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 in 2016, including market size, concentration, residual supply index, and price.[1] The MMU concludes that the PJM energy market results were competitive in 2016.

Table 3-1 The energy market results were competitive

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

- The aggregate market structure was evaluated as competitive. The hourly HHI (Herfindahl-Hirschman Index) results indicate that by the FERC standards, the PJM Energy Market in 2016 was moderately concentrated. Average HHI was 1024 with a minimum of 786 and a maximum of 1356 in 2016. The fact that the average HHI and the maximum hourly HHI were in the moderately concentrated 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 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 PJM Energy Market peaking segment of supply was highly concentrated.
- The local market structure was evaluated as not competitive due to the highly concentrated ownership of supply in local markets created by transmission constraints. 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 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 mitigated.
- 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 Day-Ahead and Real-Time Energy Markets, although the behavior of some participants both routinely and during periods of high demand is consistent with economic withholding.
- 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 during periods of high demand 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

1 Analysis of 2016 market results requires comparison to prior years. In 2004 and 2005, PJM conducted the phased integration of five control zones: ComEd, American Electric Power (AEP), The Dayton Power & Light Company (DAY), Duquesne Light Company (DLCO) and Dominion. In June 2011, PJM integrated the American Transmission Systems, Inc. (ATSI) Control Zone. In January 2012, PJM integrated the Duke Energy Ohio/Kentucky (DEOK) Control Zone. In June 2013, PJM integrated the Eastern Kentucky Power Cooperative (EKPC). By convention, control zones bear the name of a large utility service provider working within their boundaries. The nomenclature applies to the geographic area, not to any single company. For additional information on the control zones, the integrations, their timing and their impact on the footprint of the PJM service territory, see the *2015 State of the Market Report for PJM*, Appendix A, "PJM Geography."

of UTCs in the Day-Ahead Energy Market continues to cause concerns.

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 primary goals is to identify actual or potential market design flaws.[2] 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.[3] 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 in energy offers that need to be addressed. There are issues related to the level of variable operating and 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. Now that generators will be allowed to modify offers hourly, 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 new rules permitting cost-based offers in excess of $1,000 per MWh.

2 PJM. OATT Attachment M (PJM Market Monitoring Plan).

3 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.

Overview

Market Structure

- **Supply.** Supply includes physical generation and imports and virtual transactions. The maximum of average offered real-time generation increased by 3,957 MW, or 2.4 percent, from 167,343 MW in the summer of 2015 to 171,300 MW in the summer of 2016. In 2016, 5,421.4 MW of new capacity resources were added. In 2016, 395.5 MW were retired.

  PJM average real-time cleared generation in 2016 increased by 2,676 MW, or 3.0 percent, from 2015, from 88,628 MW to 91,304 MW.

  PJM average day-ahead cleared supply in 2016, including INCs and up to congestion transactions, increased by 14.6 percent from 2015, from 114,889 MW to 131,634 MW, primarily as a result of an increase in UTC volumes.

- **Market Concentration.** The PJM Energy Market was moderately concentrated overall with moderate concentration in the baseload and intermediate segments, but high concentration in the peaking segment.

- **Generation Fuel Mix.** In 2016, coal units provided 33.9 percent, nuclear units 34.4 percent and natural gas units 26.5 percent of total generation. Compared to 2015, generation from coal units decreased 3.3 percent, generation from natural gas units increased 18.3 percent and generation from nuclear units increased 0.2 percent.

- **Fuel Diversity.** In 2016, the fuel diversity of energy generation, measured by the fuel diversity index for energy (FDI_e), increased 0.9 percent over the 2015 FDI_e.

- **Marginal Resources.** In the PJM Real-Time Energy Market, in 2016, coal units were 44.9 percent of marginal resources and natural gas units were 43.8 percent of marginal resources. In 2015, coal units were 51.7 percent and natural gas units were 35.5 percent of the marginal resources.

  In the PJM Day-Ahead Energy Market, in 2016, up to congestion transactions were 82.4 percent of marginal resources, INCs were 4.2 percent of marginal resources, DECs were 8.6 percent of marginal resources, and generation resources were 4.7 percent of marginal resources. In 2015, up to congestion transactions were 76.1 percent of marginal resources, INCs were 5.1 percent of marginal resources, DECs were 8.9 percent of marginal resources, and generation resources were 9.6 percent of marginal resources.

- **Demand.** Demand includes physical load and exports and virtual transactions. The PJM metered system peak load during 2016 was 152,177 MW in the HE 1500 on August 11, 2016, which was 8,480 MW, 5.9 percent, higher than the PJM peak load for 2015, which was 143,697 MW in the HE 1600 on July 28, 2015.

  PJM average real-time load in 2016 increased from 2015, from 88,594 MW to 88,601 MW. PJM average day-ahead demand in 2016, including DECs and up to congestion transactions, increased by 14.1 percent in 2015, from 111,644 MW to 127,390 MW.

- **Supply and Demand: Load and Spot Market.** Companies that serve load in PJM can do so using a combination of self-supply, bilateral market purchases and spot market purchases. For 2016, 12.9 percent of real-time load was supplied by bilateral contracts, 23.9 percent by spot market purchases and 63.2 percent by self-supply. Compared with 2015, reliance on bilateral contracts increased by 2.3 percentage points, reliance on spot market purchases decreased by 5.4 percentage points and reliance on self-supply increased by 3.1 percentage points.

- **Supply and Demand: Scarcity.** There were no shortage pricing events in 2016.

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 decreased from 0.2 percent in 2015 to 0.1 percent in 2016. In the Real-Time Energy Market, for units committed to provide energy for local constraint relief, offer-capped unit hours remained at 0.4 percent in 2015 and 2016.

  In 2016, 11 control zones experienced congestion resulting from one or more constraints binding for 100 or more hours. The analysis of the application of the TPS test to local markets demonstrates that it is working successfully 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, specifically for black start service and reactive service. In the Day-Ahead Energy Market, for units committed for reliability reasons, offer-capped unit hours decreased from 0.4 percent in 2015 to 0.04 percent in 2016. In the Real-Time Energy Market, for units committed for reliability reasons, offer-capped unit hours decreased from 0.4 percent in 2015 to 0.1 percent in 2016.

- **Markup Index.** The markup index is a summary measure of participant offer behavior for individual marginal units. In 2016, in the PJM Real-Time Energy Market, 90.1 percent of marginal units had offer prices less than $50 per MWh. The average dollar markups of units with offer prices less than $25 per MWh was negative when using unadjusted cost offers. The average dollar markups of units with offer prices less than $50 per MWh was negative when using unadjusted cost offers. Negative markup means the unit is offering to run at a price less than its cost-based offer, implying a revealed short run marginal cost that is less than the allowable cost-based offer under the PJM Market Rules. Some marginal units did have substantial markups. Using the unadjusted cost offers, the highest markup for any marginal unit in 2016 was $258.16 per MWh while the highest markup in 2015 was $792.21 per MWh.

  In the PJM Day-Ahead Energy Market, when using unadjusted cost offers, in 2016, 89.9 percent of marginal generating units had offer prices less than $50 per MWh and the average dollar markup was negative, and 0.4 percent of marginal generating units had offers in the $75 to $125 per MWh range and the average dollar markup and the average markup index were both negative.

- **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 imply 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.

- **Frequently Mitigated Units (FMU) and Associated Units (AU).** A new FMU rule became effective November 1, 2014, limiting the availability of FMU adders to units with net revenues less than unit going forward costs. 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 since December 2014.

- **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. In 2016, the average hourly increment offers submitted MW increased by 26.0 percent from 7,175 MW in 2015 to 9,043 MW in 2016, and cleared MW increased by 11.4 percent from 4,675 MW in 2015 to 5,207 MW in 2016. In 2016, the average hourly decrement bids submitted MW increased by 25.3 percent from 6,879 MW in 2015 to 8,618 MW in 2016, and cleared MW increased by 18.6 percent from 4,051 MW in 2015 to 4,805 MW in 2016. In 2016, the average hourly up to congestion submitted MW increased by 70.3 percent from 83,422 MW in 2015 to 142,075 MW in 2016, and cleared MW increased by 78.6 percent from 19,255 MW in 2015 to 34,385 MW in 2016.

- **Generator Offers.** Generator offers are categorized as dispatchable and self scheduled. Units which are available for economic dispatch are dispatchable. 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 offers in 2016, 53.7 percent were offered as available for economic dispatch, 4.4 percent were offered as emergency dispatch, 22.3 percent were offered as self scheduled, and 19.6 percent were offered as self scheduled and dispatchable.

Market Performance

- **Prices.** PJM LMPs are a direct measure of market performance. Price level is a good, general indicator of market performance, although the number of factors influencing the overall level of prices means it must be analyzed carefully. Among other things, overall average prices reflect changes in supply and demand, generation fuel mix, the cost of fuel, emissions related expenses, markup and local price differences caused by congestion. PJM also may administratively set prices with the creation of closed loop interfaces related to demand side resources or reactive power, the application of transmission penalty factors, or the application of price setting logic.

  PJM real-time energy market prices decreased in 2016 compared to 2015. The load-weighted average real-time LMP was 19.2 percent lower in 2016 than in 2015, $29.23 per MWh versus $36.16 per MWh. PJM real-time load-weighted energy market prices were lower in 2016 that at any time in PJM history since the beginning of the competitive wholesale market on April 1, 1999.

  PJM day-ahead energy market prices decreased in 2016 compared to 2015. The load-weighted average day-ahead LMP was 19.2 percent lower in 2016 than in 2015, $29.68 per MWh versus $36.73 per MWh. PJM day-ahead load-weighted energy market prices were lower in 2016 that at any time in PJM history since the introduction of the PJM Day-Ahead Energy Market in June 2000.

- **Components of LMP.** In the PJM Real-Time Energy Market, in 2016, 45.4 percent of the load-weighted LMP was the result of coal costs, 27.2 percent was the result of gas costs and 1.89 percent was the result of the cost of emission allowances.

  In the PJM Day-Ahead Energy Market in 2016, 36.4 percent of the load-weighted LMP was the result of the cost of coal, 26.7 percent was the result of DECs, 11.0 percent was the result of the cost of gas, 1.9 percent was the result of INCs, and 2.2 percent was the result of up to congestion transactions.

- **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 2016, the adjusted markup component of LMP was $1.77 per MWh or 6.1 percent of the PJM real-time, load-weighted average LMP. August had the highest adjusted peak markup component, $4.47 per MWh, or 10.24 percent of the real-time peak hour load-weighted average LMP. Using the unadjusted cost offers, the highest markup of a marginal unit in 2016 was $258.16 per MWh. There were 33 hours in 2016 where the positive markup contribution to the PJM system wide, load-weighted, average LMP exceeded $54.51 per MWh.

  In the PJM Day-Ahead Energy Market, INCs, DECs and UTCs have zero markups. In 2016, the adjusted markup component of LMP resulting from generation resources was $0.21 per MWh or 0.7 percent of the PJM day-ahead load-weighted average LMP. August had the highest adjusted peak markup component, $5.65 per MWh or 16.5 percent of the day-ahead load-weighted average LMP.

  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 is consistent with economic withholding.

- **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 -$0.73 per MWh in 2015 and -$0.53 per MWh in 2016. 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 shortage pricing events in 2016.

Recommendations

- The MMU recommends that the market rules should explicitly require that offers into the Day-Ahead 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. (Priority: Medium. First reported 2009. Status: Not adopted.)
- The MMU recommends that PJM require every market participant to make available at least one cost schedule with the same fuel-type and parameters as that of their offered price schedule. (Priority: Medium. First reported 2015. Status: Not adopted.)
- The MMU recommends that PJM require that the level of incremental costs includable in cost offers not exceed the unit's short run marginal cost. (Priority: Medium. New recommendation. Status: Not adopted.)
- The MMU recommends that PJM require that all fuel cost policies be algorithmic, verifiable, and systematic. (Priority: Medium. New recommendation. Status: Not adopted.)
- The MMU recommends that Manual 15 be replaced with a straightforward description of the components of cost offers based on short run marginal costs and the correct calculation of cost offers. (Priority: Medium. New recommendation. Status: Not adopted.)
- The MMU recommends removal of all use of the FERC System of Accounts in the Cost Development Guidelines. (Priority: Medium. New recommendation. Status: Not adopted.)
- The MMU recommends the removal of all use of cyclic starting and peaking factors from the Cost Development Guidelines. (Priority: Medium. New recommendation. Status: Not adopted.)
- The MMU recommends the removal of all labor costs from the Cost Development Guidelines. (Priority: Medium. New recommendation. Status: Not adopted.)

- 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. (Priority: Medium. New recommendation. 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. New recommendation. Status: Not adopted.)
- The MMU recommends revising the pumped hydro fuel cost calculation to include day-ahead and real-time power purchases. (Priority: Medium. New recommendation. 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. New recommendation. Status: Not adopted.)
- The MMU recommends removing the catastrophic designation for force majeure fuel supply limitations in Schedule 2. (Priority: Medium. New recommendation. Status: Not adopted.)
- The MMU recommends that the rules governing the application of the TPS test be clarified and documented. (Priority: High. First reported 2010. 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 offers, that there be at least one cost-based offer using the same fuel as the available price-based offer. (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, 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. (Priority: High. First reported 2015. Status: Not adopted.)
- 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 under the capacity performance construct, PJM recognize the difference between operational parameters that indicate to PJM dispatchers what a unit is capable of during the operating day and the parameters that are used for capacity performance assessment as well as uplift payments. The parameters which determine nonperformance charges and the amount of uplift payments to those generators should reflect the flexibility goals of the capacity performance construct. (Priority: Medium. First reported 2015. 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.)
- The MMU recommends that PJM not allow nuclear generators which do not respond to prices or which only respond to manual instructions from the dispatcher to set the LMPs in the real-time market. (Priority: Low. New recommendation. Status: Not adopted.)
- The MMU recommends that PJM document how LMPs are calculated when demand response is marginal. The LMPs in excess of $1,800 per MWh on January 7, 2014, were potentially a result of the way in which PJM modeled zonal (not nodal) demand response as a marginal resource. (Priority: Low. First reported 2014. 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: Not adopted.)

- The MMU recommends that the definition of maximum emergency status in the tariff apply at all times rather than just during maximum emergency events.[4] (Priority: Medium. First reported 2012. Status: Not 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 the roles of PJM and the transmission owners in the decision making process to control for local contingencies be clarified, that PJM's role be strengthened and that the process be made transparent. (Priority: Low. First reported 2013. Status: Not adopted.)
- The MMU recommends that PJM include in the 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.[5] There is currently no PJM documentation in the tariff or manuals explaining how hubs are created and how their definitions are changed.[6] (Priority: Low. First reported 2013. Status: Not adopted.)
- 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 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. (Priority: Low. First reported 2013. Status: Not adopted.)
- The MMU recommends that PJM 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: Partially 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 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 continue to enhance its posting of market data to promote market efficiency. (Priority: Medium. First reported 2005. Status: Partially adopted.)
- 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 PJM require all generating units to identify the fuel type associated with each of their offered schedules. (Priority: Low. First reported 2014. Status: Adopted in full, 2014.)

Conclusion

The MMU analyzed key elements of PJM energy market structure, participant conduct and market performance in 2016, including aggregate supply and demand, concentration ratios, three pivotal supplier test results, offer capping, participation in demand response programs, loads and prices.

Average PJM real-time cleared generation increased by 2,676 MW, 3.0 percent, and peak load increased by 8,480 MW, 5.9 percent, in 2016 compared to

4 PJM. OATT Section: 6A.1.3 Maximum Emergency, (February 25, 2014), p. 1740, 1795.

5 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.

6 The general definition of a hub can be found in the PJM.com Glossary <http://www.pjm.com/Glossary.aspx>.

2015. Market concentration levels remained moderate although there is high concentration in the peaking segment of the supply curve which adds to concerns about market power when market conditions are tight. 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. While the market structure does not guarantee competitive outcomes, overall the market structure of the PJM aggregate energy market remains reasonably competitive for most hours although aggregate market power does exist during high demand hours. Low average aggregate concentration does not mean that market power cannot be exercised. It is possible that market power can be exercised at times when individual suppliers or small groups of suppliers are pivotal even when the HHI level does not indicate that the market is highly concentrated. High markups for some units demonstrate the potential to exercise market power during high demand conditions.

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 of the most expensive unit required to serve load in each hour. 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 2016 generally reflected supply-demand fundamentals, although the behavior of some participants during high demand periods is consistent with 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 take an outage.

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.[7] This is a flexible, targeted real-time measure of market structure which replaced the offer capping of all units required to relieve a constraint. A generation owner or group of generation owners is pivotal for a local market if the output of the owners' generation facilities is required in order to relieve a transmission constraint. When a generation owner or group of owners is pivotal, it has the ability to increase the market price above the competitive level. The three pivotal supplier test explicitly incorporates the impact of excess supply and implicitly accounts for the impact of the price elasticity of demand in the market power tests. The result of the introduction of the three pivotal supplier test was to limit offer capping to times when the local market structure was noncompetitive and specific owners had structural market power. The analysis of the application of the three pivotal supplier test demonstrates that it is working for most hours to exempt owners when the local market structure is competitive and to require offer capping of owners when the local market structure is noncompetitive.

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. 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 have the ability to avoid 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 requiring that markup be constant across price and cost offers, that there be at least one cost-based offer using the same fuel as the available price-based offer, that the price-MW pairs in the price-based PLS offer be exactly equal to the price-based non-PLS offer, and requiring cost-based and price-based PLS offers to be at least as flexible as price-based non-PLS offers.

Another issue 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 is related to the definition of a competitive

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

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, as interpreted by PJM, is not currently 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.

PJM also offer caps units that are committed for reliability reasons in addition to units committed to provide constraint relief. Specifically, units that are committed to provide reactive support and black start service are offer capped in the energy market. These units are committed manually in both the Day-Ahead and Real-Time Energy Markets.

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 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 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. The PJM Capacity Market is explicitly designed to provide revenue adequacy and the resultant reliability. Nonetheless, with a market design that includes a direct and explicit scarcity pricing net revenue true up mechanism, scarcity pricing can be a mechanism to appropriately increase reliance on the energy market as a source of revenues and incentives in a competitive market without reliance on the exercise of market power. PJM implemented scarcity pricing rules in 2012. There are significant issues with the scarcity pricing net revenue true up mechanism in the PJM scarcity pricing design, which will create issues when scarcity pricing occurs. 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 2014, 2015 or 2016. This is evidence of generally competitive behavior and competitive market outcomes, although the behavior of some participants during the high demand periods is consistent with economic withholding. Given the structure of the energy market which can permit the exercise of aggregate market power at times of high demand, the tighter market conditions and the change in some participants' behavior are sources of concern in the energy market and provide a reason to use cost as the sole basis for hourly changes in offers or offers greater than $1,000 per MWh. The MMU concludes that the PJM energy market results were competitive in 2016.

Market Structure

Market Concentration

Analysis of supply curve segments of the PJM Energy Market in 2016 indicates moderate concentration in the base load and intermediate segments, but high concentration in the peaking segment.[8] High concentration levels, particularly in the peaking segment, increase the probability that a generation owner will be pivotal in the aggregate market during high demand periods. The fact that the average HHI and the maximum hourly HHI were in the moderately concentrated 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 highly concentrated. It is possible to have an exercise of market power even when the HHI level does not indicate highly concentrated.

8 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.

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 2016, 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 to short run marginal costs.

The concentration ratio used here is the Herfindahl-Hirschman Index (HHI), calculated by summing the squares of the market shares of all firms in a market. Hourly PJM energy market HHIs were calculated based on the real-time energy output of generators, adjusted for hourly net imports by owner (Table 3-2).

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 is an indication of such 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 were also calculated for baseload, intermediate and peaking segments of generation supply. Hourly energy market HHIs by supply curve segment were calculated based on hourly energy market shares, unadjusted for imports.

The "Merger Policy Statement" of the 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.[9]

PJM HHI Results

Calculations for hourly HHI indicate that by the FERC standards, the PJM Energy Market during 2016 was moderately concentrated (Table 3-2).

Table 3-2 PJM hourly energy market HHI: 2015 and 2016[10]

	Hourly Market HHI (2015)	Hourly Market HHI (2016)
Average	1096	1024
Minimum	879	786
Maximum	1468	1356
Highest market share (One hour)	31%	28%
Average of the highest hourly market share	21%	20%
# Hours	8,760	8,784
# Hours HHI > 1800	0	0
% Hours HHI > 1800	0%	0%

Table 3-3 includes HHI values by supply curve segment, including base, intermediate and peaking plants for 2015 and 2016. The PJM Energy Market was moderately concentrated overall with moderate concentration in the baseload and intermediate segments, but high concentration in the peaking segment.

Table 3-3 PJM hourly energy market HHI (By supply segment): 2015 and 2016

	2015			2016		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Base	988	1132	1487	945	1106	1428
Intermediate	603	1863	6375	578	1371	5029
Peak	716	5728	10000	684	5620	10000

Figure 3-1 shows the total installed capacity (ICAP) MW of units in the baseload, intermediate and peaking segments by fuel source in 2016.

9 77 FERC ¶ 61,263, pp. 64-70 (1996), "*Inquiry Concerning the Commission's Merger Policy under the Federal Power Act: Policy Statement.*"

10 This analysis includes all hours in 2015 and 2016, regardless of congestion.

Figure 3-1 Fuel source distribution in unit segments: 2016[11]

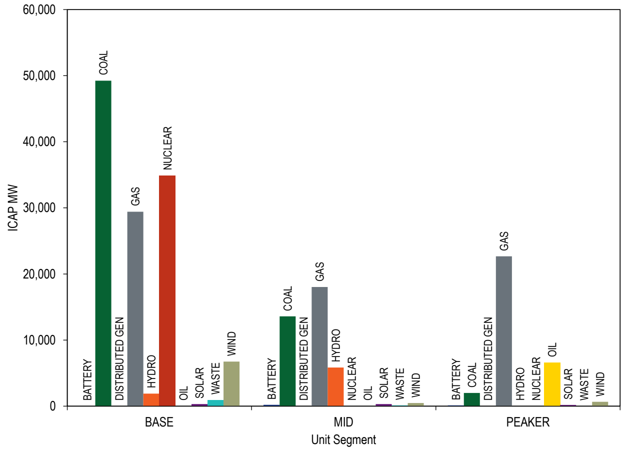
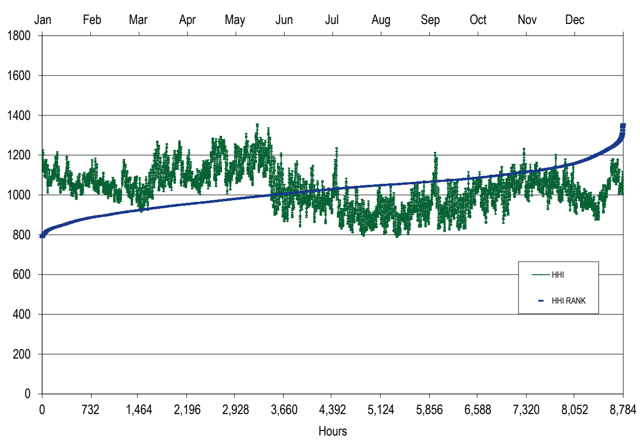


Figure 3-2 presents the hourly HHI values in chronological order and an HHI duration curve for 2016.

Figure 3-2 PJM hourly energy market HHI: 2016



Ownership of Marginal Resources

Table 3-4 shows the contribution to real-time, load-weighted LMP by individual marginal resource owner.[12] The contribution of each marginal resource to price at each load bus is calculated for each five-minute interval of 2016, and summed by the parent company that offers the marginal resource into the Real-Time Energy Market. In 2016, the offers of one company resulted in 21.9 percent of the real-time, load-weighted PJM system LMP and that the offers of the top four companies resulted in 58.8 percent of the real-time, load-weighted, average PJM system LMP. During 2015, the offers of one company resulted in 19 percent of the real time, load-weighted PJM system LMP and offers of the top four companies resulted in 55.2 percent of the real-time, load-weighted, average PJM system LMP. In 2016, the offers of one company resulted in 20.0 percent of the peak hour real-time, load weighted PJM system LMP. In 2015, the offers of one company resulted in 16.7 percent of the peak hour, real-time, load weighted PJM system LMP.

11 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) Action on Proposed Manual 28 Revisions," (July 26, 2012) <http://www.pjm.com/~/media/committees-groups/committees/mrc/20120726/20120726-item-04-nemstf-report-and-proposed-manual-revisions.ashx>.

12 See the *MMU Technical Reference for PJM Markets*, at "Calculation and Use of Generator Sensitivity/Unit Participation Factors."

Table 3-4 Marginal unit contribution to PJM real-time, load-weighted LMP (By parent company): 2015 and 2016

2015						2016					
All Hours			Peak Hours			All Hours			Peak Hours		
Company	Percent of Price	Cumulative Percent	Company	Percent of Price	Cumulative Percent	Company	Percent of Price	Cumulative Percent	Company	Percent of Price	Cumulative Percent
1	19.0%	19.0%	1	16.7%	16.7%	1	21.9%	21.9%	1	20.0%	20.0%
2	15.6%	34.5%	2	15.1%	31.8%	2	14.9%	36.9%	2	16.0%	36.0%
3	10.9%	45.5%	3	10.2%	42.0%	3	12.1%	48.9%	3	10.6%	46.6%
4	9.8%	55.2%	4	9.5%	51.5%	4	9.9%	58.8%	4	8.7%	55.3%
5	8.7%	63.9%	5	9.5%	61.0%	5	7.5%	66.3%	5	7.7%	63.0%
6	8.5%	72.4%	6	9.1%	70.1%	6	5.5%	71.8%	6	4.8%	67.8%
7	4.4%	76.8%	7	4.9%	75.0%	7	2.6%	74.5%	7	3.5%	71.3%
8	4.0%	80.7%	8	4.4%	79.4%	8	2.2%	76.7%	8	2.6%	73.9%
9	2.6%	83.4%	9	2.6%	82.0%	9	2.1%	78.8%	9	2.4%	76.3%
Other (59 companies)	16.6%	100.0%	Other (56 companies)	18.0%	100.0%	Other (72 companies)	21.2%	100.0%	Other (64 companies)	23.7%	100.0%

Table 3-5 shows the contribution to day-ahead, load-weighted LMP by individual marginal resource owners.[13] 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 2016, the offers of one company contributed 22.0 percent of the day-ahead, load-weighted PJM system LMP and that the offers of the top four companies contributed 50.4 percent of the day-ahead, load-weighted, average PJM system LMP. In 2015, the offers of one company contributed 12.5 percent of the day-ahead, load-weighted PJM system LMP and offers of the top four companies contributed 39.6 percent of the day-ahead, load-weighted, average PJM system LMP.

Table 3-5 Marginal resource contribution to PJM day-ahead, load-weighted LMP (By parent company): 2015 and 2016

2015						2016					
All Hours			Peak Hours			All Hours			Peak Hours		
Company	Percent of Price	Culmulative Percent	Company	Percent of Price	Culmulative Percent	Company	Percent of Price	Culmulative Percent	Company	Percent of Price	Culmulative Percent
1	12.5%	12.5%	1	11.6%	11.6%	1	22.0%	22.0%	1	36.0%	36.0%
2	11.3%	23.7%	2	10.9%	10.9%	2	13.4%	35.5%	2	10.9%	46.9%
3	10.0%	33.7%	3	9.7%	9.7%	3	7.6%	43.0%	3	9.4%	56.3%
4	5.9%	39.6%	4	6.6%	6.6%	4	7.4%	50.4%	4	9.3%	65.6%
5	5.4%	45.0%	5	4.9%	4.9%	5	6.8%	57.3%	5	7.0%	72.6%
6	5.1%	50.1%	6	4.7%	4.7%	6	5.8%	63.0%	6	5.2%	77.8%
7	4.0%	54.2%	7	3.8%	3.8%	7	4.4%	67.5%	7	5.0%	82.8%
8	3.7%	57.8%	8	3.8%	3.8%	8	4.3%	71.7%	8	3.3%	86.1%
9	3.6%	61.4%	9	3.6%	3.6%	9	3.0%	74.8%	9	3.2%	89.3%
Other (153 companies)	38.6%	100.0%	Other (148 companies)	40.4%	40.4%	Other (170 companies)	25.2%	100.0%	Other (162 companies)	10.7%	100.0%

Type 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 3-6 shows the type of fuel used 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 2016, coal units were 44.9 percent and natural gas units were 43.9 percent of marginal resources. In 2015, coal units were 51.7 percent and natural gas units were 35.5 percent of the total marginal resources. In 2016, 86.6 percent of the wind marginal units had negative offer prices, 11.2 percent had zero offer prices and 2.1 percent had positive offer prices.

13 See the *MMU Technical Reference for PJM Markets*, at "Calculation and Use of Generator Sensitivity/Unit Participation Factors."

The results reflect the dynamics of an LMP market. When there is a single constraint, there are two marginal units. For example, a significant west to east constraint could be binding with a gas unit marginal in the east and a coal unit marginal in the west. As a result, although the dispatch of natural gas units has increased and gas units set price for more hours as marginal resources in the Real-Time Energy Market, this does not necessarily reduce the proportion of hours in which coal units are marginal.[14]

The proportion of marginal nuclear units increased from 0.03 percent in 2015 to 1.03 percent in 2016. The increase was primarily due to a small number of nuclear units offering with a dispatchable range. Most nuclear units are offered as fixed generation in the PJM market. The dispatchable nuclear units do not always respond to dispatch instructions.

Table 3-6 Type of fuel used (By real-time marginal units): 2012 through 2016

	Year				
Type/Fuel	2012	2013	2014	2015	2016
Coal	58.84%	56.94%	52.90%	51.74%	44.90%
Gas	30.35%	34.72%	35.80%	35.52%	43.86%
Oil	6.00%	3.27%	7.45%	8.99%	7.08%
Wind	4.19%	4.76%	3.29%	3.27%	2.98%
Uranium	0.02%	0.02%	0.04%	0.03%	1.03%
Other	0.47%	0.20%	0.43%	0.39%	0.14%
Municipal Waste	0.13%	0.07%	0.05%	0.06%	0.01%
Emergency DR	0.00%	0.02%	0.04%	0.00%	0.00%

Figure 3-3 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 3-3 Type of fuel used (By real-time marginal units): 2004 through 2016

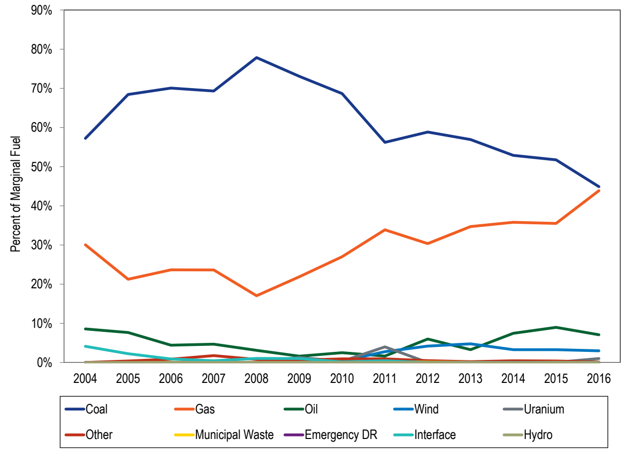


Table 3-7 shows the type and fuel type where relevant, of marginal resources in the Day-Ahead Energy Market. In 2016, up to congestion transactions were 82.38 percent of marginal resources. Up to congestion transactions were 76.14 percent of marginal resources in 2015.

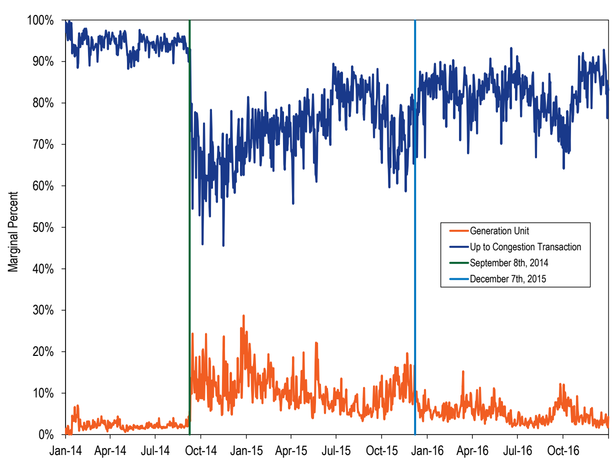
14 Prior to April 1, 2015, for the generation units that are capable of using multiple fuel types, PJM did not require the participants to disclose the fuel type associated with their offer schedule. For these units, the cleared offer schedules on a given day were compared to the cost associated with each fuel to determine the fuel type most likely to have been the basis for the cleared schedule.

Table 3-7 Day-ahead marginal resources by type/fuel: 2011 through 2016

Type/Fuel	2011	2012	2013	2014	2015	2016
Up to Congestion Transaction	73.40%	88.40%	96.44%	91.05%	76.14%	82.38%
DEC	12.38%	4.30%	1.27%	3.28%	8.87%	8.64%
INC	7.54%	3.81%	1.05%	2.28%	5.08%	4.18%
Coal	4.66%	2.31%	0.78%	2.03%	5.50%	2.14%
Gas	1.54%	1.04%	0.36%	1.16%	3.31%	1.99%
Oil	0.00%	0.00%	0.00%	0.05%	0.56%	0.42%
Uranium	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%
Wind	0.07%	0.03%	0.04%	0.05%	0.12%	0.06%
Dispatchable Transaction	0.17%	0.07%	0.05%	0.08%	0.26%	0.05%
Municipal Waste	0.01%	0.01%	0.00%	0.01%	0.01%	0.01%
Price Sensitive Demand	0.23%	0.04%	0.01%	0.01%	0.02%	0.00%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Figure 3-4 shows, for the Day-Ahead Market from January 1, 2014, through December 31, 2016, the daily proportion of marginal resources that were up to congestion transaction and/or generation units. The percent of marginal up to congestion transactions decreased significantly beginning on September 8, 2014, as a result of the FERC's UTC uplift refund notice which became effective on that date.[15] The percent of marginal up to congestion transaction decreased and that of generation units increased. That trend has begun to reverse as a result of the expiration of the fifteen month uplift refund period for UTC transactions.

Figure 3-4 Day-ahead marginal up to congestion transaction and generation units: 2014 through 2016

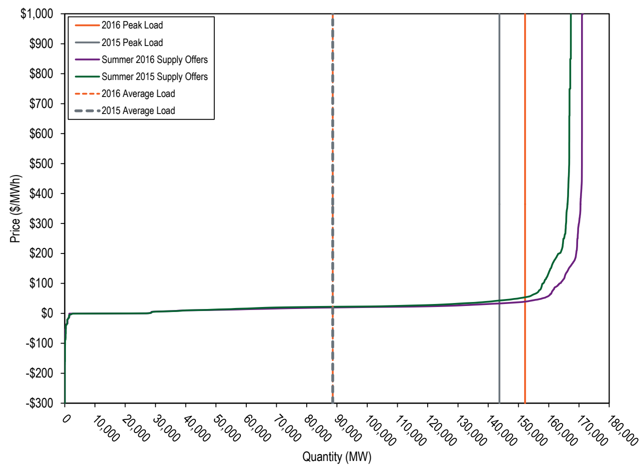


Supply

Supply includes physical generation and imports and virtual transactions.

Figure 3-5 shows the average PJM aggregate real-time generation supply curves by offer price, peak load and average load for the summer of 2015 and 2016. The maximum of average offered real-time generation increased by 3,957 MW, or 2.4 percent, from 167,343 MW in the summer of 2015 to 171,300 MW in the summer of 2016.

