

Energy Market

The PJM energy market comprises all types of energy transactions, including the sale or purchase of energy in PJM's Day-Ahead and Real-Time Energy Markets, bilateral and forward markets and self-supply. Energy transactions analyzed in this report include those in the PJM Day-Ahead and Real-Time Energy Markets. These markets provide key benchmarks against which market participants may measure results of transactions in other markets.

The Market Monitoring Unit (MMU) analyzed measures of market structure, participant conduct and market performance, including market size, concentration, pivotal suppliers, offer behavior, markup, and price. The MMU concludes that the PJM energy market results were competitive in the first three months of 2020.

Table 3-1 The energy market results were competitive

Market Element	Evaluation	Market Design
Market Structure: Aggregate Market	Partially Competitive	
Market Structure: Local Market	Not Competitive	
Participant Behavior	Competitive	
Market Performance	Competitive	Effective

- The aggregate market structure was evaluated as partially competitive because the aggregate market power test based on pivotal suppliers indicates that the aggregate day-ahead market structure was not competitive on every day. The hourly HHI (Herfindahl-Hirschman Index) results indicate that the PJM aggregate energy market in the first three months of 2020 was unconcentrated by FERC HHI standards. Average HHI was 706 with a minimum of 592 and a maximum of 996 in the first three months of 2020. The peaking segment of supply was highly concentrated. The fact that the average HHI and the maximum hourly HHI are in the unconcentrated range does not mean that the aggregate market was competitive in all hours. As demonstrated for the day-ahead market, it is possible to have pivotal suppliers in the aggregate market even when the HHI level is not in the highly concentrated range. It is possible to have an exercise of market power even when the HHI level is

not in the highly concentrated range. The number of pivotal suppliers in the energy market is a more precise measure of structural market power than the HHI. The HHI is not a definitive measure of structural market power.

- The local market structure was evaluated as not competitive due to the highly concentrated ownership of supply in local markets created by transmission constraints and local reliability issues. The results of the three pivotal supplier (TPS) test, used to test local market structure, indicate the existence of market power in local markets created by transmission constraints. The local market performance is competitive as a result of the application of the TPS test. While transmission constraints create the potential for the exercise of local market power, PJM's application of the three pivotal supplier test identified local market power and resulted in offer capping to force competitive offers, correcting for structural issues created by local transmission constraints. There are, however, identified issues with the definition of cost-based offers and the application of market power mitigation to resources whose owners fail the TPS test that need to be addressed because unit owners can exercise market power even when they fail the TPS test.
- Participant behavior was evaluated as competitive because the analysis of markup shows that marginal units generally make offers at, or close to, their marginal costs in both the day-ahead and real-time energy markets, although the behavior of some participants both routinely and during periods of high demand represents economic withholding. The ownership of marginal units is concentrated. The markups of pivotal suppliers in the aggregate market and of many pivotal suppliers in local markets remain unmitigated due to the lack of aggregate market power mitigation and the flawed implementation of offer caps for resources that fail the TPS test. The markups of those participants affected LMP.
- Market performance was evaluated as competitive because market results in the energy market reflect the outcome of a competitive market, as PJM prices are set, on average, by marginal units operating at, or close to, their marginal costs in both day-ahead and real-time energy markets, although high markups for some marginal units did affect prices.

- Market design was evaluated as effective because the analysis shows that the PJM energy market resulted in competitive market outcomes. In general, PJM's energy market design provides incentives for competitive behavior and results in competitive outcomes. In local markets, where market power is an issue, the market design identifies market power and causes the market to provide competitive market outcomes in most cases although issues with the implementation of market power mitigation and development of cost-based offers remain. The role of UTCs in the day-ahead energy market continues to cause concerns. Market design implementation issues, including inaccuracies in modeling of the transmission system and of generator capabilities as well as inefficiencies in real-time dispatch and price formation, undermine market efficiency in the energy market.

PJM markets are designed to promote competitive outcomes derived from the interaction of supply and demand in each of the PJM markets. Market design itself is the primary means of achieving and promoting competitive outcomes in PJM markets. One of the MMU's core functions is to identify actual or potential market design flaws.¹ The approach to market power mitigation in PJM has focused on market designs that promote competition (a structural basis for competitive outcomes) and on limiting market power mitigation to instances where the market structure is not competitive and thus where market design alone cannot mitigate market power. In the PJM energy market, this occurs primarily in the case of local market power. When a transmission constraint creates the potential for local market power, PJM applies a structural test to determine if the local market is competitive, applies a behavioral test to determine if generator offers exceed competitive levels and applies a market performance test to determine if such generator offers would affect the market price.² There are, however, identified issues with the application of market power mitigation to resources whose owners fail the TPS test that can result in the exercise of local market power even when market power mitigation rules are applied. These issues need to be addressed. There are issues related to the definition of gas costs includable

¹ OATT Attachment M (PJM Market Monitoring Plan).

² The market performance test means that offer capping is not applied if the offer does not exceed the competitive level and therefore market power would not affect market performance.

in energy offers that need to be addressed. There are issues related to the level of maintenance expense includable in energy offers that need to be addressed. There are currently no market power mitigation rules in place that limit the ability to exercise market power when aggregate market conditions are tight and there are pivotal suppliers in the aggregate market. Aggregate market power needs to be addressed. Market design must reflect appropriate incentives for competitive behavior, the application of local market power mitigation needs to be fixed, the definition of a competitive offer needs to be fixed, and aggregate market power mitigation rules need to be developed. The importance of these issues is amplified by the rules permitting cost-based offers in excess of \$1,000 per MWh.

Overview

Supply and Demand

Market Structure

- **Supply.** Supply includes physical generation, imports and virtual transactions. The maximum average on peak hourly offered real-time supply was 140,120 MW for the 2019-2020 winter, and 148,373 MW for the 2018-2019 winter. In the first three months of 2020, 325.3 MW of new resources were added in the energy market, 127.7 MW of internal resources and 457.0 MW of pseudo tied resources were retired.

PJM average real-time cleared generation in the first three months of 2020 decreased by 6.5 percent from the first three months of 2019, from 97,010 MWh to 90,675 MWh.

PJM average day-ahead cleared supply in the first three months of 2020, including INCs and up to congestion transactions, decreased by 7.7 percent from the first three months of 2019, from 122,368 MWh to 112,939 MWh.

- **Demand.** Demand includes physical load and exports and virtual transactions. The PJM accounting peak load in the first three months of 2020 was 116,761 MWh in the HE 0800 on January 22, 2020, which was 17,299 MWh, 12.9 percent, lower than the PJM peak load in the first three

months of 2019, which was 134,060 MWh in the HE 0800 on January 31, 2019.

PJM average real-time demand in the first three months of 2020 decreased by 6.9 percent from the first three months of 2019, from 91,962 MWh to 85,608 MWh. PJM average day-ahead demand in the first three months of 2020, including DECs and up to congestion transactions, decreased by 7.8 percent from the first three months of 2019, from 117,251 MWh to 108,144 MWh.

Market Behavior

- **Supply and Demand: Load and Spot Market.** Companies that serve load in PJM do so using a combination of self-supply, bilateral market purchases and spot market purchases. In the first three months of 2020, 16.9 percent of real-time load was supplied by bilateral contracts, 24.1 percent by spot market purchases and 59.0 percent by self-supply. Compared to the first three months of 2019, reliance on bilateral contracts increased by 1.6 percentage points, reliance on spot market purchases decreased by 1.4 percentage points and reliance on self-supply decreased by 0.1 percentage points.
- **Generator Offers.** Generator offers are categorized as pool scheduled and self scheduled. Units which are available for economic commitment are pool scheduled. Units which are self scheduled to generate fixed output are categorized as self scheduled. Units which are self scheduled at their economic minimum and are available for economic dispatch up to their economic maximum are categorized as self scheduled and dispatchable. Of all generator offered MW up to their economic maximum in the first three months of 2020, 65.9 percent were offered to be pool scheduled, 33.7 percent above economic minimum and 32.2 percent up to economic minimum. For self scheduled units, 14.1 percent were offered as self scheduled at a fixed output, and 20.0 percent were offered as self scheduled and dispatchable.
- **Virtual Offers and Bids.** Any market participant in the PJM Day-Ahead Energy Market can use increment offers, decrement bids, up to congestion

transactions, import transactions and export transactions as financial instruments that do not require physical generation or load. The hourly average submitted increment offer MW increased by 10.7 percent and cleared MW decreased by 13.0 percent in the first three months of 2020. The hourly average submitted decrement offer MW increased by 0.2 percent and cleared MW decreased by 17.8 percent in the first three months of 2020. The hourly average submitted up to congestion bid MW decreased by 42.9 percent and cleared MW decreased by 11.0 percent in the first three months of 2020.

Market Performance

- **Generation Fuel Mix.** In the first three months of 2020, coal units provided 18.0 percent, nuclear units 34.5 percent and natural gas units 39.7 percent of total generation. Compared to the first three months of 2019, generation from coal units decreased 36.6 percent, generation from natural gas units increased 14.0 percent and generation from nuclear units decreased 0.9 percent. The trend toward more energy from natural gas and less from coal accelerated in the first three months of 2020.
- **Fuel Diversity.** The fuel diversity of energy generation in the first three months of 2020, measured by the fuel diversity index for energy (FDI_e), decreased 2.9 percent compared to the first three months of 2019.
- **Marginal Resources.** In the PJM Real-Time Energy Market, in the first three months of 2020, coal units were 17.5 percent and natural gas units were 73.2 percent of marginal resources. In the first three months of 2019, coal units were 24.4 percent and natural gas units were 69.4 percent of marginal resources.

In the PJM Day-Ahead Energy Market, in the first three months of 2020, up to congestion transactions were 48.5 percent, INCs were 16.2 percent, DECs were 12.6 percent, and generation resources were 22.5 percent of marginal resources. In the first three months of 2019, up to congestion transactions were 59.9 percent, INCs were 11.9 percent, DECs were 16.7 percent, and generation resources were 11.4 percent of marginal resources.

- **Prices.** PJM real-time and day-ahead energy market prices were at the lowest level in PJM history during the first three months of 2020. Both the weather and COVID-19 played a role in this significant drop in prices. PJM real-time energy market prices decreased in the first three months of 2020. The load-weighted, average real-time LMP was 34.2 percent lower in the first three months of 2020 than in the first three months of 2019, \$19.85 per MWh versus \$30.16 per MWh.

PJM day-ahead energy market prices decreased in the first three months of 2020. The load-weighted, average day-ahead LMP was 34.6 percent lower in the first three months of 2020 than in the first three months of 2019, \$20.12 per MWh versus \$30.76 per MWh.

- **Components of LMP.** In the PJM Real-Time Energy Market, in the first three months of 2020, 30.0 percent of the load-weighted LMP was the result of coal costs, 41.8 percent was the result of gas costs and 1.7 percent was the result of the cost of emission allowances.

In the PJM Day-Ahead Energy Market, in the first three months of 2020, 34.1 percent of the load-weighted LMP was the result of coal costs, 20.7 percent was the result of gas costs, 13.2 percent was the result of INC offers, 14.4 percent was the result of DEC bids, and 2.6 percent was the result of up to congestion transaction offers.

- **Price Convergence.** Hourly and daily price differences between the day-ahead and real-time energy markets fluctuate continuously and substantially from positive to negative. The difference between the average day-ahead and real-time prices was $-\$0.24$ per MWh in the first three months of 2020, and $-\$0.52$ per MWh in the first three months of 2019 and. The difference between average day-ahead and real-time prices, by itself, is not a measure of the competitiveness or effectiveness of the day-ahead energy market.

Scarcity

- There were no intervals with five minute shortage pricing in the first three months of 2020. There were no emergency actions that resulted in Performance Assessment Intervals in the first three months of 2020.

- There were 439 five minute intervals, or 1.7 percent of all five minute intervals in the first three months of 2020 for which at least one solved RT SCED case showed a shortage of reserves, and 199 five minute intervals, or 0.8 percent of all five minute intervals in the first three months of 2020 for which more than one solved RT SCED case showed a shortage of reserves. PJM did not trigger shortage pricing in any of these intervals.

Competitive Assessment

Market Structure

- **Aggregate Pivotal Suppliers.** The PJM energy market, at times, requires generation from pivotal suppliers to meet load, resulting in aggregate market power even when the HHI level indicates that the aggregate market is unconcentrated.

Market Behavior

- **Offer Capping for Local Market Power.** PJM offer caps units when the local market structure is noncompetitive. Offer capping is an effective means of addressing local market power when the rules are designed and implemented properly. Offer capping levels have historically been low in PJM. In the day-ahead energy market, for units committed to provide energy for local constraint relief, offer-capped unit hours increased from 0.2 percent in the first three months of 2019 to 0.8 percent in the first three months of 2020. In the real-time energy market, for units committed to provide energy for local constraint relief, offer-capped unit hours increased from 0.6 percent in the first three months of 2019 to 0.7 percent in the first three months of 2020. While overall offer capping levels have been low, there are a significant number of units with persistent structural local market power that would have a significant impact on prices in the absence of local market power mitigation.

In the first three months of 2020, 10 control zones experienced congestion resulting from one or more constraints binding for 25 or more hours. The analysis of the application of the TPS test to local markets demonstrates that it is working to identify pivotal owners when the market structure is

noncompetitive and to ensure that owners are not subject to offer capping when the market structure is competitive. There are, however, identified issues with the application of market power mitigation to resources whose owners fail the TPS test that can result in the exercise of local market power. These issues need to be addressed.

- **Offer Capping for Reliability.** PJM also offer caps units that are committed for reliability reasons, including for reactive support. In the day-ahead energy market, for units committed for reliability reasons, offer-capped unit hours remained at 0.0 percent in the first three months of 2019 and 2020. In the real-time energy market, for units committed for reliability reasons, offer-capped unit hours remained at 0.0 percent in the first three months of 2019 and 2020.
- **Markup Index.** The markup index is a summary measure of participant offer behavior for individual marginal units. In the first three months of 2020, in the PJM Real-Time Energy Market, 99.6 percent of marginal units had offer prices less than \$50 per MWh. While markups in the real-time market were generally low, some marginal units did have substantial markups. The highest markup for any marginal unit in the first three months of 2020 was more than \$150 per MWh.

In the first three months of 2020, in the PJM Day-Ahead Energy Market, 99.8 percent of marginal generating units had offer prices less than \$50 per MWh. Markups in the day-ahead market were generally low. The highest markup for any marginal unit in the day-ahead market in the first three months of 2020 was about \$30 per MWh.

- **Markup.** The markup frequency distributions show that a significant proportion of units make price-based offers less than the cost-based offers permitted under the PJM market rules. This behavior means that competitive price-based offers reveal actual unit marginal costs and that PJM market rules permit the inclusion of costs in cost-based offers that are not short run marginal costs.

The markup behavior shown in the markup frequency distributions also shows that a substantial number of units were offered with high markups,

consistent with the exercise of market power. Markup for coal and gas fired units decreased in the first three months of 2020.

- **Markup and Market Power.** Comparison of the markup behavior of marginal units with TPS test results shows that for 8.3 percent of marginal unit intervals in the first three months of 2020 the marginal unit had local market power as determined by the TPS test and a positive markup. The fact that units with market power had a positive markup means that the cost-based offer was not used and that the process for offer capping units that fail the TPS test does not consistently result in competitive market outcomes in the presence of market power.
- **Frequently Mitigated Units (FMU) and Associated Units (AU).** One unit qualified for an FMU adder for the months of September and October 2019. No units have qualified for an FMU adder in any month since October 2019.

Market Performance

- **Markup.** The markup conduct of individual owners and units has an identifiable impact on market prices. Markup is a key indicator of the competitiveness of the energy market.

In the PJM Real-Time Energy Market in the first three months of 2020, the unadjusted markup component of LMP was \$0.10 per MWh or 0.5 percent of the PJM load-weighted, average LMP. January had the highest unadjusted peak markup component, \$0.91 per MWh, or 3.8 percent of the real-time, peak hour load-weighted, average LMP. There were 9 hours in the first three months of 2020 where the positive markup contribution to the PJM system wide, load-weighted, average LMP exceeded \$29.86 per MWh.

In the PJM Day-Ahead Energy Market, INCs, DECs and UTCs have zero markups. In the first three months of 2020, the unadjusted markup component of LMP resulting from generation resources was -\$0.15 per MWh or -0.8 percent of the PJM day-ahead load-weighted average LMP. January had the highest unadjusted peak markup component, \$0.29 per MWh.

Participant behavior was evaluated as competitive because the analysis of markup shows that marginal units generally make offers at, or close to, their marginal costs in both the day-ahead and real-time energy markets, although the behavior of some participants represents economic withholding.

Recommendations

Market Power

- The MMU recommends that the market rules explicitly require that offers in the energy market be competitive, where competitive is defined to be the short run marginal cost of the units. The short run marginal cost should reflect opportunity cost when and where appropriate. The MMU recommends that the level of incremental costs includable in cost-based offers not exceed the short run marginal cost of the unit. (Priority: Medium. First reported 2009. Status: Not adopted.)
- The MMU recommends that PJM require that all fuel cost policies be algorithmic, verifiable, and systematic, and accurately reflect short run marginal costs. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends that the tariff be changed to allow units to have Fuel Cost Policies that do not include fuel procurement practices, including fuel contracts. Fuel procurement practices, including fuel contracts, may be used as the basis for Fuel Cost Policies but should not be required. (Priority: Low. First reported 2018. Status: Not adopted.)
- The MMU recommends that PJM change the Fuel Cost Policy requirement to apply only to units that will be offered with non-zero cost-based offers. The PJM market rules should require that the cost-based offers of units without an approved Fuel Cost Policy be set to zero. (Priority: Low. First reported 2018. Status: Not adopted.)
- The MMU recommends that Manual 15 (Cost Development Guidelines) be replaced with a straightforward description of the components of cost-based offers based on short run marginal costs and the correct calculation of cost-based offers. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends removal of all use of FERC System of Accounts in the Cost Development Guidelines. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends the removal of all use of cyclic starting and peaking factors from the Cost Development Guidelines. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends the removal of all labor costs from the Cost Development Guidelines. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends the removal of all maintenance costs from the Cost Development Guidelines. (Priority: Medium. First reported 2019. Status: Not adopted.)
- The MMU recommends explicitly accounting for soak costs and changing the definition of the start heat input for combined cycles to include only the amount of fuel used from first fire to the first breaker close in Cost Development Guidelines. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends the removal of nuclear fuel and nonfuel operations and maintenance costs that are not short run marginal costs from the Cost Development Guidelines. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends revising the pumped hydro fuel cost calculation to include day-ahead and real-time power purchases. (Priority: Low. First reported 2016. Status: Not adopted.)
- The MMU recommends revisions to the calculation of energy market opportunity costs to incorporate all time based offer parameters and all limitations that impact the opportunity cost of generating unit output. (Priority: Medium. First reported 2016. Status: Partially adopted, 2018.)

- The MMU recommends removing the catastrophic designation for force majeure fuel supply limitations in Schedule 2. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends that the rules governing the application of the TPS test be clarified and documented. The TPS test application in the day-ahead energy market is not documented. (Priority: High. First reported 2015. Status: Partially adopted.)
- The MMU recommends that PJM require every market participant to make available at least one cost schedule based on the same hourly fuel type(s) and parameters at least as flexible as their offered price schedule. (Priority: Medium. First reported 2015. Status: Not adopted.)
- The MMU recommends, in order to ensure effective market power mitigation when the TPS test is failed, that markup be constant across the full MWh range of price and cost-based offers. (Priority: High. First reported 2015. Status: Not adopted.)
- The MMU recommends that in order to ensure effective market power mitigation when the TPS test is failed, and during high load conditions such as cold and hot weather alerts or more severe emergencies, the operating parameters in the cost-based offer and the price-based parameter limited schedule (PLS) offer be at least as flexible as the operating parameters in the available price-based non-PLS offer, and that the price-MW pairs in the price-based PLS offer be exactly equal to the price-based non-PLS offer. (Priority: High. First reported 2015. Status: Not adopted.)
- The MMU recommends that in order to ensure effective market power mitigation, PJM always enforce parameter limited values by committing units only on parameter limited schedules, when the TPS test is failed or during high load conditions such as cold and hot weather alerts or more severe emergencies. (Priority: High. First reported 2019. Status: Not adopted.)
- The MMU recommends that PJM retain the \$1,000 per MWh offer cap in the PJM energy market except when cost-based offers exceed \$1,000 per MWh, and retain other existing rules that limit incentives to exercise

market power. (Priority: High. First reported 1999. Status: Partially adopted, 1999, 2017.)

- The MMU recommends the elimination of FMU and AU adders. FMU and AU adders no longer serve the purpose for which they were created and interfere with the efficient operation of PJM markets. (Priority: Medium. First reported 2012. Status: Partially adopted, 2014.)
- The MMU recommends that market sellers not be allowed to designate any portion of an available capacity resource's ICAP equivalent of cleared UCAP capacity commitment as a Maximum Emergency offer at any time during the delivery year.³ (Priority: Medium. First reported 2012. Status: Not adopted.)

Capacity Performance Resources

- The MMU recommends that capacity performance resources and base capacity resources (during the June through September period) be held to the OEM operating parameters of the capacity market CONE reference resource for performance assessment and energy uplift payments and that this standard be applied to all technologies on a uniform basis. (Priority: Medium. First reported 2015. Status: Not adopted.)
- The MMU recommends that the parameters which determine nonperformance charges and the amounts of uplift payments should reflect the flexibility goals of the capacity performance construct. The operational parameters used by generation owners to indicate to PJM operators what a unit is capable of during the operating day should not determine capacity performance assessment or uplift payments. (Priority: Medium. First reported 2015. Status: Partially adopted.)
- The MMU recommends that PJM not include the balancing ratios calculated for localized Performance Assessment Intervals (PAIs) in the capacity market default offer cap, and only include those events that trigger emergencies at a defined zonal or higher level. (Priority: Medium. First reported 2018. Status: Not adopted.)

³ This recommendation was accepted by PJM and filed with FERC in 2014 as part of the capacity performance updates to the RPM. See PJM Filing, Attachment A (Redlines of OA Schedule 1 § 1.10.1A(d), EL15-29-000 (December 12, 2014). FERC rejected the proposed change. See 151 FERC ¶ 61,208 at P 476 (2015).

- The MMU recommends that PJM clearly define the business rules that apply to the unit specific parameter adjustment process, including PJM's implementation of the tariff rules in the PJM manuals to ensure market sellers know the requirements for their resources. (Priority: Low. First reported 2018. Status: Not adopted.)
- The MMU recommends that PJM update the tariff to clarify that all generation resources are subject to unit specific parameter limits on their cost-based offers using the same standard and process as capacity performance capacity resources. (Priority: Medium. First reported 2018. Status: Not adopted.)
- The MMU recommends that PJM institute rules to assess a penalty for resources that choose to submit real-time values that are less flexible than their unit specific parameter limits or approved parameter limit exceptions based on tariff defined reasons. (Priority: Medium. First reported 2018. Status: Not adopted.)
- The MMU recommends that PJM not approve temporary exceptions that are based on pipeline tariff terms that are not routinely enforced, and based on inferior transportation service procured by the generator. (Priority: Medium. First reported 2019. Status: Not adopted.)
- The MMU recommends that PJM routinely review all transmission facility ratings and any changes to those ratings to ensure that the normal, emergency and load dump ratings used in modeling the transmission system are accurate and reflect standard ratings practice. (Priority: Low. First reported 2013. Status: Partially adopted.)
- The MMU recommends that PJM update the outage impact studies, the reliability analyses used in RPM for capacity deliverability, and the reliability analyses used in RTEP for transmission upgrades to be consistent with the more conservative emergency operations (post contingency load dump limit exceedance analysis) in the energy market that were implemented in June 2013. (Priority: Low. First reported 2013. Status: Not adopted.)
- The MMU recommends that PJM include in the tariff or appropriate manual an explanation of the initial creation of hubs, the process for modifying hub definitions and a description of how hub definitions have changed.^{4,5} (Priority: Low. First reported 2013. Status: Not adopted.)
- The MMU recommends that all buses with a net withdrawal be treated as load for purposes of calculating load and load-weighted LMP, even if the MW are settled to the generator. The MMU recommends that during hours when a load bus shows a net injection, the energy injection be treated as generation, not negative load, for purposes of calculating generation and load-weighted LMP, even if the injection MW are settled to the load serving entity. (Priority: Low. First reported 2013. Status: Not adopted.)
- The MMU recommends that PJM identify and collect data on available behind the meter generation resources, including nodal location information and relevant operating parameters. (Priority: Low. First reported 2013. Status: Partially adopted.)
- The MMU recommends that PJM document how LMPs are calculated when demand response is marginal. (Priority: Low. First reported 2014. Status: Not adopted.)

Accurate System Modeling

- The MMU recommends that PJM approve one RT SCED case for each five minute interval to dispatch resources during that interval, and that PJM calculate prices using LPC for that five minute interval using the same approved RT SCED case. (Priority: High. First reported 2019. Status: Not adopted.)
- The MMU recommends that PJM explicitly state its policy on the use of transmission penalty factors including: the level of the penalty factors; the triggers for the use of the penalty factors; the appropriate line ratings to trigger the use of penalty factors; the allowed duration of the violation; the use of constraint relaxation logic; and when the transmission penalty factors will be used to set the shadow price. (Priority: Medium. First reported 2015. Status: Partially adopted.)

⁴ According to minutes from the first meeting of the Energy Market Committee (EMC) on January 28, 1998, the EMC unanimously agreed to be responsible for approving additions, deletions and changes to the hub definitions to be published and modeled by PJM. Since the EMC has become the Market Implementation Committee (MIC), the MIC now appears to be responsible for such changes.

⁵ There is currently no PJM documentation in the tariff or manuals explaining how hubs are created and how their definitions are changed. The general definition of a hub can be found in the PJM.com Glossary <<http://www.pjm.com/Glossary.aspx>>.

- The MMU recommends that PJM not allow nuclear generators which do not respond to prices or which only respond to manual instructions from the operator to set the LMPs in the real-time market. (Priority: Low. First reported 2016. Status: Not adopted.)
- The MMU recommends that PJM increase the interaction of outage and operational restrictions data submitted by market participants via eDART/eGADs and offer data submitted via Markets Gateway. (Priority: Low. First reported 2017. Status: Not adopted.)
- The MMU recommends that PJM model generators' operating transitions, including modeling soak time for units with a steam turbine and configuration transitions for combined cycles, and peak operating modes. (Priority: Medium. First reported 2019. Status: Not adopted.)
- The MMU recommends that PJM clarify, modify and document its process for dispatching reserves and energy when SCED indicates that supply is less than total demand including forecasted load and reserve requirements. The modifications should define: a SCED process to economically convert reserves to energy; a process for the recall of energy from capacity resources; and the minimum level of synchronized reserves that would trigger load shedding. (Priority: Medium. New recommendation. Status: Not adopted.)
- The MMU recommends that PJM continue to enhance its posting of market data to promote market efficiency. (Priority: Medium. First reported 2005. Status: Partially adopted.)
- The MMU recommends that PJM clearly define the criteria for operator approval of RT SCED cases used to send dispatch signals to resources and for pricing, to minimize operator discretion and implement a rule based, scheduled approach. (Priority: High. First reported 2018. Status: Not adopted.)

Conclusion

The MMU analyzed key elements of PJM energy market structure, participant conduct and market performance in the first three months of 2020, including aggregate supply and demand, concentration ratios, aggregate pivotal supplier results, local three pivotal supplier test results, offer capping, participation in demand response programs, virtual bids and offers, loads and prices.

PJM average hourly real-time cleared generation decreased by 6,335 MWh, 6.5 percent, and peak load decreased by 17,299 MWh, 12.9 percent, in the first three months of 2020 compared to the first three months of 2019. Both the weather and COVID-19 played a role in this significant drop in demand. The relationship between supply and demand, regardless of the specific market, balanced by market concentration and the extent of pivotal suppliers, is referred to as the supply-demand fundamentals or economic fundamentals. The market structure of the PJM aggregate energy market is partially competitive because aggregate market power does exist for a significant number of hours. The HHI is not a definitive measure of structural market power. The number of pivotal suppliers in the energy market is a more precise measure of structural market power than the HHI. It is possible to have pivotal suppliers in the aggregate market even when the HHI level is not in the highly concentrated range. The current market power mitigation rules for the PJM energy market rely on the assumption that the ownership structure of the aggregate market ensures competitive outcomes. This assumption requires that the total demand for energy can be met without the supply from any individual supplier or without the supply from a small group of suppliers. This assumption is not

Transparency

- The MMU recommends that PJM market rules require the fuel type be identified for every price and cost schedule and PJM market rules remove nonspecific fuel types such as other or co-fire other from the list of fuel types available for market participants to identify the fuel type associated with their price and cost schedules. (Priority: Medium. First reported 2015. Status: Adopted, 2019.)
- The MMU recommends that PJM allow generators to report fuel type on an hourly basis in their offer schedules and to designate schedule availability on an hourly basis. (Priority: Medium. First reported 2015. Status: Partially adopted.)

correct. There are pivotal suppliers in the aggregate energy market at times. High markups for some units demonstrate the potential to exercise market power both routinely and during high demand conditions. The existing market power mitigation measures do not address aggregate market power. The MMU is developing an aggregate market power test and will propose market power mitigation rules to address aggregate market power.

The three pivotal supplier test is applied by PJM on an ongoing basis for local energy markets in order to determine whether offer capping is required for transmission constraints.⁶ However, there are some issues with the application of market power mitigation in the day-ahead energy market and the real-time energy market when market sellers fail the TPS test. These issues can be resolved by simple rule changes.

The enforcement of market power mitigation rules is undermined if the definition of a competitive offer is not correct. A competitive offer is equal to short run marginal costs. The significance of competition metrics like markup is also undermined if the definition of a competitive offer is not correct. The definition of a competitive offer, under the PJM Market Rules, is not currently correct. The definition, that energy costs must be related to electric production, is not clear or correct. All costs and investments for power generation are related to electric production. Under this definition, some unit owners include costs that are not short run marginal costs in offers, especially maintenance costs. This issue can be resolved by simple rule changes to incorporate a clear and accurate definition of short run marginal costs.

Prices are a key outcome of markets. Prices vary across hours, days and years for multiple reasons. Price is an indicator of the level of competition in a market although individual prices are not always easy to interpret. In a competitive market, prices are directly related to the marginal cost to serve load in each market interval. The pattern of prices within days and across months and years illustrates how prices are directly related to supply and demand conditions and thus also illustrates the potential significance of the impact of the price elasticity of demand on prices. Energy market results in the first three months of 2020 generally reflected supply-demand fundamentals,

⁶ The MMU reviews PJM's application of the TPS test and brings issues to the attention of PJM.

although the behavior of some participants both routinely and during high demand periods represents economic withholding. Economic withholding is the ability to increase markups substantially in tight market conditions. There are additional issues in the energy market including the uncertainties about the pricing and availability of natural gas, the way that generation owners incorporate natural gas costs in offers, and the lack of adequate incentives for unit owners to take all necessary actions to acquire fuel and operate rather than economically withhold or physically withhold.

Prices in PJM are not too low. Prices in PJM are the result of input prices, consistent with a competitive market. Low natural gas prices have been a primary cause of low PJM energy market prices. There is no evidence to support the need for a significant change to the calculation of LMP. The underlying problem that fast start pricing and PJM's reserve pricing approach are attempting to address is actually scarcity pricing, including the impact of operator actions on the definition of scarcity. Prices do not reflect market conditions when the market is tight, because PJM is not implementing scarcity pricing when there is scarcity. Rather than undercutting the basic LMP logic that is core to market efficiency, it would make more sense to directly address scarcity pricing, operator actions and the design of reserve markets. Implementing scarcity pricing when there is scarcity is a basic first step. Targeted increases to the demand for reserves when the market is tight would address price formation in the energy market.

When the real-time security constrained economic dispatch (RT SCED) solution indicates a shortage of reserves, it should be used in calculating real-time prices and those prices should be applied to the market interval for which RT SCED calculated the shortage. There are significant issues with operator discretion and reluctance to approve RT SCED cases indicating shortage of reserves, and in using these cases to calculate prices. While it is appropriate for operators to ensure that cases that use erroneous inputs are not approved and not allowed to set prices, it is essential that operator discretion not extend beyond what is necessary and that operator discretion not prevent shortage pricing when there are shortage conditions. There are also issues with the alignment of RT SCED cases used for resource dispatch and the RT SCED

cases used to calculate real-time prices. PJM should fix its current operating practices and ensure consistency and transparency regarding approval of RT SCED cases for resource dispatch and pricing so that market participants can have confidence in the market design to produce accurate and efficient price signals. These issues are even more critical now that PJM settles real-time energy transactions on a five minute basis.

The PJM defined inputs to the dispatch tools, particularly the real-time SCED, have substantial effects on energy market outcomes. Transmission line ratings, transmission penalty factors, load forecast bias, hydro resource schedules, and unit ramp rate adjustments change the dispatch of the system, affect prices, and can create price spikes through transmission line limit violations or restrictions on the resources available to resolve constraints. The automated adjustment of ramp rates by PJM, called Degree of Generator Performance (DGP), modifies the values offered by generators and limits the MW available to the RT SCED. PJM should evaluate its interventions in the market, consider whether the interventions are appropriate, and provide greater transparency to enhance market efficiency.

The objective of efficient short run price signals is to minimize system production costs, not to minimize uplift. Repricing the market to reflect commitment costs would create a tradeoff between minimizing production costs and reduction of uplift. The tradeoff would exist because when commitment costs are included in prices, the price signal no longer equals the short run marginal cost and therefore no longer provides the correct signal for efficient behavior for market participants making decisions on the margin, whether resources, load, interchange transactions, or virtual traders. This tradeoff will be created by PJM's fast start pricing proposal as approved by FERC and would be created in a much more extensive form by PJM's convex hull pricing proposal and reserve pricing proposal.

Units that start in one hour are not fast start units, and their commitment costs are not marginal in a five minute market. The differences between the actual LMP and the fast start LMP will distort the incentive for market participants to behave competitively and to follow PJM's dispatch instructions. PJM will

pay new forms of uplift in an attempt to counter the distorted incentives. The magnitude of the new payments and their effects on behavior are not well understood.

The fast start pricing and convex hull solutions would undercut LMP logic rather than directly addressing the underlying issues. The solution is not to accept that the inflexible CT should be paid or set price based on its commitment costs rather than its short run marginal costs. The question of why units make inflexible offers should be addressed directly. Are units inflexible because they are old and inefficient, because owners have not invested in increased flexibility or because they serve as a mechanism for the exercise of market power? The question of why the unit was built, whether it was built under cost of service regulation and whether it is efficient to retain the unit should be answered directly. The question of how to provide market incentives for investment in flexible units and for investment in increased flexibility of existing units should be addressed directly. The question of whether inflexible units should be paid uplift at all should be addressed directly. Marginal cost pricing without paying excess uplift to inflexible units would create incentives for market participants to provide flexible solutions including replacing inefficient units with flexible, efficient units.

With or without a capacity market, energy market design must permit scarcity pricing when such pricing is consistent with market conditions and constrained by reasonable rules to ensure that market power is not exercised. Scarcity pricing can serve two functions in wholesale power markets: revenue adequacy and price signals. Scarcity pricing for revenue adequacy, as in PJM's ORDC proposal, is not required in PJM. Scarcity pricing for price signals that reflect market conditions during periods of scarcity is required in PJM. Scarcity pricing is also part of an appropriate incentive structure facing both load and generation owners in a working wholesale electric power market design. Scarcity pricing must be designed to ensure that market prices reflect actual market conditions, that scarcity pricing occurs with transparent triggers based on measured reserve levels and transparent prices, that scarcity pricing only occurs when scarcity exists, and that there are strong incentives for competitive behavior and strong disincentives to exercise market power.

Such administrative scarcity pricing is a key link between energy and capacity markets. Administrative scarcity pricing that establishes scarcity pricing in about 85 percent of hours, as PJM's ORDC proposal would, is not scarcity pricing but simply a revenue enhancement mechanism. When combined with PJM's failure to address the energy and ancillary services offset in the capacity market, PJM's ORDC filing is not consistent with efficient market design and is even more clearly just a revenue enhancement mechanism.

The PJM Capacity Market is explicitly designed to provide revenue adequacy and the resultant reliability. However, the explicit balancing mechanism that included net revenues directly in unit offers in the prior capacity market design is not present in the Capacity Performance design. The nature of a direct and explicit energy pricing net revenue true up mechanism in the capacity market should be addressed if energy revenues are expected to increase as a result of scarcity events, as a result of increased demand for reserves, or as a result of PJM's inappropriate proposals related to fast start pricing and the inclusion of maintenance expenses as short run marginal costs. The true up mechanism must address both cleared auctions and subsequent auctions. There are also significant issues with PJM's scarcity pricing rules, including the absence of a clear trigger based on measured reserve levels (the current triggers are based on estimated reserves) and the lack of adequate locational scarcity pricing options.

The overall energy market results support the conclusion that energy prices in PJM are set, generally, by marginal units operating at, or close to, their marginal costs, although this was not always the case in the first three months of 2020 or prior years. In the first three months of 2020, marginal units were predominantly combined cycle gas generators with low fuel costs. The frequency of combined cycle gas units as the marginal unit type has risen rapidly, from 29.6 percent in 2015 to 71.6 percent in the first three months of 2020. Overdue improvements in generator modeling in the energy market would allow PJM to more efficiently commit and dispatch combined cycle plants and to fully reflect the flexibility of these units. New combined cycle units placed competitive pressure on less efficient generators, and the market reliably served load with less congestion, less uplift, and less markup

in marginal offers than in 2018. This is evidence of generally competitive behavior and competitive market outcomes, although the behavior of some participants represents economic withholding. Given the structure of the energy market which can permit the exercise of aggregate and local market power, the change in some participants' behavior is a source of concern in the energy market and provides a reason to use correctly defined short run marginal cost as the sole basis for cost-based offers and a reason for implementing an aggregate market power test and correcting the offer capping process for resources with local market power. The MMU concludes that the PJM energy market results were competitive in the first three months of 2020.

Supply and Demand

Market Structure

Supply

Supply includes physical generation, imports and virtual transactions.

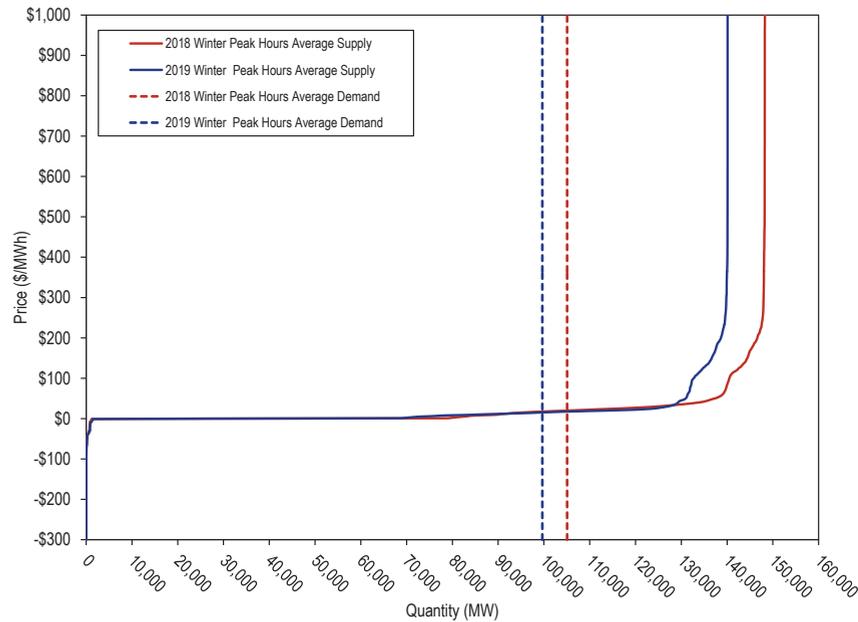
In the first three months of 2020, 325.3 MW of new resources were added in the energy market, and 127.7 MW of resources and 457.0 MW of pseudo ties were retired. Figure 3-1 shows the average hourly real-time supply curve and demand for the on peak hours in the winters of 2018-2019 and 2019-2020.^{7 8 9} This figure reflects actual available MW from units that are online or offline and available to generate power in one hour, and all units restricted by ramping capabilities.

⁷ Real-time generation offers and real-time import MWh are included.

⁸ Real-time load and export MWh are included.

⁹ The 2018 winter supply curve period is from December 1, 2018, to February 28, 2019. The 2019 winter supply curve period is from December 1, 2019, to February 29, 2020.

Figure 3-1 Average hourly real-time supply curve comparison: 2018 winter and 2019 winter



Average hourly real-time supply curves are weather sensitive. Figure 3-2 shows the typical dispatch range.

Figure 3-2 Typical dispatch range of average hourly winter real-time supply curves

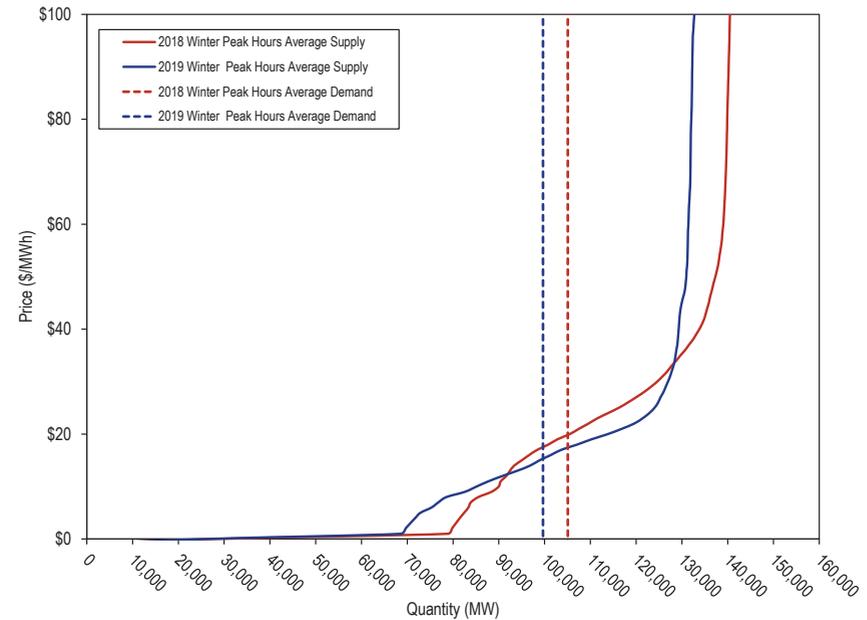


Table 3-2 shows the price elasticity of supply for the on peak hours in the 2018-2019 winter and in the 2019-2020 winter by load level. The price elasticity of supply measures the responsiveness of the quantity supplied (MWh) to a change in price:

$$\text{Elasticity of Supply} = \frac{\text{Percent change in quantity supplied}}{\text{Percent change in price}}$$

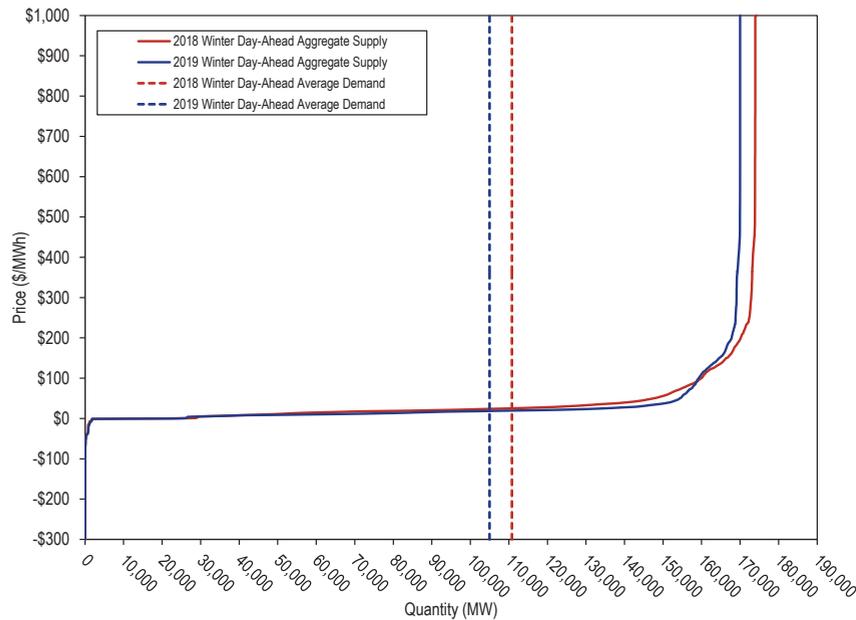
Supply is elastic when elasticity is greater than 1.0. This indicates that supply MW are relatively sensitive to changes in price. Although the aggregate supply curve appears flat in the figure as a result of the wide range in prices and quantities, in fact the calculated elasticity is quite low throughout.

Table 3-2 Price Elasticity of Supply

GWh	Elasticity of Supply	
	2018 Winter	2019 Winter
75-95	0.016	0.265
95-115	0.386	0.418
115-135	0.183	0.029
135-Max	0.004	0.005

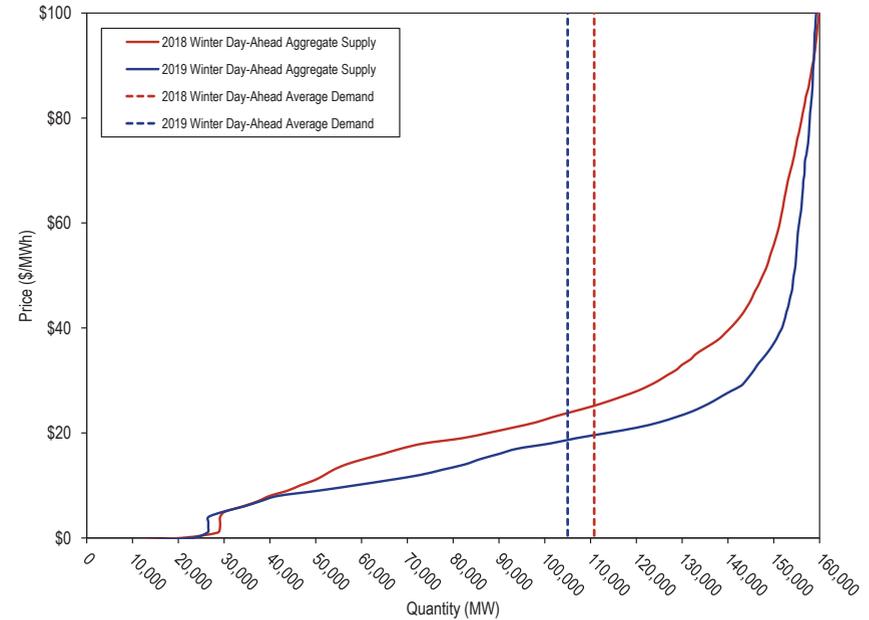
Figure 3-3 is the PJM day-ahead generation aggregate supply curve, which includes day-ahead hourly supply for the on peak hours of the 2018-2019 winter and the 2019-2020 winter.¹⁰

Figure 3-3 PJM day-ahead generation aggregate supply curve: 2018 winter and 2019 winter



¹⁰ Day-ahead generation offers, INC bid MWh, day-ahead import MWh are included. UTCs are not included due to lack of pricing point.

Figure 3-4 Typical dispatch range of average hourly winter day-ahead generation aggregate supply curves



Real-Time Supply

The maximum average on-peak hourly offered real-time supply was 140,120 MW for the 2019-2020 winter and 148,373 MW for the 2018-2019 winter. The available supply at a defined time is less than the total capacity of the PJM system because real-time supply at a defined time is restricted by unit ramp limits and start times.

PJM average real-time cleared generation in the first three months of 2020 decreased by 6.5 percent from the first three months of 2019, from 97,010 MWh to 90,675 MWh.¹¹

¹¹ Generation data are the net MWh injections and withdrawals MWh at every generation bus in PJM.

PJM average real-time cleared supply including imports in the first three months of 2020 decreased by 7.2 percent from the first three months of 2019, from 98,828 MWh to 91,698 MWh.

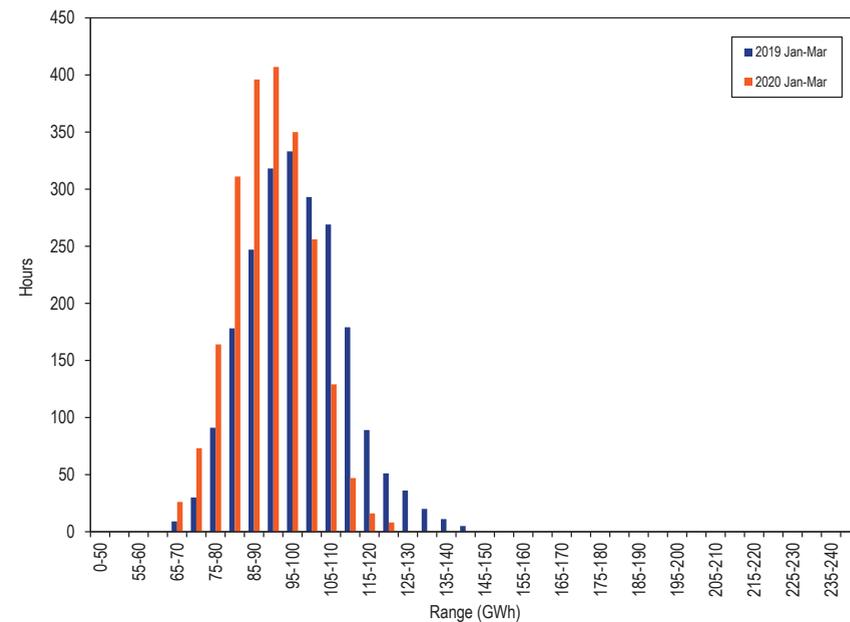
In the PJM Real-Time Energy Market, there are three types of supply offers:

- **Self Scheduled Generation Offer.** Offer to supply a fixed block of MW, as a price taker, from a unit that may also have a dispatchable component above the minimum.
- **Dispatchable Generation Offer.** Offer to supply a schedule of MW and corresponding offer prices from a specific unit.
- **Import.** An import is an external energy transaction scheduled to PJM from another balancing authority. A real-time import must have a valid OASIS reservation when offered, must have available ramp room to support the import, must be accompanied by a NERC Tag, and must pass the neighboring balancing authority checkout process.

PJM Real-Time Supply Frequency

Figure 3-5 shows the hourly distribution of PJM real-time generation plus imports for the first three months of 2019 and 2020.

Figure 3-5 Distribution of real-time generation plus imports: January through March, 2019 and 2020¹²



¹² Each range on the horizontal axis excludes the start value and includes the end value.

PJM Real-Time, Average Supply

Table 3-3 shows real-time hourly supply summary statistics for the first three months of the 20 year period from 2001 through 2020.

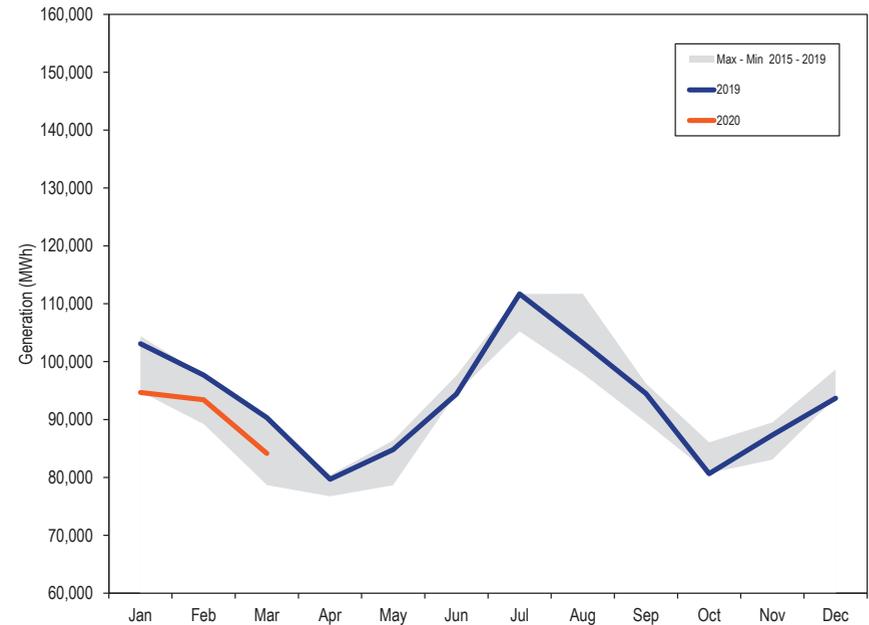
Table 3-3 Average hourly real-time generation and real-time generation plus imports: January through March, 2001 through 2020

Jan-Mar	PJM Real-Time Supply (MWh)				Year-to-Year Change			
	Generation		Generation Plus Imports		Generation		Generation Plus Imports	
	Generation	Standard Deviation	Supply	Standard Deviation	Generation	Standard Deviation	Supply	Standard Deviation
2001	30,923	3,488	33,806	3,358	NA	NA	NA	NA
2002	27,948	3,416	31,465	3,508	(9.6%)	(2.1%)	(6.9%)	4.5%
2003	38,731	5,187	42,498	5,092	38.6%	51.8%	35.1%	45.2%
2004	37,790	4,660	41,960	4,899	(2.4%)	(10.2%)	(1.3%)	(3.8%)
2005	74,187	8,269	80,184	9,017	96.3%	77.4%	91.1%	84.1%
2006	82,550	7,921	87,729	8,565	11.3%	(4.2%)	9.4%	(5.0%)
2007	86,286	10,018	91,454	11,351	4.5%	26.5%	4.2%	32.5%
2008	86,690	9,375	92,075	10,150	0.5%	(6.4%)	0.7%	(10.6%)
2009	81,987	11,417	88,148	12,213	(5.4%)	21.8%	(4.3%)	20.3%
2010	81,676	12,801	87,009	13,236	(0.4%)	12.1%	(1.3%)	8.4%
2011	83,505	10,116	88,750	10,884	2.2%	(21.0%)	2.0%	(17.8%)
2012	88,068	11,177	93,128	11,685	5.5%	10.5%	4.9%	7.4%
2013	92,776	10,030	98,002	10,812	5.3%	(10.3%)	5.2%	(7.5%)
2014	100,655	12,427	106,879	13,255	8.5%	23.9%	9.1%	22.6%
2015	97,741	13,085	105,027	14,351	(2.9%)	5.3%	(1.7%)	8.3%
2016	88,470	12,666	94,383	13,890	(9.5%)	(3.2%)	(10.1%)	(3.2%)
2017	91,076	11,009	94,390	11,673	2.9%	(13.1%)	0.0%	(16.0%)
2018	95,491	13,151	98,199	14,058	4.8%	19.5%	4.0%	20.4%
2019	97,010	12,379	98,828	12,777	1.6%	(5.9%)	0.6%	(9.1%)
2020	90,675	9,852	91,698	9,992	(6.5%)	(20.4%)	(7.2%)	(21.8%)

PJM Real-Time, Monthly Average Generation

Figure 3-6 compares the real-time, monthly average hourly generation in 2019 and the first three months of 2020 with the historic five year range.

Figure 3-6 Real-time monthly average hourly generation: January 2019 through March 2020



Day-Ahead Supply

PJM average hourly, day-ahead cleared supply in the first three months of 2020, including INCs and up to congestion transactions, decreased by 7.7 percent from the first three months of 2019, from 122,368 MWh to 112,939 MWh. When imports are added, PJM average hourly, day-ahead cleared supply in the first three months of 2020 decreased by 7.8 percent from the first three months of 2019, from 122,865 MWh to 113,274 MWh.

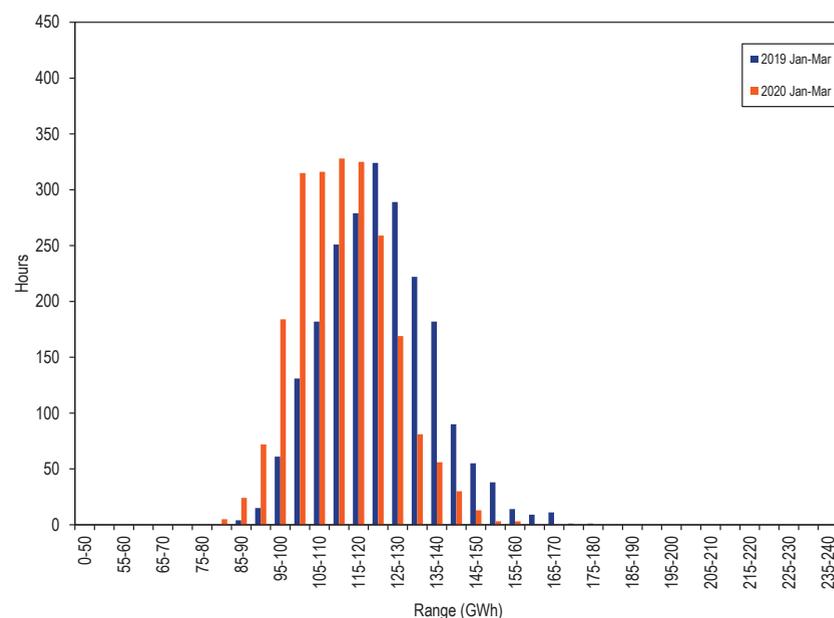
In the PJM Day-Ahead Energy Market, there are five types of financially binding supply offers:

- **Self Scheduled Generation Offer.** Offer to supply a fixed block of MW, as a price taker, from a unit that may also have a dispatchable component above the minimum.
- **Dispatchable Generation Offer.** Offer to supply a schedule of MW and corresponding offer prices from a unit.
- **Increment Offer (INC).** Financial offer to supply MW and corresponding offer prices. INCs can be submitted by any market participant.
- **Up to Congestion Transaction (UTC).** Conditional transaction that permits a market participant to specify a maximum price spread for a specific amount of MW between the transaction source and sink. An up to congestion transaction is a matched pair of an injection and a withdrawal.
- **Import.** An import is an external energy transaction for a specific MW amount scheduled to PJM from another balancing authority. An import must have a valid willing to pay congestion (WPC) OASIS reservation when offered. An import energy transaction that clears the day-ahead energy market is financially binding. There is no link between transactions submitted in the PJM Day-Ahead Energy Market and the PJM Real-Time Energy Market, so an import energy transaction approved in the day-ahead energy market will not physically flow in real time unless it is also submitted through the real-time energy market scheduling process.

PJM Day-Ahead Supply Duration

Figure 3-7 shows the hourly distribution of PJM day-ahead supply, including increment offers, up to congestion transactions, and imports for the first three months of 2019 and 2020.

Figure 3-7 Distribution of day-ahead supply plus imports: January through March, 2019 and 2020¹³



¹³ Each range on the horizontal axis excludes the start value and includes the end value.

PJM Day-Ahead, Average Supply

Table 3-4 presents day-ahead hourly supply summary statistics for the first three months of the 20 year period from 2001 through 2020.

