent of system energy, a slight decrease compared to 2015.

Market impacts of increasing renewable generation

Prices in the ISO market have changed as renewable generation – and particularly solar generation – has increased. Both day-ahead and real-time prices directly reflect the net load curve.[2] Figure 2 compares the average hourly net load curve (dashed red line) with average hourly day-ahead prices (blue line) and 15-minute real-time prices (yellow line) for 2016. The largest change in the prices was during the mid-afternoon hours. In previous years, both the shape of the net load curve and the price curves would increase or remain flat throughout the mid-day hours. However, with the significant increase in solar generation over the past few years, the net load curve and prices have declined in the early afternoon hours as solar generation comes on-line.

[2] The net load curve shows wind and solar generation subtracted from load.

Figure 2. Average hourly ISO prices compared to net load (2016)



With increasing solar generation, we have seen an increase in the frequency of negative prices and a shift in the hours with negative prices, particularly in the real-time market. Negative prices occurred in roughly 5.4 percent of 5-minute prices at the load area level in 2016. This is up from 4.3 percent of 5-minute load area prices in 2015 and 2.7 percent of these prices in 2014 (see Figure 3).

Most of the negative prices in the 5-minute market were between -$50/MWh and $0/MWh. This reflects that the vast majority of negative prices set by economic bids to decrease renewable resources, primarily from solar generation. The yellow and red bars are indicative of periods where the market may not have been able to solve the solution based on market bids and penalty parameters likely set the price. Overall, these periods were infrequent in 2016 at the system and regional level and declined compared to both 2015 and 2014.

Several years ago, most negative prices occurred in the early morning hours of the day when loads were lowest overnight. Over the few years we have seen a shift to an increased frequency of negative prices during the mid-day hours. Figure 4 shows the hourly average frequency of 5-minute market load area prices in 2012, 2014 and 2016. The highest frequency of negative prices was in the overnight hours in 2012 and 2014. In 2014, we saw an increase in negative prices in the mid-day hours. By 2016, the frequency of negative prices were highest in the mid-day hours and relatively lower during the overnight hours.

Figure 3. Frequency of negative 15-minute market prices by year [3]

