Strengthening Reliability: An Analysis of Capacity Performance

PJM Interconnection
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Highlights 1
Introduction 2
Capacity Performance — Incenting Reliability and Efficiency *2*
How Capacity Performance Works 3
Benefits and Costs of Capacity Performance 5
Analysis: Year 1 of Capacity Performance + 2018 Cold Snap *5*
Analysis: Delivery Year 1 of Capacity Performance (June 1, 2016–May 31, 2017) 6
A Review of Weather and Energy Usage in Delivery Year 1 of Capacity Performance *6*
Weather 6
Energy Usage 7
Less Restrictive Operational Parameters *8*
Minimum Down Time (Lower Is More Flexible) 9
Maximum Daily and Weekly Starts (Higher Is More Flexible) 9
Hot Notification and Hot Startup Time 10
Maximum Emergency Megawatts *10*
Generator Outage Rates *10*
Self-Scheduled Resources *11*
Product/Service Innovation *11*
Flexible Demand 11
Infrastructure 12
Liquefied Natural Gas 12
Compressed Natural Gas Delivery 12
Insurance 12
Analysis: Cold Snap Performance (Dec. 28, 2017–Jan. 7, 2018) 13
Cold Snap Weather Conditions *13*
Generator Performance during the Cold Snap *15*
Forced Outages: Polar Vortex vs. Cold Snap 15
Cold Snap Capacity Performance vs. Non-Capacity Performance 16
Common Fleet Comparison – Cold Snap and Polar Vortex *18*
Forced Outages 18
Forced Outages by Fuel Type 19
Forced Outage Causes 20
Conclusion 21
Appendix: Qualitative Analysis 22
Resource Investments *22*
Existing Resources 22
New Resources Entering the Market 23

Highlights

- Capacity Performance was designed to increase the reliability of individual resources by offering incentives for investment and penalties for non-performance during stressed conditions. This ensures that capacity offered into the market appropriately reflects performance risk, and megawatts from units less likely to perform during such conditions are offered at higher prices to reflect that risk.

- This analysis of Capacity Performance is limited by two factors: Capacity Performance will not be fully implemented in the entire generation fleet until the 2020–21 Delivery Year, and PJM has called only one Performance Assessment Interval,[1] which was a limited period of time and had a small geographic area of impact.[2]

- Based on the data analyzed in this report, overall generator performance has improved from the inception of Capacity Performance to the present day.

- Positive indicators of the effectiveness of Capacity Performance include: decrease in restrictive generator operating parameters, reported investment in major reliability work for existing resources, and new resources investing in firm gas and transportation contracts.

- PJM observed improvements of over 50 percent in many operating parameters after the implementation of Capacity Performance.

- During the cold snap of 2017–18, Capacity Performance resources' forced outage rates were significantly lower than the same resources' outage rates during the 2014 Polar Vortex (5.5 percent vs. 12.4 percent).

- Capacity Performance has helped to bring about an emerging market for financial and physical hedging products and services. These include items such as insurance products, on-site liquefied natural gas and compressed natural gas delivery and have been created, in part, to help generators remain reliable and flexible during periods of high demand.

[1]Performance Assessment Intervals (PAI) are increments of time throughout the year during which Capacity Performance generators will be held to the Capacity Performance standard of deliverability. Generators subject to appraisal during PAI are those that cleared in the capacity auction with a Capacity Performance, or "pay-for-performance," requirement.

[2] PJM called for a PAI on May 29, 2018. The event lasted for 24 minutes and was limited to the Edison area of AEP Transmission Zone. No generation was impacted by this event.

Introduction

Grid reliability is paramount to our economy and quality of life. The rapid and unprecedented shift from coal to natural gas-fired generation, the abundance of shale gas and improvements in technology have driven electricity prices sharply lower and put pressure on resources to make needed investments in plant upgrades and modernization to remain competitive.

At the same time, the Polar Vortex of 2014 made it clear to PJM Interconnection that stronger incentives were needed to encourage investment for better generation performance year-round. During that event, on the coldest day of the year, 22 percent of the generation in PJM was unexpectedly unavailable to serve customers. That event demonstrated that resources of all types could be vulnerable to extreme conditions and that years of relatively mild weather may have led to less focus on generator maintenance.