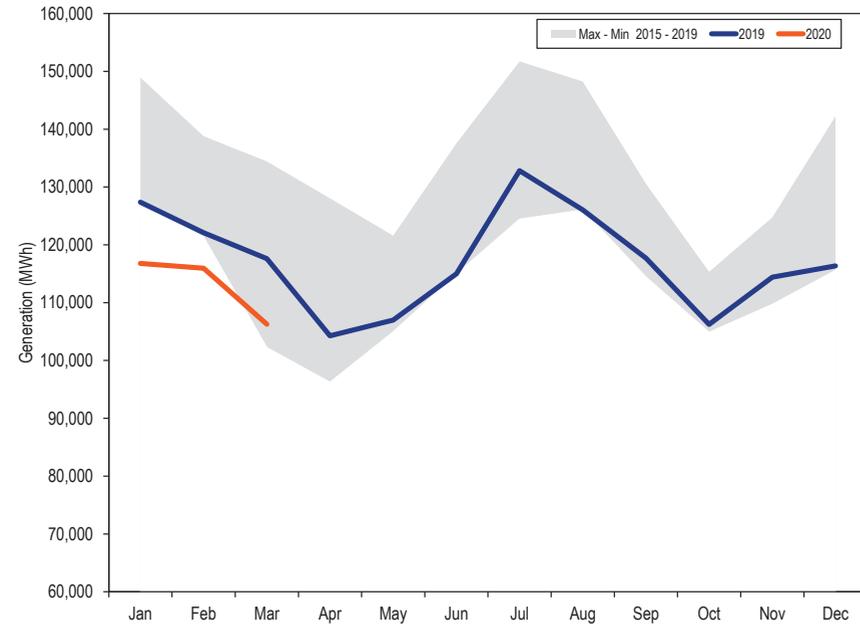
Table 3-4 Average hourly day-ahead supply and day-ahead supply plus imports: 2001 through 2020

Jan-Mar	PJM Day-Ahead Supply (MWh)				Year-to-Year Change			
	Supply		Supply Plus Imports		Supply		Supply Plus Imports	
	Supply	Standard Deviation	Supply	Standard Deviation	Supply	Standard Deviation	Supply	Standard Deviation
2001	28,494	2,941	29,252	3,021	NA	NA	NA	NA
2002	20,274	10,131	20,827	10,134	(28.8%)	244.5%	(28.8%)	235.5%
2003	37,147	4,337	37,807	4,389	83.2%	(57.2%)	81.5%	(56.7%)
2004	46,591	4,794	47,377	5,039	25.4%	10.5%	25.3%	14.8%
2005	89,011	9,434	90,502	9,443	91.0%	96.8%	91.0%	87.4%
2006	97,319	9,035	99,551	9,061	9.3%	(4.2%)	10.0%	(4.0%)
2007	110,099	11,938	112,561	12,141	13.1%	32.1%	13.1%	34.0%
2008	109,711	10,479	112,165	10,671	(0.4%)	(12.2%)	(0.4%)	(12.1%)
2009	104,880	13,895	107,325	14,031	(4.4%)	32.6%	(4.3%)	31.5%
2010	101,733	13,835	104,858	13,917	(3.0%)	(0.4%)	(2.3%)	(0.8%)
2011	110,310	12,200	112,854	12,419	8.4%	(11.8%)	7.6%	(10.8%)
2012	132,178	13,701	134,405	13,804	19.8%	12.3%	19.1%	11.2%
2013	147,246	13,054	149,300	13,244	11.4%	(4.7%)	11.1%	(4.1%)
2014	168,373	11,875	170,778	11,935	14.3%	(9.0%)	14.4%	(9.9%)
2015	123,431	14,671	125,980	14,916	(26.7%)	23.5%	(26.2%)	25.0%
2016	133,199	19,049	135,574	19,349	7.9%	29.8%	7.6%	29.7%
2017	140,771	16,923	142,094	16,938	5.7%	(11.2%)	4.8%	(12.5%)
2018	120,754	22,172	121,313	22,177	(14.2%)	31.0%	(14.6%)	30.9%
2019	122,368	13,778	122,865	13,822	1.3%	(37.9%)	1.3%	(37.7%)
2020	112,939	12,020	113,274	12,021	(7.7%)	(12.8%)	(7.8%)	(13.0%)

PJM Day-Ahead, Monthly Average Supply

Figure 3-8 compares the day-ahead, monthly average hourly supply, including increment offers and up to congestion transactions for the first three months of 2019 and 2020 with the historic five year range. In January and February 2020, the average supply is lower than the minimum of the previous five years.

Figure 3-8 Day-ahead monthly average hourly supply: January 2019 through March 2020



Real-Time and Day-Ahead Supply

Table 3-5 presents summary statistics for the first three months of 2019 and 2020, for day-ahead and real-time supply. All data are cleared MWh. The last two columns of Table 3-5 are the day-ahead supply minus the real-time supply. The first of these columns is the total physical day-ahead generation less the total physical real-time generation and the second of these columns is the total day-ahead supply less the total real-time supply. In the first three months of 2020, up to congestion transactions were 17.1 percent of the total day-ahead supply compared to 17.7 percent in the first three months of 2019.

Table 3-5 Day-ahead and real-time supply (MWh): January through March, 2019 and 2020

	Day-Ahead						Real-Time		Day-Ahead Less Real-Time	
	Jan-Mar	Generation	INC Offers	Up to Congestion	Imports	Total Supply	Generation	Total Supply	Generation	Supply
Average	2019	97,705	2,936	21,727	497	122,865	97,010	98,828	695	24,037
	2020	91,041	2,555	19,343	335	113,274	90,675	91,698	367	21,576
Median	2019	97,033	2,808	21,287	440	122,342	96,243	98,083	790	24,260
	2020	90,789	2,513	19,282	336	112,942	90,593	91,567	196	21,375
Standard Deviation	2019	12,830	938	4,001	239	13,822	12,379	12,777	450	1,045
	2020	10,768	720	3,287	155	12,021	9,852	9,992	916	2,028
Peak Average	2019	104,568	3,442	22,709	491	131,210	103,317	105,236	1,251	25,974
	2020	97,358	2,766	20,195	299	120,618	96,269	97,321	1,089	23,297
Peak Median	2019	103,642	3,349	22,266	435	129,651	102,523	104,533	1,119	25,118
	2020	97,042	2,707	20,144	300	119,888	96,152	97,229	890	22,659
Peak Standard Deviation	2019	10,907	889	3,939	244	11,226	10,799	11,205	108	21
	2020	8,427	704	3,439	157	9,884	7,779	8,003	649	1,881
Off-Peak Average	2019	91,695	2,493	20,867	501	115,556	91,486	93,216	209	22,340
	2020	85,460	2,368	18,590	367	106,785	85,732	86,730	(272)	20,055
Off-Peak Median	2019	90,618	2,397	20,520	441	114,150	90,685	92,500	(67)	21,650
	2020	84,796	2,299	18,461	387	105,297	85,191	86,194	(396)	19,103
Off-Peak Standard Deviation	2019	11,281	732	3,857	235	11,561	10,956	11,353	325	208
	2020	9,449	681	2,949	147	9,804	8,793	8,882	657	923

Figure 3-9 shows the average cleared volumes of day-ahead supply and real-time supply by hour of the day for the first three months of 2020. The day-ahead supply consists of cleared MW of physical generation, imports, increment offers and up to congestion transactions. The real-time supply consists of cleared MW of physical generation and imports.

Figure 3-9 Day-ahead and real-time supply (Average volumes by hour of the day): January through March, 2020

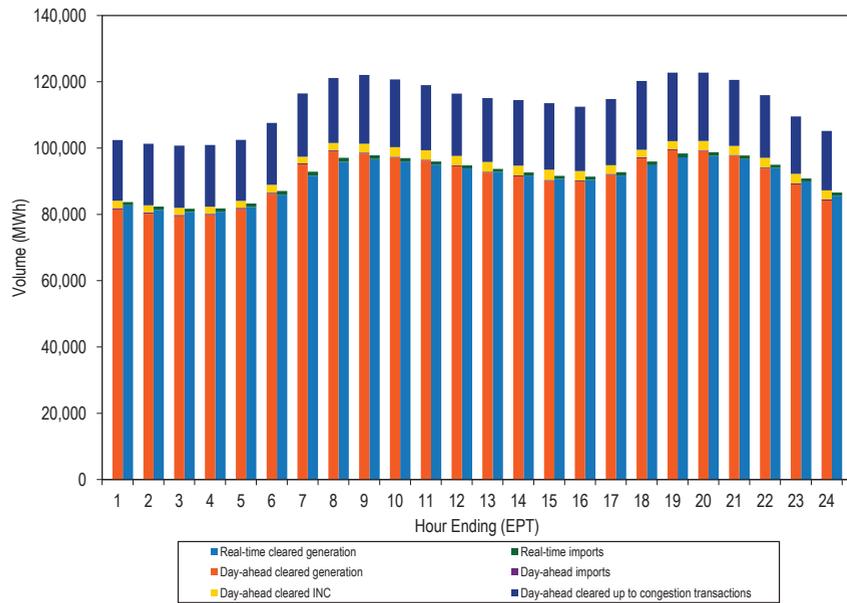
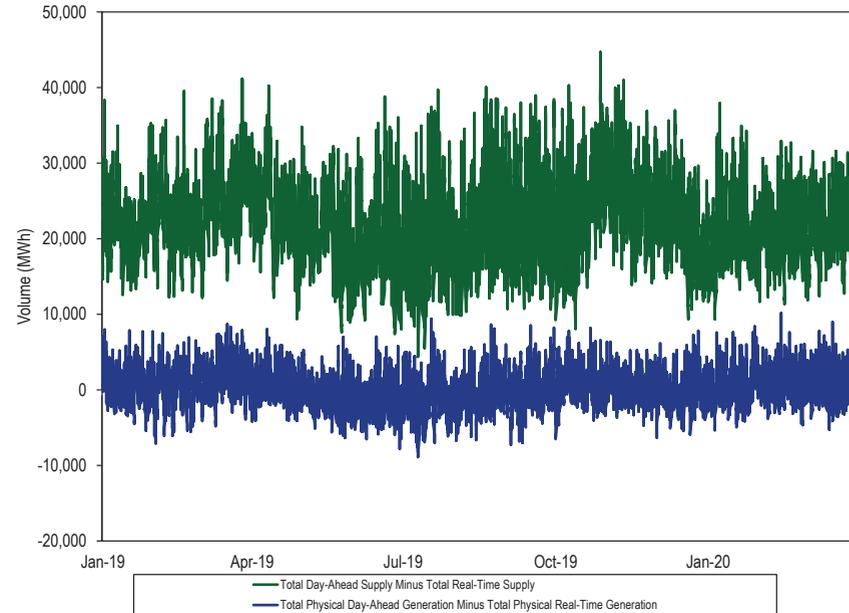


Figure 3-10 shows the difference between the day-ahead and real-time average daily supply in 2019 and the first three months of 2020.

Figure 3-10 Difference between day-ahead and real-time supply (Average daily volumes): January 2019 through March 2020



Demand

Demand includes physical load and exports and virtual transactions.

Peak Demand

In this section, demand refers to accounting load and exports and, in the day-ahead energy market, includes virtual transactions.¹⁴

The PJM system real-time hourly peak load in the first three months of 2020 was 116,761 MWh in the HE 0800 on January 22, 2020, which was 17,299 MWh, or 12.9 percent, less than the peak load in the first three months of 2019, 134,060 MWh in the HE 0800 on January 31, 2019.

Table 3-6 shows the peak loads for the first three months of 2009 through 2020.

Table 3-6 Actual footprint peak loads: January through March, 2009 through 2020^{15 16}

(Jan - Mar)	Date	Hour Ending (EPT)	PJM Load (MW)	Annual Change (MW)	Annual Change (%)
2009	Fri, January 16	19	114,765	NA	NA
2010	Mon, January 04	19	106,981	(7,784)	(6.8%)
2011	Mon, January 24	8	108,156	1,175	1.1%
2012	Tue, January 03	19	119,450	11,294	10.4%
2013	Tue, January 22	19	123,473	4,023	3.4%
2014	Tue, January 07	19	136,932	13,459	10.9%
2015	Fri, February 20	8	139,647	2,715	2.0%
2016	Tue, January 19	8	126,818	(12,830)	(9.2%)
2017	Mon, January 09	8	124,210	(2,608)	(2.1%)
2018	Fri, January 05	19	133,851	9,641	7.8%
2019	Thu, January 31	8	134,060	209	0.2%
2020	Wed, January 22	8	116,761	(17,299)	(12.9%)

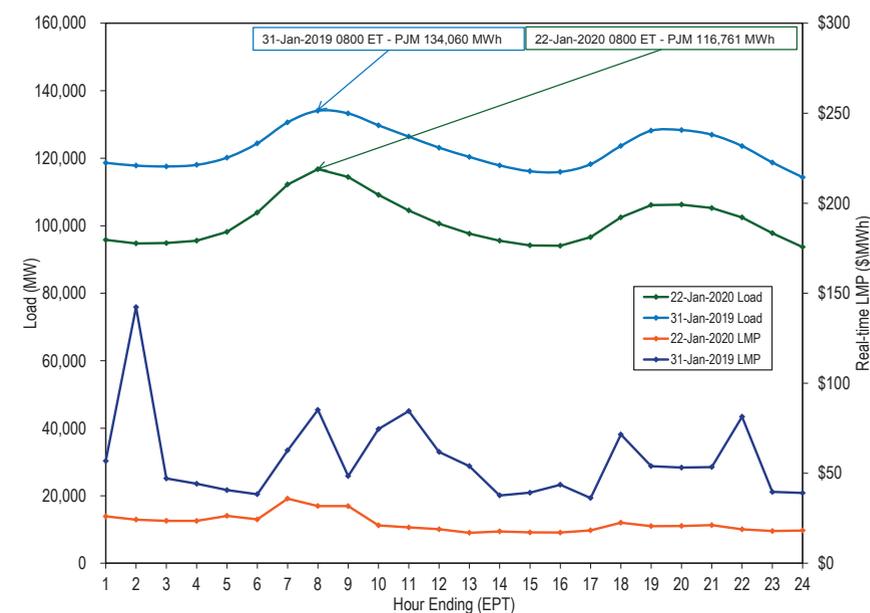
¹⁴ PJM reports peak load including accounting load plus an addback equal to PJM's estimated load drop from demand side resources. This will generally result in PJM reporting peak load values greater than accounting load values. PJM's load drop estimate is based on PJM Manual 19: Load Forecasting and Analysis; Attachment A: Load Drop Estimate Guidelines.

¹⁵ Peak loads shown are Power accounting load. See the *MMU Technical Reference for the PJM Markets*, at "Load Definitions," for detailed definitions of load. <http://www.monitoringanalytics.com/reports/Technical_References/references.shtml>.

¹⁶ Peak loads shown have been corrected to reflect the accounting load value excluding PJM loss adjustment. The values presented in this table do not include settlement adjustments made prior to January 1, 2017.

Figure 3-11 compares prices and load on the peak load days in the first three months of 2019 and 2020. The average real-time LMP for the January 22, 2020 peak load hour was \$31.76 and for the January 31, 2019 peak load hour it was \$85.21.

Figure 3-11 Peak load day comparison: Thursday, January 31, 2019 and Wednesday, January 22, 2020



Real-Time Demand

PJM average hourly real-time demand in the first three months of 2020 decreased by 6.9 percent from the first three months of 2019, from 91,962 MWh to 85,608 MWh.¹⁷ PJM average hourly real-time demand including exports in the first three months of 2020 decreased by 7.0 percent from the first three months of 2019, from 96,898 MWh to 90,093 MWh. Both the weather and COVID-19 played a role in this significant drop in demand.

¹⁷ Load data are the net MWh injections and withdrawals MWh at every load bus in PJM.

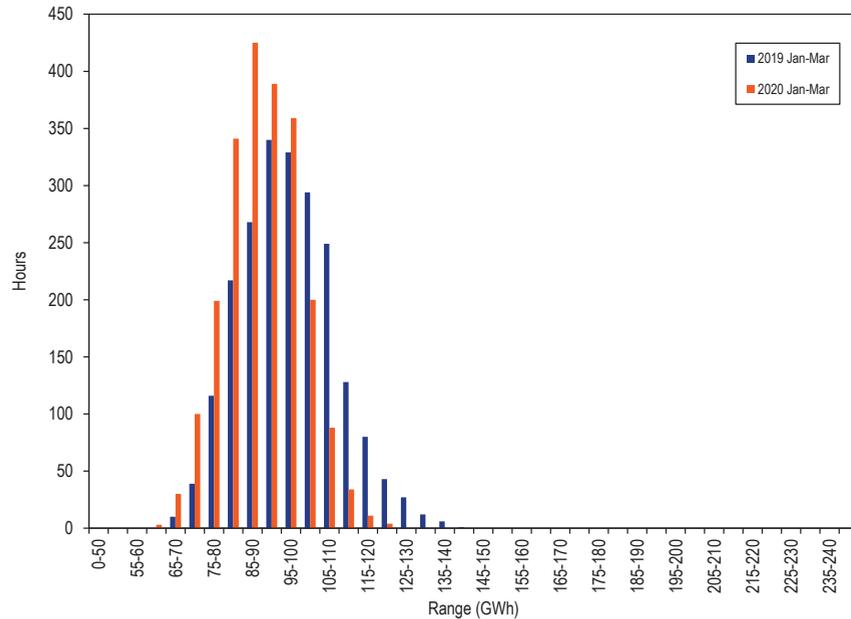
In the PJM Real-Time Energy Market, there are two types of demand:

- **Load.** The actual MWh level of energy used by load within PJM.
- **Export.** An export is an external energy transaction scheduled from PJM to another balancing authority. A real-time export must have a valid OASIS reservation when offered, must have available ramp room to support the export, must be accompanied by a NERC Tag, and must pass the neighboring balancing authority’s checkout process.

PJM Real-Time Demand Duration

Figure 3-12 shows the distribution of hourly PJM real-time load plus exports for the first three months of 2019 and 2020.¹⁸

Figure 3-12 Distribution of real-time accounting load plus exports: January through March, 2019 and 2020¹⁹



¹⁸ All real-time load data in Section 3, “Energy Market,” “Market Performance: Load and LMP,” are based on PJM accounting load. See the *Technical Reference for PJM Markets*, “Load Definitions,” for detailed definitions of accounting load. <http://www.monitoringanalytics.com/reports/Technical_References/references.shtml>.

¹⁹ Each range on the horizontal axis excludes the start value and includes the end value.

PJM Real-Time, Average Load

Table 3-7 presents real-time hourly demand summary statistics for the first three months of 2001 through 2020.²⁰

Table 3-7 Real-time load and real-time load plus exports: January through March, 2001 through 2020

Jan-Mar	PJM Real-Time Demand (MW)				Year-to-Year Change			
	Load		Load Plus Exports		Load		Load Plus Exports	
	Load	Standard Deviation	Demand	Standard Deviation	Load	Standard Deviation	Demand	Standard Deviation
2001	31,254	3,846	33,452	3,704	NA	NA	NA	NA
2002	29,968	4,083	30,988	3,932	(4.1%)	6.1%	(7.4%)	6.1%
2003	39,249	5,546	41,600	5,701	31.0%	35.8%	34.2%	45.0%
2004	39,549	5,761	41,198	5,394	0.8%	3.9%	(1.0%)	(5.4%)
2005	71,388	8,966	79,319	9,587	80.5%	55.6%	92.5%	77.8%
2006	80,179	8,977	86,567	9,378	12.3%	0.1%	9.1%	(2.2%)
2007	84,586	12,040	90,304	12,012	5.5%	34.1%	4.3%	28.1%
2008	82,235	10,184	89,092	10,621	(2.8%)	(15.4%)	(1.3%)	(11.6%)
2009	81,170	11,718	86,110	11,948	(1.3%)	15.1%	(3.3%)	12.5%
2010	81,121	10,694	86,843	11,262	(0.1%)	(8.7%)	0.9%	(5.7%)
2011	81,018	10,273	86,635	10,613	(0.1%)	(3.9%)	(0.2%)	(5.8%)
2012	86,329	10,951	91,090	11,293	6.6%	6.6%	5.1%	6.4%
2013	91,337	10,610	95,835	10,452	5.8%	(3.1%)	5.2%	(7.4%)
2014	98,317	13,484	104,454	12,843	7.6%	27.1%	9.0%	22.9%
2015	97,936	13,445	102,821	13,855	(0.4%)	(0.3%)	(1.6%)	7.9%
2016	89,322	13,262	92,777	13,409	(8.8%)	(1.4%)	(9.8%)	(3.2%)
2017	87,598	11,208	92,791	11,295	(1.9%)	(15.5%)	0.0%	(15.8%)
2018	92,761	13,244	96,216	13,487	5.9%	18.2%	3.7%	19.4%
2019	91,962	11,888	96,898	12,373	(0.9%)	(10.2%)	0.7%	(8.3%)
2020	85,608	10,004	90,093	9,736	(6.9%)	(15.8%)	(7.0%)	(21.3%)

²⁰ Accounting load is used because accounting load is the load customers pay for in PJM settlements. The use of accounting load with losses before June 1, and without losses after June 1, 2007, is consistent with PJM’s calculation of LMP. Before June 1, 2007, transmission losses were included in accounting load. After June 1, 2007, transmission losses were excluded from accounting load and losses were addressed through the incorporation of marginal loss pricing in LMP.

PJM Real-Time, Monthly Average Load

Figure 3-13 compares the real-time, monthly average loads in 2019 and the first three months of 2020, with the historic five year range.

Figure 3-13 Real-time monthly average hourly load: January 2019 through March 2020

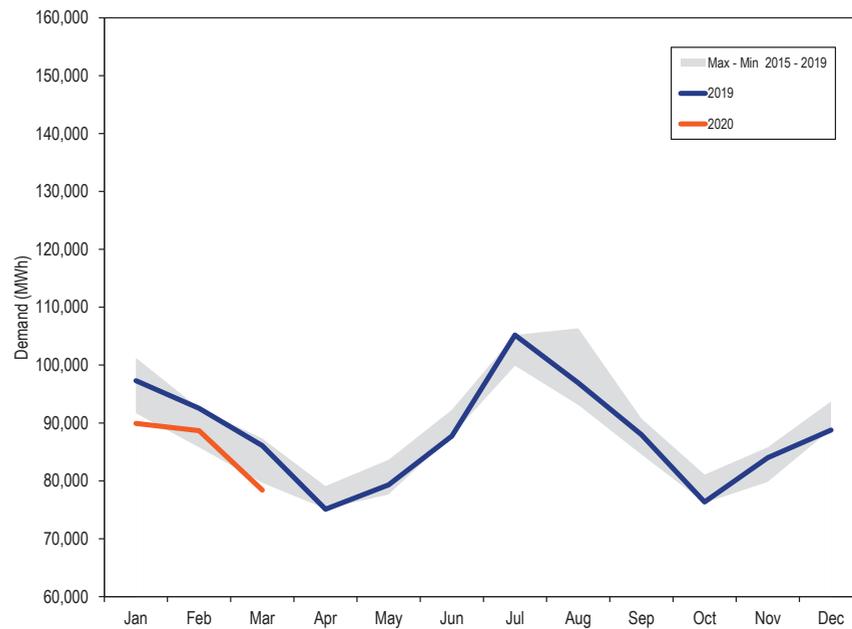
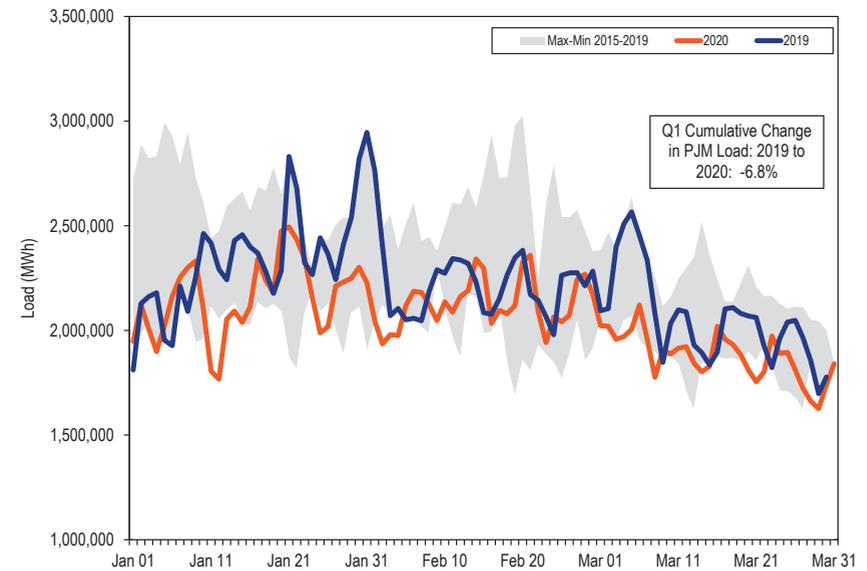


Figure 3-14 compares the real-time, average hourly loads in 2019 and the first three months of 2020, with the historic five year range.

Figure 3-14 Real-time daily load: January through March, 2019 and 2020



PJM real-time load is significantly affected by weather conditions. Table 3-8 compares the PJM monthly heating and cooling degree days in 2019 and the first three months of 2020.²¹ Heating degree days decreased 21.3 percent compared to the first three months of 2019.

²¹ A heating degree day is defined as the number of degrees that a day's average temperature is below 65 degrees F (the temperature below which buildings need to be heated). A cooling degree day is the number of degrees that a day's average temperature is above 65 degrees F (the temperature when people will start to use air conditioning to cool buildings). PJM uses 60 degrees F for a heating degree day as stated in Manual 19. Heating and cooling degree days are calculated by weighting the temperature at each weather station in the individual transmission zones using weights provided by PJM in Manual 19. Then the temperature is weighted by the real-time zonal accounting load for each transmission zone. After calculating an average hourly temperature across PJM, the heating and cooling degree formulas are used to calculate the daily heating and cooling degree days, which are summed for monthly reporting. The weather stations that provided the basis for the analysis are ABE, ACY, AVP, BWI, CAK, CLE, CMH, CRW, CVG, DAY, DCA, ERI, EWR, FWA, IAD, ILG, IPT, LEX, ORD, ORF, PHL, PIT, RIC, ROA, TOL and WAL.

Table 3-8 Heating and cooling degree days: January 2019 through March 2020

	2019		2020		Percent Change	
	Heating Degree Days	Cooling Degree Days	Heating Degree Days	Cooling Degree Days	Heating Degree Days	Cooling Degree Days
Jan	909	0	698	0	(23.3%)	0.0%
Feb	688	0	652	0	(5.2%)	0.0%
Mar	607	0	385	0	(36.6%)	0.0%
Apr	145	0				
May	23	90				
Jun	0	210				
Jul	0	423				
Aug	0	312				
Sep	0	211				
Oct	100	31				
Nov	576	0				
Dec	675	0				
Jan-Mar	2,204	0	1,734	0	(21.3%)	0.0%

Day-Ahead Demand

PJM average day-ahead demand in the first three months of 2020, including DECs and up to congestion transactions, decreased by 7.8 percent from the first three months of 2019, from 117,251 MWh to 108,144 MWh. When exports are added, PJM average day-ahead demand in the first three months of 2020 decreased by 7.7 percent from the first three months of 2019, from 120,386 MWh to 111,101 MWh.

In the PJM Day-Ahead Energy Market, five types of financially binding demand bids are made and cleared:

- **Fixed-Demand Bid.** Bid to purchase a defined MWh level of energy, regardless of LMP.
- **Price-Sensitive Bid.** Bid to purchase a defined MWh level of energy only up to a specified LMP, above which the load bid is zero.
- **Decrement Bid (DEC).** Financial bid to purchase a defined MWh level of energy up to a specified LMP, above which the bid is zero. A DEC can be submitted by any market participant.
- **Up to Congestion Transaction (UTC).** A conditional transaction that permits a market participant to specify a maximum price spread between the

transaction source and sink. An up to congestion transaction is evaluated as a matched pair of an injection and a withdrawal.

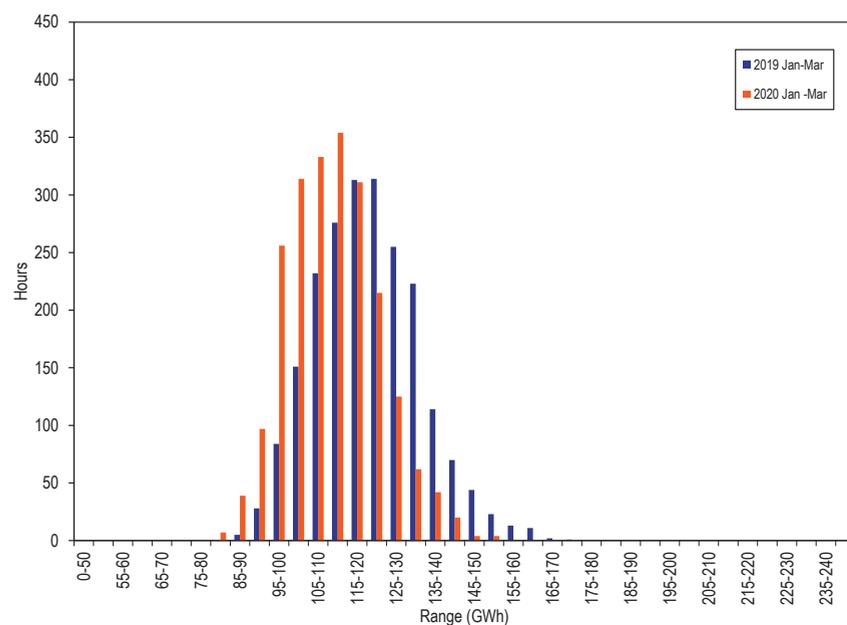
- **Export.** An external energy transaction scheduled from PJM to another balancing authority. An export must have a valid willing to pay congestion (WPC) OASIS reservation when offered. There is no link between transactions submitted in the PJM Day-Ahead Energy Market and the PJM Real-Time Energy Market, so an export energy transaction approved in the day-ahead energy market will not physically flow in real time unless it is also submitted through the real-time energy market scheduling process.

PJM day-ahead demand is the total of the five types of cleared demand bids.

PJM Day-Ahead Demand Duration

Figure 3-15 shows the hourly distribution of PJM day-ahead demand for the first three months of 2019 and 2020.

Figure 3-15 Distribution of day-ahead demand plus exports: January through March, 2019 and 2020²²



²² Each range on the horizontal axis excludes the start value and includes the end value.

PJM Day-Ahead, Average Demand

Table 3-9 presents day-ahead hourly demand summary statistics for the first three months of 2001 through 2020.

Table 3-9 Average hourly day-ahead demand and day-ahead demand plus exports: January through March, 2001 through 2020

Jan-Mar	PJM Day-Ahead Demand (MWh)				Year-to-Year Change			
	Demand		Demand Plus Exports		Demand		Demand Plus Exports	
	Demand	Standard Deviation	Demand	Standard Deviation	Demand	Standard Deviation	Demand	Standard Deviation
2001	33,731	4,557	34,523	4,390	NA	NA	NA	NA
2002	33,976	4,960	34,004	4,964	0.7%	8.8%	(1.5%)	13.1%
2003	47,034	6,841	47,147	6,853	38.4%	37.9%	38.7%	38.1%
2004	46,885	5,591	47,123	5,537	(0.3%)	(18.3%)	(0.1%)	(19.2%)
2005	87,341	9,810	90,288	9,947	86.3%	75.5%	91.6%	79.6%
2006	96,244	9,453	99,342	9,777	10.2%	(3.6%)	10.0%	(1.7%)
2007	108,699	12,601	111,831	12,746	12.9%	33.3%	12.6%	30.4%
2008	105,995	10,677	109,428	10,975	(2.5%)	(15.3%)	(2.1%)	(13.9%)
2009	102,366	13,619	105,023	13,758	(3.4%)	27.6%	(4.0%)	25.4%
2010	101,012	11,937	104,866	12,103	(1.3%)	(12.4%)	(0.1%)	(12.0%)
2011	107,116	11,890	110,865	12,157	6.0%	(0.4%)	5.7%	0.4%
2012	129,258	13,163	132,757	13,481	20.7%	10.7%	19.7%	10.9%
2013	143,585	13,120	146,878	13,108	11.1%	(0.3%)	10.6%	(2.8%)
2014	163,031	11,914	167,318	11,717	13.5%	(9.2%)	13.9%	(10.6%)
2015	119,084	14,227	123,115	14,573	(27.0%)	19.4%	(26.4%)	24.4%
2016	130,469	18,627	133,137	18,806	9.6%	30.9%	8.1%	29.0%
2017	135,574	16,264	139,299	16,454	3.9%	(12.7%)	4.6%	(12.5%)
2018	116,635	21,378	119,023	21,606	(14.0%)	31.4%	(14.6%)	31.3%
2019	117,251	13,075	120,386	13,423	0.5%	(38.8%)	1.1%	(37.9%)
2020	108,144	11,625	111,101	11,658	(7.8%)	(11.1%)	(7.7%)	(13.1%)

PJM Day-Ahead, Monthly Average Demand

Figure 3-16 compares the day-ahead, monthly average hourly demand, including decrement bids and up to congestion transactions in 2019 and first three months of 2020 with the historic five-year range.

Figure 3-16 Day-ahead monthly average hourly demand: January 2019 through March 2020



Real-Time and Day-Ahead Demand

Table 3-10 presents summary statistics for the first three months of 2019 and 2020 day-ahead and real-time demand. All data are cleared MWh. The last two columns of Table 3-10 are the day-ahead demand minus the real-time demand: the first column is the total physical day-ahead load (fixed demand plus price-sensitive demand) less the physical real-time load; and the second column is the total day-ahead demand less the total real-time demand.

Table 3-10 Cleared day-ahead and real-time demand (MWh): January through March, 2019 and 2020

Jan-Mar	Year	Day-Ahead					Real-Time		Day-Ahead Less Real-Time		
		Fixed Demand	Price Sensitive	DEC Bids	Up-to Congestion	Exports	Total Demand	Load	Total Demand	Load	Demand
Average	2019	90,574	1,408	3,542	21,727	3,135	120,386	91,962	96,898	20	23,488
	2020	84,744	1,146	2,911	19,343	2,956	111,101	85,608	90,093	283	21,008
Median	2019	90,363	1,407	3,292	21,287	2,961	119,836	91,278	96,173	492	23,663
	2020	84,696	1,159	2,614	19,282	2,960	110,797	85,475	89,916	380	20,881
Standard Deviation	2019	11,425	195	1,371	4,001	929	13,423	11,888	12,373	(269)	1,050
	2020	9,968	214	1,374	3,287	661	11,658	10,004	9,736	178	1,923
Peak Average	2019	97,280	1,517	3,703	22,709	3,311	128,520	98,040	103,180	757	25,340
	2020	90,524	1,242	3,287	20,195	3,055	118,303	91,075	95,610	691	22,693
Peak Median	2019	96,585	1,539	3,444	22,266	3,156	127,051	97,285	102,625	839	24,426
	2020	90,525	1,296	3,123	20,144	3,084	117,551	91,247	95,541	574	22,010
Peak Standard Deviation	2019	9,372	196	1,314	3,939	914	10,904	10,323	10,829	(755)	75
	2020	7,815	235	1,304	3,439	578	9,507	8,061	7,779	(12)	1,728
Off-Peak Average	2019	84,702	1,312	3,401	20,867	2,981	113,263	86,639	91,397	(625)	21,866
	2020	79,637	1,061	2,579	18,590	2,869	104,737	80,777	85,218	(78)	19,519
Off-Peak Median	2019	83,993	1,309	3,167	20,520	2,716	111,873	85,956	90,714	(654)	21,159
	2020	79,396	1,064	2,245	18,461	2,838	103,381	80,293	84,739	167	18,641
Off-Peak Standard Deviation	2019	9,700	134	1,404	3,857	915	11,190	10,543	10,941	(709)	249
	2020	8,811	149	1,348	2,949	715	9,480	9,021	8,628	(61)	852

Figure 3-17 shows the average hourly cleared volumes of day-ahead demand and real-time demand for the first three months of 2020. The day-ahead demand includes day-ahead load, day-ahead exports, decrement bids and up to congestion transactions. The real-time demand includes real-time load and real-time exports.

Figure 3-17 Day-ahead and real-time demand (Average hourly volumes): January through March, 2020

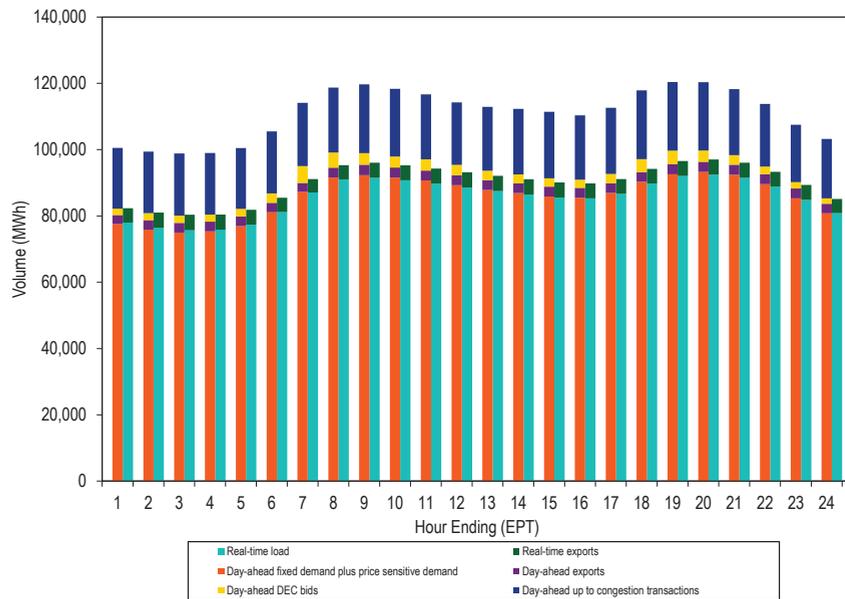
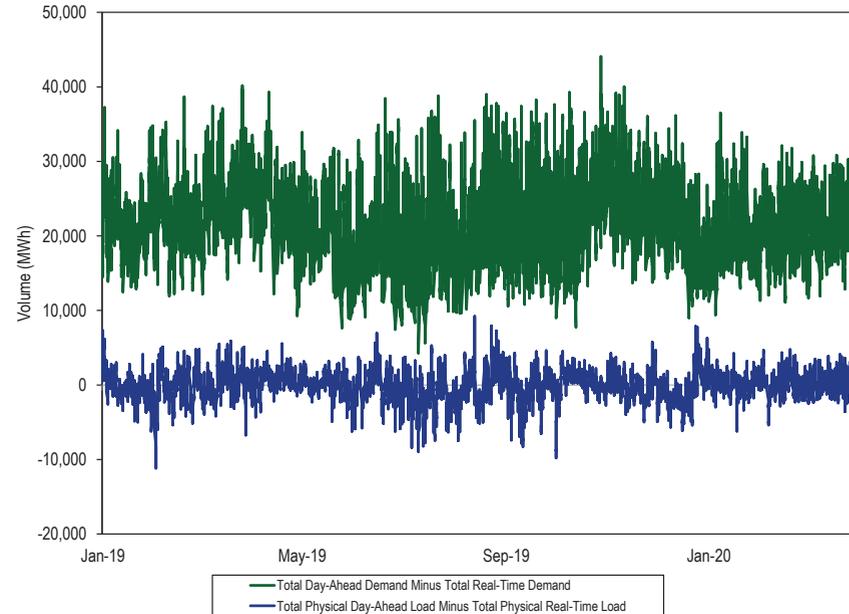


Figure 3-18 shows the difference between the day-ahead and real-time average daily demand for 2019 and the first three months of 2020.

Figure 3-18 Difference between day-ahead and real-time demand (Average daily volumes): 2019 through March 2020



Market Behavior

Supply and Demand: Load and Spot Market

Participants in the PJM Real-Time and Day-Ahead Energy Markets can use their own generation to meet load, to sell in the bilateral market or to sell in the spot market in any hour. Participants can both buy and sell via bilateral contracts and buy and sell in the spot market in any hour. If a participant has positive net bilateral transactions in an hour, it is buying energy through bilateral contracts (bilateral purchase). If a participant has negative net bilateral transactions in an hour, it is selling energy through bilateral contracts (bilateral sale). If a participant has positive net spot transactions in an hour,

it is buying energy from the spot market (spot purchase). If a participant has negative net spot transactions in an hour, it is selling energy to the spot market (spot sale).

Load is served by a combination of self-supply, bilateral market purchases and spot market purchases. From the perspective of a parent company of a PJM billing organization that serves load, its load could be supplied by any combination of its own generation, net bilateral market purchases and net spot market purchases. In addition to directly serving load, load serving entities can also transfer their responsibility to serve load to other parties through InSchedule transactions referred to as wholesale load responsibility (WLR), retail load responsibility (RLR) transactions and generation responsibility. When the responsibility to serve load is transferred via a bilateral contract, the entity to which the responsibility is transferred becomes the load serving entity. Supply from its own generation (self-supply) means that the parent company is generating power from plants that it owns in order to meet demand. Supply from bilateral purchases means that the parent company is purchasing power under bilateral contracts from a nonaffiliated company at the same time that it is meeting load. Supply from spot market purchases means that the parent company is generating less power from owned plants and/or purchasing less power under bilateral contracts than required to meet load at a defined time and, therefore, is purchasing the required balance from the spot market.

The PJM system's reliance on self-supply, bilateral contracts and spot purchases to meet real-time load is calculated by summing across all the parent companies of PJM billing organizations that serve load in the real-time and day-ahead energy markets for each hour.

Real-Time Load and Spot Market

Table 3-11 shows the monthly average share of real-time load served by each parent company's self-supply, bilateral contracts and spot purchase in the first three months of 2019 and 2020. In the first three months of 2020, 16.9 percent of real-time load was supplied by bilateral contracts, 24.1 percent by

spot market purchase and 59.0 percent by self-supply. Compared with the first three months of 2019, reliance on bilateral contracts increased by 1.6 percentage points, reliance on spot supply decreased by 1.4 percentage points and reliance on self-supply increased by 0.1 percentage points.

Table 3-11 Sources of real-time supply: January through March, 2019 and 2020²³

	2019			2020			Difference in Percentage Points		
	Bilateral Contract	Spot	Self-Supply	Bilateral Contract	Spot	Self-Supply	Bilateral Contract	Spot	Self-Supply
Jan	15.4%	23.9%	60.7%	17.1%	24.7%	58.2%	1.7%	0.8%	(2.5%)
Feb	15.4%	25.2%	59.4%	16.6%	23.8%	59.6%	1.2%	(1.3%)	0.1%
Mar	15.2%	27.5%	57.4%	16.9%	23.8%	59.3%	1.8%	(3.7%)	2.0%
Apr	16.7%	24.8%	58.5%						
May	16.0%	24.3%	59.7%						
Jun	15.0%	23.8%	61.1%						
Jul	14.4%	23.8%	61.8%						
Aug	15.3%	24.1%	60.6%						
Sep	15.5%	25.5%	58.9%						
Oct	16.7%	27.7%	55.6%						
Nov	15.7%	28.6%	55.6%						
Dec	19.8%	22.6%	57.6%						
Jan-Mar	15.3%	25.5%	59.2%	16.9%	24.1%	59.0%	1.6%	(1.4%)	(0.1%)

Day-Ahead Load and Spot Market

In the PJM Day-Ahead Energy Market, participants can use not only their own generation, bilateral contracts and spot market purchases to supply their load serving obligation, but also virtual resources to meet their load serving obligations in the day-ahead market in any hour. Virtual supply is treated as supply in the day-ahead market and virtual demand is treated as demand in the day-ahead market.

Table 3-12 shows the monthly average share of day-ahead demand served by each parent company's self-supply, bilateral contracts and spot purchases in the first three months of 2019 and 2020. In the first three months of 2020, 15.9 percent of day-ahead demand was supplied by bilateral contracts, 24.7 percent by spot market purchases and 59.4 percent by self-supply. Compared with the first three months of 2019, reliance on bilateral contracts increased

²³ Table 3-11 and Table 3-12 were calculated as of April 17, 2020. The values may change slightly as billing values are updated by PJM.

by 1.4 percentage points, reliance on spot supply decreased by 1.1 percentage points, and reliance on self-supply decreased by 0.3 percentage points.

Table 3-12 Sources of day-ahead supply: January through March, 2019 and 2020

	2019			2020			Difference in Percentage Points		
	Bilateral Contract	Spot	Self-Supply	Bilateral Contract	Spot	Self-Supply	Bilateral Contract	Spot	Self-Supply
Jan	14.6%	24.4%	61.0%	16.2%	25.2%	58.6%	1.7%	0.8%	(2.4%)
Feb	14.6%	25.4%	60.0%	15.6%	24.2%	60.2%	1.0%	(1.1%)	0.2%
Mar	14.3%	27.6%	58.1%	15.8%	24.6%	59.6%	1.5%	(3.0%)	1.5%
Apr	15.9%	25.5%	58.6%						
May	14.9%	25.5%	59.6%						
Jun	14.3%	25.1%	60.6%						
Jul	13.9%	24.3%	61.8%						
Aug	14.8%	24.6%	60.6%						
Sep	14.8%	26.3%	58.9%						
Oct	16.0%	28.1%	55.9%						
Nov	15.0%	28.7%	56.2%						
Dec	19.1%	22.9%	58.0%						
Jan-Mar	14.5%	25.8%	59.7%	15.9%	24.7%	59.4%	1.4%	(1.1%)	(0.3%)

Generator Offers

Generator offers are categorized as pool scheduled (Table 3-13) or self scheduled (Table 3-14).²⁴ Units which are available for economic dispatch are pool scheduled. Units which are self scheduled to generate fixed output are self scheduled and must run. Units which are self scheduled at their economic minimum and are available for economic dispatch up to their economic maximum are self scheduled and dispatchable. Table 3-13 and Table 3-14 do not include units that did not indicate their offer status or units that were offered as available to run only during emergency events. Units that do not indicate their offer status are unavailable for dispatch by PJM. The MW offered above the economic range of a unit are categorized as emergency MW. Emergency MW offered above the self scheduled or dispatchable MW are included in both tables. Generators may have multiple available offers. In order to select one offer, if there are active emergency conditions, a PLS offer is used, if there is no active emergency the lowest price-based offer is

²⁴ Each range in the tables is greater than or equal to the lower value and less than the higher value. The unit type battery is not included in these tables because batteries do not make energy offers. The unit type fuel cell is not included in these tables because of the small number of owners and the small number of units.

used, if there is no price-based offer a cost-based offer is used, and if there are multiple cost-based offers the lowest commitment cost offer is used.

Table 3-13 shows the proportion of day-ahead MW offered by pool scheduled units, by unit type and by offer price range, in the first three months of 2020. Pool scheduled units offer with an economic commitment status. For example, 41.5 percent of all CC offer MW were the economic minimum offered MW and 37.4 percent of CC offer MW were dispatchable and in the \$0 to \$200 per MWh offer price range. The total column is the proportion of all MW offers by unit type that were dispatchable, including the economic minimum and emergency MW. For example, 83.0 percent of all CC unit offers were dispatchable, including the 41.5 percent of economic minimum MW and 4.1 percent of emergency MW offered by CC units. The dispatchable range of a unit is between the economic minimum and emergency range. For example, 37.5 percent of all CC unit offers have an economic dispatch range. The all dispatchable offers row is the proportion of MW that were offered as available for economic dispatch within a given range by all unit types. For example, 26.7 percent of all dispatchable offers were in the \$0 to \$200 per MWh price range. The total column in the all dispatchable offers row is the proportion of all MW offers that were offered as available for economic dispatch, including emergency MW. Among all the generator offers in the first three months of 2020, 29.4 percent of all dispatchable offers had an economic dispatch range.

Table 3-13 Distribution of day-ahead MW for pool scheduled unit offer prices: January through March, 2020

Unit Type	Economic Minimum	Dispatchable (Range)							Emergency	Total
		(\$200) - \$0	\$0 - \$200	\$200 - \$400	\$400 - \$600	\$600 - \$800	\$800 - \$1,000	\$1,000 -		
CC	41.5%	0.0%	37.4%	0.1%	0.0%	0.0%	0.0%	0.0%	4.1%	83.0%
CT	62.9%	0.0%	27.6%	1.3%	0.3%	0.0%	0.0%	0.0%	7.2%	99.3%
Diesel	39.8%	0.0%	18.1%	4.1%	0.0%	0.0%	0.0%	0.0%	16.2%	78.3%
Nuclear	7.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.1%
Pumped Storage	0.0%	0.0%	10.7%	0.0%	0.0%	0.0%	0.0%	0.0%	40.8%	51.5%
Run of River	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Solar	0.1%	0.0%	14.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	14.9%
Steam - Coal	25.3%	0.0%	31.9%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	59.1%
Steam - Other	31.9%	0.0%	50.7%	2.1%	0.0%	0.0%	0.0%	0.0%	2.7%	87.5%
Wind	1.1%	0.0%	8.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	10.1%
All Dispatchable Offers	32.2%	0.0%	26.7%	0.4%	0.1%	0.0%	0.0%	0.0%	4.3%	65.9%

Table 3-14 shows the proportion of day-ahead MW offers by unit type that were self scheduled by unit type, and that were self scheduled and dispatchable by price range, for the first three months of 2020. The total column is the proportion of all MW offers by unit type that were self scheduled to generate fixed output or are self scheduled and dispatchable. For example, 17.0 percent of all CC offers were either self scheduled to generate at fixed output or self scheduled to generate at economic minimum and dispatchable up to economic maximum, including the 1.4 percent of emergency MW offered by CC units. The all self scheduled offers row is the proportion of MW that were offered as either self scheduled to generate at fixed output or self scheduled to generate at economic minimum and dispatchable up to economic maximum within a given range by all unit types. For example, units that were self scheduled to generate at fixed output accounted for 14.1 percent of all offers and self scheduled and dispatchable units accounted for 18.9 percent of all offers. The total column in the all self scheduled offers row is the proportion of all MW offers that were either self scheduled to generate at fixed output or self scheduled to generate at economic minimum and dispatchable up to economic maximum, including emergency MW. Among all the generator offers in the first three months of 2020, 14.1 percent were offered as self scheduled and 18.9 percent were offered as self scheduled and dispatchable.

Table 3-14 Distribution of day-ahead MW for self scheduled and dispatchable unit offer prices: January through March, 2020

Unit Type	Self Scheduled		Self Scheduled and Dispatchable (Range)								Total
	Must Run	Emergency	Economic Minimum	(\$200) - \$0	\$0 - \$200	\$200 - \$400	\$400 - \$600	\$600 - \$800	\$800 - \$1,000	Emergency	
CC	0.2%	0.1%	8.5%	0.0%	6.8%	0.0%	0.0%	0.0%	0.0%	1.4%	17.0%
CT	0.2%	0.1%	0.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.7%
Diesel	13.6%	2.5%	2.0%	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	19.5%
Fuel Cell	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Nuclear	65.6%	0.0%	22.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	89.4%
Pumped Storage	3.5%	5.2%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.0%
Run of River	87.5%	11.8%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	99.7%
Solar	9.6%	5.9%	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	16.3%
Steam - Coal	1.5%	0.5%	18.3%	0.0%	18.3%	0.0%	0.0%	0.0%	0.0%	2.2%	40.8%
Steam - Other	2.3%	0.4%	4.9%	0.0%	2.1%	0.1%	0.0%	0.0%	0.0%	0.7%	10.4%
Wind	5.7%	5.7%	2.2%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	2.2%	17.4%
All Self-Scheduled Offers	13.5%	0.6%	11.1%	0.0%	6.8%	0.0%	0.0%	0.0%	0.0%	1.0%	34.1%

Hourly Offers and Intraday Offer Updates

All participants are able to make hourly offers. Participants must opt in on a monthly basis to make intraday offer updates. Participants that have opted in can only make updates if their Fuel Cost Policy defines the intraday offer update process. Table 3-15 shows the daily average number of units that make hourly offers, that opted in to intraday offer updates and that make intraday offer updates. In the first three months of 2020, an average of 296 units made hourly offers per day, an increase of 19 units from the first three months of 2019. In the first three months of 2020, 391 units opted in for intraday offer updates, an increase of 25 units from the first three months of 2019. In the first three months of 2020, an average of 132 units made intraday offer updates each day, a decrease of 13 units from the first three months of 2019.

Table 3-15 Daily average number of units making hourly offers, opted in for intraday offers and making intraday offer updates: January through March, 2019 and 2020

	Fuel Type	2019	2020	Difference
Hourly Offers	Natural Gas	260	278	18
	Other Fuels	17	18	1
	Total	277	296	19
Opt In	Natural Gas	329	344	15
	Other Fuels	37	46	9
	Total	366	391	25
Intraday Offer Updates	Natural Gas	137	125	(12)
	Other Fuels	7	7	0
	Total	145	132	(13)

Parameter Limited Schedules

Cost-Based Offers

All capacity resources in PJM are required to submit at least one cost-based offer. For the 2018/2019 and 2019/2020 delivery years, PJM procured two types of capacity resources, capacity performance resources and base capacity resources. Since June 1, 2018, there are no longer any RPM resources committed as the legacy annual capacity product that existed prior to the 2018/2019 Delivery Year. All cost-based offers, submitted by capacity

performance resources and base capacity resources, are parameter limited in accordance with predetermined unit specific parameter limits.

Price-Based Offers

All capacity resources that choose to offer price-based offers are required to make available at least one price-based parameter limited offer (referred to as price-based PLS). For resources that are not capacity performance resources or not base capacity resources, the price-based parameter limited schedule is to be used by PJM for committing generation resources when a maximum emergency generation alert is declared. For capacity performance resources, the price-based parameter limited schedule is to be used by PJM for committing generation resources when hot weather alerts and cold weather alerts are declared. For base capacity resources (during the 2018/2019 and 2019/2020 delivery years only), the price-based parameter limited schedule is to be used by PJM for committing generation resources when hot weather alerts are declared. For all resources, a parameter limited schedule is to be used by PJM for committing generation resources that fail the Three Pivotal Supplier (TPS) test.

The MMU recommends that in order to ensure effective market power mitigation, PJM always enforce parameter limited values when the TPS test is failed and during high load conditions such as cold and hot weather alerts and emergency conditions.²⁵ Instead of ensuring that parameter limits apply, PJM chooses the lower of the price-based schedule and the price-based parameter limited schedule during hot and cold weather alerts. Instead of ensuring that parameter limits apply, PJM chooses the lower of the price-based schedule and the cost-based parameter limited schedule when a resource fails the TPS test. The current implementation is not consistent with Operating Agreement Schedule 1, Section 6.6.

The MMU analyzed the extent of parameter mitigation in the day-ahead energy market when units are committed after failing the TPS test for transmission constraints in the first three months of 2020. Table 3-16 shows the number and percentage of day-ahead unit run hours that failed the TPS test but were

²⁵ See Protest of the Independent Market Monitor for PJM, Docket No. ER20-995 (February 25, 2020).

committed on price schedules. Table 3-16 shows that 41.7 percent of unit hours for units that failed the TPS test were committed on their price based schedules that were less flexible than their cost based schedules.

Table 3-16 Parameter mitigation for units failing TPS test: January through March, 2020

Day-ahead commitment for units that failed TPS test	Day-ahead Unit Hours	Percent Day-ahead Unit Hours
Committed on price schedule less flexible than cost	7,731	41.7%
Committed on price schedule as flexible as cost	2,157	11.6%
Total committed on price schedule without parameter limits	9,888	53.3%
Committed on cost (cost capped)	8,529	46.0%
Committed on price PLS	120	0.6%
Total committed on PLS schedules (cost or price PLS)	8,649	46.7%

The MMU analyzed the extent of parameter mitigation in the day-ahead energy market for units in regions where a cold weather alert was declared in the first three months of 2020. PJM declared cold weather alerts on three days in the first three months of 2020, only in the ComEd zone.²⁶ The analysis includes units with a CP commitment in ComEd on the days when the cold weather alerts were declared. Base capacity resources are subject to commitment on the price PLS schedule during hot weather alerts and not during cold weather alerts. Table 3-17 shows that 27.5 percent of unit hours in the day-ahead energy market were committed on price based schedules that were less flexible than their price PLS schedules.

Table 3-17 Parameter mitigation during cold weather alerts: January through March, 2020

Day-ahead commitment during cold weather alerts	Day-ahead Unit Hours	Percent Day-ahead Unit Hours
Committed on price schedule less flexible than PLS	651	27.5%
Committed on price schedule as flexible as PLS	1209	51.1%
Total committed on price schedule without parameter limits	1860	78.6%
Committed on cost (cost capped)	0	0.0%
Committed on price PLS	506	21.4%
Total committed on PLS schedules (cost or price PLS)	506	21.4%

²⁶ 2020 Quarterly State of the Market Report for PJM: January through March, Section 3: Energy Market, at Emergency Procedures.

Currently, there are no rules in the PJM tariff or manuals that limit the markup attributes of price-based PLS offers. The intent of the price-based PLS offer is to prevent the exercise of market power during high demand conditions by preventing units from offering inflexible operating parameters in order to extract higher market revenues or higher uplift payments. However, a generator can include a higher markup in the price-based PLS offer than in the price-based non-PLS schedule. The result is that the offer is higher and market prices are higher as a result of the exercise of market power using the PLS offer. This defeats the purpose of requiring price-based PLS offers.

The MMU recommends that in order to ensure effective market power mitigation when the TPS test is failed and during high load conditions such as cold and hot weather alerts or more severe emergencies, the operating parameters in the cost-based offer and the price-based parameter limited schedule (PLS) offer be at least as flexible as the operating parameters in the available non-PLS price-based offer, and that the price-MW pairs in the price-based PLS offer be exactly equal to the price-based non-PLS offer. This recommendation would ensure compliance with Operating Agreement Schedule 1, Section 6.6.

Parameter Limits

Beginning in the 2016/2017 Delivery Year, resources that had capacity performance (CP) commitments were required to submit, in their parameter limited schedules (cost-based offers and price-based PLS offers), unit specific parameters that reflect the physical capability of the technology type of the resource. For the 2018/2019 and 2019/2020 delivery years, resources that have base capacity commitments are also required to submit, in their parameter limited schedules, unit specific parameters that reflect the physical capability of the technology type of the resource. Startup and notification times are limited for capacity performance resources beginning June 1, 2016, and base capacity resources beginning June 1, 2018, in accordance with predetermined unit specific parameter limits. The unit specific parameter limits for capacity performance and base capacity resources are based on default minimum operating parameter limits posted by PJM by technology type, and any adjustments based on a unit specific review process. These default parameters were based on analysis by the MMU.

Beginning June 1, 2018, all RPM procured capacity resources were either capacity performance or base capacity resources. Entities that elected the fixed resource requirement (FRR) option were allowed to procure the legacy annual capacity product for the 2018/2019 Delivery Year. Beginning June 1, 2019, all capacity resources, including resources in FRR capacity plans, are either capacity performance or base capacity resources. The PJM tariff specifies that all generation capacity resources, regardless of the current commitment status, are subject to parameter limits on their cost-based offers. However, the tariff currently does not make it clear what parameter limit values are applicable for resources without a capacity commitment. The MMU recommends that PJM update the tariff to clarify that all generation resources are subject to unit specific parameter limits on their cost-based offers using the same standard and process as capacity performance and base capacity resources.

Unit Specific Adjustment Process

Market participants can request an adjustment to the default values of parameter limits for capacity performance and base capacity resources, by submitting supporting documentation, which is reviewed by PJM and the MMU. The default minimum operating parameter limits or approved adjusted values are used by capacity performance resources and base capacity resources for their parameter limited schedules.

PJM has the authority to approve adjusted parameters with input from the MMU. PJM has inappropriately applied different review standards to coal units than to CTs and CCs despite the objections of the MMU. PJM has approved parameter limits for steam units based on historical performance and existing equipment while holding CTs and CCs to higher standards based on OEM documentation and a best practices equipment configuration.