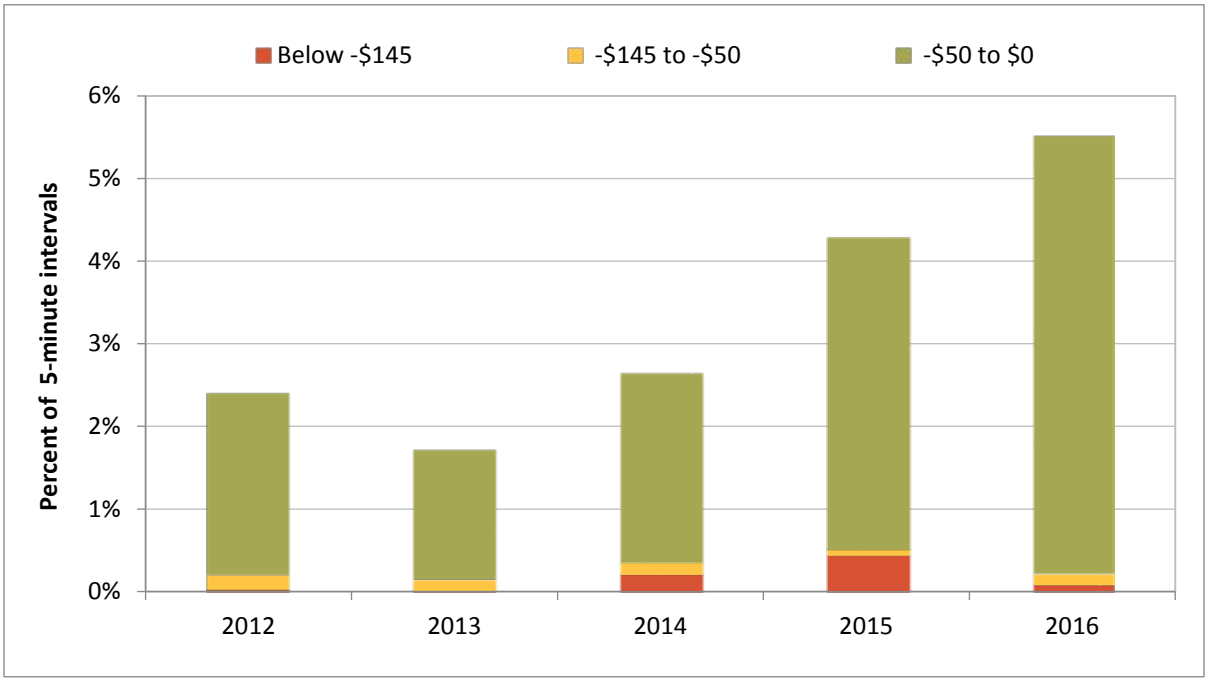
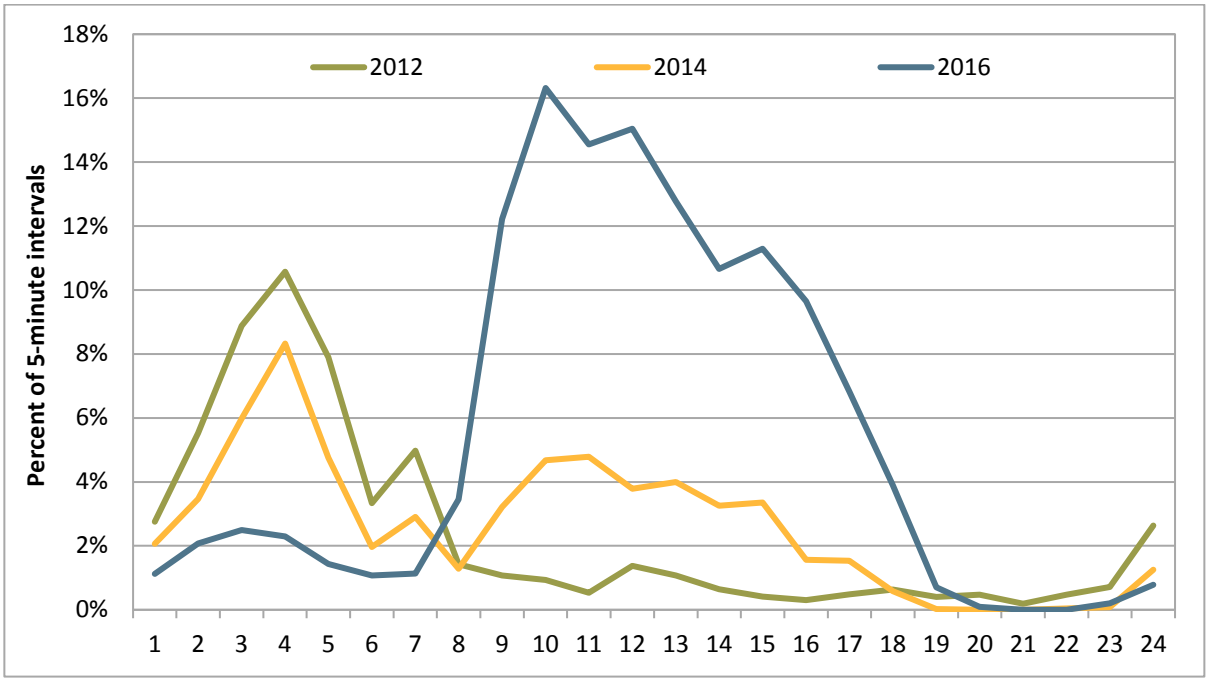