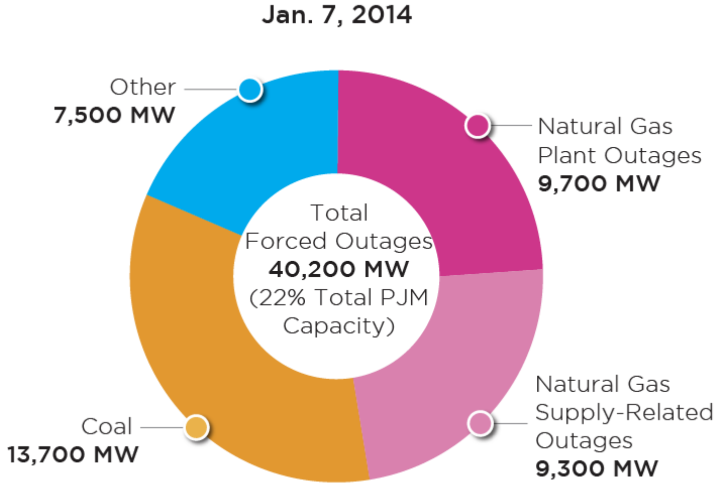
In response to changing grid conditions and generator performance, on June 1, 2016, PJM implemented Capacity Performance rules to ensure that capacity resources are available whenever they are needed and to transition unit performance risk from load to generation, especially in extreme weather conditions. These rules are intended specifically to encourage resources to make needed upgrades in plant equipment, weatherization measures, fuel procurement arrangements, fuel supply infrastructure and other factors.

Capacity Performance — Incenting Reliability and Efficiency

The 2014 Polar Vortex brought prolonged, deep cold to the entire PJM footprint and surrounding regions. Eight of the 10 highest historic winter demands for electricity on the PJM system occurred in January 2014 (Figure 1). During the peak demand hour, 22 percent of generation capacity — including coal, gas and nuclear — was out of service (Figure 2). The generation forced outage rate was two to three times higher than the normal peak winter outage rate of around 7 to 10 percent. This event highlighted that resources of all types are vulnerable to extreme weather conditions. Following the 2014 Polar Vortex, Capacity Performance incentives were instituted to ensure that capacity is available year-round and to ensure generator improvements are made and sustained over time.