The PJM process for the review of unit specific parameter limit adjustments is generally described in Manual 11: Energy and Ancillary Services Market Operations. The standards used by PJM to review the requests are currently not described in the tariff or PJM manuals. The MMU recommends that PJM clearly define the business rules that apply to the unit specific parameter

adjustment process, including PJM’s implementation of the tariff rules in the PJM manuals to ensure market sellers know the requirements for their resources.

Only certain technology types are subject to limits on operating parameters in their parameter limited schedules.²⁷ Solar units, wind units, run of river hydro units, and nuclear units are currently not subject to parameter limits. The MMU analyzed, for the units that are subject to parameter limits, the proportion of units that use the default limits published by PJM and the proportion of units that have been provided unit specific adjustments for some of the parameters. Table 3-18 shows, for the delivery year beginning June 1, 2019, the number of units that submitted and had approved unit specific parameter limit adjustments, and the number of units that used the default parameter limits published by PJM. Table 3-18 shows that 77.5 percent of subcritical coal steam units and 89.1 percent of supercritical coal steam units had an adjustment approved to one or more parameter limits from the default limits published by PJM, while only 34.2 percent of combined cycle units, and 35.4 percent of frame combustion turbine units, and 18.9 percent of aero derivative combustion turbine units had an adjustment approved to one or more parameter limits from the default limits published by PJM.

Table 3-18 Adjusted unit specific parameter limit statistics: Delivery Year 2019/2020

Technology Classification	Units Using Default Parameter Limits	Units with One or More Adjusted Parameter Limits	Percentage of Units with One or More Adjusted Parameter Limits
Aero CT	137	32	18.9%
Frame CT	190	104	35.4%
Combined Cycle	73	38	34.2%
Reciprocating Internal Combustion Engines	70	3	4.1%
Solid Fuel NUG	43	5	10.4%
Oil and Gas Steam	13	18	58.1%
Subcritical Coal Steam	20	69	77.5%
Supercritical Coal Steam	5	41	89.1%
Pumped Storage	10	0	0.0%

²⁷ For the default parameter limits by technology type, see PJM. "Unit-Specific Minimum Operating Parameters for Capacity Performance and Base Capacity Resources," which can be accessed at <<https://www.pjm.com/~media/committees-groups/committees/elc/postings/20150612-june-2015-capacity-performance-parameter-limitations-informational-posting.ashx>>.

Real-Time Values

The MMU recommends that PJM market rules recognize the difference between operational parameters that indicate to PJM operators what a unit is capable of during the operating day and the parameters that result in uplift payments. The parameters provided to PJM operators each day should reflect what units are physically capable of so that operators can operate the system. However, the parameters which determine the amount of uplift payments to those generators should reflect the flexibility goals of the capacity performance construct and the assignment of performance risk to generation owners. PJM implemented the real-time value variable in Markets Gateway to address this, but there are problems with the implementation.

PJM market rules allow generators to communicate a resource's current operational capabilities to PJM when a resource cannot operate according to the unit specific parameters. These values are called real-time values (RTVs). The real-time values submittal process is not specified in the PJM Operating Agreement. The process is defined in PJM Manual 11. Unlike parameter exceptions, the use of real-time values makes a unit ineligible for make whole payments, unless the market seller can justify such operation based on an actual constraint.²⁸

In practice, real-time values are generally used to communicate lower Turn Down Ratios which result from reduced Economic Max MW due to a derate (partial outage) on a unit, or from a requirement to operate at a defined output for equipment tests, environmental tests, or inspections. The RTV functionality allows units to communicate accurate short term operational parameters to PJM without requiring PJM customers to pay additional uplift charges, if the unit operates out of the money for routine tests and inspections. However, using real-time values to extend the time to start parameters (startup times and notification times) is inconsistent with the goal of real-time values. The protection offered by making units ineligible for uplift is only effective if the unit is committed and operated out of the money because of the RTVs. In the case of the notification time parameter, start time parameter, minimum run time and minimum down time parameters, a longer real-time value

²⁸ See PJM Operating Agreement, Schedule 1, Section 3.2.3 (e).

decreases the likelihood of the unit being committed at all and may prohibit unit commitment in real time, making the RTV a mechanism for withholding.

The use of real-time values to extend startup times, notification times, minimum run time and minimum down time allows generators to circumvent the parameter limited schedule rules, to avoid commitment by PJM. Using RTVs to remove a unit from the real-time look-ahead dispatch window, and avoid commitment is withholding. These concerns are exacerbated if these units can otherwise provide relief to transmission constraints, and can provide flexibility to meet peak demand conditions. Currently, a resource that is staffed or has remote start capability and offers according to its physical capability, and a resource that makes the economic choice not to staff or invest in remote start and offers to decrease the likelihood of commitment, are compensated identically in the capacity market. If a market seller makes an economic decision to not staff the unit or to not have remote start capability, and uses real-time values to communicate the longer time to start to PJM, there is currently no consequence to the market seller.

The MMU recommends that PJM institute rules to assess a penalty for resources that choose to submit real-time values that are less flexible than their unit specific parameter limits or approved parameter limit exceptions based on tariff defined justifications.

Generator Flexibility Incentives under Capacity Performance

In its June 9, 2015, order on capacity performance, the Commission determined that capacity performance resources should be able to reflect actual constraints based on not just the resource physical constraints, but also other constraints, such as contractual limits that are not based on the physical characteristics of the generator.²⁹ The Commission directed that capacity performance resources with parameters based on nonphysical constraints should receive uplift payments.³⁰ The Commission directed PJM to submit tariff language to establish a process through which capacity performance resources that

²⁹ 151 FERC ¶ 61,208 at P 437 (2015) (June 9th Order).

³⁰ *Id.* at P 439.

operate outside the defined unit-specific parameter limits can justify such operation and therefore remain eligible for make whole payments.³¹

A primary goal of the capacity performance market design is to assign performance risk to generation owners and to ensure that capacity prices reflect underlying supply and demand conditions, including the cost of taking on performance risk. The June 9th Order's determination on parameters is not consistent with that goal. By permitting generation owners to establish unit parameters based on nonphysical limits, the June 9th Order has weakened the incentives for units to be flexible and has weakened the assignment of performance risk to generation owners. Contractual limits, unlike generating unit operational limits, are a function of the interests and incentives of the parties to the contracts. If a generation owner expects to be compensated through uplift payments for running for 24 hours regardless of whether the energy is economic or needed, that generation owner has no incentive to pay more to purchase the flexible gas service that would permit the unit to be flexible in response to dispatch.

The fact that a contract may be entered into by two willing parties does not mean that is the only possible arrangement between the two parties or that it is consistent with an efficient market outcome or that such a contract can reasonably impose costs on customers who were not party to the contract. The actual contractual terms are a function of the incentives and interests of the parties, who may be affiliates or have market power. The fact that a just and reasonable contract exists between a generation owner and a gas supplier does not mean that it is appropriate or efficient to impose the resultant costs on electric customers or that it incorporates an efficient allocation of performance risk between the generation owner and other market participants.

The approach to parameters defined in the June 9th Order will increase energy market uplift payments substantially. While some uplift is necessary and efficient in an LMP market, this uplift is not. Electric customers are not in a position to determine the terms of the contracts that resources enter into. Customers rely on the market rules to create incentives that protect them

³¹ *Id.* at P 440.

by assigning operational risk to generators, who are in the best position to efficiently manage those risks.

The MMU recommends that capacity performance resources and base capacity resources (during the June through September period) be held to the OEM operating parameters of the capacity market reference resource used for the Cost of New Entry (CONE) calculation for performance assessment and energy uplift payments and that this standard be applied to all technologies on a uniform basis. This solution creates the incentives for flexibility and preserves, to the extent possible, the incentives to follow PJM's dispatch instructions during high demand conditions. The proposed operating parameters should be based on the physical capability of the Reference Resource used in the Cost of New Entry, currently two GE Frame 7FA turbines with dual fuel capability. All resources that are less flexible than the reference resource are expected to be scheduled and running during high demand conditions anyway, while the flexible CTs that are used as peaking plants would still have the incentive to follow LMP and dispatch instructions. CCs would also have the capability to be as flexible as the reference resource. These units will be exempt from nonperformance charges and made whole as long as they perform in accordance with their parameters. This ensures that all the peaking units that are needed by PJM for flexible operation do not self schedule at their maximum output, and follow PJM dispatch instructions during high demand conditions. If any of the less flexible resources need to be dispatched down by PJM for reliability reasons, they would be exempt from nonperformance charges.

Such an approach is consistent with the Commission's no excuses policy for nonperformance because the flexibility target is set based on the optimal OEM-defined capability for the marginal resource that is expected to meet peak demand, which is consistent with the level of performance that customers are paying for in the capacity market. Any resource that is less flexible is not excused for nonperformance and any resource that meets the flexibility target is performing according to the commitments made in the capacity market.

The June 9th Order pointed out that the way to ensure that a resource's parameters are exposed to market consequences is to not allow any parameter

limitations as an excuse for nonperformance. The same logic should apply to energy market uplift rules. A resource's parameters should be exposed to market consequences and the resource should not be made whole if it is operating less flexibly than the reference resource. Paying energy market uplift on the basis of parameters consistent with the flexibility goals of the capacity performance construct would ensure that performance incentives are consistent across the capacity and energy markets and ensure that performance risk is appropriately assigned to generation owners.

Parameter Impacts of Gas Pipeline Conditions

During extreme cold weather conditions, a number of gas fired generators request temporary exceptions to parameter limits for their parameter limited schedules due to restrictions imposed by natural gas pipelines. The parameters affected include notification time, minimum run time (MRT) and turn down ratio (TDR, the ratio of economic maximum MW to economic minimum MW). When pipelines issue critical notices and enforce ratable take requirements, generators may, depending on the nature of the transportation service purchased, be forced to nominate an equal amount of gas for each hour in a 24 hour period, with penalties for deviating from the nominated quantity. This leads to requests for 24 hour minimum run times and turn down ratios close to 1.0, to avoid deviations from the hourly nominated quantity.

Key parameters like startup and notification time were not included in the PLS matrix in 2017 and prior periods, even though other parameters were subject to parameter limits. Some resource owners notified PJM that they needed extended notification times based on the claimed necessity for generation owners to nominate gas prior to gas nomination cycle deadlines.

The MMU observed instances when generators submitted temporary parameter exceptions based on claimed pipeline constraints even though these constraints are based on the nature of the transportation service that the generator procured from the pipeline. In some instances, generators requested temporary exceptions based on ratable take requirements stated in pipeline tariffs, even though the requirement is not enforced by the pipelines

on a routine basis. If a unit were to be dispatched uneconomically using the inflexible parameters, the unit would receive make whole payments based on these temporary exceptions. The MMU recommends that PJM not approve temporary exceptions that are based on pipeline tariff terms that are not routinely enforced or on inferior transportation service procured by the generator.

Virtual Offers and Bids

There is a substantial volume of virtual offers and bids in the PJM Day-Ahead Energy Market and such offers and bids may be marginal, based on the way in which the PJM market clearing algorithm works.

Any market participant in the PJM Day-Ahead Energy Market can use increment offers, decrement bids, up to congestion transactions, import transactions and export transactions as financial instruments that do not require physical generation or load. Because virtual positions do not require physical generation or load, participants must buy or sell out of their virtual positions at real-time energy market prices. Increment offers and decrement bids may be submitted at any hub, transmission zone, aggregate, or single bus for which LMP is calculated. On February 20, 2018, FERC issued an order limiting the eligible bidding points for up to congestion transactions to hubs, residual metered load and interfaces.³² Up to congestion transactions may be submitted between any two buses on a list of 49 buses, eligible for up to congestion transaction bidding.³³ Import and export transactions may be submitted at any interface pricing point, where an import is equivalent to a virtual offer that is injected into PJM and an export is equivalent to a virtual bid that is withdrawn from PJM.

Figure 3-19 shows the PJM day-ahead daily aggregate supply curve of increment offers, the system aggregate supply curve of imports, the system aggregate supply curve without increment offers and imports, the system

³² 162 FERC ¶ 61,139.

³³ Market participants were required to specify an interface pricing point as the source for imports, an interface pricing point as the sink for exports or an interface pricing point as both the source and sink for transactions wheeling through PJM. On November 1, 2012, PJM eliminated this requirement. For the list of eligible sources and sinks for up to congestion transactions, see www.pjm.com/~media/etools/oasis/references/oasis-source-sink-link.xlsx.

aggregate supply curve with increment offers, and the system aggregate supply curve with increment offers and imports for an example day in 2020.

Figure 3-19 Day-ahead aggregate supply curves: 2020 example day

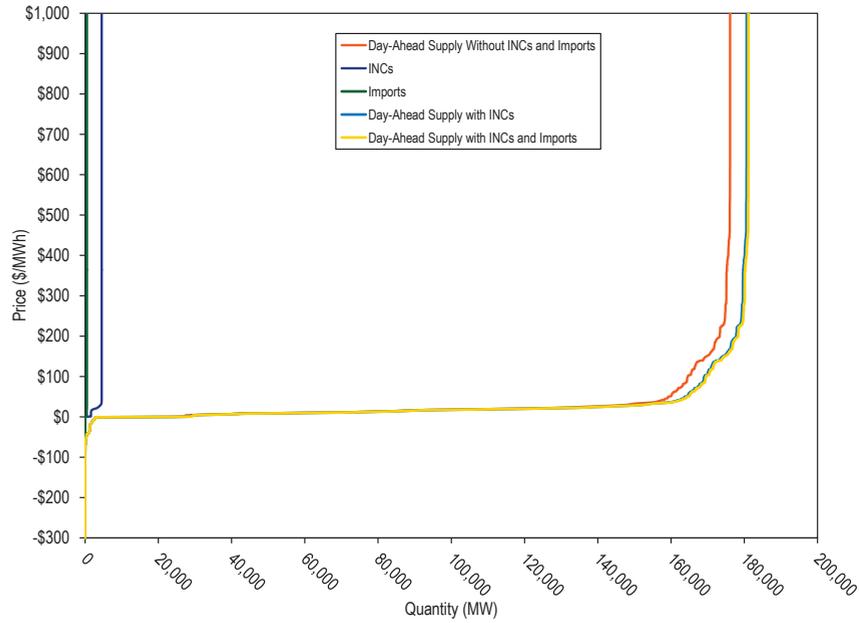


Figure 3-20 shows example PJM day-ahead aggregate supply curves for the typical dispatch price range.

Figure 3-20 Typical dispatch price range for day-ahead aggregate supply curves: 2020 example day

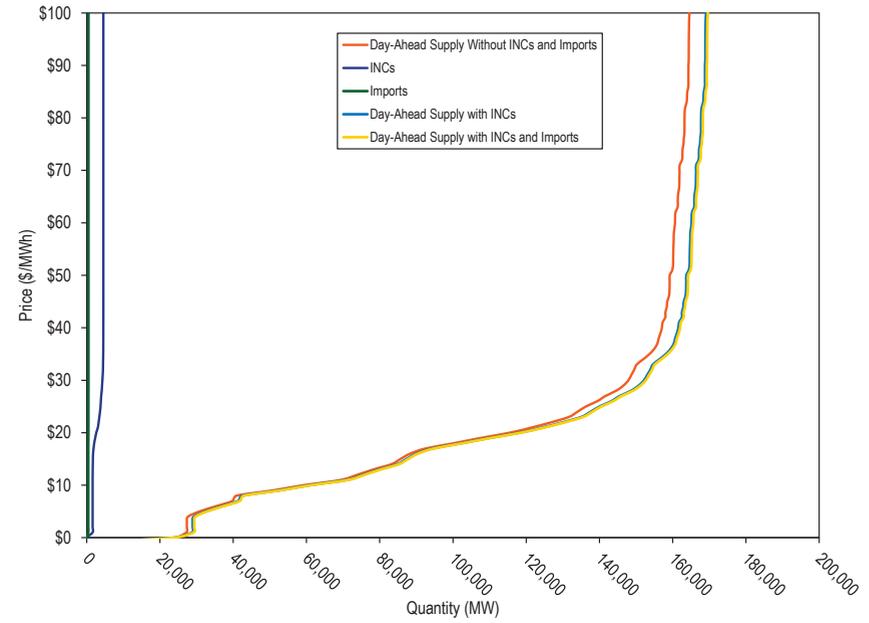


Table 3-19 shows the hourly average number of cleared and submitted increment offers and decrement bids by month from January 2019 through March 2020. The hourly average submitted MW increased by 10.7 percent and cleared increment MW decreased by 13.0 percent, from 6,185 MW and 2,936 MW in the first three months of 2019 to 6,848 MW and 2,555 MW in the first three months of 2020. The hourly average submitted MW increased by 0.2 percent and cleared decrement MW decreased by 17.8 percent, from 6,717 MW and 3,542 MW in the first three months of 2019 to 6,734 MW and 2,911 MW in the first three months of 2020.

Table 3-19 Average hourly number of cleared and submitted INCs and DECs by month: January 2019 through March 2020

Year		Increment Offers				Decrement Bids			
		Average Cleared	Average Submitted	Average Cleared	Average Submitted	Average Cleared	Average Submitted	Average Cleared	Average Submitted
		MW	MW	Volume	Volume	MW	MW	Volume	Volume
2019	Jan	2,934	6,777	282	1,122	3,856	7,149	215	834
2019	Feb	2,895	5,776	260	1,029	3,441	6,115	197	781
2019	Mar	2,973	5,961	268	1,057	3,319	6,830	181	859
2019	Apr	3,048	6,008	286	1,060	3,104	6,226	154	733
2019	May	3,107	6,468	273	1,082	4,236	6,903	178	726
2019	Jun	2,892	6,363	226	977	4,408	7,245	226	863
2019	Jul	2,655	6,712	202	1,051	4,544	9,223	251	1,086
2019	Aug	2,577	6,573	220	1,100	3,744	7,056	217	860
2019	Sep	2,715	6,737	221	972	5,046	8,790	255	900
2019	Oct	3,034	6,967	283	1,141	3,218	7,226	186	776
2019	Nov	3,373	7,896	304	1,261	2,745	6,930	187	831
2019	Dec	2,482	6,398	232	995	2,782	6,455	191	694
2019	Annual	2,889	6,558	255	1,071	3,704	7,186	203	829
2020	Jan	2,684	6,395	261	1,063	2,547	5,856	187	662
2020	Feb	2,544	7,043	233	1,046	2,990	6,653	222	702
2020	Mar	2,435	7,119	258	1,069	3,203	7,688	251	762
2020	Jan-Mar	2,555	6,848	251	1,060	2,911	6,734	220	709

Table 3-20 shows the average hourly number of up to congestion transactions and the average hourly MW from January 2019 through March 2020. In the first three months of 2020, the average hourly submitted and cleared up to congestion MW decreased by 42.9 percent and 11.0 percent, compared to the first three months of 2019.

Table 3-20 Average hourly cleared and submitted up to congestion bids by month: January 2019 through March 2020

Year		Up to Congestion			
		Average Cleared MW	Average Submitted MW	Average Cleared Volume	Average Submitted Volume
2019	Jan	20,624	65,533	1,219	2,489
2019	Feb	21,341	66,240	1,005	2,013
2019	Mar	23,205	75,760	1,045	2,144
2019	Apr	21,323	63,388	872	1,669
2019	May	19,407	59,684	862	1,713
2019	Jun	18,598	51,678	1,021	1,953
2019	Jul	19,197	56,161	1,128	2,265
2019	Aug	20,247	58,841	1,254	2,550
2019	Sep	20,005	74,494	1,136	2,523
2019	Oct	22,233	75,107	1,093	2,302
2019	Nov	23,678	77,890	1,019	2,265
2019	Dec	20,567	55,020	1,040	2,104
2019	Annual	20,864	64,952	1,059	2,168
2020	Jan	19,106	37,533	1,127	2,087
2020	Feb	19,415	40,281	1,100	2,133
2020	Mar	19,513	40,998	990	1,970
2020	Jan-Mar	19,343	39,588	1,072	2,062

Table 3-21 shows the average hourly number of day-ahead import and export transactions and the average hourly MW from January 2019 through March 2020. In the first three months of 2020, the average hourly submitted and cleared import transaction MW decreased by 39.9 and 32.6 percent, and the average hourly submitted and cleared export transaction MW decreased by 6.1 and 5.7 percent, compared to the first three months of 2019.

Table 3-21 Hourly average day-ahead number of cleared and submitted import and export transactions by month: January 2019 through March 2020

Year	Month	Imports				Exports			
		Average Cleared MW	Average Submitted MW	Average Cleared Volume	Average Submitted Volume	Average Cleared MW	Average Submitted MW	Average Cleared Volume	Average Submitted Volume
2019	Jan	545	653	7	9	3,569	3,593	22	22
2019	Feb	564	671	6	8	3,169	3,182	17	18
2019	Mar	387	449	5	7	2,675	2,686	15	15
2019	Apr	255	288	4	5	2,483	2,496	15	15
2019	May	279	298	3	4	2,426	2,458	15	15
2019	Jun	291	308	3	4	2,790	2,806	17	17
2019	Jul	283	311	4	5	3,075	3,106	15	15
2019	Aug	277	303	3	4	2,907	2,923	16	16
2019	Sep	162	177	3	3	3,163	3,193	17	17
2019	Oct	433	463	4	5	2,694	2,721	15	15
2019	Nov	540	563	5	6	2,205	2,214	12	12
2019	Dec	468	505	4	6	3,133	3,144	25	25
2019	Annual	373	414	4	6	2,857	2,876	17	17
2020	Jan	427	445	5	6	3,034	3,041	28	28
2020	Feb	324	346	4	5	2,737	2,742	29	29
2020	Mar	254	269	3	4	3,084	3,085	27	27
2020	Jan-Mar	335	353	4	5	2,956	2,961	28	28

Table 3-22 shows the frequency with which generation offers, import or export transactions, up to congestion transactions, decrement bids, increment offers and price-sensitive demand were marginal from January 2019 through March 2020.

Table 3-22 Type of day-ahead marginal resources: January 2019 through March 2020

	2019						2020					
	Generation	Dispatchable Transaction	Up to Congestion Transaction	Decrement Bid	Increment Offer	Price Sensitive Demand	Generation	Dispatchable Transaction	Up to Congestion Transaction	Decrement Bid	Increment Offer	Price Sensitive Demand
Jan	13.4%	0.3%	59.1%	17.4%	9.9%	0.0%	27.7%	0.1%	44.7%	10.6%	16.9%	0.0%
Feb	11.7%	0.1%	60.0%	15.4%	12.8%	0.0%	20.7%	0.1%	48.5%	12.5%	18.2%	0.0%
Mar	9.3%	0.1%	60.5%	17.0%	13.1%	0.0%	19.5%	0.0%	52.2%	14.7%	13.6%	0.0%
Apr	8.3%	0.1%	64.9%	14.8%	11.9%	0.0%						
May	9.9%	0.1%	53.1%	21.0%	15.9%	0.0%						
Jun	10.5%	0.0%	49.0%	23.7%	16.8%	0.0%						
Jul	9.1%	0.0%	51.5%	26.0%	13.4%	0.0%						
Aug	13.0%	0.1%	63.1%	14.1%	9.6%	0.0%						
Sep	14.0%	0.1%	60.5%	13.4%	12.0%	0.0%						
Oct	16.4%	0.1%	55.9%	13.8%	13.8%	0.0%						
Nov	16.2%	0.0%	57.9%	13.2%	12.8%	0.0%						
Dec	23.2%	0.1%	55.2%	10.9%	10.5%	0.0%						
Annual	12.7%	0.1%	57.4%	17.0%	12.8%	0.0%	22.5%	0.1%	48.5%	12.6%	16.2%	0.0%

Figure 3-21 shows the monthly volume of bid and cleared INC, DEC and up to congestion bids by month from January 2005 through March 2020.

Figure 3-21 Monthly bid and cleared INCs, DECs and UTCs (MW): January 2005 through March 2020

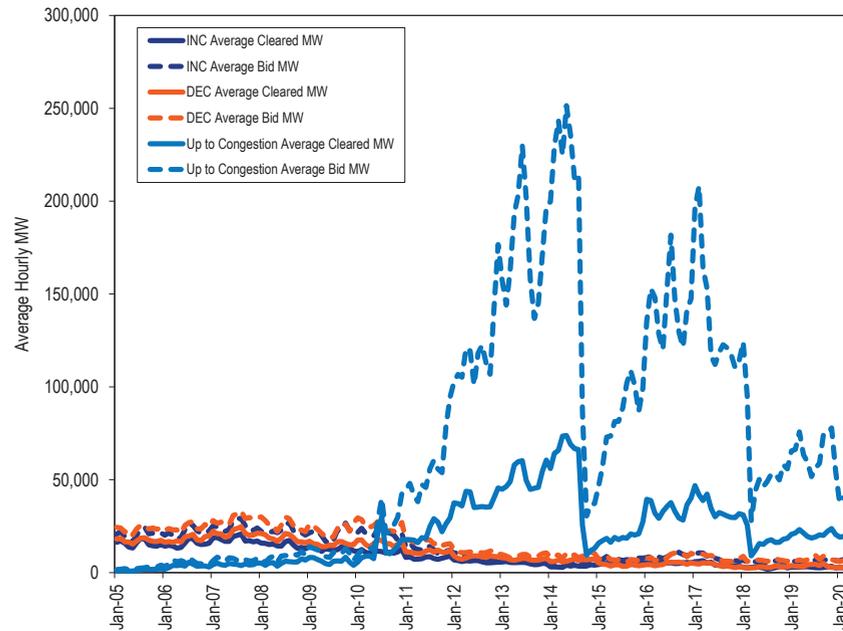
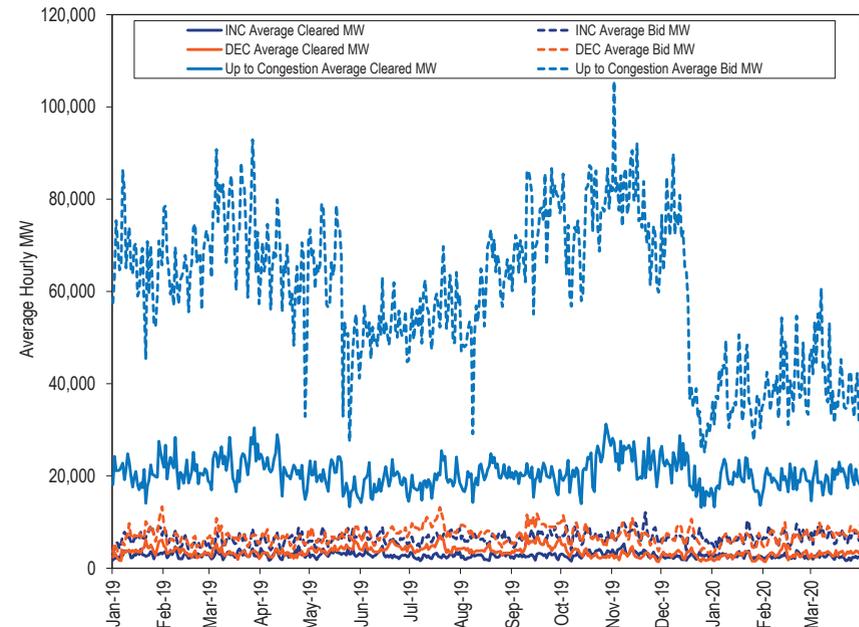


Figure 3-22 shows the daily volume of bid and cleared INC, DEC and up to congestion bids from January 1, 2019 through March 31, 2020.

Figure 3-22 Daily bid and cleared INCs, DECs, and UTCs (MW): January 2019 through March 2020



In order to evaluate the ownership of virtual bids, the MMU categorizes all participants making virtual bids in PJM as either physical or financial. Physical entities include utilities and customers which primarily take physical positions in PJM markets. Financial entities include banks and hedge funds which primarily take financial positions in PJM markets. International market participants that primarily take financial positions in PJM markets are generally considered to be financial entities even if they are utilities in their own countries.

Table 3-23 shows, in the first three months of 2019 and 2020, the total increment offers and decrement bids and cleared MW by type of parent organization.

Table 3-23 INC and DEC bids and cleared MWh by type of parent organization (MWh): January through March, 2019 and 2020

Category	2019 (Jan-Mar)				2020 (Jan-Mar)			
	Total Virtual Bid		Total Virtual Cleared		Total Virtual Bid		Total Virtual Cleared	
	MWh	Percent	MWh	Percent	MWh	Percent	MWh	Percent
Financial	23,732,617	85.2%	11,355,770	81.2%	25,754,885	86.9%	9,953,228	83.5%
Physical	4,123,739	14.8%	2,629,675	18.8%	3,871,807	13.1%	1,962,890	16.5%
Total	27,856,356	100.0%	13,985,445	100.0%	29,626,693	100.0%	11,916,118	100.0%

Table 3-24 shows, in the first three months of 2019 and 2020, the total up to congestion bids and cleared MWh by type of parent organization.

Table 3-24 Up to congestion transactions by type of parent organization (MWh): January through March, 2019 and 2020

Category	2019 (Jan-Mar)				2020 (Jan-Mar)			
	Total Up to Congestion Bid		Total Up to Congestion Cleared		Total Up to Congestion Bid		Total Up to Congestion Cleared	
	MWh	Percent	MWh	Percent	MWh	Percent	MWh	Percent
Financial	145,031,747	97.0%	44,087,670	94.0%	79,649,232	92.2%	38,148,831	90.3%
Physical	4,527,955	3.0%	2,838,926	6.0%	6,772,283	7.8%	4,076,902	9.7%
Total	149,559,702	100.0%	46,926,595	100.0%	86,421,514	100.0%	42,225,733	100.0%

Table 3-25 shows in the first three months of 2019 and 2020, the total import and export transactions by whether the parent organization was financial or physical.

Table 3-25 Import and export transactions by type of parent organization (MW): January through March, 2019 and 2020

Category	2019 (Jan-Mar)			2020 (Jan-Mar)		
	Total Import and Export		Percent	Total Import and Export		Percent
	MW			MW		
Day-Ahead	Financial	1,980,116	25.3%	2,085,351	29.0%	
	Physical	5,859,839	74.7%	5,099,457	71.0%	
	Total	7,839,955	100.0%	7,184,808	100.0%	
Real-Time	Financial	3,240,009	22.2%	3,434,767	28.6%	
	Physical	11,342,196	77.8%	8,589,992	71.4%	
	Total	14,582,205	100.0%	12,024,759	100.0%	

Table 3-26 shows increment offers and decrement bids by top 10 locations in the first three months of 2019 and 2020.

Table 3-26 Virtual offers and bids by top 10 locations (MW): January through March, 2019 and 2020

2019 (Jan-Mar)					2020 (Jan-Mar)				
Aggregate/Bus Name	Aggregate/Bus Type	INC MW	DEC MW	Total MW	Aggregate/Bus Name	Aggregate/Bus Type	INC MW	DEC MW	Total MW
MISO	INTERFACE	33,393	802,657	836,049	MISO	INTERFACE	14,445	1,169,382	1,183,827
WESTERN HUB	HUB	281,346	423,323	704,669	WESTERN HUB	HUB	167,868	467,388	635,255
SOUTHIMP	INTERFACE	615,089	0	615,089	BGE_RESID_AGG	RESIDUAL METERED EDC	78,576	272,351	350,927
LINDENVFT	INTERFACE	8,498	597,682	606,181	SOUTHIMP	INTERFACE	350,635	0	350,635
DOMINION HUB	HUB	221,472	148,001	369,472	AEP-DAYTON HUB	HUB	94,756	226,372	321,128
AEP-DAYTON HUB	HUB	145,009	215,149	360,158	DOM_RESID_AGG	RESIDUAL METERED EDC	56,211	237,552	293,762
DOM_RESID_AGG	RESIDUAL METERED EDC	83,662	226,237	309,899	PECO_RESID_AGG	RESIDUAL METERED EDC	211,336	47,647	258,983
NYIS	INTERFACE	175,673	118,939	294,612	NORTHWEST	INTERFACE	170,458	69,208	239,666
N ILLINOIS HUB	HUB	111,645	149,357	261,001	NYIS	INTERFACE	188,901	16,389	205,290
HUDSONTP	INTERFACE	11,691	222,044	233,735	N ILLINOIS HUB	HUB	67,208	129,870	197,078
Top ten total		1,687,477	2,903,388	4,590,865			1,400,393	2,636,158	4,036,551
PJM total		6,338,067	7,647,378	13,985,445			5,576,998	6,355,354	11,932,352
Top ten total as percent of PJM total		26.6%	38.0%	32.8%			25.1%	41.5%	33.8%

Table 3-27 shows up to congestion transactions by import bids for the top 10 locations and associated profits at each path in the first three months of 2019 and 2020.³⁴

Table 3-27 Cleared up to congestion import bids by top 10 source and sink pairs (MW): January through March, 2019 and 2020

2019 (Jan-Mar)							
Imports							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
NORTHWEST	INTERFACE	N ILLINOIS HUB	HUB	1,681,452	\$25,922	\$314,058	\$339,980
NORTHWEST	INTERFACE	COMED_RESID_AGG	AGGREGATE	975,678	\$103,441	\$246,474	\$349,915
NORTHWEST	INTERFACE	CHICAGO GEN HUB	HUB	824,074	\$158,618	(\$54,605)	\$104,013
SOUTHIMP	INTERFACE	AEPAPCO_RESID_AGG	AGGREGATE	454,733	\$462,439	(\$132,807)	\$329,631
NORTHWEST	INTERFACE	CHICAGO HUB	HUB	419,845	(\$19,931)	\$24,391	\$4,460
NYIS	INTERFACE	RECO_RESID_AGG	AGGREGATE	399,990	(\$648,719)	\$794,477	\$145,758
SOUTHIMP	INTERFACE	AEP GEN HUB	HUB	397,834	\$787,122	(\$341,020)	\$446,102
NEPTUNE	INTERFACE	JCPL_RESID_AGG	AGGREGATE	345,919	\$92,882	(\$38,867)	\$54,015
SOUTHIMP	INTERFACE	DOMINION HUB	HUB	311,025	\$426,021	(\$358,688)	\$67,333
MISO	INTERFACE	AEPIM_RESID_AGG	AGGREGATE	291,584	\$36,133	\$18,002	\$54,135
Top ten total				6,102,133	\$1,423,926	\$471,415	\$1,895,341
PJM total				11,006,603	\$5,398,988	(\$1,785,395)	\$3,613,593
Top ten total as percent of PJM total				55.4%	26.4%	(26.4%)	52.5%
2020 (Jan-Mar)							
Imports							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
NORTHWEST	INTERFACE	N ILLINOIS HUB	HUB	1,574,058	\$1,328,622	(\$768,663)	\$559,959
NORTHWEST	INTERFACE	COMED_RESID_AGG	AGGREGATE	1,176,513	\$1,160,149	(\$553,878)	\$606,271
NORTHWEST	INTERFACE	CHICAGO GEN HUB	HUB	797,190	\$742,282	(\$447,924)	\$294,358
NEPTUNE	INTERFACE	JCPL_RESID_AGG	AGGREGATE	640,146	(\$245,889)	\$244,783	(\$1,106)
NYIS	INTERFACE	RECO_RESID_AGG	AGGREGATE	443,387	(\$58,877)	\$98,424	\$39,547
MISO	INTERFACE	AEPIM_RESID_AGG	AGGREGATE	356,197	\$150,933	(\$110,249)	\$40,684
NORTHWEST	INTERFACE	CHICAGO HUB	HUB	203,022	\$225,946	(\$145,495)	\$80,452
NORTHWEST	INTERFACE	AEP-DAYTON HUB	HUB	191,333	\$346,308	(\$144,246)	\$202,062
NEPTUNE	INTERFACE	PSEG_RESID_AGG	AGGREGATE	173,940	\$87,335	(\$90,519)	(\$3,184)
NORTHWEST	INTERFACE	FEOHIO_RESID_AGG	AGGREGATE	155,590	\$245,319	(\$180,293)	\$65,026
Top ten total				5,711,376	\$3,982,129	(\$2,098,059)	\$1,884,070
PJM total				8,369,907	\$5,001,442	(\$3,023,534)	\$1,977,908
Top ten total as percent of PJM total				68.2%	79.6%	69.4%	95.3%

³⁴ The source and sink aggregates in these tables refer to the name and location of a bus and do not include information about the behavior of any individual market participant.

Table 3-28 shows up to congestion transactions by export bids for the top 10 locations and associated profits at each path in the first three months of 2019 and 2020.

Table 3-28 Cleared up to congestion export bids by top 10 source and sink pairs (MW): January through March, 2019 and 2020

2019 (Jan-Mar)							
Exports							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
N ILLINOIS HUB	HUB	NIPSCO	INTERFACE	373,678	\$760,038	(\$461,562)	\$298,476
CHICAGO GEN HUB	HUB	NIPSCO	INTERFACE	284,431	\$112,680	\$92,284	\$204,964
COMED_RESID_AGG	AGGREGATE	NIPSCO	INTERFACE	268,681	\$334,388	\$159,591	\$493,978
CHICAGO GEN HUB	HUB	NORTHWEST	INTERFACE	245,361	(\$304,905)	\$298,395	(\$6,510)
CHICAGO HUB	HUB	NIPSCO	INTERFACE	240,796	\$683,630	\$400,514	\$1,084,144
CHICAGO HUB	HUB	MISO	INTERFACE	236,673	\$268,901	(\$212,876)	\$56,025
CHICAGO GEN HUB	HUB	MISO	INTERFACE	193,199	\$69,519	(\$48,039)	\$21,480
N ILLINOIS HUB	HUB	MISO	INTERFACE	192,426	(\$151,775)	\$107,233	(\$44,542)
N ILLINOIS HUB	HUB	NORTHWEST	INTERFACE	146,656	(\$2,012)	(\$118,683)	(\$120,695)
AEP GEN HUB	HUB	NIPSCO	INTERFACE	144,412	\$79,730	\$50,254	\$129,984
Top ten total				2,326,313	\$1,850,195	\$267,111	\$2,117,305
PJM total				4,573,556	\$2,459,098	\$490,894	\$2,949,992
Top ten total as percent of PJM total				50.9%	75.2%	54.4%	71.8%
2020 (Jan-Mar)							
Exports							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
COMED_RESID_AGG	AGGREGATE	NIPSCO	INTERFACE	946,486	\$1,012,324	(\$926,318)	\$86,005
CHICAGO HUB	HUB	NIPSCO	INTERFACE	482,558	\$195,142	(\$47,650)	\$147,492
COMED_RESID_AGG	AGGREGATE	MISO	INTERFACE	391,482	\$202,228	(\$159,647)	\$42,581
N ILLINOIS HUB	HUB	NIPSCO	INTERFACE	362,074	\$140,762	(\$56,136)	\$84,626
COMED_RESID_AGG	AGGREGATE	NORTHWEST	INTERFACE	304,337	(\$29,015)	\$301,362	\$272,347
CHICAGO GEN HUB	HUB	NIPSCO	INTERFACE	289,883	\$265,772	(\$237,036)	\$28,735
CHICAGO GEN HUB	HUB	MISO	INTERFACE	163,710	\$136,640	(\$138,780)	(\$2,140)
COMED_RESID_AGG	AGGREGATE	SOUTHEXP	INTERFACE	140,327	\$35,820	\$11,863	\$47,683
CHICAGO HUB	HUB	MISO	INTERFACE	107,321	\$87,351	(\$75,009)	\$12,342
RECO_RESID_AGG	AGGREGATE	HUDSONTP	INTERFACE	102,652	(\$29,599)	\$47,141	\$17,542
Top ten total				3,290,830	\$2,017,425	(\$1,280,211)	\$737,214
PJM total				4,636,874	\$2,430,307	(\$1,121,312)	\$1,308,995
Top ten total as percent of PJM total				71.0%	83.0%	114.2%	56.3%

Table 3-29 shows up to congestion transactions by wheel bids and associated profits at each path for the top 10 locations in the first three months of 2019 and 2020.

Table 3-29 Cleared up to congestion wheel bids by top 10 source and sink pairs (MW): January through March, 2019 and 2020

2019 (Jan-Mar)							
Wheels							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
MISO	INTERFACE	NIPSCO	INTERFACE	460,975	\$472,388	(\$214,603)	\$257,784
NORTHWEST	INTERFACE	MISO	INTERFACE	394,199	\$326,378	(\$168,207)	\$158,171
NORTHWEST	INTERFACE	NIPSCO	INTERFACE	381,223	\$179,002	\$69,209	\$248,211
MISO	INTERFACE	NORTHWEST	INTERFACE	321,758	(\$122,155)	\$330,924	\$208,769
SOUTHIMP	INTERFACE	NIPSCO	INTERFACE	235,441	\$300,120	\$480,575	\$780,695
SOUTHIMP	INTERFACE	MISO	INTERFACE	222,316	\$108,978	\$121,898	\$230,877
LINDENVFT	INTERFACE	HUDSONTP	INTERFACE	100,588	(\$7,210)	\$59,357	\$52,147
NYIS	INTERFACE	HUDSONTP	INTERFACE	35,743	\$20,825	(\$27,424)	(\$6,599)
NYIS	INTERFACE	IMO	INTERFACE	26,809	(\$62,350)	\$54,838	(\$7,512)
SOUTHIMP	INTERFACE	NORTHWEST	INTERFACE	25,129	\$37,004	(\$2,044)	\$34,960
Top ten total				2,204,180	\$1,252,979	\$704,523	\$1,957,503
PJM total				2,506,551	\$1,412,519	\$603,397	\$2,015,916
Top ten total as percent of PJM total				87.9%	88.7%	116.8%	97.1%
2020 (Jan-Mar)							
Wheels							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
NORTHWEST	INTERFACE	MISO	INTERFACE	681,539	\$900,044	(\$480,500)	\$419,545
MISO	INTERFACE	NIPSCO	INTERFACE	547,270	\$197,931	(\$77,884)	\$120,047
NORTHWEST	INTERFACE	NIPSCO	INTERFACE	454,872	\$244,297	(\$74,218)	\$170,079
SOUTHIMP	INTERFACE	MISO	INTERFACE	241,635	(\$123,015)	\$114,527	(\$8,488)
MISO	INTERFACE	SOUTHEXP	INTERFACE	192,105	\$125,677	(\$54,796)	\$70,881
LINDENVFT	INTERFACE	HUDSONTP	INTERFACE	167,918	(\$17,632)	\$23,039	\$5,407
MISO	INTERFACE	NORTHWEST	INTERFACE	59,949	\$31,317	(\$3,978)	\$27,340
NEPTUNE	INTERFACE	HUDSONTP	INTERFACE	42,476	\$6,755	(\$12,804)	(\$6,049)
NYIS	INTERFACE	HUDSONTP	INTERFACE	31,420	(\$38,893)	\$40,618	\$1,725
SOUTHIMP	INTERFACE	NORTHWEST	INTERFACE	31,029	\$30,993	(\$7,235)	\$23,758
Top ten total				2,450,213	\$1,357,473	(\$533,230)	\$824,243
PJM total				2,626,014	\$1,370,028	(\$532,318)	\$837,709
Top ten total as percent of PJM total				93.3%	99.1%	100.2%	98.4%

On November 1, 2012, PJM eliminated the requirement for market participants to specify an interface pricing point as either the source or sink of an up to congestion transaction. The top 10 internal up to congestion transaction locations were 26.9 percent of the PJM total internal up to congestion transactions MW in the first three months of 2020.

Table 3-30 shows up to congestion transactions by internal bids for the top 10 locations and associated profits at each path in the first three months of 2019 and 2020. The total internal UTC profits increased by \$1.0 million, from -\$0.3 million in the first three months of 2019 to \$0.8 million in the first three months

of 2020. The total internal cleared MW decreased by 2.2 million MW, or 7.8 percent, from 28.8 million MW in the first three months of 2019 to 26.6 million MW in the first three months of 2020.

Table 3-30 Cleared up to congestion internal bids by top 10 source and sink pairs (MW): January through March, 2019 and 2020

2019 (Jan-Mar)							
Internal							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
OVEC_RESID_AGG	AGGREGATE	DEOK_RESID_AGG	AGGREGATE	986,270	\$471,401	(\$711,647)	(\$240,245)
AEP GEN HUB	HUB	AEPOHIO_RESID_AGG	AGGREGATE	599,675	\$329,624	(\$329,783)	(\$159)
SMECO_RESID_AGG	AGGREGATE	BGE_RESID_AGG	AGGREGATE	592,863	\$1,087,083	(\$887,858)	\$199,226
OVEC_RESID_AGG	AGGREGATE	DAY_RESID_AGG	AGGREGATE	519,883	\$161,073	(\$184,709)	(\$23,635)
AEP GEN HUB	HUB	FEOHIO_RESID_AGG	AGGREGATE	489,781	\$542,077	(\$726,649)	(\$184,573)
AEP GEN HUB	HUB	AEP-DAYTON HUB	HUB	460,432	\$339,789	(\$354,880)	(\$15,091)
AEP GEN HUB	HUB	ATSI GEN HUB	HUB	412,440	\$236,886	(\$417,725)	(\$180,838)
N ILLINOIS HUB	HUB	CHICAGO HUB	HUB	402,038	(\$651,411)	\$725,860	\$74,448
DOM_RESID_AGG	AGGREGATE	DOMINION HUB	HUB	341,138	\$282,968	(\$242,329)	\$40,639
PECO_RESID_AGG	AGGREGATE	PSEG_RESID_AGG	AGGREGATE	323,959	(\$220,808)	\$169,721	(\$51,087)
Top ten total				5,128,479	\$2,578,683	(\$2,959,999)	(\$381,316)
PJM total				28,839,885	\$16,296,480	(\$16,584,985)	(\$288,506)
Top ten total as percent of PJM total				17.8%	15.8%	17.8%	132.2%
2020 (Jan-Mar)							
Internal							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
SMECO_RESID_AGG	AGGREGATE	BGE_RESID_AGG	AGGREGATE	1,200,986	\$590,728	(\$650,182)	(\$59,454)
AEP GEN HUB	HUB	AEPOHIO_RESID_AGG	AGGREGATE	1,167,229	\$669,595	(\$647,868)	\$21,727
OVEC_RESID_AGG	AGGREGATE	DEOK_RESID_AGG	AGGREGATE	797,813	\$463,922	(\$478,652)	(\$14,731)
AEP GEN HUB	HUB	EKPC_RESID_AGG	AGGREGATE	651,478	\$408,650	(\$313,382)	\$95,268
OVEC_RESID_AGG	AGGREGATE	DAY_RESID_AGG	AGGREGATE	643,826	\$258,214	(\$298,187)	(\$39,973)
N ILLINOIS HUB	HUB	AEPIM_RESID_AGG	AGGREGATE	556,030	\$160,171	(\$55,530)	\$104,642
AEP GEN HUB	HUB	DEOK_RESID_AGG	AGGREGATE	541,332	\$282,220	(\$254,688)	\$27,533
AEP GEN HUB	HUB	AEP-DAYTON HUB	HUB	536,643	\$245,021	(\$252,278)	(\$7,256)
CHICAGO GEN HUB	HUB	AEPIM_RESID_AGG	AGGREGATE	529,436	\$274,631	(\$215,483)	\$59,148
AEP GEN HUB	HUB	DAY_RESID_AGG	AGGREGATE	521,709	\$353,687	(\$327,389)	\$26,299
Top ten total				7,146,482	\$3,706,839	(\$3,493,637)	\$213,202
PJM total				26,592,938	\$10,279,959	(\$9,521,706)	\$758,253
Top ten total as percent of PJM total				26.9%	36.1%	36.7%	28.1%

Table 3-31 shows the number of source-sink pairs that were offered and cleared monthly for January 1, 2019 through March 31, 2020.

Table 3-31 Number of offered and cleared source and sink pairs: January 2019 through March 2020

Daily Number of Source-Sink Pairs					
Year	Month	Average Offered	Max Offered	Average Cleared	Max Cleared
2019	Jan	1,693	1,893	1,527	1,712
2019	Feb	1,701	1,881	1,496	1,733
2019	Mar	1,673	1,806	1,506	1,653
2019	Apr	1,555	1,806	1,395	1,653
2019	May	1,584	1,856	1,424	1,718
2019	Jun	1,770	1,970	1,601	1,797
2019	Jul	1,767	1,950	1,635	1,819
2019	Aug	1,880	2,034	1,690	1,879
2019	Sep	1,891	2,007	1,702	1,842
2019	Oct	1,837	1,935	1,607	1,756
2019	Nov	1,796	1,984	1,576	1,700
2019	Dec	1,687	1,935	1,507	1,769
2019	Annual	1,736	1,921	1,555	1,753
2020	Jan	1,658	1,942	1,523	1,857
2020	Feb	1,710	1,975	1,568	1,725
2020	Mar	1,789	2,013	1,591	1,832
2020	Jan-Mar	1,719	1,977	1,561	1,805

Table 3-32 and Figure 3-23 show total cleared up to congestion transactions by type in the first three months of 2019 and 2020. Total up to congestion transactions in the first three months of 2020 decreased by 10.0 percent from 46.9 million MW in the first three months of 2019 to 42.2 million MW in the first three months of 2020. Internal up to congestion transactions in the first three months of 2020 were 63.0 percent of all up to congestion transactions compared to 61.5 percent in the first three months of 2019.

Table 3-32 Cleared up to congestion transactions by type (MW): January through March, 2019 and 2020

2019 (Jan-Mar)					
Cleared Up to Congestion Bids					
	Import	Export	Wheel	Internal	Total
Top ten total (MW)	6,102,133	2,326,313	2,204,180	5,128,479	15,761,106
PJM total (MW)	11,006,603	4,573,556	2,506,551	28,839,885	46,926,595
Top ten total as percent of PJM total	55.4%	50.9%	87.9%	17.8%	33.6%
PJM total as percent of all up to congestion transactions	23.5%	9.7%	5.3%	61.5%	100.0%
2020 (Jan-Mar)					
Cleared Up to Congestion Bids					
	Import	Export	Wheel	Internal	Total
Top ten total (MW)	5,711,376	3,290,830	2,450,213	7,146,482	18,598,902
PJM total (MW)	8,369,907	4,636,874	2,626,014	26,592,938	42,225,733
Top ten total as percent of PJM total	68.2%	71.0%	93.3%	26.9%	44.0%
PJM total as percent of all up to congestion transactions	19.8%	11.0%	6.2%	63.0%	100.0%

Figure 3-23 shows the initial increase and continued increase in internal up to congestion transactions by month following the November 1, 2012, rule change permitting such transactions, until September 8, 2014. The reduction in up to congestion transactions (UTC) that followed a FERC order setting September 8, 2014, as the effective date for any uplift charges subsequently assigned to UTCs, was reversed.³⁵ There was an increase in up to congestion volume as a result of the expiration of the 15 month refund period for the proceeding related to uplift charges for UTC transactions. But in 2018, the percent of marginal up to congestion transactions again decreased significantly as the result of a FERC order issued on February 20, 2018, and implemented on February 22, 2018.³⁶ The order limited UTC trading to hubs, residual metered load, and interfaces. The reduction in UTC bid locations effective February

³⁵ See 162 FERC ¶ 61,139 (2018).

³⁶ *Id.*

22, 2018, resulted in a significant reduction in total activity. UTC activity has increased, following that reduction.

Figure 3-23 Monthly cleared up to congestion transactions by type (MW): January 2005 through March 2020

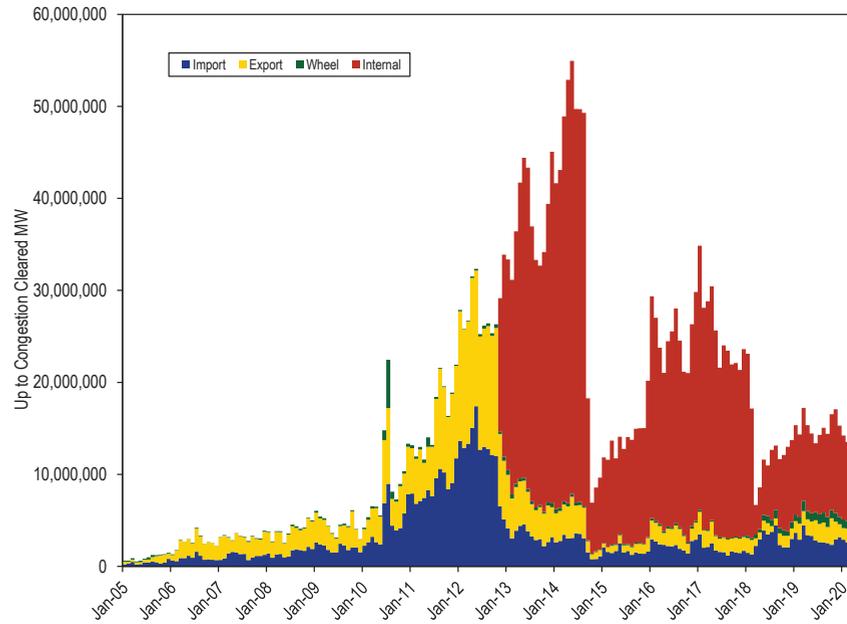
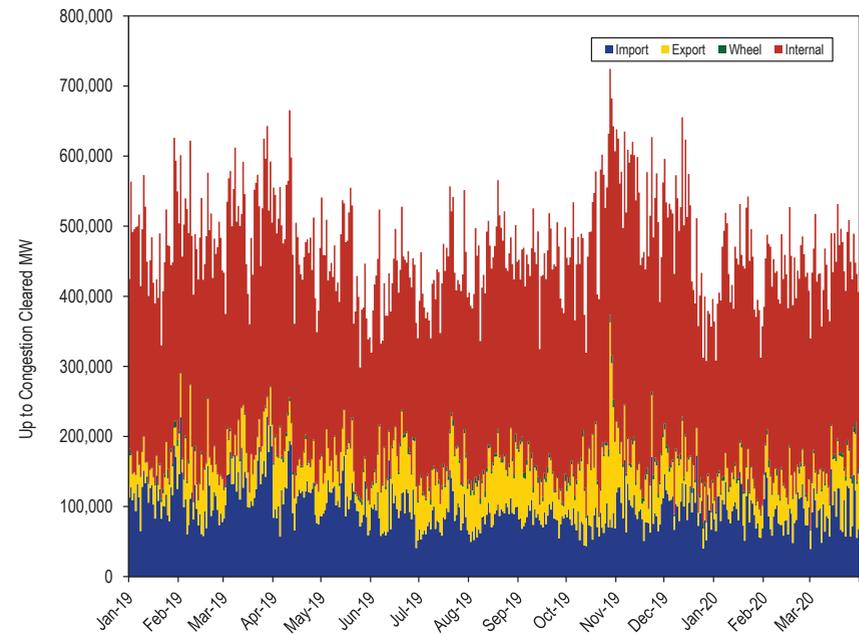


Figure 3-24 shows the daily cleared up to congestion MW by transaction type from January 1, 2019 through March 31, 2020.

Figure 3-24 Daily cleared up to congestion transaction by type (MW): January 2019 through March 2020



Market Performance

PJM locational marginal prices (LMPs) are a direct measure of market performance. The market performs optimally when the market structure provides incentives for market participants to behave competitively. In a competitive market, prices equal the short run marginal cost of the marginal unit of output and reflect the most efficient and least cost allocation of resources to meet demand.

LMP

The behavior of individual market entities within a market structure is reflected in market prices. PJM locational marginal prices (LMPs) are a direct measure of market performance. Price level is a good, general indicator of market performance, although overall price results must be interpreted carefully because of the multiple factors that affect them. Among other things, overall average prices reflect changes in supply and demand, generation fuel mix, the cost of fuel, emission related expenses, markup and local price differences caused by congestion. PJM also may administratively set prices with the creation of a closed loop interface related to demand side resources or reactive power or influence prices through manual interventions such as load biasing, changing constraint limits and penalty factors, and committing reserves beyond the requirement.

Real-time and day-ahead energy market load-weighted prices were 34.2 percent and 34.6 percent lower in the first three months of 2020 than in the first three months of 2019. Both the weather and COVID-19 played a role in this significant drop in prices.

PJM real-time energy market prices decreased in the first three months of 2020 compared to the first three months of 2019. The average LMP was 33.3 percent lower in the first three months of 2020 than in the first three months of 2019, \$19.42 per MWh versus \$29.13 per MWh. The load-weighted average real-time LMP was 34.2 percent lower in the first three months of 2020 than in the first three months of 2019, \$19.85 per MWh versus \$30.16 per MWh.

The real-time load-weighted average LMP for the first three months of 2020 was 19.4 percent lower than the real-time fuel-cost adjusted, load-weighted, average LMP for the first three months of 2020. If fuel and emission costs in the first three months of 2020 had been the same as in the first three months of 2019, holding everything else constant, the load-weighted LMP would have been higher, \$24.64 per MWh instead of the observed \$19.85 per MWh.

PJM day-ahead energy market prices decreased in the first three months of 2020 compared to the first three months of 2019. The day-ahead average LMP was 33.7 percent lower in the first three months of 2020 than in the first three months of 2019, \$19.66 per MWh versus \$29.65 per MWh. The day-ahead load-weighted average LMP was 34.6 percent lower in the first three months of 2020 than in the first three months of 2019, \$20.12 per MWh versus \$30.76 per MWh.

Occasionally, in a constrained market, the LMPs at some pricing nodes can exceed the offer price of the highest cleared generator in the supply curve.³⁷ In the nodal pricing system, the LMP at a pricing node is the total cost of meeting incremental demand at that node. When there are binding transmission constraints, satisfying the marginal increase in demand at a node may require increasing the output of some generators while simultaneously decreasing the output of other generators, such that the transmission constraints are not violated. The total cost of redispatching multiple generators can at times exceed the cost of marginally increasing the output of the most expensive generator offered. Thus, the LMPs at some pricing nodes exceed \$1,000 per MWh, the cap on the generators' offer price in the PJM market.³⁸

LMP may, at times, be set by transmission penalty factors, which exceed \$1,000 per MWh. When a transmission constraint is binding and there are no generation alternatives to resolve the constraint, system operators may allow the transmission limit to be violated. When this occurs, the shadow price of the constraint is set by transmission penalty factors. The shadow price directly

³⁷ See O'Neill R. P, Mead D. and Malvadkar P. "On Market Clearing Prices Higher than the Highest Bid and Other Almost Paranormal Phenomena." *The Electricity Journal* 2005; 18(2) at 19-27.

³⁸ The offer cap in PJM was temporarily increased to \$1,800 per MWh prior to the winter of 2014/2015. A new cap of \$2,000 per MWh, only for offers with costs exceeding \$1,000 per MWh, went into effect on December 14, 2015. See 153 FERC ¶ 61,289 (2015).

affects the LMP. Transmission penalty factors are administratively determined and can be thought of as a form of locational scarcity pricing.