Figure 4. Frequency of negative 5-minute market prices by operating hour

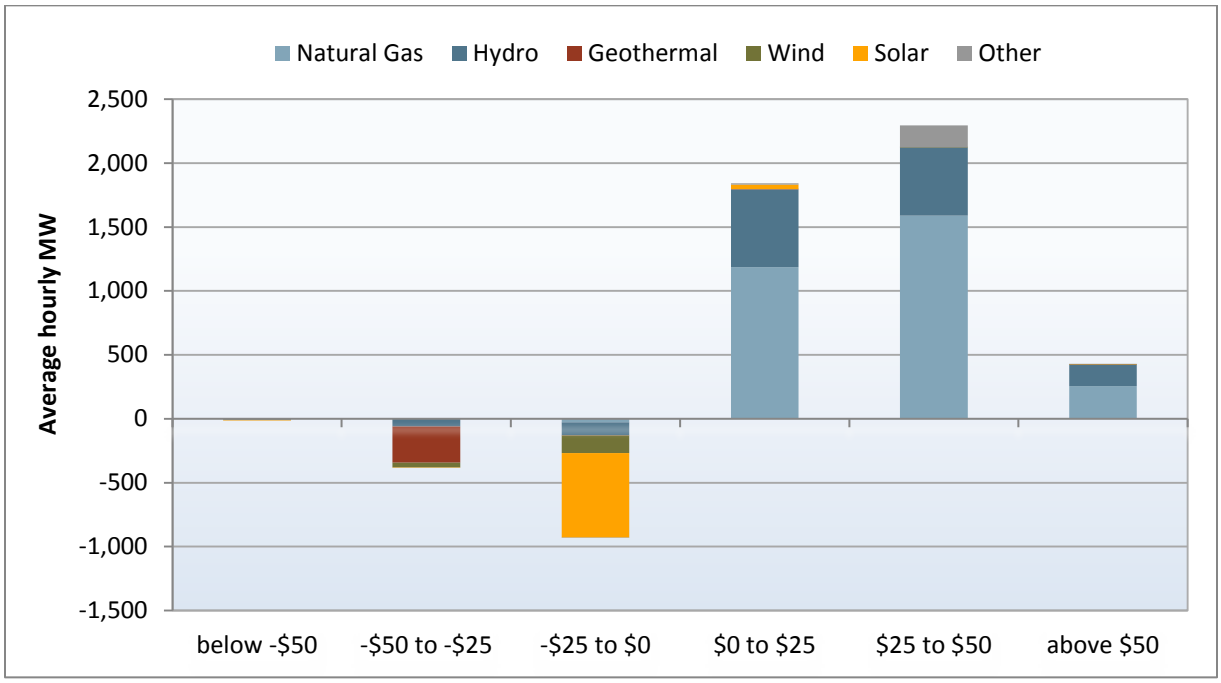


[3] The price floor dropped from -$30/MWh to -$150/MWh in May 2014.

Negative prices are indicative of oversupply conditions. The market can resolve oversupply conditions by decrementally dispatching generation. For solar and wind generation, decrementally dispatching generation reduces the output of these resources from their forecasted output level. Decrementally dispatching renewable generation is preferred to uneconomic curtailment because it provides an economic signal to help the ISO market software solve oversupply without operator intervention or setting prices at administrative levels.

However, decrementally dispatching renewable generation and uneconomic curtailment both reduce renewable generation output. As shown in Figure 5, most negatively bid generation in the real-time market in 2016 was renewable generation including solar (yellow bar), wind (green bar), and geothermal (red bar).

Figure 5. Real-time economic bids by bid range and resource type (2016)