Figure 3-5 Average PJM aggregate real-time generation supply curves by offer price: summer of 2015 and 2016



Energy Production by Fuel Source

Table 3-8 shows PJM generation by fuel source in GWh for 2015 and 2016. In 2016, generation from coal units decreased 3.3 percent and generation from natural gas units increased 18.8 percent compared to 2015.[16]

15 See 18 CFR § 385.213 (2014).

16 Generation data are the sum of MWh for each fuel by source at every generation bus in PJM with positive output and reflect gross generation without offset for station use of any kind.

Table 3-8 PJM generation (By fuel source (GWh)): 2015 and 2016[17 18]

	2015		2016		Change in
	GWh	Percent	GWh	Percent	Output
Coal	284,757.4	36.2%	275,281.7	33.9%	(3.3%)
Bituminous	257,700.0	32.8%	241,050.2	29.7%	(6.5%)
Sub Bituminous	22,528.7	2.9%	28,949.7	3.6%	28.5%
Other Coal	4,528.6	0.6%	5,281.7	0.7%	16.6%
Nuclear	279,106.5	35.5%	279,546.4	34.4%	0.2%
Gas	183,650.7	23.3%	217,214.5	26.7%	18.3%
Natural Gas	180,948.7	23.0%	215,022.4	26.5%	18.8%
Landfill Gas	2,275.8	0.3%	2,176.2	0.3%	(4.4%)
Other Gas	426.3	0.1%	15.9	0.0%	(96.3%)
Hydroelectric	13,067.2	1.7%	13,686.8	1.7%	4.7%
Pumped Storage	4,660.2	0.6%	4,840.2	0.6%	3.9%
Run of River	6,736.3	0.9%	7,332.8	0.9%	8.9%
Other Hydro	1,670.8	0.2%	1,513.8	0.2%	(9.4%)
Wind	16,609.7	2.1%	17,716.0	2.2%	6.7%
Waste	4,365.1	0.6%	4,139.8	0.5%	(5.2%)
Solid Waste	4,175.4	0.5%	4,139.8	0.5%	(0.9%)
Miscellaneous	189.7	0.0%	0.0	0.0%	(100%)
Oil	3,276.2	0.4%	2,163.6	0.3%	(34.0%)
Heavy Oil	622.9	0.1%	270.6	0.0%	(56.6%)
Light Oil	1,122.0	0.1%	341.1	0.0%	(69.6%)
Diesel	163.8	0.0%	59.4	0.0%	(63.7%)
Gasoline	0.0	0.0%	0.0	0.0%	NA
Kerosene	413.0	0.1%	74.8	0.0%	(81.9%)
Jet Oil	0.0	0.0%	0.0	0.0%	NA
Other Oil	954.5	0.1%	1,417.7	0.2%	48.5%
Solar, Net Energy Metering	548.4	0.1%	1,019.4	0.1%	85.9%
Energy Storage	7.6	0.0%	15.7	0.0%	106.7%
Battery	7.6	0.0%	15.7	0.0%	106.7%
Compressed Air	0.0	0.0%	0.0	0.0%	NA
Biofuel	1,309.6	0.2%	1,760.3	0.2%	34.4%
Geothermal	0.0	0.0%	0.0	0.0%	NA
Other Fuel Type	0.0	0.0%	0.0	0.0%	NA
Total	786,698.5	100.0%	812,544.1	100.0%	3.3%

17 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, or power to run pumped storage pumps.

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

Table 3-9 Monthly PJM generation (By fuel source (GWh)): 2016

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Coal	25,328.3	21,848.4	15,326.5	17,832.4	17,160.0	25,275.1	30,485.4	30,935.7	24,840.8	19,955.1	18,363.5	27,930.4	275,281.7
Bituminous	22,444.6	19,659.8	13,958.0	15,568.4	15,706.1	21,748.2	26,378.3	26,653.9	21,741.7	17,207.8	15,860.3	24,123.1	241,050.2
Sub Bituminous	2,366.8	1,723.9	998.4	1,909.9	1,125.9	3,082.2	3,535.5	3,713.3	2,663.8	2,424.1	2,122.3	3,283.7	28,949.8
Other Coal	516.9	464.8	370.1	354.1	328.0	444.7	571.6	568.5	435.3	323.2	380.9	523.6	5,281.8
Nuclear	25,876.0	22,914.1	22,788.2	21,022.7	23,790.7	22,579.5	23,324.2	24,804.7	22,793.1	21,577.2	23,065.1	25,010.8	279,546.4
Gas	16,134.0	15,639.3	17,215.8	13,748.5	15,022.1	20,441.7	25,681.8	25,858.0	19,752.7	16,206.2	15,867.0	15,647.3	217,214.5
Natural Gas	15,950.9	15,468.1	17,034.7	13,572.8	14,852.5	20,267.1	25,498.9	25,671.8	19,573.3	16,025.4	15,674.8	15,432.1	215,022.4
Landfill Gas	183.1	171.2	181.1	175.7	169.6	174.7	182.6	186.2	179.5	180.5	192.2	200.0	2,176.2
Other Gas	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.0	15.2	15.9
Hydroelectric	1,456.2	1,422.0	1,278.6	1,071.6	1,269.7	1,178.0	1,146.0	1,240.5	867.4	942.7	740.5	1,073.6	13,686.8
Pumped Storage	358.6	304.3	322.8	298.7	310.8	537.5	581.7	644.8	503.0	348.6	276.3	353.1	4,840.2
Run of River	987.5	1,014.2	859.7	666.1	851.4	465.2	362.4	368.3	207.6	506.7	408.8	635.1	7,332.8
Other Hydro	110.2	103.4	96.1	106.7	107.6	175.4	202.0	227.4	156.9	87.4	55.5	85.4	1,513.8
Wind	2,095.6	1,925.5	1,781.6	1,588.0	1,230.6	1,029.1	691.7	603.5	1,017.7	1,647.4	1,851.4	2,254.1	17,716.0
Waste	344.8	297.0	337.5	344.3	366.7	366.0	349.9	361.0	321.6	336.1	353.0	361.6	4,139.8
Solid Waste	344.8	297.0	337.5	344.3	366.7	366.0	349.9	361.0	321.6	336.1	353.0	361.6	4,139.8
Miscellaneous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil	226.6	228.6	161.9	125.6	168.9	198.0	244.4	246.4	152.1	143.7	115.5	151.8	2,163.6
Heavy Oil	91.4	45.3	1.0	0.0	0.0	30.3	45.8	40.2	2.0	2.4	2.8	9.4	270.7
Light Oil	88.1	23.2	30.7	22.7	27.7	7.8	34.8	34.0	29.2	20.6	8.0	14.3	341.1
Diesel	11.6	13.6	1.3	0.7	3.3	1.8	6.1	9.8	2.0	0.2	0.6	8.5	59.4
Gasoline	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kerosene	8.3	57.1	0.0	0.4	0.4	0.6	0.5	0.5	0.6	0.1	0.2	6.1	74.8
Jet Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Oil	27.2	89.4	128.9	101.8	137.5	157.5	157.2	161.8	118.4	120.5	104.0	113.5	1,417.7
Solar, Net Energy Metering	45.6	50.4	85.2	98.5	89.7	114.9	114.9	114.2	85.8	82.2	79.7	58.2	1,019.4
Energy Storage	1.3	1.5	1.4	1.4	1.2	1.3	1.3	1.5	1.2	1.2	1.2	1.3	15.7
Battery	1.3	1.5	1.4	1.4	1.2	1.3	1.3	1.5	1.2	1.2	1.2	1.3	15.7
Compressed Air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biofuel	182.9	166.7	167.4	109.5	96.2	149.0	181.6	188.1	173.0	91.2	91.1	163.6	1,760.3
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Fuel Type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	71,691.4	64,493.4	59,144.2	55,942.4	59,195.8	71,332.7	82,221.4	84,353.5	70,005.5	60,982.9	60,528.1	72,652.9	812,544.1

Figure 3-6 shows the fuel diversity index (FDI_e) for PJM energy generation.[19]

The FDI_e 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_e is zero, corresponding to all generation from a single fuel type. The maximum possible value for the FDI_e is achieved 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_e are the ten primary fuel sources in Table 3-8 with nonzero generation values. The FDI_e exhibits seasonality with most of the peaks occurring in the spring and summer months, and the valleys occurring in the fall and winter months. A significant drop in the FDI_e occurred in 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.[20] The increasing trend that begins in 2008 corresponds with a period of decreasing coal generation and increasing gas generation. Coal generation as a share of total generation dropped 20.5 percentage points from 2008 to 2016, and gas generation as a share of total generation increased 19.3 percentage points. Wind generation, at 2.2 percent of total generation in 2016, also contributes to the rising trend. The FDI_e increased on average 0.0061 (0.9 percent) from 2015 to 2016.

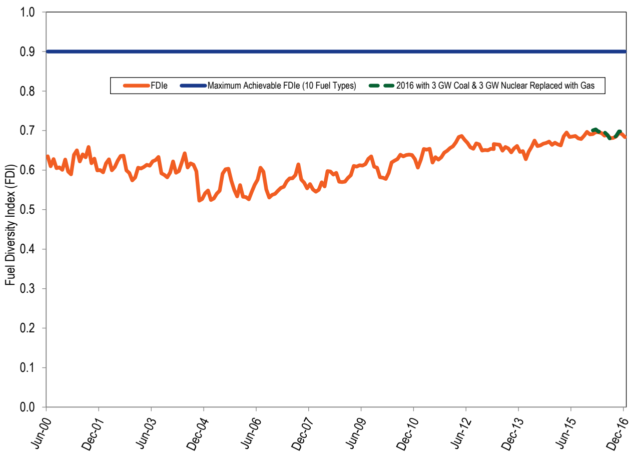
The FDI_e was used to measure the impact of potential retirements of coal and nuclear generators. The dotted line in Figure 3-6 shows the FDI_e calculated assuming that 3,000 MW of coal generation and 3,000 MW of nuclear generation were replaced by gas generation in 2016. The FDI_e under the coal and nuclear retirement

19 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.

20 See the *2016 State of the Market Report for PJM*, Volume II, 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.

assumptions would have increased in nine of twelve months. The coal and nuclear retirements would have increased the FDI_e by 0.6 percent over the actual 2016 FDI_e.

Figure 3-6 Fuel diversity index for PJM monthly generation: 2000 through 2016



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 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.

Real-Time Supply

The maximum of average offered real-time generation increased by 3,957 MW, or 2.4 percent, from 167,343 MW in the summer months of 2015 to 171,300 MW in the summer months 2016.[21]

In 2016, 5,421.4 MW of new capacity resources were added. In 2016, 395.5 MW were retired.

PJM average real-time cleared generation in 2016 increased by 3.0 percent from 2015, from 88,628 MW to 91,304 MW.[22]

PJM average real-time cleared supply including imports increased by 0.8 percent in 2016 from 2015, from 94,329 MW to 95,054 MW.

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 MWh, 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 MWh 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.

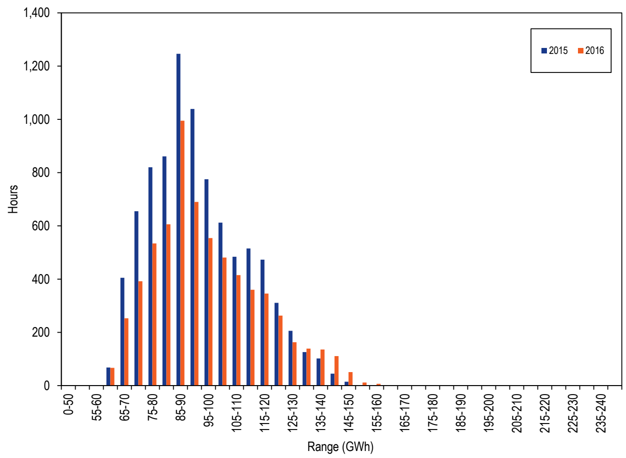
PJM Real-Time Supply Duration

Figure 3-7 shows the hourly distribution of PJM real-time generation plus imports for 2015 and 2016.

21 Calculated values shown in Section 3, "Energy Market," are based on unrounded, underlying data and may differ from calculations based on the rounded values shown in tables.

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

Figure 3-7 Distribution of PJM real-time generation plus imports: January through December, 2015 and 2016[23]



PJM Real-Time, Average Supply

Table 3-10 presents summary real-time supply statistics for each year for the 17-year period from 2000 through 2016.[24]

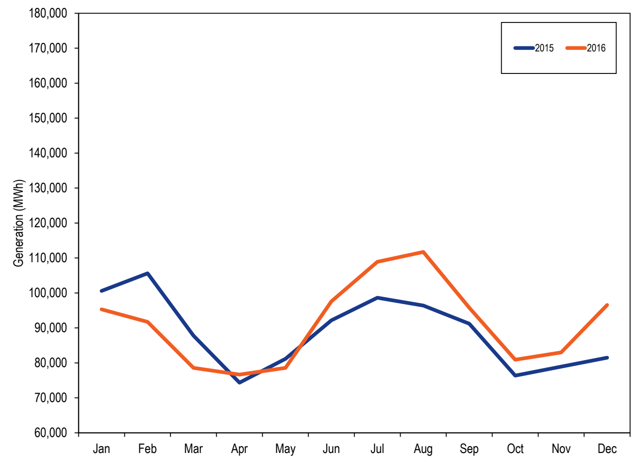
Table 3-10 PJM real-time average hourly generation and real-time average hourly generation plus average hourly imports: 2000 through 2016

	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
2000	30,301	4,980	33,256	5,456	NA	NA	NA	NA
2001	29,553	4,937	32,552	5,285	(2.5%)	(0.9%)	(2.1%)	(3.1%)
2002	34,928	7,535	38,535	7,751	18.2%	52.6%	18.4%	46.7%
2003	36,628	6,165	40,205	6,162	4.9%	(18.2%)	4.3%	(20.5%)
2004	51,068	13,790	55,781	14,652	39.4%	123.7%	38.7%	137.8%
2005	81,127	15,452	86,353	15,981	58.9%	12.0%	54.8%	9.1%
2006	82,780	13,709	86,978	14,402	2.0%	(11.3%)	0.7%	(9.9%)
2007	85,860	14,018	90,351	14,763	3.7%	2.3%	3.9%	2.5%
2008	83,476	13,787	88,899	14,256	(2.8%)	(1.7%)	(1.6%)	(3.4%)
2009	78,026	13,647	83,058	14,140	(6.5%)	(1.0%)	(6.6%)	(0.8%)
2010	82,585	15,556	87,386	16,227	5.8%	14.0%	5.2%	14.8%
2011	85,775	15,932	90,511	16,759	3.9%	2.4%	3.6%	3.3%
2012	88,708	15,701	94,083	16,505	3.4%	(1.4%)	3.9%	(1.5%)
2013	89,769	15,012	94,833	15,878	1.2%	(4.4%)	0.8%	(3.8%)
2014	90,894	15,151	96,295	16,199	1.3%	0.9%	1.5%	2.0%
2015	88,628	16,118	94,329	17,312	(2.5%)	6.4%	(2.0%)	6.9%
2016	91,304	17,731	95,054	17,979	3.0%	10.0%	0.8%	3.9%

PJM Real-Time, Monthly Average Generation

Figure 3-8 compares the real-time, monthly average hourly generation in 2016 to 2015.

Figure 3-8 PJM real-time average monthly hourly generation: 2015 through 2016



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

24 The import data in this table is not available before June 1, 2000. The data that includes imports in 2000 is calculated from the last six months of that year.

Day-Ahead Supply

PJM average day-ahead supply in 2016, including INCs and up to congestion transactions, increased by 14.6 percent from 2015, from 114,889 MW to 131,634 MW.

PJM average day-ahead supply in 2016, including INCs, up to congestion transactions, and imports, increased by 13.8 percent from 2015, from 117,146 MW to 133,262 MW. The increase in PJM day-ahead supply was a result of an increase in UTCs beginning in December 2015 based on a FERC order setting December 8, 2015, as the last effective date for any uplift charges subsequently assigned to UTCs.[25]

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

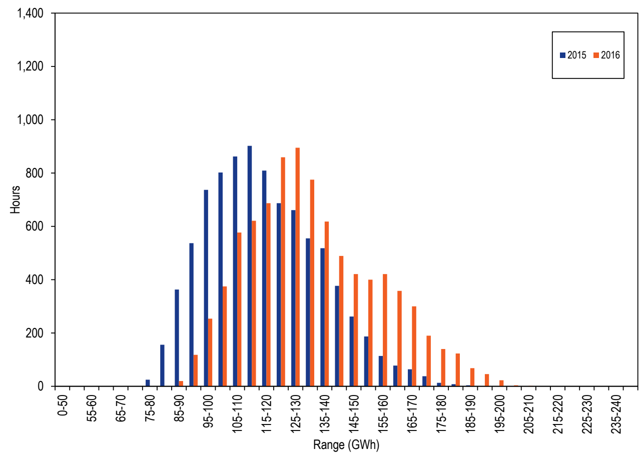
- **Self-Scheduled Generation Offer.** Offer to supply a fixed block of MWh, as a price taker, from a unit that may also have a dispatchable component above the minimum.
- **Dispatchable Generation Offer.** Offer to supply a schedule of MWh and corresponding offer prices from a unit.
- **Increment Offer (INC).** Financial offer to supply MWh 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 between the transaction source and sink. An up to congestion transaction is evaluated as a matched pair of an injection and a withdrawal analogous to a matched pair of an INC offer and a DEC bid.
- **Import.** An import is an external energy transaction 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.

25 148 FERC ¶ 61,144 (2014).

PJM Day-Ahead Supply Duration

Figure 3-9 shows the hourly distribution of PJM day-ahead supply, including increment offers, up to congestion transactions, and imports for 2015 and 2016. There was an increase in up to congestion volume, which resulted in an increase in day-ahead supply, as a result of the expiration of the fifteen month potential refund period for uplift charges for UTC transactions on December 7, 2015.

Figure 3-9 Distribution of PJM day-ahead supply plus imports: 2015 and 2016[26]



PJM Day-Ahead, Average Supply

Table 3-11 presents summary day-ahead supply statistics for each year of the 17-year period from 2000 through 2016.[27]

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

27 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 six months of that year.

Table 3-11 PJM day-ahead average hourly supply and day-ahead average hourly supply plus average hourly imports: 2000 through 2016

	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
2000	27,135	4,858	27,589	4,895	NA	NA	NA	NA
2001	26,762	4,595	27,497	4,664	(1.4%)	(5.4%)	(0.3%)	(4.7%)
2002	31,434	10,007	31,982	10,015	17.5%	117.8%	16.3%	114.7%
2003	40,642	8,292	41,183	8,287	29.3%	(17.1%)	28.8%	(17.3%)
2004	62,755	17,141	63,654	17,362	54.4%	106.7%	54.6%	109.5%
2005	94,438	17,204	96,449	17,462	50.5%	0.4%	51.5%	0.6%
2006	100,056	16,543	102,164	16,559	5.9%	(3.8%)	5.9%	(5.2%)
2007	108,707	16,549	111,023	16,729	8.6%	0.0%	8.7%	1.0%
2008	105,485	15,994	107,885	16,136	(3.0%)	(3.4%)	(2.8%)	(3.5%)
2009	97,388	16,364	100,022	16,397	(7.7%)	2.3%	(7.3%)	1.6%
2010	107,307	21,655	110,026	21,837	10.2%	32.3%	10.0%	33.2%
2011	117,130	20,977	119,501	21,259	9.2%	(3.1%)	8.6%	(2.6%)
2012	134,479	17,905	136,903	18,080	14.8%	(14.6%)	14.6%	(15.0%)
2013	148,323	18,783	150,595	18,978	10.3%	4.9%	10.0%	5.0%
2014	146,672	33,145	148,906	33,346	(1.1%)	76.5%	(1.1%)	75.7%
2015	114,889	19,164	117,146	19,405	(21.7%)	(42.2%)	(21.3%)	(41.8%)
2016	131,634	22,342	133,262	22,381	14.6%	16.6%	13.8%	15.3%

PJM Day-Ahead, Monthly Average Supply

Figure 3-10 compares the day-ahead, monthly average hourly supply, including increment offers and up to congestion transactions, for 2015 and 2016.

Figure 3-10 PJM day-ahead monthly average hourly supply: 2015 and 2016

Real-Time and Day-Ahead Supply

Table 3-12 presents summary statistics for 2015 and 2016, for day-ahead and real-time supply. All data are cleared MW. The last two columns of Table 3-12 are the day-ahead supply minus the real-time supply. The first of these columns is the total day-ahead supply less the total real-time supply and the second of these columns is the total physical day-ahead generation less the total physical real-time generation. In 2016, up-to congestion transactions were 25.4 percent of the total day-ahead supply compared to 16.4 percent in 2015.

Table 3-12 Day-ahead and real-time supply (MW): 2015 and 2016

		Day Ahead					Real Time		Day Ahead Less Real Time	
		Generation	INC	Up to Congestion	Imports	Total Supply	Generation	Total Supply	Total Supply	Total Generation
Average	2015	90,959	4,675	19,255	2,257	117,146	88,628	94,329	22,817	2,331
	2016	93,714	5,171	34,201	1,792	134,881	92,799	96,907	37,974	915
Median	2015	88,874	4,599	18,435	2,215	114,964	85,989	91,318	23,647	2,885
	2016	90,172	5,027	33,655	1,727	130,994	89,013	93,041	37,953	1,159
Standard Deviation	2015	17,341	791	5,230	503	19,405	16,118	17,312	2,093	1,223
	2016	19,435	1,054	6,936	651	23,403	19,003	19,067	4,336	432
Peak Average	2015	100,528	4,765	20,779	2,416	128,487	96,809	103,211	25,275	3,718
	2016	104,030	5,281	36,337	1,835	147,495	101,857	106,350	41,145	2,173
Peak Median	2015	97,480	4,714	19,777	2,428	126,042	93,304	99,485	26,558	4,176
	2016	102,122	5,146	35,655	1,722	146,045	98,442	103,478	42,567	3,680
Peak Standard Deviation	2015	14,481	715	5,336	504	16,480	14,438	15,379	1,102	43
	2016	17,542	1,019	6,660	722	21,042	18,233	17,897	3,145	(691)
Off-Peak Average	2015	82,242	4,594	17,867	2,112	106,815	81,176	86,238	20,578	1,067
	2016	84,307	5,071	32,254	1,753	123,379	84,539	88,296	35,082	(232)
Off-Peak Median	2015	79,108	4,485	17,186	2,059	103,524	78,333	82,832	20,692	775
	2016	81,898	4,903	31,398	1,735	120,145	81,922	85,881	34,264	(24)
Off-Peak Standard Deviation	2015	14,976	847	4,722	455	15,757	13,787	14,832	925	1,189
	2016	16,002	1,075	6,602	575	19,134	15,630	15,735	3,399	372

Figure 3-11 shows the average hourly cleared volumes of day-ahead supply and real-time supply for 2016. The day-ahead supply consists of cleared MW of day-ahead generation, imports, increment offers and up to congestion transactions. The real-time generation includes generation and imports.

Figure 3-11 Day-ahead and real-time supply (Average hourly volumes): 2016

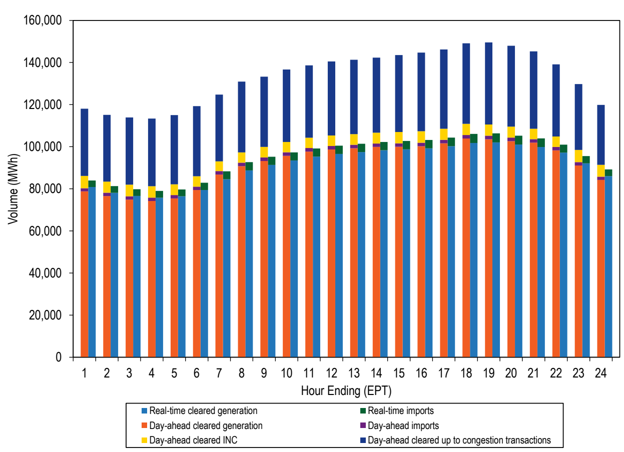


Figure 3-12 shows the difference between the day-ahead and real-time average daily supply for 2015 and 2016.

Figure 3-12 Difference between day-ahead and real-time supply (Average daily volumes): 2015 and 2016

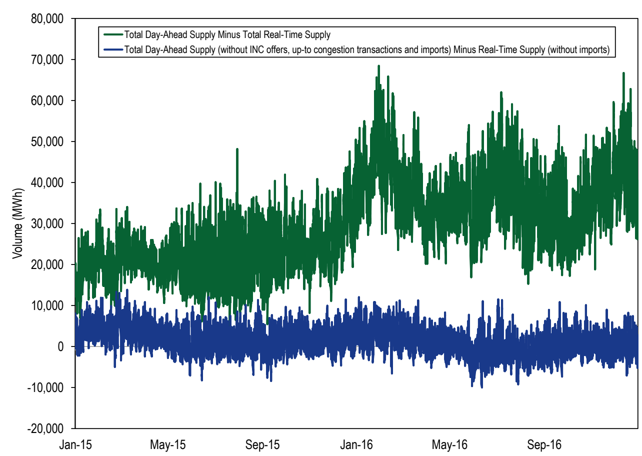
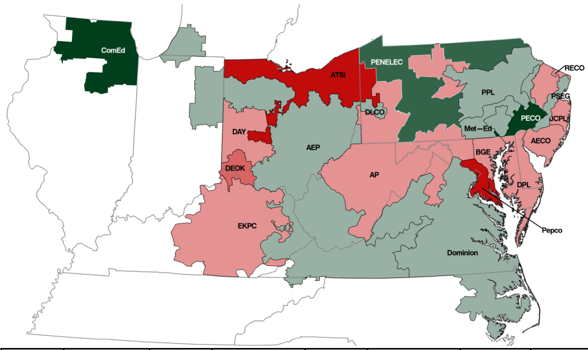


Figure 3-13 shows the difference between the PJM real-time generation and real-time load by zone in 2016. Figure 3-13 is color coded on a scale on which red shades represent zones that have less generation than load and green shades represent zones that have more generation than load, with darker shades 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 3-13 shows the difference between the PJM real-time generation and real-time load by zone in 2015 and 2016.

Figure 3-13 Map of PJM real-time generation less real-time load by zone: 2016[28]



Zone	Net Gen Minus Load (GWh)	Zone	Net Gen Minus Load (GWh)	Zone	Net Gen Minus Load (GWh)	Zone	Net Gen Minus Load (GWh)
AECO	(3,427)	ComEd	31,369	DPL	(9,806)	PENELEC	20,307
AEP	14,986	DAY	(1,908)	EKPC	(2,765)	Pepco	(20,204)
AP	(574)	DEOK	(10,616)	JCPL	(4,712)	PPL	9,668
ATSI	(24,444)	DLCO	3,361	Met-Ed	6,937	PSEG	1,800
BGE	(9,363)	Dominion	264	PECO	24,506	RECO	(1,481)

Table 3-13 PJM real-time generation less real-time load by zone (GWh): 2015 and 2016

Zonal Generation and Load (GWh)						
	2015			2016		
Zone	Generation	Load	Net	Generation	Load	Net
AECO	6,208.5	10,436.1	(4,227.6)	6,712.8	10,140.1	(3,427.3)
AEP	134,241.8	126,850.3	7,391.5	141,703.3	126,717.0	14,986.3
AP	44,431.4	48,207.0	(3,775.5)	47,489.1	48,063.0	(573.9)
ATSI	48,684.8	66,651.7	(17,966.9)	42,776.0	67,220.3	(24,444.3)
BGE	22,244.0	32,072.4	(9,828.5)	22,065.3	31,428.3	(9,363.0)
ComEd	125,658.7	95,365.1	30,293.6	129,371.6	98,002.4	31,369.2
DAY	13,661.1	16,884.0	(3,223.0)	15,380.9	17,288.8	(1,907.9)
DEOK	17,115.3	26,843.3	(9,727.9)	16,659.5	27,275.5	(10,616.0)
DLCO	16,604.9	14,167.8	2,437.1	17,258.8	13,897.4	3,361.3
Dominion	88,335.4	95,884.1	(7,548.8)	96,504.9	96,240.9	264.1
DPL	7,479.8	18,578.0	(11,098.2)	8,398.6	18,204.8	(9,806.2)
EKPC	8,603.7	12,169.1	(3,565.4)	9,799.9	12,564.8	(2,764.9)
JCPL	14,415.1	23,172.8	(8,757.7)	18,119.0	22,831.3	(4,712.3)
Met-Ed	22,081.5	15,208.6	6,872.9	22,197.7	15,260.5	6,937.2
PECO	60,404.2	40,056.7	20,347.4	64,614.9	40,109.1	24,505.8
PENELEC	37,224.2	17,105.7	20,118.5	37,177.8	16,870.8	20,307.0
Pepco	8,868.6	30,398.5	(21,529.9)	10,135.6	30,339.2	(20,203.6)
PPL	52,504.7	40,586.7	11,918.0	50,035.8	40,368.0	9,667.8
PSEG	47,617.7	43,664.3	3,953.4	45,616.5	43,816.1	1,800.4
RECO	0.0	1,521.2	(1,521.2)	0.0	1,481.2	(1,481.2)

Demand

Demand includes physical load and exports and virtual transactions.

Peak Demand

In this section, demand refers to metered physical load and exports and in the Day-Ahead Energy Market also includes virtual transactions.[29]

The PJM system real-time peak load for 2016 was 152,177 MW in the HE 15 on August 11, 2016, which was 8,480 MW, or 5.9 percent, higher than the peak load for 2015, which was 143,697 MW in the HE 16 on July 28, 2015.

Table 3-14 shows the peak loads for 1999 through 2016.

28 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>.

29 PJM reports peak load including metered 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 actual metered values. PJM's load drop estimate is based PJM Manual 19: Load Forecasting and Analysis Attachment A: Load Drop Estimate Guidelines at <http://www.pjm.com/~/media/documents/manuals/m19.ashx>.

Table 3-14 Actual PJM footprint peak loads: 1999 to 2016[30]

	Date	Hour Ending (EPT)	PJM Load (MW)	Annual Change (MW)	Annual Change (%)
1999	Fri, July 30	17	120,227	NA	NA
2000	Wed, August 09	17	114,036	(6,191)	(5.1%)
2001	Wed, August 08	17	128,535	14,499	12.7%
2002	Thu, August 01	17	130,159	1,625	1.3%
2003	Thu, August 21	17	126,259	(3,900)	(3.0%)
2004	Wed, June 09	17	120,218	(6,041)	(4.8%)
2005	Tue, July 26	16	133,761	13,543	11.3%
2006	Wed, August 02	17	144,644	10,883	8.1%
2007	Wed, August 08	16	139,428	(5,216)	(3.6%)
2008	Mon, June 09	17	130,100	(9,328)	(6.7%)
2009	Mon, August 10	17	126,798	(3,302)	(2.5%)
2010	Tue, July 06	17	136,460	9,662	7.6%
2011	Thu, July 21	17	158,016	21,556	15.8%
2012	Tue, July 17	17	154,344	(3,672)	(2.3%)
2013	Thu, July 18	17	157,508	3,165	2.1%
2014	Tue, June 17	17	141,673	(15,835)	(10.1%)
2015	Tue, July 28	17	143,697	2,023	1.4%
2016	Thu, August 11	16	152,177	8,480	5.9%

Figure 3-14 shows the peak loads for 1999 through 2016.

Figure 3-14 PJM footprint calendar year peak loads: 1999 to 2016

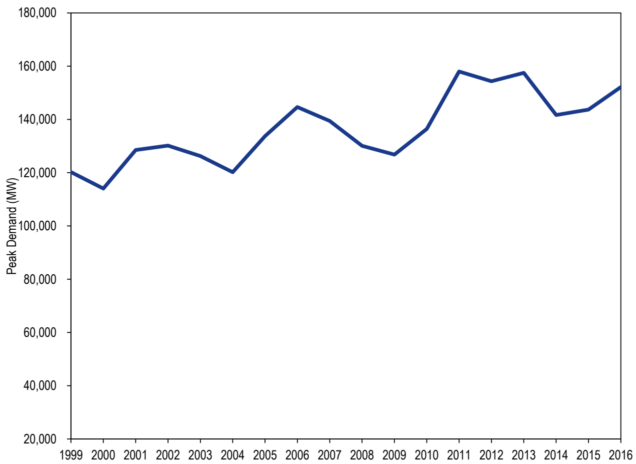
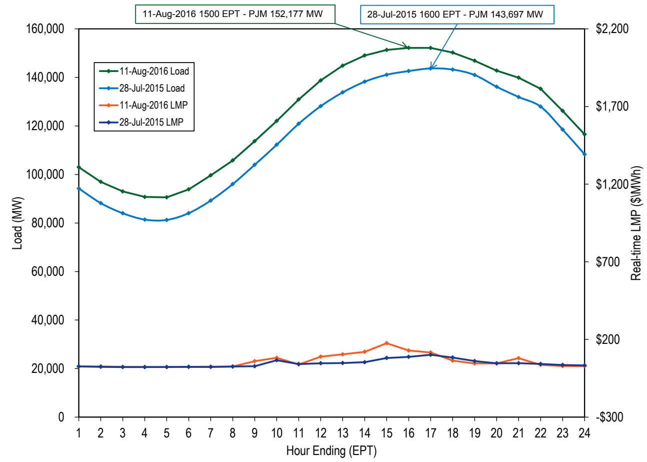


Figure 3-15 compares the peak load days of 2015 and 2016. The highest average hourly real-time LMP on August 11, 2016 was $175.88 and on July 28, 2015 was $101.40.

Figure 3-15 PJM peak-load comparison Thursday, August 11, 2016 and Tuesday, July 28, 2015



Real-Time Demand

PJM average real-time load in 2016 increased from 2015, from 88,594 MW to 88,601MW.[31]

PJM average real-time demand in 2016 increased 1.0 percent from 2015, from 92,665 MW to 93,551 MW.

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 checkout process.

PJM Real-Time Demand Duration

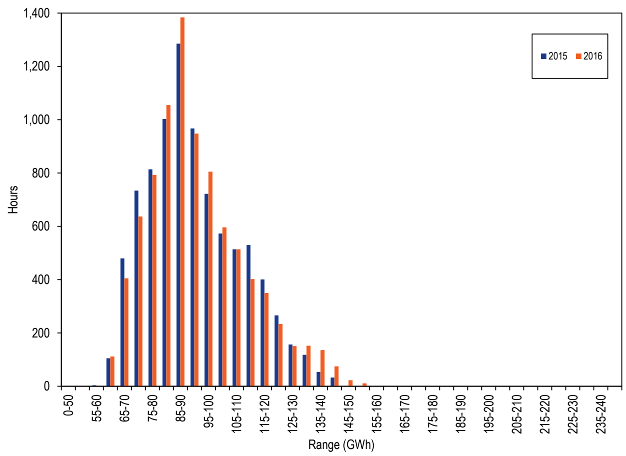
Figure 3-16 shows the hourly distribution of PJM real-time load plus exports for 2015 and 2016.[32]

30 Peak loads shown are Power Meter 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>.

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

32 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>.