Real-Time Average LMP

Real-time average LMP is the hourly average LMP for the PJM Real-Time Energy Market.³⁹

PJM Real-Time, Average LMP

Table 3-33 shows the PJM real-time, average LMP for the first three months of 1998 through 2020.⁴⁰

Table 3-33 Real-time, average LMP (Dollars per MWh): January through March, 1998 through 2020

	Real-Time LMP			Year-to-Year Change		
	Average	Median	Standard Deviation	Average	Median	Standard Deviation
1998	\$17.51	\$15.30	\$7.84	NA	NA	NA
1999	\$18.79	\$16.56	\$7.29	7.3%	8.3%	(7.0%)
2000	\$23.66	\$17.73	\$16.22	25.9%	7.0%	122.4%
2001	\$33.77	\$26.01	\$20.79	42.8%	46.8%	28.2%
2002	\$22.23	\$19.22	\$9.61	(34.2%)	(26.1%)	(53.8%)
2003	\$49.57	\$43.08	\$30.54	123.0%	124.2%	217.9%
2004	\$46.37	\$41.04	\$24.07	(6.5%)	(4.8%)	(21.2%)
2005	\$46.51	\$40.62	\$22.07	0.3%	(1.0%)	(8.3%)
2006	\$52.98	\$46.15	\$23.29	13.9%	13.6%	5.5%
2007	\$55.34	\$47.15	\$33.29	4.5%	2.2%	43.0%
2008	\$66.75	\$57.05	\$35.54	20.6%	21.0%	6.8%
2009	\$47.29	\$40.56	\$21.99	(29.2%)	(28.9%)	(38.1%)
2010	\$44.13	\$37.82	\$21.87	(6.7%)	(6.8%)	(0.6%)
2011	\$44.76	\$38.14	\$23.10	1.4%	0.8%	5.6%
2012	\$30.38	\$28.82	\$11.63	(32.1%)	(24.4%)	(49.7%)
2013	\$36.33	\$32.29	\$18.47	19.6%	12.1%	58.9%
2014	\$84.04	\$48.77	\$119.84	131.3%	51.0%	548.8%
2015	\$47.39	\$31.95	\$42.42	(43.6%)	(34.5%)	(64.6%)
2016	\$25.60	\$22.91	\$12.99	(46.0%)	(28.3%)	(69.4%)
2017	\$29.39	\$25.71	\$12.28	14.8%	12.2%	(5.4%)
2018	\$44.65	\$26.83	\$49.68	51.9%	4.4%	304.5%
2019	\$29.13	\$25.36	\$15.09	(34.8%)	(5.5%)	(69.6%)
2020	\$19.42	\$18.56	\$6.98	(33.3%)	(26.8%)	(53.8%)

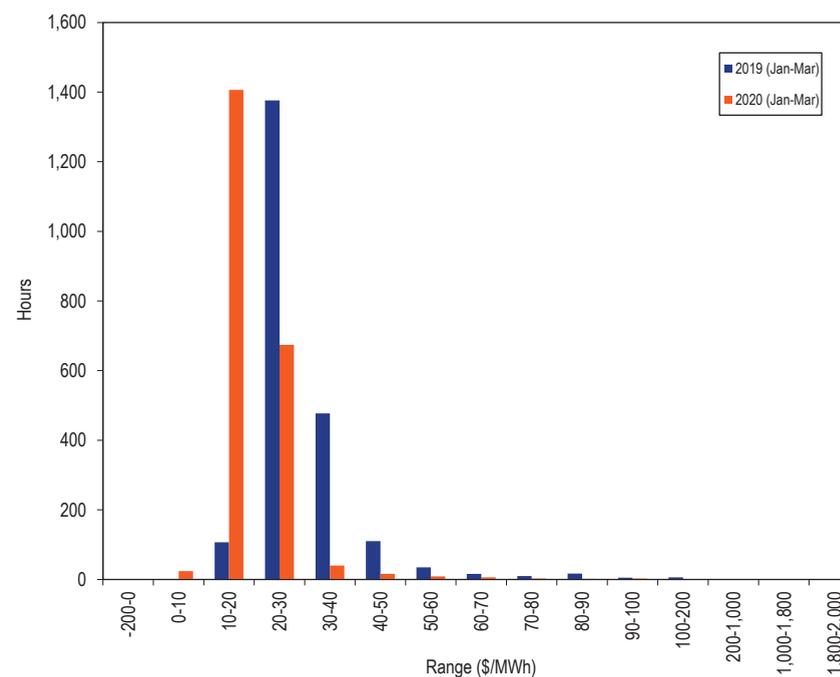
³⁹ See the *Technical Reference for PJM Markets*, at "Calculating Locational Marginal Price," p 16-18 for detailed definition of Real-Time LMP. <http://www.monitoringanalytics.com/reports/Technical_References/references.shtml>.

⁴⁰ The system average LMP is the average of the hourly LMP without any weighting. The only exception is that market-clearing prices (MCPs) are included for January to April 1998. MCP was the single market-clearing price calculated by PJM prior to implementation of LMP.

PJM Real-Time Average LMP Duration

Figure 3-25 shows the hourly distribution of PJM real-time average LMP for the first three months of 2019 and 2020.

Figure 3-25 Average LMP for the Real-Time Energy Market: January through March, 2019 and 2020



Real-Time, Load-Weighted, Average LMP

Higher demand (load) generally results in higher prices, all else constant. As a result, load-weighted, average prices are generally higher than average prices. Load-weighted LMP reflects the average LMP paid for actual MWh consumed during a year. Load-weighted, average LMP is the average of PJM hourly LMP, each weighted by the PJM total hourly load.

PJM Real-Time, Load-Weighted, Average LMP

Table 3-34 shows the PJM real-time, load-weighted, average LMP for the first three months of 1998 through 2020.

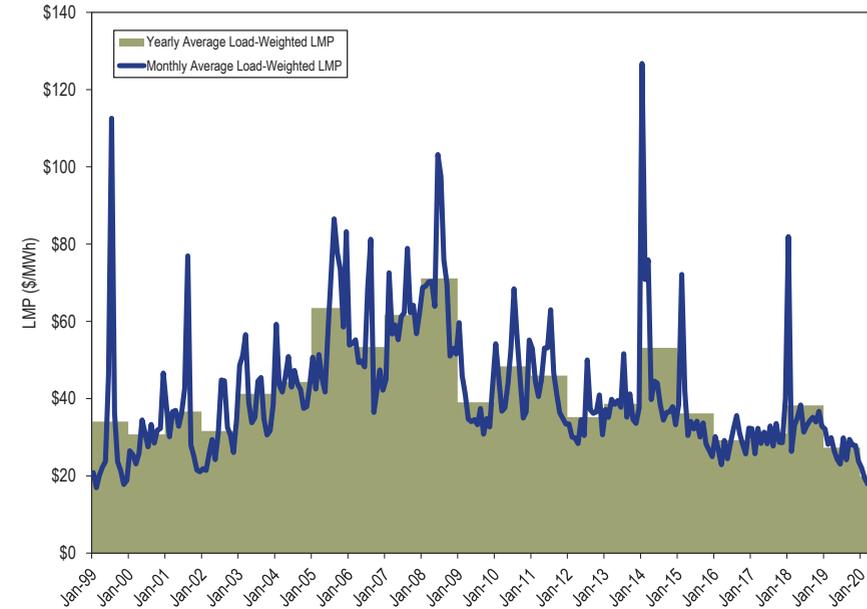
Table 3-34 Real-time, load-weighted, average LMP (Dollars per MWh): January through March, 1998 through 2020

(Jan-Mar)	Real-Time, Load-Weighted, Average LMP			Year-to-Year Change		
	Average	Median	Standard Deviation	Average	Median	Standard Deviation
1998	\$18.13	\$15.80	\$8.14	NA	NA	NA
1999	\$19.38	\$16.90	\$7.66	6.9%	7.0%	(5.9%)
2000	\$25.10	\$18.25	\$17.22	29.5%	8.0%	124.9%
2001	\$35.16	\$27.38	\$21.52	40.1%	50.0%	25.0%
2002	\$23.01	\$19.89	\$9.93	(34.6%)	(27.4%)	(53.8%)
2003	\$51.93	\$46.12	\$30.99	125.6%	131.9%	211.9%
2004	\$48.77	\$43.22	\$24.62	(6.1%)	(6.3%)	(20.6%)
2005	\$48.37	\$42.20	\$22.62	(0.8%)	(2.4%)	(8.1%)
2006	\$54.43	\$47.62	\$23.69	12.5%	12.9%	4.7%
2007	\$58.07	\$50.60	\$34.44	6.7%	6.3%	45.4%
2008	\$69.35	\$60.11	\$36.56	19.4%	18.8%	6.2%
2009	\$49.60	\$42.23	\$23.38	(28.5%)	(29.8%)	(36.1%)
2010	\$45.92	\$39.01	\$22.99	(7.4%)	(7.6%)	(1.7%)
2011	\$46.35	\$39.11	\$24.26	0.9%	0.3%	5.5%
2012	\$31.21	\$29.25	\$12.02	(32.7%)	(25.2%)	(50.5%)
2013	\$37.41	\$32.79	\$19.90	19.9%	12.1%	65.7%
2014	\$92.98	\$51.62	\$134.40	148.5%	57.4%	575.3%
2015	\$50.91	\$33.51	\$46.43	(45.2%)	(35.1%)	(65.5%)
2016	\$26.80	\$23.45	\$13.98	(47.4%)	(30.0%)	(69.9%)
2017	\$30.28	\$26.26	\$13.08	13.0%	12.0%	(6.4%)
2018	\$49.45	\$27.96	\$55.22	63.3%	6.5%	322.1%
2019	\$30.16	\$25.84	\$16.18	(39.0%)	(7.6%)	(70.7%)
2020	\$19.85	\$18.87	\$7.20	(34.2%)	(27.0%)	(55.5%)

PJM Real-Time, Monthly, Load-Weighted, Average LMP

Figure 3-26 shows the PJM real-time monthly and annual load-weighted LMP for January 1999 through March 2020.

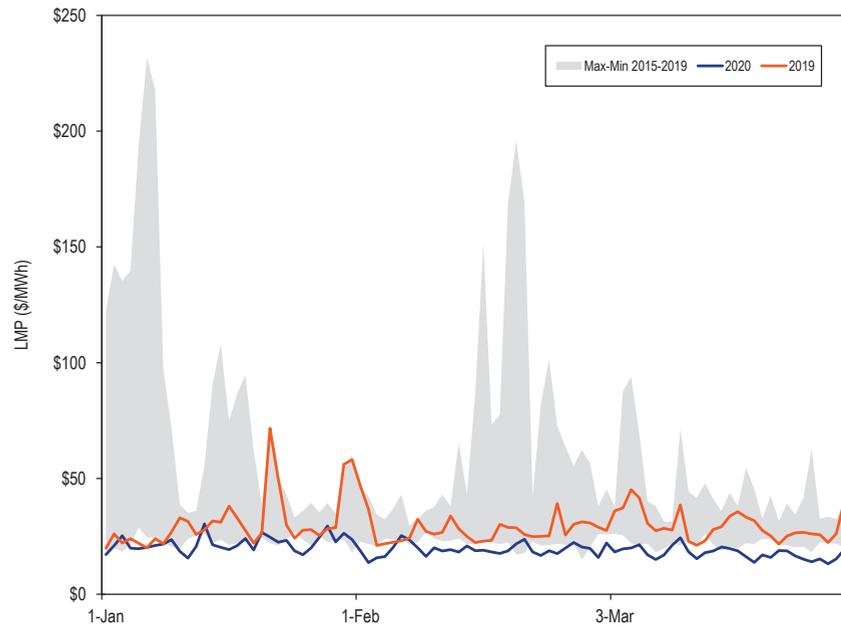
Figure 3-26 Real-time, monthly and annual, load-weighted, average LMP: January 1999 through March 2020



PJM Real-Time, Daily, Load-Weighted, Average LMP

Figure 3-27 shows the PJM real-time daily load-weighted LMP for the first three months of 2019 and 2020. Both the weather and COVID-19 played a role in this significant drop in prices.

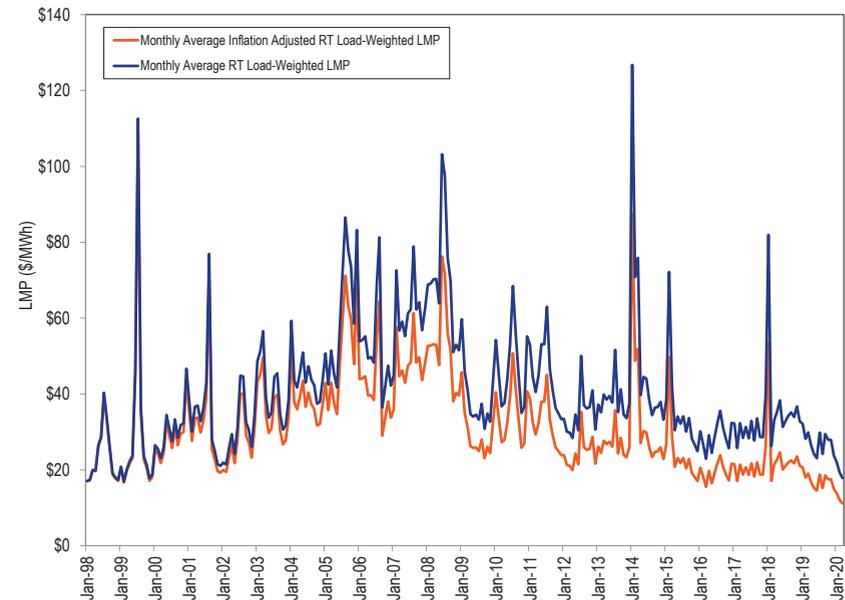
Figure 3-27 Real-time, daily, load-weighted, average LMP: January through March, 2019 and 2020



PJM Real-Time, Monthly, Inflation Adjusted Load-Weighted, Average LMP

Figure 3-28 shows the PJM real-time monthly load-weighted average LMP and inflation adjusted monthly load-weighted average LMP from January 1998 through March 2020.⁴¹ Table 3-35 shows the PJM real-time load-weighted average LMP and inflation adjusted load-weighted average LMP for the first three months of every year from 1998 through 2020. The PJM real-time inflation adjusted load-weighted average LMP for the first three months of 2020 was the lowest value (\$12.42 per MWh) since PJM real-time markets started on April 1, 1999. The real-time inflation adjusted monthly load-weighted average LMP for March 2020 (\$11.18 per MWh) was the lowest monthly value since PJM markets started in April 1999.

Figure 3-28 Real-time, monthly, load-weighted, average LMP unadjusted and adjusted for inflation: January 1998 through March 2020



⁴¹ To obtain the inflation adjusted monthly load-weighted average LMP, the PJM system-wide load-weighted average LMP is deflated using the US Consumer Price Index for all items, Urban Consumers (base period: January 1998), published by Bureau of Labor Statistics <<http://download.bls.gov/pub/time.series/cu/cu.data.1.AllItems>> (Accessed April 5, 2020)

Table 3-35 Real-time, yearly, load-weighted, average LMP unadjusted and adjusted for inflation: January through March, 1998 through 2020

	Load-Weighted, Average LMP (Jan-Mar)	Inflation Adjusted Load-Weighted, Average LMP (Jan-Mar)
1998	\$18.13	\$18.10
1999	\$19.38	\$19.03
2000	\$25.10	\$23.89
2001	\$35.16	\$32.35
2002	\$23.01	\$20.90
2003	\$51.93	\$45.86
2004	\$48.77	\$42.36
2005	\$48.37	\$40.73
2006	\$54.43	\$44.21
2007	\$58.07	\$46.05
2008	\$69.35	\$52.85
2009	\$49.60	\$37.83
2010	\$45.92	\$34.21
2011	\$46.35	\$33.83
2012	\$31.21	\$22.14
2013	\$37.41	\$26.09
2014	\$92.98	\$64.01
2015	\$50.91	\$35.04
2016	\$26.80	\$18.25
2017	\$30.28	\$20.11
2018	\$49.45	\$32.17
2019	\$30.16	\$19.28
2020	\$19.85	\$12.42

Real-Time Dispatch and Pricing

The PJM Real-Time Energy Market consists of a series of applications that produce the generator dispatch for energy and reserves, and five minute locational marginal prices (LMPs). These applications include the ancillary services optimizer (ASO), real-time security constrained economic dispatch (RT SCED), and the locational pricing calculator (LPC).⁴² The final real-time LMPs and ancillary service clearing prices are determined for every five minute interval by LPC.

The dispatch of reserves in LPC determines whether PJM implements scarcity pricing. Scarcity pricing transparency requires greater transparency around

⁴² See PJM, "Manual 11: Energy & Ancillary Services Market Operations," Rev. 108 (Dec. 3, 2019)

the processes used to determine load bias in RT SCED, to approve RT SCED cases, and the use of RT SCED cases by LPC.

Real-Time SCED and LPC

LPC uses data from an approved RT SCED solution that was used to dispatch the resources in the system. On average, PJM operators approve more than one RT SCED case per five minute interval to send dispatch signals to resources. PJM uses only a subset of these approved RT SCED cases in LPC to calculate real-time LMPs. As a result, a number of dispatch directives are not reflected in real-time energy market prices. Generally, LPC uses the latest available approved RT SCED case to calculate prices, regardless of the target dispatch time of the RT SCED case. However, LPC assigns the prices to a five minute interval that does not contain the target time of the RT SCED case it used.

Table 3-36 shows, on a monthly basis for the first three months of 2020, the number of RT SCED case solutions, the number of solutions that were approved and the number and percent of approved solutions used in LPC. Until February 24, 2020, RT SCED was executed every three minutes. Beginning February 24, 2020, PJM changed the RT SCED execution frequency to once every four minutes. PJM operators can also execute additional RT SCED cases. Each execution of RT SCED produces three solutions, using three different levels of load bias. Since prices are calculated every five minutes while three SCED solutions are produced every three or four minutes, there is, by definition, a larger number of solved SCED case solutions than there are five minute intervals in any given period. PJM operators approve a subset of RT SCED solutions to send dispatch signals to resources at an irregular frequency. Table 3-36 shows that in the first three months of 2020 only 70.2 percent of approved RT SCED case solutions that are used to send dispatch signals to generators are used in calculating real-time energy market prices. The percent of approved solutions used for pricing increased from 69.0 percent to 78.7 percent from February to March with the change in the frequency of executed RT SCED cases. This lack of a direct and regular direct connection between the dispatch signal and the price signal weakens the incentives to follow dispatch by generators, especially when RT SCED solutions that reflect shortage pricing are not used in calculating real-time prices in LPC.

Table 3-36 RT SCED cases solved, approved and used in pricing: January through March, 2020

Month (2020)	Number of RT SCED Case Solutions	Number of Approved RT SCED Case Solutions	Number of Approved RT SCED Solutions Used in LPC	RT SCED Solutions Used in LPC as Percent of Approved RT SCED Solutions
Jan	51,022	11,860	7,612	64.2%
Feb	46,247	10,149	7,005	69.0%
Mar	38,680	9,914	7,799	78.7%
Total	135,949	31,923	22,416	70.2%

PJM's process for solving and approving RT SCED cases, and selecting approved RT SCED cases to use in LPC to calculate LMPs has inconsistencies that lead to downstream impacts for energy and reserve dispatch and settlements. PJM does not link dispatch and settlement intervals. RT SCED is now solved every four minutes and cases are approved irregularly, while settlements are linked to five minute intervals. RT SCED solves the dispatch problem for a target time that is generally 10 to 14 minutes in the future. An RT SCED case is approved and sends dispatch signals to generators based on a 10 minute ramp time. The look ahead time for the load forecast and the look ahead time for the resource dispatch target do not match, and a new RT SCED case overrides the previously approved case before resources have time to achieve the previous target dispatch. The interval that is priced in LPC is consistently before the target time from the RT SCED case used for the dispatch signal. LPC takes the most recently approved RT SCED case to calculate LMPs. For example, the LPC case that calculates prices for the interval beginning 10:00 EPT uses an approved RT SCED case that sent MW dispatch signals for the target time of 10:10 EPT. This discrepancy creates a mismatch between the MW dispatch and real-time LMPs and undermines generators' incentive to follow dispatch.

Table 3-37 compares the RT SCED target time and LPC interval beginning times for the first three months of 2020. LPC interval beginning time is the beginning time of the five minute interval for which LPC calculates LMPs. Table 3-37 shows that in the first three months of 2020, 67.4 percent of the five minute intervals have prices assigned for an interval that began 10 minutes prior to the dispatch target time and 27.6 percent of five minute

intervals have prices assigned for a target interval that began five minutes prior to the dispatch target time.

Table 3-37 Difference in RT SCED target time and LPC interval beginning time: January through March, 2020

Difference between RT SCED target time and LPC interval beginning time (mins)	Percent of Five Minute Intervals
(10)	0.0%
(5)	0.4%
0	4.3%
5	31.7%
10	63.5%

For correct price signals and compensation, energy (LMP) and ancillary service pricing should align with the dispatch solution that is the basis for those prices for each and every real-time market interval.⁴³ The MMU recommends that PJM approve one RT SCED case for each five minute interval to dispatch resources during that interval, and that PJM calculate prices using LPC for that five minute interval using the same approved SCED case. This will result in prices used to settle energy for the five minute interval that ends at the SCED dispatch target time.

Recalculation of Five Minute Real-Time Prices

PJM's five minute interval LMPs are obtained from solved LPC cases. PJM recalculates five minute interval real-time LMPs as it believes necessary to correct errors. To do so, PJM reruns LPC cases with modified inputs. The PJM OATT allows for posting of recalculated real-time prices no later than 5:00 p.m. of the tenth calendar day following the operating day. The OATT also requires PJM to notify market participants of the underlying error no later than 5:00 pm of the second business day following the operating day.⁴⁴ Table 3-38 shows the number of five minute intervals in each month and number of five minute intervals in each month for which PJM recalculated real-time prices. In the first three months of 2020, PJM recalculated LMPs for 315 five

⁴³ See *Settlement Intervals and Shortage Pricing in Markets Operated by Regional Transmission Organizations and Independent System Operators*, Order No. 825, 155 FERC ¶ 61,276 (2016).

⁴⁴ OA Schedule 1 § 1.10.8(e).

minute intervals or 1.20 percent of the total 26,196 five minute intervals in the first three months.

Table 3-38 Number of five minute interval real-time prices recalculated: January through March, 2020

Month (2020)	Number of Five Minute Intervals	Number of Five Minute Intervals for which LMPs were recalculated
January	8,928	193
February	8,352	12
March	8,916	110
Total	26,196	315

Day-Ahead Average LMP

Day-ahead average LMP is the hourly average LMP for the PJM Day-Ahead Energy Market.⁴⁵

PJM Day-Ahead, Average LMP

Table 3-38 shows the PJM day-ahead, average LMP in the first three months of 2000 through 2020.

Table 3-39 Day-ahead, average LMP (Dollars per MWh): January through March, 2000 through 2020

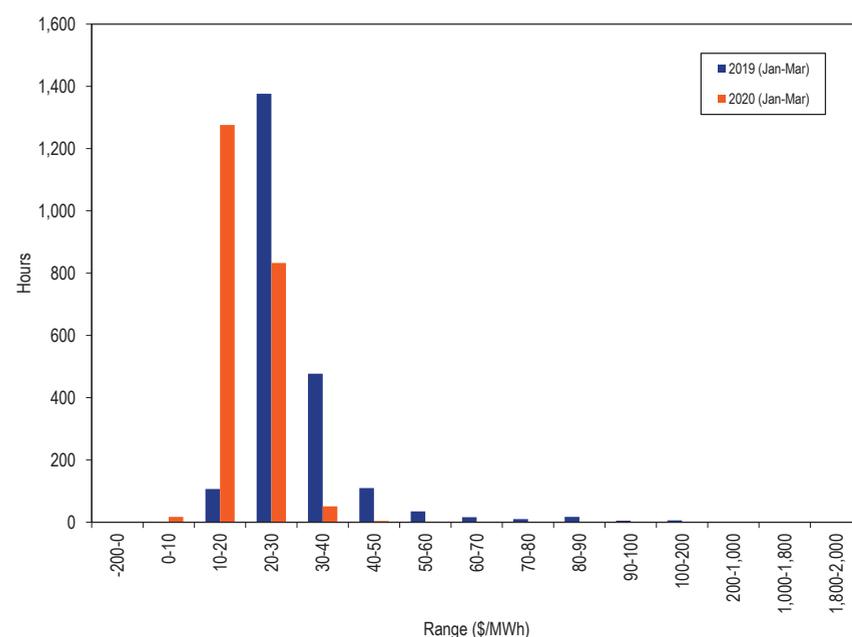
(Jan-Mar)	Day-Ahead LMP			Year-to-Year Change		
	Average	Median	Standard Deviation	Average	Median	Standard Deviation
2000	NA	NA	NA	NA	NA	NA
2001	\$36.45	\$32.72	\$16.39	NA	NA	NA
2002	\$22.43	\$20.59	\$7.56	(38.5%)	(37.1%)	(53.9%)
2003	\$51.20	\$46.06	\$25.65	128.2%	123.7%	239.3%
2004	\$45.84	\$43.01	\$18.85	(10.5%)	(6.6%)	(26.5%)
2005	\$45.14	\$41.56	\$16.19	(1.5%)	(3.4%)	(14.1%)
2006	\$51.23	\$48.53	\$14.16	13.5%	16.8%	(12.6%)
2007	\$52.76	\$49.43	\$22.59	3.0%	1.9%	59.5%
2008	\$66.10	\$62.57	\$23.90	25.3%	26.6%	5.8%
2009	\$47.41	\$43.43	\$16.85	(28.3%)	(30.6%)	(29.5%)
2010	\$46.13	\$41.99	\$15.93	(2.7%)	(3.3%)	(5.5%)
2011	\$45.60	\$41.10	\$16.82	(1.2%)	(2.1%)	5.6%
2012	\$30.82	\$30.04	\$6.63	(32.4%)	(26.9%)	(60.6%)
2013	\$36.46	\$34.45	\$9.78	18.3%	14.7%	47.5%
2014	\$86.52	\$52.80	\$92.80	137.3%	53.3%	848.8%
2015	\$48.62	\$35.48	\$36.77	(43.8%)	(32.8%)	(60.4%)
2016	\$26.90	\$25.11	\$8.83	(44.7%)	(29.2%)	(76.0%)
2017	\$29.59	\$27.33	\$8.54	10.0%	8.8%	(3.3%)
2018	\$43.59	\$29.01	\$38.64	47.3%	6.2%	352.5%
2019	\$29.65	\$26.82	\$11.28	(32.0%)	(7.6%)	(70.8%)
2020	\$19.66	\$19.14	\$4.43	(33.7%)	(28.6%)	(60.7%)

⁴⁵ See the *MMU Technical Reference for the PJM Markets*, at "Calculating Locational Marginal Price" for a detailed definition of Day-Ahead LMP. <http://www.monitoringanalytics.com/reports/Technical_References/references.shtml>.

PJM Day-Ahead Average LMP Duration

Figure 3-29 shows the hourly distribution of PJM day-ahead average LMP in the first three months of 2019 and 2020.

Figure 3-29 Average LMP for the Day-Ahead Energy Market: January through March, 2019 and 2020



Day-Ahead, Load-Weighted, Average LMP

Day-ahead, load-weighted LMP reflects the average LMP paid for day-ahead MWh. Day-ahead, load-weighted LMP is the average of PJM day-ahead hourly LMP, each weighted by the PJM total cleared day-ahead hourly load, including day-ahead fixed load, price-sensitive load, decrement bids and up to congestion.

PJM Day-Ahead, Load-Weighted, Average LMP

Table 3-40 shows the PJM day-ahead, load-weighted, average LMP in the first three months of 2000 through 2020.

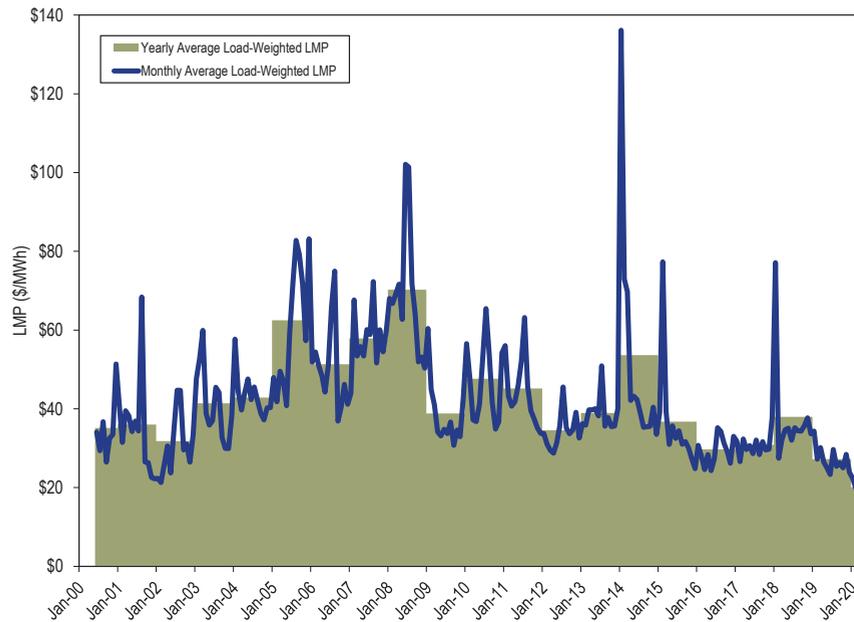
Table 3-40 Day-ahead, load-weighted, average LMP (Dollars per MWh): January through March, 2000 through 2020

(Jan-Mar)	Day-Ahead, Load-Weighted, Average LMP			Year-to-Year Change		
	Average	Median	Standard Deviation	Average	Median	Standard Deviation
2000	NA	NA	NA	NA	NA	NA
2001	\$37.70	\$34.55	\$16.66	NA	NA	NA
2002	\$23.17	\$21.18	\$7.76	(38.5%)	(38.7%)	(53.4%)
2003	\$53.16	\$48.69	\$25.75	129.5%	129.9%	231.7%
2004	\$47.75	\$45.02	\$19.19	(10.2%)	(7.5%)	(25.4%)
2005	\$46.54	\$42.88	\$16.46	(2.5%)	(4.8%)	(14.2%)
2006	\$52.40	\$49.51	\$14.29	12.6%	15.5%	(13.2%)
2007	\$54.87	\$51.89	\$23.16	4.7%	4.8%	62.0%
2008	\$68.00	\$64.70	\$24.35	23.9%	24.7%	5.1%
2009	\$49.44	\$44.85	\$17.54	(27.3%)	(30.7%)	(28.0%)
2010	\$47.77	\$43.62	\$16.52	(3.4%)	(2.7%)	(5.8%)
2011	\$47.14	\$42.49	\$17.73	(1.3%)	(2.6%)	7.3%
2012	\$31.51	\$30.44	\$6.83	(33.2%)	(28.3%)	(61.5%)
2013	\$37.26	\$35.02	\$10.26	18.3%	15.0%	50.3%
2014	\$94.97	\$56.53	\$102.23	154.9%	61.4%	896.7%
2015	\$52.02	\$36.94	\$40.10	(45.2%)	(34.7%)	(60.8%)
2016	\$27.94	\$25.99	\$9.28	(46.3%)	(29.6%)	(76.8%)
2017	\$30.40	\$27.99	\$8.98	8.8%	7.7%	(3.3%)
2018	\$47.55	\$30.24	\$42.58	56.4%	8.0%	374.2%
2019	\$30.76	\$27.28	\$12.56	(35.3%)	(9.8%)	(70.5%)
2020	\$20.12	\$19.54	\$4.54	(34.6%)	(28.4%)	(63.9%)

PJM Day-Ahead, Monthly, Load-Weighted, Average LMP

Figure 3-30 shows the PJM day-ahead, monthly and annual, load-weighted LMP from June 1, 2000 through March 31, 2019.⁴⁶

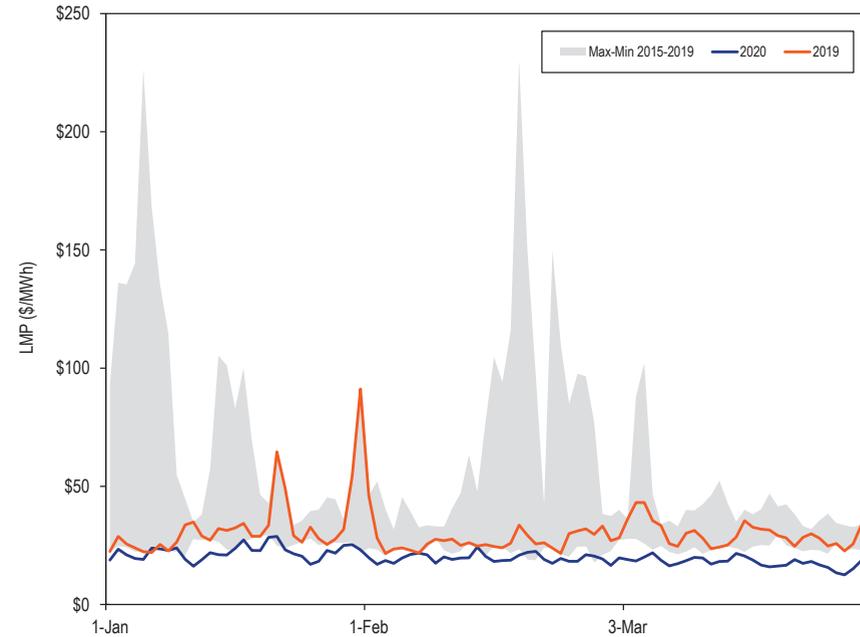
Figure 3-30 Day-ahead, monthly and annual, load-weighted, average LMP: June 2000 through March 2020



⁴⁶ Since the Day-Ahead Energy Market did not start until June 1, 2000, the day-ahead data for 2000 only includes data for the last seven months of that year.

Figure 3-31 shows the PJM day-ahead daily load-weighted LMP for the first three months of 2019 and 2020. Both the weather and COVID-19 played a role in this significant drop in prices.

Figure 3-31 Day-ahead, daily, load-weighted, average LMP: January through March, 2019 and 2020



PJM Day-Ahead, Monthly, Inflation Adjusted Load-Weighted, Average LMP

Figure 3-32 shows the PJM day-ahead monthly load-weighted average LMP and inflation adjusted monthly day-ahead load-weighted average LMP for June 2000 through March 2020.⁴⁷ Table 3-41 shows the PJM day-ahead load-weighted average LMP and inflation adjusted load-weighted average LMP for the first three months of every year from 2001 through 2020. The PJM day-

⁴⁷ To obtain the inflation adjusted monthly load-weighted average LMP, the PJM system-wide load-weighted average LMP is deflated using US Consumer Price Index for all items, Urban Consumers (base period: January 1998), published by Bureau of Labor Statistics. <<http://download.bls.gov/pub/time.series/cu/cu.data.1.AllItems>> (Accessed April 5, 2020).

ahead inflation adjusted load-weighted average LMP for first three months of 2020 was the lowest first three month value (\$12.59 per MWh) since PJM day-ahead markets started in 2000. The day-ahead inflation adjusted monthly load-weighted average LMP for March 2020 (\$11.22 per MWh) was the lowest monthly value since the day-ahead markets started.

Figure 3-32 Day-ahead, monthly, load-weighted, average LMP unadjusted and inflation adjusted: June 2000 through March 2020

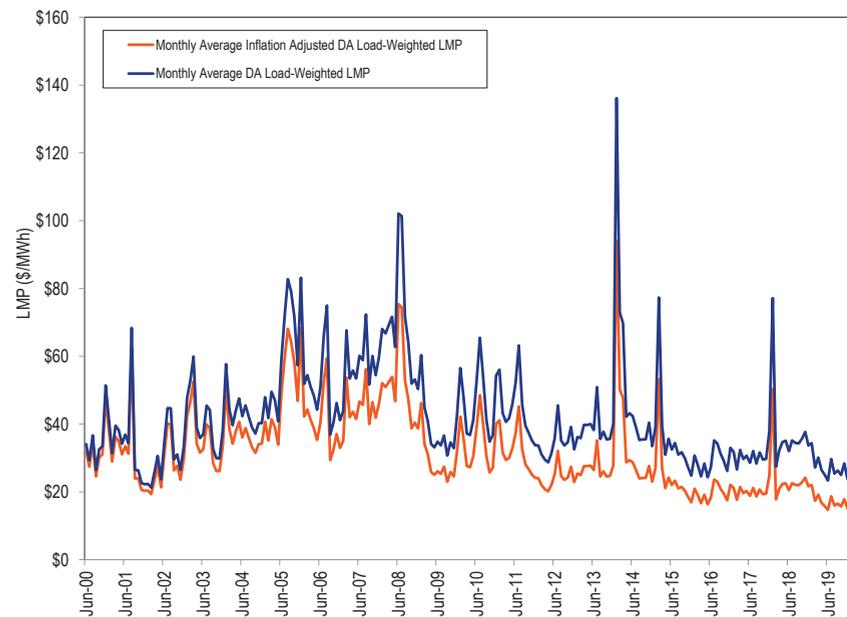


Table 3-41 Day-ahead, yearly, load-weighted, average LMP unadjusted and inflation adjusted: January through March, 2001 through 2020

	Load-Weighted, Average LMP (Jan-Mar)	Inflation Adjusted Load-Weighted, Average LMP (Jan-Mar)
2001	\$37.70	\$34.68
2002	\$23.17	\$21.04
2003	\$53.16	\$46.94
2004	\$47.75	\$41.47
2005	\$46.54	\$39.19
2006	\$52.40	\$42.57
2007	\$54.87	\$43.51
2008	\$68.00	\$51.82
2009	\$49.44	\$37.71
2010	\$47.77	\$35.59
2011	\$47.14	\$34.41
2012	\$31.51	\$22.35
2013	\$37.26	\$25.98
2014	\$94.97	\$65.40
2015	\$52.02	\$35.80
2016	\$27.94	\$19.03
2017	\$30.40	\$20.18
2018	\$47.55	\$30.93
2019	\$30.76	\$19.66
2020	\$20.12	\$12.59

Price Convergence

The introduction of the PJM Day-Ahead Energy Market with virtuals as part of the design created the possibility that competition, exercised through the use of virtual offers and bids, could tend to cause prices in the day-ahead and real-time energy markets to converge more than would be the case without virtuals. Convergence is not the goal of virtual trading, but it is a possible outcome. The degree of convergence, by itself, is not a measure of the competitiveness or effectiveness of the day-ahead energy market. Price convergence does not necessarily mean a zero or even a very small difference in prices between day-ahead and real-time energy markets. There may be factors, from operating reserve charges to differences in risk that result in a competitive, market-based differential. In addition, convergence in the sense that day-ahead and real-time prices are equal at individual buses or aggregates on a day to day basis is not a realistic expectation as a result of uncertainty, lags in response

time and modeling differences, such as differences in modeled contingencies and marginal loss calculations, between the day-ahead and real-time energy market.

Where arbitrage opportunities are created by differences between day-ahead and real-time energy market expectations, reactions by market participants may lead to more efficient market outcomes but there is no guarantee that the results of virtual bids and offers will result in more efficient market outcomes.

Where arbitrage incentives are created by systematic modeling differences, such as differences between the day-ahead and real-time modeled transmission contingencies and marginal loss calculations, virtual bids and offers cannot result in more efficient market outcomes. Such offers may be profitable but cannot change the underlying reason for the price difference. The virtual transactions will continue to profit from the activity for that reason regardless of the volume of those transactions. This is termed false arbitrage.

INCs, DECs and UTCs allow participants to profit from price differences between the day-ahead and real-time energy market. The seller of an INC must buy energy in the real-time energy market to fulfill the financial obligation to provide energy. If the day-ahead price for energy is higher than the real-time price for energy, the INC makes a profit. The buyer of a DEC must sell energy in the real-time energy market to fulfill the financial obligation to buy energy. If the day-ahead price for energy is lower than the real-time price for energy, the DEC makes a profit.

The profitability of a UTC transaction is the net of the separate profitability of the component INC and DEC. A UTC can be net profitable if the profit on one side of the UTC transaction exceeds the losses on the other side.

Table 3-42 shows the number of cleared UTC transactions, the number of profitable cleared UTCs, the number of cleared UTCs that were profitable at their source point and the number of cleared UTCs that were profitable at their

sink point in the first three months of 2019 and 2020. In the first three months of 2020, 54.1 percent of all cleared UTC transactions were net profitable. Of cleared UTC transactions, 65.3 percent were profitable on the source side and 35.5 were profitable on the sink side but only 6.7 percent were profitable on both the source and sink side.

Table 3-42 Cleared UTC profitability by source and sink point: January through March, 2019 and 2020⁴⁸

(Jan-Mar)	Cleared UTCs	UTC Profitable UTCs	UTC Profitable at Source Bus	UTC Profitable at Sink Bus	UTC Profitable at Source and Sink	Profitable UTC	Profitable Source	Profitable Sink	Profitable at Source and Sink
2019	2,358,790	1,084,678	1,633,112	717,336	133,590	46.0%	69.2%	30.4%	5.7%
2020	2,339,677	1,266,098	1,528,029	831,405	157,537	54.1%	65.3%	35.5%	6.7%

Table 3-43 shows the number of cleared INC and DEC transactions and the number of profitable cleared transactions in the first three months of 2019 and 2020. Of cleared INC and DEC transactions in the first three months of 2020, 65.3 percent of INCs were profitable and 39.3 percent of DECs were profitable.

Table 3-43 Cleared INC and DEC profitability: January through March, 2019 and 2020

(Jan-Mar)	Profitable INC			Profitable DEC		
	Cleared INC	Profitable INC	Percent	Cleared DEC	Profitable DEC	Profitable DEC Percent
2019	583,639	412,336	70.6%	426,598	146,173	34.3%
2020	548,430	357,950	65.3%	480,129	188,496	39.3%

⁴⁸ Calculations exclude PJM administrative charges.

Figure 3-33 shows total UTC daily gross profits, the sum of all positive profit UTC transactions, gross losses, the sum of all negative profit UTC transactions, and net profits and losses in the first three months of 2020.

Figure 3-33 UTC daily gross profits and losses and net profits: January through March, 2020⁴⁹

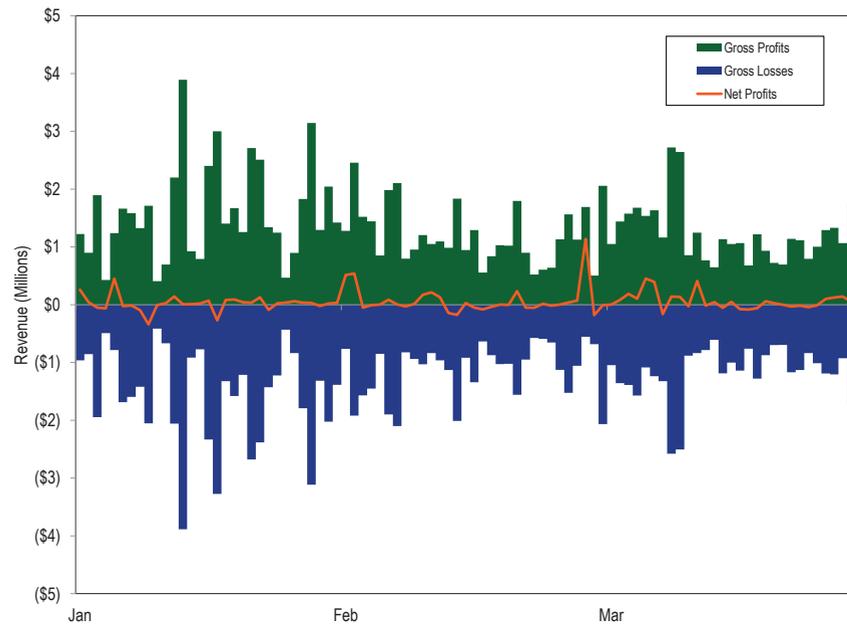
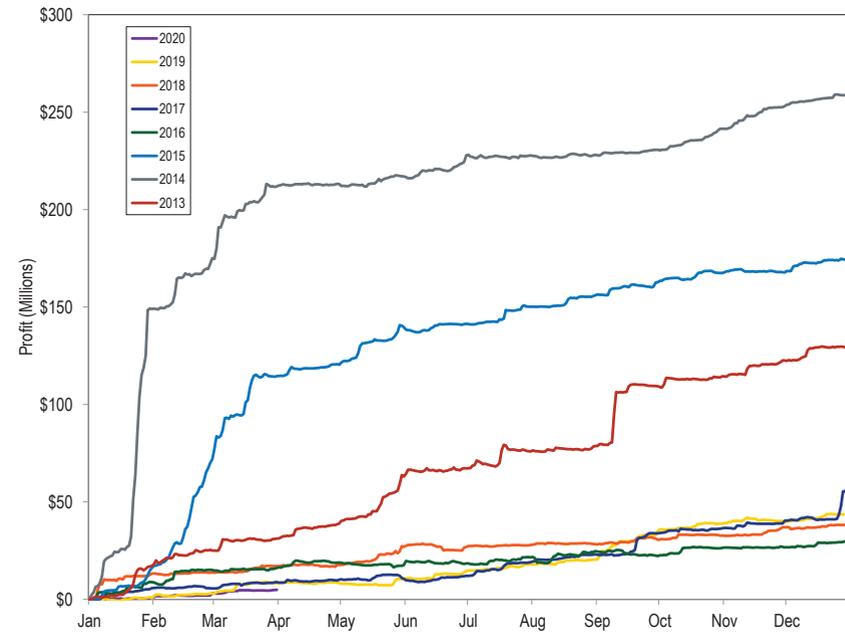


Figure 3-34 shows the cumulative UTC daily profits for each year from 2013 through March 2020.

Figure 3-34 Cumulative daily UTC profits: 2013 through March 2020



⁴⁹ Calculations exclude PJM administrative charges.

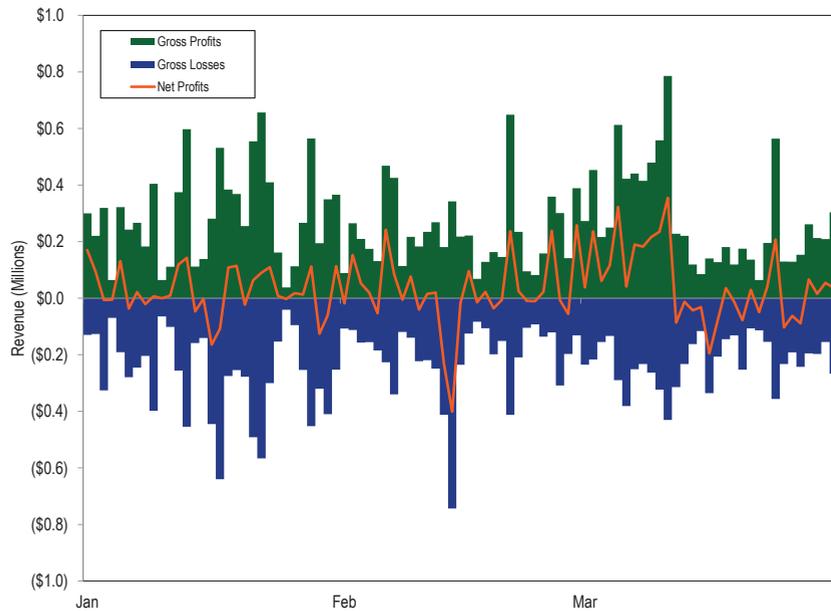
Table 3-44 shows UTC profits by month for 2013 through March 2020. May 2016, September 2016, February 2017 and June 2018 were the only months in this seven year period in which monthly profits were negative.

Table 3-44 UTC profits by month: January 2013 through March 2020

	January	February	March	April	May	June	July	August	September	October	November	December	Total
2013	\$17,048,654	\$8,304,767	\$5,629,392	\$7,560,773	\$25,219,947	\$3,484,372	\$8,781,526	\$2,327,168	\$31,160,618	\$4,393,583	\$8,730,701	\$6,793,990	\$129,435,490
2014	\$148,973,434	\$23,235,621	\$39,448,716	\$1,581,786	\$3,851,636	\$7,353,460	\$3,179,356	\$287,824	\$2,727,763	\$10,889,817	\$11,042,443	\$6,191,101	\$258,762,955
2015	\$16,132,319	\$53,830,098	\$44,309,656	\$6,392,939	\$19,793,475	\$824,817	\$8,879,275	\$5,507,608	\$6,957,012	\$4,852,454	\$392,876	\$6,620,581	\$174,493,110
2016	\$8,874,363	\$6,118,477	\$1,119,457	\$2,768,591	(\$1,333,563)	\$841,706	\$3,128,346	\$3,200,573	(\$2,518,408)	\$4,216,717	\$254,684	\$3,271,368	\$29,942,312
2017	\$5,716,757	(\$17,860)	\$3,083,167	\$944,939	\$1,245,988	\$868,400	\$7,053,390	\$4,002,063	\$10,960,012	\$2,360,817	\$2,716,950	\$15,936,217	\$54,870,839
2018	\$13,184,346	\$506,509	\$3,410,577	\$688,796	\$9,499,735	(\$768,614)	\$1,163,380	\$692,736	\$2,845,649	\$1,452,515	\$4,339,363	\$1,358,446	\$38,373,436
2019	\$574,901	\$2,407,307	\$5,287,985	\$332,036	\$1,833,879	\$3,382,009	\$4,066,461	\$2,442,971	\$12,599,278	\$5,914,042	\$1,171,145	\$3,722,403	\$43,734,418
2020	\$664,972	\$2,497,856	\$1,720,037										\$4,882,865

Figure 3-35 shows total INC and DEC daily gross profits, the sum of all positive profit transactions, gross losses, the sum of all negative profit transactions, and net profits and losses in the first three months of 2020.

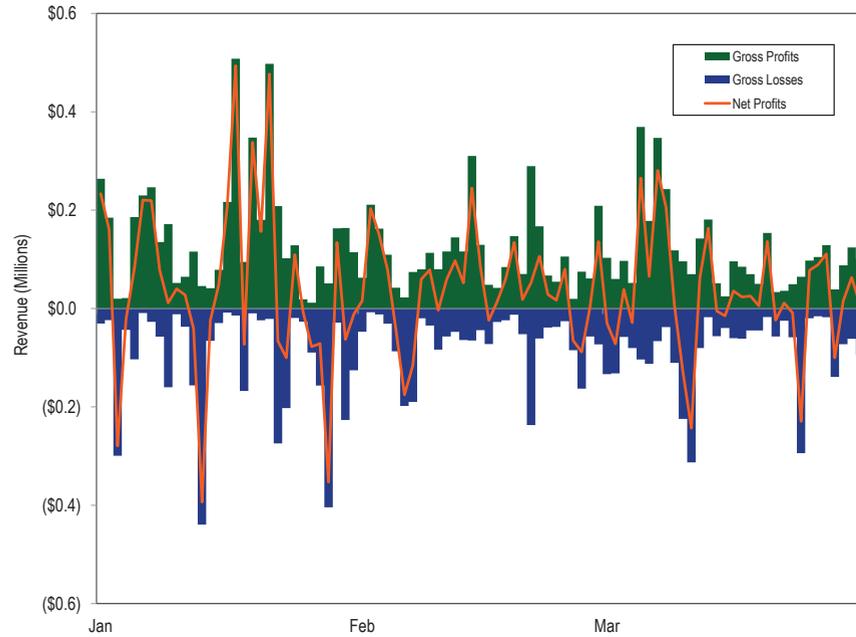
Figure 3-35 INC and DEC daily gross profits and losses and net profits: January through March, 2020⁵⁰



⁵⁰ Calculations exclude PJM administrative charges.

Figure 3-36 shows total INC daily gross profits and losses and net profits and losses in the first three months of 2020.

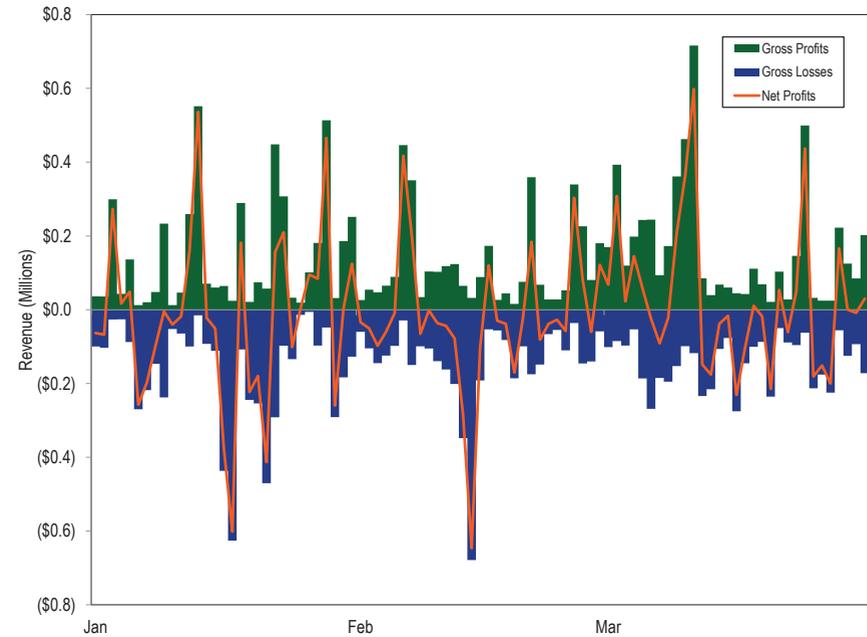
Figure 3-36 INC daily gross profits and losses and net profits: January through March, 2020⁵¹



⁵¹ Calculations exclude PJM administrative charges.

Figure 3-37 shows total DEC daily gross profits and losses and net profits and losses in the first three months of 2020.

Figure 3-37 DEC daily gross profits and losses and net profits: January through March, 2020⁵²



⁵² Calculations exclude PJM administrative charges.

Figure 3-38 shows the cumulative INC and DEC daily profits for January 1, through March 31, 2020.

Figure 3-38 Cumulative daily INC and DEC profits: January through March, 2020

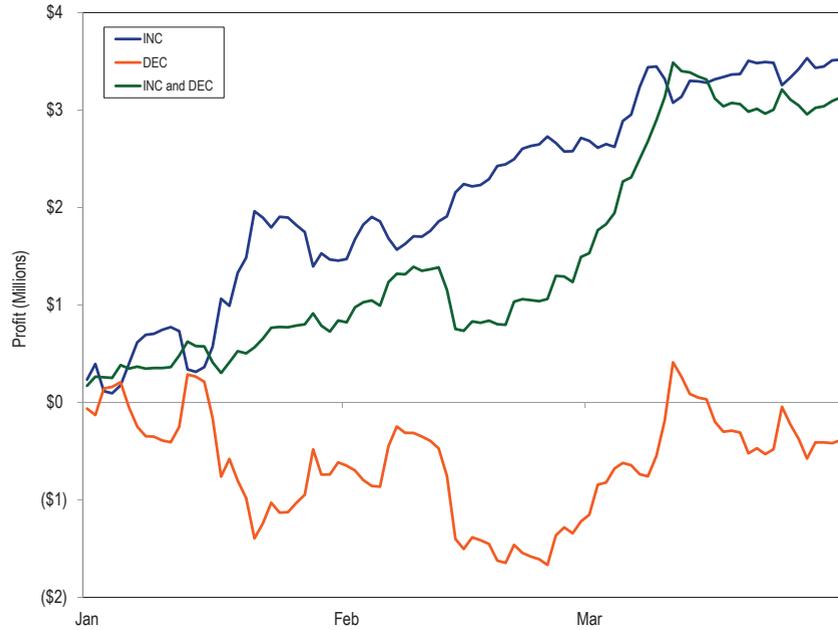


Table 3-45 shows INC and DEC profits by month for January through March, 2020.

Table 3-45 INC and DEC profits by month: January through March, 2020

	January	February	March	Total
INCs	\$1,455,089	\$1,259,625	\$803,233	\$3,517,947
DECs	(\$614,734)	(\$606,579)	\$833,364	(\$387,949)
INCs and DECs	\$840,356	\$653,046	\$1,636,597	\$3,129,999

There are incentives to use virtual transactions to profit from price differences between the day-ahead and real-time energy markets, but there is no guarantee that such activity will result in price convergence and no data to support that claim. As a general matter, virtual offers and bids are based on expectations about both day-ahead and real-time energy market conditions and reflect the uncertainty about conditions in both markets and the fact that these conditions change hourly and daily. PJM markets do not provide a mechanism that could result in immediate convergence after a change in system conditions as there is at least a one day lag after any change in system conditions before offers could reflect such changes.

Substantial virtual trading activity does not guarantee that market power cannot be exercised in the day-ahead energy market. Hourly and daily price differences between the day-ahead and real-time energy markets fluctuate continuously and substantially from positive to negative. There may be substantial, persistent differences between day-ahead and real-time prices even on a monthly basis

Table 3-46 shows that the difference between the average real-time price and the average day-ahead price was $-\$0.52$ per MWh in the first three months of 2019, and $-\$0.24$ per MWh in the first three months of 2020. The difference between average peak real-time price and the average peak day-ahead price was $-\$1.17$ per MWh in the first three months of 2019 and $-\$0.18$ per MWh in the first three months of 2020.

Table 3-46 Day-ahead and real-time average LMP (Dollars per MWh): January through March, 2019 and 2020⁵³

	2019 (Jan-Mar)				2020 (Jan-Mar)			
	Day-Ahead	Real-Time	Difference	Percent of Real Time	Day-Ahead	Real-Time	Difference	Percent of Real Time
Average	\$29.65	\$29.13	(\$0.52)	(1.8%)	\$19.66	\$19.42	(\$0.24)	(1.3%)
Median	\$26.82	\$25.36	(\$1.46)	(5.8%)	\$19.14	\$18.56	(\$0.58)	(3.1%)
Standard deviation	\$11.28	\$15.09	\$3.81	25.3%	\$4.43	\$6.98	\$2.55	36.6%
Peak average	\$33.21	\$32.04	(\$1.17)	(3.7%)	\$21.74	\$21.56	(\$0.18)	(0.8%)
Peak median	\$29.45	\$27.60	(\$1.85)	(6.7%)	\$20.77	\$20.08	(\$0.70)	(3.5%)
Peak standard deviation	\$13.07	\$17.18	\$4.11	23.9%	\$4.15	\$7.97	\$3.82	47.9%
Off peak average	\$26.53	\$26.58	\$0.05	0.2%	\$17.83	\$17.53	(\$0.30)	(1.7%)
Off peak median	\$24.72	\$24.04	(\$0.67)	(2.8%)	\$17.62	\$17.25	(\$0.37)	(2.2%)
Off peak standard deviation	\$8.26	\$12.45	\$4.19	33.6%	\$3.81	\$5.30	\$1.48	28.0%

The price difference between the real-time and the day-ahead energy markets results in part, from conditions in the real-time energy market that are difficult, or impossible, to anticipate in the day-ahead energy market.

Table 3-47 shows the difference between the real-time load-weighted and the day-ahead load-weighted energy market prices for the first three months of 2001 through 2020.

Table 3-47 Day-ahead load-weighted and real-time load-weighted average LMP (Dollars per MWh): January through March, 2001 through 2020

(Jan-Mar)	Day-Ahead	Real-Time	Difference	Percent of Real Time
2001	\$36.45	\$33.77	(\$2.68)	(7.3%)
2002	\$22.43	\$22.23	(\$0.20)	(0.9%)
2003	\$51.20	\$49.57	(\$1.63)	(3.2%)
2004	\$45.84	\$46.37	\$0.52	1.1%
2005	\$45.14	\$46.51	\$1.37	3.0%
2006	\$51.23	\$52.98	\$1.75	3.4%
2007	\$52.76	\$55.34	\$2.58	4.9%
2008	\$66.10	\$66.75	\$0.65	1.0%
2009	\$47.41	\$47.29	(\$0.12)	(0.2%)
2010	\$46.13	\$44.13	(\$2.00)	(4.3%)
2011	\$45.60	\$44.76	(\$0.84)	(1.8%)
2012	\$30.82	\$30.38	(\$0.43)	(1.4%)
2013	\$36.46	\$36.33	(\$0.13)	(0.4%)
2014	\$86.52	\$84.04	(\$2.48)	(2.9%)
2015	\$48.62	\$47.39	(\$1.23)	(2.5%)
2016	\$26.90	\$25.60	(\$1.30)	(4.8%)
2017	\$29.59	\$29.39	(\$0.20)	(0.7%)
2018	\$43.59	\$44.65	\$1.07	2.4%
2019	\$29.65	\$29.13	(\$0.52)	(1.7%)
2020	\$19.66	\$19.42	(\$0.24)	(1.2%)

⁵³ The averages used are the annual average of the hourly average PJM prices for day-ahead and real-time.