Figure 1. Peak Demand during 2014 Polar Vortex vs. Previous Winter Peaks

Figure 2. Generator Outages during 2014 Polar Vortex



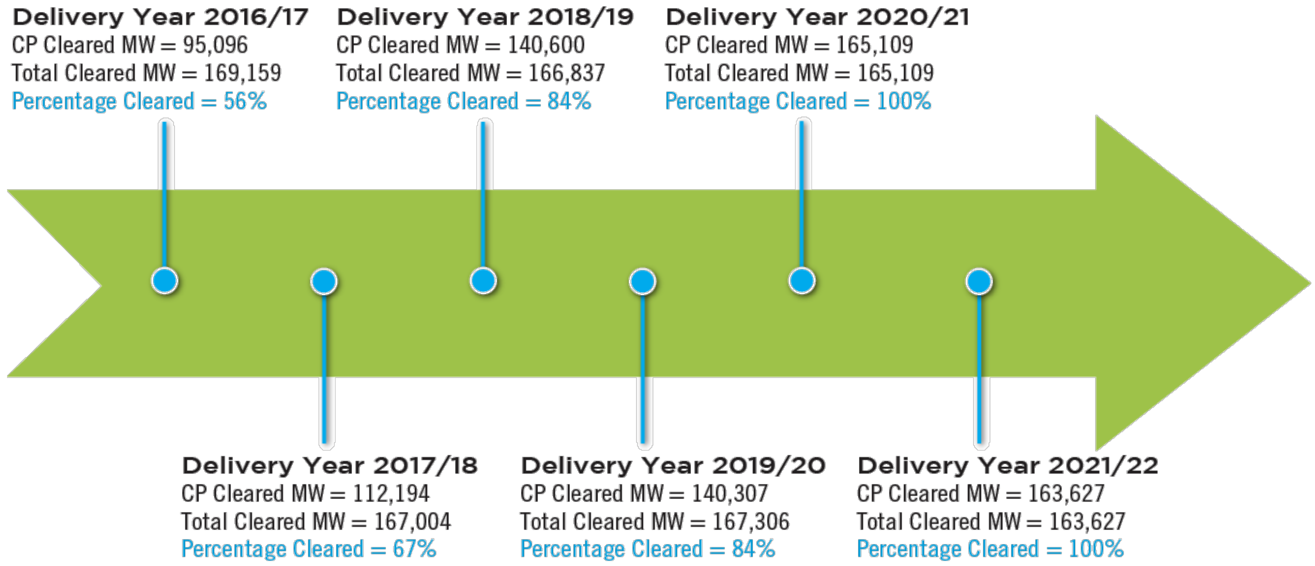
How Capacity Performance Works

Capacity Performance is similar to an insurance policy; for a cost, consumers have greater protection from power interruptions – especially when extreme weather challenges the grid. The better individual resources perform during peak system conditions, the more reliable the system is to serve demand. Resources that exceed performance requirements are entitled to funds collected from resources that underperform. Resources assume virtually all financial risks if they do not meet their power supply obligations.

Under Capacity Performance, resources must meet their commitments to deliver electricity whenever PJM determines they are needed to meet power system emergencies. As a “pay-for-performance” requirement, resources may receive higher capacity payments and, in return, are expected to invest in modernizing equipment, firming up fuel supplies and adapting to use different fuels. Capacity Performance also incentivizes investment in new resources that are very reliable, available to meet demand during peak system conditions and help to reduce costs in the energy markets.

PJM has taken a phased approach to implementing Capacity Performance. The number of megawatts cleared in the Reliability Pricing Model (RPM) capacity market as Capacity Performance will increase each year until the delivery year 2020–21, when all PJM resources are required to meet Capacity Performance requirements. PJM transition auctions provided a “glide path” for capacity resources committed to the higher performance requirements for the 2016–17 and 2017–18 delivery years (Figure 3).

Figure 3. Implementation of Capacity Performance



Performance Assessment Intervals

A Performance Assessment Interval (PAI) is an increment of time throughout the year during which Capacity Performance generators will be held to the Capacity Performance standard of deliverability. Generators subject to appraisal during PAI are those that cleared in the capacity auction with a Capacity Performance, or "pay-for-performance," requirement.

PAI are assessed for the duration of certain emergency actions declared by PJM. Emergency Procedures are issued to mitigate capacity and transmission emergencies as detailed in Manual 13 and can include but are not limited to voltage reduction warnings, voltage reduction actions, manual load dump warnings or manual load dump actions.

Performance is assessed for each interval in which PJM declares the following:

- Pre-emergency load management reduction action
- Emergency load management reduction action
- Primary reserve warning
- Maximum generation emergency action
- Emergency voluntary energy only demand response reductions
- Voltage reduction warning and reduction of non-critical plant load
- Curtailment of non-essential business load
- Deploy all resources action
- Manual load dump warning
- Voltage reduction action
- Manual load dump action
- Load shed directive

Benefits and Costs of Capacity Performance

While Capacity Performance increases capacity costs in the market, the increase is offset by lower energy market prices during performance assessment intervals. To explain further, large investments are needed to ensure improved reliability and availability during extreme weather events. However, the result of those investments will be lower energy market prices during extreme weather events because more generation will be available. Additionally, decreases to operational limitations on generation resources will result in improvements to the flexibility and availability of the generation fleet, which reduce out-of-market (uplift) payments. On the other hand, during mild or average weather conditions, the offset may be minimized. Pre-auction estimates of the incremental cost of procuring Capacity Performance in the 2016/17 and 2017/18 Transition Auctions were between $5.6 billion and $7.8 billion. The actual incremental cost from the two auctions was $4 billion.

Analysis: Year 1 of Capacity Performance + 2018 Cold Snap

In this analysis, PJM reviews the first year of Capacity Performance resources in the energy market (2016–17) and compares it to the prior year (2015–16), including grid conditions, resources' operational parameters, generator investment and other measures. In addition, we analyze Capacity Performance resources during the Dec. 28, 2017, to Jan. 7, 2018, cold snap.