Figure 3-16 Distribution of PJM real-time accounting load plus exports: January through December, 2015 and 2016[33]



PJM Real-Time, Average Load

Table 3-15 presents summary real-time demand statistics for 1998 to 2016. 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 marginal loss pricing.[34]

Table 3-15 PJM real-time average hourly load and real-time average hourly load plus average hourly exports: January through December, 1998 through 2016[35]

	PJM Real-Time Demand (MWh)				Year-to-Year Change			
	Load		Load Plus Exports		Load		Load Plus Exports	
	Load	Standard Deviation	Demand	Standard Deviation	Load	Standard Deviation	Demand	Standard Deviation
1998	28,578	5,511	28,578	5,511	NA	NA	NA	NA
1999	29,641	5,955	29,641	5,955	3.7%	8.1%	3.7%	8.1%
2000	30,113	5,529	31,341	5,728	1.6%	(7.2%)	5.7%	(3.8%)
2001	30,297	5,873	32,165	5,564	0.6%	6.2%	2.6%	(2.9%)
2002	35,776	7,976	37,676	8,145	18.1%	35.8%	17.1%	46.4%
2003	37,395	6,834	39,380	6,716	4.5%	(14.3%)	4.5%	(17.5%)
2004	49,963	13,004	54,953	14,947	33.6%	90.3%	39.5%	122.6%
2005	78,150	16,296	85,301	16,546	56.4%	25.3%	55.2%	10.7%
2006	79,471	14,534	85,696	15,133	1.7%	(10.8%)	0.5%	(8.5%)
2007	81,681	14,618	87,897	15,199	2.8%	0.6%	2.6%	0.4%
2008	79,515	13,758	86,306	14,322	(2.7%)	(5.9%)	(1.8%)	(5.8%)
2009	76,034	13,260	81,227	13,792	(4.4%)	(3.6%)	(5.9%)	(3.7%)
2010	79,611	15,504	85,518	15,904	4.7%	16.9%	5.3%	15.3%
2011	82,541	16,156	88,466	16,313	3.7%	4.2%	3.4%	2.6%
2012	87,011	16,212	92,135	16,052	5.4%	0.3%	4.1%	(1.6%)
2013	88,332	15,489	92,879	15,418	1.5%	(4.5%)	0.8%	(3.9%)
2014	89,099	15,763	94,471	15,677	0.9%	1.8%	1.7%	1.7%
2015	88,594	16,663	92,665	16,784	(0.6%)	5.7%	(1.9%)	7.1%
2016	88,601	17,229	93,551	17,498	0.0%	3.4%	1.0%	4.3%

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

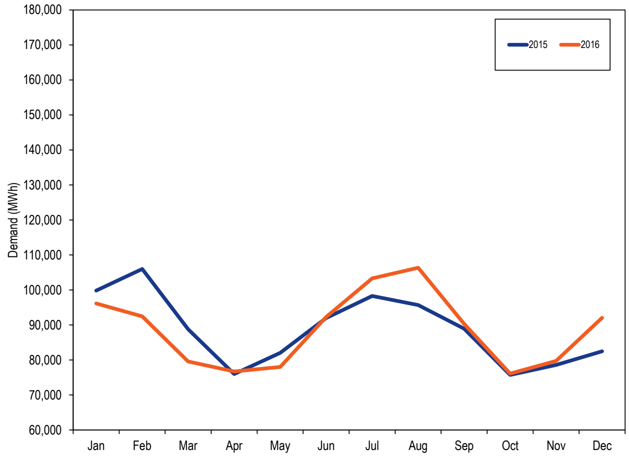
34 Accounting load is used here because PJM uses accounting load in the settlement process, which determines how much load customers pay for. In addition, the use of accounting load with losses before June 1, and without losses after June 1, 2007, is consistent with PJM's calculation of LMP, which excluded losses prior to June 1 and includes losses after June 1.

35 Export data are not available before June 1, 2000. The export data for 2000 are for the last six months of 2000.

PJM Real-Time, Monthly Average Load

Figure 3-17 compares the real-time, monthly average hourly loads for 2015 and 2016.

Figure 3-17 PJM real-time monthly average hourly load: January 2015 through December 2016



PJM real-time load is significantly affected by temperature. Figure 3-18 and Table 3-16 compare the PJM monthly heating and cooling degree days in 2015 and 2016.[36] Heating degree days decreased 6.4 percent, and cooling degree days increased 16.2 percent from 2015 to 2016.

Figure 3-18 PJM heating and cooling degree days: 2015 and 2016

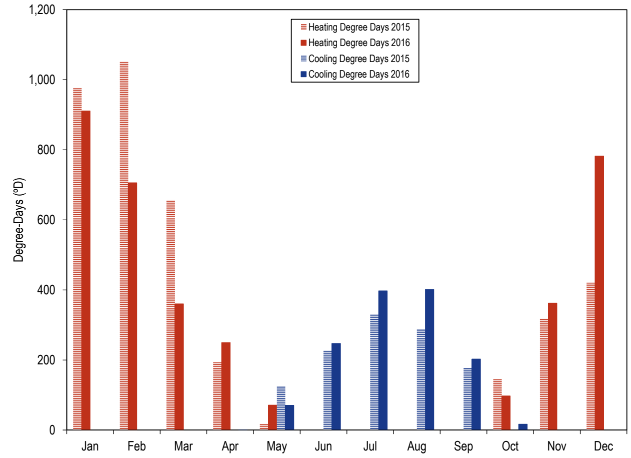


Table 3-16 PJM heating and cooling degree days: 2015 and 2016

	2015		2016		Percent Change	
	Heating Degree Days	Cooling Degree Days	Heating Degree Days	Cooling Degree Days	Heating Degree Days	Cooling Degree Days
Jan	977	0	911	0	(6.7%)	0.0%
Feb	1,051	0	706	0	(32.8%)	0.0%
Mar	656	0	360	0	(45.1%)	0.0%
Apr	193	0	250	1	29.1%	0.0%
May	18	125	71	71	299.6%	(43.7%)
Jun	1	228	0	247	(100%)	8.6%
Jul	0	330	0	397	0.0%	20.2%
Aug	0	289	0	402	0.0%	39.0%
Sep	0	179	0	203	0.0%	13.6%
Oct	145	0	98	17	(32.8%)	0.0%
Nov	319	0	363	0	13.7%	0.0%
Dec	421	0	782	0	85.8%	0.0%
Total	3,781	1,151	3,541	1,337	(6.4%)	16.2%

Day-Ahead Demand

PJM average day-ahead demand in 2016, including DECs and up to congestion transactions, increased by 14.1 percent from 2015, from 111,644 MW to 127,390 MW.

PJM average day-ahead demand in 2016, including DECs, up to congestion transactions, and exports, increased by 15.0 percent from 2015, from 115,007 MW to 131,006 MW.

The reduction in up to congestion transactions (UTC) that had followed a FERC order setting September 8, 2014, as the effective date for any uplift charges subsequently assigned to UTCs, was reversed. There was an increase in up to congestion volume as a result of the expiration

36 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.

of the 15 month refund period for the proceeding related to uplift charges for UTC transactions.[37]

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

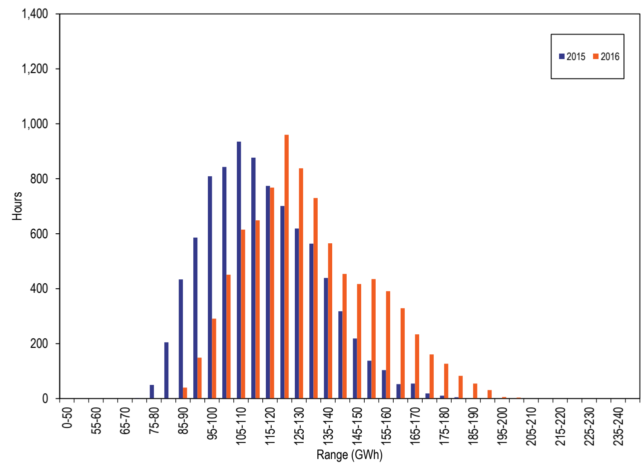
- **Fixed-Demand Bid.** Bid to purchase a defined MWh level of energy, regardless of LMP.
- **Price-Sensitive Bid.** Bid to purchase a defined MWh level of energy only up to a specified LMP, above which the load bid is zero.
- **Decrement Bid (DEC).** Financial bid to purchase a defined MWh level of 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 analogous to a matched pair of an INC offer and a DEC bid.
- **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. An export 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 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 hourly total of the five types of cleared demand bids.

PJM Day-Ahead Demand Duration

Figure 3-19 shows the hourly distribution of PJM day-ahead demand, including decrement bids, up to congestion transactions, and exports for 2015 and 2016.

Figure 3-19 Distribution of PJM day-ahead demand plus exports: January through December 2015 and 2016[38]



PJM Day-Ahead, Average Demand

Table 3-17 presents summary day-ahead demand statistics for each year from 2000 to 2016.[39]

37 148 FERC ¶ 61,144 (2014).

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

39 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 six months of that year.

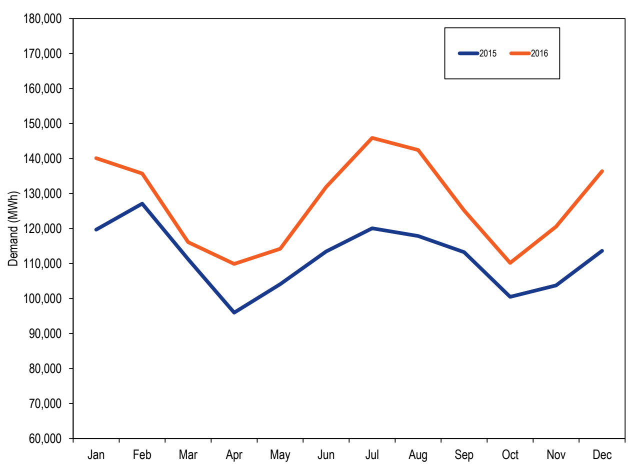
Table 3-17 PJM day-ahead average demand and day-ahead average hourly demand plus average hourly exports: 2000 through 2016

	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
2000	33,039	6,852	33,411	6,757	NA	NA	NA	NA
2001	33,370	6,562	33,757	6,431	1.0%	(4.2%)	1.0%	(4.8%)
2002	42,305	10,161	42,413	10,208	26.8%	54.9%	25.6%	58.7%
2003	44,674	7,841	44,807	7,811	5.6%	(22.8%)	5.6%	(23.5%)
2004	62,101	16,654	63,455	17,730	39.0%	112.4%	41.6%	127.0%
2005	93,534	17,643	96,447	17,952	50.6%	5.9%	52.0%	1.3%
2006	98,527	16,723	101,592	17,197	5.3%	(5.2%)	5.3%	(4.2%)
2007	105,503	16,686	108,932	17,030	7.1%	(0.2%)	7.2%	(1.0%)
2008	101,903	15,871	105,368	16,119	(3.4%)	(4.9%)	(3.3%)	(5.3%)
2009	94,941	15,869	98,094	15,999	(6.8%)	(0.0%)	(6.9%)	(0.7%)
2010	103,937	21,358	108,069	21,640	9.5%	34.6%	10.2%	35.3%
2011	113,866	20,708	117,681	20,929	9.6%	(3.0%)	8.9%	(3.3%)
2012	131,612	17,421	134,947	17,527	15.6%	(15.9%)	14.7%	(16.3%)
2013	144,858	18,489	148,132	18,570	10.1%	6.1%	9.8%	5.9%
2014	142,251	32,664	146,120	32,671	(1.8%)	76.7%	(1.4%)	75.9%
2015	111,644	18,715	115,007	18,867	(21.5%)	(42.7%)	(21.3%)	(42.3%)
2016	127,390	21,527	131,006	21,817	14.1%	15.0%	13.9%	15.6%

PJM Day-Ahead, Monthly Average Demand

Figure 3-20 compares the day-ahead, monthly average hourly demand, including decrement bids and up to congestion transactions, for 2015 and 2016.

Figure 3-20 PJM day-ahead monthly average hourly demand: 2015 and 2016



Real-Time and Day-Ahead Demand

Table 3-18 presents summary statistics for 2015 and 2016 day-ahead and real-time demand. All data are cleared MW. The last two columns of Table 3-18 are the day-ahead demand minus the real-time demand. The first such column is the total day-ahead demand less the total real-time demand and the second such column is the total physical day-ahead load (fixed demand plus price-sensitive demand) less the physical real-time load.

Table 3-18 Cleared day-ahead and real-time demand (MWh): 2015 and 2016

		Day-Ahead						Real-Time		Day-Ahead Less Real-Time	
	Year	Fixed Demand	Price Sensitive	Dec	Up to Congestion	Exports	Total Demand	Load	Total Demand	Total Demand	Total Load
Average	2015	85,171	3,167	4,051	19,255	3,363	115,007	88,596	92,664	22,343	66,253
	2016	86,989	3,134	4,743	34,201	3,536	132,607	90,599	95,340	37,266	53,332
Median	2015	82,980	3,214	3,821	18,435	3,213	112,811	86,029	89,791	23,019	63,009
	2016	83,781	3,122	4,494	33,655	3,332	128,866	86,646	91,595	37,271	49,375
Standard Deviation	2015	15,726	553	1,311	5,230	926	18,867	16,643	16,764	2,103	14,540
	2016	16,989	412	1,422	6,936	1,081	22,817	18,183	18,571	4,246	13,937
Peak Average	2015	94,077	3,438	4,428	20,779	3,327	126,049	97,395	101,295	24,754	72,641
	2016	96,483	3,398	5,124	36,337	3,552	144,907	99,962	104,538	40,369	59,593
Peak Median	2015	90,912	3,481	4,213	19,777	3,138	123,781	94,082	97,709	26,073	68,009
	2016	94,579	3,364	4,950	35,655	3,328	143,460	97,178	101,755	41,705	55,473
Peak Standard Deviation	2015	13,302	512	1,241	5,336	969	16,062	14,507	14,887	1,175	13,332
	2016	15,104	323	1,411	6,660	1,058	20,531	16,657	17,443	3,088	13,568
Off-Peak Average	2015	77,057	2,921	3,706	17,867	3,396	104,947	80,580	84,801	20,146	60,434
	2016	78,331	2,893	4,395	32,254	3,522	121,390	82,061	86,953	34,437	47,624
Off-Peak Median	2015	74,197	2,924	3,445	17,186	3,283	101,821	77,617	81,568	20,253	57,364
	2016	76,211	2,843	4,145	31,398	3,340	118,189	79,399	84,686	33,503	45,896
Off-Peak Standard Deviation	2015	13,166	466	1,277	4,722	883	15,263	14,242	14,335	928	13,314
	2016	13,662	329	1,340	6,602	1,102	18,634	15,043	15,314	3,321	11,722

Figure 3-21 shows the average hourly cleared volumes of day-ahead demand and real-time demand for 2016. 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 3-21 Day-ahead and real-time demand (Average hourly volumes): 2016

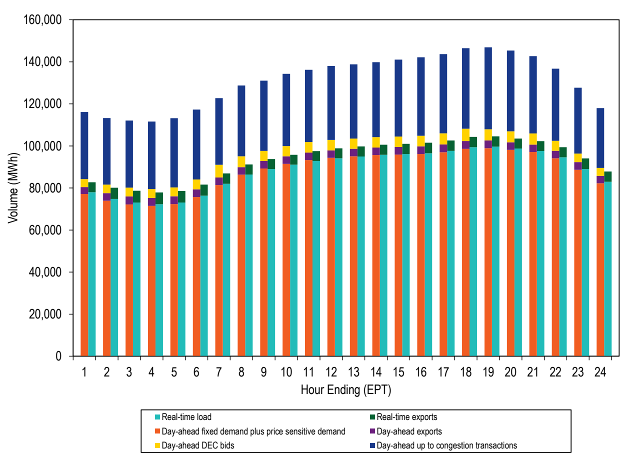
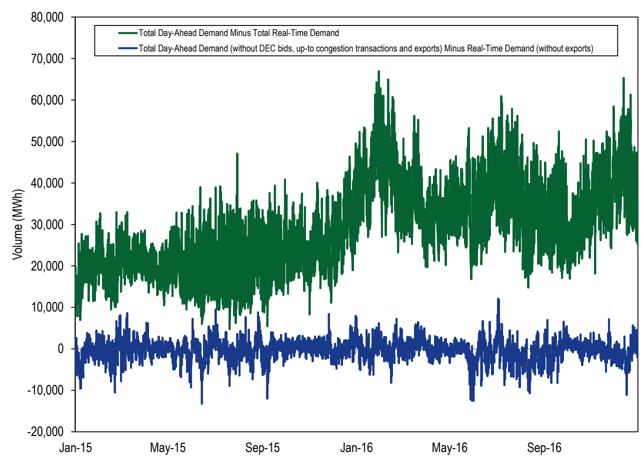


Figure 3-22 shows the difference between the day-ahead and real-time average daily demand from 2015 through 2016. There was an increase in up to congestion volume as a result of the expiration of the fifteen month potential refund period for the proceeding related to uplift charges for UTC transactions on December 7, 2015.

Figure 3-22 Difference between day-ahead and real-time demand (Average daily volumes): 2015 through 2016



Supply and Demand: Load and Spot Market

Real-Time Load and Spot Market

Participants in the PJM Real-Time Energy Market 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).

Real-time 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 eSchedules transactions referred to as wholesale load responsibility (WLR) or retail load responsibility (RLR) transactions. 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 Energy Market for each hour. Table 3-19 shows the monthly average share of real-time load served by self-supply, bilateral contracts and spot purchase in 2015 and 2016 based on parent company. In 2016, 12.9 percent of real-time load was supplied by bilateral contracts, 23.9 percent by spot market purchase and 63.2 percent by self-supply. Compared with 2015, reliance on bilateral contracts increased by 2.3 percentage points, reliance on spot supply decreased by 5.4 percentage points and reliance on self-supply increased by 3.1 percentage points.

Table 3-19 Monthly average percent of real-time self-supply load, bilateral-supply load and spot-supply load based on parent companies: 2015 through 2016[40]

	2015			2016			Difference in Percentage Points		
	Bilateral Contract	Spot	Self-Supply	Bilateral Contract	Spot	Self-Supply	Bilateral Contract	Spot	Self-Supply
Jan	11.1%	29.0%	59.8%	11.1%	25.9%	63.0%	(0.0%)	(3.1%)	3.2%
Feb	10.4%	29.7%	59.9%	11.5%	25.5%	63.0%	1.0%	(4.2%)	3.2%
Mar	9.7%	32.1%	58.2%	11.7%	26.4%	61.9%	2.0%	(5.7%)	3.7%
Apr	10.4%	34.4%	55.3%	12.7%	24.0%	63.4%	2.3%	(10.4%)	8.1%
May	9.3%	32.8%	58.1%	12.6%	24.5%	62.9%	3.3%	(8.2%)	4.7%
Jun	10.1%	30.0%	59.9%	12.5%	24.2%	63.2%	2.4%	(5.8%)	3.4%
Jul	10.5%	28.1%	61.4%	12.8%	23.3%	63.9%	2.3%	(4.8%)	2.5%
Aug	10.5%	27.3%	62.3%	12.7%	23.6%	63.7%	2.3%	(3.7%)	1.4%
Sep	10.3%	28.0%	61.7%	12.4%	22.7%	64.9%	2.1%	(5.2%)	3.2%
Oct	11.1%	27.3%	61.6%	14.6%	21.4%	64.0%	3.5%	(5.9%)	2.4%
Nov	10.9%	27.0%	62.1%	14.3%	23.2%	62.4%	3.4%	(3.8%)	0.4%
Dec	12.2%	26.0%	61.8%	15.6%	22.3%	62.1%	3.4%	(3.7%)	0.2%
Annual	10.5%	29.3%	60.2%	12.9%	23.9%	63.2%	2.3%	(5.4%)	3.1%

Day-Ahead Load and Spot Market

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

The PJM system's reliance on self-supply, bilateral contracts, and spot purchases to meet day-ahead demand (cleared fixed-demand, price-sensitive load and decrement bids) is calculated by summing across all the parent companies of PJM billing organizations that serve demand in the Day-Ahead Energy Market for each hour. Table 3-20 shows the monthly average share of day-ahead demand served by self-supply, bilateral contracts and spot purchases in 2015 through 2016, based on parent companies. In 2016, 8.9 percent of day-ahead demand was supplied by bilateral contracts, 25.0 percent by spot market purchases, and 66.1 percent by self-supply. Compared with 2015, reliance on bilateral contracts remained the same, reliance on spot supply

40 Table 3-19 and Table 3-20 were calculated as of January 26, 2017. The values may change slightly as billing values are updated by PJM.

decreased by 2.0 percentage points, and reliance on self-supply increased by 2.0 percentage points.

Table 3-20 Monthly average share of day-ahead self-supply demand, bilateral supply demand, and spot-supply demand based on parent companies: 2015 through 2016

	2015			2016			Difference in Percentage Points		
	Bilateral Contract	Spot	Self-Supply	Bilateral Contract	Spot	Self-Supply	Bilateral Contract	Spot	Self-Supply
Jan	10.5%	25.5%	64.0%	8.2%	26.2%	65.7%	(2.3%)	0.7%	1.7%
Feb	9.9%	25.2%	64.9%	8.4%	25.8%	65.7%	(1.5%)	0.6%	0.9%
Mar	9.3%	27.8%	62.9%	7.9%	27.8%	64.3%	(1.4%)	(0.1%)	1.4%
Apr	9.5%	30.3%	60.2%	9.9%	24.5%	65.7%	0.3%	(5.8%)	5.5%
May	9.1%	27.9%	63.0%	9.6%	24.6%	65.8%	0.5%	(3.2%)	2.7%
Jun	8.1%	28.2%	63.8%	8.5%	24.2%	67.3%	0.4%	(4.0%)	3.6%
Jul	8.5%	27.2%	64.3%	8.8%	24.3%	66.9%	0.3%	(2.9%)	2.6%
Aug	8.2%	26.9%	64.9%	8.6%	24.5%	66.8%	0.4%	(2.3%)	1.9%
Sep	7.9%	27.6%	64.4%	8.1%	24.3%	67.7%	0.2%	(3.4%)	3.2%
Oct	8.5%	26.5%	65.0%	9.5%	25.6%	64.9%	1.1%	(1.0%)	(0.1%)
Nov	8.3%	26.1%	65.6%	9.4%	25.7%	64.9%	1.1%	(0.4%)	(0.7%)
Dec	9.3%	25.8%	64.9%	10.4%	23.5%	66.1%	1.2%	(2.4%)	1.2%
Annual	8.9%	27.0%	64.0%	8.9%	25.0%	66.1%	(0.0%)	(2.0%)	2.0%

Market Behavior

Offer Capping for Local Market Power

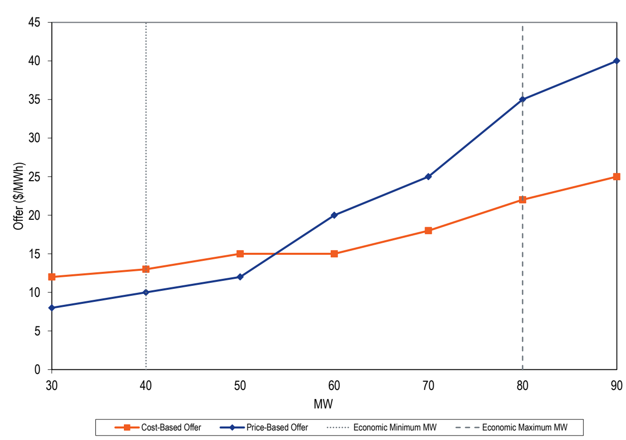
In the PJM Energy Market, offer capping occurs as a result of structurally noncompetitive local markets and noncompetitive offers in the Day-Ahead and Real-Time Energy Markets. PJM also uses offer capping for units that are committed for reliability reasons, specifically for providing black start and 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. PJM's market power mitigation goals have focused on market designs that promote competition and that limit local market power mitigation to situations where the local market structure is not competitive and thus where market design alone cannot mitigate market power.

The analysis of the application of the three pivotal supplier test demonstrates that it is working for most hours to exempt owners when the local market structure is competitive and to offer cap owners when the local market structure is noncompetitive. However, 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 have the ability to avoid 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.

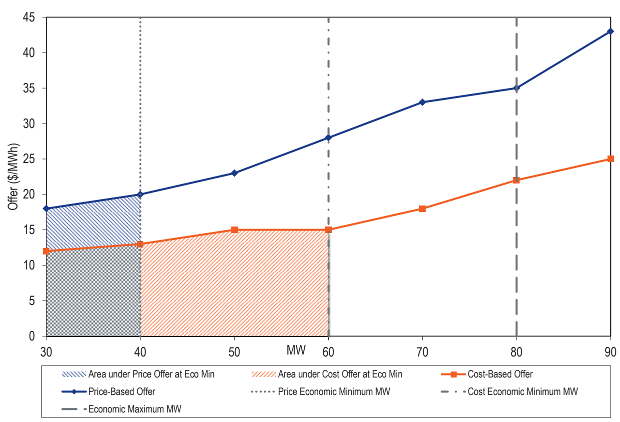
When an owner fails the TPS test, the units offered by the owner that are committed to provide relief are committed on the cheaper of cost or price-based offers. With the ability to submit offer curves with varying markups at different output levels in the price-based offer, units can avoid mitigation by using a low markup at low output levels and a high markup at higher output levels. Figure 3-23 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 even though the price-based offer is higher than cost at higher output levels and includes positive markups, inconsistent with the explicit goal of local market power mitigation.

Figure 3-23 Offers with varying markups at different MW output levels



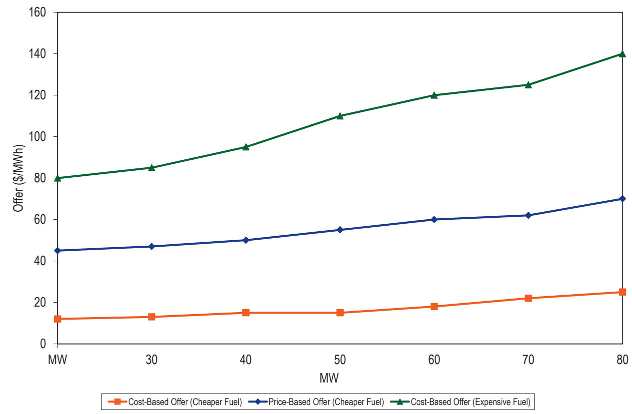
Offering a different economic minimum MW level, different minimum run times, different start up and notification times on the cost-based and price-based offers can also be used to avoid mitigation. For example, a unit may offer its price-based offer with a negative markup, but have a longer minimum run time (MRT) on the price-based offer. For example, 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 because the total cost of commitment (calculated as a product of MW and the offer in dollars per MWh plus the startup and no-load cost) can be lower on price-based offer at the lower economic minimum level compared to cost-based offer at a higher economic minimum level. Figure 3-24 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. The cost of commitment (area under the curve) 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 3-24 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 3-25 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 3-25 Dual fuel unit offers



These issues can be solved by simple rule changes.[41] 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 3-21. The offer capping percentages shown in Table 3-21 include units that are committed to provide constraint relief whose owners failed the TPS test in the energy market as well as units committed as part of conservative operations, excluding units that were committed for providing black start and reactive service.

Table 3-21 Offer capping statistics – energy only: 2012 to 2016

	Real Time		Day Ahead	
Year	Unit Hours Capped	MW Capped	Unit Hours Capped	MW Capped
2012	0.8%	0.4%	0.1%	0.1%
2013	0.4%	0.2%	0.1%	0.0%
2014	0.5%	0.2%	0.2%	0.1%
2015	0.4%	0.2%	0.2%	0.1%
2016	0.4%	0.2%	0.1%	0.0%

Table 3-22 shows the offer capping percentages including units committed to provide constraint relief and units committed to provide black start service and reactive support. The units that are committed and

41 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.

offer capped for black start service and reactive support reasons increased from 2012 through 2013. Before 2011, the units that ran to provide black start service and reactive support were generally economic in the energy market. From 2011 through 2013, the percentage of hours when these units were not economic (and were therefore committed on their cost schedule for reliability reasons) increased. This trend reversed in 2014, 2015 and 2016 because higher LMPs (in the first six months) resulted in the increased economic dispatch of black start and reactive service resources. 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, 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 3-21.

Table 3-22 Offer capping statistics for energy and reliability: 2012 to 2016

	Real Time		Day Ahead	
Year	Unit Hours Capped	MW Capped	Unit Hours Capped	MW Capped
2012	1.7%	1.0%	0.9%	0.5%
2013	2.9%	2.4%	3.2%	2.1%
2014	0.8%	0.5%	0.6%	0.4%
2015	0.7%	0.8%	0.6%	0.7%
2016	0.4%	0.3%	0.1%	0.1%

Table 3-23 shows the offer capping percentages for units committed to provide black start service and reactive support. The data in Table 3-23 is the difference between the offer cap percentages shown in Table 3-22 and Table 3-21.

Table 3-23 Offer capping statistics for reliability: 2012 to 2016

	Real Time		Day Ahead	
Year	Unit Hours Capped	MW Capped	Unit Hours Capped	MW Capped
2012	0.9%	0.6%	0.8%	0.4%
2013	2.5%	2.2%	3.1%	2.1%
2014	0.3%	0.3%	0.4%	0.3%
2015	0.4%	0.6%	0.4%	0.6%
2016	0.1%	0.1%	0.0%	0.0%

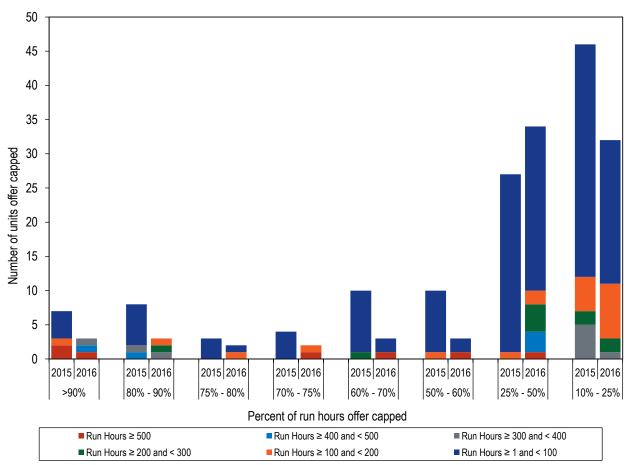
Table 3-24 presents data on the frequency with which units were offer capped in 2015 and 2016 for failing the TPS test to provide energy for constraint relief in the Real-Time Energy Market. Table 3-24 shows that three units were offer capped for 90 percent or more of their run hours in 2016 compared to seven in 2015.

Table 3-24 Real-time offer capped unit statistics: 2015 and 2016

		Offer-Capped Hours					
Run Hours Offer-Capped, Percent Greater Than Or Equal To:	Year	Hours ≥ 500	Hours ≥ 400 and < 500	Hours ≥ 300 and < 400	Hours ≥ 200 and < 300	Hours ≥ 100 and < 200	Hours ≥ 1 and < 100
	2016	1	1	1	0	0	0
90%	2015	2	0	0	0	1	4
	2016	0	0	1	1	1	0
80% and < 90%	2015	0	1	1	0	0	6
	2016	0	0	0	0	1	1
75% and < 80%	2015	0	0	0	0	0	3
	2016	1	0	0	0	1	0
70% and < 75%	2015	0	0	0	0	0	4
	2016	1	0	0	0	0	2
60% and < 70%	2015	0	0	0	1	0	9
	2016	1	0	0	0	0	2
50% and < 60%	2015	0	0	0	0	1	9
	2016	1	3	0	4	2	24
25% and < 50%	2015	0	0	0	0	1	26
	2016	0	0	1	2	8	21
10% and < 25%	2015	0	0	5	2	5	34

Figure 3-26 shows the frequency with which units were offer capped in 2015 and 2016 for failing the TPS test to provide energy for constraint relief in the Real-Time Energy Market.

Figure 3-26 Real-time offer capped unit statistics: 2015 and 2016



TPS Test Statistics

In 2016, the AECO, AEP, ATSI, BGE, ComEd, Dominion, DPL, JCPL, PECO, PENELEC, and PPL control zones experienced congestion resulting from one or more constraints binding for 100 or more hours or resulting from an interface constraint (Table 3-25). The AP, DAY, DEOK, DLCO, EKPC, Met-Ed, Pepco, PSEG and RECO control zones did not have constraints binding for 100 or more hours in 2016. Table 3-25 shows that BGE, ComEd, and PPL were the control zones that experienced congestion resulting from one or more constraints binding for 100 or more hours or resulting from an interface constraint that was binding for one or more hours in every year from 2009 through 2016.

Table 3-25 Numbers of hours when control zones experienced congestion resulting from one or more constraints binding for 100 or more hours or from an interface constraint: 2009 through 2016

	2009	2010	2011	2012	2013	2014	2015	2016
AECO	149	172	234	0	208	0	394	439
AEP	1,045	1,192	2,253	0	2,611	2,710	1,274	796
AP	509	1,714	0	206	0	170	167	0
ATSI	157	0	0	208	270	489	242	141
BGE	152	470	1,041	2,970	1,760	6,255	9,601	11,434
ComEd	1,212	2,080	1,134	4,554	5,143	4,119	5,878	7,336
DEOK	0	0	0	109	0	0	112	0
DLCO	156	475	206	209	0	223	617	0
Dominion	468	905	1,179	1,020	664	0	1,172	459
DPL	0	122	0	1,542	639	3,071	2,066	2,719
JCPL	0	0	0	0	0	0	0	398
Met-Ed	0	180	162	0	0	0	222	0
PECO	247	0	788	386	732	1,953	895	692
PENELEC	103	284	0	0	176	4,281	1,683	451
Pepco	149	1	0	143	245	41	0	0
PPL	176	118	40	350	452	148	266	936
PSEG	303	549	1,107	913	3,021	4,688	2,665	0

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 2016.[42] The three pivotal supplier (TPS) test is

42 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>.

applied every time the system solution indicates that out of merit resources are needed to relieve a transmission constraint. Only uncommitted resources, which would be started to relieve the transmission constraint, are subject to offer capping. Already committed units that can provide incremental relief cannot be offer capped. The results of the TPS test are shown for tests that could have resulted in offer capping and tests that resulted in offer capping.

Overall, the results confirm that the three pivotal supplier test results in offer capping when the local market is structurally noncompetitive and does not result in offer capping when that is not the case. Local markets are noncompetitive when the number of suppliers is relatively small.

Table 3-26 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 3-26 Three pivotal supplier test details for interface constraints: 2016

Constraint	Period	Average Constraint Relief (MW)	Average Effective Supply (MW)	Average Number Owners	Average Number Owners Passing	Average Number Owners Failing
AEP - DOM	Peak	423	684	10	0	10
	Off Peak	372	548	10	0	10
AP South	Peak	282	539	11	3	8
	Off Peak	187	638	12	8	3
Bedington - Black Oak	Peak	149	238	12	3	10
	Off Peak	89	119	10	2	8
Western	Peak	157	232	12	4	8
	Off Peak	89	106	11	1	10
Cleveland	Peak	107	108	1	0	1
	Off Peak	0	0	0	0	0
Warren	Peak	37	38	1	0	1
	Off Peak	49	57	1	0	1

The three pivotal supplier test is applied every time the PJM market system 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 capping. Only uncommitted resources, which would be started as a result of incremental relief needs, are eligible to be offer capped. Already committed units that can provide incremental relief cannot, regardless of test score, be switched from price to cost offers. Table 3-27 provides, for the identified interface constraints, information on total tests applied, the subset of three pivotal supplier tests that could have resulted in the offer capping of uncommitted units and the portion of those tests that did result in offer capping uncommitted units.