Table 3-48 includes frequency distributions of the differences between PJM real-time, load-weighted hourly LMP and PJM day-ahead load-weighted hourly LMP for the first three months of 2019 and 2020.

Table 3-48 Frequency distribution by hours of real-time, load-weighted LMP minus day-ahead load-weighted LMP (Dollars per MWh): January through March, 2019 and 2020

LMP	2019 (Jan-Mar)		2020 (Jan-Mar)	
	Frequency	Cumulative Percent	Frequency	Cumulative Percent
< (\$1,000)	0	0.00%	0	0.00%
(\$1,000) to (\$750)	0	0.00%	0	0.00%
(\$750) to (\$500)	0	0.00%	0	0.00%
(\$500) to (\$450)	0	0.00%	0	0.00%
(\$450) to (\$400)	0	0.00%	0	0.00%
(\$400) to (\$350)	0	0.00%	0	0.00%
(\$350) to (\$300)	0	0.00%	0	0.00%
(\$300) to (\$250)	0	0.00%	0	0.00%
(\$250) to (\$200)	0	0.00%	0	0.00%
(\$200) to (\$150)	1	0.05%	0	0.00%
(\$150) to (\$100)	3	0.19%	0	0.00%
(\$100) to (\$50)	25	1.34%	4	0.19%
(\$50) to \$0	1,427	67.44%	1,535	71.28%
\$0 to \$50	630	96.62%	601	99.12%
\$50 to \$100	48	98.84%	12	99.68%
\$100 to \$150	13	99.44%	6	99.95%
\$150 to \$200	4	99.63%	0	99.95%
\$200 to \$250	5	99.86%	1	100.00%
\$250 to \$300	1	99.91%	0	100.00%
\$300 to \$350	1	99.95%	0	100.00%
\$350 to \$400	0	99.95%	0	100.00%
\$400 to \$450	1	100.00%	0	100.00%
\$450 to \$500	0	100.00%	0	100.00%
\$500 to \$750	0	100.00%	0	100.00%
\$750 to \$1,000	0	100.00%	0	100.00%
\$1,000 to \$1,250	0	100.00%	0	100.00%
>= \$1,250	0	100.00%	0	100.00%

Figure 3-39 shows the hourly differences between day-ahead and real-time hourly LMP in the first three months of 2020.

Figure 3-39 Real-time hourly LMP minus day-ahead hourly LMP: January through March, 2020

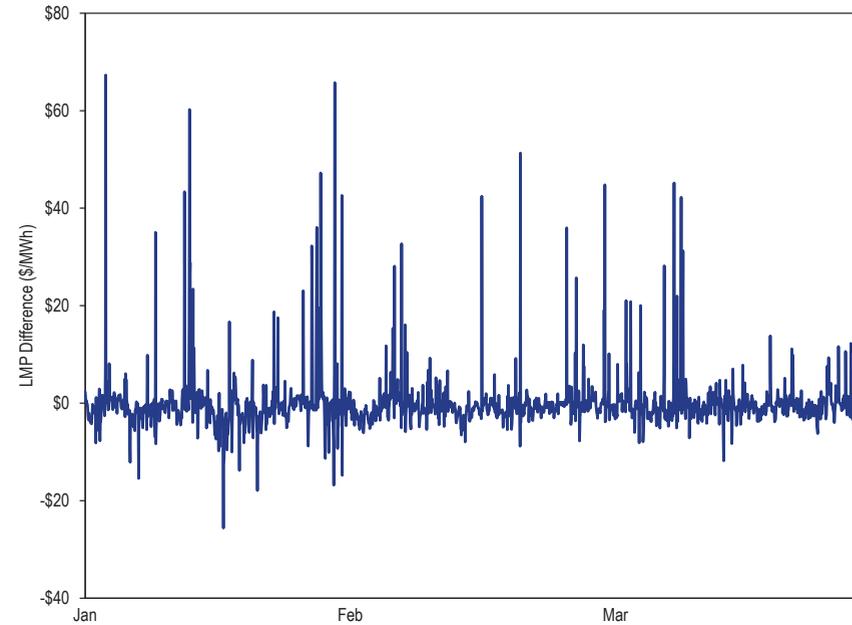
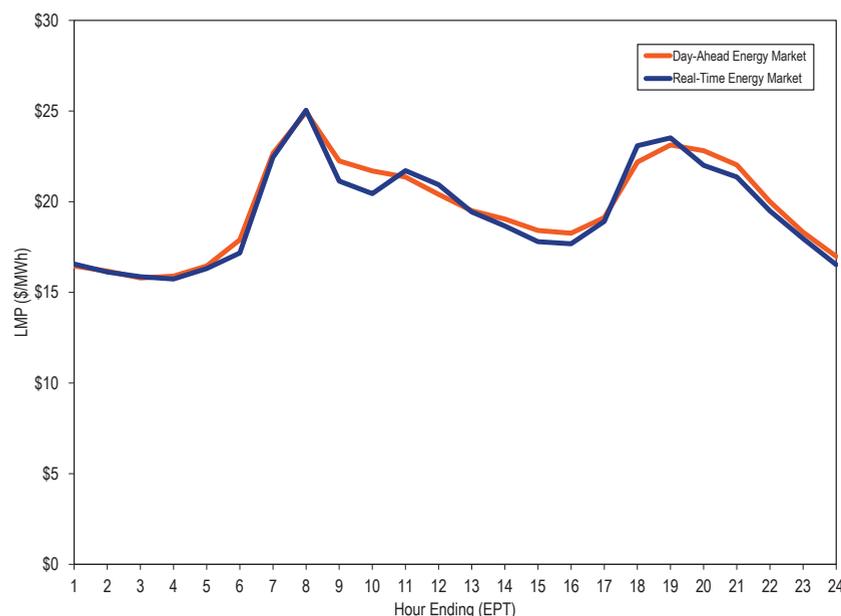


Figure 3-40 shows day-ahead and real-time load-weighted LMP on an average hourly basis for the first three months of 2020. Hour ending 10 had the largest difference between the DA and RT load-weighted LMP, at \$1.25 per MWh, and hour ending 2 had the smallest difference at \$0.01 per MWh. The average for 2019 was \$0.01 per MWh.

Figure 3-40 System hourly average LMP: January through March, 2020



Zonal LMP and Dispatch

Table 3-49 shows zonal real-time, and real-time, load-weighted, average LMP in the first three months of 2019 and 2020.

Table 3-49 Zonal real-time and real-time, load-weighted, average LMP (Dollars per MWh): January through March, 2019 and 2020

Zone	Real-Time Average LMP			Real-Time, Load-Weighted, Average LMP		
	2019 (Jan-Mar)	2020 (Jan-Mar)	Percent Change	2019 (Jan-Mar)	2020 (Jan-Mar)	Percent Change
AECO	\$30.34	\$18.75	(38.2%)	\$31.90	\$19.23	(39.7%)
AEP	\$28.90	\$19.83	(31.4%)	\$29.80	\$20.23	(32.1%)
APS	\$29.34	\$19.65	(33.0%)	\$30.37	\$20.09	(33.9%)
ATSI	\$29.46	\$19.97	(32.2%)	\$30.19	\$20.36	(32.6%)
BGE	\$31.24	\$20.65	(33.9%)	\$32.76	\$21.30	(35.0%)
ComEd	\$26.25	\$18.40	(29.9%)	\$26.82	\$18.80	(29.9%)
DAY	\$29.83	\$20.80	(30.3%)	\$30.82	\$21.29	(30.9%)
DEOK	\$28.49	\$20.01	(29.8%)	\$29.35	\$20.42	(30.4%)
DLCO	\$29.97	\$19.75	(34.1%)	\$31.34	\$20.29	(35.3%)
Dominion	\$29.89	\$18.96	(36.6%)	\$32.08	\$19.54	(39.1%)
DPL	\$28.74	\$19.84	(31.0%)	\$29.45	\$20.22	(31.3%)
EKPC	\$28.08	\$19.92	(29.0%)	\$29.37	\$20.46	(30.4%)
JCPL	\$29.98	\$18.84	(37.2%)	\$31.52	\$19.34	(38.6%)
Met-Ed	\$29.79	\$18.91	(36.5%)	\$31.05	\$19.45	(37.4%)
OVEC	\$27.85	\$19.53	(29.9%)	\$28.09	\$19.64	(30.1%)
PECO	\$29.09	\$18.49	(36.5%)	\$30.49	\$18.92	(37.9%)
PENELEC	\$28.54	\$19.07	(33.2%)	\$29.29	\$19.46	(33.6%)
Pepco	\$30.58	\$20.21	(33.9%)	\$32.02	\$20.86	(34.9%)
PPL	\$27.55	\$17.70	(35.7%)	\$28.75	\$18.14	(36.9%)
PSEG	\$30.94	\$18.92	(38.8%)	\$32.38	\$19.34	(40.3%)
RECO	\$30.49	\$18.87	(38.1%)	\$31.70	\$19.32	(39.1%)
PJM	\$29.13	\$19.42	(33.3%)	\$30.16	\$19.85	(34.2%)

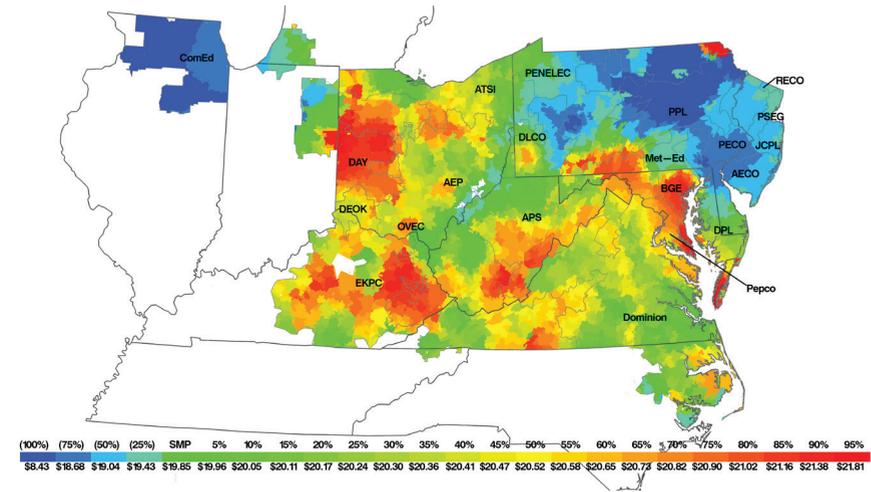
Table 3-50 shows zonal day-ahead, and day-ahead, load-weighted, average LMP in the first three months of 2019 and 2020.

Table 3-50 Zonal day-ahead and day-ahead, load-weighted, average LMP (Dollars per MWh): January through March, 2019 and 2020

Zone	Day-Ahead Average LMP			Day-Ahead, Load-Weighted, Average LMP		
	2019 (Jan-Mar)	2020 (Jan-Mar)	Percent Change	2019 (Jan-Mar)	2020 (Jan-Mar)	Percent Change
AECO	\$30.23	\$18.51	(38.8%)	\$31.55	\$18.95	(40.0%)
AEP	\$29.40	\$20.16	(31.4%)	\$30.45	\$20.56	(32.5%)
APS	\$30.11	\$19.97	(33.7%)	\$31.21	\$20.45	(34.5%)
ATSI	\$30.33	\$20.37	(32.8%)	\$31.21	\$20.81	(33.3%)
BGE	\$32.13	\$21.42	(33.3%)	\$33.63	\$22.18	(34.1%)
ComEd	\$26.30	\$18.72	(28.8%)	\$26.90	\$19.10	(29.0%)
DAY	\$30.48	\$21.15	(30.6%)	\$31.52	\$21.67	(31.2%)
DEOK	\$29.43	\$20.38	(30.8%)	\$30.48	\$20.83	(31.7%)
DLCO	\$31.10	\$20.17	(35.1%)	\$32.76	\$20.73	(36.7%)
Dominion	\$30.18	\$18.75	(37.9%)	\$32.31	\$19.40	(39.9%)
DPL	\$29.50	\$20.25	(31.4%)	\$30.29	\$20.73	(31.6%)
EKPC	\$28.55	\$20.19	(29.3%)	\$29.91	\$20.87	(30.2%)
JCPL	\$29.68	\$18.61	(37.3%)	\$30.97	\$19.12	(38.3%)
Met-Ed	\$29.60	\$18.89	(36.2%)	\$30.73	\$19.41	(36.8%)
OVEC	\$28.29	\$19.83	(29.9%)	\$25.46	\$20.40	(19.9%)
PECO	\$28.99	\$18.14	(37.4%)	\$30.18	\$18.57	(38.5%)
PENELEC	\$29.77	\$19.46	(34.6%)	\$31.12	\$20.00	(35.7%)
Pepco	\$31.71	\$20.82	(34.3%)	\$33.37	\$21.57	(35.4%)
PPL	\$27.93	\$17.82	(36.2%)	\$28.92	\$18.23	(37.0%)
PSEG	\$30.69	\$18.69	(39.1%)	\$31.92	\$19.12	(40.1%)
RECO	\$30.88	\$18.97	(38.6%)	\$32.33	\$19.52	(39.6%)
PJM	\$29.65	\$19.66	(33.7%)	\$30.76	\$20.12	(34.6%)

Figure 3-41 is a map of the real-time, load-weighted, average LMP in the first three months of 2020. In the legend, green represents the system marginal price (SMP) and each increment to the right and left of the SMP represents five percent of the pricing nodes above and below the SMP.

Figure 3-41 Real-time, load-weighted, average LMP: January through March, 2020



Net Generation by Zone

Figure 3-42 shows the difference between the PJM real-time generation and real-time load by zone in the first three months of 2020. Figure 3-42 is color coded using a scale on which red shades represent zones that have less generation than load and green shades represent zones that have more generation than load, with darker shades meaning greater amounts of net generation or load. For example, the Pepco Control Zone has less generation than load, while the PENELEC Control Zone has more generation than load. Table 3-51 shows the difference between the PJM real-time generation and real-time load by zone in the first three months of 2019 and 2020.

Figure 3-42 Map of real-time generation, less real-time load, by zone: January through March, 2020⁵⁴

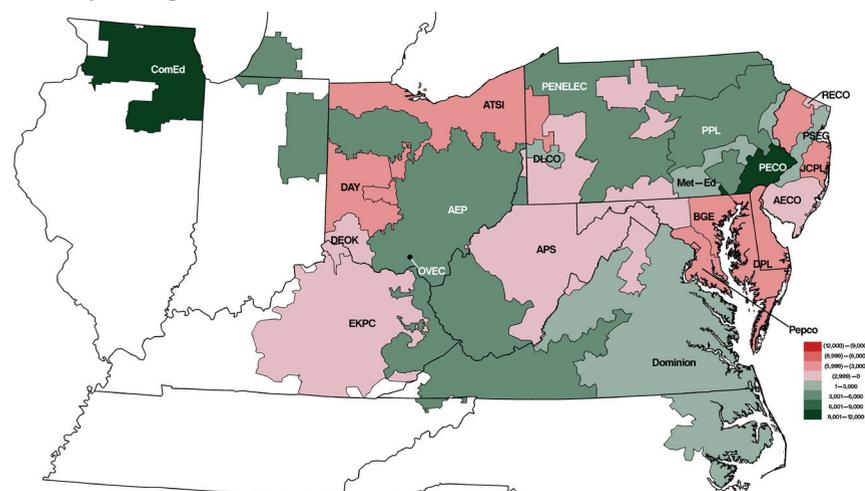


Table 3-51 Real-time generation less real-time load by zone (GWh): January through March, 2019 and 2020

Jan-Mar	Zonal Generation and Load (GWh)					
	2019			2020		
Zone	Generation	Load	Net	Generation	Load	Net
AECO	1,256.2	2,276.7	(1,020.5)	880.2	2,119.2	(1,239.0)
AEP	39,847.5	33,077.5	6,770.0	34,767.8	31,499.9	3,267.9
APS	12,176.7	13,382.3	(1,205.6)	12,110.2	12,342.8	(232.6)
ATSI	9,461.8	16,843.4	(7,381.6)	9,972.3	15,935.3	(5,963.0)
BGE	4,117.0	8,047.7	(3,930.8)	3,382.5	7,350.7	(3,968.2)
ComEd	34,205.6	23,739.2	10,466.4	31,997.3	22,534.9	9,462.4
DAY	88.6	4,455.3	(4,366.7)	93.0	4,183.0	(4,090.0)
DEOK	5,580.2	6,715.4	(1,135.1)	4,565.7	6,350.7	(1,785.0)
Dominion	24,405.5	25,460.4	(1,054.9)	26,936.8	24,211.9	2,725.0
DPL	1,024.7	4,753.0	(3,728.3)	874.6	4,363.1	(3,488.5)
DLCO	4,294.5	3,294.5	1,000.0	4,066.0	3,141.2	924.8
EKPC	1,786.5	3,503.4	(1,716.9)	1,743.5	3,358.5	(1,615.0)
JCPL	2,320.2	5,280.5	(2,960.2)	1,870.1	4,971.3	(3,101.3)
Met-Ed	6,172.0	4,084.1	2,087.9	5,745.0	3,814.3	1,930.7
OVEC	3,110.5	38.3	3,072.2	2,317.5	34.0	2,283.5
PECO	17,323.1	9,999.3	7,323.7	19,098.9	9,210.0	9,888.9
PENELEC	11,794.6	4,522.1	7,272.5	10,029.7	4,305.8	5,723.9
Pepco	2,633.0	7,428.1	(4,795.1)	2,541.9	6,786.3	(4,244.3)
PPL	16,478.2	11,066.6	5,411.6	14,633.4	10,305.1	4,328.3
PSEG	11,367.2	10,250.8	1,116.4	10,316.2	9,754.6	561.6
RECO	0.0	326.9	(326.9)	0.0	308.8	(308.8)

Net Generation and Load

PJM sums all negative (injections) and positive (withdrawals) load at each designated load bus when calculating net load (accounting load). PJM sums all of the negative (withdrawals) and positive (injections) generation at each generation bus when calculating net generation. Netting withdrawals and injections by bus type (generation or load) affects the measurement of total load and total generation. Energy withdrawn at a generation bus to provide, for example, auxiliary/parasitic power or station power, power to synchronous condenser motors, or power to run pumped storage pumps, is actually load, not negative generation. Energy injected at load buses by behind the meter generation is actually generation, not negative load.

The zonal load-weighted LMP is calculated by weighting the zone's load bus LMPs by the zone's load bus accounting load. The definition of injections and

⁵⁴ Zonal real-time generation data for the map and corresponding table is based on the zonal designation for every bus listed in the most current PJM LMP bus model, which can be found at <<http://www.pjm.com/markets-and-operations/energy/lmp-model-info.aspx>>.

withdrawals of energy as generation or load affects PJM’s calculation of zonal load-weighted LMP.

The MMU recommends that during hours when a generation bus shows a net withdrawal, the energy withdrawal be treated as load, not negative generation, for purposes of calculating load and load-weighted LMP. The MMU also recommends that during hours when a load bus shows a net injection, the energy injection be treated as generation, not negative load, for purposes of calculating generation and load-weighted LMP.

Fuel Prices, LMP, and Dispatch Energy Production by Fuel Source

Table 3-52 shows PJM generation by fuel source in GWh for the first three months of 2019 and 2020. In the first three months of 2020, generation from coal units decreased 36.6 percent, generation from natural gas units increased 14.0 percent, and generation from oil decreased 7.1 percent compared to the first three months of 2019. Wind and solar output rose by 765 GWh compared to the first three months of 2019, supplying 4.3 percent of PJM energy in the first three months of 2020.

Table 3-52 Generation (By fuel source (GWh)): January through March, 2019 and 2020^{55 56 57}

	2019 (Jan – Mar)		2020 (Jan – Mar)		Change in Output
	GWh	Percent	GWh	Percent	
Coal	57,014.6	26.9%	36,129.2	18.0%	(36.6%)
Bituminous	47,484.3	22.4%	33,412.1	16.7%	(29.6%)
Sub Bituminous	7,384.8	3.5%	1,259.0	0.6%	(83.0%)
Other Coal	2,145.5	1.0%	1,458.1	0.7%	(32.0%)
Nuclear	69,798.2	33.0%	69,142.2	34.5%	(0.9%)
Gas	70,359.5	33.2%	80,158.9	40.0%	13.9%
Natural Gas	69,813.4	33.0%	79,605.3	39.7%	14.0%
Landfill Gas	546.1	0.3%	553.5	0.3%	1.4%
Other Gas	0.0	0.0%	0.0	0.0%	NA
Hydroelectric	4,958.1	2.3%	4,522.4	2.3%	(8.8%)
Pumped Storage	986.3	0.5%	1,004.8	0.5%	1.9%
Run of River	3,687.8	1.7%	3,224.2	1.6%	(12.6%)
Other Hydro	284.0	0.1%	293.4	0.1%	3.3%
Wind	7,307.2	3.5%	7,893.6	3.9%	8.0%
Waste	1,034.8	0.5%	1,054.6	0.5%	1.9%
Solid Waste	967.6	0.5%	986.5	0.5%	2.0%
Miscellaneous	67.2	0.0%	68.0	0.0%	1.2%
Oil	487.1	0.2%	452.5	0.2%	(7.1%)
Heavy Oil	6.5	0.0%	0.0	0.0%	(100.0%)
Light Oil	70.3	0.0%	19.3	0.0%	(72.6%)
Diesel	62.0	0.0%	7.9	0.0%	(87.2%)
Gasoline	0.0	0.0%	0.0	0.0%	NA
Kerosene	9.7	0.0%	0.0	0.0%	(99.8%)
Jet Oil	0.0	0.0%	0.0	0.0%	NA
Other Oil	338.5	0.2%	425.3	0.2%	25.6%
Solar, Net Energy Metering	506.3	0.2%	684.6	0.3%	35.2%
Battery	6.1	0.0%	8.0	0.0%	30.2%
Biofuel	296.2	0.1%	288.8	0.1%	(2.5%)
Total	211,768.2	100.0%	200,334.8	100.0%	(5.4%)

⁵⁵ All generation is total gross generation output and does not net out the MWh withdrawn at a generation bus to provide auxiliary/parasitic power or station power, power to synchronous condenser motors, power to run pumped hydro pumps or power to charge batteries.

⁵⁶ Net Energy Metering is combined with Solar due to data confidentiality reasons.

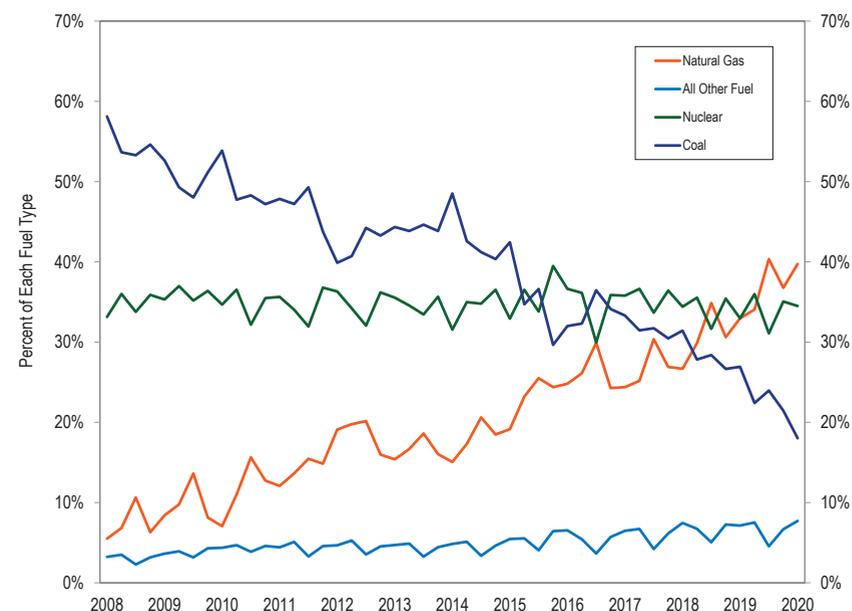
⁵⁷ Other Gas includes: Propane, Butane, Hydrogen, Gasified Coal, and Refinery Gas. Other Coal includes: Lignite, Liquefied Coal, Gasified Coal, and Waste Coal.

Table 3-53 Monthly generation (By fuel source (GWh)): January through March, 2020

	Jan	Feb	Mar	Total
Coal	13,301.6	12,829.4	9,998.2	36,129.2
Bituminous	12,414.8	11,741.5	9,255.7	33,412.1
Sub Bituminous	348.1	570.5	340.4	1,259.0
Other Coal	538.6	517.3	402.2	1,458.1
Nuclear	25,012.5	22,067.6	22,062.1	69,142.2
Gas	28,107.5	25,976.7	26,074.6	80,158.9
Natural Gas	27,919.7	25,799.6	25,886.0	79,605.3
Landfill Gas	187.9	177.1	188.6	553.5
Other Gas	0.0	0.0	0.0	0.0
Hydroelectric	1,474.0	1,558.7	1,489.8	4,522.4
Pumped Storage	370.7	309.2	324.9	1,004.8
Run of River	1,014.4	1,127.3	1,082.5	3,224.2
Other Hydro	88.9	122.2	82.4	293.4
Wind	2,589.6	2,564.5	2,739.5	7,893.6
Waste	366.3	297.0	391.2	1,054.6
Solid Waste	342.8	274.1	369.6	986.5
Miscellaneous	23.5	22.9	21.6	68.0
Oil	128.2	159.1	165.2	452.5
Heavy Oil	0.0	0.0	0.0	0.0
Light Oil	10.7	6.4	2.2	19.3
Diesel	7.5	0.2	0.3	7.9
Gasoline	0.0	0.0	0.0	0.0
Kerosene	0.0	0.0	0.0	0.0
Jet Oil	0.0	0.0	0.0	0.0
Other Oil	109.9	152.6	162.7	425.3
Solar, Net Energy Metering	187.3	208.8	288.5	684.6
Battery	2.0	2.4	3.6	8.0
Biofuel	84.7	101.9	102.2	288.8
Total	71,253.7	65,766.2	63,314.9	200,334.8

Figure 3-43 shows total generation percentage of natural gas, coal, nuclear and all other fuel types in the real-time energy market since 2008.

Figure 3-43 Generation by fuel source (Percent): January 2008 through March 2020



Fuel Diversity

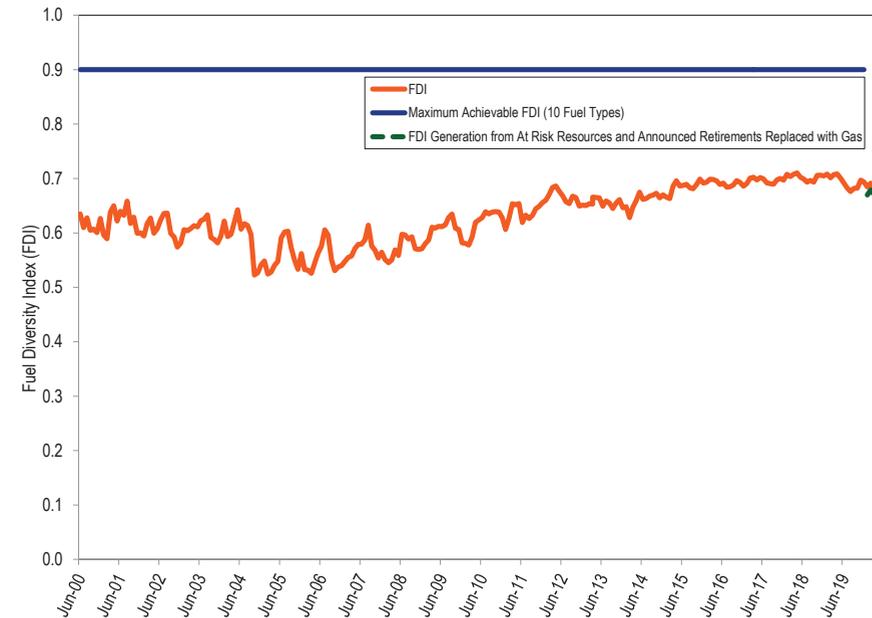
Figure 3-44 shows the fuel diversity index (FDI_c) for PJM energy generation.⁵⁸ The FDI_c is defined as $1 - \sum_{i=1}^N s_i^2$, where s_i is the share of fuel type i . The minimum possible value for the FDI_c is zero, corresponding to all generation from a single fuel type. The maximum possible value for the FDI_c results when each fuel type has an equal share of total generation. For a generation fleet composed of 10 fuel types, the maximum achievable index is 0.9. The fuel type categories used in the calculation of the FDI_c are the 10 primary fuel sources in Table 3-53 with nonzero generation values. As fuel diversity has

⁵⁸ Monitoring Analytics developed the FDI to provide an objective metric of fuel diversity. The FDI metric is similar to the HHI used to measure market concentration. The FDI is calculated separately for energy output and for installed capacity.

increased, seasonality in the FDI_c has decreased and the FDI_c has exhibited less volatility. Since 2012, the monthly FDI_c has been less volatile as a result of the decline in the share of coal from 51.3 percent prior to 2012 to 35.4 percent from 2012 through 2019. A significant drop in the FDI_c occurred in the fall of 2004 as a result of the expansion of the PJM market footprint into ComEd, AEP, and Dayton Power & Light control zones and the increased shares of coal and nuclear that resulted.⁵⁹ The increasing trend that began in 2008 is a result of decreasing coal generation, increasing gas generation and increasing wind generation. Coal generation as a share of total generation was 54.9 percent for 2008 and 18.0 percent for the first three months of 2020. Gas generation as a share of total generation was 7.4 percent for 2008 and 40.0 percent for the first three months of 2020. Wind generation as a share of total generation was 0.5 percent for 2008 and 3.9 percent for the first three months of 2020.

The average FDI_c decreased 2.9 percent for the first three months of 2020 compared to the first three months of 2019. The FDI_c was also used to measure the impact on fuel diversity of potential retirements. A total of 9,543.0 MW of coal, CT, diesel, and nuclear capacity were identified as being at risk of retirement.⁶⁰ Generation owners that intend to retire a generator are required by the tariff to notify PJM at least 90 days in advance.⁶¹ There are 5,342.8 MW of generation that have requested retirement after March 31, 2020.⁶² The at risk units and other generators with deactivation notices generated 8,064.6 GWh in the first three months of 2020.⁶³ The dashed line in Figure 3-44 shows a counterfactual result for FDI_c assuming the 8,064.6 GWh of generation from at risk units and other generators with deactivation notices were replaced by gas generation. The FDI_c for the first three months of 2020 under the counterfactual assumption would have been 1.9 percent lower than the actual FDI_c .

Figure 3-44 Fuel diversity index for monthly generation: June 2000 through March 2020



Types of Marginal Resources

LMPs result from the operation of a market based on security-constrained, least-cost dispatch in which marginal resources determine system LMPs, based on their offers. Marginal resource designation is not limited to physical resources in the day-ahead energy market. INC offers, DEC bids and up to congestion transactions are dispatchable injections and withdrawals in the day-ahead energy market that can set price via their offers and bids.

Table 3-54 shows the type of fuel used and technology by marginal resources in the real-time energy market. There can be more than one marginal resource in any given interval as a result of transmission constraints. In the first three months of 2020, coal units were 17.6 percent and natural gas units were 73.2 percent of marginal resources. In the first three months of 2020, natural gas

⁵⁹ See the 2019 State of the Market Report for PJM, Volume 2, Appendix A, "PJM Geography" for an explanation of the expansion of the PJM footprint. The integration of the ComEd Control Area occurred in May 2004 and the integration of the AEP and Dayton control zones occurred in October 2004.
⁶⁰ See the 2019 State of the Market Report for PJM, Volume 2, Section 7: Net Revenue, Units at Risk.
⁶¹ See PJM. OATT: § V "Generation Deactivation."
⁶² Includes the generators in Table 12-9 plus one pseudo tied generator.
⁶³ Previous state of the market reports incorrectly reported the generation by the at risk units and generators with deactivation notices in TWh rather than GWh.

combined cycle units were 71.5 percent of marginal resources. In the first three months of 2019, coal units were 24.4 percent and natural gas units were 69.4 percent of the total marginal resources. In the first three months of 2019, natural gas combined cycle units were 62.1 percent of the total marginal resources. In the first three months of 2020, 98.9 percent of the wind marginal units had negative offer prices, 1.1 percent had zero offer prices and none had positive offer prices. In the first three months of 2019, 78.3 percent of the wind marginal units had negative offer prices, 21.7 percent had zero offer prices and none had positive offer prices.

The proportion of marginal nuclear units increased from 1.31 percent in the first three months of 2019 to 1.48 percent in the first three months of 2020. Most nuclear units are offered as fixed generation in the PJM market. A small number of nuclear units were offered with a dispatchable range since 2015. The dispatchable nuclear units do not always respond to dispatch instructions.

Table 3-54 Type of fuel used and technology (By real-time marginal units): January through March, 2016 through 2020⁶⁴

		(Jan - Mar)				
Fuel	Technology	2016	2017	2018	2019	2020
Gas	CC	32.82%	45.37%	53.45%	62.13%	71.55%
Coal	Steam	45.86%	34.23%	27.26%	24.37%	17.51%
Wind	Wind	4.06%	7.05%	2.56%	3.81%	7.17%
Uranium	Steam	0.09%	0.78%	1.04%	1.31%	1.48%
Gas	CT	5.82%	2.79%	7.80%	5.97%	1.03%
Gas	Steam	3.33%	2.63%	1.68%	1.29%	0.60%
Other	Solar	0.04%	0.11%	0.12%	0.07%	0.33%
Oil	CT	7.34%	5.89%	4.58%	0.49%	0.02%
Other	Steam	0.16%	0.14%	0.15%	0.06%	0.02%
Landfill Gas	CT	0.00%	0.00%	0.02%	0.01%	0.00%
Municipal Waste	Steam	0.02%	0.02%	0.04%	0.02%	0.00%
Oil	Steam	0.11%	0.00%	0.29%	0.03%	0.00%
Oil	RICE	0.13%	0.66%	0.42%	0.00%	0.00%
Oil	CC	0.07%	0.00%	0.13%	0.01%	0.00%
Gas	Fuel Cell	0.00%	0.01%	0.00%	0.00%	0.00%
Municipal Waste	RICE	0.00%	0.00%	0.00%	0.00%	0.00%
Landfill Gas	Steam	0.05%	0.02%	0.00%	0.00%	0.00%
Gas	RICE	0.06%	0.26%	0.41%	0.00%	0.00%
Landfill Gas	RICE	0.04%	0.02%	0.04%	0.00%	0.00%

⁶⁴ The unit type RICE refers to Reciprocating Internal Combustion Engines.

Figure 3-45 shows the type of fuel used by marginal resources in the real-time energy market since 2004. The role of coal as a marginal resource has declined while the role of gas as a marginal resource has increased.

Figure 3-45 Type of fuel used (By real-time marginal units): January through March, 2004 through 2020

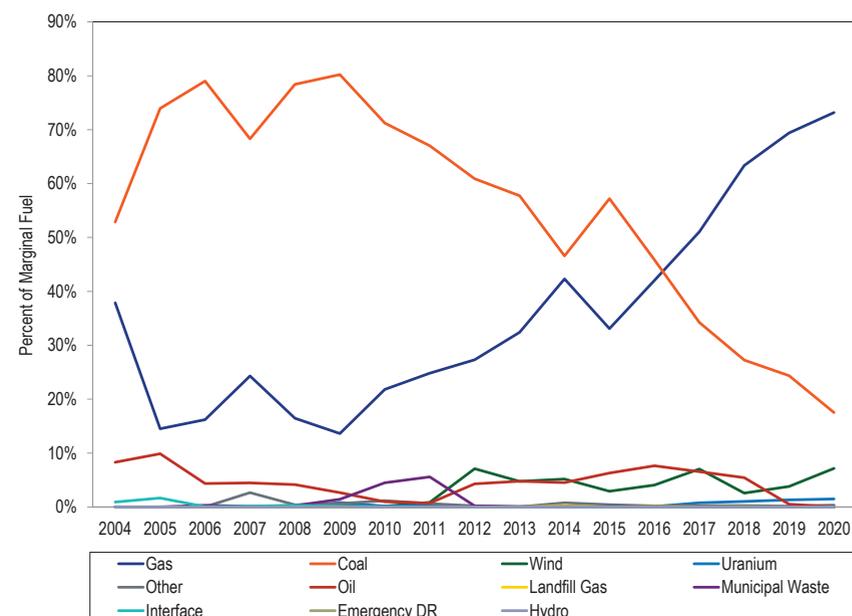


Table 3-55 shows the type of fuel used and technology where relevant, of marginal resources in the day-ahead energy market. In the first three months of 2020, up to congestion transactions were 48.5 percent of marginal resources. Up to congestion transactions were 59.9 percent of marginal resources in the first three months of 2019.

Table 3-55 Day-ahead marginal resources by type/fuel used and technology: January through March, 2016 through 2020

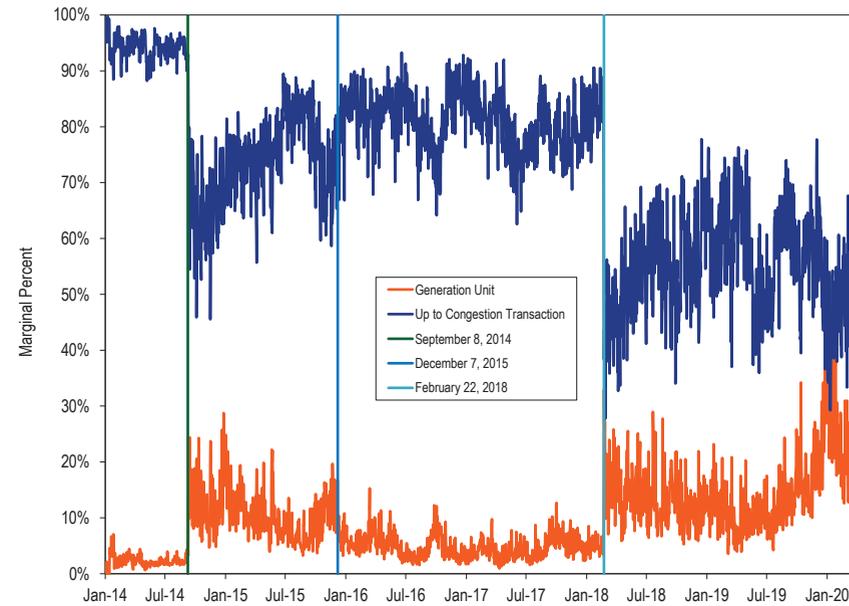
Type/Fuel	Technology	(Jan - Mar)				
		2016	2017	2018	2019	2020
Up to Congestion Transaction	NA	82.36%	83.14%	76.13%	59.89%	48.54%
INC	NA	3.95%	4.54%	6.15%	11.88%	16.21%
Gas	CC	2.73%	1.98%	3.67%	6.32%	15.68%
DEC	NA	6.79%	7.57%	10.12%	16.67%	12.63%
Coal	Steam	3.00%	1.74%	3.12%	4.68%	5.94%
Wind	Wind	0.04%	0.16%	0.17%	0.11%	0.35%
Uranium	Steam	0.04%	0.02%	0.01%	0.00%	0.24%
Gas	Steam	0.37%	0.39%	0.13%	0.09%	0.16%
Gas	CT	0.02%	0.03%	0.16%	0.10%	0.10%
Dispatchable Transaction	NA	0.06%	0.04%	0.12%	0.16%	0.08%
Oil	CT	0.60%	0.34%	0.01%	0.00%	0.03%
Gas	RICE	0.00%	0.01%	0.04%	0.06%	0.02%
Other	Steam	0.01%	0.00%	0.01%	0.01%	0.01%
Other	Solar	0.00%	0.00%	0.00%	0.00%	0.01%
Municipal Waste	RICE	0.02%	0.00%	0.01%	0.02%	0.01%
Oil	Steam	0.01%	0.00%	0.08%	0.00%	0.00%
Oil	RICE	0.00%	0.04%	0.00%	0.00%	0.00%
Oil	CC	0.00%	0.00%	0.05%	0.00%	0.00%
Water	Hydro	0.00%	0.00%	0.00%	0.00%	0.00%
Price Sensitive Demand	NA	0.00%	0.00%	0.02%	0.01%	0.00%
Total		100.00%	100.00%	100.00%	100.00%	100.00%

Figure 3-46 shows, for the day-ahead energy market from January 2014 through March 2020, the daily proportion of marginal resources that were up to congestion transaction and/or generation units. The UTC share decreased from 59.9 percent in the first three months of 2019 to 48.5 percent in the first three months of 2020.

The average number of up to congestion bids submitted in the day-ahead energy market decreased by 7.3 percent, from 53,376 bids per day in the first three months of 2019 to 49,461 bids per day in the first three months of 2020.

The average cleared volume of up to congestion bids submitted in the day-ahead energy market decreased by 11.1 percent, from 521,709 MWh per day in 2019, to 464,019 MWh per day in the first three months of 2020.

Figure 3-46 Day-ahead marginal up to congestion transaction and generation units: January 2014 through March 2020

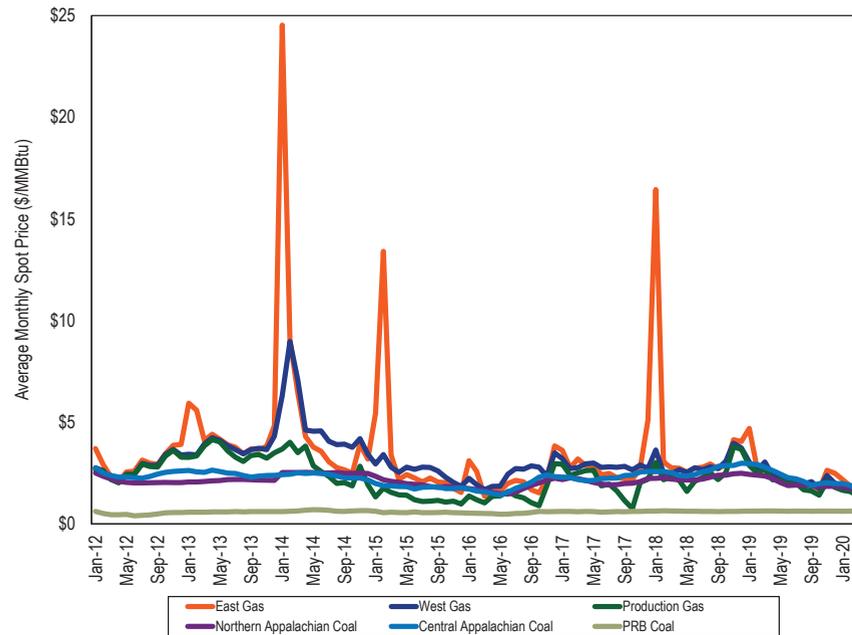


Fuel Price Trends and LMP

In a competitive market, changes in LMP follow changes in the marginal costs of marginal units, the units setting LMP. In general, fuel costs make up between 80 percent and 90 percent of short run marginal cost depending on generating technology, unit efficiency, unit age and other factors. The impact of fuel cost on marginal cost and on LMP depends on the fuel burned by marginal units and changes in fuel costs. Changes in emission allowance costs also contribute to changes in the marginal cost of marginal units. Natural gas prices decreased in the first three months of 2020 compared to the first three months of 2019. The price of natural gas in the Marcellus Shale production

area is lower than in other areas of PJM. A number of new combined cycle plants have located in the production area since 2016. In the first three months of 2020, the price of production gas was 42.9 percent lower than in the first three months of 2019. The price of eastern natural gas was 46.2 percent lower and the price of western natural gas was 41.7 percent lower. (Figure 3-47) The price of Northern Appalachian coal was 28.0 percent lower; the price of Central Appalachian coal was 36.2 percent lower; and the price of Powder River Basin coal was 1.0 percent lower.⁶⁵ The price of ULSD NY Harbor Barge was 47.2 percent lower.

Figure 3-47 Spot average fuel price comparison: January 2012 through March 2020 (\$/MMBtu)



⁶⁵ Eastern natural gas consists of the average of Texas M3, Transco Zone 6 non-NY, Transco Zone 6 NY and Transco Zone 5 daily indices. Western natural gas prices are the average of Columbia Appalachia and Chicago Citygate daily indices. Production gas prices are the average of Dominion South Point, Tennessee Zone 4, and Transco Leidy Line receipts daily indices. Coal prices are the average of daily fuel prices for Central Appalachian coal, Northern Appalachian coal, and Powder River Basin coal. All fuel prices are from Platts.

Figure 3-48 shows fuel prices from January 1, 2020, through March 31, 2020.

Figure 3-48 Spot average fuel price comparison: January through March, 2020 (\$/MMBtu)

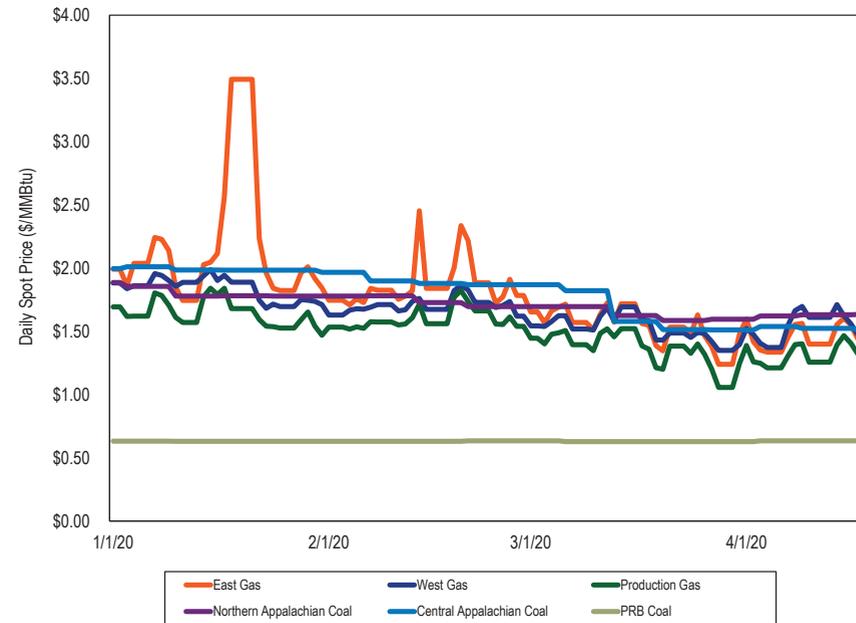


Table 3-56 compares the PJM real-time fuel-cost adjusted, load-weighted, average LMP in the first three months of 2020 to the load-weighted, average LMP in the first three months of 2019.⁶⁶ The real-time, load-weighted average LMP in the first three months of 2020 decreased by \$10.31 or -34.2 percent from the real-time load-weighted, average LMP in the first three months of 2019. The real-time load-weighted, average LMP for the first three months of 2020 was 19.4 percent lower than the real-time fuel-cost adjusted, load-weighted average LMP for the first three months of 2020. The real-time, fuel-cost adjusted, load-weighted average LMP for the first three months of 2020 was 18.3 percent lower than the real-time load-weighted, average LMP for

⁶⁶ The fuel-cost adjusted LMP reflects both the fuel and emissions where applicable, including NO_x, CO₂ and SO_x costs.

the first three months of 2019. If fuel and emissions costs in the first three months of 2020 had been the same as in the first three months of 2019, holding everything else constant, the real-time, load-weighted, average LMP in the first three months of 2020 would have been higher, \$24.64 per MWh, than the observed \$19.85 per MWh. Only 46.4 percent of the decrease in real-time, load-weighted, average LMP, \$4.79 per MWh out of \$10.31 per MWh, is directly attributable to fuel costs. Contributors to the other \$5.52 per MWh are decreased load, adjusted dispatch, including adjustments to dispatch due to changes in relative fuel costs among units, and lower markups.

Table 3-56 Real-time, fuel-cost adjusted, load-weighted average LMP (Dollars per MWh): January through March, 2019 and 2020

	2020 Fuel-Cost Adjusted, Load-Weighted LMP	2020 Load-Weighted LMP	Change	Percent Change
Average	\$24.64	\$19.85	(\$4.79)	(19.4%)
	2019 Load-Weighted LMP	2020 Fuel-Cost Adjusted, Load-Weighted LMP	Change	Percent Change
Average	\$30.16	\$24.64	(\$5.52)	(18.3%)
	2019 Load-Weighted LMP	2020 Load-Weighted LMP	Change	Percent Change
Average	\$30.16	\$19.85	(\$10.31)	(34.2%)

Table 3-57 shows the impact of each fuel type on the difference between the fuel-cost adjusted, load-weighted average LMP and the load-weighted LMP in the first three months of 2020. Table 3-57 shows that lower natural gas prices explain 89.3 percent of the fuel-cost related decrease in the real-time annual, load-weighted average LMP in the first three months of 2020 from the first three months of 2019.

Table 3-57 Share of change in fuel-cost adjusted LMP (\$/MWh) by fuel type: January through March, 2020 adjusted to 2019 fuel prices

Fuel Type	Share of Change in Fuel Cost Adjusted, Load Weighted LMP	Percent
Gas	(\$4.28)	89.3%
Coal	(\$0.51)	10.7%
Oil	(\$0.00)	0.0%
Uranium	\$0.00	0.0%
Municipal Waste	\$0.00	0.0%
Other	\$0.00	0.0%
NA	\$0.00	0.0%
Wind	\$0.00	0.0%
Total	(\$4.79)	100.0%

Components of LMP

Components of Real-Time, Load-Weighted LMP

LMPs result from the operation of a market based on security-constrained, economic (least cost) dispatch (SCED) in which marginal units determine system LMPs, based on their offers and ten minute ahead forecasts of system conditions. Those offers can be decomposed into components including fuel costs, emission costs, variable operation and maintenance (VOM) costs, markup, FMU adder and the 10 percent cost adder. As a result, it is possible to decompose LMP by the components of unit offers.

Cost offers of marginal units are separated into their component parts. The fuel related component is based on unit specific heat rates and spot fuel prices. Emission costs are calculated using spot prices for NO_x, SO₂ and CO₂ emission credits, emission rates for NO_x, emission rates for SO₂ and emission rates for CO₂. The CO₂ emission costs are applicable to PJM units in the PJM states that participate in RGGI: Delaware, Maryland, and New Jersey.⁶⁷ The FMU adder is the calculated contribution of the FMU and AU adders to LMP that results when units with FMU or AU adders are marginal.

Since the implementation of scarcity pricing on October 1, 2012, PJM jointly optimizes the commitment and dispatch of energy and ancillary services. In periods of scarcity when generators providing energy have to be dispatched

⁶⁷ New Jersey withdrew from RGGI, effective January 1, 2012, and rejoined RGGI effective January 1, 2020.

down from their economic operating level to meet reserve requirements, the joint optimization of energy and reserves takes into account the opportunity cost of the reduced generation and the associated incremental cost to maintain reserves. If a unit incurring such opportunity costs is a marginal resource in the energy market, this opportunity cost will contribute to LMP. In addition, in periods when the SCED solution does not meet the reserve requirements, PJM should invoke shortage pricing. During shortage conditions, the LMPs of marginal generators reflect the cost of not meeting the reserve requirements, the scarcity adder, which is defined by the operating reserve demand curve.

LMP may, at times, be set by transmission penalty factors. When a transmission constraint is binding and there are no generation alternatives to resolve the constraint, system operators may allow the transmission limit to be violated. When this occurs, the shadow price of the constraint is set by transmission penalty factors. The shadow price directly affects the LMP. Transmission penalty factors are administratively determined and can be thought of as a form of locational scarcity pricing.

Table 3-58 shows the frequency and average shadow price of transmission constraints in PJM. In the first three months of 2020, there were 43,521 transmission constraint intervals in the real-time market with a nonzero shadow price. For nearly one percent of these transmission constraint intervals, the line limit was violated, meaning that the flow exceeded the facility limit.⁶⁸ In the first three months of 2020, the average shadow price of transmission constraints when the line limit was violated was nearly 39 times higher than when the transmission constraint was binding at its limit.

⁶⁸ The line limit of a facility associated with a transmission constraint is not necessarily the rated line limit. In PJM, the dispatcher has the discretion to lower the rated line limit.

Table 3-58 Frequency and average shadow price of transmission constraints: January through March, 2019 and 2020

Description	Frequency (Constraint Intervals)		Average Shadow Price	
	2019	2020	2019	2020
	(Jan - Mar)	(Jan - Mar)	(Jan - Mar)	(Jan - Mar)
PJM Internal Violated Transmission Constraints	1,753	386	\$1,296.54	\$1,677.98
PJM Internal Binding Transmission Constraints	21,820	34,071	\$113.15	\$42.74
Market to Market Transmission Constraints	13,885	9,064	\$121.59	\$153.46
All Transmission Constraints	37,458	43,521	\$171.66	\$80.30

Transmission penalty factors should be stated explicitly and publicly and applied without discretion. Penalty factors should be set high enough so that they do not act to suppress prices based on available generator solutions. PJM adopted the MMU's recommendation to remove the constraint relaxation logic and allow transmission penalty factors to set prices in the day-ahead and real-time markets for all internal transmission constraints. PJM also revised the tariff to list the conditions under which transmission penalty factors would be changed from their default value of \$2,000 per MWh. The new rules went into effect on February 1, 2019. The Commission approved the PJM and MISO joint filing to remove the constraint relaxation logic for market to market constraints on March 6, 2020. PJM and MISO are expected to implement the changes to their dispatch software in the second half of 2020. PJM continues the practice of discretionary reduction in line ratings.

Table 3-59 shows the frequency of changes to the magnitude of transmission penalty factors for binding and violated transmission constraints in the PJM real-time market. In the first three months of 2020, there were 312 or 81 percent of internal violated transmission constraint intervals in the real-time market with transmission penalty factor equal to the default \$2,000 per MWh.

Table 3-59 Frequency of changes to the magnitude of transmission penalty factor (constraint intervals): January through March, 2019 and 2020

Description	2019 (Jan - Mar)			2020 (Jan - Mar)		
	\$2,000 per MWh (Default)	Above \$2,000 per MWh	Below \$2,000 per MWh	\$2,000 per MWh (Default)	Above \$2,000 per MWh	Below \$2,000 per MWh
PJM Internal Violated Transmission Constraints	1,083	35	635	312	-	74
PJM Internal Binding Transmission Constraints	20,300	619	901	32,759	-	1,312
Market to Market Transmission Constraints	2,729	2	11,154	362	-	8,702
All Transmission Constraints	24,112	656	12,690	33,433	-	10,088

Table 3-60 Components of real-time (Unadjusted), load-weighted, average LMP: January through March, 2019 and 2020

Element	2019 (Jan - Mar)		2020 (Jan - Mar)		Change Percent
	Contribution to LMP	Percent	Contribution to LMP	Percent	
Gas	\$14.00	46.4%	\$8.30	41.8%	(4.6%)
Coal	\$7.61	25.2%	\$5.95	30.0%	4.8%
Ten Percent Adder	\$2.35	7.8%	\$1.61	8.1%	0.3%
VOM	\$1.58	5.2%	\$1.49	7.5%	2.3%
NA	\$0.03	0.1%	\$1.34	6.7%	6.7%
LPA Rounding Difference	\$0.33	1.1%	\$0.35	1.7%	0.6%
CO ₂ Cost	\$0.23	0.8%	\$0.34	1.7%	0.9%
Constraint Violation Adder	\$1.27	4.2%	\$0.32	1.6%	(2.6%)
Markup	\$2.04	6.8%	\$0.10	0.5%	(6.3%)
Increase Generation Adder	\$0.09	0.3%	\$0.06	0.3%	(0.0%)
Opportunity Cost Adder	\$0.04	0.1%	\$0.02	0.1%	(0.0%)
Ancillary Service Redispatch Cost	\$0.32	1.1%	\$0.02	0.1%	(1.0%)
LPA-SCED Differential	\$0.01	0.0%	\$0.01	0.1%	0.0%
Renewable Energy Credits	(\$0.00)	(0.0%)	\$0.00	0.0%	0.0%
Market-to-Market Adder	\$0.00	0.0%	\$0.00	0.0%	(0.0%)
Other	\$0.01	0.0%	\$0.00	0.0%	(0.0%)
SO ₂ Cost	\$0.00	0.0%	\$0.00	0.0%	0.0%
Oil	\$0.03	0.1%	\$0.00	0.0%	(0.1%)
NO _x Cost	\$0.00	0.0%	\$0.00	0.0%	0.0%
Uranium	\$0.00	0.0%	\$0.00	0.0%	0.0%
Scarcity Adder	\$0.24	0.8%	\$0.00	0.0%	(0.8%)
Decrease Generation Adder	(\$0.01)	(0.0%)	(\$0.02)	(0.1%)	(0.1%)
Landfill Gas	\$0.00	0.0%	(\$0.03)	(0.1%)	(0.2%)
Total	\$30.16	100.0%	\$19.85	100.0%	0.0%

The components of LMP are shown in Table 3-60, including markup using unadjusted cost-based offers.⁶⁹ Table 3-60 shows that in the first three months of 2019, 30.0 percent of the load-weighted LMP was the result of coal costs, 41.8 percent was the result of gas costs and 1.70 percent was the result of the cost of emission allowances. Using adjusted cost-based offers, markup was 8.6 percent of the load-weighted LMP. The fuel-related components of LMP reflect the degree to which the cost of the identified fuel affects LMP and does not reflect the other components of the offers of units burning that fuel. The component NA is the unexplained portion of load-weighted LMP. For several intervals, PJM failed to provide all the data needed to accurately calculate generator sensitivity factors. As a result, the LMP for those intervals cannot be decomposed into component costs. The NA component is the cumulative effect of excluding those five minute intervals. In the first three months of 2020, nearly 11 percent of all five minute intervals had insufficient data. The percent column is the difference (in percentage points) in the proportion of LMP represented by each component in the first three months of 2020 and the first three months of 2019.

In order to accurately assess the markup behavior of market participants, real-time and day-ahead LMPs are decomposed using two different approaches. In the first approach (Table 3-60 and Table 3-62), markup is simply the difference between the price offer and the cost-based offer (unadjusted markup). In the second approach (Table 3-61 and Table 3-63), the 10 percent markup is removed from the cost-based offers of coal gas and oil units (adjusted markup).

The components of LMP are shown in Table 3-61, including markup using adjusted cost-based offers.

⁶⁹ These components are explained in the *Technical Reference for PJM Markets*, at p 27 "Calculation and Use of Generator Sensitivity/Unit Participation Factors," <http://www.monitoringanalytics.com/reports/Technical_References/references.shtml>.