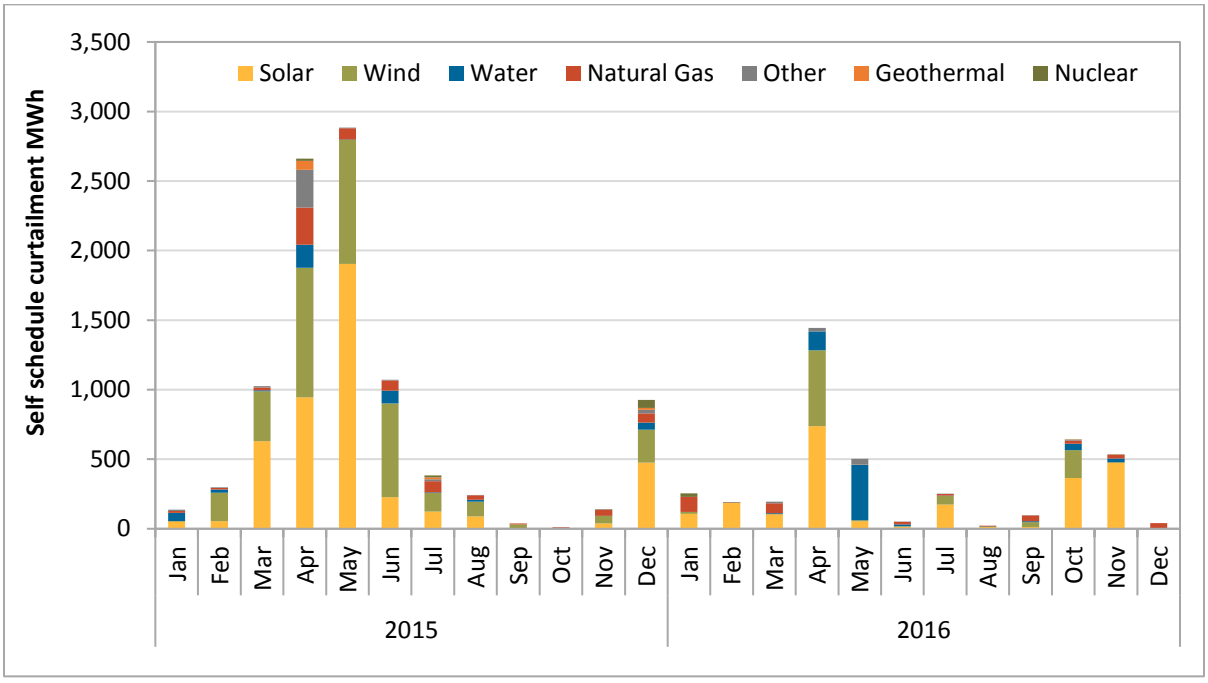


The amount of solar generation decrementally dispatched to reduce output below forecasted levels totaled about 1.6 percent of total solar generation in 2016 compared to about 1.2 percent in 2015. The largest monthly decremental dispatch of solar generation was 3.4 percent of total solar generation in March 2016, compared to 3.2 percent in May 2016.

The amount of wind generation decrementally dispatched totaled about 0.3 percent of forecasted wind output in 2016 compared to about 0.2 percent in 2015. The largest monthly decremental dispatch of wind generation was 0.6 percent in December 2016, compared to 0.4 percent in April 2016. Solar was decrementally dispatched more than wind primarily because participants bid more economic downward capacity for solar than for wind, and because solar bids tended to be slightly higher than the wind bids.

While in most cases the market can resolve oversupply by dispatching bids, there are times when no additional generation is available to be decrementally dispatched and generation needs to be curtailed by the market software or manual dispatches by ISO operators. Such uneconomic curtailment of generation was down in 2016 compared to 2015 by almost 60 percent, with most months having fewer curtailments of generation in 2016 compared to 2015 (see Figure 6).

Figure 6. Monthly total self-schedule curtailment by resource type (2015 – 2016)



The decline in uneconomic curtailment occurred even as solar output increased by about 32 percent in 2016 and hydro-electric generation more than doubled compared to 2015. This low and declining level of uneconomic curtailment indicates that the current bid floor is sufficiently low to allow for sufficient levels of economic decremental bids.[4]

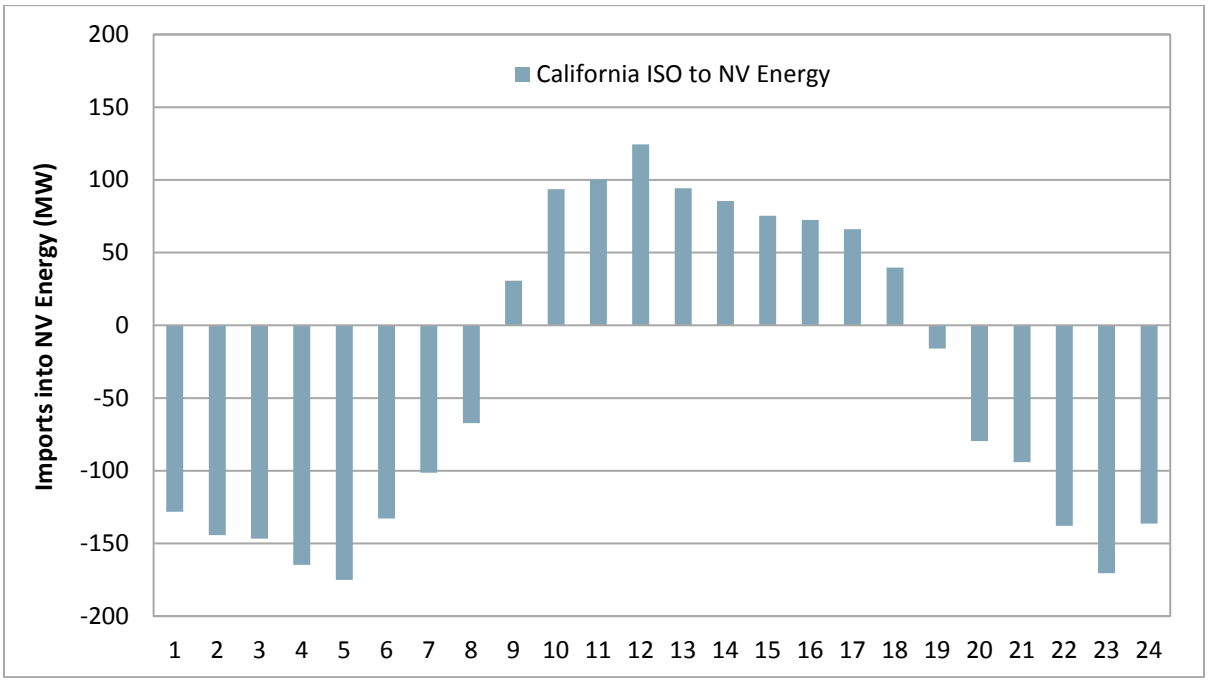
[4] The ISO had considered lowering the bid floor form -$150/MWh to -$300/MWh in 2016. However, the ISO deferred lowering the bid floor at this time based on the declining levels of uneconomic curtailment and will reconsider lowering the bid floor should evidence show that the negative bid floor resulted in increasing levels of uneconomic curtailment.