Table 3-27 Summary of three pivotal supplier tests applied for interface constraints: 2016

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
AEP - DOM	Peak	8	3	38%	2	25%	67%
	Off Peak	19	3	16%	2	11%	67%
AP South	Peak	23	2	9%	1	4%	50%
	Off Peak	11	6	55%	0	0%	0%
Bedington - Black Oak	Peak	246	24	10%	5	2%	21%
	Off Peak	155	11	7%	5	3%	45%
Western	Peak	12	2	17%	1	8%	50%
	Off Peak	5	0	0%	0	0%	0%
Cleveland	Peak	6	0	0%	0	0%	0%
	Off Peak	0	0	0%	0	0%	0%
Warren	Peak	149	0	0%	0	0%	0%
	Off Peak	13	0	0%	0	0%	0%

Parameter Limited Schedules

Cost-Based Offers

All capacity resources in PJM are required to submit at least one cost-based offer. During the 2016/2017 and 2017/2018 delivery years, all cost-based offers, submitted by resources that are not capacity performance resources, are parameter limited in accordance with the Parameter Limited Schedule (PLS) matrix or with the level of an approved exception.[43] During the 2016/2017 and 2017/2018 delivery years, all cost-based offers, submitted by capacity performance resources, are parameter limited in accordance with predetermined unit specific parameter limits. During the 2016/2017 and 2017/2018 delivery years, there was no base capacity procured.

For the 2018/2019 and 2019/2020 delivery years, PJM procured two types of capacity resources, capacity performance resources and base capacity resources. Beginning June 1, 2018, there will no longer be any resources committed as the current annual capacity product. 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.

Parameter Limits

During the extreme cold weather conditions in the first three months of 2016, as well as 2015 and 2014, a number of gas fired generators requested temporary exceptions to parameter limits for their parameter limited schedules due to restrictions imposed by natural gas pipelines. The parameters that were affected because of gas pipeline restrictions include 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 led 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 2016 and prior periods for annual resources that do not have capacity performance obligations. 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. Startup and notification times are limited for capacity performance resources beginning June 1, 2016, in accordance with predetermined unit specific parameter limits. The unit specific parameter limits for capacity performance resources were based on default minimum operating parameter limits posted by PJM by technology type. These default parameters were based on analysis by the MMU. Market participants could request an adjustment to the default values by submitting supporting documentation, which was reviewed by PJM and the MMU. The default minimum operating parameter limits or approved adjusted values are used by capacity performance 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

43 See PJM, OATT, § 6.6 Minimum Generator Operating Parameters - Parameter-Limited Schedules, (September 10, 2014), pp. 1937- 1940.

holding CTs and CCs to higher standards based on OEM documentation and up to date equipment configuration.

Currently, there are no rules in the PJM tariff or manuals that limit the nonparameter 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 rigorous market power mitigation when the TPS test is failed, 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.

Parameter Limited Schedules under Capacity Performance

Beginning in the 2016/2017 delivery year, resources that have capacity performance (CP) commitments are 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. In its 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.[44] The Commission directed that capacity performance resources with parameters based on nonphysical constraints should receive uplift payments.[45] The Commission directed PJM to submit tariff language to establish a process through which capacity performance resources that operate outside the defined unit-specific parameter limits can justify such operation and therefore remain eligible for make whole payments.[46]

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 just and reasonable because it was an arm's length contract 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. 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

44 *PJM Interconnection, L.L.C. et al.*, 151 FERC ¶ 61,208 at P 437 (June 9th Order).

45 *Id* at P 439.

46 *Id* at P 440.

substantially. Uplift costs are unpredictable, opaque and unhedgeable. 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 by assigning operational risk to generators, who are in the best position to efficiently manage those risks.

The MMU recommends that the revised rules recognize the difference between operational parameters that indicate to PJM dispatchers what a unit is capable of during the operating day and the parameters that are reflected in uplift payments. The parameters provided to PJM dispatchers each day should reflect what units are physically capable of. That is an operational necessity. 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.

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. 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.

Markup Index

Markup is a summary measure of participant offer behavior or conduct for individual units. The markup index for each marginal unit is calculated as (Price – Cost)/Price.[47] The markup index is normalized and can vary from -1.00 when the offer price is less than short run marginal cost, to 1.00 when the offer price is higher than short run marginal cost. 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

Table 3-28 shows the average markup index of marginal units in the Real-Time Energy Market, by offer price category using unadjusted cost offers. Table 3-29

47 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 (Price – Cost)/Price when price is greater than cost, and (Price – Cost)/Cost when price is less than cost.

shows the average markup index of marginal units in the Real-Time Energy Market, by offer price category using adjusted cost offers. The unadjusted markup is the difference between the price offer and the cost offer including the 10 percent adder in the cost offer. The adjusted markup is the difference between the price offer and the cost offer excluding the 10 percent adder from the cost offer. The adjusted markup is calculated only for coal units because coal units have consistently had price-based offers less than cost-based offers.[48] The markup is negative if the cost-based offer of the marginal unit exceeds its price-based offer at its operating point.

In 2016, 90.1 percent of marginal units had offer prices less than $50 per MWh. The average dollar markups of units with offer prices less than $25 was negative (-$0.56 per MWh) when using unadjusted cost offers. The average dollar markups of units with offer prices less than $50 was negative (-$1.18 per MWh) when using unadjusted cost offers. Negative markup means the unit is offering to run at a price less than its cost-based offer, implying a revealed short run marginal cost that is less than the allowable cost-based offer under the PJM Market Rules.

Some marginal units did have substantial markups. Among the units that were marginal in 2016, none had offer prices above $400 per MWh. Among the units that were marginal in 2015, 0.17 percent of units had offer prices greater than $400 per MWh, with an average dollar markup of $56.87 per MWh. Using the unadjusted cost offers, the highest markup for any marginal unit in 2016 was $258.16 while the highest markup in 2015 was $792.21.

Table 3-30 shows the percentage of marginal units that had markups, calculated using unadjusted cost offers, below, above and equal to zero for coal, gas and oil fuel types.[49] Table 3-31 shows the percentage of marginal units that had markups, calculated using adjusted cost offers, below, above and equal to zero for coal, gas and oil fuel types. In 2016, nearly 58.41 percent of marginal coal units had negative markups. In 2016, using adjusted cost-based offers for coal units, 38.56 percent of coal units had negative markups.

Table 3-28 Average, real-time marginal unit markup index (By offer price category unadjusted): 2015 and 2016

	2015			2016		
Offer Price Category	Average Markup Index	Average Dollar Markup	Frequency	Average Markup Index	Average Dollar Markup	Frequency
< $25	(0.04)	($2.45)	47.1%	0.03	($0.56)	64.2%
$25 to $50	(0.02)	($1.32)	38.9%	(0.01)	($1.18)	25.9%
$50 to $75	0.08	$4.39	2.8%	0.18	$9.94	1.6%
$75 to $100	0.13	$10.46	1.1%	0.28	$24.07	0.6%
$100 to $125	0.11	$11.48	1.2%	0.05	$5.13	1.8%
$125 to $150	0.03	$3.33	3.1%	0.01	$1.74	4.3%
>= $150	0.05	$12.54	5.8%	0.05	$9.47	1.6%

Table 3-29 Average, real-time marginal unit markup index (By offer price category adjusted): 2015 and 2016

	2015			2016		
Offer Price Category	Average Markup Index	Average Dollar Markup	Frequency	Average Markup Index	Average Dollar Markup	Frequency
< $25	(0.00)	($1.45)	47.1%	0.06	$0.28	64.2%
$25 to $50	0.03	$0.31	38.9%	0.04	$0.52	25.9%
$50 to $75	0.10	$5.44	2.8%	0.20	$10.94	1.6%
$75 to $100	0.14	$10.93	1.1%	0.29	$24.49	0.6%
$100 to $125	0.11	$11.75	1.2%	0.05	$5.16	1.8%
$125 to $150	0.03	$3.40	3.1%	0.01	$1.75	4.3%
>= $150	0.05	$12.75	5.8%	0.05	$9.54	1.6%

48 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.

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

Table 3-30 Percent of marginal units with markup below, above and equal to zero (by fuel type unadjusted): 2015 and 2016

	2015			2016		
Type/Fuel	Negative	Zero	Positive	Negative	Zero	Positive
Coal	57.59%	24.11%	18.30%	58.41%	22.29%	19.30%
Gas	25.98%	27.82%	46.19%	22.51%	16.51%	60.98%
Oil	6.19%	80.09%	13.72%	11.90%	84.49%	3.61%

Table 3-31 Percent of marginal units with markup below, above and equal to zero (by fuel type adjusted): 2015 and 2016

	2015			2016		
Type/Fuel	Negative	Zero	Positive	Negative	Zero	Positive
Coal	39.26%	24.85%	35.89%	38.56%	18.06%	43.37%
Gas	25.98%	27.82%	46.19%	22.51%	16.51%	60.98%
Oil	6.19%	80.09%	13.72%	11.90%	84.49%	3.61%

Figure 3-27 shows the frequency distribution of hourly markups for all gas units offered in 2015 and 2016. The highest markup within the economic operating range of the unit's offer curve was used for creating the frequency distributions.[50] Of the gas units offered in the PJM market in 2016, nearly 25 percent of gas unit-hours had a maximum markup that was negative. More than 5 percent of gas fired unit-hours had a highest markup within the economic operating range above $100 per MWh.

Figure 3-27 Frequency distribution of highest markup of gas units offered in 2015 and 2016

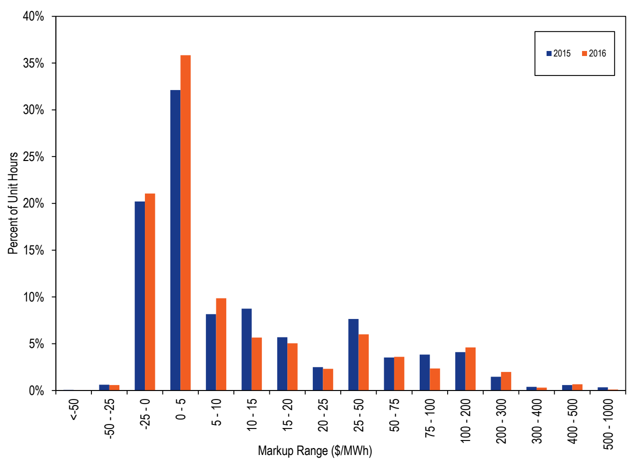


Figure 3-28 shows the frequency distribution of hourly markups for all coal units offered in 2015 and 2016. Of the coal units offered in the PJM market in 2016, nearly 40 percent of coal unit-hours had a maximum markup that was negative.

Figure 3-28 Frequency distribution of highest markup of coal units offered in 2015 and 2016

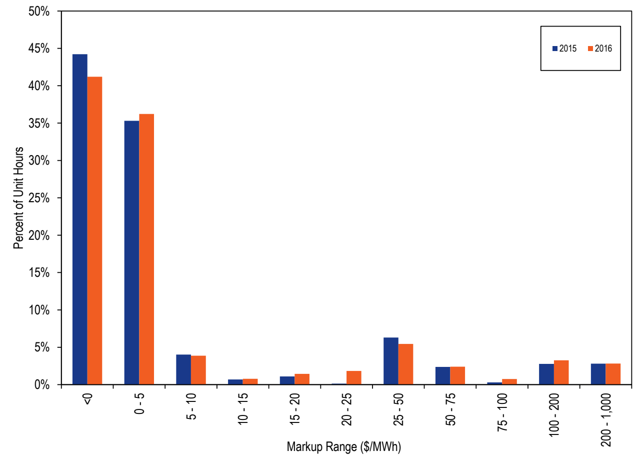
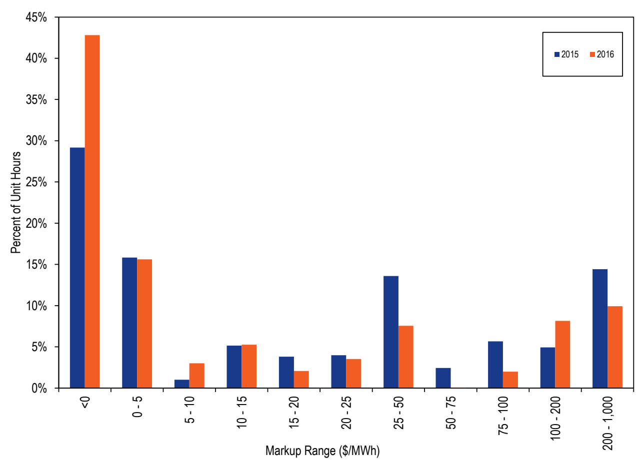


Figure 3-29 shows the frequency distribution of hourly markups for all offered oil units in 2015 and 2016. Of the oil units offered in the PJM market in 2016, nearly 40 percent of oil unit-hours had a maximum markup that was negative.

Figure 3-29 Frequency distribution of highest markup of oil units offered in 2015 and 2016



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

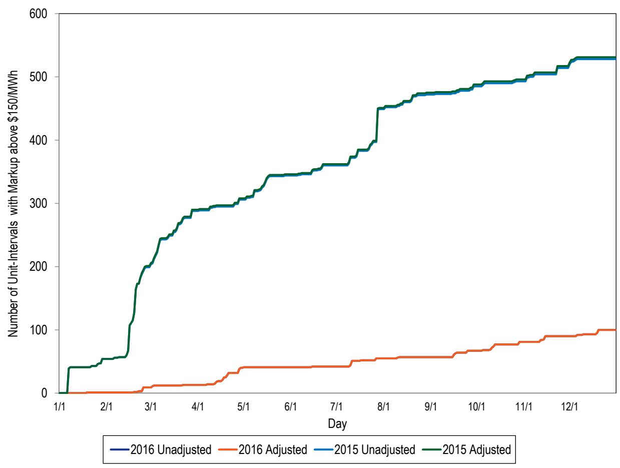
50 The categories in the frequency distribution were chosen so as to maintain data confidentiality.

price-based offers reveal actual unit marginal costs and imply 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 3-30 and Table 3-32 show the number of marginal unit intervals in 2016 and 2015 with markup above $150 per MWh. Compared to 2015, 2016 had fewer marginal unit intervals with high markups.

Figure 3-30 Cumulative Number of Unit Intervals with markups above $150 per MWh: 2015 and 2016



Day-Ahead Markup

Table 3-32 shows the average markup index of marginal generating units in the Day-Ahead Energy Market, by offer price category using unadjusted offers. The majority of marginal units are virtual transactions, which do not have markup. In the PJM Day-Ahead Energy Market, when using unadjusted cost offers, in 2016, 89.9 percent of marginal generating units had offer prices less than $50 per MWh and the average dollar markup was negative, and 0.4 percent of marginal generating units had offers in the $75 to $125 per MWh range and the average dollar markup and the average markup index were both negative.

Table 3-32 Average day-ahead marginal unit markup index (By offer price category, unadjusted): 2015 and 2016

	2015			2016		
Offer Price Category	Average Markup Index	Average Dollar Markup	Frequency	Average Markup Index	Average Dollar Markup	Frequency
< $25	0.01	($1.54)	44.2%	0.18	($0.98)	62.3%
$25 to $50	0.00	($0.89)	45.3%	0.03	($0.09)	27.6%
$50 to $75	0.12	$7.01	2.4%	0.09	$4.94	1.5%
$75 to $100	0.07	$5.37	1.0%	(0.02)	($2.70)	0.1%
$100 to $125	(0.00)	($2.40)	0.8%	(0.01)	($0.72)	0.3%
$125 to $150	0.00	($0.51)	3.2%	0.00	$0.00	7.2%
>= $150	0.02	$3.07	3.1%	0.01	$2.62	1.0%

Table 3-33 shows the average markup index of marginal generating units in the Day-Ahead Energy Market, by offer price category using adjusted offers. In 2016, 0.4 percent of marginal generating units had offers in the $75 to $125 per MWh range and the average dollar markup and the average markup index were both negative. The average markup index increased from 0.06 in 2015, to 0.22 in 2016 in the offer price category less than $25.

Table 3-33 Average day-ahead marginal unit markup index (By offer price category, adjusted): 2015 and 2016

	2015			2016		
Offer Price Category	Average Markup Index	Average Dollar Markup	Frequency	Average Markup Index	Average Dollar Markup	Frequency
< $25	0.06	($0.19)	44.2%	0.22	$0.04	62.3%
$25 to $50	0.06	$1.16	45.3%	0.07	$1.68	27.6%
$50 to $75	0.15	$8.59	2.4%	0.14	$7.74	1.5%
$75 to $100	0.08	$5.69	1.0%	(0.02)	($2.70)	0.1%
$100 to $125	(0.00)	($2.08)	0.8%	(0.01)	($0.72)	0.3%
$125 to $150	0.00	($0.51)	3.2%	0.00	$0.00	7.2%
>= $150	0.02	$3.08	3.1%	0.01	$2.62	1.0%

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 structure market power. But 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, as interpreted by PJM, is not currently 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.

Short Run Marginal Costs

There are three types of costs identified under PJM rules:

- Short run marginal costs (or incremental costs). Short run costs incurred directly as a result of producing energy for an hour;
- Avoidable costs. Annual costs that would be avoided if energy were not produced over an annual period;
- Fixed costs. Costs associated with an investment in a facility including the return on and of capital.

Marginal costs are the only costs relevant to the energy market. Specifically, the competitive energy offer level is the short run marginal cost of production.

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

Fuel Cost Policies

The fuel cost policy documents the process by which the Market Seller calculates the fuel cost component of its cost-based offers. Short run marginal fuel costs include commodity costs, transportation costs, fees, and taxes for the purchase of fuel. Fuel handling costs and fuel additive costs are included in the cost-based offer as variable operations and maintenance (VOM) costs. The fuel cost policy documents the frequency with which the Market Seller updates VOM and other nonfuel cost inputs.

The verification of accurate fuel costs in cost-based offers is not possible unless the fuel cost policy is algorithmic, verifiable, and systematic. Algorithmic means that the fuel cost policy must use a set of defined, logical steps to use defined inputs to get to defined outputs. Verifiable means that the fuel cost policy must provide a fuel price that can be calculated by the Market Monitor after the fact with the same data available to the generation owner at the time the decision was made, and documentation for that data from a public or a private source. Systematic means that the fuel cost policy must document a standardized method or methods for calculating fuel costs including objective triggers for each method.

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

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 Manual 15 be replaced with a straightforward description of the components of cost offers based on short run marginal costs and the correct calculation of cost offers.

FERC System of Accounts

PJM Manual 15 relies heavily on the FERC System of Accounts, which predates markets and does not define costs consistently with market economics.

The MMU recommends removal of all use of the FERC System of Accounts in the Cost Development Guidelines.

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 cost 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.

The MMU recommends the removal of all cyclic starting and peaking factors from the Cost Development Guidelines.

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 avoidable costs, not short run marginal costs, and are correctly includable in the RPM Avoidable Cost Rate.

The MMU recommends the removal of all labor costs from the Cost Development Guidelines.

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.

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.

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 Cost Development Guidelines.

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 Section 12 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 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.

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 and Associated Units

An FMU is a frequently mitigated unit. The results reported here include units that were mitigated for any reason, including both structural market power in the energy market and units called on for reliability reasons, including reactive and black start service.

The FMU adder was filed with FERC in 2005, and approved effective February 2006.[51] The goal, in 2005, was to ensure that units that were offer capped for most of their run hours could cover their going forward or avoidable costs (also known as ACR in the PJM Capacity Market). That function became unnecessary with the introduction of the RPM capacity market design in 2007, and changes to the scarcity pricing rules in 2012. Under the RPM design, units can make offers in the capacity market that include their ACR net of net revenues. Thus, if there is a shortfall in ACR recovery, that shortfall is included in the RPM offer. If the unit clears in RPM, it covers its shortfall in ACR costs. If the unit does not clear, then the market result means that PJM can provide reliability without the unit and no additional revenue is needed.

For those reasons, the MMU recommended the elimination of FMU and AU adders.[52] FMU and AU adders no longer serve the purpose for which they were created and interfere with the efficient operation of PJM markets.

The MMU and PJM proposed a compromise on the elimination of FMU adders that maintains the ability of generating units to qualify for FMU adders when units have net revenues less than unit going forward costs or ACR. PJM submitted the joint MMU/PJM proposal to the Commission pursuant to section 206 of the Federal Power Act. On October 31, 2014, the Commission conditionally approved the filing and the new rule became effective November 1, 2014.

The definition of FMUs provides for a set of graduated adders associated with increasing levels of offer capping. Units capped for 60 percent or more of their run hours and less than 70 percent are eligible for an adder of either 10 percent of their cost-based offer or $20 per MWh. Units capped for 70 percent or more of their run hours and less than 80 percent are eligible for an adder of either 10 percent of their cost-based offer or $30 per MWh. Units capped for 80 percent or more of their run hours are eligible for an adder of either 10 percent of their cost-based offer or $40 per MWh. These categories are designated Tier 1, Tier 2 and Tier 3.

In addition to being offer capped for the designated percent of run hours, in order to qualify for an FMU adder, a generating unit's Projected PJM Market Revenues plus the unit's PJM capacity market revenues on a rolling 12-month basis, divided by the unit's MW of installed capacity (in $/MW-year) must be less than its accepted unit specific Avoidable Cost Rate (in $/MW-year) (excluding APIR and ARPIR), or its default Avoidable Cost Rate (in $/MW-year) if no unit-specific Avoidable Cost Rate is accepted for the BRAs for the Delivery Years included in the rolling 12-month period, determined pursuant to Sections 6.7 and 6.8 of Attachment DD of the Tariff. (The relevant Avoidable Cost Rate is the weighted average of the Avoidable Cost Rates for each Delivery Year included in the rolling 12-month period, weighted by month.) No portion of the unit may be included in an FRR capacity plan or be receiving compensation under Part V of the PJM Tariff and the unit must be internal to the PJM Region and subject only to PJM dispatch.[53]

An AU, or associated unit, is a unit that is physically, electrically and economically identical to an FMU, but does not qualify for the same FMU adder based on the number of run-hours the unit is offer capped.[54] For example, if a generating station had two identical units with identical electrical impacts on the system, one of which was offer capped for more than 80 percent of its run hours, that unit would be designated a Tier 3 FMU.

51 110 FERC ¶ 61,053 (2005).

52 See the "*FMU Problem Statement and Issue Charge*," <http://www.monitoringanalytics.com/reports/Presentations/2013/IMM_MIC_FMU_Problem_Statement_and_Issue_Charge_20130306.pdf>.

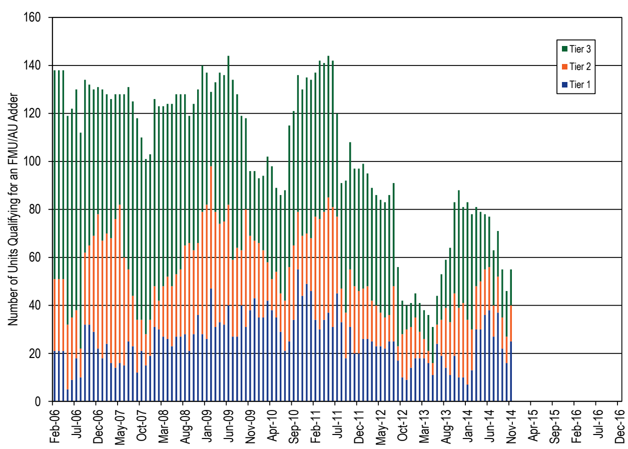
53 PJM. OA, Schedule 1 § 6.4.2.

54 An associated unit (AU) must belong to the same design class (where a design class includes generation that is the same size and uses the same technology, without regard to manufacturer) and uses the identical primary fuel as the FMU.

If the second unit were capped for 30 percent of its run hours, that unit would be an AU and receive the same Tier 3 adder as the FMU at the site. The AU designation was implemented to ensure that the associated unit is not dispatched in place of the FMU, resulting in no effective adder for the FMU. In the absence of the AU designation, the associated unit would be an FMU after its dispatch and the FMU would be dispatched in its place after losing its FMU designation.

Figure 3-31 shows the total number of FMUs and AUs that qualified for an adder since the inception of the business rule in February 2006. The new rules for determining the qualification of a unit as an FMU or AU became effective November 1, 2014. FMUs and AUs are designated monthly, and a unit's capping percentage is based on a rolling 12-month average, effective with a one-month lag.[55] 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 since December 2014.

Figure 3-31 Frequently mitigated units and associated units (By month): February, 2006 through December, 2016



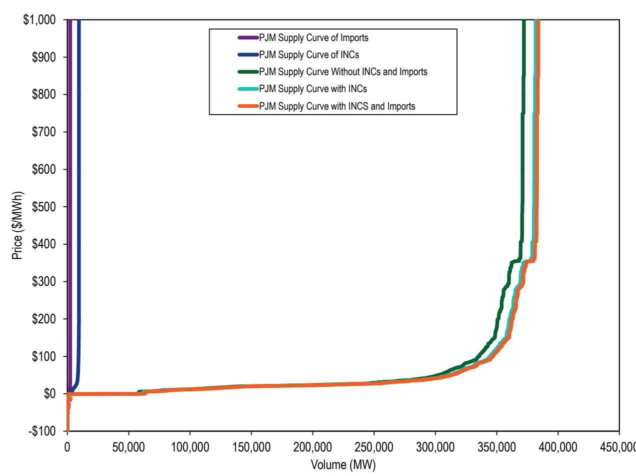
Virtual Offers and Bids

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 optimization 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. Increment offers and decrement bids may be submitted at any hub, transmission zone, aggregate, or single bus for which LMP is calculated. Up to congestion transactions may be submitted between any two buses on a list of 431 buses, eligible for up to congestion transaction bidding.[56] Financial Transaction Rights (FTRs) bids may be submitted at any bus on a list of selected buses that change every planning period, eligible for FTRs. 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 3-32 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 aggregate supply curve with increment offers, and the system aggregate supply curve with increment offers and imports for an example day in 2016.

Figure 3-32 PJM day-ahead aggregate supply curves: 2016 example day



55 PJM. OA, Schedule 1 § 6.4.2. In 2007, the FERC approved OA revisions to clarify the AU criteria.

56 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 "*OASIS-Source-Sink-Link.xls*," <http://www.pjm.com/~/media/etools/oasis/references/oasis-source-sink-link.ashx>.

Table 3-34 shows the hourly average number of cleared and submitted increment offers and decrement bids by month in 2015 and 2016. The hourly average submitted and cleared increment MW increased by 26.0 and 11.4 percent, from 7,175 MW and 4,675 MW in 2015 to 9,043 MW and 5,207 MW in 2016. The hourly average submitted and cleared decrement MW increased by 25.3 percent and 18.6 percent, from 6,879 MW and 4,051 MW in 2015 to 8,618 MW and 4,805 MW in 2016.

Table 3-34 Hourly average number of cleared and submitted INCs, DECs by month: 2015 and 2016

		Increment Offers				Decrement Bids			
Year		Average Cleared MW	Average Submitted MW	Average Cleared Volume	Average Submitted Volume	Average Cleared MW	Average Submitted MW	Average Cleared Volume	Average Submitted Volume
2015	Jan	4,350	6,447	78	398	5,153	7,320	76	295
2015	Feb	4,754	7,109	116	578	4,511	7,445	72	409
2015	Mar	4,973	8,689	142	760	4,305	8,894	101	648
2015	Apr	4,511	6,351	187	558	3,453	6,990	84	451
2015	May	5,089	7,459	181	656	4,171	6,823	94	404
2015	Jun	4,592	7,043	143	697	4,196	6,696	89	410
2015	Jul	4,101	6,534	128	745	3,335	5,830	86	448
2015	Aug	4,457	6,956	135	749	3,433	5,506	74	398
2015	Sep	4,527	6,772	148	733	4,391	7,030	112	437
2015	Oct	4,631	7,112	199	846	3,990	6,757	112	462
2015	Nov	5,022	7,822	223	1,008	3,671	6,435	109	482
2015	Dec	5,102	7,775	189	1,010	4,028	6,869	129	486
2015	Annual	4,675	7,175	156	729	4,051	6,879	95	444
2016	Jan	5,035	8,093	174	1,066	4,286	7,569	100	534
2016	Feb	4,831	8,710	178	1,150	4,259	8,158	113	572
2016	Mar	5,715	8,548	208	1,045	3,690	6,357	101	502
2016	Apr	5,630	8,343	186	964	4,115	7,066	101	509
2016	May	5,113	7,652	161	976	4,321	6,256	103	477
2016	Jun	5,130	8,291	153	1,054	5,344	8,107	128	585
2016	Jul	5,238	9,857	176	1,316	5,528	9,901	134	880
2016	Aug	4,872	9,873	191	1,408	5,516	10,521	147	952
2016	Sep	4,961	10,952	204	1,519	5,624	10,368	149	926
2016	Oct	5,227	9,660	260	1,345	5,224	10,207	148	792
2016	Nov	5,473	9,294	222	1,169	4,446	8,521	130	653
2016	Dec	5,250	9,238	196	1,262	5,283	10,344	128	760
2016	Annual	5,207	9,043	193	1,190	4,805	8,618	123	679

Table 3-35 shows the average hourly number of up to congestion transactions and the average hourly MW in 2015 and 2016. In 2016, the average hourly up to congestion submitted MW increased 70.3 percent and cleared MW increased 78.6 percent, compared to 2015, as a result of the expiration of the fifteen month potential refund period for the proceeding related to uplift charges for UTC transactions in December 2015.[57]

57 See 148 FERC ¶ 61,144 (2014); 16 U.S.C. § 824e.

Table 3-35 Hourly average of cleared and submitted up to congestion bids by month: 2015 and 2016

		Up to Congestion			
Year		Average Cleared MW	Average Submitted MW	Average Cleared Volume	Average Submitted Volume
2015	Jan	15,903	46,626	806	2,132
2015	Feb	17,255	57,318	892	2,695
2015	Mar	18,407	73,004	979	2,913
2015	Apr	16,300	73,446	811	2,734
2015	May	18,929	81,358	941	3,219
2015	Jun	17,714	81,452	896	3,220
2015	Jul	18,883	88,543	952	3,502
2015	Aug	18,490	102,084	1,126	4,291
2015	Sep	20,779	108,730	1,451	4,909
2015	Oct	20,183	100,673	1,493	4,736
2015	Nov	20,852	86,740	1,466	4,062
2015	Dec	27,124	99,083	1,933	4,841
2015	Annual	19,255	83,422	1,147	3,611
2016	Jan	39,639	135,369	2,466	6,015
2016	Feb	38,814	152,891	2,091	5,748
2016	Mar	31,817	147,963	1,703	5,094
2016	Apr	29,212	128,349	2,689	6,079
2016	May	32,883	120,132	2,977	6,006
2016	Jun	35,469	151,414	2,528	6,406
2016	Jul	37,668	181,720	2,413	7,158
2016	Aug	32,986	147,289	2,294	6,774
2016	Sep	29,368	129,498	2,309	6,065
2016	Oct	28,250	121,377	2,612	6,498
2016	Nov	36,506	141,688	2,927	7,335
2016	Dec	40,090	147,343	3,552	8,803
2016	Annual	34,387	142,075	2,549	6,503

Table 3-36 Hourly average day-ahead number of cleared and submitted import and export transactions by month: 2015 and 2016

		Imports				Exports			
Year		Average Cleared MW	Average Submitted MW	Average Cleared Volume	Average Submitted Volume	Average Cleared MW	Average Submitted MW	Average Cleared Volume	Average Submitted Volume
2015	Jan	2,579	2,716	15	17	4,473	4,559	26	26
2015	Feb	2,588	2,726	17	19	4,383	4,469	23	25
2015	Mar	2,484	2,668	16	18	3,268	3,302	16	17
2015	Apr	2,531	2,638	18	21	2,624	2,626	13	13
2015	May	2,339	2,482	18	20	2,612	2,623	17	17
2015	Jun	2,269	2,349	14	16	2,895	2,906	14	14
2015	Jul	2,319	2,445	16	18	2,961	2,983	14	14
2015	Aug	2,410	2,549	14	16	3,209	3,239	15	15
2015	Sep	1,854	2,015	11	14	3,873	3,913	18	18
2015	Oct	1,889	1,485	12	9	2,802	2,197	15	15
2015	Nov	1,840	1,988	15	17	2,715	2,734	15	15
2015	Dec	1,998	2,137	18	20	2,475	2,483	13	13
2015	Annual	2,257	2,348	15	17	3,183	3,160	16	17
2016	Jan	2,633	2,103	20	20	3,044	2,571	16	16
2016	Feb	2,396	2,480	20	22	2,634	2,653	13	13
2016	Mar	2,097	2,145	17	18	2,324	2,330	11	11
2016	Apr	2,150	2,180	16	16	2,620	2,635	13	13
2016	May	1,889	1,947	12	14	2,484	2,492	14	15
2016	Jun	1,335	1,366	6	7	4,428	4,471	23	24
2016	Jul	1,315	1,247	6	6	4,327	3,389	21	21
2016	Aug	1,384	1,424	6	7	4,331	4,351	20	20
2016	Sep	939	956	5	5	3,997	4,004	21	21
2016	Oct	1,104	997	6	6	3,800	2,902	22	22
2016	Nov	1,012	1,030	6	7	2,883	2,894	17	17
2016	Dec	1,302	1,354	8	9	4,284	4,306	22	22
2016	Annual	1,628	1,600	11	11	3,434	3,250	18	17

Table 3-36 shows the average hourly number of import and export transactions and the average hourly MW in 2015 and 2016. In 2016, the average hourly submitted and cleared import transaction MW decreased by 31.9 and 27.9 percent, and the average hourly submitted and cleared export transaction MW increased 2.9 and 3.4 percent, compared to 2015.

Table 3-37 shows the frequency with which generation offers, import or export transactions, up to congestion transactions, decrement bids, increment offers and price-sensitive demand are marginal in 2015 and 2016.

Table 3-37 Type of day-ahead marginal units: 2015 and 2016

	2015						2016					
	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	14.2%	0.5%	71.9%	6.9%	6.3%	0.08%	5.3%	0.1%	85.2%	5.6%	3.8%	0.00%
Feb	13.1%	0.4%	73.1%	7.6%	5.6%	0.12%	5.5%	0.0%	83.5%	7.4%	3.6%	0.00%
Mar	10.0%	0.7%	73.3%	10.6%	5.3%	0.01%	7.0%	0.1%	80.6%	7.7%	4.7%	0.00%
Apr	10.4%	0.3%	73.2%	10.8%	5.3%	0.00%	5.8%	0.0%	82.3%	8.1%	3.7%	0.00%
May	10.2%	0.1%	75.2%	9.2%	5.3%	0.02%	6.2%	0.1%	83.8%	6.5%	3.4%	0.01%
Jun	8.0%	0.1%	78.2%	9.5%	4.1%	0.01%	3.5%	0.0%	84.2%	8.5%	3.7%	0.00%
Jul	7.2%	0.1%	81.1%	7.8%	3.8%	0.01%	3.0%	0.0%	83.1%	10.1%	3.7%	0.01%
Aug	6.0%	0.1%	83.4%	7.1%	3.3%	0.01%	3.1%	0.0%	78.4%	13.1%	5.4%	0.00%
Sep	7.2%	0.2%	80.0%	7.5%	5.1%	0.01%	6.1%	0.0%	76.3%	11.4%	6.2%	0.01%
Oct	9.8%	0.1%	72.4%	11.2%	6.6%	0.00%	6.1%	0.1%	77.0%	10.9%	5.9%	0.01%
Nov	11.8%	0.1%	72.0%	10.7%	5.3%	0.00%	4.0%	0.0%	86.5%	6.3%	3.1%	0.00%
Dec	7.3%	0.1%	79.8%	8.0%	4.8%	0.01%	3.1%	0.0%	86.6%	6.9%	3.3%	0.00%
Annual	9.6%	0.3%	76.1%	8.9%	5.1%	0.02%	4.7%	0.0%	82.4%	8.6%	4.2%	0.00%

Figure 3-33 shows the monthly volume of bid and cleared INC, DEC and up to congestion bids by month for 2005 through 2016.