Table 3-61 Components of real-time (Adjusted), load-weighted, average LMP: January through March, 2019 and 2020

Element	2019 (Jan - Mar)		2020 (Jan - Mar)		Change Percent
	Contribution to LMP	Percent	Contribution to LMP	Percent	
Gas	\$14.00	46.4%	\$8.30	41.8%	(4.6%)
Coal	\$7.61	25.2%	\$5.95	30.0%	4.8%
Markup	\$4.39	14.5%	\$1.71	8.6%	(5.9%)
VOM	\$1.58	5.2%	\$1.49	7.5%	2.3%
NA	\$0.03	0.1%	\$1.34	6.7%	6.7%
LPA Rounding Difference	\$0.33	1.1%	\$0.35	1.7%	0.6%
CO ₂ Cost	\$0.23	0.8%	\$0.34	1.7%	0.9%
Constraint Violation Adder	\$1.27	4.2%	\$0.32	1.6%	(2.6%)
Increase Generation Adder	\$0.09	0.3%	\$0.06	0.3%	(0.0%)
Opportunity Cost Adder	\$0.04	0.1%	\$0.02	0.1%	(0.0%)
Ancillary Service Redispatch Cost	\$0.32	1.1%	\$0.02	0.1%	(1.0%)
LPA-SCED Differential	\$0.01	0.0%	\$0.01	0.1%	0.0%
Renewable Energy Credits	(\$0.00)	(0.0%)	\$0.00	0.0%	0.0%
Market-to-Market Adder	\$0.00	0.0%	\$0.00	0.0%	(0.0%)
Other	\$0.01	0.0%	\$0.00	0.0%	(0.0%)
Ten Percent Adder	\$0.00	0.0%	\$0.00	0.0%	(0.0%)
SO ₂ Cost	\$0.00	0.0%	\$0.00	0.0%	0.0%
Oil	\$0.03	0.1%	\$0.00	0.0%	(0.1%)
NO _x Cost	\$0.00	0.0%	\$0.00	0.0%	0.0%
Uranium	\$0.00	0.0%	\$0.00	0.0%	0.0%
Scarcity Adder	\$0.24	0.8%	\$0.00	0.0%	(0.8%)
Decrease Generation Adder	(\$0.01)	(0.0%)	(\$0.02)	(0.1%)	(0.1%)
Landfill Gas	\$0.00	0.0%	(\$0.03)	(0.1%)	(0.2%)
Total	\$30.16	100.0%	\$19.85	100.0%	0.0%

Components of Day-Ahead, Load-Weighted LMP

LMPs result from the operation of a market based on security-constrained, least-cost dispatch in which marginal resources determine system LMPs, based on their offers. For physical units, those offers can be decomposed into their components including fuel costs, emission costs, variable operation and maintenance costs, markup, day-ahead scheduling reserve (DASR) adder and the 10 percent cost offer adder. INC offers, DEC bids and up to congestion transactions are dispatchable injections and withdrawals in the day-ahead energy market with an offer price that cannot be decomposed. Using identified marginal resource offers and the components of unit offers,

it is possible to decompose PJM system LMP using the components of unit offers and sensitivity factors.

Table 3-62 shows the components of the PJM day-ahead, annual, load-weighted average LMP. In the first three months of 2020, 34.1 percent of the load-weighted LMP was the result of coal costs, 20.7 percent of the load-weighted LMP was the result of gas costs, 14.4 percent was the result of DEC bid costs, 13.2 percent was the result of INC bid costs and 2.6 percent was the result of the up to congestion transaction costs.

Table 3-62 Components of day-ahead, (unadjusted), load-weighted, average LMP (Dollars per MWh): January through March, 2019 and 2020

Element	2019 (Jan - Mar)		2020 (Jan - Mar)		Change Percent
	Contribution to LMP	Percent	Contribution to LMP	Percent	
Coal	\$7.20	23.4%	\$6.86	34.1%	10.7%
Gas	\$6.91	22.5%	\$4.16	20.7%	(1.8%)
DEC	\$6.21	20.2%	\$2.90	14.4%	(5.8%)
INC	\$5.63	18.3%	\$2.66	13.2%	(5.1%)
VOM	\$1.26	4.1%	\$1.30	6.4%	2.4%
Ten Percent Cost Adder	\$1.55	5.0%	\$1.27	6.3%	1.3%
Up to Congestion Transaction	\$0.71	2.3%	\$0.53	2.6%	0.3%
CO ₂	\$0.16	0.5%	\$0.32	1.6%	1.1%
Dispatchable Transaction	\$0.47	1.5%	\$0.11	0.5%	(1.0%)
Constrained Off	(\$0.07)	(0.2%)	\$0.08	0.4%	0.6%
NO _x	\$0.00	0.0%	\$0.00	0.0%	0.0%
SO ₂	\$0.00	0.0%	\$0.00	0.0%	0.0%
Oil	(\$0.01)	(0.0%)	\$0.00	0.0%	0.0%
Other	\$0.02	0.1%	\$0.00	0.0%	(0.1%)
DASR LOC Adder	\$0.00	0.0%	\$0.00	0.0%	(0.0%)
DASR Offer Adder	\$0.00	0.0%	\$0.00	0.0%	(0.0%)
Uranium	\$0.00	0.0%	\$0.00	0.0%	0.0%
Municipal Waste	\$0.00	0.0%	(\$0.00)	(0.0%)	(0.0%)
Wind	(\$0.01)	(0.0%)	(\$0.00)	(0.0%)	0.0%
Markup	\$0.68	2.2%	(\$0.15)	(0.8%)	(3.0%)
Price Sensitive Demand	\$0.04	0.1%	\$0.00	0.0%	(0.1%)
NA	\$0.00	0.0%	\$0.08	0.4%	0.4%
Total	\$30.76	100.0%	\$20.12	100.0%	(0.0%)

Table 3-63 shows the components of the PJM day-ahead, annual, load-weighted average LMP including the adjusted markup calculated by excluding the 10 percent adder from the coal, gas or oil units.

Table 3-63 Components of day-ahead, (adjusted), load-weighted, average LMP (Dollars per MWh): January through March, 2019 and 2020

Element	2019 (Jan - Mar)		2020 (Jan - Mar)		Change Percent
	Contribution to LMP	Percent	Contribution to LMP	Percent	
Coal	\$7.20	23.4%	\$6.86	34.1%	10.7%
Gas	\$6.91	22.5%	\$4.16	20.7%	(1.8%)
DEC	\$6.21	20.2%	\$2.90	14.4%	(5.8%)
INC	\$5.63	18.3%	\$2.66	13.2%	(5.1%)
VOM	\$1.26	4.1%	\$1.30	6.4%	2.4%
Markup	\$2.21	7.2%	\$1.12	5.6%	(1.6%)
Up to Congestion Transaction	\$0.71	2.3%	\$0.53	2.6%	0.3%
CO ₂	\$0.16	0.5%	\$0.32	1.6%	1.1%
Dispatchable Transaction	\$0.47	1.5%	\$0.11	0.5%	(1.0%)
Constrained Off	(\$0.07)	(0.2%)	\$0.08	0.4%	0.6%
NO _x	\$0.00	0.0%	\$0.00	0.0%	0.0%
SO ₂	\$0.00	0.0%	\$0.00	0.0%	0.0%
Oil	(\$0.01)	(0.0%)	\$0.00	0.0%	0.0%
Other	\$0.02	0.1%	\$0.00	0.0%	(0.1%)
DASR LOC Adder	\$0.00	0.0%	\$0.00	0.0%	(0.0%)
DASR Offer Adder	\$0.00	0.0%	\$0.00	0.0%	(0.0%)
Uranium	\$0.00	0.0%	\$0.00	0.0%	0.0%
Ten Percent Cost Adder	\$0.02	0.1%	(\$0.00)	(0.0%)	(0.1%)
Municipal Waste	\$0.00	0.0%	(\$0.00)	(0.0%)	(0.0%)
Wind	(\$0.01)	(0.0%)	(\$0.00)	(0.0%)	0.0%
Price Sensitive Demand	\$0.04	0.1%	\$0.00	0.0%	(0.1%)
NA	\$0.00	0.0%	\$0.08	0.4%	0.4%
Total	\$30.76	100.0%	\$20.12	100.0%	(0.0%)

Scarcity

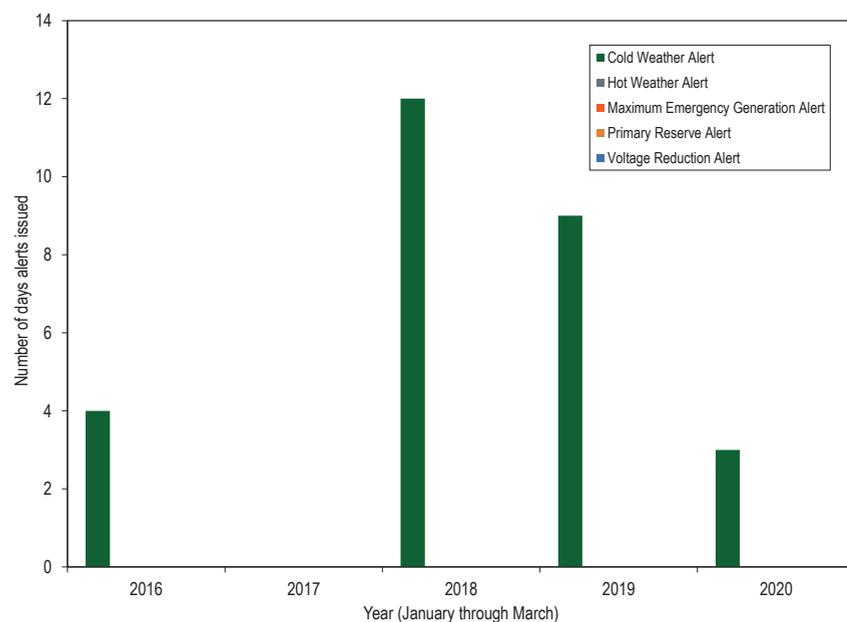
PJM’s energy market did not experience five minute shortage pricing in the first three months of 2020. Table 3-64 shows a summary of the number of days emergency alerts, warnings and actions were declared in PJM in the first three months of 2019 and 2020. In the first three months of 2020, there were no emergency actions that triggered a Performance Assessment Interval (PAI).

Table 3-64 Summary of emergency events declared: January through March, 2019 and 2020

Event Type	Number of days events declared	
	Jan - Mar, 2019	Jan - Mar, 2020
Cold Weather Alert	9	3
Hot Weather Alert	0	0
Maximum Emergency Generation Alert	0	0
Primary Reserve Alert	0	0
Voltage Reduction Alert	0	0
Primary Reserve Warning	0	0
Voltage Reduction Warning	0	0
Pre Emergency Mandatory Load Management Reduction Action	0	0
Emergency Mandatory Load Management Reduction Action (30, 60 or 120 minute lead time)	0	0
Maximum Emergency Action	0	0
Emergency Energy Bids Requested	0	0
Voltage Reduction Action	0	0
Shortage Pricing	9	0
Energy export recalls from PJM capacity resources	0	0

Figure 3-49 shows the number of days that weather and capacity emergency alerts were issued in PJM during the first three months from 2016 through 2020. There were no emergency warnings issued or actions taken in PJM during the first three months from 2016 through 2020.

Figure 3-49 Declared emergency alerts: January through March, 2016 through 2020



Emergency Procedures

PJM declares alerts at least a day prior to the operating day to warn members of possible emergency actions that could be taken during the operating day. In real time, on the operating day, PJM issues warnings notifying members of system conditions that could result in emergency actions during the operating day.

Table 3-65 provides a description of PJM declared emergency procedures.^{70 71 72 73}

Table 3-65 Description of emergency procedures

Emergency Procedure	Purpose
Cold Weather Alert	To prepare personnel and facilities for extreme cold weather conditions, generally when forecast weather conditions approach minimum or temperatures fall below ten degrees Fahrenheit.
Hot Weather Alert	To prepare personnel and facilities for extreme hot and/or humid weather conditions, generally when forecast temperatures exceed 90 degrees with high humidity.
Maximum Emergency Generation Alert	To provide an early alert at least one day prior to the operating day that system conditions may require the use of the PJM emergency procedures and resources must be able to increase generation above the maximum economic level of their offers.
Primary Reserve Alert	To alert members of a projected shortage of primary reserve for a future period. It is implemented when estimated primary reserve is less than the forecast requirement.
Voltage Reduction Alert	To alert members that a voltage reduction may be required during a future critical period. It is implemented when estimated reserve capacity is less than forecasted synchronized reserve requirement.
Pre-Emergency Load Management Reduction Action	To request load reductions from customers registered in the PJM Demand Response program that need 30, 60, or 120 minute lead time before declaring emergency load management reductions
Emergency Mandatory Load Management Reduction Action	To request load reductions from customers registered in the PJM Demand Response program that need 30, 60, or 120 minute lead time to provide additional load relief, generally declared simultaneously with NERC Energy Emergency Alert Level 2 (EEA2)
Primary Reserve Warning	To warn members that available primary reserve is less than required and present operations are becoming critical. It is implemented when available primary reserve is less than the primary reserve requirement but greater than the synchronized reserve requirement.
Maximum Emergency Generation Action	To provide real time notice to increase generation above the maximum economic level. It is implemented whenever generation is needed that is greater than the maximum economic level.
Voltage Reduction Warning & Reduction of Non-Critical Plant Load	To warn members that actual synchronized reserves are less than the synchronized reserve requirement and that voltage reduction may be required.
Deploy All Resources Action	For emergency events that do not evolve over time, but rather develop rapidly and without prior warning, PJM issues this action to instruct all generation resources to be online immediately and to all load management resources to reduce load immediately.
Manual Load Dump Warning	To warn members of the critical condition of present operations that may require manually dumping load. Issued when available primary reserve capacity is less than the largest operating generator or the loss of a transmission facility jeopardizes reliable operations after all other possible measures are taken to increase reserve.
Voltage Reduction Action	To reduce load to provide sufficient reserve capacity to maintain tie flow schedules and preserve limited energy sources. It is implemented when load relief is needed to maintain tie schedules.
Manual Load Dump Action	To provide load relief when all other possible means of supplying internal PJM RTO load have been used to prevent a catastrophe within the PJM RTO or to maintain tie schedules so as not to jeopardize the reliability of the other interconnected regions.

⁷⁰ See PJM. "Manual 13: Emergency Operations," Rev. 75 (Jan. 1, 2020), Section 3.3 Cold Weather Alert.

⁷¹ See PJM. "Manual 13: Emergency Operations," Rev. 75 (Jan. 1, 2020), Section 3.4 Hot Weather Alert.

⁷² See PJM. "Manual 13: Emergency Operations," Rev. 75 (Jan. 1, 2020), Section 2.3.1 Advanced Notice Emergency Procedures: Alerts.

⁷³ See PJM. "Manual 13: Emergency Operations," Rev. 75 (Jan. 1, 2020), 2.3.2 Real-Time Emergency Procedures (Warnings and Actions).

Table 3-66 shows the dates when emergency alerts and warnings were declared and when emergency actions were implemented in the first three months of 2020.

Table 3-66 Declared emergency alerts, warnings and actions: January through March, 2020

Date	Cold Weather Alert	Hot Weather Alert	Maximum Emergency Generation Alert	Primary Reserve Alert	Voltage Reduction Alert	Primary Reserve Warning	Voltage Reduction Warning and Reduction of Non-Critical Plant Load	Maximum Emergency Generation Action	Pre-Emergency Mandatory Load Management Reduction	Emergency Mandatory Load Management Reduction	Voltage Reduction	Manual Load Dump Warning	Manual Load Dump Action	Load Shed Directive
1/19/2020	ComEd													
1/20/2020	ComEd													
1/21/2020	ComEd													

Power Balance Constraint Violation

On October 1, 2019, in 11 approved RT SCED solutions between 1455 EPT and 1655 EPT, the power balance constraint in RT SCED was violated. On February 16, 2020, in one approved RT SCED solution, the power balance constraint in RT SCED was violated. In the RT SCED optimization, the power balance constraint enforces the requirement that total dispatched generation (supply) equals the sum total of forecasted load, losses and net interchange (demand). The power balance constraint is violated when supply is less than demand. In some cases, the power balance constraint is violated while the reserve requirements are satisfied.

The current process for meeting energy and reserve requirements in real time, and pricing the system conditions when RT SCED forecasts that energy supply is less than the demand for energy and reserves, is opaque and not defined in the PJM governing documents. It is unclear whether and how PJM would convert reserves to energy before violating power balance. It is unclear whether and when PJM would use its authority under the tariff to curtail exports from PJM capacity resources to meet the power balance constraint. It is unclear whether PJM would maintain a minimum level of synchronized reserves even if that would result in a controlled load shed. The current RT SCED does not have a mechanism to convert inflexible reserves procured

by ASO to energy to satisfy the power balance constraint.⁷⁴ SCED solutions from October 1, 2019, and February 16, 2020, indicate that the currently defined logic meets transmission constraint limits and reserve requirements but violates the power balance constraint, and does not reflect this constraint violation in prices. This logic, if correctly described, is not consistent with basic economics. The overall solution is complex and must be integrated with the approach to scarcity pricing.

The MMU recommends that PJM clarify, modify and document its process for dispatching reserves and energy when SCED indicates that supply is less than total demand including forecasted load and reserve requirements. The modifications should define: a SCED process to economically convert reserves to energy; a process for the recall of energy from capacity resources; and the minimum level of synchronized reserves that would trigger load shedding.

Table 3-67 shows the number of five minute intervals for which the RT SCED solutions used to set prices did not balance demand and supply. Subsequently, PJM reran the RT SCED with artificially increased supply to satisfy the power balance constraint. In the first three months of 2020, there were three five minute intervals using RT SCED solutions with violated power balance constraint.

⁷⁴ Inflexible reserves are those reserves that clear in the hour ahead Ancillary Service Optimizer (ASO) but cannot be dispatched in the real time dispatch tool, RT SCED.

Table 3-67 Number of five minute intervals using RT SCED solutions with violated power balance constraint by year

Year	Number of five minute intervals
2013	-
2014	655
2015	71
2016	42
2017	31
2018	16
2019	36
2020	3

Balancing Ratio for Local Emergency Events

The balancing ratio is theoretically defined as the ratio of actual load and reserve requirements in an area during an emergency event to the total committed capacity in the area. In the case of the PAIs declared in 2018, if the area is defined as the location where the load was shed, the balancing ratio is undefined because there were no committed resources in the area, other than less than 1.0 MW of demand response. It would not be appropriate or correct to calculate a balancing ratio as a measure of capacity needed during these events by defining a wider area to include committed capacity. It is also not appropriate to use a balancing ratio defined in that way in defining the capacity market offer cap. These events occurred in a very small local area where no capacity resources were held to CP performance requirements. Assessing nonperformance to resources located in the wider area would not be appropriate because their performance would not have helped, and may have even exacerbated the transmission issues identified during these events. These events also do not reflect the type of events that are modeled to define the target installed reserve margin in the capacity market. The MMU recommends that PJM not include the balancing ratios calculated for localized Performance Assessment Intervals (PAIs) in the calculation of the capacity market default offer cap, and only include those events that trigger emergencies at a defined zonal or higher level.

Scarcity and Scarcity Pricing

In electricity markets, scarcity means that demand, including reserve requirements, is nearing the limits of the currently available capacity of the system. Scarcity pricing is a mechanism for signaling scarcity conditions through energy prices. Under the PJM rules that were in place through September 30, 2012, scarcity pricing resulted from high offers by individual generation owners for specific units when the system was close to its available capacity. But this was not an efficient way to manage scarcity pricing and made it difficult to distinguish between market power and scarcity pricing. Shortage pricing is an administrative scarcity pricing mechanism in which PJM sets a high energy price at a predetermined level when the system operates with less real time reserves than required.

In the first three months of 2020, there were no five minute intervals with shortage pricing in PJM.

With Order No. 825, the Commission required each RTO/ISO to trigger shortage pricing for any dispatch and pricing interval in which a shortage of energy or operating reserves is indicated by the RTO/ISO's software.⁷⁵ As of May 11, 2017, the rule requires PJM to trigger shortage pricing for any five minute interval for which the Real-Time SCED (Security Constrained Economic Dispatch) indicates a shortage of synchronized reserves or primary reserves. Prior to May 11, 2017, if the dispatch tools (Intermediate-Term SCED and Real-Time SCED) reflected a shortage of reserves (primary or synchronized) for a time period shorter than a defined threshold (30 minutes), it was considered a transient shortage, a shortage event was not declared, and shortage pricing was not implemented.

Voltage reduction actions and manual load dump actions are also triggers for shortage pricing, reflecting the fact that when operators need to take these emergency actions to maintain reliability, the system is short reserves and prices should reflect that condition, even if the data do not show a shortage of reserves.⁷⁶

⁷⁵ 155 FERC ¶ 61,276 ("Order No. 825") at P 162.

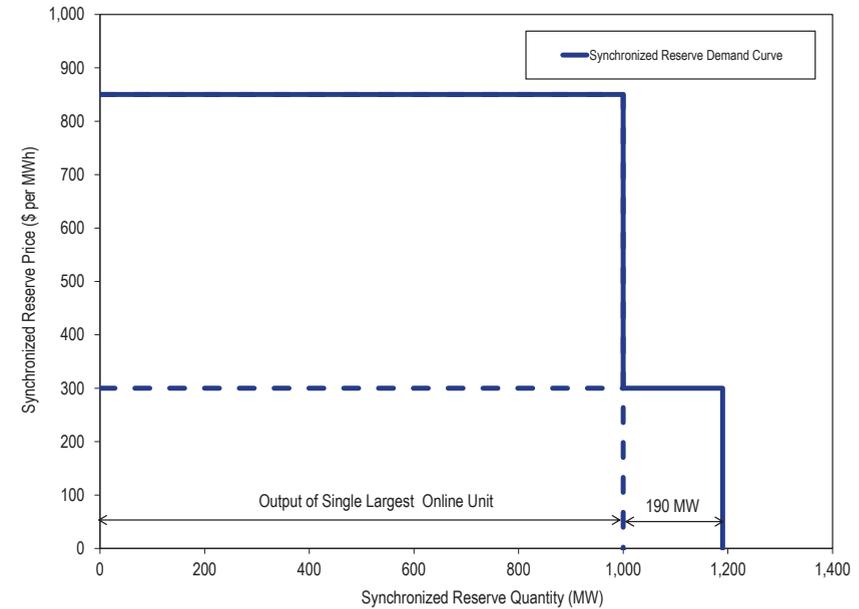
⁷⁶ See, e.g., Scarcity and Shortage Pricing, Offer Mitigation and Offer Caps Workshop, Docket No. AD14-14-000, Transcript 29:21-30:14 (Oct. 28, 2014).

PJM Tariff Revisions to Operating Reserve Demand Curves

On May 12, 2017, PJM submitted tariff revisions to reflect changes to the Operating Reserve Demand Curves (ORDC) used in the real-time energy market to price shortage of primary reserves and synchronized reserves.⁷⁷ The updates to the ORDC went into effect on July 12, 2017.

PJM revised the synchronized reserve requirement in a reserve zone or a subzone from the economic maximum of the largest unit on the system to 100 percent of the actual output of the single largest online unit in that reserve zone or subzone. PJM revised the primary reserve requirement in a reserve zone or a subzone from 150 percent of the economic maximum of the largest unit on the system to 150 percent of the actual output of the single largest online unit in that reserve zone or subzone. The first step of the demand curves for primary and synchronized reserves are set at the primary and synchronized reserve requirement. Since the primary and synchronized reserve requirements are based on the actual output of the largest resource, the MW value of the first step changes in real time based on the real-time dispatch solution. The first step continues to be priced at \$850 per MWh. PJM also added a permanent second step to the primary and synchronized reserve demand curves, set at the extended primary and synchronized reserve requirements. The extended primary and synchronized reserve requirements are defined as the primary and synchronized reserve requirements, plus 190 MW. This 190 MW second step is priced at \$300 per MWh. Figure 3-50 shows an example of the updated synchronized reserve demand curve when the output of the single largest unit in the region equals 1,000 MW.

Figure 3-50 Updated synchronized reserve demand curve showing the permanent second step



Scarcity Pricing and Energy Price Formation

The current operating reserve demand curves (ORDC) in PJM define an administrative price for estimated reserves (primary and synchronized reserves) up to the extended reserve requirement quantities. The demand curve shown in Figure 3-50 drops to a zero price for quantities above the extended reserve requirement. The price for reserve quantities less than the reserve requirement is \$850 per MWh, and the price for reserve quantities above the reserve requirement to 190 MW above the reserve requirement is \$300 per MWh. The price below the reserve requirement should be sufficient to cover the marginal cost of any generator on the system capable of responding.

Unlike an energy only market, PJM does not set scarcity prices to compensate the full fixed and avoidable cost of the resources needed to meet peak demand.

⁷⁷ See PJM Filing, FERC Docket No. ER17-1590-000 (May 12, 2017).

The PJM market compensates capacity resources through the capacity market for availability to the system when they are needed to meet demand. In addition, because consumers do not see, and do not and generally cannot respond in the short run to, real-time energy market prices, scarcity pricing cannot ration scarce energy among consumers according to their marginal willingness to pay. By extension, PJM cannot measure consumers' willingness to pay for reserves to avoid a loss of load. Therefore, the ORDC appropriately does not attempt to administratively represent consumers' willingness to pay for reserves, or customers' value of lost load.

Locational Reserve Requirements

In addition to the construction of the operating reserve demand curves to reflect the value of maintaining reserves and avoiding a loss of load event, the modeling of reserve requirements should reflect locational needs and should price operator actions, for example, to commit more reserves than required.

The current operating reserve demand curves are modeled for reserve requirements for the RTO level (RTO Reserve Zone) and for the Mid-Atlantic and Dominion region (MAD Subzone). This was a result of historical congestion patterns where limits to transmission capacity to deliver power from outside the MAD Subzone into the MAD Subzone necessitated maintaining reserves in the MAD area to respond to disturbances within the subzone. However, in real-time operations, due to generator outages, transmission outages, and local weather patterns, PJM may need to maintain or operate resources in other local areas to maintain local reliability, in addition to the RTO and MAD reserve levels. Currently, these units are committed out of market for reliability reasons, or are modeled as artificial closed loop interfaces with limited deliverability modeled inside the closed loop from resources located outside. The value of operating these resources, including generators that are manually committed for reliability and demand resources that may be dispatched inside a closed loop, is not correctly reflected in prices. A more efficient way to reflect these requirements would be to have locational reserve requirements that are adjusted based on PJM forecasts and reliability studies.

Operator Actions

Actions taken by PJM operators to maintain reliability, such as committing more reserves than required, may suppress reserve prices. The need to commit more reserves could instead be reflected in the ORDC, allowing the market to efficiently account for the reliability commitment in the energy and reserves markets.

Reserve Shortages in 2020

Reserve Shortage in Real-Time SCED

The MMU analyzed the RT SCED solved cases to determine how many of the solved RT SCED cases indicated a shortage of any of the reserve products (synchronized reserve and primary reserve at RTO Reserve Zone and MAD Reserve Subzone), how many of these solved cases were approved by PJM, and how many of these were used in LPC to calculate prices. Reserves are considered short if the quantity (MW) of reserves dispatched by RT SCED for a five minute interval was less than the extended reserve requirement. Table 3-68 shows the number and percent of RT SCED cases solved that indicated a shortage of any of the four reserve products (RTO synchronized reserve, RTO primary reserve, MAD synchronized reserve, and MAD primary reserve), the number and percent of the solved RT SCED cases with shortage that were approved by PJM, and the number and percent of the RT SCED cases with shortage that were used in LPC to calculate real-time prices.

Table 3-68 shows that, in the first three months of 2020, PJM operators approved zero RT SCED cases that indicated a shortage of reserves, from a total of 805 RT SCED solutions that indicated shortage. Without any approved RT SCED cases with reserve shortage, none were used in LPC for reserve clearing prices. In comparison, in the first three months of 2019, PJM operators approved nineteen cases that indicated a shortage of reserves, from a total of 1,181 RT SCED solutions that indicated shortage. It is unclear what criteria PJM operators use to approve the RT SCED solutions to send dispatch signals to resources. The RT SCED approval process remains inconsistent and undefined.

Table 3-68 RT SCED cases with reserve shortage: January through March, 2020

Month (2020)	Number of Solved RT SCED Cases	Number of Solved RT SCED Cases With Reserve Shortage	Number of Approved RT SCED Cases With Reserve Shortage	Number of Approved RT SCED Cases With Reserve Shortage Used in LPC	Cases With Reserve Shortage as Percent of Solved RT SCED Cases	Approved RT SCED Cases With Reserve Shortage as Percent of Solved RT SCED Cases With Shortage	RT SCED Cases With Shortage Used in LPC as Percent of Solved RT SCED Cases With Shortage
Jan	51,022	337	0	0	0.7%	0.0%	0.0%
Feb	46,247	186	0	0	0.4%	0.0%	0.0%
Mar	38,680	282	0	0	0.7%	0.0%	0.0%
Total	135,949	805	0	0	0.6%	0.0%	0.0%

While there were 805 solved RT SCED solutions that indicated shortage, the number of five minute intervals where RT SCED indicated shortage was only 439. This is because PJM solves multiple RT SCED cases with three solutions per case, for each five minute target interval.⁷⁸

The MMU analyzed the intervals where one or more RT SCED case solutions indicated a shortage of one or more reserve products. Table 3-69 shows, for each month of 2020, the total number of five minute intervals, the number of intervals where at least one RT SCED solution showed a shortage of reserves, the number of intervals where more than one RT SCED solution showed a shortage of reserves, and the number of five minute intervals where the LPC solution showed a shortage of reserves. Table 3-69 shows that 439 intervals, or 1.7 percent of all five minute intervals in the first three months of 2020 had at least one RT SCED solution showing a shortage of reserves, and 199 intervals, or 0.8 percent of all five minute intervals in the first three months of 2020 had more than one RT SCED solution showing a shortage of reserves.

Table 3-69 Five minute intervals with shortage: January through March, 2020

Month (2020)	Number of Five Minute Intervals	Number of Intervals With At Least One Solved SCED Case Short of Reserves	Percent Intervals With At Least One Solved SCED Case Short of Reserves	Number of Intervals With Multiple Solved SCED Cases Short of Reserves	Percent Intervals With Multiple Solved SCED Cases Short of Reserves	Number of Intervals With Five Minute Shortage Prices in LPC	Percent Intervals With Five Minute Shortage Prices in LPC
Jan	8,928	172	1.9%	89	1.0%	0	0.0%
Feb	8,352	94	1.1%	44	0.5%	0	0.0%
Mar	8,916	173	1.9%	66	0.7%	0	0.0%
Total	26,196	439	1.7%	199	0.8%	0	0.0%

While a single solved RT SCED solution indicating a shortage for a target interval among multiple RT SCED solutions that solved for that interval could be the result of operator bias or erroneous inputs, it is less likely that an interval with multiple RT SCED solutions indicating shortage was the result of an error. There were zero five minute intervals with shortage pricing that occurred in the first three months of 2020, while there were 199 five minute intervals where multiple RT SCED solutions showed a shortage of reserves. In the first three months of 2019, out of 622 intervals where one or more RT SCED solutions indicated a shortage of reserves, there were 13 five minute intervals, or 0.1 percent, with shortage pricing. In the first three months of 2020, out of 439 intervals where one or more RT SCED solutions indicated a shortage of reserves, there were zero five minute intervals, or 0.0 percent, with shortage pricing.

The PJM Real-Time Energy Market produces an efficient outcome only when prices are allowed to reflect the fundamental supply and demand conditions in the market in real time. While it is appropriate for operators to ensure that cases use data that reflect the actual state of the system, it is essential that operator

⁷⁸ A case is executed when it begins to solve. Most but not all cases are solved. RT SCED cases take about one to two minutes to solve.

discretion not extend beyond what is necessary and that operator discretion not prevent shortage pricing when there are shortage conditions. This is a critical issue now that PJM settles all real-time energy transactions on a five minute basis using the prices calculated by LPC. The MMU recommends that PJM clearly define the criteria for operator approval of RT SCED cases used to send dispatch signals to resources, and for pricing, to minimize operator discretion and implement a rule based approach.

Shortage Pricing Intervals in LPC

There were no five minute intervals with shortage pricing in the first three months of 2020, compared to 13 intervals in the first three months of 2019, in PJM.

Accuracy of Reserve Measurement

The definition of a shortage of synchronized and primary reserves is based on the measured and estimated levels of load, generation, interchange, demand response, and reserves from the real-time SCED software. The definition of such shortage also includes discretionary operator inputs to the ASO (Ancillary Service Optimizer) or RT SCED software, such as tier 1 bias or operator load bias. For shortage pricing to be accurate, there must be accurate measurement of real-time reserves. That does not appear to be the case at present in PJM, but there does not appear to be any reason that PJM cannot accurately measure reserves. Without accurate measurement of reserves on a minute by minute basis, system operators cannot know with certainty that there is a shortage condition and a reliable trigger for five minute shortage pricing does not exist. The benefits of five minute shortage pricing are based on the assumption that a shortage can be precisely and transparently defined.⁷⁹ PJM cannot accurately measure or price reserves due to the inaccuracy of its generator models. PJM's commitment and dispatch models rely on generator data to properly commit and dispatch generators. Generator data includes offers and parameters. When the models do not properly account for the different generator characteristics, both PJM dispatchers and generators have to make simplifications and assumptions using the tools available. Most of

⁷⁹ See Comments of the Independent Market Monitor for PJM, Docket No. RM15-24-000 (December 1, 2015) at 9.

these actions taken by generators and by PJM dispatchers are not transparent. PJM manuals do not provide clarity regarding what actions generators can take when the PJM models and tools do not reflect their operational characteristics and PJM manuals do not provide sufficient clarity regarding the actions PJM dispatchers can take when generators do not follow dispatch.

In the energy and reserve markets, the actions that both generators and PJM dispatchers take have a direct impact on the amount of supply available for energy and reserves and the prices for energy and reserves. These flaws in PJM's models do not allow PJM to accurately calculate the amount of reserves available. PJM does not accurately model discontinuities in generator ramp rates, such as duct burners on combined cycle plants. PJM's generator models do not account for the complexities that may result in generators underperforming their submitted ramp rates. Instead of addressing these complexities through generator modeling improvements, PJM relies on a nontransparent method of adjusting generator parameters, called Degree of Generator Performance (DGP).⁸⁰ PJM also fails to accurately model unit starts. The market software does not account for the energy output a resource produces prior to reaching its economic minimum output level, during its soak time.

PJM adjusts ramp rates using DGP, deselects specific units from providing reserves, and overrides the dispatch signal to certain units to set the dispatch signal equal to actual resource output. These manual interventions are, at best, rough approximations of the capability of generators and result in an inaccurate measurement of reserves.

PJM Cold Weather Operations 2020

Natural Gas Supply and Prices

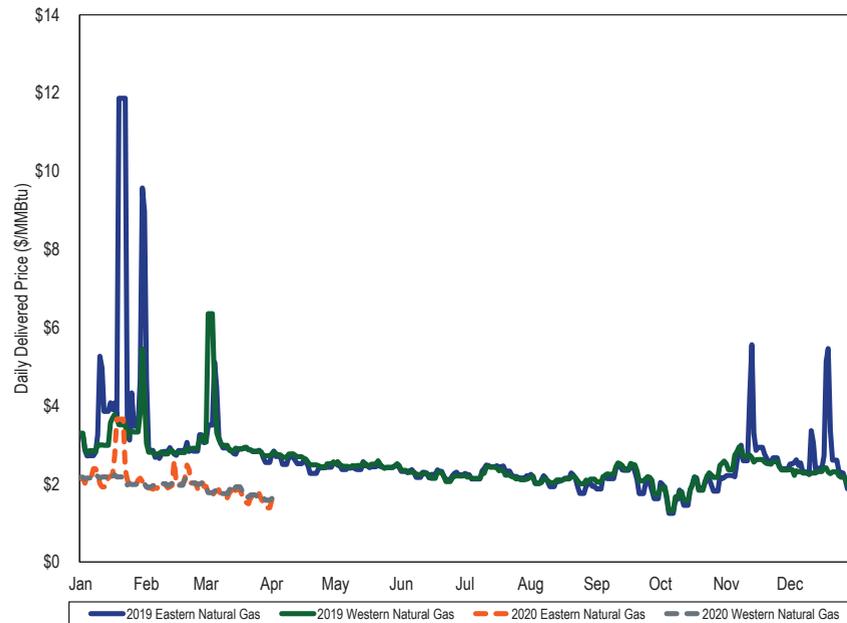
As of March 31, 2020, gas fired generation was 42.8 percent (79,249.9 MW) of the total installed PJM capacity (185,188.7 MW).⁸¹ Figure 3-51 shows the

⁸⁰ See "PJM Manual 12: Balancing Operations," Rev. 39 (Feb. 21, 2019) Attachment A, P78. PJM Manual 11: Energy and Ancillary Services Market Operations, does not mention the use of DGP in the market clearing engine.

⁸¹ 2020 Quarterly State of the Market Report for PJM: January through March, Section 5: Capacity Market, at Installed Capacity.

average daily price of delivered natural gas for eastern and western parts of PJM service territory in 2019 and 2020.⁸²

Figure 3-51 Average daily delivered price for natural gas: 2019 and 2020 (\$/MMBtu)



In 2019 and the first three months of 2020, a number of interstate gas pipelines that supply fuel for generators in the PJM service territory issued restriction notices limiting the availability of nonfirm transportation services. These notices include warnings of operational flow orders (OFO) and actual OFOs. These notices may, depending on the nature of the transportation service purchased, permit the pipelines to restrict the provision of gas to 24 hour ratable takes which means that hourly nominations must be the same for each of the 24 hours in the gas day, with penalties for deviating from the nominated

⁸² Eastern natural gas consists of the average of Texas Eastern M3, Transco Zone 6 non-NY, Transco Zone 6 NY and Transco Zone 5 daily fuel price indices. Western natural gas prices are the average of Dominion North Point, Columbia Appalachia and Chicago City gate daily fuel price indices.

quantities. Pipelines may also enforce strict balancing constraints which limit the ability of gas users, depending on the nature of the transportation service purchased, to deviate from the 24 hour ratable take and which may limit the ability of users to have access to unused gas.

Pipeline operators use restrictive and inflexible rules to manage the balance of supply and demand during extreme operating conditions. The independent operations of geographically overlapping pipelines during extreme conditions highlights the potential shortcomings of a gas pipeline network that relies on individual pipelines to manage the balancing of supply and demand. The independent operational restrictions imposed by pipelines and the impact on electric generators during extreme conditions demonstrates the potential benefits to creating a separate gas ISO/RTO structure to coordinate the supply of gas across pipelines and with the electric RTOs and to facilitate the interoperability of the pipelines in an explicit network.

The increase in natural gas fired capacity in PJM in recent years also highlighted issues with the dependence of the PJM system reliability on the fuel transportation arrangements entered into by generators. The risks to the fuel supply for gas generators, including the risk of interruptible supply on cold days and the ability to get gas on short notice during times of critical pipeline operations, creates risks for the bulk power system. PJM should collect data on each individual generator’s fuel supply arrangements, and analyze the associated locational and regional risks to reliability.

Competitive Assessment

Market Structure

Market Concentration

Analysis of supply curve segments of the PJM energy market in the first three months of 2020 indicates low concentration in the base load segment, moderate concentration in the intermediate segment, and high concentration in the peaking segment.⁸³ High concentration levels, particularly in the

⁸³ A unit is classified as base load if it runs for more than 50 percent of hours, as intermediate if it runs for less than 50 percent but greater than 10 percent of hours, and as peak if it runs for less than 10 percent of hours.

peaking segment, increase the probability that a generation owner will be pivotal in the aggregate market. The fact that the average HHI and the maximum hourly HHI are in the unconcentrated range does not mean that the aggregate market was competitive in all hours. It is possible to have pivotal suppliers in the aggregate market even when the HHI level does not indicate a highly concentrated market structure. It is possible to have an exercise of market power even when the HHI level does not indicate a highly concentrated market structure.

When transmission constraints exist, local markets are created with ownership that is typically significantly more concentrated than the overall energy market. PJM offer capping rules that limit the exercise of local market power were generally effective in preventing the exercise of market power in the first three months of 2020, although there are issues with the application of market power mitigation for resources whose owners fail the TPS test that permit local market power to be exercised even when mitigation rules are applied. These issues include the lack of a method for consistently determining the cheaper of the cost and price schedules and the lack of rules requiring that cost-based offers equal short run marginal costs.

The Herfindahl-Hirschman Index (HHI) concentration ratio is calculated by summing the squares of the market shares of all firms in a market. Hourly PJM energy market HHIs are based on the real-time energy output of generators adjusted with scheduled imports (Table 3-70).

The HHI may not accurately capture market power issues in situations where, for example, there is moderate concentration in all on line resources but there is a high level of concentration in resources needed to meet increases in load. The HHIs for supply curve segments indicate issues with the ownership of incremental resources. An aggregate pivotal supplier test is required to accurately measure the ability of incremental resources to exercise market power when load is high, for example.

Hourly HHIs for the baseload, intermediate and peaking segments of generation supply are based on hourly energy market shares, unadjusted for imports.

The “Merger Policy Statement” of FERC states that a market can be broadly characterized as:

- **Unconcentrated.** Market HHI below 1000, equivalent to 10 firms with equal market shares;
- **Moderately Concentrated.** Market HHI between 1000 and 1800; and
- **Highly Concentrated.** Market HHI greater than 1800, equivalent to between five and six firms with equal market shares.⁸⁴

PJM HHI Results

Calculations for hourly HHI indicate that by FERC standards, the PJM energy market during the first three months of 2020 was unconcentrated (Table 3-70).

Table 3-70 Hourly energy market HHI: January through March, 2019 and 2020⁸⁵

	Hourly Market HHI (Jan - Mar, 2019)	Hourly Market HHI (Jan - Mar, 2020)
Average	765	706
Minimum	602	592
Maximum	1075	996
Highest market share (One hour)	25%	25%
Average of the highest hourly market share	18%	18%
# Hours	2,159	2,183
# Hours HHI > 1800	0	0
% Hours HHI > 1800	0%	0%

Table 3-71 includes HHI values by supply curve segment, including base, intermediate and peaking plants for the first three months of 2019 and 2020. The PJM energy market was unconcentrated overall with low concentration in the baseload segment, moderate concentration in the intermediate segment, and high concentration in the peaking segment.

⁸⁴ See *Inquiry Concerning the Commission's Merger Policy under the Federal Power Act: Policy Statement*, 77 FERC ¶ 61,263 mimeo at 80 (1996).

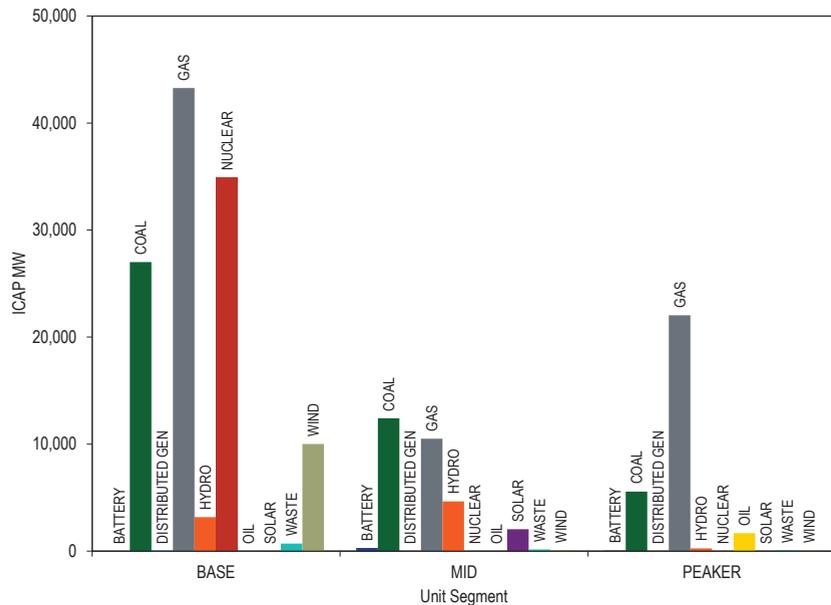
⁸⁵ This analysis includes all hours in the first three months of 2019 and 2020, regardless of congestion.

Table 3-71 Hourly energy market HHI (By supply segment): January through March, 2019 and 2020

	Jan - Mar, 2019			Jan - Mar, 2020		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Base	649	791	1084	605	735	1032
Intermediate	860	2185	10000	704	1616	6726
Peak	773	6343	10000	1077	6055	10000

Figure 3-52 shows the total installed capacity (ICAP) MW of units in the baseload, intermediate and peaking segments by fuel source in the first three months of 2020.

Figure 3-52 Fuel source distribution in unit segments: January through March, 2020⁸⁶



⁸⁶ The units classified as Distributed Gen are buses within Electric Distribution Companies (EDCs) that are modeled as generation buses to accurately reflect net energy injections from distribution level load buses. The modeling change was the outcome of the Net Energy Metering Task Force stakeholder group in July, 2012. See PJM. "Net Energy Metering Senior Task Force (NEMSTF) 1st Read - Final Report and Proposed Manual Revisions," (June 28, 2012) <<http://www.pjm.com/~media/committees-groups/task-forces/nemstf/postings/20120628-first-read-item-04-nemstf-report-and-proposed-manual-revisions.aspx>>.

Figure 3-53 shows the ICAP of coal fired and gas fired units in PJM that are classified as baseload, intermediate and peaking segments in the first three months from 2016 through 2020. Figure 3-53 shows that the total ICAP of coal fired units in PJM that are classified as baseload has been steadily decreasing and the total ICAP of gas fired units in PJM that are classified as baseload is steadily increasing, based on operating history for the period from the first three months of 2016 through 2020. In the first three months of 2019, the ICAP of gas fired units classified as baseload exceeded the ICAP of coal fired units classified as baseload for the first time.

Figure 3-53 Unit segment classification by fuel: January through March, 2016 through 2020

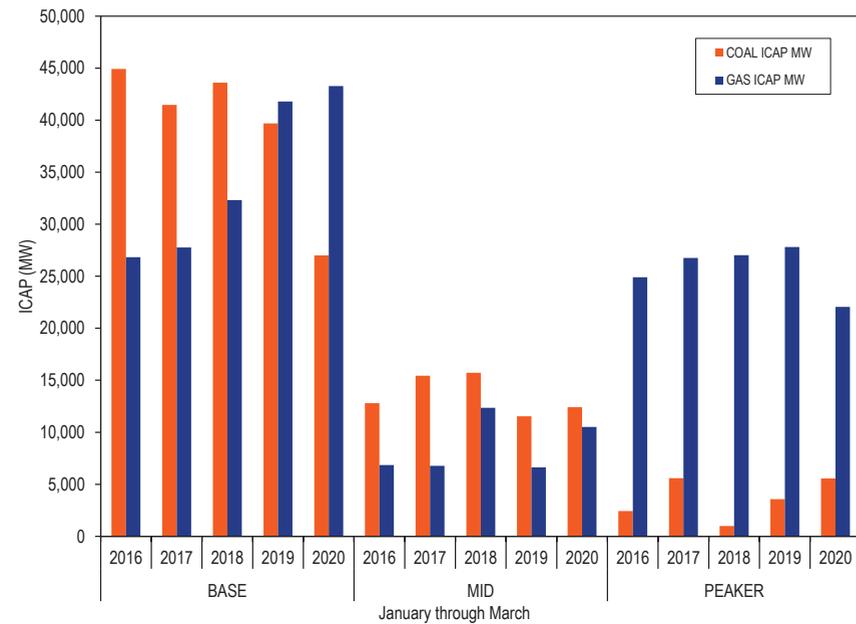
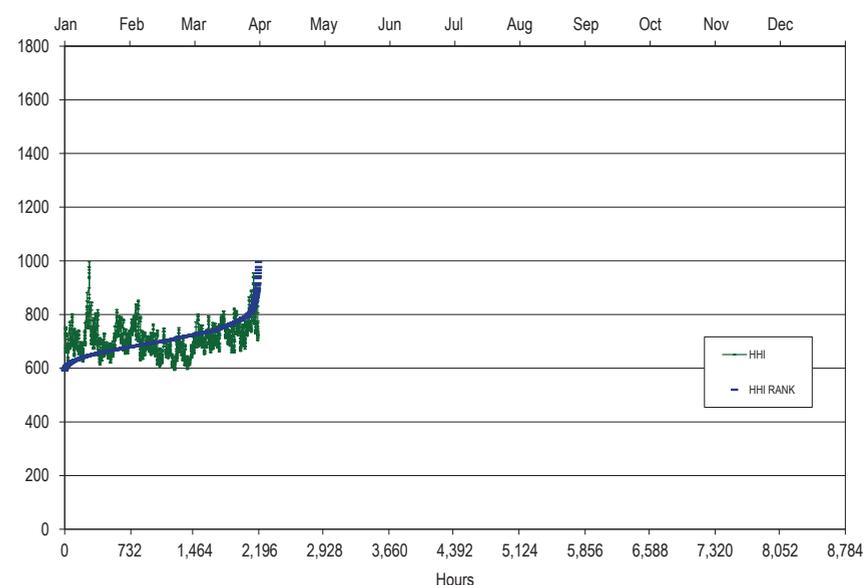


Figure 3-54 presents the hourly HHI values in chronological order and an HHI duration curve for the first three months of 2020.

Figure 3-54 Hourly energy market HHI: January through March, 2020



Merger Reviews

FERC reviews contemplated dispositions, consolidations, acquisitions, and changes in control of jurisdictional generating units and transmission facilities under section 203 of the Federal Power Act to determine whether such transactions are “consistent with the public interest.”⁸⁷

FERC applies tests set forth in the 1996 Merger Policy Statement.⁸⁸ FERC is currently reviewing those guidelines.⁸⁹

⁸⁷ 18 U.S.C. § 824b.

⁸⁸ See Order No. 592, FERC Stats. & Regs. ¶ 31,044 (1996) (1996 Merger Policy Statement), *reconsideration denied*, Order No. 592-A, 79 FERC ¶ 61,321 (1997). See also FPA Section 203 Supplemental Policy Statement, FERC Stats. & Regs. ¶ 31,253 (2007), *order on clarification and reconsideration*, 122 FERC ¶ 61,157 (2008).

⁸⁹ See 156 FERC ¶ 61,214 (2016); FERC Docket No. RM16-21-000.

The 1996 Merger Policy Statement provides for review of jurisdictional transactions based on “(1) the effect on competition; (2) the effect on rates; and (3) the effect on regulation.” FERC adopted the 1992 Department of Justice Guidelines and the Federal Trade Commission Horizontal Merger Guideline (1992 Guidelines) to evaluate the effect on competition. Following the 1992 Guidelines, FERC applies a five step framework, which includes: (1) defining the market; (2) analyze market concentration; (3) analyze mitigative effects of new entry; (4) assess efficiency gains; and (5) assess viability of parties without merger. FERC also applies a Competitive Analysis Screen.

The MMU reviews proposed mergers based on a three pivotal supplier test applied to the actual operation of the PJM market. The MMU routinely files comments including such analyses.⁹⁰ The MMU has proposed that FERC adopt this approach when evaluating mergers in PJM.⁹¹ FERC has considered the MMU’s analysis in reviewing mergers.⁹²

The MMU also reviews transactions that involve ownership changes of PJM generation resources that are submitted to the Commission pursuant to section 203 of the Federal Power Act. Table 3-72 shows transactions that involved an entire generation unit or unit owner that were completed in the first three months of 2020, as reported to the Commission.

⁹⁰ See, e.g., Comments of the Independent Market Monitor for PJM, FERC Docket No. EC14-141-000 (Nov. 10, 2014); Comments of the Independent Market Monitor for PJM, FERC Docket No. EC14-96-000 (July 21, 2014) Comments of the Independent Market Monitor for PJM, FERC Docket No. EC11-83-000 (July 21, 2011); Comments of the Independent Market Monitor for PJM, FERC Docket No. EC14-14 (Dec. 9, 2013) Comments of the Independent Market Monitor for PJM, FERC Docket No. EC14-112-000 (Sept. 15, 2014)

⁹¹ See Comments of the Independent Market Monitor for PJM, Docket No. RM16-21 (Dec. 12, 2016).

⁹² See *Dynegy Inc., et al.*, 150 FERC ¶ 61, 231 (2015); *Exelon Corporation, Constellation Energy Group, Inc.*, 138 FERC ¶ 61,167 (2012); *NRG Energy Holdings, Inc., Edison Mission Energy*, 146 FERC ¶ 61,196 (2014); see also *Analysis of Horizontal Market Power under the Federal Power Act*, 138 FERC ¶ 61,109 (2012).

Table 3-72 Completed transfers of entire PJM resources: January through March, 2020

Generator or Generation Owner Name	From	To	Transaction	
			Completion Date	Docket
FE Coal and Nuclear (Mansfield(retired), Sammis, Eastlake 6, Pleasants, Davis Besse, Perry, Beaver Valley)	FirstEnergy Generation	Avenue Capital (15-20%), Nuveen Asset Management (35 - 40%)	February 27, 2020	EC19-123
Energy Center Dover	Clearway Thermal LLC (Global Infrastructure Management LLC)	DB Energy Assets (DCO Energy and Basalt Infrastructure Partners)	March 2, 2020	EC19-142
Krayn Wind	Krayn Wind LLC	Oppidum Capital, S.L.	March 4, 2020	EC20-26

The MMU has also facilitated settlements for mitigation of market power, in cases where market power concerns have been identified.⁹³ Such mitigation is designed to mitigate behavior over the long term, in addition to or instead of imposing short term asset divestiture requirements.

In February 2019, in response to 2017 amendments to Section 203 of the Federal Power Act, the Commission issued Order No. 855, implementing a \$10,000,000 minimum value for transactions requiring the Commission’s review.⁹⁴

Aggregate Market Pivotal Supplier Results

Notwithstanding the HHI level, a supplier may have the ability to raise energy market prices. If reliably meeting the PJM system load requires energy from a single supplier, that supplier is pivotal and has monopoly power in the aggregate energy market. If a small number of suppliers are jointly required to meet load, those suppliers are jointly pivotal and have oligopoly power. The number of pivotal suppliers in the energy market is a more precise measure of structural market power than the HHI. The HHI is not a definitive measure of structural market power.

The current market power mitigation rules for the PJM energy market rely on the assumption that the aggregate market includes sufficient competing sellers to ensure competitive market outcomes. With sufficient competition, any attempt to economically or physically withhold generation would not result in higher market prices, because another supplier would replace the

⁹³ See 138 FERC ¶ 61,167 at P 19.
⁹⁴ See 166 FERC ¶ 61,120 (2019), Docket No. RM19-4.

generation at a similar price. This assumption requires that the total demand for energy can be met without the supply from any individual supplier or without the supply from a small group of suppliers. This assumption is not always

correct, as demonstrated by these results. There are pivotal suppliers in the aggregate energy market.

The existing market power mitigation measures do not address aggregate market power.⁹⁵ The MMU is developing an aggregate market power test for the day-ahead and real-time energy markets based on pivotal suppliers and will propose appropriate market power mitigation rules to address aggregate market power.

Day-Ahead Energy Market Aggregate Pivotal Suppliers

To assess the number of pivotal suppliers in the day-ahead energy market, the MMU determined, for each supplier, the MW available for economic commitment that were already running or were available to start between the close of the Day-Ahead Energy Market and the peak load hour of the operating day. The available supply is defined as MW offered at a price less than 150 percent of the applicable LMP because supply available at higher prices is not competing to meet the demand for energy.⁹⁶ Generating units, import transactions, economic demand response, and INCs, are included for each supplier. Demand is the total MW required by PJM to meet physical load, cleared load bids, export transactions, and DEC’s. A supplier is pivotal if PJM would require some portion of the supplier’s available economic capacity in the peak hour of the operating day in order to meet demand. Suppliers are jointly pivotal if PJM would require some portion of the joint suppliers’

⁹⁵ One supplier, Exelon, is partially mitigated for aggregate market power through its merger agreement. The agreement is not part of the PJM market rules. See Monitoring Analytics, LLC, Letter attaching Settlement Terms and Conditions, FERC Docket No. EC11-83-000 and Maryland PSC Case No. 9271 (October 11, 2011).

⁹⁶ Each LMP is scaled by 150 percent to determine the relevant supply, resulting in a different price threshold for each LMP value. The analysis does not solve a redispatch of the PJM market.

available economic capacity in the peak hour of the operating day in order to meet demand.

Figure 3-55 shows the number of days in 2019 and in the first three months of 2020 with one pivotal supplier, two jointly pivotal suppliers, and three jointly pivotal suppliers for the day-ahead energy market. One supplier was singly pivotal on the summer peak day in 2019. Two suppliers were jointly pivotal on 35 days in 2019 and on five days in the first three months of 2020. Three suppliers were jointly pivotal on 228 days in 2019 and on 54 days in the first three months of 2020, despite average HHIs at persistently unconcentrated levels. In 2019, the highest levels of aggregate market power occurred in the third quarter, PJM's peak load season. The frequency of pivotal suppliers also increased on high demand days in the first week of October 2019, around the Martin Luther King Jr. Day holiday in 2019 and 2020, and on March 1 and 23, 2020.

Figure 3-55 Days with pivotal suppliers and numbers of pivotal suppliers in the Day-Ahead Energy Market by quarter

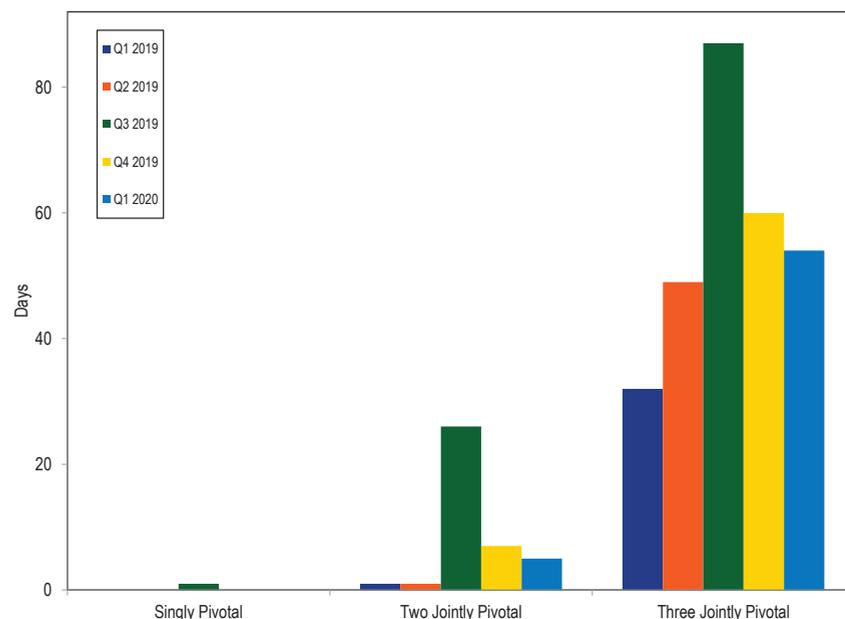


Table 3-73 provides the frequency with which each of the top 10 pivotal suppliers was singly or jointly pivotal for the day-ahead energy market in the first three months of 2020. The first and second pivotal suppliers were jointly pivotal with one another on 5.5 percent of days in the first three months of 2020. All of the top 10 suppliers were one of three pivotal suppliers on at least 20 days in the first three months of 2020.

Table 3-73 Day-ahead market pivotal supplier frequency: January through March, 2020

Pivotal Supplier Rank	Days Singly Pivotal	Percent of Days	Days Jointly Pivotal with One Other Supplier		Days Jointly Pivotal with Two Other Suppliers	
			Days	Percent of Days	Days	Percent of Days
1	0	0.0%	5	5.5%	54	59.3%
2	0	0.0%	5	5.5%	54	59.3%
3	0	0.0%	2	2.2%	54	59.3%
4	0	0.0%	0	0.0%	41	45.1%
5	0	0.0%	0	0.0%	31	34.1%
6	0	0.0%	0	0.0%	26	28.6%
7	0	0.0%	0	0.0%	25	27.5%
8	0	0.0%	0	0.0%	24	26.4%
9	0	0.0%	0	0.0%	23	25.3%
10	0	0.0%	0	0.0%	20	22.0%

Market Behavior

Local Market Power

In the PJM energy market, market power mitigation rules currently apply only for local market power. Local market power exists when transmission constraints or reliability issues create local markets that are structurally noncompetitive. If the owners of the units required to solve the constraint or reliability issue are pivotal or jointly pivotal, they have the ability to set the price. Absent market power mitigation, unit owners that submit noncompetitive offers, or offers with inflexible operating parameters, could exercise market power. This could result in LMPs being set at higher than competitive levels, or could result in noncompetitive uplift payments.