The first full delivery year of Capacity Performance had relatively mild temperatures, which meant the full worth of Capacity Performance was not tested. Only 56 percent of megawatts in the PJM footprint were Capacity Performance during the 2016–17 Delivery Year. In the winter of 2017–18, 67 percent of megawatts were Capacity Performance, and that winter included a cold snap that was a clearer trial of generation performance.

Despite the fact that there has only been one PAI called to date, PJM has found positive indicators of the effectiveness of Capacity Performance, including a decrease in restrictive generator operating parameters. The cold snap of 2017–18 helped further affirm these indicators, as, overall, Capacity Performance resources performed better than they did during the 2014 Polar Vortex. In particular, fuel supply-related generation outages decreased.

Analysis: Delivery Year 1 of Capacity Performance (June 1, 2016–May 31, 2017)

The performance of capacity resources during emergency events is assessed during certain emergency intervals known as PAI. PAI are the periods of time in which Capacity Performance resources are most needed due to extreme system conditions.

For this analysis, PJM compared the delivery year prior to the implementation of Capacity Performance (2015–16) to the first delivery year of Capacity Performance (2016–17). As mentioned earlier, weather was relatively mild in both delivery years. Consequently, there were no PAI called during the first year of Capacity Performance. Therefore, this analysis examines other metrics (e.g., generator flexibility, investment in improvements in current and new generation) primarily on summer and winter peak days and hot and cold weather alert days.

A Review of Weather and Energy Usage in Delivery Year 1 of Capacity Performance

Weather

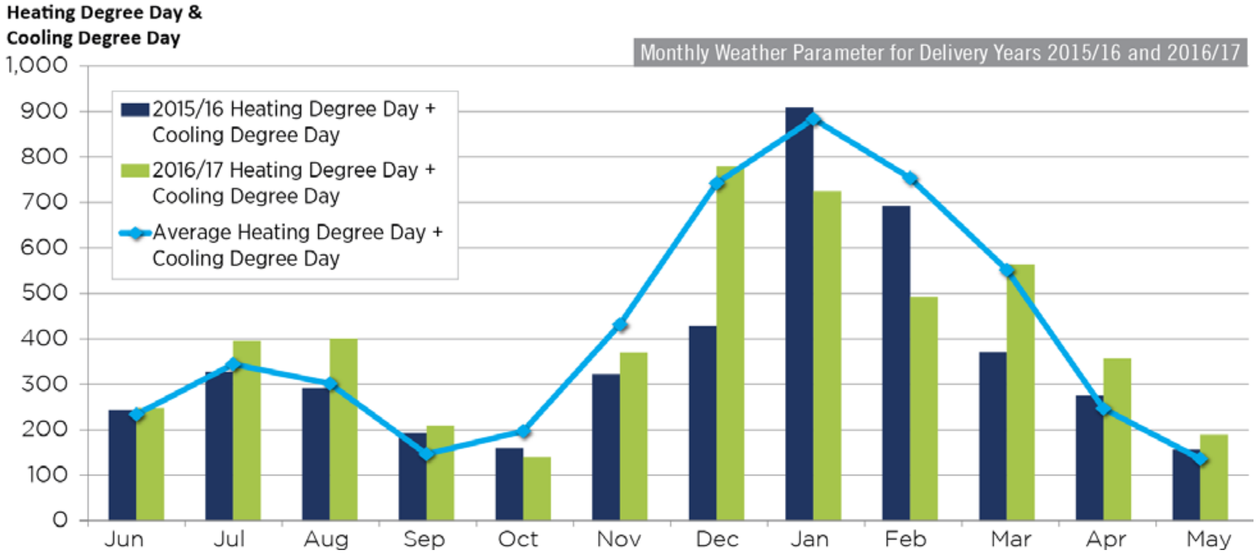
For purposes of this analysis, the weather parameter for the Capacity Performance years is a monthly sum of daily heating degree days (HDDs) and cooling degree days (CDDs). Degree days represent a deviation from a baseline temperature – in this case, 60 degrees for HDD and 65 degrees for CDD. As temperatures become colder, HDDs increase and as temperatures become warmer, CDDs increase. Typically, winter months will have HDDs, and summer months will have CDDs. Shoulder months (in the spring and fall) may include both HDDs and CDDs.[3]

As mentioned previously, in both of the study years the weather was average to mild. In some months, particularly in the winter of 2016–17, the weather was extremely mild (see Figure 4). The cold snap of 2017–18 provided some better data for analysis of Capacity Performance, which is contained in the Analysis: Cold Snap Performance (Dec. 28, 2017–Jan. 7, 2018) section of this paper.