Figure 3-33 Monthly bid and cleared INCs, DECs and UTCs (MW): 2005 through 2016

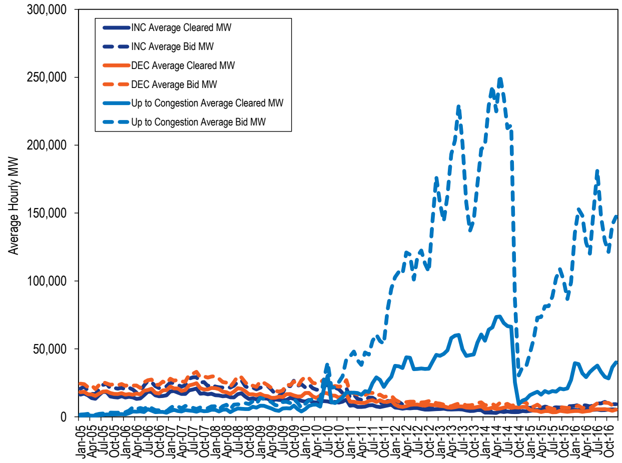
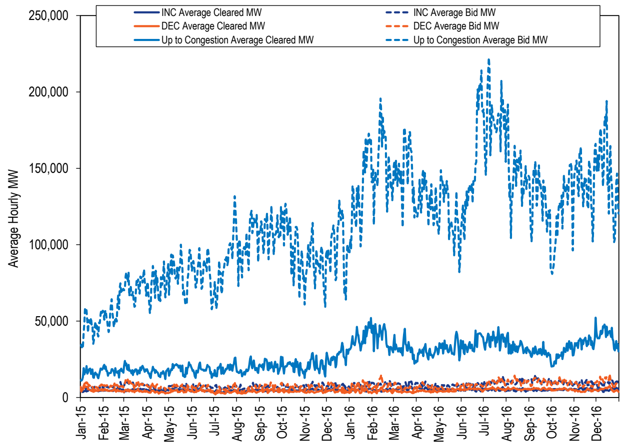


Figure 3-34 shows the daily volume of bid and cleared INC, DEC and up to congestion bids for the period 2015 through 2016.

Figure 3-34 Daily bid and cleared INCs, DECs, and UTCs (MW): 2015 through 2016



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 3-38 shows, in 2015 and 2016, the total increment offers and decrement bids and cleared MW by whether the parent organization is financial or physical.

Table 3-38 PJM INC and DEC bids and cleared MW by type of parent organization (MW): 2015 and 2016

	2015				2016			
Category	Total Virtual Bid MW	Percent	Total Virtual Cleared MW	Percent	Total Virtual Bid MW	Percent	Total Virtual Cleared MW	Percent
Financial	54,424,992	44.2%	15,669,170	22.4%	85,011,917	54.8%	31,255,057	35.5%
Physical	68,682,193	55.8%	54,194,529	77.6%	70,123,047	45.2%	56,693,484	64.5%
Total	123,107,185	100.0%	69,863,698	100.0%	155,134,964	100.0%	87,948,540	100.0%

Table 3-39 shows, in 2015 and 2016, the total up to congestion bids and cleared MW by whether the parent organization was financial or physical.

Table 3-39 PJM up to congestion transactions by type of parent organization (MW): 2015 and 2016

	2015				2016			
Category	Total Up to Congestion Bid MW	Percent	Total Up to Congestion Cleared MW	Percent	Total Up to Congestion Bid MW	Percent	Total Up to Congestion Cleared MW	Percent
Financial	643,199,888	88.0%	134,523,544	79.8%	1,199,246,273	96.1%	283,295,621	93.8%
Physical	87,572,419	12.0%	34,149,529	20.2%	48,737,575	3.9%	18,744,457	6.2%
Total	730,772,307	100.0%	168,673,073	100.0%	1,247,983,848	100.0%	302,040,077	100.0%

Table 3-40 shows, in 2015 and 2016, the total import and export transactions by whether the parent organization was financial or physical.

Table 3-40 PJM import and export transactions by type of parent organization (MW): 2015 and 2016

		2015		2016	
	Category	Total Import and Export MW	Percent	Total Import and Export MW	Percent
Day-Ahead	Financial	19,015,698	39.9%	18,842,285	42.4%
	Physical	28,635,508	60.1%	25,620,597	57.6%
	Total	47,651,206	100.0%	44,462,883	100.0%
Real-Time	Financial	25,595,400	30.4%	26,873,422	35.8%
	Physical	58,569,000	69.6%	48,147,619	64.2%
	Total	84,164,400	100.0%	75,021,041	100.0%

Table 3-41 shows increment offers and decrement bids bid by top ten locations in 2015 and 2016.

Table 3-41 PJM virtual offers and bids by top ten locations (MW): 2015 and 2016

2015					2016				
Aggregate/Bus Name	Aggregate/ Bus Type	INC MW	DEC MW	Total MW	Aggregate/Bus Name	Aggregate/ Bus Type	INC MW	DEC MW	Total MW
WESTERN HUB	HUB	19,527,215	21,691,683	41,218,898	WESTERN HUB	HUB	23,814,905	22,211,825	46,026,730
SOUTHIMP	INTERFACE	7,136,144	0	7,136,144	MISO	INTERFACE	394,038	4,965,920	5,359,958
N ILLINOIS HUB	HUB	905,858	2,733,941	3,639,799	SOUTHIMP	INTERFACE	3,883,473	0	3,883,473
IMO	INTERFACE	3,530,900	70,753	3,601,653	N ILLINOIS HUB	HUB	1,157,102	2,568,493	3,725,595
NYIS	INTERFACE	1,895,475	400,046	2,295,521	NYIS	INTERFACE	1,644,784	1,492,322	3,137,107
BGE	ZONE	223,721	1,750,290	1,974,011	BGE	ZONE	589,850	2,524,058	3,113,908
MISO	INTERFACE	414,835	1,216,550	1,631,385	AEP-DAYTON HUB	HUB	1,795,772	1,095,818	2,891,591
BAGLEY 34 KV 230-1LD	LOAD	403,792	912,882	1,316,673	PEPCO	ZONE	573,729	899,139	1,472,868
AEP-DAYTON HUB	HUB	651,596	649,136	1,300,732	PECO	ZONE	995,878	314,897	1,310,775
DOMINION HUB	HUB	365,184	811,772	1,176,956	IMO	INTERFACE	1,087,467	66,638	1,154,105
Top ten total		35,054,718	30,237,052	65,291,770			35,936,998	36,139,112	72,076,110
PJM total		62,628,496	60,111,808	122,740,304			79,422,390	75,700,997	155,123,387
Top ten total as percent of PJM total		56.0%	50.3%	53.2%			45.2%	47.7%	46.5%

Table 3-42 shows up to congestion transactions by import bids for the top ten locations and associated profits at each path in 2015 and 2016.[58]

Table 3-42 PJM cleared up to congestion import bids by top ten source and sink pairs (MW): 2015 and 2016

2015							
Imports							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
SOUTHIMP	INTERFACE	NAGELAEP	EHVAGG	1,480,928	$2,329,200	$2,030,590	$4,359,789
NORTHWEST	INTERFACE	N ILLINOIS HUB	HUB	445,796	$589,628	$41,074	$630,703
SOUTHEAST	INTERFACE	CLOVER	EHVAGG	413,115	$877,279	$27,768	$905,047
NORTHWEST	INTERFACE	COMED	ZONE	412,351	$731,599	($76,144)	$655,455
SOUTHEAST	INTERFACE	HALIFXDP TX1	AGGREGATE	364,808	$1,026,764	($831,029)	$195,735
OVEC	INTERFACE	AEP-DAYTON HUB	HUB	356,720	($42,397)	$77,601	$35,205
SOUTHIMP	INTERFACE	WOLF HILLS 1-5	AGGREGATE	342,579	$579,140	$374,141	$953,282
SOUTHEAST	INTERFACE	DOM	ZONE	277,721	$51,806	$174,166	$225,972
OVEC	INTERFACE	MALISZEWSKI	EHVAGG	258,387	$217,635	($131,660)	$85,975
MISO	INTERFACE	21 KINCA ATR24304	AGGREGATE	244,650	$215,385	$529,247	$744,632
Top ten total				4,597,055	$6,576,039	$2,215,755	$8,791,794
PJM total				19,561,806	$22,964,465	$3,098,774	$26,063,239
Top ten total as percent of PJM total				23.5%	28.6%	71.5%	33.7%
2016							
Imports							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
MISO	INTERFACE	COOK	EHVAGG	924,623	$324,666	($116,950)	$207,716
HUDSONTP	INTERFACE	LEONIA 230 T-2	AGGREGATE	621,050	$823,501	($790,051)	$33,450
SOUTHWEST	INTERFACE	DUMONT	EHVAGG	496,135	$183,774	($96,395)	$87,378
NEPTUNE	INTERFACE	SOUTHRIV 230	AGGREGATE	493,953	$374,916	($111,860)	$263,056
SOUTHWEST	INTERFACE	COOK	EHVAGG	446,275	$341,360	($62,815)	$278,544
SOUTHIMP	INTERFACE	NAGELAEP	EHVAGG	424,592	$580,390	($661,851)	($81,460)
MISO	INTERFACE	112 WILTON	EHVAGG	414,904	$534,468	($438,828)	$95,640
OVEC	INTERFACE	DEOK	ZONE	376,077	$226,257	($177,879)	$48,378
OVEC	INTERFACE	BUCKEYE - AEP	AGGREGATE	352,277	$344,727	($308,143)	$36,584
OVEC	INTERFACE	ATSI	ZONE	333,697	$83,965	$139,439	$223,405
Top ten total				4,883,581	$3,818,025	($2,625,333)	$1,192,692
PJM total				27,794,147	$19,515,405	($13,793,283)	$5,722,122
Top ten total as percent of PJM total				17.6%	19.6%	19.0%	20.8%

58 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 3-43 shows up to congestion transactions by export bids for the top ten locations and associated profits at each path in 2015 and 2016.

Table 3-43 PJM cleared up to congestion export bids by top ten source and sink pairs (MW): 2015 and 2016

				2015			
				Exports			
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
SULLIVAN-AEP	EHVAGG	OVEC	INTERFACE	460,314	$677,890	($483,724)	$194,166
FOWLER 34.5 KV FWLR1AWF	AGGREGATE	SOUTHWEST	INTERFACE	378,483	$1,224,460	($580,052)	$644,408
21 KINCA ATR24304	AGGREGATE	SOUTHWEST	INTERFACE	367,085	$325,308	($177,390)	$147,918
FOWLER RIDGE II WF	AGGREGATE	SOUTHWEST	INTERFACE	360,994	$558,913	$175,675	$734,589
ROCKPORT	EHVAGG	SOUTHWEST	INTERFACE	303,419	$372,743	($202,796)	$169,947
COMED	ZONE	NIPSCO	INTERFACE	274,034	$49,989	$162,774	$212,762
21 KINCA ATR24304	AGGREGATE	NIPSCO	INTERFACE	270,867	$12,820	$120,330	$133,149
SULLIVAN-AEP	EHVAGG	SOUTHWEST	INTERFACE	222,668	($124,221)	$347,221	$223,000
21 KINCA ATR24404	AGGREGATE	SOUTHWEST	INTERFACE	217,732	$312,596	($437,928)	($125,332)
SULLIVAN-AEP	EHVAGG	MISO	INTERFACE	167,996	$423,665	($260,111)	$163,554
Top ten total				3,023,589	$3,834,163	($1,336,002)	$2,498,161
PJM total				9,849,007	$12,605,146	($1,387,105)	$11,218,042
Top ten total as percent of PJM total				30.7%	30.4%	96.3%	22.3%
				2016			
				Exports			
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
COMED	ZONE	NIPSCO	INTERFACE	1,427,296	$1,150,528	$271,313	$1,421,841
21 KINCA ATR24304	AGGREGATE	SOUTHWEST	INTERFACE	984,202	$1,074,369	($776,386)	$297,984
SULLIVAN-AEP	EHVAGG	OVEC	INTERFACE	865,527	$964,583	($657,405)	$307,179
21 KINCA ATR24304	AGGREGATE	NIPSCO	INTERFACE	766,929	$745,474	$47,324	$792,799
POWERTON 5	AGGREGATE	NORTHWEST	INTERFACE	550,217	$736,607	($596,755)	$139,852
ROCKPORT	EHVAGG	SOUTHWEST	INTERFACE	521,855	$21,884	$45,506	$67,390
STMARYSGEN	AGGREGATE	NIPSCO	INTERFACE	452,574	$333,034	($241,863)	$91,170
EAST BEND 2	AGGREGATE	SOUTHWEST	INTERFACE	398,268	$393,612	($305,651)	$87,962
GRAND RIDGE WF	AGGREGATE	NIPSCO	INTERFACE	361,733	$168,945	$39,281	$208,226
21 KINCA ATR24404	AGGREGATE	SOUTHWEST	INTERFACE	361,040	($62,242)	$222,140	$159,898
Top ten total				6,689,640	$5,526,794	($1,952,495)	$3,574,299
PJM total				21,121,645	$13,506,455	($5,059,150)	$8,447,305
Top ten total as percent of PJM total				31.7%	40.9%	38.6%	42.3%

Table 3-44 shows up to congestion transactions by wheel bids and associated profits at each path for the top ten locations in 2015 and 2016.

Table 3-44 PJM cleared up to congestion wheel bids by top ten source and sink pairs (MW): 2015 and 2016

2015							
Wheels							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
MISO	INTERFACE	NORTHWEST	INTERFACE	361,210	$81,340	$660,033	$741,373
NORTHWEST	INTERFACE	MISO	INTERFACE	232,735	$559,645	($161,761)	$397,884
MISO	INTERFACE	NIPSCO	INTERFACE	221,536	$16,028	$137,545	$153,572
NYIS	INTERFACE	IMO	INTERFACE	129,966	($17,939)	$84,447	$66,508
IMO	INTERFACE	NYIS	INTERFACE	113,455	($31,774)	$130,923	$99,149
SOUTHWEST	INTERFACE	SOUTHEXP	INTERFACE	47,741	$49,972	$13,339	$63,311
SOUTHWEST	INTERFACE	IMO	INTERFACE	33,166	$140,955	($39,290)	$101,665
NIPSCO	INTERFACE	IMO	INTERFACE	29,379	$55,483	($13,026)	$42,456
SOUTHEAST	INTERFACE	SOUTHEXP	INTERFACE	21,292	$133,495	($86,234)	$47,262
MISO	INTERFACE	SOUTHWEST	INTERFACE	20,984	$30,255	($81,670)	($51,415)
Top ten total				1,211,465	$1,017,459	$644,306	$1,661,765
PJM total				1,453,602	$961,914	$1,516,081	$2,477,995
Top ten total as percent of PJM total				83.3%	105.8%	42.5%	67.1%
2016							
Wheels							
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
NORTHWEST	INTERFACE	MISO	INTERFACE	483,587	$205,487	($138,661)	$66,826
MISO	INTERFACE	NIPSCO	INTERFACE	456,491	$407,571	($101,219)	$306,352
SOUTHWEST	INTERFACE	SOUTHEXP	INTERFACE	355,456	$712,746	($580,097)	$132,648
MISO	INTERFACE	NORTHWEST	INTERFACE	249,915	$248,663	($15,678)	$232,985
NYIS	INTERFACE	IMO	INTERFACE	235,084	$17,499	$41,318	$58,817
IMO	INTERFACE	NYIS	INTERFACE	125,377	$92,270	($146,944)	($54,673)
SOUTHWEST	INTERFACE	NIPSCO	INTERFACE	89,731	$111,695	($63,301)	$48,394
IMO	INTERFACE	MISO	INTERFACE	76,985	$33,213	($103,413)	($70,200)
MISO	INTERFACE	SOUTHEXP	INTERFACE	40,226	$104,721	($76,174)	$28,547
NEPTUNE	INTERFACE	NYIS	INTERFACE	33,963	$41,687	($35,445)	$6,242
Top ten total				2,146,815	$1,975,552	($1,219,614)	$755,937
PJM total				2,492,100	$2,189,382	($1,291,897)	$897,485
Top ten total as percent of PJM total				86.1%	90.2%	94.4%	84.2%

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 ten internal up to congestion transaction locations were 4.4 percent of the PJM total internal up to congestion transactions in 2016.

Table 3-45 shows up to congestion transactions by internal bids for the top ten locations and associated profits at each path in 2015 and 2016. The total UTC profit by top ten locations decreased by $20.6 million, or 89.6 percent, from $23.0 million in 2015 to $2.4 million in 2016. The total internal cleared MW increased by 112.8 million MW, or 81.9 percent, from 137.8 million MW in 2015 to 250.6 million MW in 2016.

Table 3-45 PJM cleared up to congestion internal bids by top ten source and sink pairs (MW): 2015 and 2016

			2015				
			Internal				
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
BERGEN 2CC	AGGREGATE	LEONIA 230 T-1	AGGREGATE	2,362,692	($6,122,031)	$22,202,119	$16,080,088
ROCKPORT	EHVAGG	JEFFERSON	EHVAGG	1,763,337	$1,787,375	($912,169)	$875,206
BYRON 1	AGGREGATE	ROCKFORD	AGGREGATE	1,465,725	$1,275,618	$944,399	$2,220,017
BERGEN 2CC	AGGREGATE	LEONIA 230 T-2	AGGREGATE	1,017,317	($1,177,921)	$3,924,751	$2,746,830
JEFFERSON	EHVAGG	COOK	EHVAGG	958,975	$444,466	$98,393	$542,860
MARYSVILLE	EHVAGG	MALISZEWSKI	EHVAGG	892,606	$1,253,142	($219,667)	$1,033,476
BLACKOAK	EHVAGG	BEDINGTON	EHVAGG	718,298	$152,573	($940,892)	($788,319)
PSEG	ZONE	WESTERN HUB	HUB	711,099	$330,764	($291,938)	$38,826
WHIPPANY BK 7	AGGREGATE	TRAYNOR	AGGREGATE	686,989	$1,019,109	($976,308)	$42,801
21 KINCA ATR24304	AGGREGATE	DUMONT - OLIVE	AGGREGATE	673,830	($242,743)	$486,655	$243,912
Top ten total				11,250,868	($1,279,647)	$24,315,342	$23,035,695
PJM total				137,808,658	$149,441,842	($5,136,252)	$144,305,590
Top ten total as percent of PJM total				8.2%	(.9%)	(473.4%)	16.0%
			2016				
			Internal				
Source	Source Type	Sink	Sink Type	MW	Source Profit	Sink Profit	UTC Profit
21 KINCA ATR24304	AGGREGATE	MICHFE	AGGREGATE	1,723,607	$152,078	$417,191	$569,268
21 KINCA ATR24404	AGGREGATE	MICHFE	AGGREGATE	1,376,889	($261,431)	$444,443	$183,012
BERGEN 2CC	AGGREGATE	LEONIA 230 T-1	AGGREGATE	1,238,324	$1,483,047	($1,494,384)	($11,337)
WHIPPANY BK 7	AGGREGATE	TRAYNOR	AGGREGATE	1,134,144	$806,939	($745,745)	$61,194
BYRON 1	AGGREGATE	ROCKFORD	AGGREGATE	1,092,315	$712,354	$187,518	$899,873
AEP-DAYTON HUB	HUB	N ILLINOIS HUB	HUB	970,055	$249,345	($453,393)	($204,048)
BLACKOAK	EHVAGG	BEDINGTON	EHVAGG	927,715	$702,188	($1,303,092)	($600,904)
BRISTERS	EHVAGG	OX	EHVAGG	900,322	$1,344,558	($1,275,869)	$68,689
WAUKEGAN TR412	AGGREGATE	COMED	ZONE	871,975	$435,670	($175,527)	$260,142
CLOVERDALE	EHVAGG	CLOVERD2 138 KV T4	AGGREGATE	870,196	$627,455	$534,600	$1,162,055
Top ten total				11,105,541	$6,252,202	($3,864,258)	$2,387,944
PJM total				250,632,186	$166,288,531	($133,865,767)	$32,422,766
Top ten total as percent of PJM total				4.4%	3.8%	2.9%	7.4%

Table 3-46 shows the number of source-sink pairs that were offered and cleared monthly in 2013 through 2016. The annual row in Table 3-46 is the average hourly number of offered and cleared source-sink pairs for the year for the average columns and the maximum hourly number of offered and cleared source-sink pairs for the year for the maximum columns. The increase in average offered and cleared source-sink pairs beginning in January 2013 and continuing through the first eight months of 2014 illustrates that PJM's modification of the rules governing the location of up to congestion transactions bids resulted in a significant increase in the number of offered and cleared up to congestion transactions. The subsequent 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. There was an increase in up to congestion volume as a result of the expiration of the fifteen month refund period for the proceeding related to uplift charges for UTC transactions on December 7, 2015.[59]

59 See 148 FERC ¶ 61,144 (2014)..

Table 3-46 Number of PJM offered and cleared source and sink pairs: 2013 through 2016

		Daily Number of Source-Sink Pairs			
Year	Month	Average Offered	Max Offered	Average Cleared	Max Cleared
2013	Jan	6,580	10,548	3,291	5,060
2013	Feb	4,891	7,415	2,755	3,907
2013	Mar	4,858	7,446	2,868	4,262
2013	Apr	6,426	9,064	3,464	4,827
2013	May	5,729	7,914	3,350	4,495
2013	Jun	6,014	8,437	3,490	4,775
2013	Jul	5,955	9,006	3,242	4,938
2013	Aug	6,215	9,751	3,642	5,117
2013	Sep	3,496	4,222	2,510	3,082
2013	Oct	4,743	7,134	3,235	4,721
2013	Nov	8,605	14,065	5,419	8,069
2013	Dec	8,346	11,728	6,107	7,415
2013	Annual	5,996	14,065	3,620	8,069
2014	Jan	7,977	11,191	5,179	7,714
2014	Feb	10,087	11,688	7,173	8,463
2014	Mar	11,360	14,745	7,284	9,943
2014	Apr	11,487	14,106	8,589	10,253
2014	May	11,215	13,477	7,734	9,532
2014	Jun	10,613	14,112	7,374	10,143
2014	Jul	10,057	12,304	7,202	8,486
2014	Aug	10,877	12,863	7,609	9,254
2014	Sep	5,618	11,269	4,281	8,743
2014	Oct	2,871	4,092	1,972	2,506
2014	Nov	2,463	3,988	1,812	3,163
2014	Dec	2,803	3,672	2,197	2,786
2014	Annual	8,109	10,614	5,690	7,570
2015	Jan	3,337	5,422	2,263	3,270
2015	Feb	4,600	7,041	2,775	4,147
2015	Mar	4,061	5,799	2,625	3,244
2015	Apr	3,777	6,967	2,343	3,378
2015	May	4,025	5,513	2,587	3,587
2015	Jun	3,852	5,967	2,781	3,748
2015	Jul	3,957	5,225	2,786	4,044
2015	Aug	4,996	6,143	3,702	4,378
2015	Sep	5,775	7,439	4,222	5,462
2015	Oct	6,000	7,414	4,221	5,397
2015	Nov	5,846	7,148	4,494	5,842
2015	Dec	7,097	8,250	5,709	6,610
2015	Annual	4,259	6,152	2,897	3,912
2016	Jan	7,714	8,793	6,174	7,374
2016	Feb	9,200	11,172	7,203	7,957
2016	Mar	8,826	11,572	6,338	8,126
2016	Apr	7,697	8,473	5,958	6,767
2016	May	8,521	9,398	6,707	7,273
2016	Jun	9,261	10,948	6,913	7,770
2016	Jul	12,401	16,103	8,571	11,695
2016	Aug	12,464	13,576	8,725	9,224
2016	Sep	12,297	16,324	7,736	9,230
2016	Oct	11,248	13,114	7,648	8,539
2016	Nov	13,151	16,725	8,173	11,581
2016	Dec	12,688	15,868	8,101	9,630
2016	Annual	10,455	12,672	7,354	8,764

Table 3-47 and Figure 3-35 show total cleared up to congestion transactions by type in 2015 and 2016. Total up to congestion transactions in 2016 increased by 79.1 percent from 168.7 million MW in 2015 to 302.0 million MW in 2016. Internal up to congestion transactions in 2016 were 83.0 percent of all up to congestion transactions compared to 81.7 percent in 2015.

Table 3-47 PJM cleared up to congestion transactions by type (MW): 2015 and 2016

	2015				
	Cleared Up to Congestion Bids				
	Import	Export	Wheel	Internal	Total
Top ten total (MW)	4,597,055	3,023,589	1,211,465	11,250,868	20,082,977
PJM total (MW)	19,561,806	9,849,007	1,453,602	137,808,658	168,673,073
Top ten total as percent of PJM total	23.5%	30.7%	83.3%	8.2%	11.9%
PJM total as percent of all up to congestion transactions	11.6%	5.8%	0.9%	81.7%	100.0%
	2016				
	Cleared Up to Congestion Bids				
	Import	Export	Wheel	Internal	Total
Top ten total (MW)	4,883,581	6,689,640	2,146,815	11,105,541	24,825,577
PJM total (MW)	27,794,147	21,121,645	2,492,100	250,632,186	302,040,078
Top ten total as percent of PJM total	17.6%	31.7%	86.1%	4.4%	8.2%
PJM total as percent of all up to congestion transactions	9.2%	7.0%	0.8%	83.0%	100.0%

Figure 3-35 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. There was an increase in up to congestion volume as a result of the expiration of the fifteen month refund period for the proceeding related to uplift charges for UTC transactions.[60]

Figure 3-35 PJM monthly cleared up to congestion transactions by type (MW): 2005 through 2016

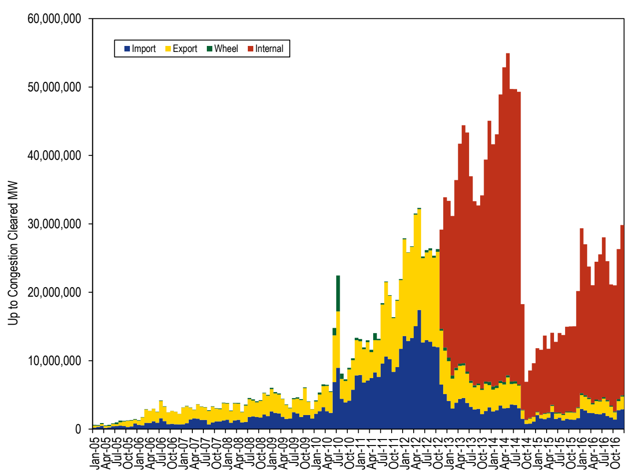
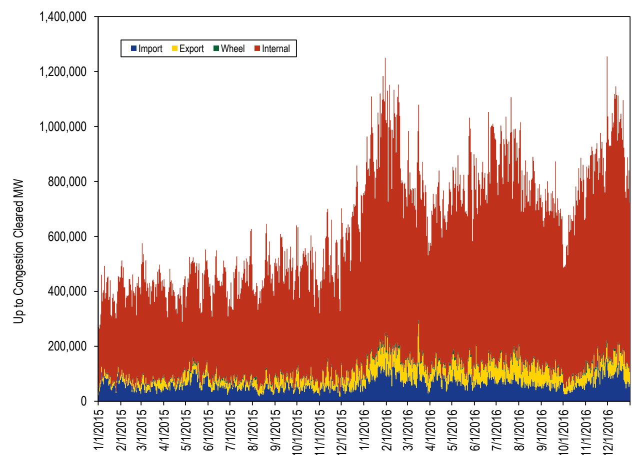


Figure 3-36 shows the daily cleared up to congestion MW by transaction type for the period from January 2015 through December 2016.

Figure 3-36 PJM daily cleared up to congestion transaction by type (MW): 2015 through 2016



Generator Offers

Generator offers are categorized as dispatchable (Table 3-48) or self scheduled (Table 3-49).[61] Units which are available for economic dispatch are dispatchable. 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 3-48 and Table 3-49 do not include units that did not indicate their offer status and 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 beyond the economic range

60 See 148 FERC ¶ 61,144 (2014).

61 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 owners and the small number of units of this type of generation.

of a unit are categorized as emergency MW. Emergency MW are included in both tables.

Table 3-48 shows the proportion of MW offers by dispatchable units, by unit type and by offer price range, in 2016. For example, 77.8 percent of CC offers were dispatchable and in the $0 to $200 per MWh price range. The total column is the proportion of all MW offers by unit type that were dispatchable. For example, 85.0 percent of all CC MW offers were dispatchable, including the 6.7 percent of emergency MW offered by CC units. 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, 49.7 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 2016, 53.7 percent were offered as available for economic dispatch.

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 20.9 percent of all offers and self scheduled and dispatchable units accounted for 18.1 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 of 2016, 22.4 percent were offered as self scheduled and 19.5 percent were offered as self scheduled and dispatchable.

Table 3-48 Distribution of MW for dispatchable unit offer prices: 2016

	Dispatchable (Range)							
Unit Type	($200) - $0	$0 - $200	$200 - $400	$400 - $600	$600 - $800	$800 - $1,000	Emergency	Total
CC	0.0%	77.8%	0.3%	0.2%	0.0%	0.0%	6.7%	85.0%
CT	0.0%	82.2%	4.7%	0.7%	0.3%	0.0%	10.4%	98.2%
Diesel	1.5%	33.0%	18.6%	3.9%	0.0%	0.0%	16.7%	73.7%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Nuclear	0.0%	5.4%	0.0%	0.0%	0.0%	0.0%	0.1%	5.4%
Pumped Storage	62.7%	0.2%	0.0%	0.0%	0.0%	0.0%	2.2%	65.2%
Run of River	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Solar	38.3%	5.0%	0.0%	0.0%	0.0%	0.0%	0.8%	44.1%
Steam	0.1%	50.4%	0.5%	0.0%	0.0%	0.3%	3.0%	54.3%
Transaction	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Wind	51.3%	9.7%	0.0%	0.0%	0.0%	0.0%	0.5%	61.5%
All Dispatchable Offers	2.5%	49.7%	1.1%	0.2%	0.0%	0.1%	4.4%	58.1%

Table 3-49 shows the proportion of MW offers by unit type that were self scheduled to generate fixed output and by unit type and price range for self-scheduled and dispatchable units, for 2016. For example, 10.1 percent of CC offers were self scheduled and dispatchable and in the $0 to $200 price range. The total column is the proportion of all MW offers by unit type that were self scheduled to generate fixed output and are self scheduled and dispatchable. For example, 15.0 percent of all CC MW 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 0.8 percent of emergency MW

Table 3-49 Distribution of MW for self scheduled and dispatchable unit offer prices: 2016

	Self Scheduled		Self Scheduled and Dispatchable (Range)							
Unit Type	Must Run	Emergency	($200) - $0	$0 - $200	$200 - $400	$400 - $600	$600 - $800	$800 - $1,000	Emergency	Total
CC	2.9%	0.9%	0.3%	10.1%	0.0%	0.0%	0.0%	0.0%	0.8%	15.0%
CT	0.5%	0.1%	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	0.1%	1.8%
Diesel	20.0%	0.9%	2.7%	1.5%	0.0%	0.0%	0.0%	0.0%	1.1%	26.3%
Fuel Cell	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Nuclear	86.4%	1.1%	4.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.1%	94.6%
Pumped Storage	17.9%	9.3%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	4.2%	34.8%
Run of River	60.0%	13.7%	0.3%	20.8%	0.0%	0.0%	0.0%	0.4%	4.7%	99.8%
Solar	39.0%	14.4%	2.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	55.9%
Steam	4.6%	1.5%	0.1%	36.8%	0.0%	0.0%	0.0%	0.0%	2.6%	45.7%
Transaction	76.2%	23.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Wind	4.9%	4.0%	22.8%	3.1%	0.0%	0.0%	0.0%	0.0%	3.5%	38.5%
All Self-Scheduled Offers	20.9%	1.4%	1.5%	16.6%	0.0%	0.0%	0.0%	0.0%	1.4%	41.9%

Market Performance

The PJM average locational marginal price (LMP) reflects the configuration of the entire RTO. The PJM Energy Market includes the Real-Time Energy Market and the Day-Ahead Energy Market.

Markup

The markup index is a measure of participant conduct for individual marginal 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 translate to different impacts on total system price. Markup can also affect prices when units with high markups are not marginal.

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 offer and the cost-based offer of each actual marginal unit on the system.[62]

The MMU calculated an explicit measure of the impact of marginal unit markups on LMP using the mathematical relationships among LMPs given the market solution. The markup impact includes the impact of the identified markup conduct on a unit by unit basis, but the inclusion of negative markup impacts has an offsetting effect. The markup analysis does not distinguish between intervals in which a unit has local market power or has a price impact in an unconstrained interval. The markup analysis is a more general measure of the competitiveness of the energy market.

The price impact of markup must be interpreted carefully. The markup calculation is not based on a full 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. The results do not reflect a counterfactual market outcome based on the assumption that all units made all offers at short run marginal cost. It is important to note that 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

62 This is the same method used to calculate the fuel cost adjusted LMP and the components of LMP. *See* Calculation and Use of Generator Sensitivity/Unit Participation Factors, 2010 State of the Market Report for PJM: Technical Reference for PJM Markets.

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 3-50 shows the average unit markup component of LMP for marginal units, by unit type and primary fuel. The markup component of LMP is a measure of the impact of the markups of marginal units shown in Table 3-50 on the system-wide load-weighted LMP. The negative markup components of LMP reflect the negative markups shown in the Table 3-28.

All generating units, including coal units, are allowed to add an additional 10 percent to their cost offer. The additional 10 percent was included in the definition of cost offers 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. Coal units do not face the same cost uncertainty as gas-fired CTs. A review of actual participant behavior supports this view, as the owners of coal units, facing competition, typically exclude the additional 10 percent from their actual offers. The unadjusted markup is calculated as the difference between the price offer and the cost offer including the additional 10 percent in the cost offer for coal units. The adjusted markup is calculated as the difference between the price offer and the cost offer excluding the additional 10 percent from the cost offer. Even the adjusted markup overestimates the negative markup because coal units facing increased competitive pressure have excluded both the 10 percent and some or all components of operating and maintenance cost. While both these elements are permitted under the definition of cost-based offers in the PJM Market Rules, they are not part of a competitive offer because they are not actually short run marginal costs, and actual market behavior reflected that fact.[63]

Table 3-50 shows the mark-up component of the load-weighted LMP by fuel type and unit type using unadjusted and adjusted offers. The adjusted markup component of LMP increased from $1.75 per MWh in 2015 to $1.77 per MWh in 2016. The adjusted markup contribution of coal units in 2016 was $0.04 per MWh. The mark-up component of gas-fired units in 2016 was $1.75 per MWh, a decrease of $0.55 per MWh from 2015. The markup component of wind units was $0.02 per MWh. If a price-based offer is negative, but less negative than a cost-based offer, the markup is positive. In 2016, among the wind units that were marginal, 2.13 percent had positive offer prices. Almost three quarters of the positive markup component of day ahead LMP was a result of the markup in the offers of combined cycle gas generators.