The three pivotal supplier (TPS) test is the test for local market power in the energy market.⁹⁷ If the TPS test is failed, market power mitigation is applied by offer capping the resources of the owners who have been identified as having local market power. Offer capping is designed to set offers at competitive levels. Competitive offers are defined to be cost-based energy offers. In the PJM energy market, units are required to submit cost-based energy offers, defined by fuel cost policies, and have the option to submit market-based or price-based offers. Units are committed and dispatched on price-based offers, if offered, as the default offer. When a unit that submits both cost-based and price-based offers is mitigated to its cost-based offer by PJM, it is considered offer capped. A unit that submits only cost-based offers, or that requests PJM to dispatch it on its cost-based offer, is not considered offer capped.

Local market power mitigation is implemented in both the day-ahead and real-time energy markets. However, the implementation of the TPS test and offer capping differ in the day-ahead and real-time energy markets.

TPS Test Statistics for Local Market Power

The TPS test in the energy market defines whether one, two or three suppliers are jointly pivotal in a defined local market. The TPS test is applied every time the system solution indicates that out of merit resources are needed to relieve a transmission constraint. The TPS test result for a constraint for a specific interval indicates whether a supplier failed or passed the test for that constraint for that interval. A failed test indicates that the resource owner has structural market power.

A metric to describe the number of local markets created by transmission constraints and the applicability of the TPS is the number of hours that each transmission constraint was binding in the real-time energy market over a period, by zone.

In the first three months of 2020, the 500 kV system, the AEP, APS, ATSI, BGE, ComEd, Dominion, Met-Ed, PENELEC, and PPL Control Zones, and MISO experienced congestion resulting from one or more constraints binding for

⁹⁷ See the MMU Technical Reference for PJM Markets, at "Three Pivotal Supplier Test" for a more detailed explanation of the three pivotal supplier test. <http://www.monitoringanalytics.com/reports/Technical_References/references.shtml>.

25 or more hours or resulting from an interface constraint (Table 3-74).⁹⁸ The Ontario Hydro flowgate is mapped to EXT and it was binding for 51 hours in the first three months of 2020. The AECO, DAY, DEOK, DLCO, DPL, EKPC, JCPL, OVEC, PECO, Pepco, PSEG, and RECO Control Zones did not have constraints binding for 25 or more hours in the first three months of 2020. Table 3-74 shows that the 500 kV system, the AEP and ComEd Control Zones, and the MISO experienced congestion resulting from one or more constraints binding for 25 or more hours or resulting from an interface constraint that was binding for one or more hours in every year from January through March, 2009 through 2020.

Table 3-74 Congestion hours resulting from one or more constraints binding for 100 or more hours or from an interface constraint: January through March, 2009 through 2020

	(Jan - Mar)											
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
500 kV System	1,704	1,457	1,932	228	512	1,368	688	579	144	315	524	1,107
AECO	149	0	70	40	32	0	41	252	0	0	112	0
AEP	890	157	556	100	447	840	1,405	283	54	517	154	205
APS	125	165	89	56	38	309	417	72	0	0	30	148
ATSI	101	37	0	1	46	428	391	30	349	637	55	200
BGE	0	25	0	650	150	29	232	1,418	551	875	133	265
ComEd	325	816	123	525	973	1,233	651	1,426	766	409	278	673
DEOK	0	0	0	33	0	68	0	0	0	25	0	0
DLCO	0	141	0	146	0	211	674	0	0	57	0	0
Dominion	130	114	73	0	0	124	423	500	52	91	0	236
DPL	43	0	28	133	0	297	388	694	389	141	0	0
EKPC	0	0	0	0	0	0	0	0	0	45	0	0
EXT	0	0	0	0	0	0	0	0	348	0	0	51
JCPL	0	0	0	0	0	44	79	0	0	0	0	0
MISO	1,728	110	1,306	3,353	5,045	4,877	3,372	2,739	1,805	1,548	1,919	1,376
Met-Ed	0	0	0	0	70	34	144	0	0	666	182	162
NYISO	0	0	0	0	159	107	174	1,014	332	0	0	0
PECO	30	0	158	0	77	327	242	287	537	32	80	0
PENELEC	0	0	58	32	29	179	517	237	578	883	859	1,004
Pepco	0	0	44	66	71	39	0	0	0	0	0	0
PPL	0	0	52	0	97	41	0	0	166	0	432	294
PSEG	336	344	281	199	1,408	1,445	2,550	55	0	151	285	0
TVA	0	0	0	0	126	0	98	26	0	0	162	0

⁹⁸ A constraint is mapped to the 500 kV system if its voltage is 500 kV and it is located in one of the Control Zones including AECO, BGE, DPL, JCPK, Met-Ed, PECO, PENELEC, Pepco, PPL and PSEG. All PJM/MISO reciprocally coordinated flowgates (RCF) are mapped to MISO regardless of the location of the flowgates. All PJM/NYISO RCF are mapped to NYISO as location regardless of the location of the flowgates.

The local market structure in the real-time energy market associated with each of the frequently binding constraints was analyzed using the three pivotal supplier results in the first three months of 2020.⁹⁹ While the real-time constraint hours include constraints that were binding in the five minute real-time pricing solution (LPC), IT SCED may contain different binding constraints because IT SCED looks ahead to intervals that are in the near future to solve for constraints that could be binding, using the load forecast for these intervals. The TPS statistics shown in this section present the data from the IT SCED TPS solution. The results of the TPS test are shown for tests that could have resulted in offer capping and tests that resulted in offer capping.

Table 3-75 shows the average constraint relief required on the constraint, the average effective supply available to relieve the constraint, the average number of owners with available relief in the defined market and the average number of owners passing and failing for the transfer interface constraints. Table 3-76 shows the average constraint relief required on the constraint, the average effective supply available to relieve the constraint, the average number of owners with available relief in the defined market and the average number of owners passing and failing for the ten constraints that were binding for the most hours in the PJM Real-Time Energy Market. Table 3-75 and Table 3-76 include analysis of all the tests for every interval where IT SCED determined that constraint relief was needed for each of the constraints shown. The same interval can be evaluated by multiple IT SCED cases at different look ahead times.

Table 3-75 Three pivotal supplier test details for interface constraints: January through March, 2020

Constraint	Period	Average Constraint Relief (MW)	Average Effective Supply (MW)	Average Number Owners	Average Number Owners Passing	Average Number Owners Failing
AP South	Peak	507	828	23	3	20
	Off Peak	125	509	15	8	7
CPL - DOM	Peak	98	436	7	1	6
	Off Peak	0	0	0	0	0
PA Central	Peak	38	352	4	0	4
	Off Peak	67	363	4	0	4

⁹⁹ See the *MMU Technical Reference for PJM Markets*, p. 38 "Three Pivotal Supplier Test" for a more detailed explanation of the three pivotal supplier test. <http://www.monitoringanalytics.com/reports/Technical_References/references.shtml>.

Table 3-76 Three pivotal supplier test details for top 10 congested constraints: January through March, 2020

Constraint	Period	Average Constraint Relief (MW)	Average Effective Supply (MW)	Average Number Owners	Average Number Owners Passing	Average Number Owners Failing
PA Central	Peak	38	352	4	0	4
	Off Peak	67	363	4	0	4
Lenox - North Meshoppen	Peak	12	46	2	0	2
	Off Peak	6	36	2	0	2
Prince George	Peak	17	37	1	0	1
	Off Peak	13	34	1	0	1
Paradise - BR Tap	Peak	29	4	2	0	2
	Off Peak	33	5	3	0	3
Nottingham	Peak	50	83	8	2	7
	Off Peak	42	88	8	2	6
Haumesser Road - Steward	Peak	25	71	2	0	2
	Off Peak	24	72	2	0	2
Powerton - Towerline	Peak	9	29	1	0	1
	Off Peak	16	26	2	0	2
Bagley - Gracetown	Peak	41	89	11	5	7
	Off Peak	44	111	11	6	5
Vermilion - Tilton Energy Center	Peak	21	21	1	0	1
	Off Peak	21	21	1	0	1
Sub 85 - Rock Island	Peak	28	15	3	0	3
	Off Peak	31	15	3	0	3

The three pivotal supplier test is applied every time the IT SCED solution indicates that incremental relief is needed to relieve a transmission constraint. While every system solution that requires incremental relief to transmission constraints will result in a test, not all tested providers of effective supply are eligible for offer capping. Steam unit offers that are offer capped in the day-ahead energy market continue to be offer capped in the real-time energy market regardless of their inclusion in the TPS test in real time or the outcome of the TPS test in real time. Steam unit offers that are not offer capped in the day-ahead energy market continue to not be offer capped in the real-time energy market regardless of their inclusion in the TPS test in real time or the outcome of the TPS test in real time.¹⁰⁰ Offline units that are committed to provide relief for a transmission constraint, whose owners fail the TPS test, are committed on the cheaper of their cost or price-based offers. Beginning November 1, 2017, with the introduction of hourly offers and intraday offer

¹⁰⁰ If a steam unit were to lower its cost-based offer in real-time, it would become eligible for offer capping based on the online TPS test.

updates, certain online units whose commitment is extended beyond the day-ahead or real-time commitment, whose owners fail the TPS test, are also switched to the cost-based offer if it is cheaper than the price-based offer.

Table 3-77 and Table 3-78 provide, for the identified constraints, information on total tests applied, the subset of three pivotal supplier tests that could have resulted in offer capping and the portion of those tests that did result in offer capping. The three pivotal supplier tests that resulted in offer capping do not explain all the offer capped units in the real-time energy market. PJM operators also manually commit units for reliability reasons other than providing relief to a binding constraint.

Table 3-77 Summary of three pivotal supplier tests applied for interface constraints: January through March, 2020

Constraint	Period	Total Tests Applied	Total Tests that Could Have Resulted in Offer Capping	Percent Total Tests that Could Have Resulted in Offer Capping	Total Tests Resulted in Offer Capping	Percent Total Tests Resulted in Offer Capping	Tests Resulted in Offer Capping as Percent of Tests that Could Have Resulted in Offer Capping
AP South	Peak	24	24	100%	0	0%	0%
	Off Peak	6	6	100%	0	0%	0%
CPL - DOM	Peak	130	130	100%	0	0%	0%
	Off Peak	0	0	NA	0	NA	NA
PA Central	Peak	14,216	9,582	67%	0	0%	0%
	Off Peak	14,384	9,917	69%	4	0%	0%

Table 3-78 Summary of three pivotal supplier tests applied for top 10 congested constraints: January through March, 2020

Constraint	Period	Total Tests Applied	Total Tests that Could Have Resulted in Offer Capping	Percent Total Tests that Could Have Resulted in Offer Capping	Total Tests Resulted in Offer Capping	Percent Total Tests Resulted in Offer Capping	Tests Resulted in Offer Capping as Percent of Tests that Could Have Resulted in Offer Capping
PA Central	Peak	14,216	9,582	67%	0	0%	0%
	Off Peak	14,384	9,917	69%	4	0%	0%
Lenox - North Meshoppen	Peak	12,961	9,778	75%	0	0%	0%
	Off Peak	9,857	3,981	40%	0	0%	0%
Prince George	Peak	5,290	885	17%	0	0%	0%
	Off Peak	1,287	96	7%	0	0%	0%
Paradise - BR Tap	Peak	1,310	344	26%	0	0%	0%
	Off Peak	1,284	718	56%	0	0%	0%
Nottingham	Peak	3,934	3,863	98%	13	0%	0%
	Off Peak	1,958	1,895	97%	6	0%	0%
Haumesser Road - Steward	Peak	2,018	148	7%	0	0%	0%
	Off Peak	2,689	255	9%	0	0%	0%
Powerton - Towerline	Peak	860	171	20%	0	0%	0%
	Off Peak	3,606	605	17%	0	0%	0%
Bagley - Graceton	Peak	4,667	4,562	98%	31	1%	1%
	Off Peak	1,846	1,807	98%	5	0%	0%
Vermilion - Tilton Energy Center	Peak	206	200	97%	0	0%	0%
	Off Peak	1,297	1,193	92%	0	0%	0%
Sub 85 - Rock Island	Peak	1,928	452	23%	0	0%	0%
	Off Peak	1,778	196	11%	0	0%	0%

Offer Capping for Local Market Power

In the PJM energy market, offer capping occurs as a result of structurally noncompetitive local markets and noncompetitive offers in the day-ahead and real-time energy markets. PJM also uses offer capping for units that are committed for reliability reasons, specifically for providing black start and reactive service as well as for conservative operations. There are no explicit rules governing market structure or the exercise of market power in the aggregate energy market.

There are some issues with the application of mitigation in the day-ahead energy market and the real-time energy market when market sellers fail the TPS test. There is no tariff or manual language that defines in detail the application of the TPS test and offer capping in the day-ahead energy market and the real-time energy market.

In both the day-ahead and real-time energy markets, generators with market power have the ability to evade mitigation by using varying markups in their price-based offers, offering different operating parameters in their price-based and cost-based offers, and using different fuels in their price-based and cost-based offers. These issues can be resolved by simple rule changes.

When an owner fails the TPS test, the units offered by the owner that are committed to provide relief are committed on the cheaper of cost-based or price-based offers. In the day-ahead energy market, PJM commits a unit on the schedule that results in the lower overall system production cost. This is consistent with the day-ahead energy market objective of clearing resources (including physical and virtual resources) to meet the total demand (including physical and virtual demand) at the lowest bid production cost for the system over the 24 hour period. In the real-time energy market, PJM uses a dispatch cost formula to compare price-based offers and cost-based offers to select the cheaper offer.¹⁰¹ Prior to the implementation of hourly offers, dispatch cost was calculated as:

$$\{(Incremental\ Energy\ Offer@EcoMin \times EcoMin\ MW) + No\ Load\ Cost\} \times Min\ Run\ Time + Start\ Cost$$

¹⁰¹ See PJM Operating Agreement Schedule 1 § 6.4.1(g).

Beginning November 1, 2017, with hourly differentiated offers, the cheaper of cost and price based offers are determined using total dispatch cost, where:

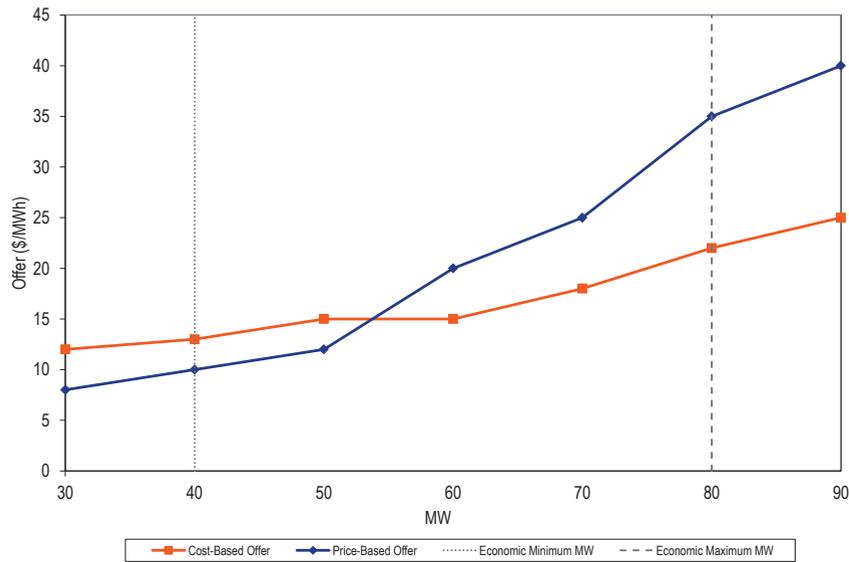
$$Total\ Dispatch\ Cost = Startup\ Cost + \sum_{Min\ Run} Hourly\ Dispatch\ Cost$$

where the hourly dispatch cost is calculated for each hour using the offers applicable for that hour as:

$$Hourly\ Dispatch\ Cost = (Incremental\ Energy\ Offer@EcoMin \times EcoMin\ MW) + NoLoad\ Cost$$

The update to the total dispatch cost formula takes into account the offers that can vary for each hour over a unit's minimum run time beginning November 1, 2017. With the ability to submit offer curves with varying markups at different output levels in the price-based offer, unit owners with market power can evade mitigation by using a low markup at low output levels and a high markup at higher output levels. Figure 3-56 shows an example of offers from a unit that has a negative markup at the economic minimum MW level and a positive markup at the economic maximum MW level. The result would be that a unit that failed the TPS test would be committed on its price-based offer that has a lower dispatch cost, even though the price-based offer is higher than cost-based offer at higher output levels and includes positive markups, inconsistent with the explicit goal of local market power mitigation.

Figure 3-56 Offers with varying markups at different MW output levels

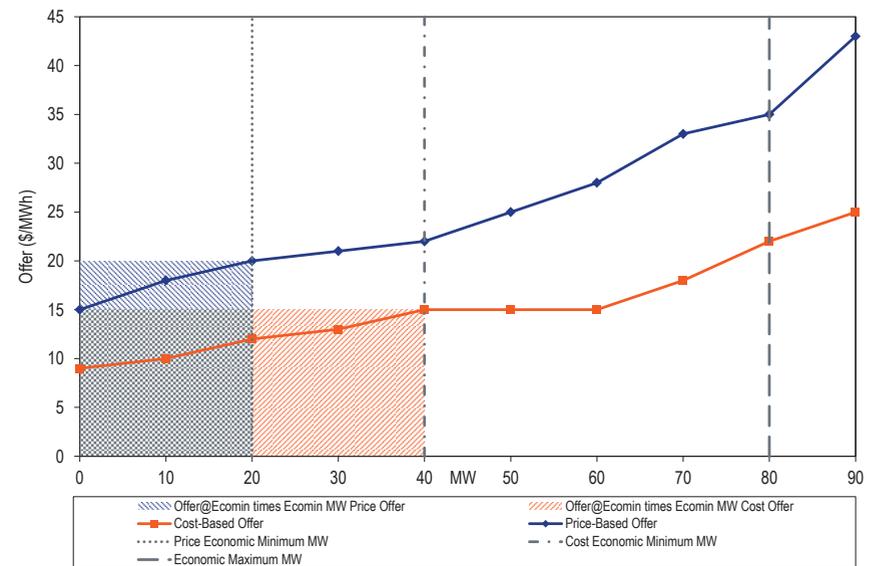


Offering a different economic minimum MW level, different minimum run times, or different start up and notification times in the cost-based and price-based offers can also be used to evade mitigation. For example, a unit may offer its price-based offer with a positive markup, but have a shorter minimum run time (MRT) in the price-based offer resulting in a lower dispatch cost for the price-based offer but setting prices at a level that includes a positive markup.

A unit may offer a lower economic minimum MW level on the price-based offer than the cost-based offer. Such a unit may appear to be cheaper to commit on the price-based offer even with a positive markup. A unit with a positive markup can have lower dispatch cost with the price-based offer with a lower economic minimum level compared to cost-based offer. Figure 3-57 shows an example of offers from a unit that has a positive markup and a price-based offer with a lower economic minimum MW than the cost-based offer. Keeping the startup cost, Minimum Run Time and no load cost constant

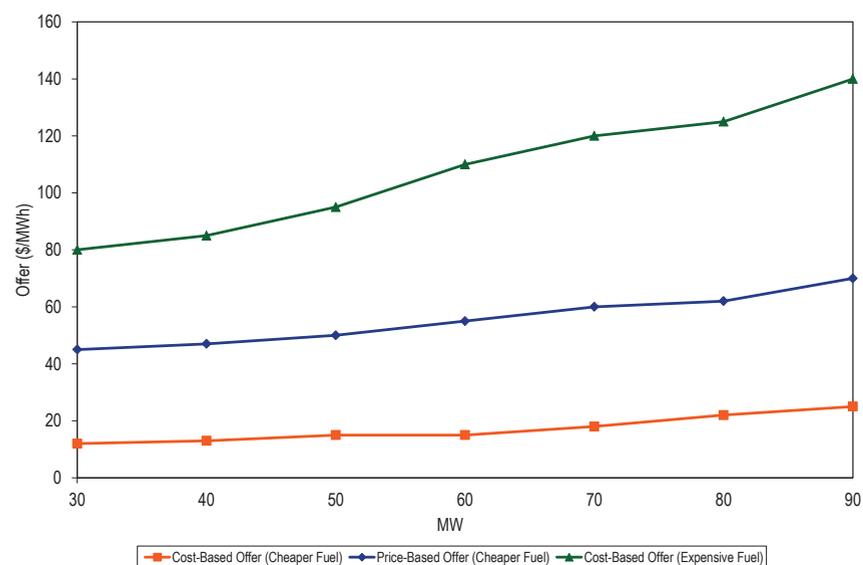
between the price-based offer and cost-based offer, the dispatch cost for this unit is lower on the price-based offer than on the cost-based offer. However, the price-based offer includes a positive markup and could result in setting the market price at a noncompetitive level even after the resource owner fails the TPS test.

Figure 3-57 Offers with a positive markup but different economic minimum MW



In case of dual fuel units, if the price-based offer uses a cheaper fuel and the cost-based offer uses a more expensive fuel, the price-based offer will appear to be lower cost even when it includes a markup. Figure 3-58 shows an example of offers by a dual fuel unit, where the active cost-based offer uses a more expensive fuel and the price-based offer uses a cheaper fuel and includes a markup.

Figure 3-58 Dual fuel unit offers



These issues can be solved by simple rule changes.¹⁰² The MMU recommends that markup of price-based offers over cost-based offers be constant across the offer curve, that there be at least one cost-based offer using the same fuel as the available price-based offer, and that operating parameters on parameter limited schedules (PLS) be at least as flexible as price-based non-PLS offers.

Levels of offer capping have historically been low in PJM, as shown in Table 3-80. But offer capping remains a critical element of PJM market rules because it is designed to prevent the exercise of local market power. While overall offer capping levels have been low, there are a significant number of units with persistent structural local market power that would have a significant impact on prices in the absence of local market power mitigation. Until November 1, 2017, only uncommitted resources, started to relieve the transmission constraint, were subject to offer capping. Beginning November

¹⁰² The MMU proposed these offer rule changes as part of a broader reform to address generator offer flexibility and associated impact on market power mitigation rules in the Generator Offer Flexibility Senior Task Force (GOFSTF) and subsequently in the MMU's protest in the hourly offers proceeding in Docket No. ER16-372-000, filed December 14, 2015.

1, 2017, under certain circumstances, online resources that are committed beyond their original commitment (day-ahead or real-time) can be offer capped if the owner fails the TPS test, and the latest available cost-based offer is determined to be lower than the price-based offer.¹⁰³ Units running in real time as part of their original commitment on the price-based offer on economics, and that can provide incremental relief to a constraint, cannot be switched to their cost-based offer.

The offer capping percentages shown in Table 3-79 include units that are committed to provide constraint relief whose owners failed the TPS test in the energy market excluding units that were committed for reliability reasons, providing black start and providing reactive support. Offer capped unit run hours and offer capped generation (in MWh) are shown as a percentage of the total run hours and the total generation (MWh) from all the units in the PJM energy market.¹⁰⁴ Beginning November 1, 2017, with the introduction of hourly offers, certain online units, whose owners fail the TPS test in the real-time energy market for providing constraint relief, can be offer capped and dispatched on their cost-based offer subsequent to a real-time hourly offer update. This is reflected in the higher offer capping percentages in the real-time energy market in 2018 and 2019 compared to 2017.

Table 3-79 Offer capping statistics – energy only: January through March, 2016 to 2020

(Jan-Mar)	Real-Time		Day-Ahead	
	Unit Hours		Unit Hours	
	Capped	MW Capped	Capped	MW Capped
2016	0.4%	0.2%	0.1%	0.1%
2017	0.2%	0.1%	0.0%	0.1%
2018	1.0%	0.4%	0.1%	0.1%
2019	0.6%	0.5%	0.2%	0.2%
2020	0.7%	1.1%	0.8%	0.8%

¹⁰³ See OATT Attachment K Appendix § 6.4.1.

¹⁰⁴ Prior to the 2018 Quarterly State of the Market report for PJM: January through June, these tables presented the offer cap percentages based on total bid unit hours and total load MWh. Beginning with the quarterly report for January through June, 2018, the statistics have been updated with percentages based on run hours and total generation MWh from units modeled in the energy market.

Table 3-80 shows the offer capping percentages including units committed to provide constraint relief and units committed for reliability reasons, including units committed to provide black start service and reactive support. As of April 2015, the Automatic Load Rejection (ALR) units that were committed for black start previously no longer provide black start service, and are not included in the offer capping statistics for black start. PJM also created closed loop interfaces to, in some cases, model reactive constraints. The result was higher LMPs in the closed loops, which increased economic dispatch, which contributed to the reduction in units offer capped for reactive support. In instances where units are now committed for the modeled closed loop interface constraints, they are considered offer capped for providing constraint relief. They are included in the offer capping percentages in Table 3-79.

Table 3-80 Offer capping statistics for energy and reliability: January through March, 2016 to 2020

(Jan-Mar)	Real-Time		Day-Ahead	
	Unit Hours Capped	MW Capped	Unit Hours Capped	MW Capped
2016	0.5%	0.3%	0.2%	0.1%
2017	0.4%	0.7%	0.3%	0.6%
2018	1.1%	0.5%	0.1%	0.1%
2019	0.6%	0.5%	0.2%	0.2%
2020	0.7%	1.1%	0.8%	0.8%

Table 3-81 shows the offer capping percentages for units committed for reliability reasons, including units committed to provide black start service and reactive support. The data in Table 3-81 is the difference between the offer cap percentages shown in Table 3-80 and Table 3-79.

Table 3-81 Offer capping statistics for reliability: January through March, 2016 to 2020

(Jan-Mar)	Real-Time		Day-Ahead	
	Unit Hours Capped	MW Capped	Unit Hours Capped	MW Capped
2016	0.1%	0.0%	0.1%	0.1%
2017	0.2%	0.6%	0.2%	0.5%
2018	0.1%	0.1%	0.0%	0.0%
2019	0.0%	0.0%	0.0%	0.0%
2020	0.0%	0.0%	0.0%	0.0%

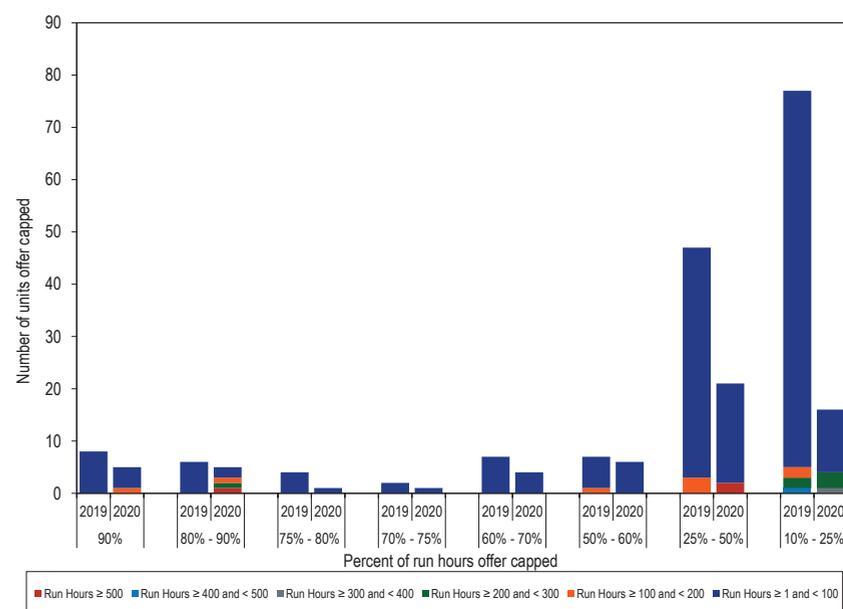
Table 3-82 presents data on the frequency with which units were offer capped in the first three months of 2019 and 2020 as a result of failing the TPS test to provide energy for constraint relief in the real-time energy market and for reliability reasons. Table 3-82 shows that five units were offer capped for 90 percent or more of their run hours in the first three months of 2020 compared to eight units in the first three months of 2019.

Table 3-82 Real-time offer capped unit statistics: January through March, 2019 and 2020

Run Hours Offer-Capped, Percent Greater Than Or Equal To:	Jan - Mar	Offer-Capped Hours					
		Hours ≥ 500	Hours ≥ 400 and < 500	Hours ≥ 300 and < 400	Hours ≥ 200 and < 300	Hours ≥ 100 and < 200	Hours ≥ 1 and < 100
90%	2019	0	0	0	0	0	8
	2020	0	0	0	0	1	4
80% and < 90%	2019	0	0	0	0	0	6
	2020	1	0	0	1	1	2
75% and < 80%	2019	0	0	0	0	0	4
	2020	0	0	0	0	0	1
70% and < 75%	2019	0	0	0	0	0	2
	2020	0	0	0	0	0	1
60% and < 70%	2019	0	0	0	0	0	7
	2020	0	0	0	0	0	4
50% and < 60%	2019	0	0	0	0	1	6
	2020	0	0	0	0	0	6
25% and < 50%	2019	0	0	0	0	3	44
	2020	2	0	0	0	0	19
10% and < 25%	2019	0	1	0	2	2	72
	2020	0	0	1	3	0	12

Figure 3-59 shows the frequency with which units were offer capped in the first three months of 2019 and 2020 for failing the TPS test to provide energy for constraint relief in the real-time energy market and for reliability reasons.

Figure 3-59 Real-time offer capped unit statistics: January through March, 2019 and 2020



Markup Index

Markup is a summary measure of participant offer behavior or conduct for individual units. When a seller responds competitively to a market price, markup is zero. When a seller exercises market power in its pricing, markup is positive. The degree of markup increases with the degree of market power. The markup index for each marginal unit is calculated as $(\text{Price} - \text{Cost})/\text{Price}$.¹⁰⁵ The markup index is normalized and can vary from -1.00 when the offer price is less than the cost-based offer price, to 1.00 when the offer price is

¹⁰⁵ In order to normalize the index results (i.e., bound the results between +1.00 and -1.00) for comparison across both low and high cost units, the index is calculated as $(\text{Price} - \text{Cost})/\text{Price}$ when price is greater than cost, and $(\text{Price} - \text{Cost})/\text{Cost}$ when price is less than cost.

higher than the cost-based offer price. The markup index does not measure the impact of unit markup on total LMP. The dollar markup for a unit is the difference between price and cost.

Real-Time Markup Index

Table 3-83 shows the average markup index of marginal units in the Real-Time Energy Market, by offer price category using unadjusted cost-based offers. Table 3-84 shows the average markup index of marginal units in the Real-Time Energy Market, by offer price category using adjusted cost-based offers. The unadjusted markup is the difference between the price-based offer and the cost-based offer including the 10 percent adder in the cost-based offer. The adjusted markup is the difference between the price-based offer and the cost-based offer excluding the 10 percent adder from the cost-based offer. The adjusted markup is calculated for coal, gas and oil units because these units have consistently had price-based offers less than cost-based offers.¹⁰⁶ The markup is negative if the cost-based offer of the marginal unit exceeds its price-based offer at its operating point.

All generating units are allowed to add an additional 10 percent to their cost-based offer. The 10 percent adder was included prior to the implementation of PJM markets in 1999, based on the uncertainty of calculating the hourly operating costs of CTs under changing ambient conditions. The owners of coal units, facing competition, typically exclude the additional 10 percent from their actual offers. The owners of many gas fired and oil fired units have also begun to exclude the 10 percent adder. The introduction of hourly offers and intraday offer updates in November 2017 allows gas and oil generators to directly incorporate the impact of ambient temperature changes in fuel consumption in offers.

Even the adjusted markup overestimates the negative markup because units facing increased competitive pressure have excluded both the 10 percent and components of operating and maintenance costs that are not short run marginal costs. While the 10 percent adder is permitted under the definition of cost-based offers in the PJM Market Rules and some have interpreted the rules

¹⁰⁶ The MMU will calculate adjusted markup for gas units also in future reports because gas units also more consistently have price-based offers less than cost-based offers.

to permit maintenance costs that are not short run marginal costs, neither are part of a competitive offer because they are not actually short run marginal costs, and actual market behavior reflects that fact.¹⁰⁷

In the first three months of 2020, 99.6 percent of marginal units had offer prices less than \$50 per MWh. The average dollar markups of units with offer prices less than \$10 was negative (-\$0.96 per MWh) when using unadjusted cost-based offers. The average dollar markups of units with offer prices between \$10 and \$15 was positive (\$0.88 per MWh) when using unadjusted cost-based offers. Negative markup means the unit is offering to run at a price less than its cost-based offer, revealing a short run marginal cost that is less than the maximum allowable cost-based offer under the PJM Market Rules.

Some marginal units did have substantial markups. Among the units that were marginal in the first three months of 2020, none had offer prices above \$400 per MWh. Among the units that were marginal in the first three months of 2019, less than one percent had offer prices greater than \$400 per MWh. Using the unadjusted cost-based offers, the highest markup for any marginal unit in the first three months of 2020 was more than \$150, while the highest markup in the first three months of 2019 was more than \$350.

Table 3-83 Average, real-time marginal unit markup index (By offer price category unadjusted): January through March, 2019 and 2020

Offer Price Category	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Average Markup Index	Average Dollar Markup	Frequency	Average Markup Index	Average Dollar Markup	Frequency
< \$10	0.14	(\$4.66)	4.0%	(0.06)	(\$0.96)	9.2%
\$10 to \$15	(0.19)	(\$3.90)	0.7%	0.07	\$0.88	43.6%
\$15 to \$20	0.05	\$0.88	25.0%	0.01	(\$0.35)	33.1%
\$20 to \$25	0.05	\$0.98	38.6%	0.04	\$0.71	11.6%
\$25 to \$50	0.05	\$1.13	28.2%	0.14	\$4.46	2.1%
\$50 to \$75	0.25	\$14.05	1.8%	0.57	\$33.52	0.2%
\$75 to \$100	0.34	\$29.09	0.6%	0.77	\$71.01	0.0%
\$100 to \$125	0.45	\$49.12	0.4%	0.79	\$88.32	0.0%
\$125 to \$150	0.30	\$40.76	0.1%	0.39	\$49.93	0.0%
\$150 to \$400	0.12	\$26.07	0.5%	0.31	\$56.38	0.1%
>= \$400	0.94	\$375.51	0.0%	0.00	\$0.00	0.0%

¹⁰⁷ See PJM, "Manual 15: Cost Development Guidelines," Rev. 33 (Dec. 3, 2019).

Table 3-84 Average, real-time marginal unit markup index (By offer price category adjusted): January through March, 2019 and 2020

Offer Price Category	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Average Markup Index	Average Dollar Markup	Frequency	Average Markup Index	Average Dollar Markup	Frequency
< \$10	0.14	(\$4.62)	4.0%	(0.03)	(\$0.69)	9.2%
\$10 to \$15	(0.11)	(\$2.25)	0.7%	0.15	\$2.02	43.6%
\$15 to \$20	0.14	\$2.49	25.0%	0.09	\$1.26	33.1%
\$20 to \$25	0.14	\$2.93	38.6%	0.13	\$2.62	11.6%
\$25 to \$50	0.13	\$3.76	28.2%	0.21	\$6.74	2.1%
\$50 to \$75	0.32	\$17.99	1.8%	0.61	\$35.71	0.2%
\$75 to \$100	0.40	\$34.02	0.6%	0.79	\$72.93	0.0%
\$100 to \$125	0.50	\$54.75	0.4%	0.81	\$90.45	0.0%
\$125 to \$150	0.36	\$49.37	0.1%	0.45	\$57.35	0.0%
\$150 to \$400	0.21	\$40.08	0.5%	0.37	\$66.60	0.1%
>= \$400	0.94	\$377.74	0.0%	0.00	\$0.00	0.0%

Table 3-85 shows the percentage of marginal units that had markups, calculated using unadjusted cost-based offers, below, above and equal to zero for coal, gas and oil fuel types.¹⁰⁸ Table 3-86 shows the percentage of marginal units that had markups, calculated using adjusted cost-based offers, below, above and equal to zero for coal, gas and oil fuel types. In the first three months of 2020, using unadjusted cost-based offers for coal units, 55.04 percent of marginal coal units had negative markups. In the first three months of 2020, using adjusted cost-based offers for coal units, 35.20 percent of marginal coal units had negative markups.

Table 3-85 Percent of marginal units with markup below, above and equal to zero (By fuel type unadjusted): January through March, 2019 and 2020

Type/Fuel	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Negative	Zero	Positive	Negative	Zero	Positive
Coal	48.29%	19.22%	32.49%	55.04%	26.87%	18.09%
Gas	25.96%	16.31%	57.73%	30.77%	2.64%	66.59%
Oil	3.41%	93.17%	3.41%	0.00%	100.00%	0.00%

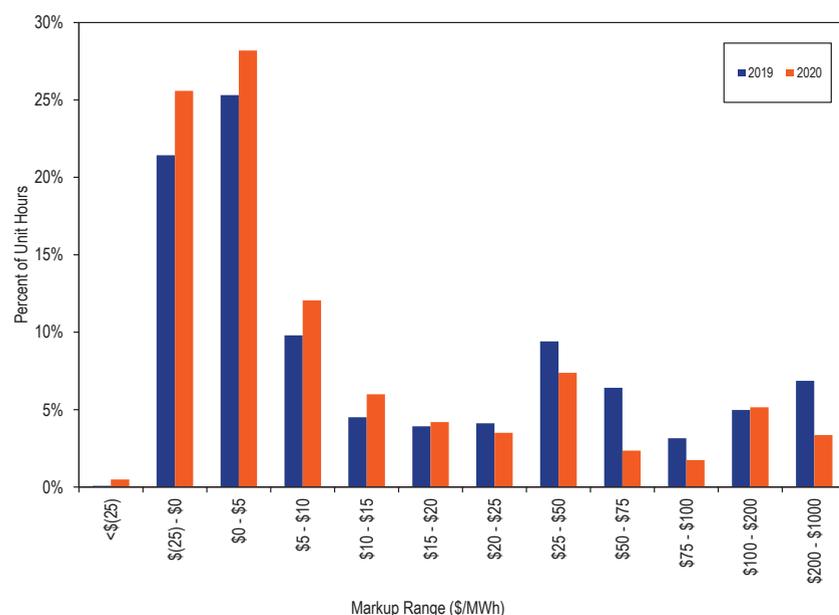
¹⁰⁸ Other fuel types were excluded based on data confidentiality rules.

Table 3-86 Percent of marginal units with markup below, above and equal to zero (By fuel type adjusted): January through March, 2019 and 2020

Type/Fuel	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Negative	Zero	Positive	Negative	Zero	Positive
Coal	35.49%	14.09%	50.42%	35.20%	20.17%	44.63%
Gas	8.98%	7.60%	83.42%	17.82%	1.35%	80.83%
Oil	1.37%	93.17%	5.46%	0.00%	70.45%	29.55%

Figure 3-60 shows the frequency distribution of hourly markups for all gas units offered in the first three months of 2019 and 2020 using unadjusted cost-based offers. The highest markup within the economic operating range of the unit’s offer curve was used in the frequency distributions.¹⁰⁹ Of the gas units offered in the PJM market in the first three months of 2020, 26.0 percent of gas unit-hours had a maximum markup that was negative. More than 8.0 percent of gas fired unit-hours had a maximum markup above \$100 per MWh.

Figure 3-60 Frequency distribution of highest markup of gas units offered using unadjusted cost offers: January through March 2019 and 2020



¹⁰⁹ The categories in the frequency distribution were chosen so as to maintain data confidentiality.

Figure 3-61 shows the frequency distribution of hourly markups for all coal units offered in the first three months of 2019 and 2020 using unadjusted cost-based offers. Of the coal units offered in the PJM market in the first three months of 2020, 52.0 percent of coal unit-hours had a maximum markup that was negative or equal to zero.

Figure 3-61 Frequency distribution of highest markup of coal units offered using unadjusted cost offers: January through March, 2019 and 2020

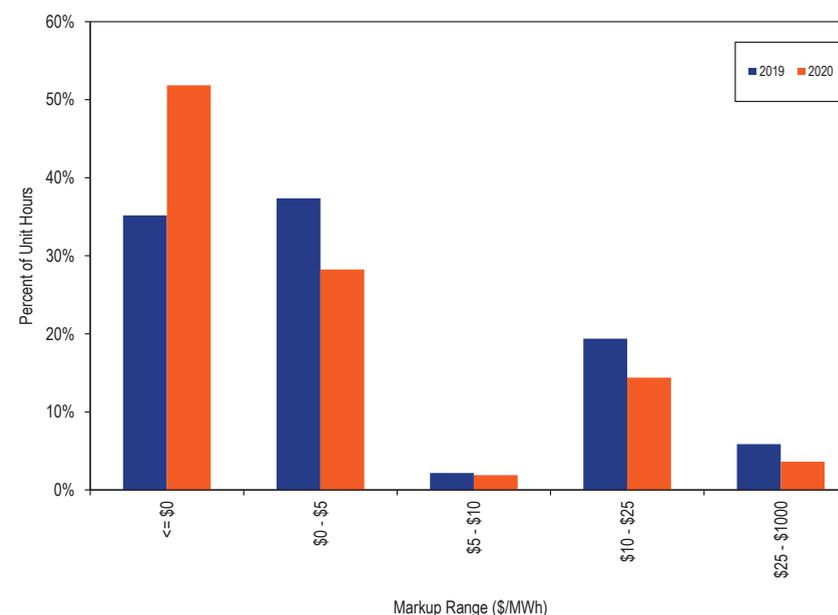
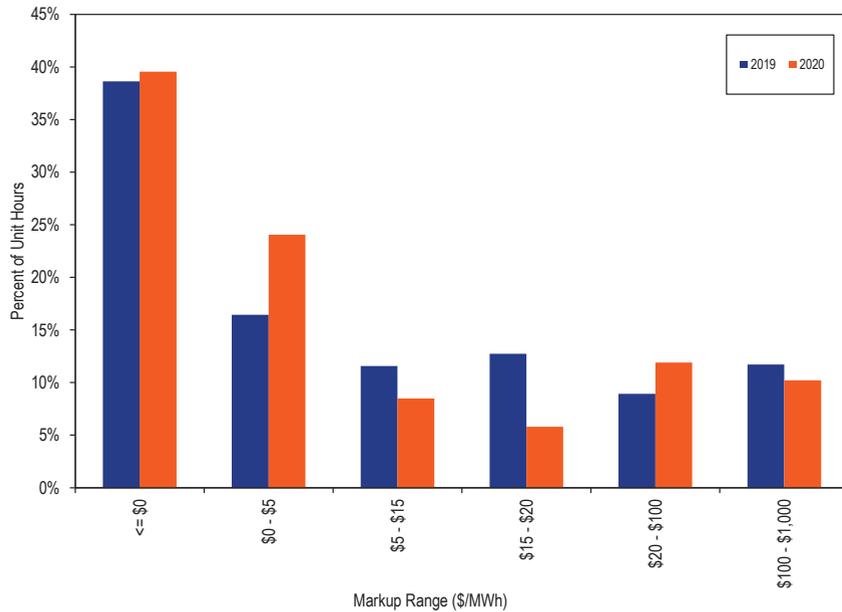


Figure 3-62 shows the frequency distribution of hourly markups for all offered oil units in the first three months of 2019 and 2020 using unadjusted cost-based offers. Of the oil units offered in the PJM market in the first three months of 2020, 40.0 percent of oil unit-hours had a maximum markup that was negative or equal to zero. More than 10.0 percent of oil fired unit-hours had a maximum markup above \$100 per MWh.

Figure 3-62 Frequency distribution of highest markup of oil units offered using unadjusted cost offers: January through March, 2019 and 2020

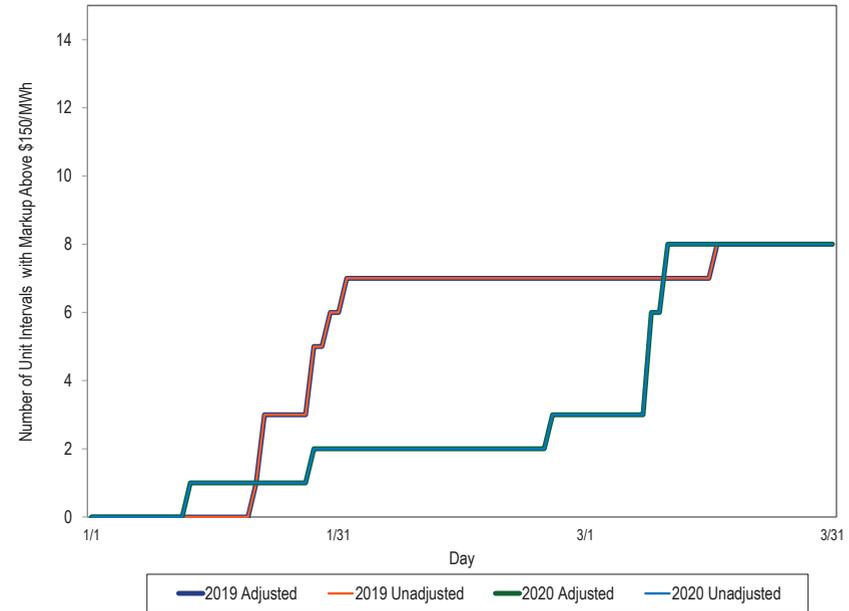


The markup frequency distributions show that a significant proportion of units make price-based offers less than the cost-based offers permitted under the PJM market rules. This behavior means that competitive price-based offers reveal actual unit marginal costs and that PJM market rules permit the inclusion of costs in cost-based offers that are not short run marginal costs.

The markup behavior shown in the markup frequency distributions also shows that a substantial number of units were offered with high markups, consistent with the exercise of market power.

Figure 3-63 shows the number of marginal unit intervals in the first three months of 2020 and 2019 with markup above \$150 per MWh.

Figure 3-63 Cumulative number of unit intervals with markups above \$150 per MWh: January through March, 2019 and 2020



Day-Ahead Markup Index

Table 3-87 shows the average markup index of marginal generating units in the day-ahead energy market, by offer price category using unadjusted cost-based offers. The majority of marginal units are virtual transactions, which do not have markup. In the first three months of 2020, 99.8 percent of marginal generating units had offer prices less than \$50 per MWh. The average dollar markups of units with offer prices less than \$10 was negative (-\$2.31 per MWh) when using unadjusted cost-based offers. The average dollar markups of units with offer prices between \$10 and \$15 was positive (\$1.04 per MWh) when using unadjusted cost-based offers.

Some marginal units did have substantial markups. Among the units that were marginal in the day-ahead market in the first three months of 2019

and 2020, none had offer prices above \$400 per MWh. Using the unadjusted cost-based offers, the highest markup for any marginal unit in the day-ahead market in the first three months of 2020 was about \$30 per MWh while the highest markup in the first three months of 2019 was about \$90 per MWh.

Table 3-87 Average day-ahead marginal unit markup index (By offer price category, unadjusted): January through March, 2019 and 2020

Offer Price Category	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Average Markup Index	Average Dollar Markup	Frequency	Average Markup Index	Average Dollar Markup	Frequency
< \$10	1.03	\$3.38	1.4%	0.02	(\$2.31)	4.7%
\$10 to \$15	(0.13)	(\$2.76)	0.8%	0.08	\$1.04	30.3%
\$15 to \$20	0.04	\$0.53	16.3%	0.23	\$3.37	48.4%
\$20 to \$25	0.05	\$0.92	40.0%	0.01	\$0.03	14.2%
\$25 to \$50	0.05	\$1.59	39.1%	0.02	\$0.26	2.3%
\$50 to \$75	0.18	\$10.37	1.4%	0.00	\$0.00	0.0%
\$75 to \$100	0.30	\$27.58	0.2%	0.00	\$0.00	0.0%
\$100 to \$125	0.48	\$49.48	0.2%	0.00	\$0.00	0.0%
\$125 to \$150	0.32	\$45.31	0.3%	0.00	\$0.00	0.1%
>= \$150	0.30	\$51.79	0.2%	0.15	\$25.35	0.0%

Table 3-88 shows the average markup index of marginal generating units in the day-ahead energy market, by offer price category using adjusted cost-based offers. In the first three months of 2020, 48.4 percent of marginal generating units had offers between \$15 and \$20 per MWh, and the average dollar markup and the average markup index were both positive. The average markup index decreased from 1.05 in the first three months of 2019, to 0.08 in the first three months of 2020 in the offer price category less than \$10.

Table 3-88 Average day-ahead marginal unit markup index (By offer price category, adjusted): January through March, 2019 and 2020

Offer Price Category	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Average Markup Index	Average Dollar Markup	Frequency	Average Markup Index	Average Dollar Markup	Frequency
< \$10	1.05	\$3.38	1.4%	0.08	(\$1.93)	4.7%
\$10 to \$15	(0.05)	(\$1.20)	0.8%	0.16	\$2.17	30.3%
\$15 to \$20	0.12	\$2.13	16.3%	0.29	\$4.62	48.4%
\$20 to \$25	0.13	\$2.88	40.0%	0.10	\$2.02	14.2%
\$25 to \$50	0.13	\$4.16	39.1%	0.11	\$2.84	2.3%
\$50 to \$75	0.25	\$14.61	1.4%	0.00	\$0.00	0.0%
\$75 to \$100	0.36	\$33.15	0.2%	0.00	\$0.00	0.0%
\$100 to \$125	0.53	\$54.38	0.2%	0.00	\$0.00	0.0%
\$125 to \$150	0.38	\$53.81	0.3%	0.09	\$12.16	0.1%
>= \$150	0.32	\$54.54	0.2%	0.15	\$25.35	0.0%

Energy Market Cost-Based Offers

The application of market power mitigation rules in the day-ahead energy market and the real-time energy market helps ensure competitive market outcomes even in the presence of structural market power.

Cost-based offers in PJM affect all aspects of the PJM energy market. Cost-based offers affect prices when units are committed and dispatched on their cost-based offers. In the first three months of 2020, 7.6 percent of the marginal units set prices based on cost-based offers, 0.9 percentage points less than the first three months of 2019.

The efficacy of market power mitigation rules depends on the definition of a competitive offer. A competitive offer is equal to short run marginal costs. The enforcement of market power mitigation rules is undermined if the definition of a competitive offer is not correct. The significance of competition metrics like markup is also undermined if the definition of a competitive offer is not correct. The definition of a competitive offer in the PJM market rules is not correct. Some unit owners include costs that are not short run marginal costs in offers, including maintenance costs. This issue can be resolved by simple changes to the PJM market rules to incorporate a clear and accurate definition of short run marginal costs.

The efficacy of market power mitigation rules also depends on the accuracy of cost-based offers. Some unit owners use fuel cost policies that are not algorithmic, verifiable, and systematic. These inadequate fuel cost policies permit overstated fuel costs in cost-based offers.

When market power mitigation is not effective due to inaccurate cost-based offers that exceed short run marginal costs, market power causes increases in market prices above the competitive level.

Short Run Marginal Costs

Short run marginal costs are the only costs relevant to competitive offers in the energy market. Specifically, the competitive energy offer level is the short run marginal cost of production. The current PJM market rules distinguish costs includable in cost-based energy offers from costs includable in cost-based capacity market offers based on whether costs are directly related to energy production. The rules do not provide a clear standard. Energy production is the sole purpose of a power plant. Therefore, all costs, including the sunk costs, are directly related to energy production. This current ambiguous criterion is incorrect and, in addition, allows for multiple interpretations, which could lead to tariff violations. The incorrect rules will lead to higher energy market prices and higher uplift.

There are three types of costs identified under PJM rules as of April 15, 2019: variable costs, avoidable costs, and fixed costs. The criterion for whether a generator may include a cost in an energy market cost-based offer is that the cost is “directly related to electric production.”¹¹⁰

Variable costs are comprised of short run marginal costs and avoidable costs that are directly related to electric production. Short run marginal costs are the cost of inputs consumed or converted to produce energy, and the costs associated with byproducts that result from consuming or converting materials to produce energy, net of any revenues from the sale of those byproducts. The categories of short run marginal costs are fuel costs, emission allowance costs, operating costs, and energy market opportunity costs.¹¹¹

¹¹⁰ See *PJM Interconnection LLC*, 167 FERC ¶ 61,030 (April 15, 2019).

¹¹¹ See PJM Operating Agreement Schedule 2 (a)

Avoidable costs are annual costs that would be avoided if energy were not produced over an annual period. The PJM rules divide avoidable costs into those that are directly related to electric production and those not directly related to electric production. The distinction is ambiguous at best. PJM includes overhaul and maintenance costs and overtime staffing costs in costs related to electric production. PJM includes taxes, preventative maintenance to auxiliary equipment, and pipeline reservation charges in costs not related to electric production.

Fixed costs are costs associated with an investment in a facility including the return on and of capital.

The MMU recommends that PJM require that the level of costs includable in cost-based offers not exceed the unit’s short run marginal cost.

Fuel Cost Policies

Fuel cost policies (FCP) document the process by which market sellers calculate the fuel cost component of their cost-based offers. Short run marginal fuel costs include commodity costs, transportation costs, fees, and taxes for the purchase of fuel.

Fuel Cost Policy Review

Table 3-89 shows the status of all Fuel Cost Policies as of March 31, 2020. As of March 31, 2020, 1,213 units (92 percent) had an FCP passed by the MMU, zero units had an FCP under the MMU review (submitted) and 106 units (8 percent) had an FCP failed by the MMU. The number of units with fuel cost policies failed by the MMU included units with 16,809 MW. All units had an FCP approved by PJM. The number of units with fuel cost policies passed by the MMU remained constant at 92 percent in the 2019 Annual Fuel Cost Policy Review and as of March 31, 2020.

Table 3-89 FCP Status: March 31, 2020

PJM Status	MMU Status			Total
	Pass	Submitted	Fail	
Submitted	0	0	0	0
Under Review	0	0	0	0
Customer Input Required	0	0	0	0
Approved	1,214	0	106	1,320
Revoked	0	0	0	0
Expired	0	0	0	0
Total	1,214	0	106	1,320

The MMU performed a detailed review of every FCP. PJM approved the FCPs that the MMU passed. PJM approved every FCP failed by the MMU.

The standards for the MMU's market power evaluation are that FCPs be algorithmic, verifiable and systematic, accurately reflecting the short run marginal cost of producing energy. In its filings with FERC, PJM agreed with the MMU that FCPs should be verifiable and systematic:¹¹² Verifiable means that the FCP must provide that a market seller provide a fuel price that can be calculated by the MMU after the fact with the same data available to the market seller at the time the decision was made, and documentation for that data from a public or a private source. Systematic means that the FCP must document a standardized method or methods for calculating fuel costs including objective triggers for each method.¹¹³ PJM and FERC did not agree that Fuel Cost Policies should be algorithmic:¹¹⁴ Algorithmic means that the FCP must use a set of defined, logical steps, analogous to a recipe, to calculate the fuel costs. These steps may be as simple as a single number from a contract, a simple average of broker quotes, a simple average of bilateral offers, or the weighted average index price posted on the Intercontinental Exchange trading platform ('ICE').¹¹⁵

FCPs are not verifiable and systematic if they are not algorithmic. The natural gas FCPs failed by the MMU and approved by PJM are not verifiable and systematic.

¹¹² Answer of PJM Interconnection, L.L.C. to Protests and Comments, Docket No. ER16-372-002 (October 7, 2016) ("October 7th Filing") at P 11.

¹¹³ Protest of the Independent Market Monitor for PJM, Docket No. ER16-372-002 (September 16, 2016) ("September 16th Filing") at P 8.

¹¹⁴ October 7th Filing at P12; 158 FERC ¶ 61,133 at P 57 (2017) ("February 3rd Order").

¹¹⁵ September 16th Filing at P 8.

Not all FCPs approved by PJM met the standard of the PJM tariff. The tariff standards that some Fuel Cost Policies did not meet are: accuracy (reflect applicable costs accurately); procurement practices (provide information sufficient for the verification of the market seller's fuel procurement practices where relevant); fuel contracts (reflect the market seller's applicable commodity and/or transportation contracts where it holds such contracts).¹¹⁶

The MMU failed FCPs not related to natural gas submitted by some market sellers because they do not accurately describe the short run marginal cost of fuel. Some policies include contractual terms (in \$ per MWh or in \$ per MMBtu) that do not reflect the actual cost of fuel. The MMU determined that the terms used in these policies do not reflect the cost of fuel based on the information provided by the market sellers and information gathered by the MMU for similar resources.

The MMU failed the remaining FCPs because they do not accurately reflect the cost of natural gas. The main issues identified by the MMU in the natural gas policies were:

- Unverifiable cost estimates. Some of these policies include options under which the estimate of the natural gas commodity cost would be calculated by the market seller without specifying a verifiable, objective, quantitative method. For example, some FCPs specify that the source of the natural gas cost would be communications with traders within the market seller's organization. A fuel cost from discretionary and undocumented decision making within the market seller's organization is not verifiable. The point of FCPs is to eliminate such practices as the basis for fuel costs, as most companies have done. Verifiability requires that fuel cost estimates be transparently derived from market information and that PJM or the MMU could reproduce the same fuel cost estimates after the fact by applying the methods documented in the FCP to the same inputs. Verifiable is a key requirement of an FCP. If it is not verifiable, an FCP is meaningless and has no value. Unverifiable fuel costs permit the exercise of market power.
- Use of available market information that results in inaccurate expected costs. Some market sellers include the use of offers to sell natural gas

¹¹⁶ See PJM Operating Agreement Schedule 2 § 2.3 (a).

on ICE as the sole basis for the cost of natural gas. An offer to sell is generally not an accurate indication of the expected fuel cost. The price of uncleared offers on the exchange generally exceeds the price of cleared transactions, often by a wide margin. Use of sell offers alone is equivalent to using the supply curve alone to determine the market price of a good without considering the demand curve. It is clearly incorrect.

The FCPs that failed the MMU’s evaluation also fail to meet the standards defined in the PJM tariff. PJM should not have approved inaccurate Fuel Cost Policies.

The MMU recommends that PJM require that all fuel cost policies be algorithmic, verifiable, and systematic.

The MMU recommends that the tariff be changed to allow units to have Fuel Cost Policies that do not include fuel procurement practices, including fuel contracts. Fuel procurement practices, including fuel contracts, may be used as the basis for Fuel Cost Policies but should not be required. In a large number of approved Fuel Cost Policies, the actual fuel procurement process plays no role in calculating the Market Seller’s accurate estimate of the daily replacement value of their fuel.

The MMU recommends that PJM change the Fuel Cost Policy requirement to apply only to units that will be offered with nonzero cost-based offers. PJM should set to zero the cost-based offers of units without an approved Fuel Cost Policy.

Cost-Based Offer Penalties

In addition to implementing the Fuel Cost Policy approval process, the February 3, 2017, FERC order created a process for penalizing generators identified by PJM or the MMU with cost-based offers that do not comply with Schedule 2 of the PJM Operating Agreement and PJM Manual 15.¹¹⁷ Penalties became effective May 15, 2017.

¹¹⁷ 158 FERC ¶ 61,133 (2017) (“February 3rd Order”).

In the first three months of 2020, 58 penalty cases were identified, 44 resulted in assessed cost-based offer penalties, two resulted in disagreement between the MMU and PJM, and 12 remain pending PJM’s determination. These cases were from 50 units owned by 11 different companies. Table 3-91 shows the penalties by the year in which participants were notified.