Despite the mild weather, the weather pattern across the months was not completely alike between the two delivery years. With the exception of a very mild December and March, the remaining months in the 2015–16 Delivery Year had average weather. January and February of 2016–17 were far milder than average, whereas July and August were above average. Despite the difference in the distribution of more extreme weather, in both delivery years, hot weather alerts were called on 15 days and cold weather alerts were called on two days.

[3] Degree days are calculated using a daily load weighting that weights values from weather stations in each transmission zone according to the zonal contribution to the regional transmission organization peak on that day. Average values use data from 1998 to the most recent complete year, in this case, 2015. Averages include load data for all transmission owner zones in the current RTO footprint.

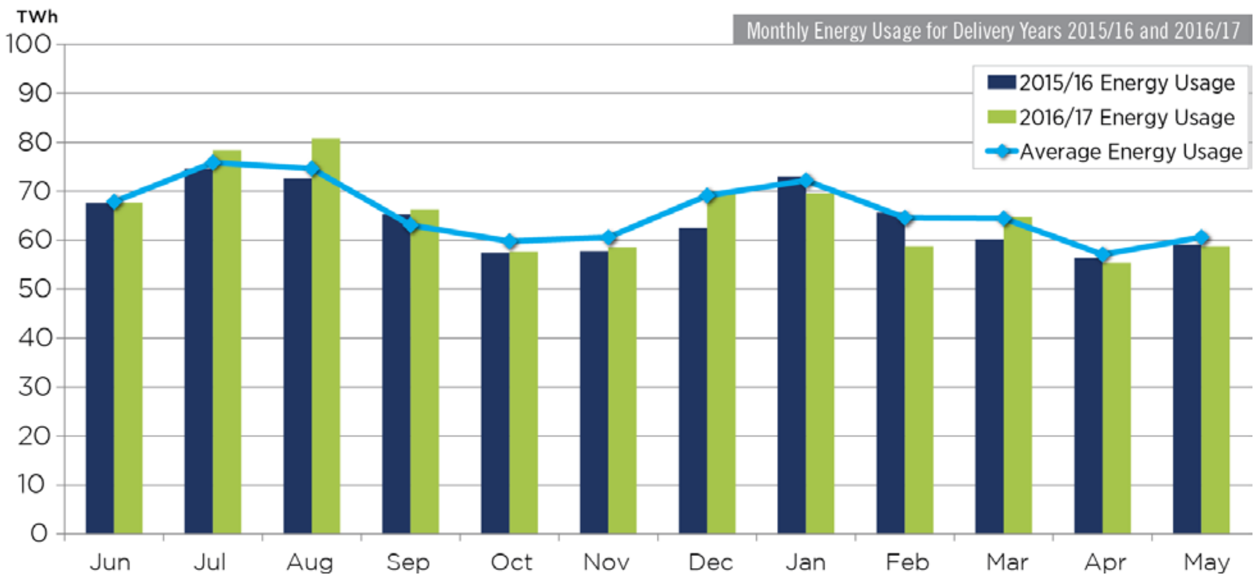
Figure 4. Monthly Heating and Cooling Degree Days 2015–16 and 2016–17



Energy Usage

Energy use corresponds with the weather, and was at or below average levels in 2015–16 and 2016–17 for nearly every month in each delivery year (Figure 5).