Table 3-50 Markup component of the overall PJM real-time, load-weighted, average LMP by primary fuel type and unit type: 2015 and 2016[64]

		2015		2016	
Fuel Type	Unit Type	Markup Component of LMP (Unadjusted)	Markup Component of LMP (Adjusted)	Markup Component of LMP (Unadjusted)	Markup Component of LMP (Adjusted)
Coal	Steam	($1.26)	$0.37	($1.33)	$0.04
Gas	CC	$1.29	$1.29	$1.29	$1.29
Gas	CT	($0.13)	($0.13)	$0.19	$0.19
Gas	Diesel	$0.02	$0.02	$0.01	$0.01
Gas	Steam	$0.02	$0.02	$0.26	$0.26
Municipal Waste	Steam	($0.01)	($0.01)	$0.00	$0.00
Oil	CC	$0.05	$0.05	$0.00	$0.00
Oil	CT	$0.03	$0.03	$0.01	$0.01
Oil	Diesel	$0.00	$0.00	$0.00	$0.00
Oil	Steam	$0.12	$0.12	$0.07	$0.07
Other	Steam	($0.04)	($0.04)	($0.12)	($0.12)
Uranium	Steam	$0.00	$0.00	$0.00	$0.00
Wind	Wind	$0.03	$0.03	$0.02	$0.02
Total		$0.13	$1.76	$0.40	$1.77

63 See PJM. "Manual 15: Cost Development Guidelines," Revision 27 (April 20, 2016).

64 The Unit Type Diesel refers to power generation using reciprocating internal combustion engines. Such Diesel units can use a variety of fuel types including diesel, natural gas, oil and gas from municipal waste.

Markup Component of Real-Time Price

Table 3-51 shows the markup component, calculated using unadjusted offers, of average prices and of average monthly on-peak and off-peak prices. Table 3-52 shows the markup component, calculated using adjusted offers, of average prices and of average monthly on-peak and off-peak prices. In 2016, when using unadjusted cost offers, $0.40 per MWh of the PJM real-time load-weighted average LMP was attributable to markup. Using adjusted cost offers, $1.77 per MWh of the PJM real-time load-weighted average LMP was attributable to markup. In 2016, the peak markup component was highest in August, $3.34 per MWh using unadjusted cost offers and $4.47 per MWh using adjusted cost offers. This corresponds to 7.67 percent and 10.24 percent of the real-time peak load-weighted average LMP in August.

Table 3-51 Monthly markup components of real-time load-weighted LMP (Unadjusted): 2015 and 2016

	2015			2016		
	Markup Component (All Hours)	Off Peak Markup Component	Peak Markup Component	Markup Component (All Hours)	Off Peak Markup Component	Peak Markup Component
Jan	($1.42)	($2.62)	**($0.15)**	($1.65)	($1.56)	($1.74)
Feb	$4.62	$1.72	**$7.46**	($1.06)	($0.84)	($1.26)
Mar	$1.84	$1.82	**$1.86**	($0.35)	($1.22)	$0.42
Apr	($0.42)	($0.69)	**($0.18)**	$0.45	($0.90)	$1.74
May	($1.85)	($3.59)	**($0.01)**	($1.20)	($1.14)	($1.26)
Jun	($0.43)	($1.20)	**$0.21**	$0.81	$0.62	$0.97
Jul	($0.46)	($1.29)	**$0.21**	$0.22	($0.92)	$1.36
Aug	($0.90)	($0.96)	**($0.83)**	$1.92	$0.16	$3.34
Sep	($0.55)	($0.64)	**($0.47)**	$1.76	$1.46	$2.03
Oct	($0.13)	($0.35)	**$0.08**	$1.48	($0.05)	$2.99
Nov	$0.57	($0.42)	**$1.62**	$1.26	$0.28	$2.22
Dec	$0.38	($0.22)	**$0.95**	$1.06	($0.10)	$2.29
Total	$0.12	($0.72)	**$0.92**	$0.40	($0.37)	$1.14

Table 3-52 Monthly markup components of real-time load-weighted LMP (Adjusted): 2015 and 2016

	2015			2016		
	Markup Component (All Hours)	Off Peak Markup Component	Peak Markup Component	Markup Component (All Hours)	Off Peak Markup Component	Peak Markup Component
Jan	$0.61	($0.61)	$1.90	($0.01)	($0.13)	$0.12
Feb	$6.44	$3.57	$9.24	$0.53	$0.58	$0.48
Mar	$3.71	$3.69	$3.74	$0.97	$0.01	$1.82
Apr	$1.22	$0.72	$1.65	$2.08	$0.61	$3.50
May	($0.45)	($2.41)	$1.64	$0.27	($0.06)	$0.60
Jun	$1.18	$0.06	$2.10	$2.17	$1.65	$2.60
Jul	$1.17	$0.16	$1.97	$1.60	$0.35	$2.84
Aug	$0.65	$0.43	$0.86	$3.18	$1.59	$4.47
Sep	$0.86	$0.71	$1.00	$2.98	$2.66	$3.27
Oct	$1.43	$0.91	$1.91	$2.82	$1.37	$4.24
Nov	$2.06	$0.80	$3.39	$2.33	$1.28	$3.37
Dec	$1.79	$0.84	$2.68	$2.20	$1.14	$3.31
Total	$1.75	$0.75	$2.70	$1.77	$0.91	$2.59

Hourly Markup Component of Real-Time Prices

Figure 3-37 shows the markup contribution to the hourly load-weighted LMP using unadjusted cost offers in 2016 and 2015. Figure 3-38 shows the markup contribution to the hourly load-weighted LMP using adjusted cost offers in 2016 and 2015. In 2015, high markups were seen during the cold winter days observed in February and March. In contrast, the first six months of 2016 had low markups. Markups increased during the summer high demand days.

Figure 3-37 Markup contribution to real-time hourly load-weighted LMP (Unadjusted): 2015 and 2016

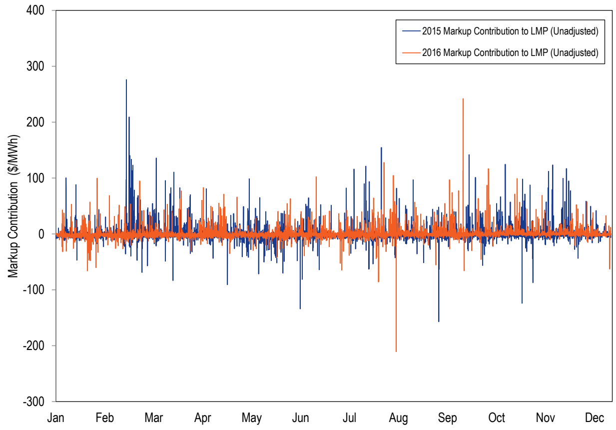
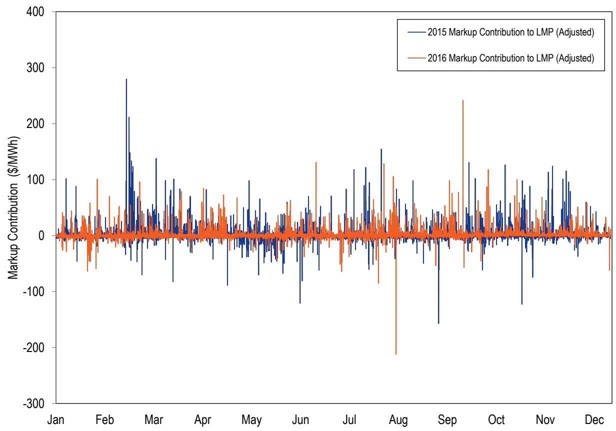


Figure 3-38 Markup contribution to real-time hourly load-weighted LMP (Adjusted): 2015 and 2016



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 2015 and 2016 in Table 3-53 and for adjusted offers in Table 3-54. The smallest zonal all hours average markup component using unadjusted offers in 2016 was in the BGE Zone, -$0.61 per MWh, while the highest was in the DPL Control Zone, $1.59 per MWh. The smallest zonal on peak average markup was in the Pepco Control Zone, $0.39 per MWh, while the highest was in the DPL Control Zone, $2.34 per MWh.

Table 3-53 Average real-time zonal markup component (Unadjusted): 2015 and 2016

	2015			2016		
	Markup Component (All Hours)	Off Peak Markup Component	Peak Markup Component	Markup Component (All Hours)	Off Peak Markup Component	Peak Markup Component
AECO	($0.62)	($1.32)	$0.05	$1.48	$0.69	$2.25
AEP	$0.04	($0.97)	$1.00	$0.07	($0.71)	$0.83
APS	$0.56	($0.31)	$1.41	$0.22	($0.60)	$1.03
ATSI	$0.03	($0.89)	$0.89	$0.28	($0.63)	$1.13
BGE	$1.64	$1.00	$2.26	($0.61)	($1.70)	$0.44
ComEd	($0.22)	($1.04)	$0.53	$0.26	($0.49)	$0.95
DAY	$0.10	($0.97)	$1.09	$0.05	($0.67)	$0.71
DEOK	($0.01)	($1.10)	$1.03	$0.09	($0.65)	$0.80
DLCO	($0.15)	($0.98)	$0.63	$0.43	($0.54)	$1.35
DPL	($0.67)	($1.11)	($0.25)	$1.59	$0.81	$2.34
Dominion	$0.79	$0.09	$1.46	($0.04)	($0.75)	$0.65
EKPC	$0.05	($1.16)	$1.27	$0.01	($0.47)	$0.50
JCPL	($0.60)	($1.24)	($0.02)	$1.50	$0.77	$2.16
Met-Ed	($0.52)	($1.22)	$0.13	$1.08	$0.57	$1.55
PECO	($0.61)	($1.26)	($0.00)	$1.38	$0.71	$2.02
PENELEC	$0.20	($0.77)	$1.11	$0.57	($0.20)	$1.29
PPL	($0.27)	($1.10)	$0.50	$1.24	$0.59	$1.86
PSEG	($0.19)	($1.10)	$0.63	$1.42	$0.69	$2.10
Pepco	$1.19	$0.36	$1.94	($0.35)	($1.13)	$0.39
RECO	$0.04	($1.28)	$1.17	$1.50	$0.62	$2.28

Table 3-54 Average real-time zonal markup component (Adjusted): 2015 and 2016

	2015			2016		
	Markup Component (All Hours)	Off Peak Markup Component	Peak Markup Component	Markup Component (All Hours)	Off Peak Markup Component	Peak Markup Component
AECO	$0.44	($0.32)	$1.16	$2.18	$1.38	$2.96
AEP	$1.78	$0.59	$2.93	$1.56	$0.67	$2.42
APS	$2.32	$1.28	$3.33	$1.74	$0.82	$2.64
ATSI	$1.76	$0.66	$2.79	$1.69	$0.71	$2.62
BGE	$4.13	$3.16	$5.06	$1.84	$0.65	$3.00
ComEd	$1.34	$0.33	$2.27	$1.64	$0.75	$2.46
DAY	$1.90	$0.60	$3.10	$1.56	$0.73	$2.32
DEOK	$1.75	$0.43	$3.00	$1.53	$0.71	$2.31
DLCO	$1.54	$0.53	$2.49	$1.80	$0.77	$2.79
DPL	$0.44	($0.05)	$0.92	$2.27	$1.49	$3.04
Dominion	$2.77	$1.89	$3.62	$1.76	$0.93	$2.58
EKPC	$1.77	$0.42	$3.14	$1.51	$0.92	$2.11
JCPL	$0.47	($0.24)	$1.10	$2.21	$1.43	$2.93
Met-Ed	$0.53	($0.24)	$1.25	$1.79	$1.21	$2.32
PECO	$0.42	($0.26)	$1.05	$2.05	$1.36	$2.71
PENELEC	$1.67	$0.57	$2.69	$1.70	$0.87	$2.48
PPL	$0.79	($0.09)	$1.61	$1.97	$1.25	$2.65
PSEG	$0.95	($0.03)	$1.85	$2.13	$1.35	$2.87
Pepco	$3.39	$2.29	$4.41	$1.70	$0.79	$2.56
RECO	$1.34	($0.05)	$2.52	$2.26	$1.31	$3.09

Markup by Real Time Price Levels

Table 3-55 shows 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 average LMP was in the identified price range.

Table 3-55 Average real-time markup component (By price category, unadjusted): 2015 and 2016

	2015		2016	
LMP Category	Average Markup Component	Frequency	Average Markup Component	Frequency
< $25	($0.14)	89.9%	$0.03	86.8%
$25 to $50	($0.01)	9.2%	$0.17	12.2%
$50 to $75	$0.11	0.6%	$0.12	0.7%
$75 to $100	$0.09	0.2%	$0.07	0.1%
$100 to $125	$0.02	0.1%	$0.03	0.0%
$125 to $150	$0.04	0.1%	$0.00	0.0%
>= $150	$0.01	0.0%	$0.01	0.0%

Table 3-56 Average real-time markup component (By price category, adjusted): 2015 and 2016

	2015		2016	
LMP Category	Average Markup Component	Frequency	Average Markup Component	Frequency
< $25	$1.32	89.9%	$1.26	86.8%
$25 to $50	$0.15	9.2%	$0.33	12.2%
$50 to $75	$0.12	0.6%	$0.12	0.7%
$75 to $100	$0.10	0.2%	$0.07	0.1%
$100 to $125	$0.02	0.1%	$0.03	0.0%
$125 to $150	$0.04	0.1%	$0.00	0.0%
>= $150	$0.01	0.0%	$0.00	0.0%

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 3-57. INC, DEC and up to congestion transactions have zero markups. INCs were 4.2 percent of marginal resources and DECs were 8.6 percent of marginal resources in 2016. The share of marginal up to congestion transactions decreased significantly beginning on September 8, 2014, as a result of the FERC's UTC uplift refund notice which became effective on September 8, 2014.[65] However, the share of marginal up to congestion transactions increased from 76.1 percent in 2015 to 82.4 percent in 2016 due to the expiration of the fifteen months resettlement period for the proceeding related to uplift charges for UTC transactions.

The adjusted markup of coal units is calculated as the difference between the price offer, and the cost offer excluding the 10 percent adder. Table 3-57 shows the markup component of LMP for marginal generating resources. Generating resources were only 4.7 percent of marginal resources in 2016. Using adjusted offers, the markup component of LMP for marginal generating resources increased for coal-fired steam units from a negative markup to a less negative markup and for gas-fired steam units from a negative markup to a small positive markup. The markup component of LMP for coal-fired steam units increased from -$1.28 in 2015 to -$1.11 in 2016 using unadjusted offers. The markup component of LMP for gas-fired steam units increased from -$0.38 in 2015 to $0.15 in 2016 using adjusted offers.

65 See 18 CFR § 385.213 (2014).

Table 3-57 Markup component of the annual PJM day-ahead, load-weighted, average LMP by primary fuel type and unit type: 2015 and 2016

		2015		2016	
Fuel Type	Unit Type	Markup Component of LMP (Unadjusted)	Markup Component of LMP (Adjusted)	Markup Component of LMP (Unadjusted)	Markup Component of LMP (Adjusted)
Coal	Steam	($1.28)	$0.04	($1.11)	$0.13
Gas	CT	$0.07	$0.07	$0.03	$0.03
Gas	Diesel	$0.01	$0.01	$0.00	$0.00
Gas	Steam	($0.38)	($0.38)	$0.15	$0.15
Municipal Waste	Steam	$0.00	$0.00	($0.12)	($0.12)
Oil	CT	$0.00	$0.00	$0.00	$0.00
Oil	Steam	$0.04	$0.04	($0.00)	($0.00)
Other	Steam	($0.00)	($0.00)	$0.00	$0.00
Wind	Wind	$0.05	$0.05	$0.02	$0.02
Total		($1.49)	($0.17)	($1.03)	$0.21

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 3-58 shows the markup component of average prices and of average monthly on-peak and off-peak prices using unadjusted offers. In 2016, when using unadjusted cost-based offers, -$1.03 per MWh of the PJM day-ahead load-weighted average LMP was attributable to markup. In 2016, the peak markup component was highest in July, $3.41 per MWh using unadjusted cost offers.

Table 3-58 Monthly markup components of day-ahead (Unadjusted), load-weighted LMP: 2015 and 2016

	2015			2016		
	Markup Component (All Hours)	Peak Markup Component	Off-Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off-Peak Markup Component
Jan	($2.10)	($1.38)	($2.79)	($2.40)	($1.94)	($2.80)
Feb	$1.15	$3.03	($0.78)	($1.94)	($2.11)	($1.77)
Mar	($1.34)	($1.41)	($1.27)	($3.16)	($3.19)	($3.14)
Apr	($2.15)	($1.84)	($2.51)	($1.21)	$0.21	($2.68)
May	($2.43)	($3.83)	($1.10)	($1.50)	($1.06)	($1.94)
Jun	($2.26)	($2.07)	($2.49)	($1.07)	($1.34)	($0.76)
Jul	($3.09)	($2.46)	($3.89)	$0.76	$3.41	($1.88)
Aug	($2.00)	($1.40)	($2.62)	($0.17)	$0.01	($0.40)
Sep	($0.88)	($0.35)	($1.49)	($1.53)	($0.82)	($2.33)
Oct	$0.93	$2.61	($0.91)	($0.22)	$0.26	($0.70)
Nov	($2.01)	($1.72)	($2.28)	($0.79)	($0.88)	($0.70)
Dec	($1.51)	($1.70)	($1.30)	$0.26	$0.89	($0.34)
Annual	($1.49)	($1.04)	($1.97)	($1.03)	($0.49)	($1.61)

Table 3-59 shows the markup component of average prices and of average monthly on-peak and off-peak prices using adjusted offers. In 2016, when using adjusted cost-based offers, $0.21 per MWh of the PJM day-ahead load-weighted average LMP was attributable to markup. In 2016, the peak markup component was highest in August, $5.65 per MWh using adjusted cost offers.

Table 3-59 Monthly markup components of day-ahead (Adjusted), load-weighted LMP: 2015 and 2016

	2015			2016		
	Markup Component (All Hours)	Peak Markup Component	Off-Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off-Peak Markup Component
Jan	($0.41)	$0.07	($0.86)	($1.01)	($0.64)	($1.34)
Feb	$2.58	$4.21	$0.90	($0.75)	($0.84)	($0.65)
Mar	$0.13	($0.05)	$0.32	($2.04)	($2.02)	($2.05)
Apr	($0.84)	($0.71)	($0.99)	($0.20)	$1.00	($1.44)
May	($0.85)	($2.03)	$0.28	($0.57)	($0.18)	($0.96)
Jun	($1.00)	($0.81)	($1.23)	($0.15)	($0.39)	$0.14
Jul	($1.88)	($1.18)	($2.77)	$1.71	$4.12	($0.69)
Aug	($0.79)	($0.16)	($1.44)	$3.42	$5.65	$0.62
Sep	$0.27	$0.77	($0.30)	($0.69)	($0.16)	($1.30)
Oct	$1.97	$3.32	$0.49	$0.63	$0.75	$0.50
Nov	($0.78)	($0.46)	($1.09)	$0.06	($0.19)	$0.32
Dec	($0.42)	($0.36)	($0.47)	$1.01	$1.35	$0.68
Annual	($0.17)	$0.22	($0.60)	$0.21	$0.88	($0.50)

Markup Component of Day-Ahead Zonal Prices

The markup component of annual average day-ahead price using unadjusted offers is shown for each zone in Table 3-60. The markup component of annual average day-ahead price using adjusted offers is shown for each zone in Table 3-61. Using unadjusted offers, the markup component of the average day-ahead price increased in all zones from 2015 to 2016 except BGE, ComEd, DLCO, EKPC and Pepco control zones. The smallest zonal all hours average markup component using adjusted offers for 2016 was in the ComEd Zone, -$0.56 per MWh, while the highest was in the BGE Control Zone, $1.35 per MWh. The smallest zonal on peak average markup using adjusted offers was in the ComEd Control Zone, -$0.71 per MWh, while the highest was in the DPL Control Zone, $2.92 per MWh.

Table 3-60 Day-ahead, average, zonal markup component (Unadjusted): 2015 and 2016

	2015			2016		
	Markup Component (All Hours)	Peak Markup Component	Off-Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off-Peak Markup Component
AECO	($2.19)	($1.94)	($2.45)	($0.55)	$0.45	($1.61)
AEP	($1.64)	($1.29)	($2.01)	($0.99)	($0.39)	($1.61)
AP	($1.33)	($0.93)	($1.75)	($0.91)	($0.17)	($1.68)
ATSI	($1.55)	($0.99)	($2.16)	($1.12)	($0.55)	($1.73)
BGE	($0.72)	($0.14)	($1.35)	($0.76)	($0.20)	($1.34)
ComEd	($1.43)	($0.83)	($2.09)	($1.63)	($1.72)	($1.54)
DAY	($1.62)	($1.02)	($2.26)	($1.34)	($1.06)	($1.64)
DEOK	($1.66)	($1.27)	($2.08)	($1.53)	($1.46)	($1.62)
DLCO	($1.41)	($0.67)	($2.22)	($1.76)	($1.83)	($1.67)
Dominion	($1.31)	($1.07)	($1.56)	($1.14)	($0.73)	($1.55)
DPL	($1.71)	($1.35)	($2.09)	$0.18	$1.97	($1.69)
EKPC	($1.41)	($0.89)	($1.94)	($1.45)	($1.34)	($1.56)
JCPL	($1.88)	($1.53)	($2.27)	($0.38)	$0.70	($1.59)
Met-Ed	($1.92)	($1.74)	($2.11)	($0.51)	$0.52	($1.63)
PECO	($1.81)	($1.38)	($2.26)	($1.36)	($1.09)	($1.65)
PENELEC	($1.34)	($0.80)	($1.92)	($0.91)	($0.15)	($1.69)
Pepco	($0.73)	$0.01	($1.53)	($0.88)	($0.03)	($1.78)
PPL	($1.75)	($1.40)	($2.12)	($0.59)	$0.41	($1.66)
PSEG	($1.72)	($1.23)	($2.28)	($0.53)	$0.50	($1.65)
RECO	($1.52)	($1.02)	($2.12)	($0.31)	$0.80	($1.57)

Table 3-61 Day-ahead, average, zonal markup component (Adjusted): 2015 and 2016

	2015			2016		
	Markup Component (All Hours)	Peak Markup Component	Off-Peak Markup Component	Markup Component (All Hours)	Peak Markup Component	Off-Peak Markup Component
AECO	($0.95)	($0.66)	($1.26)	$0.41	$1.56	($0.80)
AEP	($0.19)	$0.17	($0.56)	$0.33	$1.06	($0.43)
AP	($0.04)	$0.27	($0.36)	$0.41	$1.28	($0.49)
ATSI	($0.18)	$0.29	($0.69)	$0.07	$0.65	($0.57)
BGE	$0.64	$1.06	$0.18	$1.35	$2.64	($0.02)
ComEd	($0.12)	$0.43	($0.72)	($0.56)	($0.71)	($0.39)
DAY	($0.20)	$0.32	($0.76)	$0.05	$0.50	($0.44)
DEOK	($0.25)	$0.11	($0.63)	($0.01)	$0.36	($0.39)
DLCO	($0.14)	$0.47	($0.79)	($0.56)	($0.62)	($0.50)
Dominion	$0.10	$0.33	($0.16)	$0.25	$0.84	($0.36)
DPL	($0.59)	($0.29)	($0.90)	$1.09	$2.92	($0.82)
EKPC	($0.02)	$0.44	($0.49)	($0.29)	($0.23)	($0.36)
JCPL	($0.72)	($0.43)	($1.05)	$0.63	$1.84	($0.71)
Met-Ed	($0.78)	($0.65)	($0.93)	$0.40	$1.45	($0.74)
PECO	($0.69)	($0.32)	($1.10)	($0.49)	($0.22)	($0.77)
PENELEC	($0.16)	$0.23	($0.57)	$0.18	$0.97	($0.62)
Pepco	$0.63	$1.28	($0.08)	$1.06	$2.57	($0.51)
PPL	($0.57)	($0.25)	($0.93)	$0.32	$1.33	($0.75)
PSEG	($0.59)	($0.13)	($1.09)	$0.48	$1.61	($0.77)
RECO	($0.42)	$0.02	($0.93)	$0.75	$2.01	($0.68)

Markup by Day-Ahead Price Levels

Table 3-62 and Table 3-63 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 3-62 Average, day-ahead markup (By LMP category, unadjusted): 2015 and 2016

	2015		2016	
LMP Category	Average Markup Component	Frequency	Average Markup Component	Frequency
< $25	($2.55)	30.3%	($2.13)	49.1%
$25 to $50	($1.78)	59.9%	($1.10)	47.5%
$50 to $75	($0.58)	5.3%	$6.14	2.9%
$75 to $100	($0.66)	2.3%	$2.17	0.4%
$100 to $125	$1.62	1.1%	($9.87)	0.1%
$125 to $150	$8.99	0.5%	$0.00	0.0%
>= $150	$12.34	0.7%	$0.00	0.0%

Table 3-63 Average, day-ahead markup (By LMP category, adjusted): 2015 and 2016

	2015		2016	
LMP Category	Average Markup Component	Frequency	Average Markup Component	Frequency
< $25	($1.17)	30.3%	($0.79)	49.1%
$25 to $50	($0.21)	59.9%	($0.06)	47.5%
$50 to $75	$0.60	5.3%	$13.90	2.9%
$75 to $100	($0.06)	2.3%	$2.20	0.4%
$100 to $125	$2.26	1.1%	($4.39)	0.1%
$125 to $150	$9.64	0.5%	$0.00	0.0%
>= $150	$12.86	0.7%	$0.00	0.0%

Prices

The conduct 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.

Real-time and day-ahead energy market load-weighted prices were 19.2 percent and 19.2 percent lower in 2016 than in 2015 as a result of lower fuel costs and lower demand in 2016.

PJM real-time energy market prices decreased in 2016 compared to 2015. The average LMP was 1percent lower in 2016 than in 2015, $27.57 per MWh versus $33.39 per MWh. The load-weighted average LMP was 19.2 percent lower in 2016 than in 2015, $29.23 per MWh versus $36.16 per MWh. PJM real-time load-weighted energy market prices were lower in 2016 that at any time in PJM history since the beginning of the competitive wholesale market on April 1, 1999.

The fuel-cost adjusted, load-weighted, average LMP in 2016 was 1.7 percent higher than the load-weighted, average LMP for 2016. If fuel and emission costs in 2016 had been the same as in 2015, holding everything else constant, the load-weighted LMP would have been slightly higher, $29.72 per MWh instead of the observed $29.23 per MWh.

PJM day-ahead energy market prices decreased in 2016 compared to 2015. The average LMP was 17.7 percent lower in 2016 than in 2015, $28.10 per MWh versus $34.12 per MWh. The day-ahead load-weighted average

LMP was 19.2 percent lower in 2016 than in 2015, $29.68 per MWh versus $36.73 per MWh. PJM day-ahead load-weighted energy market prices were lower in 2016 that at any time in PJM history since the introduction of the PJM Day-Ahead Energy Market in June 2000.

Occasionally, in a constrained market, the LMPs at some pricing nodes can exceed the offer price of the highest cleared generator in the supply stack.[66] 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.[67]

Real-Time LMP

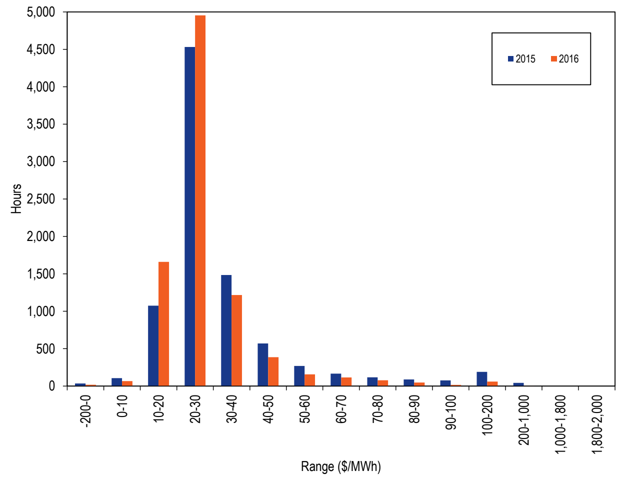
Real-time average LMP is the hourly average LMP for the PJM Real-Time Energy Market.[68]

Real-Time Average LMP

PJM Real-Time Average LMP Duration

Figure 3-39 shows the hourly distribution of PJM real-time average LMP for 2015 and 2016.

Figure 3-39 Average LMP for the PJM Real-Time Energy Market: 2015 and 2016



PJM Real-Time, Average LMP

Table 3-64 shows the PJM real-time, average LMP for each year from 1998 through 2016.[69]

Table 3-64 PJM real-time, average LMP (Dollars per MWh): 1998 through 2016

	Real-Time LMP			Year-to-Year Change		
	Average	Median	Standard Deviation	Average	Median	Standard Deviation
1998	$21.72	$16.60	$31.45	NA	NA	NA
1999	$28.32	$17.88	$72.42	30.4%	7.7%	130.3%
2000	$28.14	$19.11	$25.69	(0.6%)	6.9%	(64.5%)
2001	$32.38	$22.98	$45.03	15.1%	20.3%	75.3%
2002	$28.30	$21.08	$22.41	(12.6%)	(8.3%)	(50.2%)
2003	$38.28	$30.79	$24.71	35.2%	46.1%	10.3%
2004	$42.40	$38.30	$21.12	10.8%	24.4%	(14.5%)
2005	$58.08	$47.18	$35.91	37.0%	23.2%	70.0%
2006	$49.27	$41.45	$32.71	(15.2%)	(12.1%)	(8.9%)
2007	$57.58	$49.92	$34.60	16.9%	20.4%	5.8%
2008	$66.40	$55.53	$38.62	15.3%	11.2%	11.6%
2009	$37.08	$32.71	$17.12	(44.1%)	(41.1%)	(55.7%)
2010	$44.83	$36.88	$26.20	20.9%	12.7%	53.1%
2011	$42.84	$35.38	$29.03	(4.4%)	(4.1%)	10.8%
2012	$33.11	$29.53	$20.67	(22.7%)	(16.5%)	(28.8%)
2013	$36.55	$32.25	$20.57	10.4%	9.2%	(0.5%)
2014	$48.22	$34.46	$65.08	31.9%	6.8%	216.4%
2015	$33.39	$26.61	$27.80	(30.7%)	(22.8%)	(57.3%)
2016	$27.57	$24.10	$14.76	(17.4%)	(9.4%)	(46.9%)

66 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): pp 19-27.

67 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, 153 FERC ¶ 61,289 (2015).

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

69 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.

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. The real-time, load-weighted, average LMP decreased by 19.2 percent compared to 2015.

PJM Real-Time, Load-Weighted, Average LMP

Table 3-65 shows the PJM real-time, load-weighted, average LMP in 1998 through 2016.

Table 3-65 PJM real-time, load-weighted, average LMP (Dollars per MWh): 1998 through 2016

	Real-Time, Load-Weighted, Average LMP			Year-to-Year Change		
	Average	Median	Standard Deviation	Average	Median	Standard Deviation
1998	$24.16	$17.60	$39.29	NA	NA	NA
1999	$34.07	$19.02	$91.49	41.0%	8.1%	132.8%
2000	$30.72	$20.51	$28.38	(9.8%)	7.9%	(69.0%)
2001	$36.65	$25.08	$57.26	19.3%	22.3%	101.8%
2002	$31.60	$23.40	$26.75	(13.8%)	(6.7%)	(53.3%)
2003	$41.23	$34.96	$25.40	30.5%	49.4%	(5.0%)
2004	$44.34	$40.16	$21.25	7.5%	14.9%	(16.3%)
2005	$63.46	$52.93	$38.10	43.1%	31.8%	79.3%
2006	$53.35	$44.40	$37.81	(15.9%)	(16.1%)	(0.7%)
2007	$61.66	$54.66	$36.94	15.6%	23.1%	(2.3%)
2008	$71.13	$59.54	$40.97	15.4%	8.9%	10.9%
2009	$39.05	$34.23	$18.21	(45.1%)	(42.5%)	(55.6%)
2010	$48.35	$39.13	$28.90	23.8%	14.3%	58.7%
2011	$45.94	$36.54	$33.47	(5.0%)	(6.6%)	15.8%
2012	$35.23	$30.43	$23.66	(23.3%)	(16.7%)	(29.3%)
2013	$38.66	$33.25	$23.78	9.7%	9.3%	0.5%
2014	$53.14	$36.20	$76.20	37.4%	8.9%	220.4%
2015	$36.16	$27.66	$31.06	(31.9%)	(23.6%)	(59.2%)
2016	$29.23	$25.01	$16.12	(19.2%)	(9.6%)	(48.1%)

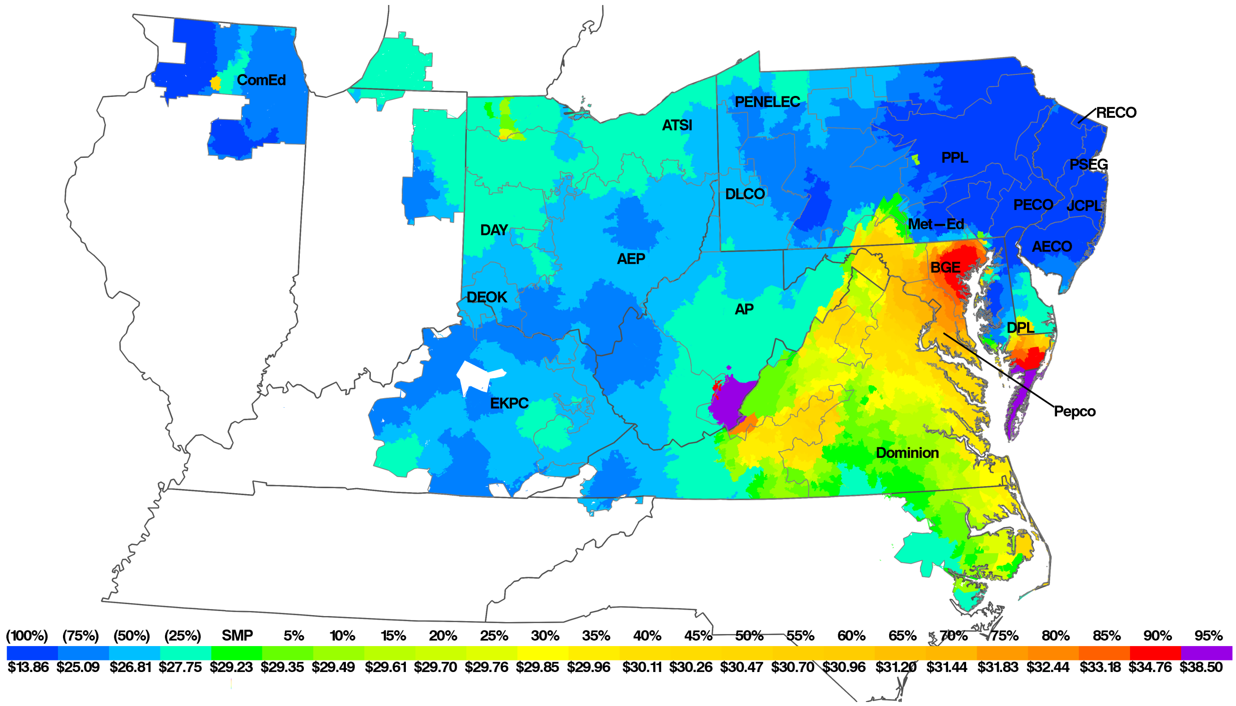
Table 3-66 shows zonal real-time, and real-time, load-weighted, average LMP in 2015 and 2016.