Wind curtailment declined by over 75 percent and solar curtailment dropped by about 50 percent compared to 2015. This decline is likely driven by renewable generation, particularly solar, continuing to bid more downward generation into the market and the expansion of the energy imbalance market. The addition of NV Energy beginning in December 2015 added almost 1,000 MW of additional transfer capacity out of the ISO in the real-time market as well as several hundred megawatts of transfer capacity with PacifiCorp East.[5]

The prevailing flows of EIM transfers during the early afternoon hours ─ when solar generation is at its highest and the net load curve is at its lowest ─ is frequently out of the ISO and going into other EIM areas. This trend typically reversed in the non-solar hours as EIM transfers would frequently come into the ISO from other EIM areas.

Figure 7 highlights this trend by showing average hourly imports and exports into NV Energy from the ISO in 2016. Positive values in Figure 7 represent imports into NV Energy from the ISO area, while negative values represent exports from NV Energy to the ISO area. As shown in this figure, imports to NV Energy from the ISO were highest in hour 12, whereas exports from NV Energy to the ISO were highest in hour 5. Imports to NV Energy from the ISO were highest in the spring months as renewable and hydro-electric generation increased during periods of low system load.

Figure 7. Average hourly EIM transfers from the ISO to NV Energy (2016)



[5] The ISO quantifies the overall benefits of EIM including the avoided decrease in renewable generation due to EIM its quarterly benefits reports at: http://www.caiso.com/informed/Pages/EIMOverview/Default.aspx.

Conclusion

Overall, DMM views the level of decremental economic dispatch and non-economic curtailment of solar and wind resources as relatively low given the total amount of renewable generation on the system. Renewable generation can help integrate additional renewable resources by providing downward dispatch flexibility to the market when needed. However, the ISO still seeks to minimize the need to decrement renewable energy sources as a means of maximizing market efficiency and greenhouse gas reductions.

Decrementally dispatching renewable generation through bids is preferred to uneconomic curtailment because it provides an economic signal to help the ISO market software solve oversupply without operator intervention or setting prices at administrative levels. DMM's analysis of bid data and the fact that almost all oversupply has been resolved by decrementing generation based on market bids indicates that the current bid floor of -$150/MWh is sufficient and does not need to be lowered.

However, decrementally dispatching renewable generation and uneconomic curtailment both reduce renewable generation output. As the volume of renewable energy increases – including within EIM areas – it will be important for the ISO to continue to encourage flexibility and minimize commitment of inflexible resources, including gas-fired units operating at minimum load. Continuing the ISO's efforts to improve load and renewable forecasting, the residual unit commitment process, and how capacity constraints are incorporated into the market model have helped to reduce commitment of inflexible resources. DMM also supports efforts to identify modifications to bid cost recovery provisions that may reduce self-scheduling of some resources.[6]

DMM also believes that the ISO should help minimize the decremental economic dispatch and non-economic curtailment of renewable resources by adopting market rules that encourage the flexibility of the area's gas-fired fleet. DMM continues to recommend that the ISO ensure that unit characteristics entered into the Master File reflect the actual unit constraints, rather than values that may be selected by scheduling coordinators to limit unit cycling or flexibility. DMM also believes it is inefficient for the ISO to treat contractual limitations as physical limitations in the ISO market optimization.

In the first two months of 2017, renewable and hydro-electric generation has continued to increase compared to 2016. This has contributed to increased levels of negative prices in both the real-time and the day-ahead markets. DMM will continue to track these effects and will report on them to the Board and in our quarterly and annual public reports.

[6] For example, see *Bid Cost Recovery Enhancements: Draft Final Proposal,* February 3, 2017, p.5. http://www.caiso.com/Documents/DraftFinalProposal-BidCostRecoveryEnhancements.pdf