Figure 5. Monthly Energy Usage



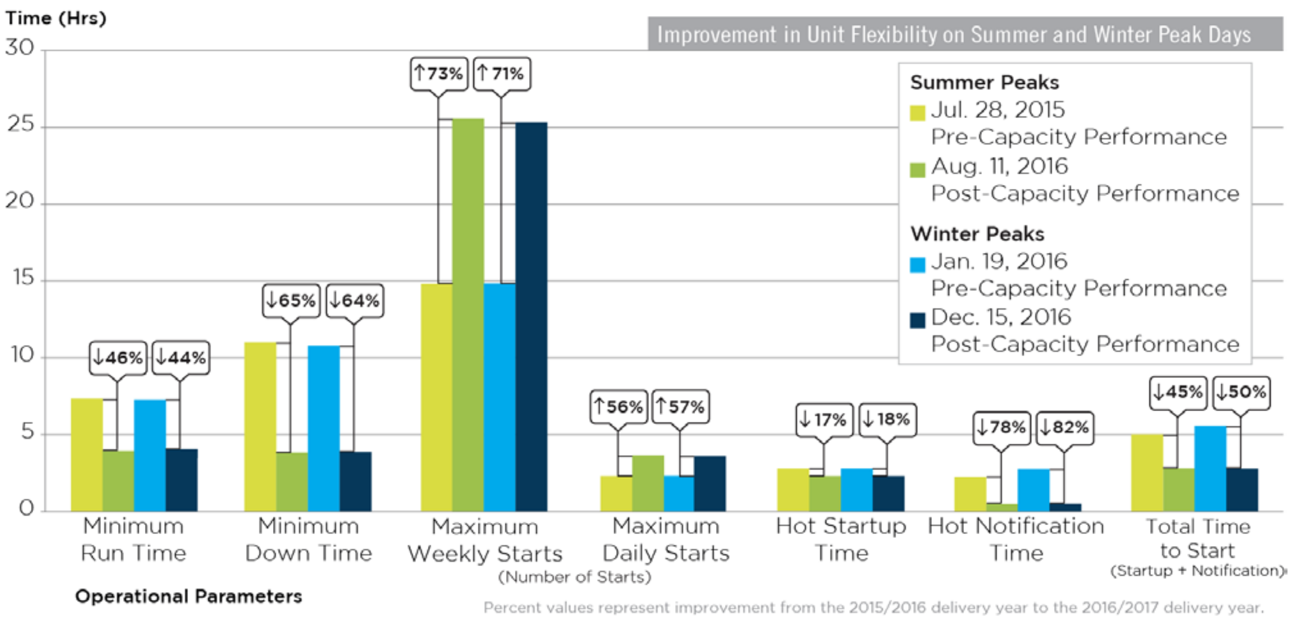
Less Restrictive Operational Parameters

The unit-specific operational parameters established for Capacity Performance resources not only improve system reliability, but also reduce dispatch inefficiencies. Since the inception of Capacity Performance, PJM has enforced flexible operational parameters across the footprint in the unit-specific parameters for Capacity Performance resources. These operational parameters include items such as minimum run time, minimum down time and total time to start, among others.

PJM's default minimum operating parameters are outlined in PJM Manual 11: Energy & Ancillary Services Market Operations.[4] Resources that do not meet these minimum operating parameters are not eligible for make-whole (i.e., uplift) payments. Improvements in their operating parameters increase resources' ability to be dispatched offline during uneconomic times and provide a larger pool of flexible resources to dispatch.