Table 3-66 Zone real-time and real-time, load-weighted, average LMP (Dollars per MWh): 2015 and 2016

	Real-Time Average LMP			Real-Time, Load-Weighted, Average LMP		
Zone	2015	2016	Percent Change	2015	2016	Percent Change
AECO	$32.86	$24.42	(25.7%)	$35.85	$26.93	(24.9%)
AEP	$31.76	$27.82	(12.4%)	$33.90	$29.14	(14.1%)
AP	$34.78	$28.25	(18.8%)	$38.04	$29.75	(21.8%)
ATSI	$32.10	$28.19	(12.2%)	$34.00	$29.78	(12.4%)
BGE	$42.84	$36.07	(15.8%)	$47.22	$38.62	(18.2%)
ComEd	$28.21	$26.05	(7.7%)	$29.85	$27.66	(7.3%)
Day	$32.11	$27.90	(13.1%)	$34.20	$29.36	(14.2%)
DEOK	$31.19	$27.12	(13.1%)	$33.28	$28.62	(14.0%)
DLCO	$30.45	$27.51	(9.6%)	$32.21	$29.20	(9.3%)
Dominion	$37.24	$30.27	(18.7%)	$41.42	$32.15	(22.4%)
DPL	$36.79	$26.65	(27.6%)	$42.27	$29.66	(29.8%)
EKPC	$30.10	$26.79	(11.0%)	$32.93	$28.21	(14.3%)
JCPL	$32.36	$23.86	(26.3%)	$35.65	$26.36	(26.1%)
Met-Ed	$32.17	$24.13	(25.0%)	$35.79	$26.04	(27.2%)
PECO	$31.80	$23.52	(26.0%)	$35.11	$25.57	(27.2%)
PENELEC	$33.47	$26.28	(21.5%)	$36.13	$27.57	(23.7%)
Pepco	$39.21	$32.16	(18.0%)	$43.04	$34.12	(20.7%)
PPL	$31.93	$23.77	(25.6%)	$35.95	$25.43	(29.3%)
PSEG	$34.38	$24.25	(29.5%)	$36.97	$26.24	(29.0%)
RECO	$35.02	$24.54	(29.9%)	$37.58	$27.05	(28.0%)
PJM	$33.39	$27.57	(17.4%)	$36.16	$29.23	(19.2%)

Figure 3-40 is a contour map of the real-time, load-weighted, average LMP in 2016. 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. The LMP for each five percent increment is the highest nodal average LMP for that set of nodes. Each increment to the left of the SMP is the lowest nodal average LMP for that set of nodes.

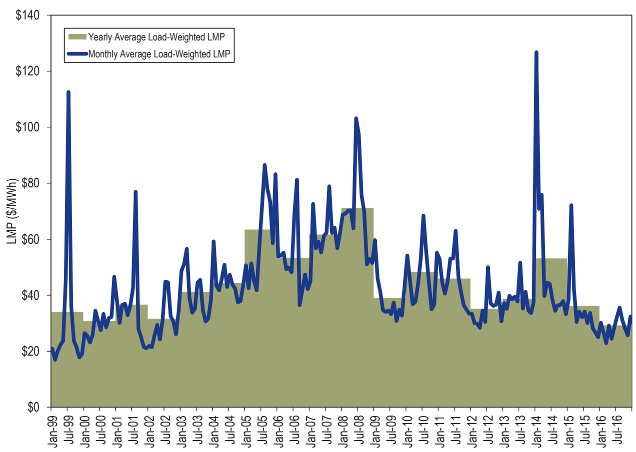
Figure 3-40 PJM real-time, load-weighted, average LMP: 2016



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

Figure 3-41 shows the PJM real-time monthly and annual load-weighted LMP in 1999 through 2016. PJM real-time monthly load-weighted average LMP in March 2016 was $22.90, which is the lowest real-time monthly load-weighted average LMP since February 2002 at $21.39.

Figure 3-41 PJM real-time, monthly and annual, load-weighted, average LMP: 1999 through 2016



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

Figure 3-42 shows the PJM real-time monthly load-weighted average LMP and inflation adjusted monthly load-weighted average LMP for 1998 through 2016.[70] PJM real-time inflation adjusted monthly load-weighted average LMP in March 2016 was $15.54, which is the lowest real-time monthly load-weighted average real LMP observed since PJM real-time markets started on April 1, 1999. Table 3-67 shows the PJM real-time yearly load- weighted average LMP and inflation adjusted yearly load-weighted average LMP for 1998 through 2016.

Figure 3-42 PJM real-time, monthly, load-weighted, average LMP and real-time, monthly inflation adjusted load-weighted, average LMP: 1998 through 2016

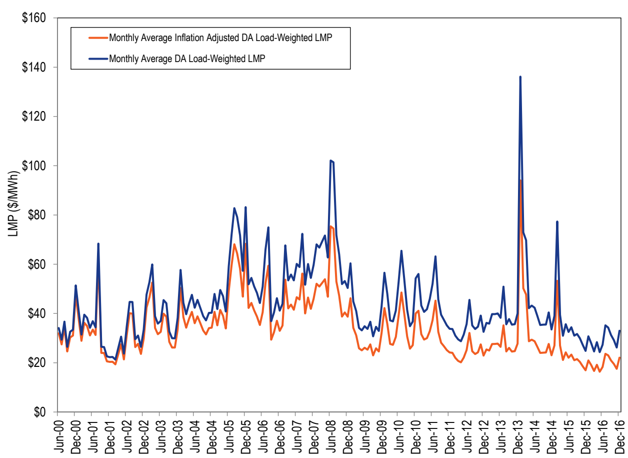


Table 3-67 PJM real-time, yearly, load-weighted, average LMP and real-time, yearly inflation adjusted load-weighted, average LMP: 1998 through 2016

Year	Load-Weighted, Average LMP	Inflation Adjusted Load-Weighted, Average LMP
1998	$24.16	$23.94
1999	$34.07	$33.04
2000	$30.72	$28.80
2001	$36.65	$33.45
2002	$31.60	$28.35
2003	$41.23	$36.24
2004	$44.34	$37.91
2005	$63.46	$52.37
2006	$53.35	$42.73
2007	$61.66	$48.06
2008	$71.13	$53.27
2009	$39.05	$29.46
2010	$48.35	$35.83
2011	$45.94	$33.01
2012	$35.23	$24.80
2013	$38.66	$26.82
2014	$53.14	$36.37
2015	$36.16	$24.69
2016	$29.23	$19.68

Fuel Price Trends and LMP

Changes in LMP can result from 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 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 are another contributor to changes in the marginal cost of marginal units. Natural gas prices decreased in 2016 and coal prices decreased or remained constant. Comparing fuel prices in 2016 to 2015, the price of Northern Appalachian coal was 10.1 percent lower; the price of Central Appalachian coal was 0.1 percent higher; the price of Powder River Basin coal was 5.1 percent lower; the price of eastern natural gas was 35.6 percent lower; and the price of western natural gas was 4.2 percent lower. Figure 3-43 shows monthly average spot fuel prices.[71]

70 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> (January27, 2017)

71 Eastern natural gas consists of the average of Texas 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 Citygate daily fuel price 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 3-43 Spot average fuel price comparison with fuel delivery charges: 2012 through 2016 ($/MMBtu)

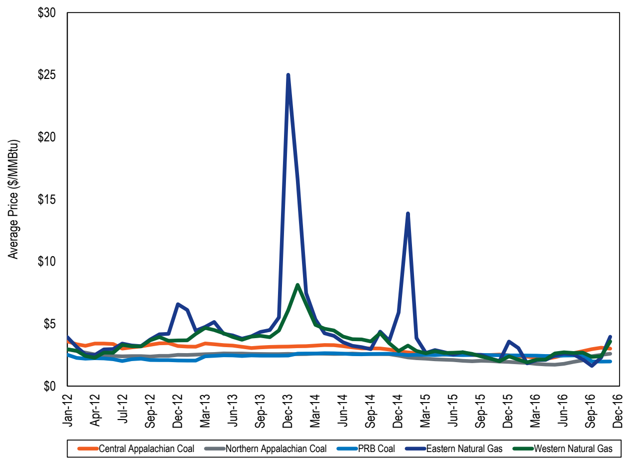


Table 3-68 compares the 2016 PJM real-time fuel-cost adjusted, load-weighted, average LMP to 2016 load-weighted, average LMP.[72] The real-time fuel-cost adjusted, load-weighted, average LMP for 2016 was 1.7 percent higher than the real-time load-weighted, average LMP for 2016. The real-time, fuel-cost adjusted, load-weighted, average LMP for 2016 was 17.8 percent lower than the real-time load-weighted LMP for 2015. If fuel and emissions costs in 2016 had been the same as in 2015, holding everything else constant, the real-time load-weighted LMP in 2016 would have been slightly higher, $29.72 per MWh, than the observed $29.23 per MWh.

Table 3-68 PJM real-time annual, fuel-cost adjusted, load-weighted average LMP (Dollars per MWh): year over year

	2016 Load-Weighted LMP	2016 Fuel-Cost Adjusted, Load-Weighted LMP	Change
Average	$29.23	$29.72	1.7%
	2015 Load-Weighted LMP	2016 Fuel-Cost Adjusted, Load-Weighted LMP	Change
Average	$36.16	$29.72	(17.8%)
	2015 Load-Weighted LMP	2016 Load-Weighted LMP	Change
Average	$36.16	$29.23	(19.2%)

Table 3-69 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 2016. Table 3-69 shows that slightly lower coal and natural gas prices explain almost all of the fuel-cost related decrease in the real-time annual load-weighted average LMP in 2016.

Table 3-69 Change in PJM real-time annual, fuel-cost adjusted, load-weighted average LMP (Dollars per MWh) by fuel type: year over year

Fuel Type	Share of Change in Fuel Cost Adjusted, Load Weighted LMP	Percent
Coal	($0.19)	38.2%
Gas	($0.28)	57.2%
Municipal Waste	$0.00	0.0%
Oil	($0.02)	4.4%
Other	$0.00	(0.0%)
Uranium	($0.00)	0.0%
Wind	$0.00	(0.0%)
Total	($0.49)	100.0%

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 five minute ahead forecasts of system conditions. Those offers can be decomposed into components including fuel costs, emission costs, variable operation and maintenance 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, SO_2 and CO_2 emission credits, emission rates for NO_x, emission rates for SO_2 and emission rates for CO_2. The CO_2 emission costs are applicable to PJM units in the PJM states that participate in RGGI: Delaware and Maryland.[73] 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 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

72 The fuel-cost adjusted LMP reflects both the fuel and emissions where applicable, including NO_x, CO_2 and SO_x costs.

73 New Jersey withdrew from RGGI, effective January 1, 2012.

resource in the energy market, this opportunity cost will contribute to LMP. In addition, in periods when generators providing energy cannot meet the reserve requirements, PJM can invoke shortage pricing. PJM invoked shortage pricing on January 6 and January 7 of 2014.[74] During the 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 3-72 shows the frequency and average shadow price of transmission constraints in PJM. In 2016, there were 205,243 transmission constraints in the real time market with a non-zero shadow price. For nearly 10 percent of these transmission constraints, the line limit was violated, meaning that the flow exceeded the facility limit.[75] In 2016, the average shadow price of transmission constraints when the line limit was violated was nearly five times higher than when transmission constraint was binding at its limit.

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. But rather than permit the transmission penalty factor to set the shadow price when line limits are violated, PJM uses a procedure called constraint relaxation logic to prevent the penalty factors from directly setting the shadow price of the constraint. The result is that the transmission penalty factor does not directly set the shadow price. The details of PJM's logic and practice are not entirely clear. But in 2016, for all transmission constraints for which the penalty factor was greater than or equal to $2,000 per MWh, 41 percent of the constraints' shadow prices were within ten percent of the penalty factor.

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.

The components of LMP are shown in Table 3-70, including markup using unadjusted cost offers.[76] Table 3-70 shows that in 2016, 45.4 percent of the load-weighted LMP was the result of coal costs, 27.2 percent was the result of gas costs and 1.89 percent was the result of the cost of emission allowances. Using adjusted cost offers, markup was 6.1 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. Occasionally, PJM fails 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 cumulative effect of excluding those five-minute intervals is the component NA. In 2016, nearly 14.9 percent of all five-minute intervals had insufficient data. The percent column is the difference in the proportion of LMP represented by each component between 2016 and 2015.

74 PJM triggered shortage pricing on January 6, 2015, following a RTO-wide voltage reduction action. PJM triggered shortage pricing on January 7, 2014, due to a RTO-wide shortage of synchronized reserve.

75 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.

76 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 3-70 Components of PJM real-time (Unadjusted), load-weighted, average LMP: 2015 and 2016

	2015		2016		
Element	Contribution to LMP	Percent	Contribution to LMP	Percent	Change Percent
Coal	$15.62	43.2%	$13.28	45.4%	2.2%
Gas	$9.85	27.2%	$7.96	27.2%	(0.0%)
Ten Percent Adder	$3.02	8.4%	$2.43	8.3%	(0.0%)
VOM	$2.38	6.6%	$2.04	7.0%	0.4%
NA	$0.89	2.4%	$1.23	4.2%	1.8%
NO_x Cost	$0.29	0.8%	$0.42	1.4%	0.6%
Markup	$0.12	0.3%	$0.40	1.4%	1.0%
Increase Generation Adder	$0.24	0.7%	$0.35	1.2%	0.5%
Ancillary Service Redispatch Cost	$1.06	2.9%	$0.33	1.1%	(1.8%)
LPA Rounding Difference	$0.94	2.6%	$0.29	1.0%	(1.6%)
Oil	$1.25	3.5%	$0.29	1.0%	(2.5%)
Other	$0.15	0.4%	$0.14	0.5%	0.1%
SO_2 Cost	$0.35	1.0%	$0.07	0.3%	(0.7%)
CO_2 Cost	$0.21	0.6%	$0.06	0.2%	(0.4%)
Market-to-Market Adder	$0.01	0.0%	$0.01	0.0%	(0.0%)
Uranium	($0.00)	(0.0%)	$0.00	0.0%	0.0%
FMU Adder	$0.00	0.0%	$0.00	0.0%	(0.0%)
Municipal Waste	$0.01	0.0%	$0.00	0.0%	(0.0%)
Constraint Violation Adder	($0.00)	(0.0%)	$0.00	0.0%	0.0%
LPA-SCED Differential	($0.11)	(0.3%)	($0.01)	(0.0%)	0.3%
Decrease Generation Adder	($0.06)	(0.2%)	($0.03)	(0.1%)	0.1%
Wind	($0.07)	(0.2%)	($0.05)	(0.2%)	0.0%
Total	$36.16	100.0%	$29.23	100.0%	0.0%

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 3-70 and Table 3-77), markup is simply the difference between the price offer and the cost offer (unadjusted markup). In the second approach (Table 3-71 and Table 3-78), the 10 percent markup is removed from the cost offers of coal units (adjusted markup).

The components of LMP are shown in Table 3-71, including markup using adjusted cost offers.

Table 3-71 Components of PJM real-time (Adjusted), load-weighted, average LMP: 2015 and 2016

	2015		2016		
Element	Contribution to LMP	Percent	Contribution to LMP	Percent	Change Percent
Coal	$15.62	43.2%	$13.28	45.4%	2.2%
Gas	$9.85	27.2%	$7.96	27.2%	(0.0%)
VOM	$2.38	6.6%	$2.04	7.0%	0.4%
Markup	$1.75	4.8%	$1.77	6.1%	1.2%
NA	$0.89	2.4%	$1.23	4.2%	1.8%
Ten Percent Adder	$1.40	3.9%	$1.06	3.6%	(0.2%)
NO_x Cost	$0.29	0.8%	$0.42	1.4%	0.6%
Increase Generation Adder	$0.24	0.7%	$0.35	1.2%	0.5%
Ancillary Service Redispatch Cost	$1.06	2.9%	$0.33	1.1%	(1.8%)
LPA Rounding Difference	$0.94	2.6%	$0.29	1.0%	(1.6%)
Oil	$1.25	3.5%	$0.29	1.0%	(2.5%)
Other	$0.15	0.4%	$0.14	0.5%	0.1%
SO_2 Cost	$0.35	1.0%	$0.07	0.3%	(0.7%)
CO_2 Cost	$0.21	0.6%	$0.06	0.2%	(0.4%)
Market-to-Market Adder	$0.01	0.0%	$0.01	0.0%	(0.0%)
Uranium	($0.00)	(0.0%)	$0.00	0.0%	0.0%
FMU Adder	$0.00	0.0%	$0.00	0.0%	(0.0%)
Municipal Waste	$0.01	0.0%	$0.00	0.0%	(0.0%)
Constraint Violation Adder	($0.00)	(0.0%)	$0.00	0.0%	0.0%
LPA-SCED Differential	($0.11)	(0.3%)	($0.01)	(0.0%)	0.3%
Decrease Generation Adder	($0.06)	(0.2%)	($0.03)	(0.1%)	0.1%
Wind	($0.07)	(0.2%)	($0.05)	(0.2%)	0.0%
Total	$36.16	100.0%	$29.23	100.0%	0.0%

Table 3-72 Frequency and average shadow price of transmission constraints in PJM: 2015 and 2016

	Frequency		Average Shadow Price	
Description	2015	2016	2015	2016
PJM Internal Binding Transmission Constraints	140,545	130,855	$159.27	$120.13
PJM Internal Violated Transmission Constraints	20,255	19,536	$957.49	$643.04
Market to Market Transmission Constraints	51,683	54,852	$281.89	$264.34
All Transmission Constraints	212,483	205,243	$265.19	$208.44

Day-Ahead LMP

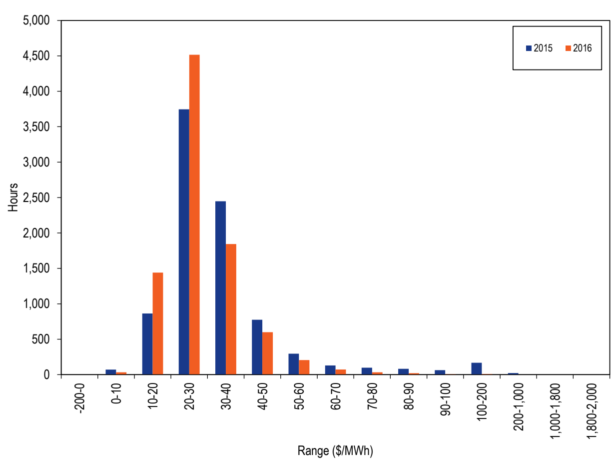
Day-ahead average LMP is the hourly average LMP for the PJM Day-Ahead Energy Market.[77]

Day-Ahead Average LMP

PJM Day-Ahead Average LMP Duration

Figure 3-44 shows the hourly distribution of PJM day-ahead average LMP in 2015 and 2016.

Figure 3-44 Average LMP for the PJM Day-Ahead Energy Market: 2015 and 2016



PJM Day-Ahead, Average LMP

Table 3-73 shows the PJM day-ahead, average LMP in each year of the 16-year period 2001 through 2016.

Table 3-73 PJM day-ahead, average LMP (Dollars per MWh): 2001 through 2016

	Day-Ahead LMP			Year-to-Year Change		
	Average	Median	Standard Deviation	Average	Median	Standard Deviation
2001	$32.75	$27.05	$30.42	NA	NA	NA
2002	$28.46	$23.28	$17.68	(13.1%)	(14.0%)	(41.9%)
2003	$38.73	$35.22	$20.84	36.1%	51.3%	17.8%
2004	$41.43	$40.36	$16.60	7.0%	14.6%	(20.4%)
2005	$57.89	$50.08	$30.04	39.7%	24.1%	81.0%
2006	$48.10	$44.21	$23.42	(16.9%)	(11.7%)	(22.0%)
2007	$54.67	$52.34	$23.99	13.7%	18.4%	2.4%
2008	$66.12	$58.93	$30.87	20.9%	12.6%	28.7%
2009	$37.00	$35.16	$13.39	(44.0%)	(40.3%)	(56.6%)
2010	$44.57	$39.97	$18.83	20.5%	13.7%	40.6%
2011	$42.52	$38.13	$20.48	(4.6%)	(4.6%)	8.8%
2012	$32.79	$30.89	$13.27	(22.9%)	(19.0%)	(35.2%)
2013	$37.15	$34.63	$15.46	13.3%	12.1%	16.5%
2014	$49.15	$38.10	$51.88	32.3%	10.0%	235.6%
2015	$34.12	$29.09	$22.59	(30.6%)	(23.7%)	(56.5%)
2016	$28.10	$25.76	$10.68	(17.7%)	(11.4%)	(52.7%)

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 3-74 shows the PJM day-ahead, load-weighted, average LMP in each year of the 16-year period 2001 through 2016.

77 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>.

Table 3-74 PJM day-ahead, load-weighted, average LMP (Dollars per MWh): 2001 through 2016

	Day-Ahead, Load-Weighted, Average LMP			Year-to-Year Change		
	Average	Median	Standard Deviation	Average	Median	Standard Deviation
2001	$36.01	$29.02	$37.48	NA	NA	NA
2002	$31.80	$26.00	$20.68	(11.7%)	(10.4%)	(44.8%)
2003	$41.43	$38.29	$21.32	30.3%	47.3%	3.1%
2004	$42.87	$41.96	$16.32	3.5%	9.6%	(23.4%)
2005	$62.50	$54.74	$31.72	45.8%	30.4%	94.3%
2006	$51.33	$46.72	$26.45	(17.9%)	(14.6%)	(16.6%)
2007	$57.88	$55.91	$25.02	12.8%	19.7%	(5.4%)
2008	$70.25	$62.91	$33.14	21.4%	12.5%	32.4%
2009	$38.82	$36.67	$14.03	(44.7%)	(41.7%)	(57.7%)
2010	$47.65	$42.06	$20.59	22.7%	14.7%	46.8%
2011	$45.19	$39.66	$24.05	(5.2%)	(5.7%)	16.8%
2012	$34.55	$31.84	$15.48	(23.5%)	(19.7%)	(35.6%)
2013	$38.93	$35.77	$18.05	12.7%	12.3%	16.6%
2014	$53.62	$39.84	$59.62	37.8%	11.4%	230.4%
2015	$36.73	$30.60	$25.46	(31.5%)	(23.2%)	(57.3%)
2016	$29.68	$27.00	$11.64	(19.2%)	(11.8%)	(54.3%)

Table 3-75 shows zonal day-ahead, and day-ahead, load-weighted, average LMP in 2015 and 2016.

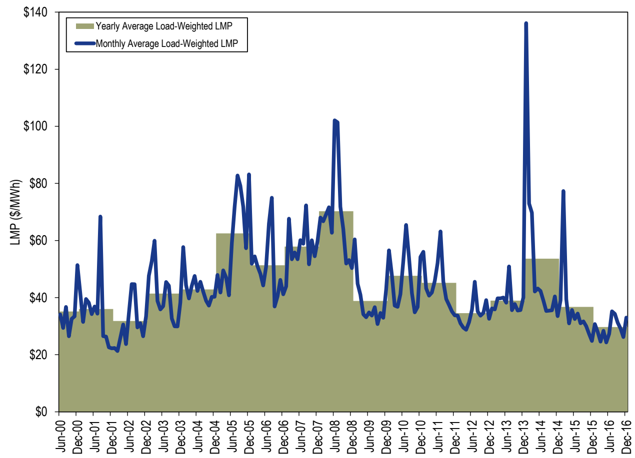
Table 3-75 Zone day-ahead and day-ahead, load-weighted, average LMP (Dollars per MWh): 2015 and 2016

	Day-Ahead Average LMP			Day-Ahead, Load-Weighted, Average LMP		
Zone	2015	2016	Percent Change	2015	2016	Percent Change
AECO	$33.98	$24.91	(26.7%)	$36.86	$27.48	(25.4%)
AEP	$32.21	$28.19	(12.5%)	$34.20	$29.46	(13.8%)
AP	$35.01	$28.79	(17.8%)	$37.95	$30.18	(20.5%)
ATSI	$32.63	$28.35	(13.1%)	$34.34	$29.77	(13.3%)
BGE	$43.73	$36.77	(15.9%)	$47.92	$39.59	(17.4%)
ComEd	$28.01	$26.49	(5.4%)	$29.45	$28.00	(4.9%)
Day	$32.45	$28.33	(12.7%)	$34.39	$29.67	(13.7%)
DEOK	$31.82	$27.78	(12.7%)	$33.90	$29.30	(13.6%)
DLCO	$30.94	$27.62	(10.7%)	$32.57	$29.12	(10.6%)
Dominion	$38.67	$31.08	(19.6%)	$43.09	$33.02	(23.4%)
DPL	$37.48	$27.93	(25.5%)	$42.28	$31.00	(26.7%)
EKPC	$30.61	$27.17	(11.3%)	$33.42	$28.62	(14.4%)
JCPL	$33.80	$24.30	(28.1%)	$36.86	$26.52	(28.1%)
Met-Ed	$32.94	$24.68	(25.1%)	$35.82	$26.22	(26.8%)
PECO	$33.13	$24.01	(27.5%)	$35.96	$25.90	(28.0%)
PENELEC	$33.65	$26.77	(20.4%)	$35.90	$27.86	(22.4%)
Pepco	$40.81	$33.08	(18.9%)	$44.38	$34.95	(21.2%)
PPL	$33.01	$24.24	(26.6%)	$36.62	$25.68	(29.9%)
PSEG	$35.17	$24.87	(29.3%)	$37.82	$26.83	(29.1%)
RECO	$35.37	$25.00	(29.3%)	$38.10	$27.28	(28.4%)
PJM	$34.12	$28.10	(17.7%)	$36.73	$29.68	(19.2%)

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

Figure 3-45 shows the PJM day-ahead, monthly and annual, load-weighted LMP from June 2000 through December 2016.[78] The PJM day-ahead monthly load-weighted average LMP in May 2016 was $24.32, which is the lowest day-ahead monthly load-weighted average since May 2002 at $23.74.

Figure 3-45 Day-ahead, monthly and annual, load-weighted, average LMP: June 2000 through 2016



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

Figure 3-48 shows the PJM day-ahead monthly load-weighted average LMP and inflation adjusted monthly day-ahead load-weighted average LMP for June 2000 through December 2016.[79] The PJM day-ahead inflation adjusted monthly load-weighted average LMP in May 2016 was $16.36, which is the lowest day-ahead monthly load-weighted average real LMP observed since PJM day-ahead markets started in 2000. Table 3-76 shows the PJM day-ahead yearly load- weighted average LMP and inflation adjusted yearly load-weighted average LMP for 2000 through 2016.

78 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 six months of that year.

79 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>.(January 27, 2017).

Figure 3-46 PJM day-ahead, monthly, load-weighted, average LMP and day-ahead, monthly inflation adjusted load-weighted, average LMP: June 2000 through 2016

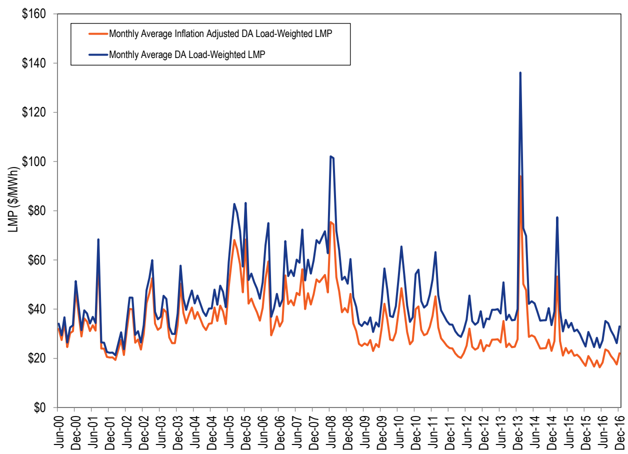


Table 3-76 PJM day-ahead, yearly, load-weighted, average LMP and day-ahead, yearly inflation adjusted load-weighted, average LMP: 2000 through 2016

Year	Load-Weighted, Average LMP	Inflation Adjusted Load-Weighted, Average LMP
2000	$35.13	$32.74
2001	$36.01	$32.87
2002	$31.80	$28.53
2003	$41.43	$36.42
2004	$42.87	$36.65
2005	$62.50	$51.58
2006	$51.33	$41.12
2007	$57.88	$45.11
2008	$70.25	$52.61
2009	$38.82	$29.29
2010	$47.65	$35.32
2011	$45.19	$32.48
2012	$34.55	$24.33
2013	$38.93	$27.00
2014	$53.62	$36.71
2015	$36.73	$25.08
2016	$29.68	$19.98

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, FMU adder, 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.

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, SO_2 and CO_2 emission credits, emission rates for NO_X, emission rates for SO_2 and emission rates for CO_2. CO_2 emission costs are applicable to PJM units in the PJM states that participate in RGGI: Delaware and Maryland.[80] Day-ahead scheduling reserve (DASR) lost opportunity cost (LOC) and DASR offer adders are the calculated contribution to LMP when redispatch of resources is needed in order to satisfy DASR requirements. 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 cost.

Table 3-77 shows the components of the PJM day-ahead, annual, load-weighted average LMP. In 2016, 36.4 percent of the load-weighted LMP was the result of coal cost, 11.0 percent of the load-weighted LMP was the result of gas cost, 2.2 percent was the result of the up to congestion transaction cost, 26.7 percent was the result of DEC bid cost and 1.9 percent was the result of INC bid cost.

80 New Jersey withdrew from RGGI, effective January 1, 2012.

Table 3-77 Components of PJM day-ahead, (unadjusted), load-weighted, average LMP (Dollars per MWh): 2015 and 2016

	2015		2016		
Element	Contribution to LMP	Percent	Contribution to LMP	Percent	Change Percent
Coal	$11.63	31.7%	$10.81	36.4%	4.8%
DEC	$8.27	22.5%	$7.92	26.7%	4.2%
Gas	$6.42	17.5%	$3.28	11.0%	(6.4%)
DASR LOC Adder	$0.28	0.7%	$2.06	6.9%	6.2%
Ten Percent Cost Adder	$2.04	5.6%	$1.63	5.5%	(0.1%)
Dispatchable Transaction	$1.05	2.9%	$1.61	5.4%	2.6%
VOM	$1.64	4.5%	$1.31	4.4%	(0.1%)
Up to Congestion Transaction	$1.56	4.3%	$0.65	2.2%	(2.1%)
INC	$4.27	11.6%	$0.57	1.9%	(9.7%)
CO_2	$0.10	0.3%	$0.29	1.0%	0.7%
NO_x	$0.19	0.5%	$0.28	1.0%	0.4%
Oil	$0.23	0.6%	$0.12	0.4%	(0.2%)
Municipal Waste	$0.00	0.0%	$0.12	0.4%	0.4%
SO_2	$0.25	0.7%	$0.06	0.2%	(0.5%)
Price Sensitive Demand	$0.04	0.1%	$0.03	0.1%	(0.0%)
Constrained Off	$0.00	0.0%	$0.00	0.0%	(0.0%)
Uranium	$0.00	0.0%	$0.00	0.0%	0.0%
Wind	($0.04)	(0.1%)	($0.01)	(0.0%)	0.1%
DASR Offer Adder	$0.17	0.5%	($0.02)	(0.1%)	(0.5%)
Markup	($1.49)	(4.0%)	($1.03)	(3.5%)	0.6%
Other	$0.00	0.0%	$0.00	0.0%	(0.0%)
NA	$0.11	0.3%	$0.00	0.0%	(0.3%)
Total	$36.73	100.0%	$29.68	100.0%	0.0%

Table 3-78 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 units.

Table 3-78 Components of PJM day-ahead, (adjusted), load-weighted, average LMP (Dollars per MWh): 2015 and 2016

	2015		2016		
Element	Contribution to LMP	Percent	Contribution to LMP	Percent	Change Percent
Coal	$11.63	31.7%	$10.81	36.4%	4.8%
DEC	$8.27	22.5%	$7.92	26.7%	4.2%
Gas	$6.42	17.5%	$3.28	11.0%	(6.4%)
DASR LOC Adder	$0.28	0.7%	$2.06	6.9%	6.2%
Dispatchable Transaction	$1.05	2.9%	$1.61	5.4%	2.6%
VOM	$1.64	4.5%	$1.31	4.4%	(0.1%)
Up to Congestion Transaction	$1.56	4.3%	$0.65	2.2%	(2.1%)
INC	$4.27	11.6%	$0.57	1.9%	(9.7%)
Ten Percent Cost Adder	$0.73	2.0%	$0.38	1.3%	(0.7%)
CO_2	$0.10	0.3%	$0.29	1.0%	0.7%
NO_x	$0.19	0.5%	$0.28	1.0%	0.4%
Markup	($0.17)	(0.5%)	$0.21	0.7%	1.2%
Oil	$0.23	0.6%	$0.12	0.4%	(0.2%)
Municipal Waste	$0.00	0.0%	$0.12	0.4%	0.4%
SO_2	$0.25	0.7%	$0.06	0.2%	(0.5%)
Price Sensitive Demand	$0.04	0.1%	$0.03	0.1%	(0.0%)
Constrained Off	$0.00	0.0%	$0.00	0.0%	(0.0%)
Uranium	$0.00	0.0%	$0.00	0.0%	0.0%
Wind	($0.04)	(0.1%)	($0.01)	(0.0%)	0.1%
DASR Offer Adder	$0.17	0.5%	($0.02)	(0.1%)	(0.5%)
Other	$0.00	0.0%	$0.00	0.0%	(0.0%)
NA	$0.11	0.3%	$0.00	0.0%	(0.3%)
Total	$36.73	100.0%	$29.68	100.0%	0.0%

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. Absent a physical position in real time, 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. Absent a physical position in real time, 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 3-79 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 2015 and 2016. In 2016, 48.3 percent of all cleared UTC transactions were net profitable. Of cleared UTC transactions, 64.4 percent were profitable on the source side and 35.0 were profitable on the sink side but only 5.6 percent were profitable on both the source and sink side.

Table 3-79 Cleared UTC profitability by source and sink point: 2015 and 2016[81]

	Cleared UTCs	Profitable UTCs	UTC Profitable at Source Bus	UTC Profitable at Sink Bus	Profitable UTC	Profitable Source	Profitable Sink
2015	10,052,055	5,198,147	6,771,210	3,394,829	51.7%	67.4%	33.8%
2016	22,382,027	10,807,587	14,409,047	7,844,293	48.3%	64.4%	35.0%

81 Calculations exclude PJM administrative charges.

Figure 3-47 shows total UTC daily gross profits and losses and net profits and losses in 2016.

Figure 3-47 UTC daily gross profits and losses and net profits: 2016[82]

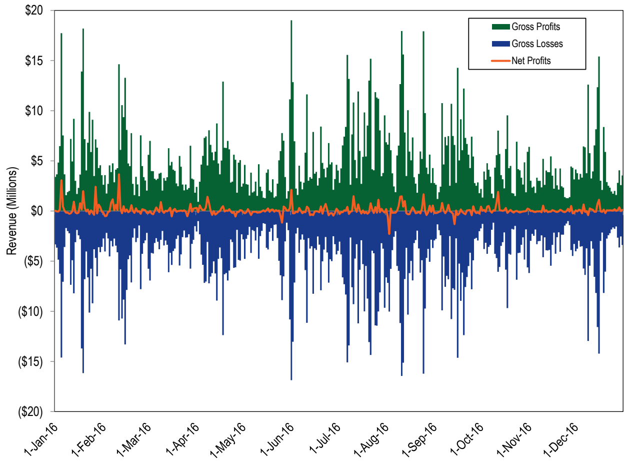


Figure 3-48 shows the cumulative UTC daily profits for the years 2013 through 2016. UTC profits during this period were primarily a result of significant unanticipated price differences between day ahead and real time LMPs. For example, the cumulative daily UTC profits in 2014 were greater than for the other three years as a result of profits from the significant and unanticipated day-ahead and real-time price differences that resulted from the polar vortex conditions in January 2014. Similarly, cumulative daily UTC profits increased during late February 2015 as a result of profits from the significant day-ahead and real-time prices differences that resulted from cold weather conditions. The cumulative daily UTC profits for 2016 are the lowest of these four years as a result of low and stable LMPs and stable prices during 2016.