Table 3-90 Cost-based offer penalty cases by year notified: May 2017 through March 2020

Year notified	Cases	Assessed penalties	MMU and PJM Disagreement	Pending cases	Number of units impacted	Number of companies impacted
2017	57	56	1	0	55	16
2018	187	160	26	1	138	35
2019	58	57	0	1	58	19
2020	58	44	2	12	50	11
Total	360	317	29	14	273	53

Since 2017, 360 penalty cases have been identified, 317 resulted in assessed cost-based offer penalties, 29 resulted in disagreement between the MMU and PJM, and 14 remain pending PJM’s determination. The 317 cases were from 273 units owned by 53 different companies. The total penalties were \$2.4 million, charged to units that totaled 65,730 available MW. The average penalty was \$1.67 per available MW.¹¹⁸ Table 3-91 shows the total cost-based offer penalties since 2017 by year.

Table 3-91 Cost-based offer penalties by year: May 2017 through March 2020

Year	Number of units	Number of companies	Penalties	Average Available Capacity Charged (MW)	Average Penalty (\$/MW)
2017	92	20	\$556,826	16,930	\$1.56
2018	126	34	\$1,257,713	26,063	\$2.28
2019	72	18	\$488,930	19,722	\$1.10
2020	38	5	\$77,443	3,015	\$1.07
Total	328	52	\$2,380,912	65,730	\$1.67

The incorrect cost-based offers resulted from incorrect application of Fuel Cost Policies, lack of approved Fuel Cost Policies, Fuel Cost Policy violations, miscalculation of no load costs, inclusion of prohibited maintenance costs,

¹¹⁸ Cost-based offer penalties are assessed by hour. Therefore, a \$1 per available MW penalty results in a total of \$24 for a 1 MW unit if the violation is for the entire day.

use of incorrect incremental heat rates, use of incorrect start cost, and use of incorrect emission costs.

Cost Development Guidelines

The Cost Development Guidelines contained in PJM Manual 15 do not clearly or accurately describe the short run marginal cost of generation. The MMU recommends that PJM Manual 15 be replaced with a straightforward description of the components of cost-based offers based on short run marginal costs and the correct calculation of cost-based offers.

Variable Operating and Maintenance Costs

PJM Manual 15 and the PJM Operating Agreement Schedule 2 include rules related to VOM costs. On October 29, 2018, PJM filed tariff revisions changing the rules related to VOM costs.¹¹⁹ The changes proposed by PJM attempted to clarify the rules. The proposed rules defined all costs directly related to electricity production as includable in cost-based offers. This also included the long term maintenance costs of combined cycles and combustion turbines, which had been explicitly excluded in PJM Manual 15.

On April 15, 2019, FERC accepted PJM's filing order, subject to revisions requested by FERC.¹²⁰ On October 28, 2019, FERC issued a final order accepting PJM's compliance filing.¹²¹ Regardless of the changes, the rules remain unclear and are now inconsistent with economic theory. The purpose of cost-based energy offers is to prevent the exercise of market power in the PJM energy market. PJM administers market power mitigation in the energy market by replacing a generator's market-based offer with its cost-based offer when the generator owner fails the structural test for local market power, the Three Pivotal Supplier ("TPS") test, or is required for reliability. The effectiveness of market power mitigation in delivering competitive market outcomes is based entirely on cost-based offers as the measure of the competitive offer level. When market power is not mitigated, energy prices exceed the competitive level, uplift payments exceed the efficient level, and economic withholding allows generators to collect capacity payments without running, while raising

¹¹⁹ See PJM Interconnection Maintenance Adder Revisions to the Amended and Restated Operating Agreement, L.L.C., Docket No. EL19-8-000.

¹²⁰ 167 FERC ¶ 61,030.

¹²¹ 168 FERC ¶ 61,134.

prices for other generators and for load. The competitive offer level is the short run marginal cost of the generator for the relevant market hour.

Maintenance costs are not short run marginal costs. Generators perform maintenance during outages. Generators do not perform maintenance in the short run, while operating the generating unit. Generators do not perform maintenance in real time to increase the output of a unit. Some maintenance costs are correlated with the historic operation of a generator. Correlation between operating hours or starts and maintenance expenditures over a long run, multiyear time frame does not indicate the necessity of any specific maintenance expenditure to produce power in the short run.

A generating unit does not consume a defined amount of maintenance parts and labor in order to start. A generating unit does not consume a defined amount of maintenance parts and labor in order to produce an additional MWh. Maintenance events do not occur in the short run. The company cannot optimize its maintenance costs in the short run.

PJM allows for the calculation of VOM costs in dollars per MWh, dollars per MMBtu, dollars per run hour, dollars per equivalent operating hour (EOH) and dollars per start. The MMU converted all VOM costs into dollars per MWh using the units' heat rates, the average economic maximum and average minimum run time of the units in 2018 and 2019.

The average variable operating and maintenance cost approved by PJM for combustion turbines and diesels for 2019 was 43 percent higher than the approved variable operating and maintenance cost approved by PJM in 2018. The increase reflects PJM's implementation of the new rules that allow major maintenance and overhauls.¹²²

The average variable operating and maintenance cost approved by PJM for combined cycles for 2019 was 19 percent higher than the approved variable operating and maintenance cost approved by PJM in 2018. The increase reflects PJM's implementation of the new rules that allow major maintenance and overhauls.

¹²² PJM reviews VOM once per year. The results reflect PJM's most recent review.

The average variable operating and maintenance cost approved by PJM for coal units for 2019 was 37 percent higher than the approved variable operating and maintenance cost approved by PJM in 2018. The increase reflects PJM's implementation of the new rules that allow major maintenance and overhauls and the inclusion of other fuel related costs such as fuel handling, chemicals and ash disposal that previously were not part of variable operating and maintenance costs and were part of total fuel related costs.

High VOM levels allow generators to economically withhold energy and to exercise market power even when offers are set to cost to mitigate market power. The MMU recommendation to limit cost-based offers to short run marginal costs would prevent such withholding. When units are not committed due to high VOM costs and instead a unit with higher short run marginal costs is committed, the market outcome is inefficient. When units that fail the TPS test are committed on their price-based offer when their short run marginal cost is lower, the market outcome is inefficient.

MMU analysis shows that as a unit runs more, the VOM cost as approved by PJM, decreases. This is the result for CTs, CCs and coal plants. This is an indication that fixed costs are being included in VOM costs. By comparison, fuel costs per MWh remain constant or increase as run hours and the heat rate increase. Fixed costs should not be includable in cost-based energy offers.

FERC System of Accounts

PJM Manual 15 relies on the FERC System of Accounts, which predates markets and does not define costs consistent with market economics. Market sellers should not rely solely on the FERC System of Accounts for the calculation of their variable operating and maintenance costs. The FERC System of Accounts does not differentiate between short run marginal costs and avoidable costs. The FERC System of Accounts does not differentiate between costs directly related to energy production and costs not directly related to energy production. Reliance on the FERC System of Accounts for the calculation of variable operating and maintenance costs is likely to lead to incorrect, overstated costs.

The MMU recommends removal of all references to and reliance on the FERC System of Accounts in PJM Manual 15.

Cyclic Starting and Peaking Factors

The use of cyclic starting and peaking factors for calculating VOM costs for combined cycles and combustion turbines is designed to allocate a greater proportion of long term maintenance costs to starts and the tail block of the incremental offer curve. The use of such factors is not appropriate given that long term maintenance costs are not short run marginal costs and should not be included in cost offers. PJM Manual 15 allows for a peaking cyclic factor of three, which means that a unit with a \$300 per hour (EOH) VOM cost can add \$180 per MWh to a 5 MW peak segment.¹²³

The MMU recommends the removal of all cyclic starting and peaking factors from PJM Manual 15.

Labor Costs

PJM Manual 15 allows for the inclusion of plant staffing costs in energy market cost offers. This is inappropriate given that labor costs are not short run marginal costs.

The MMU recommends the removal of all labor costs from the PJM Manual 15.

Combined Cycle Start Heat Input Definition

PJM Manual 15 defines the start heat input of combined cycles as the amount of fuel used from the firing of the first combustion turbine to the close of the steam turbine breaker plus any fuel used by other combustion turbines in the combined cycle from firing to the point at which the HRSG steam pressure matches the steam turbine steam pressure. This definition is inappropriate given that after each combustion turbine is synchronized, some of the fuel is used to produce energy for which the resource is compensated in the energy market. To account for this, PJM Manual 15 requires reducing the station service MWh used during the start sequence by the output in MWh produced by each combustion turbine after synchronization and before the HRSG steam

¹²³ The peak adder is equal to \$300 times three divided by 5 MW.

pressure matches the steam turbine steam pressure. The formula and the language in this definition are not appropriate and are unclear.

The MMU recommends changing the definition of the start heat input for combined cycles to include only the amount of fuel used from firing each combustion turbine in the combined cycle to the breaker close of each combustion turbine. This change will make the treatment of combined cycles consistent with steam turbines. Exceptions to this definition should be granted when the amount of fuel used from synchronization to steam turbine breaker close is greater than the no load heat plus the output during this period times the incremental heat rate.

Nuclear Costs

The fuel costs for nuclear plants are fixed in the short run and amortized over the period between refueling outages. The short run marginal cost of fuel for nuclear plants is zero. Operations and maintenance costs for nuclear power plants consist primarily of labor and maintenance costs incurred during outages, which are also fixed in the short run.

The MMU recommends the removal of nuclear fuel and nonfuel operations and maintenance costs that are not short run marginal costs from the PJM Manual 15.

Pumped Hydro Costs

The calculation of pumped hydro costs for energy storage in Section 7.3 of PJM Manual 15 is inaccurate. The mathematical formulation contains an error in the calculation of the weighted average pumping cost, and it does not take into account the purchase of power for pumping in the day-ahead market.

The MMU recommends revising the pumped hydro fuel cost calculation to include day-ahead and real-time power purchases.

Energy Market Opportunity Costs

The calculation of energy market opportunity costs for energy limited units in Sections 12.3-12.6 of PJM Manual 15 fails to account for a number of physical unit characteristics and environmental restrictions that influence

opportunity costs. These include start up time, notification time, minimum down time, multiple fuel capability, multiple emissions limitations, and fuel usage limitations. The solution algorithm described in Sections 12.5-12.6 is flawed, most notably in its incomplete estimate of a generator's optimal revenue and the algorithm's inability to simultaneously impose multiple environmental or operational constraints typically associated with permits that have rolling limits.

The MMU Opportunity Cost Calculator, described in Manual 15, Section 12.7, is a constrained optimization software application that uses an integer programming solver to find the optimal commitment, dispatch, and lost opportunity cost for a generator based on forward power prices and fuel costs. The MMU calculator incorporates start up time, notification time, minimum down time, multiple fuel capability, multiple emissions limitations, and fuel usage limitations. The MMU recommends that the PJM Opportunity Cost Calculator, which adheres to the solution method described in Sections 12.5-12.6, be discontinued and that the MMU Opportunity Cost Calculator be used for all opportunity cost calculations.

The use of Catastrophic Force Majeure as the criterion for the use of opportunity costs for fuel supply limitations in Schedule 2 of the Operating Agreement is overly restrictive. This criterion would not allow the use of opportunity costs to allocate limited fuel in the case of regional fuel transportation disruptions or extreme weather events.

The MMU recommends removing the catastrophic designation for force majeure fuel supply limitations in Schedule 2.

Frequently Mitigated Units (FMU) and Associated Units (AU)

The new rules for determining the qualification of a unit as an FMU or AU became effective November 1, 2014. The number of units that were eligible for an FMU or AU adder declined from an average of 70 units during the first 11 months of 2014, to zero units eligible for an FMU or AU adder for the period between December 2014 and August 2019.¹²⁴ One unit qualified for an FMU

¹²⁴ For a definition of FMUs and AUs, and for historical FMU/AU results, see the 2018 State of the Market Report for PJM, Volume 2, Section 3, Energy Market, at Frequently Mitigated Units (FMU) and Associated Units (AU).

adder for the months of September and October 2019. No units have qualified for an FMU adder in any month since October 2019.

Effective in planning year 2020/2021, default Avoidable Cost Rates will no longer be defined. If a generating unit's Projected PJM Market Revenues plus the unit's PJM capacity market revenues on a rolling 12-month basis (in \$/MW-year) are greater than zero, and if the generating unit does not have an approved unit specific Avoidable Cost Rate, the generating unit will not qualify as an FMU as the Avoidable Cost Rate will be assumed to be zero for FMU qualification purposes.

The MMU recommends the elimination of FMU and AU adders. FMU and AU adders no longer serve the purpose for which they were created and interfere with the efficient operation of PJM markets.

Market Performance

Ownership of Marginal Resources

Table 3-92 shows the contribution to real-time, load-weighted LMP by individual marginal resource owners.¹²⁵ The contribution of each marginal resource to price at each load bus is calculated for each five-minute interval of the first three months of 2020, and summed by the parent company that offers the marginal resource into the real-time energy market. In the first three months of 2020, the offers of one company resulted in 17.2 percent of the real-time, load-weighted PJM system LMP and the offers of the top four companies resulted in 55.4 percent of the real-time, load-weighted, average PJM system LMP. In the first three months of 2020, the offers of one company resulted in 18.3 percent of the peak hour real-time, load-weighted PJM system LMP.

Table 3-92 Marginal unit contribution to real-time, load-weighted LMP (By parent company): January through March 2019 and 2020

Company	2019 (Jan - Mar)						2020 (Jan - Mar)					
	All Hours			Peak Hours			All Hours			Peak Hours		
	Percent of Price	Cumulative Percent	Company	Percent of Price	Cumulative Percent	Company	Percent of Price	Cumulative Percent	Company	Percent of Price	Cumulative Percent	
1	12.8%	12.8%	1	13.7%	13.7%	1	17.2%	17.2%	1	18.3%	18.3%	
2	10.0%	22.8%	2	10.4%	24.1%	2	12.3%	29.5%	2	15.4%	33.6%	
3	9.3%	32.1%	3	8.8%	32.9%	3	11.3%	40.8%	3	11.9%	45.5%	
4	9.3%	41.5%	4	7.2%	40.1%	4	9.2%	50.0%	4	8.7%	54.2%	
5	4.8%	46.3%	5	5.1%	45.2%	5	5.4%	55.4%	5	4.7%	58.9%	
6	4.5%	50.8%	6	4.1%	49.3%	6	4.5%	59.9%	6	4.5%	63.4%	
7	4.4%	55.3%	7	4.1%	53.4%	7	4.4%	64.3%	7	3.6%	67.0%	
8	3.6%	58.9%	8	3.9%	57.2%	8	4.3%	68.7%	8	3.0%	70.0%	
9	3.6%	62.5%	9	3.9%	61.1%	9	3.7%	72.4%	9	2.8%	72.9%	
Other (74 companies)	37.5%	100.0%	Other (70 companies)	38.9%	100.0%	Other (53 companies)	27.6%	100.0%	Other (46 companies)	27.1%	100.0%	

¹²⁵ See the MMU Technical Reference for PJM Markets, at "Calculation and Use of Generator Sensitivity/Unit Participation Factors."

Figure 3-64 shows the first three month marginal unit markup contribution to the real-time, load-weighted PJM system LMP summed by parent companies since 2012. The decline in the concentration of marginal resource ownership largely paralleled the decline in the share of marginal coal resources in the real time energy market. In the PJM energy market, the ownership of coal resources is highly concentrated unlike the ownership of new entrant natural gas resources.

Figure 3-64 Marginal unit contribution to real-time, load-weighted LMP (By parent company): January through March 2012 through 2020

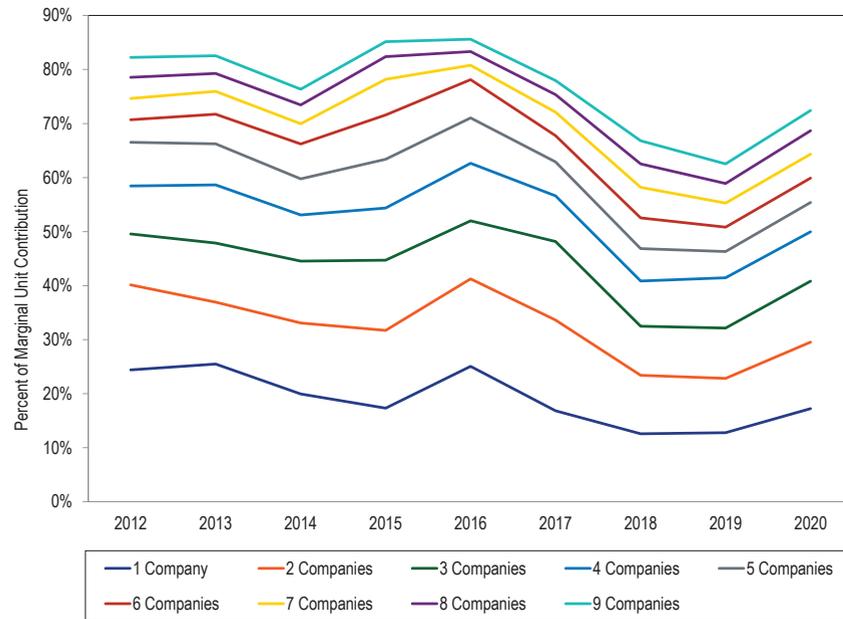


Table 3-93 shows the contribution to day-ahead, load-weighted LMP by individual marginal resource owners.¹²⁶ The contribution of each marginal resource to price at each load bus is calculated hourly, and summed by the parent company that offers the marginal resource into the day-ahead energy market. The results show that in the first three months of 2020, the offers of one company contributed 15.0 percent of the day-ahead, load-weighted, PJM system LMP and that the offers of the top four companies contributed 39.1 percent of the day-ahead, load-weighted, average, PJM system LMP.

¹²⁶ Id.

Table 3-93 Marginal resource contribution to day-ahead, load-weighted LMP (By parent company): January through March, 2019 and 2020

Company	2019 (Jan - Mar)						2020 (Jan - Mar)					
	All Hours			Peak Hours			All Hours			Peak Hours		
	Percent of Price	Cumulative Percent	Company	Percent of Price	Cumulative Percent	Company	Percent of Price	Cumulative Percent	Company	Percent of Price	Cumulative Percent	Company
1	8.4%	8.4%	1	9.5%	9.5%	1	15.0%	15.0%	1	15.7%	15.7%	
2	8.3%	16.7%	2	7.5%	7.5%	2	12.7%	27.8%	2	15.3%	31.0%	
3	7.1%	23.8%	3	6.6%	6.6%	3	6.6%	34.4%	3	5.4%	36.4%	
4	5.1%	28.9%	4	4.8%	4.8%	4	4.7%	39.1%	4	4.1%	40.5%	
5	4.5%	33.4%	5	4.3%	4.3%	5	4.3%	43.4%	5	3.8%	44.3%	
6	3.7%	37.1%	6	3.9%	3.9%	6	3.3%	46.7%	6	3.6%	47.9%	
7	3.3%	40.4%	7	3.9%	3.9%	7	3.2%	49.9%	7	3.5%	51.4%	
8	3.2%	43.6%	8	3.6%	3.6%	8	3.1%	53.0%	8	3.5%	54.9%	
9	3.1%	46.6%	9	2.9%	2.9%	9	3.0%	56.0%	9	3.2%	58.1%	
Other (123 companies)	53.4%	100.0%	Other (114 companies)	53.0%	53.0%	Other (116 companies)	44.0%	100.0%	Other (107 companies)	41.9%	100.0%	

Markup

The markup index is a measure of the competitiveness of participant behavior for individual units. The markup in dollars is a measure of the impact of participant behavior on the generator bus market price when a unit is marginal. As an example, if unit A has a \$90 cost and a \$100 price, while unit B has a \$9 cost and a \$10 price, both would show a markup index of 10 percent, but the price impact of unit A’s markup at the generator bus would be \$10 while the price impact of unit B’s markup at the generator bus would be \$1. Depending on each unit’s location on the transmission system, those bus level impacts could also have different impacts on total system price. Markup can also affect prices when units with markups are not marginal by altering the economic dispatch order of supply.

The MMU calculates an explicit measure of the impact of marginal unit incremental energy offer markups on LMP using the mathematical relationships among LMPs in the market solution.¹²⁷ The markup impact calculation sums, over all marginal units, the product of the dollar markup of the unit and the

¹²⁷ The MMU calculates the impact on system prices of marginal unit price-cost markup, based on analysis using sensitivity factors. The calculation shows the markup component of LMP based on a comparison between the price-based incremental energy offer and the cost-based incremental energy offer of each actual marginal unit on the system. This is the same method used to calculate the fuel cost adjusted LMP and the components of LMP. The markup analysis does not include markup in start up or no load offers. See Calculation and Use of Generator Sensitivity/Unit Participation Factors, 2010 State of the Market Report for PJM: Technical Reference for PJM Markets.

marginal impact of the unit’s offer on the system load-weighted LMP. The markup impact includes the impact of the identified markup behavior of all marginal units. Positive and negative markup impacts may offset one another. The markup analysis is a direct measure of market performance. It does not take into account whether or not marginal units have either locational or aggregate structural market power.

The markup calculation is not based on a counterfactual redispatch of the system to determine the marginal units and their marginal costs that would have occurred if all units had made all offers at short run marginal cost. A full redispatch analysis is practically impossible and a limited redispatch analysis would not be dispositive. Nonetheless, such a hypothetical counterfactual analysis would reveal the extent to which the actual system dispatch is less than competitive if it showed a difference between dispatch based on short run marginal cost and actual dispatch. It is possible that the unit-specific markup, based on a redispatch analysis, would be lower than the markup component of price if the reference point were an inframarginal unit with a lower price and a higher cost than the actual marginal unit. If the actual marginal unit has short run marginal costs that would cause it to be inframarginal, a new

unit would be marginal. If the offer of that new unit were greater than the cost of the original marginal unit, the markup impact would be lower than the MMU measure. If the newly marginal unit is on a price-based schedule, the analysis would have to capture the markup impact of that unit as well.

Real-Time Markup

Markup Component of Real-Time Price by Fuel, Unit Type

The markup component of price is the difference between the system price, when the system price is determined by the active offers of the marginal units, whether price or cost-based, and the system price, based on the cost-based offers of those marginal units.

Table 3-94 shows the impact (markup component of LMP) of the marginal unit markup behavior by fuel type and unit type on the real-time load-weighted average system LMP, using unadjusted and adjusted offers. The adjusted markup component of LMP decreased from \$4.38 per MWh in the first three months of 2019 to \$1.71 per MWh in the first three months of 2020. The adjusted markup contribution of coal units in the first three months of 2020 was \$0.13 per MWh. The adjusted markup component of gas fired units in the first three months of 2020 was \$1.58 per MWh, a decrease of \$1.60 per MWh from the first three months of 2019. The markup component of wind units was less than \$0.0 per MWh. If a price-based offer is negative, but less negative than a cost-based offer, the markup is positive. In the first three months of 2020, among the wind units that were marginal, 98.9 percent had negative offer prices.

Table 3-94 Markup component of real-time, load-weighted, average LMP by primary fuel type and unit type: January through March, 2019 and 2020¹²⁸

Fuel	Technology	2019 (Jan - Mar)		2020 (Jan - Mar)	
		Markup Component of LMP (Unadjusted)	Markup Component of LMP (Adjusted)	Markup Component of LMP (Unadjusted)	Markup Component of LMP (Adjusted)
Coal	Steam	\$0.31	\$1.18	(\$0.55)	\$0.13
Gas	CC	\$1.69	\$3.00	\$0.69	\$1.55
Gas	CT	\$0.01	\$0.13	\$0.00	\$0.03
Gas	RICE	\$0.02	\$0.03	\$0.07	\$0.07
Gas	Steam	(\$0.01)	\$0.02	(\$0.11)	(\$0.08)
Landfill Gas	CT	(\$0.00)	(\$0.00)	\$0.00	\$0.00
Municipal Waste	RICE	\$0.00	\$0.00	\$0.00	\$0.00
Oil	CC	(\$0.00)	\$0.00	\$0.00	\$0.00
Oil	CT	\$0.02	\$0.02	\$0.00	\$0.00
Oil	RICE	\$0.00	\$0.00	\$0.00	\$0.00
Oil	Steam	(\$0.00)	\$0.00	\$0.00	\$0.00
Other	Steam	\$0.00	\$0.00	(\$0.00)	(\$0.00)
Wind	Wind	\$0.01	\$0.01	(\$0.00)	(\$0.00)
Total		\$2.04	\$4.38	\$0.10	\$1.71

Markup Component of Real-Time Price

Table 3-95 shows the markup component, calculated using unadjusted offers, of average prices and of average monthly on peak and off peak prices. Table 3-96 shows the markup component, calculated using adjusted offers, of average prices and of average monthly on peak and off peak prices. In the first three months of 2020, when using unadjusted cost-based offers, \$0.10 per MWh of the PJM real-time load-weighted average LMP was attributable to markup. Using adjusted cost-based offers, \$1.71 per MWh of the PJM real-time load-weighted, average LMP was attributable to markup. In the first three months of 2020, the peak markup component was highest in January, \$0.91 per MWh using unadjusted cost-based offers and peak markup component was highest in January, \$2.75 per MWh using adjusted cost-based offers. This corresponds to 3.8 percent and 11.4 percent of the real-time peak load-weighted average LMP in January.

¹²⁸ The unit type RICE refers to Reciprocating Internal Combustion Engines.

Table 3-95 Monthly markup components of real-time load-weighted LMP (Unadjusted): January through March, 2019 and 2020

	2019			2020		
	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component
Jan	\$1.89	\$2.43	\$1.33	\$0.47	\$0.91	\$0.03
Feb	\$2.15	\$2.85	\$1.46	(\$0.11)	\$0.04	(\$0.26)
Mar	\$2.11	\$2.57	\$1.67	(\$0.09)	\$0.46	(\$0.65)
Apr	\$1.38	\$2.01	\$0.67			
May	\$1.27	\$2.02	\$0.45			
Jun	\$1.36	\$1.74	\$0.98			
Jul	\$3.25	\$4.40	\$1.99			
Aug	\$0.86	\$0.78	\$0.95			
Sep	\$1.57	\$2.58	\$0.55			
Oct	\$1.39	\$2.01	\$0.64			
Nov	\$1.12	\$1.79	\$0.51			
Dec	\$0.19	\$0.29	\$0.08			
Total	\$1.58	\$2.16	\$0.97	\$0.10	\$0.49	(\$0.28)

Table 3-96 Monthly markup components of real-time load-weighted LMP (Adjusted): January through March, 2019 and 2020

	2019			2020		
	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component
Jan	\$4.45	\$5.21	\$3.65	\$2.18	\$2.75	\$1.60
Feb	\$4.33	\$5.11	\$3.55	\$1.44	\$1.65	\$1.24
Mar	\$4.37	\$4.93	\$3.84	\$1.44	\$2.07	\$0.81
Apr	\$3.40	\$4.16	\$2.53			
May	\$3.23	\$4.15	\$2.22			
Jun	\$3.21	\$3.79	\$2.64			
Jul	\$5.38	\$6.71	\$3.92			
Aug	\$2.81	\$3.03	\$2.55			
Sep	\$3.61	\$4.85	\$2.36			
Oct	\$3.17	\$4.00	\$2.17			
Nov	\$3.18	\$3.95	\$2.49			
Dec	\$2.12	\$2.38	\$1.88			
Total	\$3.64	\$4.40	\$2.86	\$1.71	\$2.18	\$1.23

Hourly Markup Component of Real-Time Prices

Figure 3-65 shows the markup contribution to the hourly load-weighted LMP using unadjusted cost offers in 2019 and the first three months of 2020. Figure 3-66 shows the markup contribution to the hourly load-weighted LMP using adjusted cost-based offers in 2019 and the first three months of 2020.

Figure 3-65 Markup contribution to real-time hourly load-weighted LMP (Unadjusted): 2019 and 2020

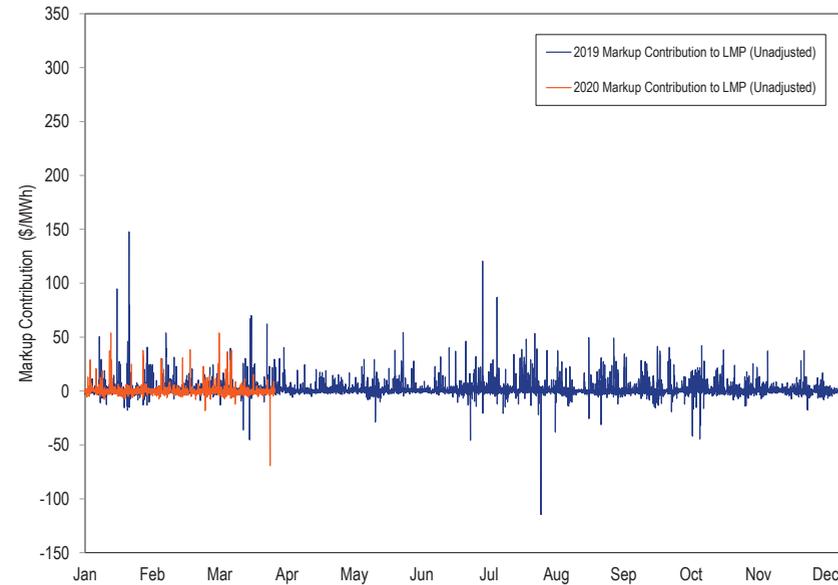
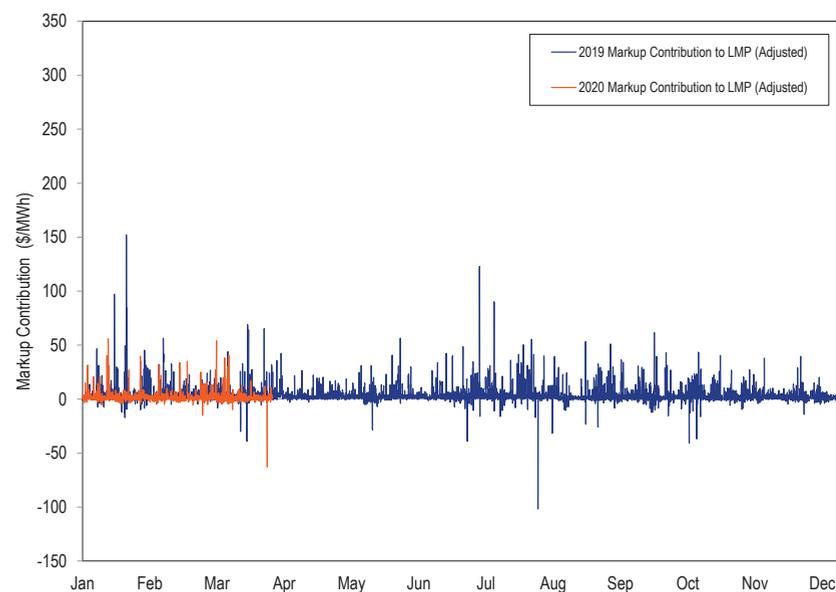


Figure 3-66 Markup contribution to real-time hourly load-weighted LMP (Adjusted): 2019 and 2020



Markup Component of Real-Time Zonal Prices

The unit markup component of average real-time price using unadjusted offers is shown for each zone in the first three months of 2019 and 2020 in Table 3-97 and for adjusted offers in Table 3-98¹²⁹. The smallest zonal all hours average markup component using unadjusted offers in the first three months of 2020, was in the RECO Control Zone, -\$0.06 per MWh, while the highest was in the BGE Control Zone, \$0.21 per MWh. The smallest zonal on peak average markup component using unadjusted offers in the first three months of 2020, was in the RECO Control Zone, \$0.22 per MWh, while the highest was in the BGE Control Zone, \$0.65 per MWh.

Table 3-97 Average real-time zonal markup component (Unadjusted): January through March, 2019 and 2020

	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component
AECO	\$2.65	\$3.24	\$2.09	\$0.03	\$0.34	(\$0.28)
AEP	\$1.85	\$2.34	\$1.37	\$0.11	\$0.54	(\$0.33)
APS	\$1.88	\$2.37	\$1.40	\$0.09	\$0.53	(\$0.33)
ATSI	\$1.89	\$2.37	\$1.40	\$0.09	\$0.46	(\$0.30)
BGE	\$2.05	\$2.59	\$1.54	\$0.17	\$0.65	(\$0.30)
ComEd	\$1.78	\$2.78	\$0.75	\$0.19	\$0.54	(\$0.16)
DAY	\$1.90	\$2.45	\$1.33	\$0.08	\$0.50	(\$0.35)
DEOK	\$1.70	\$2.17	\$1.22	\$0.10	\$0.59	(\$0.39)
DLCO	\$1.81	\$2.28	\$1.32	\$0.14	\$0.54	(\$0.27)
Dominion	\$1.95	\$2.47	\$1.46	\$0.08	\$0.54	(\$0.36)
DPL	\$2.90	\$3.23	\$2.58	\$0.01	\$0.31	(\$0.28)
EKPC	\$1.62	\$2.08	\$1.21	\$0.08	\$0.60	(\$0.40)
JCPL	\$2.61	\$3.12	\$2.10	\$0.00	\$0.26	(\$0.26)
Met-Ed	\$2.04	\$2.50	\$1.57	\$0.07	\$0.35	(\$0.21)
OVEC	\$1.55	\$2.03	\$1.12	(\$0.03)	\$0.35	(\$0.36)
PECO	\$2.56	\$2.98	\$2.13	\$0.02	\$0.30	(\$0.27)
PENELEC	\$2.00	\$2.39	\$1.59	\$0.10	\$0.47	(\$0.28)
Pepco	\$1.99	\$2.48	\$1.49	\$0.15	\$0.60	(\$0.31)
PPL	\$2.34	\$2.88	\$1.81	\$0.21	\$0.40	\$0.02
PSEG	\$2.87	\$3.58	\$2.15	(\$0.00)	\$0.27	(\$0.28)
RECO	\$2.39	\$2.97	\$1.75	(\$0.06)	\$0.22	(\$0.36)

¹²⁹ A marginal unit's offer price affects LMPs in the entire PJM market. The markup component of average zonal real-time price is based on offers of units located within the zone and units located outside the transmission zone.

Table 3-98 Average real-time zonal markup component (Adjusted): January through March, 2019 and 2020

	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component
AECO	\$4.94	\$5.65	\$4.27	\$1.60	\$1.99	\$1.24
AEP	\$4.18	\$4.82	\$3.56	\$1.73	\$2.26	\$1.20
APS	\$4.27	\$4.91	\$3.65	\$1.71	\$2.24	\$1.19
ATSI	\$4.26	\$4.91	\$3.60	\$1.72	\$2.20	\$1.23
BGE	\$4.60	\$5.30	\$3.92	\$1.87	\$2.44	\$1.31
ComEd	\$3.89	\$5.03	\$2.72	\$1.72	\$2.20	\$1.23
DAY	\$4.31	\$5.03	\$3.58	\$1.79	\$2.30	\$1.25
DEOK	\$4.01	\$4.63	\$3.39	\$1.74	\$2.32	\$1.16
DLCO	\$4.13	\$4.77	\$3.50	\$1.75	\$2.26	\$1.24
Dominion	\$4.42	\$5.10	\$3.78	\$1.71	\$2.25	\$1.20
DPL	\$5.26	\$5.70	\$4.84	\$1.61	\$1.98	\$1.27
EKPC	\$3.96	\$4.55	\$3.42	\$1.71	\$2.32	\$1.15
JCPL	\$4.96	\$5.61	\$4.31	\$1.60	\$1.94	\$1.26
Met-Ed	\$4.39	\$4.98	\$3.78	\$1.66	\$2.00	\$1.31
OVEC	\$3.79	\$4.43	\$3.22	\$1.56	\$2.04	\$1.13
PECO	\$4.86	\$5.41	\$4.30	\$1.58	\$1.93	\$1.23
PENELEC	\$4.29	\$4.81	\$3.75	\$1.66	\$2.11	\$1.19
Pepco	\$4.50	\$5.14	\$3.85	\$1.81	\$2.36	\$1.26
PPL	\$4.61	\$5.30	\$3.92	\$1.70	\$1.95	\$1.45
PSEG	\$5.20	\$6.02	\$4.37	\$1.59	\$1.95	\$1.23
RECO	\$4.51	\$5.15	\$3.82	\$1.52	\$1.88	\$1.12

Markup by Real-Time Price Levels

Table 3-99 shows the markup contribution to the LMP, based on the unadjusted cost-based offers and adjusted cost-based offers of the marginal units, when the PJM system wide load-weighted average LMP was in the identified price range.

Table 3-99 Real-time markup contribution (By PJM load-weighted LMP category, unadjusted): January through March, 2019 and 2020

LMP Category	2019 (Jan - Mar)		2020 (Jan - Mar)	
	Markup Component	Frequency	Markup Component	Frequency
< \$10	(\$2.52)	0.1%	(\$0.90)	1.1%
\$10 to \$15	(\$0.38)	0.1%	(\$0.13)	17.2%
\$15 to \$20	(\$0.01)	9.2%	(\$1.16)	48.8%
\$20 to \$25	\$0.23	37.4%	\$0.13	24.5%
\$25 to \$50	\$1.95	48.1%	\$5.12	7.2%
\$50 to \$75	\$12.38	3.0%	\$19.82	0.9%
\$75 to \$100	\$23.05	1.3%	\$19.38	0.2%
\$100 to \$125	\$22.69	0.2%	\$0.00	0.0%
\$125 to \$150	\$33.06	0.2%	\$0.00	0.0%
>= \$150	\$6.99	0.3%	\$0.00	0.0%

Table 3-100 Real-time markup contribution (By PJM load-weighted LMP category, adjusted): January through March, 2019 and 2020

LMP Category	2019 (Jan - Mar)		2020 (Jan - Mar)	
	Markup Component	Frequency	Markup Component	Frequency
< \$10	(\$1.40)	0.1%	\$0.01	1.1%
\$10 to \$15	\$0.89	0.1%	\$1.10	17.2%
\$15 to \$20	\$1.73	9.3%	\$0.51	48.6%
\$20 to \$25	\$2.25	37.4%	\$2.03	24.8%
\$25 to \$50	\$4.46	48.1%	\$7.10	7.2%
\$50 to \$75	\$15.92	3.0%	\$21.99	0.9%
\$75 to \$100	\$27.08	1.3%	\$21.43	0.2%
\$100 to \$125	\$28.69	0.2%	\$0.00	0.0%
\$125 to \$150	\$37.12	0.2%	\$0.00	0.0%
>= \$150	\$9.54	0.3%	\$0.00	0.0%

Markup by Company

Table 3-101 shows the markup contribution based on the unadjusted cost-based offers and adjusted cost-based offers to real-time, load-weighted average LMP by individual marginal resource owners. The markup contribution of each marginal resource to price at each load bus is calculated for each five-minute interval, and summed by the parent company that offers the marginal resource into the real-time energy market. In the first three months of 2020, when using unadjusted cost-based offers, the markup of one company accounted for 2.1 percent of the load-weighted average LMP, the markup of the top five companies accounted for 4.4 percent of the load-weighted average LMP and the markup of all companies accounted for 0.5 percent of the load-weighted average LMP. The top five companies' markup contribution to the load-weighted average LMP and the dollar values of their markup decreased in the first three months of 2020. The markup contribution to the load-weighted average LMP and share of the markup contribution to the load-weighted average LMP also decreased in the first three months of 2020.

Table 3-101 Markup component of real-time, load-weighted, average LMP by Company: January through March, 2019 and 2020

	2019 (Jan - Mar)				2020 (Jan - Mar)			
	Markup Component of LMP (Unadjusted)		Markup Component of LMP (Adjusted)		Markup Component of LMP (Unadjusted)		Markup Component of LMP (Adjusted)	
	\$/MWh	Percent of Load Weighted LMP	\$/MWh	Percent of Load Weighted LMP	\$/MWh	Percent of Load Weighted LMP	\$/MWh	Percent of Load Weighted LMP
Top 1 Company	\$0.86	2.9%	\$1.05	3.5%	\$0.43	2.1%	\$0.67	3.4%
Top 2 Companies	\$1.24	4.1%	\$1.67	5.5%	\$0.60	3.0%	\$0.89	4.5%
Top 3 Companies	\$1.51	5.0%	\$2.10	7.0%	\$0.72	3.6%	\$1.07	5.4%
Top 4 Companies	\$1.71	5.7%	\$2.50	8.3%	\$0.80	4.0%	\$1.24	6.2%
Top 5 Companies	\$1.86	6.2%	\$2.82	9.3%	\$0.87	4.4%	\$1.35	6.8%
All Companies	\$2.04	6.8%	\$4.38	14.5%	\$0.10	0.5%	\$1.71	8.6%

Day-Ahead Markup

Markup Component of Day-Ahead Price by Fuel, Unit Type

The markup component of the PJM day-ahead, load-weighted average LMP by primary fuel and unit type is shown in Table 3-102. INC, DEC and up to congestion transactions (UTC) have zero markups. INCs were 16.2 percent of marginal resources and DEC were 12.6 percent of marginal resources in the first three months of 2020.

The adjusted markup of coal, gas and oil units is calculated as the difference between the price-based offer, and the cost-based offer excluding the 10 percent adder. Table 3-102 shows the markup component of LMP for marginal generating resources. Generating resources were only 22.5 percent of marginal resources in the first three months of 2020. Using adjusted cost-based offers, the markup component of LMP for marginal generating resources decreased for coal fired steam units from \$0.79 to \$0.07 and decreased for gas fired CC units from \$1.35 to \$1.06.

Table 3-102 Markup component of day-ahead, load-weighted, average LMP by primary fuel type and technology type: January through March, 2019 and 2020

Fuel	Technology	2019 (Jan - Mar)			2020 (Jan - Mar)		
		Markup Component of LMP (Unadjusted)	Markup Component of LMP (Adjusted)	Frequency	Markup Component of LMP (Unadjusted)	Markup Component of LMP (Adjusted)	Frequency
Coal	Steam	(\$0.04)	\$0.79	44.1%	(\$0.72)	\$0.07	34.8%
Gas	CC	\$0.68	\$1.35	51.4%	\$0.61	\$1.06	59.1%
Gas	CT	\$0.04	\$0.05	1.1%	(\$0.00)	\$0.00	0.6%
Gas	RICE	\$0.00	\$0.00	0.7%	(\$0.00)	(\$0.00)	0.1%
Gas	Steam	(\$0.02)	\$0.00	1.0%	(\$0.05)	(\$0.03)	1.1%
Municipal Waste	RICE	\$0.00	\$0.00	0.2%	\$0.00	\$0.00	0.0%
Oil	CT	\$0.00	\$0.00	0.0%	\$0.00	\$0.00	0.2%
Oil	Steam	\$0.00	(\$0.00)	0.0%	\$0.00	\$0.00	0.0%
Other	Solar	\$0.00	\$0.00	0.0%	\$0.00	\$0.00	0.0%
Other	Steam	(\$0.00)	(\$0.00)	0.1%	(\$0.00)	(\$0.00)	0.1%
Uranium	Steam	\$0.00	\$0.00	0.0%	\$0.00	\$0.00	1.6%
Wind	Wind	\$0.03	\$0.03	1.3%	\$0.01	\$0.01	2.3%
Total		\$0.68	\$2.21	100.0%	(\$0.15)	\$1.12	100.0%

Markup Component of Day-Ahead Price

The markup component of price is the difference between the system price, when the system price is determined by the active offers of the marginal units, whether price or cost-based, and the system price, based on the cost-based offers of those marginal units. Only hours when generating units were marginal on either priced-based offers or on cost-based offers were included in the markup calculation.

Table 3-103 shows the markup component of average prices and of average monthly on-peak and off-peak prices using unadjusted cost-based offers. In the first three months of 2020, when using unadjusted cost-based offers, -\$0.15 per MWh of the PJM day-ahead load-weighted average LMP was attributable to markup. In the first three months of 2020, the peak markup component was highest in January, \$0.29 per MWh using unadjusted cost-based offers.

Table 3-103 Monthly markup components of day-ahead (Unadjusted), load-weighted LMP: January 2019 through March 2020

	2019			2020		
	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component
Jan	\$0.78	\$1.68	(\$0.16)	(\$0.03)	\$0.29	(\$0.35)
Feb	\$0.60	\$0.80	\$0.41	(\$0.23)	(\$0.08)	(\$0.39)
Mar	\$0.65	\$0.99	\$0.32	(\$0.21)	(\$0.19)	(\$0.23)
Apr	\$0.15	\$0.30	(\$0.03)			
May	\$0.11	\$0.13	\$0.09			
Jun	\$0.45	\$0.38	\$0.53			
Jul	\$2.50	\$4.14	\$0.66			
Aug	\$0.39	\$0.44	\$0.34			
Sep	(\$0.09)	(\$0.28)	\$0.09			
Oct	\$1.11	\$1.82	\$0.25			
Nov	\$1.71	\$1.75	\$1.68			
Dec	(\$0.34)	\$0.21	(\$0.87)			
Annual	\$0.68	\$1.19	\$0.18	(\$0.15)	\$0.02	(\$0.32)

Table 3-104 shows the markup component of average prices and of average monthly on peak and off peak prices using adjusted cost-based offers. In the first three months of 2020, when using adjusted cost-based offers, \$1.12 per MWh of the PJM day-ahead load-weighted average LMP was attributable to markup. In the first three months of 2020, the peak markup component was highest in January, \$1.65 per MWh using adjusted cost-based offers.

Table 3-104 Monthly markup components of day-ahead (Adjusted), load-weighted LMP: January 2019 through March 2020

	2019			2020		
	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component
Jan	\$2.46	\$3.34	\$1.55	\$1.35	\$1.65	\$1.03
Feb	\$2.12	\$2.35	\$1.88	\$1.03	\$1.22	\$0.84
Mar	\$2.02	\$2.28	\$1.78	\$0.96	\$1.02	\$0.90
Apr	\$1.26	\$1.28	\$1.24			
May	\$1.29	\$1.17	\$1.43			
Jun	\$1.64	\$1.62	\$1.67			
Jul	\$3.67	\$5.17	\$2.00			
Aug	\$1.55	\$1.48	\$1.64			
Sep	\$1.06	\$0.81	\$1.32			
Oct	\$2.02	\$2.55	\$1.36			
Nov	\$2.92	\$3.01	\$2.84			
Dec	\$1.12	\$1.65	\$0.61			
Annual	\$2.21	\$2.69	\$1.73	\$1.12	\$1.31	\$0.93

Markup Component of Day-Ahead Zonal Prices

The markup component of annual average day-ahead price using unadjusted cost-based offers is shown for each zone in Table 3-105. The markup component of annual average day-ahead price using adjusted cost-based offers is shown for each zone in Table 3-106. The smallest zonal all hours average markup component using adjusted cost-based offers for the first three months of 2020 was in the BGE Zone, \$0.75 per MWh, while the highest was in the PPL Control Zone, \$2.72 per MWh. The smallest zonal on peak average markup using adjusted cost-based offers was in the DLCO Control Zone, \$0.81 per MWh, while the highest was in the PPL Control Zone, \$3.22 per MWh.

Table 3-105 Day-ahead, average, zonal markup component (Unadjusted): January through March, 2019 and 2020

	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component
AECO	\$1.14	\$1.78	\$0.50	\$0.15	\$0.30	(\$0.01)
AEP	\$0.59	\$1.04	\$0.15	(\$0.36)	(\$0.22)	(\$0.49)
APS	\$0.62	\$1.10	\$0.15	(\$0.32)	(\$0.14)	(\$0.51)
ATSI	\$0.56	\$0.98	\$0.13	(\$0.35)	(\$0.21)	(\$0.49)
BGE	\$0.45	\$1.05	(\$0.13)	(\$0.59)	(\$0.42)	(\$0.76)
ComEd	\$0.42	\$0.77	\$0.06	(\$0.32)	(\$0.17)	(\$0.47)
DAY	\$0.58	\$0.98	\$0.17	(\$0.36)	(\$0.21)	(\$0.51)
DEOK	\$0.54	\$0.92	\$0.16	(\$0.36)	(\$0.23)	(\$0.50)
DLCO	\$0.60	\$1.00	\$0.19	(\$0.51)	(\$0.47)	(\$0.56)
Dominion	\$0.52	\$1.08	(\$0.02)	(\$0.44)	(\$0.32)	(\$0.56)
DPL	\$1.16	\$1.75	\$0.58	\$0.21	\$0.38	\$0.04
EKPC	\$0.66	\$1.15	\$0.20	(\$0.37)	(\$0.23)	(\$0.50)
JCPL	\$1.09	\$1.73	\$0.41	\$0.15	\$0.29	(\$0.01)
Met-Ed	\$0.84	\$1.43	\$0.22	\$0.26	\$0.39	\$0.12
OVEC	\$0.67	\$0.00	\$0.67	\$0.01	(\$0.28)	\$0.22
PECO	\$1.20	\$1.88	\$0.50	\$0.19	\$0.34	\$0.04
PENELEC	\$0.88	\$1.27	\$0.45	\$0.04	\$0.23	(\$0.19)
Pepco	\$0.49	\$1.09	(\$0.12)	(\$0.36)	(\$0.16)	(\$0.56)
PPL	\$1.08	\$1.66	\$0.49	\$1.62	\$2.13	\$1.10
PSEG	\$1.17	\$1.89	\$0.42	\$0.15	\$0.31	(\$0.01)
RECO	\$1.06	\$1.72	\$0.34	\$0.29	\$0.63	(\$0.08)

Table 3-106 Day-ahead, average, zonal markup component (Adjusted): January through March, 2019 and 2020

	2019 (Jan - Mar)			2020 (Jan - Mar)		
	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off Peak Markup Component
AECO	\$2.64	\$3.26	\$2.02	\$1.39	\$1.58	\$1.20
AEP	\$2.12	\$2.55	\$1.70	\$0.94	\$1.10	\$0.79
APS	\$2.18	\$2.62	\$1.74	\$0.98	\$1.19	\$0.77
ATSI	\$2.12	\$2.52	\$1.70	\$0.96	\$1.11	\$0.80
BGE	\$2.05	\$2.60	\$1.51	\$0.75	\$0.95	\$0.55
ComEd	\$1.91	\$2.27	\$1.54	\$0.93	\$1.10	\$0.74
DAY	\$2.14	\$2.52	\$1.76	\$0.98	\$1.13	\$0.81
DEOK	\$2.06	\$2.42	\$1.70	\$0.94	\$1.10	\$0.79
DLCO	\$2.15	\$2.55	\$1.74	\$0.76	\$0.81	\$0.71
Dominion	\$2.06	\$2.54	\$1.60	\$0.87	\$1.02	\$0.72
DPL	\$2.68	\$3.24	\$2.13	\$1.44	\$1.65	\$1.25
EKPC	\$2.18	\$2.68	\$1.73	\$0.92	\$1.07	\$0.79
JCPL	\$2.65	\$3.28	\$1.98	\$1.42	\$1.60	\$1.23
Met-Ed	\$2.36	\$2.92	\$1.79	\$1.48	\$1.64	\$1.31
OVEC	\$1.65	\$0.00	\$1.65	\$1.25	\$1.01	\$1.41
PECO	\$2.72	\$3.39	\$2.03	\$1.43	\$1.61	\$1.24
PENELEC	\$2.34	\$2.70	\$1.96	\$1.25	\$1.43	\$1.04
Pepco	\$2.10	\$2.67	\$1.52	\$0.97	\$1.19	\$0.74
PPL	\$2.59	\$3.17	\$2.00	\$2.72	\$3.22	\$2.21
PSEG	\$2.66	\$3.35	\$1.94	\$1.39	\$1.58	\$1.20
RECO	\$2.52	\$3.13	\$1.84	\$1.53	\$1.89	\$1.13

Markup by Day-Ahead Price Levels

Table 3-107 and Table 3-108 show the average markup component of LMP, based on the unadjusted cost-based offers and adjusted cost-based offers of the marginal units, when the PJM system LMP was in the identified price range.

Table 3-107 Average, day-ahead markup component (By LMP category, unadjusted): January through March, 2019 and 2020

LMP Category	2019 (Jan - Mar)		2020 (Jan - Mar)	
	Average Markup Component	Frequency	Average Markup Component	Frequency
< \$10	\$0.00	0.0%	\$0.00	0.7%
\$10 to \$15	\$0.00	0.0%	\$0.01	9.6%
\$15 to \$20	(\$0.01)	5.6%	(\$0.25)	49.8%
\$20 to \$25	(\$0.05)	31.1%	\$0.04	30.3%
\$25 to \$50	\$0.42	59.1%	\$0.05	9.5%
\$50 to \$75	\$0.10	2.3%	\$0.00	0.1%
\$75 to \$100	\$0.09	1.6%	\$0.00	0.0%
\$100 to \$125	\$0.06	0.2%	\$0.00	0.0%
\$125 to \$150	\$0.05	0.1%	\$0.00	0.0%
>= \$150	\$0.03	0.1%	\$0.00	0.0%

Table 3-108 Average, day-ahead markup component (By LMP category, adjusted): January through March, 2019 and 2020

LMP Category	2019 (Jan - Mar)		2020 (Jan - Mar)	
	Average Markup Component	Frequency	Average Markup Component	Frequency
< \$10	\$0.00	0.0%	\$0.00	0.7%
\$10 to \$15	\$0.00	0.0%	\$0.08	9.6%
\$15 to \$20	\$0.05	5.6%	\$0.41	49.8%
\$20 to \$25	\$0.37	31.1%	\$0.47	30.3%
\$25 to \$50	\$1.38	59.1%	\$0.15	9.5%
\$50 to \$75	\$0.13	2.3%	\$0.00	0.1%
\$75 to \$100	\$0.12	1.6%	\$0.00	0.0%
\$100 to \$125	\$0.08	0.2%	\$0.00	0.0%
\$125 to \$150	\$0.05	0.1%	\$0.00	0.0%
>= \$150	\$0.04	0.1%	\$0.00	0.0%

Market Structure, Participant Behavior, and Market Performance

The goal of regulation through competition is to achieve competitive market outcomes even in the presence of market power. Market structure in the PJM energy market is not competitive in local markets created by transmission constraints. At times, market structure is not competitive in the aggregate energy market. Market sellers pursuing their financial interests may choose behavior that benefits from structural market power in the absence of an effective market power mitigation program. The overall competitive assessment determines the extent to which that participant behavior results in competitive or above competitive pricing. The competitive assessment brings together the structural measures of market power, HHI and pivotal suppliers, with participant behavior, specifically markup, and pricing outcomes.

HHI and Markup

In theory, the HHI provides insight into the relationship between market structure, behavior, and performance. In the case where participants compete by producing output at constant, but potentially different, marginal costs, the HHI is directly proportional to the expected average price cost markup in the market:¹³⁰

$$\frac{HHI}{\varepsilon} = \frac{P - MC}{P}$$

where ε is the absolute value of the price elasticity of demand, P is the market price, and MC is the average marginal cost of production. This is called the Lerner Index. The left side of the equation quantifies market structure, and the right side of the equation measures market performance. The assumed participant behavior is profit maximization. If HHI is very low, implying a more competitive market, prices converge to marginal cost, the competitive market outcome. But even a low HHI may result in substantial markup with a low price elasticity of demand. If HHI is very high, meaning competition is lacking, prices approach the monopoly level. Price elasticity of demand (ε) determines the degree to which suppliers with market power can impose

¹³⁰ See Tirole, Jean. *The Theory of Industrial Organization*, MIT (1988), Chapter 5: Short-Run Price Competition.

higher prices on customers. The Lerner Index is a measure of market power that connects market structure (HHI and demand elasticity) to market performance (markup).

The PJM energy market HHIs and application of the FERC concentration categories may understate the degree of market power because, in the absence of aggregate market power mitigation, even the unconcentrated HHI level would imply substantial markups due to the low short run price elasticity of demand. For example, research estimates find short run electricity demand elasticity ranging from -0.2 to -0.4.¹³¹ Using the Lerner Index, the elasticities imply, for example, an average markup ranging from 25 to 50 percent at the unconcentrated to moderately concentrated threshold HHI of 1000:¹³²

$$\frac{HHI}{\epsilon} = \frac{0.1}{0.2} = \frac{P - MC}{P} = 50\%$$

With knowledge of HHI, elasticity, and marginal cost, one can solve for the price level theoretically indicated by the Lerner Index, based on profit maximizing behavior including the exercise of market power. With marginal costs of \$19.78 per MWh and an average HHI of 706 in the first three months of 2020, average PJM prices would theoretically range from \$24 to \$31 per MWh using the elasticity range of -0.2 to -0.4.¹³³ The theoretical prices exceed marginal costs because the exercise of market power is profit maximizing in the absence of market power mitigation. Actual prices, averaging \$19.85 per MWh, and markups, at 0.4 percent, are lower than the theoretical range, supporting the MMU’s competitive assessment of the market. However, markup is not zero. In some market intervals, markup and prices reach levels that reflect the exercise of market power.

¹³¹ See Patrick, Robert H. and Frank A. Wolak (1997), "Estimating the Customer-Level Demand for Electricity Under Real-Time Market Prices," <https://web.stanford.edu/group/fwolak/cgi-bin/sites/default/files/files/Estimating%20the%20Customer-Level%20Demand%20for%20Electricity%20Under%20Real-Time%20Market%20Prices_Aug%201997_Patrick,%20Wolak.pdf>, last accessed August 3, 2018 and Fan, Shu and Rob Hyndman (2010), "The price elasticity of electricity demand in South Australia," <<https://robjhyndman.com/papers/Elasticity2010.pdf>>.

¹³² The HHI used in the equation is based on market shares. For the FERC HHI thresholds and standard HHI reporting, market shares are multiplied by 100 prior to squaring the market shares.

¹³³ The average HHI is found in Table 3-70. Marginal costs are the sum of all components of LMP except markup, as shown in Table 3-60.

Market Power Mitigation and Markup

Fully effective market power mitigation would not allow a seller that fails the structural market power test (the TPS test) to set prices with a positive markup. With the flaws in PJM’s implementation of the TPS test, resources can and do set prices with a positive markup while failing the TPS test.

Table 3-109 categorizes real-time marginal unit intervals by markup level and TPS test status. In the first three months of 2020, 8.3 percent of marginal unit intervals included a positive markup even though the resource failed the TPS test for local market power. Unmitigated local market power affects PJM market prices. Zero markup with a TPS test failure indicates the mitigation of a marginal unit. The 8.3 percent of marginal unit intervals failing the TPS test with unmitigated positive markup exceeds the 1.7 percent of marginal unit intervals failing the TPS with zero markup. Marginal units with positive markup are mitigated less often than not.

Table 3-109 Percent of real-time marginal unit intervals with markup and local market power: January through March, 2020

Markup Category	Not Failing TPS Test	Failing TPS Test	Percent in Category
Negative Markup	29.9%	5.3%	35.2%
Zero Markup	10.7%	1.7%	12.4%
\$0 to \$5	39.1%	7.5%	46.6%
\$5 to \$10	3.3%	0.5%	3.8%
\$10 to \$15	0.5%	0.1%	0.7%
\$15 to \$20	0.3%	0.0%	0.3%
\$20 to \$25	0.6%	0.0%	0.6%
\$25 to \$50	0.2%	0.0%	0.2%
\$50 to \$75	0.1%	0.0%	0.1%
\$75 to \$100	0.0%	0.0%	0.0%
Above \$100	0.1%	0.0%	0.1%
Total Positive Markup	44.2%	8.3%	52.4%
Total	84.7%	15.3%	100.0%

The markup of marginal units is zero or negative in 47.6 percent of marginal unit intervals in 2020. The flaws in the offer capping process that allow positive markup to affect prices in the presence of market power are a vulnerability to the overall competitiveness of the PJM energy market.