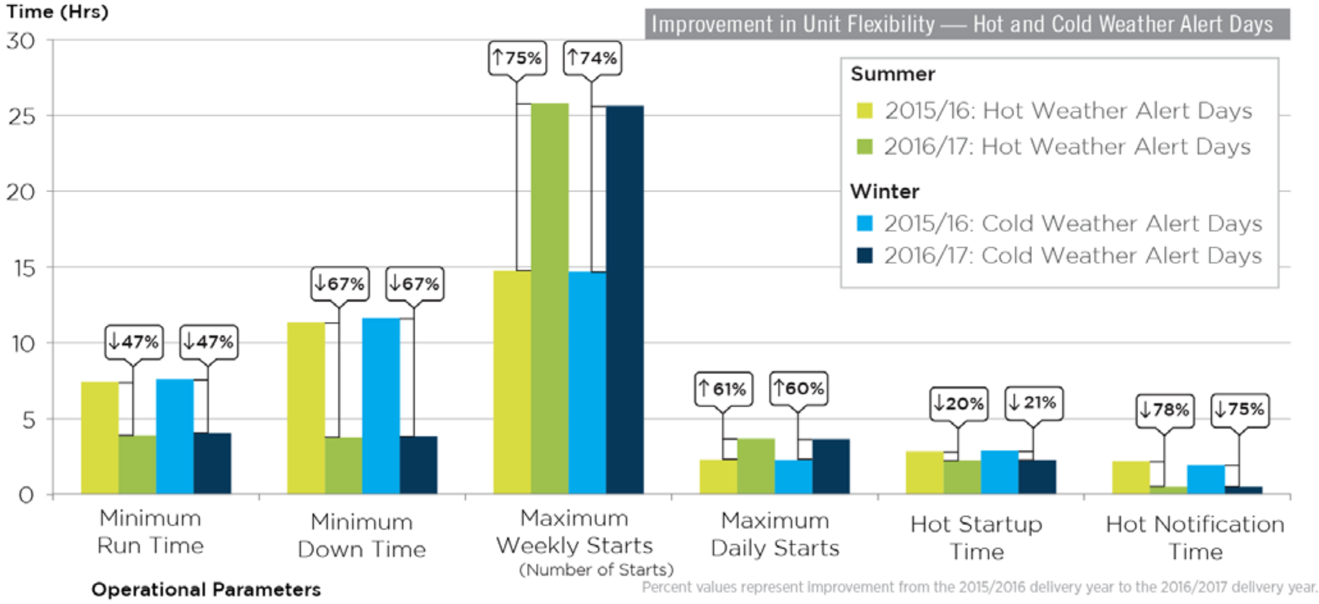
PJM compared the Capacity Performance resources' operating parameters for the peak summer and winter days, as well as during all hot weather alert and cold weather alert days in both delivery years. As shown in Figure 6 and Figure 7, there has been a more than 50 percent improvement in many operating parameters after the implementation of Capacity Performance.

Figure 6. Improvement in Unit Flexibility — Summer and Winter Peak Days



[4] http://www.pjm.com/~/media/documents/manuals/m11.ashx

Figure 7. Improvement in Unit Flexibility — Hot and Cold Weather Alert Days



All of the following parameters are based on generator equipment limitations, as well as state and local regulations, and are reported and set by the generators themselves. Generator equipment limitations can include temperature, emissions, noise standards and original equipment manufacturer requirements, among other criteria.

Minimum Run Time (Lower Is More Flexible)

Minimum run time is the minimum amount of time that a generator must run before it can be dispatched offline. Reducing minimum run time allows PJM to run generation during peak demand and take generation offline when it is no longer economic.

Minimum Down Time (Lower Is More Flexible)

Minimum down time is the minimum number of hours between unit shutdown and unit startup. For example, if a generator is online and has a minimum down time of 72 hours, PJM Dispatch has limited options if the unit will be needed again in the next few days — once that generator is offline, it cannot be dispatched back on for another 72 hours (three days). Reducing minimum down time allows PJM to dispatch the unit offline during hours of low demand, but bring it back online for the next peak period.

Maximum Daily and Weekly Starts (Higher Is More Flexible)

Similar to minimum down time, PJM dispatch and the PJM Day-Ahead Energy Market must consider how many times a generator can be started in a day or week before taking the unit offline. For example, even if a generator has short minimum run and minimum down times, it may need to be kept online if its maximum weekly starts are low and the unit is needed later in the week. Increased maximum daily and weekly starts increases unit flexibility.

Hot Notification and Hot Startup Time[5] (Lower Is More Flexible)

Hot notification time is how long a generator needs from the time it receives a dispatch instruction to the beginning of the startup sequence, if it has only been offline for a relatively short period. This time is primarily used for transmission owner notifications and procuring fuel for natural gas resources. Similarly, hot startup time is how long it takes from the time a generator begins its startup sequence to the first breaker close. Notification time plus startup time is a generator's total time to start. Total time to start is used to determine how long it will take a generator to come online after being notified to do so by PJM. Reducing total time to start improves flexibility by making resources available for dispatch closer to real-time conditions.

Maximum Emergency Megawatts

When a generator, or part of a generator's output, is designated as Maximum Emergency, those megawatts are available to PJM only when PJM declares a Maximum Emergency event.[6] The fewer megawatts designated as Maximum Emergency, the more generation that is available when needed, and the lower prices are.