Figure 3-48 Cumulative daily UTC profits: 2013 through 2016

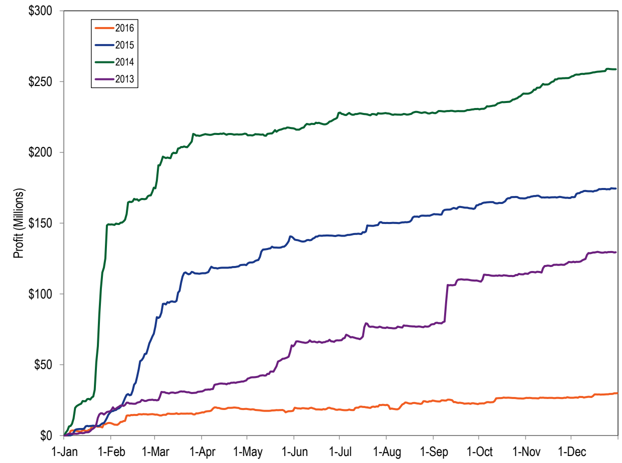


Table 3-80 shows UTC profits by month for 2013 through 2016. May and September 2016 were the only months in the past four years where the total monthly profits were negative.

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.

Table 3-80 UTC profits by month: 2013 through 2016

	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

82 Calculations exclude PJM administrative charges.

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 (Figure 3-50).

Analysis of the data from September 1, 2013, through September 30, 2015, does not support the conclusion that UTCs contribute in any measurable way to price convergence. In addition, the sudden and significant reduction in UTC activity in September of 2014 did not cause a measurable change in price convergence.

Table 3-81 shows that the difference between the average real-time price and the average day-ahead price was -$0.73 per MWh in 2015, and -$0.53 per MWh in 2016. The difference between average peak real-time price and the average peak day-ahead price was -$1.53 per MWh in 2015 and -$0.73 per MWh in 2016.

Table 3-81 Day-ahead and real-time average LMP (Dollars per MWh): 2015 and 2016[83]

	2015				2016			
	Day-Ahead	Real-Time	Difference	Percent of Real Time	Day-Ahead	Real-Time	Difference	Percent of Real Time
Average	$34.12	$33.39	($0.73)	(2.2%)	$28.10	$27.57	($0.53)	(1.9%)
Median	$29.09	$26.61	($2.47)	(9.3%)	$25.76	$24.10	($1.66)	(6.9%)
Standard deviation	$22.59	$27.80	$5.22	18.8%	$10.68	$14.76	$4.08	27.7%
Peak average	$40.97	$39.44	($1.53)	(3.9%)	$33.43	$32.71	($0.73)	(2.2%)
Peak median	$33.69	$29.95	($3.74)	(12.5%)	$30.36	$27.33	($3.03)	(11.1%)
Peak standard deviation	$26.30	$30.23	$3.93	13.0%	$11.16	$17.05	$5.89	34.5%
Off peak average	$28.11	$28.08	($0.03)	(0.1%)	$23.47	$23.12	($0.35)	(1.5%)
Off peak median	$24.51	$23.62	($0.90)	(3.8%)	$22.15	$21.60	($0.55)	(2.5%)
Off peak standard deviation	$16.54	$24.28	$7.74	31.9%	$7.66	$10.57	$2.91	27.5%

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 3-82 shows the difference between the real-time and the day-ahead energy market prices for each year from 2001 through 2016.

Table 3-82 Day-ahead and real-time average LMP (Dollars per MWh): 2001 through 2016

	Day-Ahead	Real-Time	Difference	Percent of Real Time
2001	$32.75	$32.38	($0.37)	(1.1%)
2002	$28.46	$28.30	($0.16)	(0.6%)
2003	$38.73	$38.28	($0.45)	(1.2%)
2004	$41.43	$42.40	$0.97	2.3%
2005	$57.89	$58.08	$0.18	0.3%
2006	$48.10	$49.27	$1.17	2.4%
2007	$54.67	$57.58	$2.90	5.3%
2008	$66.12	$66.40	$0.28	0.4%
2009	$37.00	$37.08	$0.08	0.2%
2010	$44.57	$44.83	$0.26	0.6%
2011	$42.52	$42.84	$0.32	0.7%
2012	$32.79	$33.11	$0.32	1.0%
2013	$37.15	$36.55	($0.60)	(1.6%)
2014	$49.15	$48.22	($0.93)	(1.9%)
2015	$34.12	$33.39	($0.73)	(2.1%)
2016	$28.10	$27.57	($0.53)	(1.9%)

Table 3-83 provides frequency distributions of the differences between PJM real-time hourly LMP and PJM day-ahead hourly LMP for 2007 through 2016.

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

Table 3-83 Frequency distribution by hours of PJM real-time LMP minus day-ahead LMP (Dollars per MWh): 2007 through 2016

	2007		2008		2009		2010		2011	
LMP	Frequency	Cumulative Percent	Frequency	Cumulative Percent	Frequency	Cumulative Percent	Frequency	Cumulative Percent	Frequency	Cumulative Percent
< ($1,000)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($1,000) to ($750)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($750) to ($500)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($500) to ($450)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($450) to ($400)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($400) to ($350)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($350) to ($300)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($300) to ($250)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($250) to ($200)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($200) to ($150)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.01%
($150) to ($100)	0	0.00%	1	0.01%	0	0.00%	0	0.00%	2	0.03%
($100) to ($50)	33	0.38%	88	1.01%	3	0.03%	13	0.15%	49	0.59%
($50) to $0	4,600	52.89%	5,120	59.30%	5,108	58.34%	5,543	63.42%	5,614	64.68%
$0 to $50	3,827	96.58%	3,247	96.27%	3,603	99.47%	3,004	97.72%	2,880	97.56%
$50 to $100	255	99.49%	284	99.50%	41	99.94%	164	99.59%	185	99.67%
$100 to $150	31	99.84%	37	99.92%	5	100.00%	25	99.87%	21	99.91%
$150 to $200	5	99.90%	4	99.97%	0	100.00%	9	99.98%	2	99.93%
$200 to $250	1	99.91%	2	99.99%	0	100.00%	2	100.00%	3	99.97%
$250 to $300	3	99.94%	0	99.99%	0	100.00%	0	100.00%	0	99.97%
$300 to $350	2	99.97%	1	100.00%	0	100.00%	0	100.00%	0	99.97%
$350 to $400	1	99.98%	0	100.00%	0	100.00%	0	100.00%	0	99.97%
$400 to $450	1	99.99%	0	100.00%	0	100.00%	0	100.00%	0	99.97%
$450 to $500	1	100.00%	0	100.00%	0	100.00%	0	100.00%	0	99.97%
$500 to $750	0	100.00%	0	100.00%	0	100.00%	0	100.00%	3	100.00%
$750 to $1,000	0	100.00%	0	100.00%	0	100.00%	0	100.00%	0	100.00%
$1,000 to $1,250	0	100.00%	0	100.00%	0	100.00%	0	100.00%	0	100.00%
>= $1,250	0	100.00%	0	100.00%	0	100.00%	0	100.00%	0	100.00%

	2012		2013		2014		2015		2016	
LMP	Frequency	Cumulative Percent	Frequency	Cumulative Percent	Frequency	Cumulative Percent	Frequency	Cumulative Percent	Frequency	Cumulative Percent
< ($1,000)	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
($1,000) to ($750)	0	0.00%	0	0.00%	2	0.02%	0	0.00%	0	0.00%
($750) to ($500)	0	0.00%	0	0.00%	3	0.06%	0	0.00%	0	0.00%
($500) to ($450)	0	0.00%	0	0.00%	1	0.07%	0	0.00%	0	0.00%
($450) to ($400)	0	0.00%	0	0.00%	6	0.14%	0	0.00%	0	0.00%
($400) to ($350)	0	0.00%	0	0.00%	5	0.19%	0	0.00%	0	0.00%
($350) to ($300)	0	0.00%	0	0.00%	5	0.25%	0	0.00%	0	0.00%
($300) to ($250)	0	0.00%	0	0.00%	6	0.32%	0	0.00%	0	0.00%
($250) to ($200)	1	0.01%	1	0.01%	14	0.48%	1	0.01%	0	0.00%
($200) to ($150)	4	0.06%	3	0.05%	14	0.64%	4	0.06%	0	0.00%
($150) to ($100)	6	0.13%	5	0.10%	45	1.15%	17	0.25%	0	0.00%
($100) to ($50)	17	0.32%	9	0.21%	91	2.19%	65	0.99%	13	0.15%
($50) to $0	5,576	63.80%	5,994	68.63%	5,829	68.73%	6,034	69.87%	5,780	65.95%
$0 to $50	3,061	98.65%	2,659	98.98%	2,525	97.56%	2,467	98.04%	2,919	99.18%
$50 to $100	82	99.58%	64	99.71%	120	98.93%	126	99.47%	58	99.84%
$100 to $150	17	99.77%	12	99.85%	39	99.37%	34	99.86%	13	99.99%
$150 to $200	12	99.91%	10	99.97%	18	99.58%	7	99.94%	1	100.00%
$200 to $250	5	99.97%	1	99.98%	9	99.68%	3	99.98%	0	100.00%
$250 to $300	1	99.98%	2	100.00%	8	99.77%	1	99.99%	0	100.00%
$300 to $350	2	100.00%	0	100.00%	3	99.81%	1	100.00%	0	100.00%
$350 to $400	0	100.00%	0	100.00%	3	99.84%	0	100.00%	0	100.00%
$400 to $450	0	100.00%	0	100.00%	2	99.86%	0	100.00%	0	100.00%
$450 to $500	0	100.00%	0	100.00%	0	99.86%	0	100.00%	0	100.00%
$500 to $750	0	100.00%	0	100.00%	7	99.94%	0	100.00%	0	100.00%
$750 to $1,000	0	100.00%	0	100.00%	0	99.94%	0	100.00%	0	100.00%
$1,000 to $1,250	0	100.00%	0	100.00%	1	99.95%	0	100.00%	0	100.00%
>= $1,250	0	100.00%	0	100.00%	4	100.00%	0	100.00%	0	100.00%

Figure 3-49 shows the hourly differences between day-ahead and real-time hourly LMP in 2016.

Figure 3-49 Real-time hourly LMP minus day-ahead hourly LMP: 2016

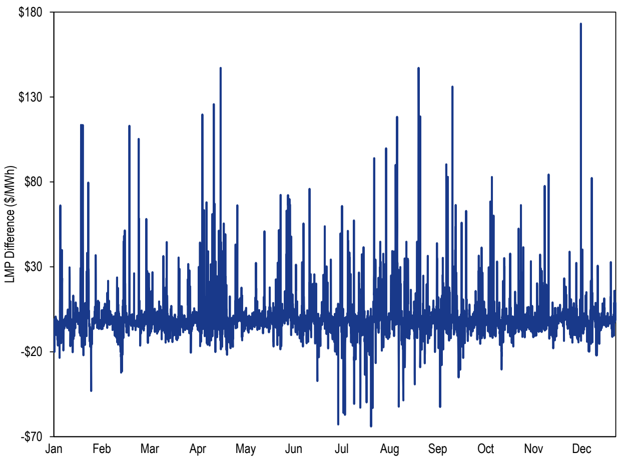


Figure 3-50 shows the monthly average of the differences between the day-ahead and real-time PJM average LMPs from January 2013, through December, 2016.

Figure 3-50 Monthly average of real-time minus day-ahead LMP: 2013 through 2016

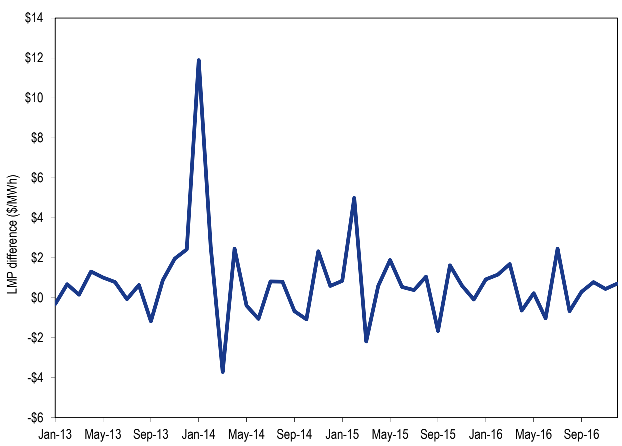


Figure 3-51 shows the monthly average of the absolute value of the differences between the day-ahead and real-time hourly, nodal LMPs from January 2013, through December 2016.

Figure 3-51 Monthly average of the absolute value of real-time minus day-ahead LMP by pnode: 2013 through 2016

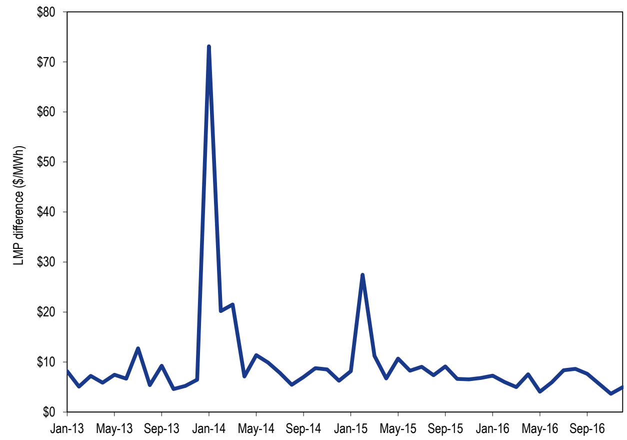
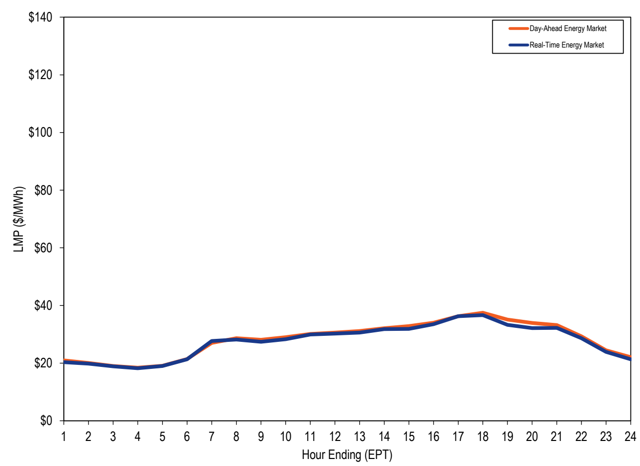


Figure 3-52 shows day-ahead and real-time LMP on an average hourly basis for 2016.

Figure 3-52 PJM system hourly average LMP: 2016



Scarcity

PJM's Energy Market experienced no shortage pricing events in 2016. Table 3-84 shows a summary of the number of days emergency alerts, warnings and actions were declared in PJM in 2015 and 2016.

Table 3-84 Summary of emergency events declared: 2015 and 2016

	Number of days events declared	
Event Type	2015	2016
Cold Weather Alert	26	8
Hot Weather Alert	19	22
Maximum Emergency Generation Alert	1	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	2	0
Emergency Mandatory Load Management Reduction Action (30, 60 or 120 minute lead time)	2	0
Maximum Emergency Action	1	0
Emergency Energy Bids Requested	0	0
Voltage Reduction Action	0	0
Shortage Pricing	0	0
Energy export recalls from PJM capacity resources	0	0

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.

PJM declared cold weather alerts on eight days in 2016 compared to 26 days in 2015.[84] The purpose of a cold weather alert is to prepare personnel and facilities for expected extreme cold weather conditions, generally when temperatures are forecast to approach minimums or fall below 10 degrees Fahrenheit.

PJM declared hot weather alerts on 22 days in 2016 compared to 19 days in 2015.[85] The purpose of a hot weather alert is to prepare personnel and facilities for expected extreme hot and humid weather conditions, generally when temperatures are forecast to exceed 90 degrees Fahrenheit with high humidity.

PJM did not declare any maximum emergency generation alert in 2016 compared to one day in 2015. The purpose of a maximum emergency generation alert is to provide an alert at least one day prior to the operating day that system conditions may require use of PJM emergency actions. It is called to alert PJM members that maximum emergency generation may be requested in the operating capacity.[86] This means that if PJM directs members to load maximum emergency generation during the operating day, the resources must be able to increase generation above the maximum economic level of their offer.

PJM did not declare any primary reserve alerts in 2016 and 2015. The purpose of a primary reserve alert is to alert members at least one day prior to the operating day that available primary reserves are anticipated to be short of the primary reserve requirement on the operating day. It is issued when the estimated primary reserves are less than the forecast primary reserve requirement.

PJM did not declare any voltage reduction alert in 2016 and 2015. The purpose of a voltage reduction alert is to alert members at least one day prior to the operating day that a voltage reduction may be required on the operating day. It is issued when the estimated operating reserve is less than the forecast synchronized reserve requirement.

PJM did not declare any primary reserve warning in 2016 and 2015. The purpose of a primary reserve warning is to warn members that available primary reserves are less than the primary reserve requirement but greater than the synchronized reserve requirement.

PJM did not declare any voltage reduction warnings and reductions of noncritical plant load in 2016 and 2015. The purpose of a voltage reduction warning and reduction of noncritical plant load is to warn members that available synchronized reserves are less than the synchronized reserve requirement and that a voltage

84 See PJM. "Manual 13: Emergency Operations," Revision 61 (January 1, 2017), Section 3.3 Cold Weather Alert, p. 54.
85 See PJM. "Manual 13: Emergency Operations," Revision 61 (January 1, 2017), Section 3.4 Hot Weather Alert, p. 58.
86 See PJM. "Manual 13: Emergency Operations," Revision 61 (January 1, 2017), Section 2.3.1 Advance Notice Emergency Procedures: Alerts, p. 18.

reduction may be required. It can be issued for the RTO or for specific control zones.

PJM did not declare any emergency mandatory load management reductions in 2016, compared to two days in 2015 in all or parts of the PJM service territory. The purpose of emergency mandatory load management is to request curtailment service providers (CSP) to implement load reductions from demand resources registered in PJM demand response programs that have a lead time of between one and two hours (long lead time) and a lead time of up to one hour (short lead time). Starting in June 2014, PJM combined the long lead and short lead emergency load management action procedures into Emergency Mandatory Load Management Reduction Action (30, 60 or 120 minute lead time). PJM dispatch declares NERC Energy Emergency Alert level 2 (EEA2) concurrent with Emergency Mandatory load Management Reductions. PJM also added a Pre-Emergency Mandatory Load Management Reduction Action (30, 60 or 120 minute lead time) step to request load reductions before declaring emergency load management reductions.

PJM did not declare any maximum emergency generation actions in 2016 compared to one day in 2015. The purpose of a maximum emergency generation action is to request generators to increase output to the maximum emergency level which unit owners may define at a level above the maximum economic level. A maximum emergency generation action can be issued for the RTO, for specific control zones or for parts of control zones.

PJM did not request any offers for emergency energy purchases in 2016 and 2015.

PJM did not declare any voltage reduction actions in 2016 and 2015. The purpose of a voltage reduction is to reduce load to provide sufficient reserves, to maintain tie flow schedules, and to preserve limited energy sources. When a voltage reduction action is issued for a reserve zone or subzone, the primary reserve penalty factor and synchronized reserve penalty factor are incorporated into the synchronized and nonsynchronized reserve market clearing prices and locational marginal prices until the voltage reduction action has been terminated.

PJM declared 16 synchronized reserve events in 2016 compared to 21 synchronized reserve events in 2015.[87] Synchronized reserve events may occur at any time of the year due to sudden loss of generation or transmission facilities and do not necessarily coincide with capacity emergency conditions such as maximum generation emergency events or emergency load management events.

Table 3-85 provides a description of PJM declared emergency procedures.

87 See *2016 State of the Market Report for PJM*, Section 10: Ancillary Service Markets for details on the spinning events.

Table 3-85 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.

Table 3-86 shows the dates when emergency alerts and warnings were declared and when emergency actions were implemented in 2016.

Table 3-86 PJM declared emergency alerts, warnings and actions: 2016

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
1/18/2016	PJM Western Region											
1/19/2016	PJM Western Region											
2/13/2016	PJM Western Region											
2/15/2016	PJM except Dominion											
7/7/2016		Mid Atlantic Region										
7/8/2016		Mid Atlantic and Dominion Regions										
7/14/2016		Mid Atlantic and Dominion Regions										
7/15/2016		Mid Atlantic and Dominion Regions										
7/18/2016		Mid Atlantic and Dominion Regions										
7/21/2016		ComEd										
7/22/2016		PJM RTO										
7/23/2016		PJM RTO										
7/24/2016		PJM RTO										
7/25/2016		PJM RTO										
7/26/2016		Mid Atlantic and Dominion Regions										
7/27/2016		Mid Atlantic and Dominion Regions										
7/28/2016		Mid Atlantic and Dominion Regions										
8/12/2016		Mid Atlantic Region										
8/13/2016		Mid Atlantic Region										
8/14/2016		Mid Atlantic Region										
8/15/2016		Mid Atlantic and Dominion Regions										
8/16/2016		Mid Atlantic and Dominion Regions										
8/29/2016		Mid Atlantic Region										
9/8/2016		Mid Atlantic and Dominion Regions										
9/9/2016		Mid Atlantic and Dominion Regions										
9/10/2016		Mid Atlantic and Dominion Regions										
12/15/2016	PJM Western Region											
12/16/2016	PJM Western Region											
12/17/2016	PJM Western Region											
12/19/2016	PJM Western Region											

Scarcity and Scarcity Pricing

In electricity markets, scarcity means that demand, including reserve requirements, is nearing the limits of the available capacity of the system. Under the PJM rules that were in place through September 30, 2012, high prices, or 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.

On October 1, 2012, PJM introduced a new administrative scarcity pricing regime. Under the current PJM Market Rules, shortage pricing conditions are triggered when there is a shortage of synchronized or primary reserves in the RTO or in the Mid-Atlantic and Dominion (MAD) Subzone. In times of reserve shortage, the value of reserves is included as a penalty factor in the optimization and in the price of energy.[88] Shortage pricing is also triggered when PJM issues a voltage reduction action or a manual load dump action for a reserve zone or a reserve subzone. When shortage pricing is triggered, the primary reserve penalty factor and the synchronized reserve penalty factor are incorporated in the calculation of the synchronized and nonsynchronized reserve market clearing prices and the locational marginal price.

In 2016, there were no shortage pricing events triggered in PJM.

88 See PJM OATT, 2.2 (d) General, (February 25, 2014), pp. 1815, 1819.

Final Rule on Shortage Pricing and Settlement Intervals

On September 17, 2015, the Commission issued a Notice of Proposed Rulemaking (NOPR) in which the Commission proposed to address price formation issues in RTOs/ISOs ("price formation NOPR").[89] In particular, the price formation NOPR proposed (i) to require the alignment of settlement and dispatch intervals for energy and operating reserves; and (ii) to require that each RTO/ISO trigger shortage pricing for any dispatch interval during which a shortage of energy or operating reserves occurs. These proposed reforms are intended to ensure that resources have price signals that provide incentives to conform their output to dispatch instructions, and that prices reflect operating needs at each dispatch interval.[90]

On June 16, 2016, the Commission issued a Final Rule in which it required each RTO/ISO to settle energy, operating reserves and intertie transactions using the same time intervals that it uses for to dispatch units or schedule these transactions.[91] In PJM, the energy market dispatch and pricing interval is five minutes, and the order requires PJM to settle energy transactions on a five minute basis. In PJM, the synchronized reserve and regulation market dispatch and pricing interval is five minutes, and the order requires PJM to settle these reserves on a five minute basis. In PJM, intertie transactions are scheduled on fifteen minute intervals, and the order requires PJM to settle intertie transactions on a fifteen minute basis. However, the Commission allowed PJM to propose a shorter time interval for settling intertie transactions.[92]

The Commission also 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.[93] In PJM, the rule would require PJM to trigger shortage pricing for any five minute interval when the Real-Time SCED (Security Constrained Economic Dispatch) indicates a shortage of synchronized reserves or primary reserves. Currently in PJM, if the dispatch tools (Intermediate-Term and Real-Time SCED) reflect a shortage of reserves (primary or synchronized) for a time period shorter than a defined threshold (30 minutes) due to ramp limitations or unit startup delays, it is considered a transient shortage, a shortage event is not declared, and shortage pricing is not implemented. Currently, both Real-Time SCED and Intermediate-Term SCED have to consistently identify that a shortage of a particular reserve product exists for a period of at least 30 minutes to trigger the shortage pricing penalty factor for that reserve product. For example, if Real-Time SCED indicates a shortage of RTO wide primary reserve for an interval but the Intermediate-Term SCED forecasts that the reserve shortage does not extend beyond its first look ahead interval (15 minutes ahead of the Real-Time SCED interval), it is considered a transient shortage, and shortage pricing is not implemented. If Real-Time SCED indicates a shortage of RTO wide primary reserve for an interval and the Intermediate-Term SCED forecasts that the reserve shortage extends for at least two look ahead intervals (30 minutes ahead of the Real-Time SCED interval), shortage pricing is implemented. The rationale for including voltage reduction actions and manual load dump actions as triggers for shortage pricing is to reflect the fact that when dispatchers need to take these emergency actions to maintain reliability, the system is short reserves and prices should reflect that condition, even if the data does not show a shortage of reserves.[94]

Accuracy of Reserve Measurement

If PJM were to move to a shortage pricing mechanism that is triggered by five minute shortages, there needs to be accurate measurement of real-time reserves that can support such a definition. That does not appear to be the case at present in PJM, but there does not appear to be any reason that PJM cannot implement that capability. Without very accurate measurement of reserves at minute by minute granularity, system operators cannot know with certainty that there is a shortage condition and therefore an appropriate trigger for five minute shortage pricing does not exist. The advantages of five minute shortage pricing are all implicitly based on the premise that the RTO knows accurately whether it is in a shortage condition. If PJM cannot demonstrate that it can accurately measure reserves at minute by minute granularity, it should not implement or continue five

89 152 FERC ¶ 61,218 (September 17, 2015).
90 *Id* at P 5.
91 155 FERC ¶ 61,276 (June 16, 2016).
92 *Id* at P 90.
93 *Id* at P 162.

94 *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)

minute shortage pricing until it can demonstrate that capability.[95]

The Commission directed in the Final Rule that, to the extent an RTO/ISO needs to enhance its measurement capabilities to implement the shortage pricing requirement, it should propose to do so in its compliance filing.[96]

The accuracy of reserve measurement in PJM can be evaluated using historical data on performance during spinning events. The level of tier 1 biasing also reflects PJM dispatchers' estimate of the error in the measurement of tier 1 synchronized reserve. Both of these data sources provide insight into the accuracy of reserve measurement based on actual historical data.

Historical Performance During Spinning Events

Historical data on response from synchronized reserves during spinning events shows the accuracy of PJM reserve estimates. Synchronized reserves consist of tier 1 and tier 2 synchronized reserves that are procured to meet the RTO and Mid-Atlantic reserve requirements. Tier 1 synchronized reserve is comprised of all online resources following economic dispatch and able to ramp up from their current output in response to a synchronized reserve event.[97]

All resources that respond to spinning events are paid for their response. Table 3-87 shows the performance of tier 1 and tier 2 synchronized reserves during spinning events, declared in 2015 and 2016, that lasted at least 10 minutes. In 2015, tier 1 response MW shown in Table 3-87 were measured as the increase in MW from all resources as a response to the spinning event declaration, regardless of whether the units were part of the tier 1 MW estimate. Since the tier 1 response MW to spinning events included resources that were not part of the tier 1 MW estimate, the 2015 estimates for tier 1 response were greater than 100 percent. In 2016, PJM reports tier 1 response only from the units that were part of the estimated tier 1 MW.

Beginning in 2016, PJM started reporting the response to spinning events only from the units that were part of its tier 1 estimate MW. Table 3-87 shows that, in 2016, the tier 1 MW response percent was never greater than 85 percent, with an average tier 1 response of 75 percent.

If PJM is going to trigger shortage pricing based on shortage of synchronized reserves that is calculated based on current estimates, system operators will be relying on estimates of synchronized reserve MW that have historically been inaccurate.

95 *See* Comments of the Independent Market Monitor for PJM, Docket No. RM15-24-000 (December 1, 2015) at 9.
96 155 FERC ¶ 61,276 at P 177 (June 16, 2016).
97 See *2016 State of the Market Report for PJM*, Section 10: Ancillary Service Markets at "Tier 1 Synchronized Reserve" for details on Tier 1 synchronized reserves.

Table 3-87 Performance of synchronized reserves during spinning events: 2015 and 2016[98]

Spin Event (Date, Hour)	Duration (Minutes)	Tier 1 Estimate MW (Adjusted by DGP)	Tier 1 Response MW	Tier 2 Scheduled MW	Tier 2 Response MW	Tier 1 Response Percent	Tier 2 Response Percent
Mar 3, 2015 12	11	1,079.0	1,365.1	484.4	272.3	126.5%	56.2%
Mar 16, 2015 06	24	541.5	576.4	248.0	180.2	106.4%	72.7%
Mar 17, 2015 19	17	1,428.9	1,693.1	247.2	232.8	118.5%	94.2%
Mar 23, 2015 19	15	851.3	1,420.0	273.5	205.8	166.8%	75.2%
Jul 30, 2015 10	10	1,458.4	2,145.7	79.7	24.0	147.1%	30.1%
Jan 18, 2016 17	12	861.0	733.5	616.7	508.8	85.2%	82.5%
Feb 8, 2016 15	10	1,750.2	1,338.2	228.4	200.1	76.5%	87.6%
Apr 14, 2016 20	10	1,182.8	1,000.6	346.3	304.8	84.6%	88.0%
Jul 28, 2016 13	15	649.4	500.4	822.9	655.8	77.1%	79.7%
Nov 4, 2016 17	11	744.5	497.1	758.0	709.2	66.8%	93.6%
Dec 31, 2016 05	12	971.2	585.0	594.4	485.7	60.2%	81.7%

Tier 1 Synchronized Reserve Estimate Bias

The tier 1 synchronized reserve for a unit is measured as the lower of the available 10 minute ramp and the difference between the economic dispatch point and the economic maximum output. The total supply of tier 1 synchronized reserve MW available to the market solution is calculated as the sum of the individual units' tier 1 MW, with further adjustments. These adjustments include eliminating tier 1 MW from nuclear, wind, solar, energy storage, and hydro units, adjusting the available tier 1 MW from remaining units using a metric called Degree of Generator Performance (DGP) and using tier 1 estimate bias.[99] Tier 1 biasing occurs when PJM market operations manually modifies (increasing or decreasing) the tier 1 synchronized reserve estimate of the market solution. This forces the market clearing engine to clear more or less tier 2 synchronized reserve and nonsynchronized reserve to satisfy the synchronized reserve and primary reserve requirements. Tier 1 biasing reflects the operators' view on the available tier 1 MW in the system and a lack of confidence on the calculated estimates of tier 1 MW, thus forcing the market clearing engine to procure more or less synchronized reserves. Table 10-14 shows the average monthly biasing of tier 1 estimates in the Ancillary Service Optimizer (ASO), the tool used to procure reserves on an hourly basis, in 2015 and 2016.

The existence of tier MW biasing raises the possibility that under a five minute shortage pricing construct, shortage pricing penalty factors may be triggered or avoided not due to actual reserve levels, but by operators' discretionary decisions on the amount of available reserves. It is possible that the market engine's estimate of tier 1 MW, even after unit level adjustments such as DGP, may be enough to satisfy the reserve requirement, but an operator's biasing of the market engine's estimate may lead to triggering shortage pricing penalty factors. There are no rules in the PJM tariff or manuals regarding the use of tier 1 MW biasing. In a five minute shortage pricing construct, the need for explicit rules governing operator discretion regarding reserve estimates becomes critical. The IMM has recommended since 2012 that PJM explicitly define the rules for using tier 1 biasing and identify which rule permits it every time tier 1 synchronized reserve estimate biasing is used.

Generator Data used for Reserve Estimates

A potential source for the error in tier 1 MW is the use of economic dispatch point to calculate the available ramp limited MW in 10 minutes as opposed to the actual metered output from the generator for any 5 minute interval. The amount of tier 1 MW available from a resource may differ due to using the metered output from a unit versus the market clearing engine's estimate of the resource's output. PJM addressed this issue partially in 2015 by adjusting a resource's available 10 minute ramp with its DGP. The available tier 1 MW estimated by the market solution for each resource is adjusted by its DGP percent. PJM communicates to generation operators whose tier 1 MW is part of the market solution the latest estimate of units' tier 1 MW and units' current resource specific DGP.

98 Beginning January 2015, Degree of Generator Performance (DGP) was introduced as a metric to improve the accuracy of the tier 1 MW estimate used by the market solution.

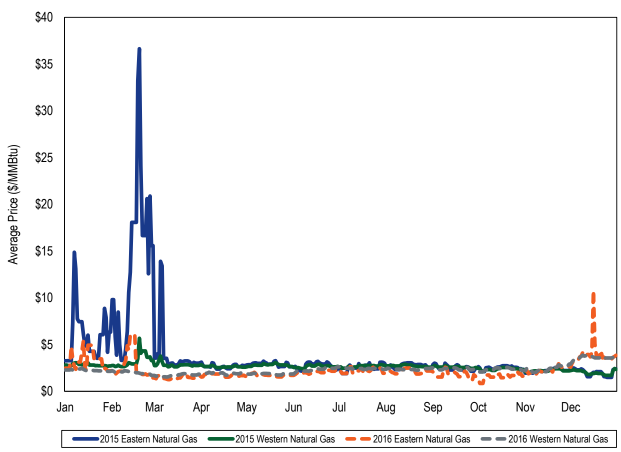
99 DGP measures how closely the unit has been following economic dispatch for the past 30 minutes.

PJM Cold Weather Operations 2016

Natural Gas Supply and Prices

As of January 1, 2017, gas fired generation was 35.7 percent (65,110.3 MW) of the total installed PJM capacity (182,449.1 MW).[100] The extreme cold weather conditions and the associated high demand for natural gas led to supply constraints on the gas transmission system which resulted in natural gas price volatility and interruptions to customers without firm transportation. Figure 3-53 shows the average daily price of delivered natural gas for eastern and western parts of PJM service territory in 2016 and 2015.[101]

Figure 3-53 Average daily delivered price for natural gas: 2015 and 2016 ($/MMBtu)



During the first three months of 2015 and 2016, 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. OFOs 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 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 suggests there may be potential benefits to creating an ISO/RTO structure to coordinate the supply of gas across pipelines and with the electric RTOs, or the creation of a gas supply coordination framework under existing electric ISO/RTOs.

100 *2016 State of the Market Report for PJM*, Section 5: Capacity Market, at Installed Capacity.

101 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.