PJM observed an improvement (i.e., a decrease) in the number of megawatts in Maximum Emergency for Capacity Performance resources during hot and cold weather alert days from 2015–16 to 2016–17. While these resources already had very low numbers of megawatts in Maximum Emergency prior to Capacity Performance (less than 1 percent), the total number of megawatts designated as Maximum Emergency on the summer peak day decreased by 34 percent. Across the 15 hot weather alert days, the total number of megawatts designated as Maximum Emergency decreased by 14 percent.

Generator Outage Rates

One of the most important factors for determining the effectiveness of Capacity Performance is improved generator performance (via decreased outage rates). PJM estimated cost savings assuming that improvements in generator outage rates would result in lower energy prices during average and extreme weather years, since less expensive generation would be available during times of stressed system conditions.

On the 10 peak load days (five in the summer and five in the winter) of the 2016–17 Delivery Year, Capacity Performance resources had lower forced outage rates than non-Capacity Performance resources (Figure 8). However, since this delivery year exhibited mild weather conditions, in order to gain a more reliable estimate of generator outage rates, more years and more varying weather conditions will be needed. The 2017–18 cold snap gave some further indication of performance and is discussed later in this paper.

[5] Hot start and hot notification were the focus of analysis because they indicate how well a unit can perform in a "ready" state (e.g., equipment is still in service, boiler hasn't been drained).

[6] To avoid a scenario in which resources designate their output as Maximum Emergency in order to avoid performing during a PAI, any Maximum Emergency megawatts not dispatched during a PAI will be assessed non-performance penalty charges.

Figure 8. Average Forced Outage Rates on Top Five Peak Days (2016–17 Delivery Year)

Forced Outage Rate on Top Five Peak Days (2016–17 Delivery Year)		
	Non-CP Resources	CP Resources
Winter	6.6%	4.8%
Summer	8.6%	5.3%

Self-Scheduled Resources

On days when there is a higher likelihood of a PAI occurring (e.g., cold weather alert or hot weather alert days), some Capacity Performance resources may self-schedule in the Day-Ahead Market in order to mitigate the risk of not starting in time for the PAI. If too many resources self-schedule in the Day-Ahead Market, PJM may have too much generation online in more highly congested areas, which would require PJM to schedule additional generation to combat the congestion or even to take some more-economic resources offline.

PJM found a 10 percent increase in the total number of resources that were self-scheduled in the Day-Ahead Market between 2015–16 and 2016–17 for all hot and cold weather alert days. However, during the cold snap, PJM did not observe an increase in self-scheduled megawatts in the Day-Ahead Market. This data suggests that there is currently no issue with too much generation self-scheduling to avoid penalties when not committed in the Day-Ahead Market.

There was an additional concern that, in anticipation of an imminent PAI, resources in real time would suddenly start ramping to full output in order to hedge risk and reap the rewards of over-performance. PJM has addressed this concern by rewarding resources only up to PJM's desired megawatt level.[7]

Product/Service Innovation

Capacity Performance has helped to bring about an emerging market for financial and physical hedging products and services. These products and services have been created in part to help generators remain reliable and flexible during periods of high demand.

Flexible Demand

Traditionally, particularly during higher gas demand periods, pipelines require that a customer's daily gas requirement is scheduled on a uniform hourly basis in order to maintain gas system flow rates and pressures in a steady operating state. Capacity Performance, in part, has driven some gas pipelines to continue to investigate the feasibility of offering flexible services for gas generators to more appropriately meet their demand requirements, which vary over the course of a 24-hour day. One interstate pipeline proposed a firm generator-specific service for the PJM region in 2017 that included provisions for increased hourly flexibility. However, there remains a rather high cost hurdle for procuring this service.

[7] Capacity Performance resources only receive bonus compensation up to the desired basepoint megawatts requested by PJM.

Infrastructure

A number of mid-stream pipeline projects are in various phases of completion, construction or are before FERC awaiting approval. There have been numerous delays with these projects due to significant local opposition from environmental protection groups along with certain landowners not wanting pipelines installed near their properties. These projects are designed to alleviate the supply bottleneck that exists in the Utica and Marcellus shale regions, where there is an enormous amount of supply and production of natural gas but not enough take-away pipeline capacity to transport the gas to the major consuming markets of the Midwest, Mid-Atlantic, Northeast and Southeast portions of the US. These mid-stream projects are being developed by a variety of companies, including several large interstate pipeline companies as well as partnerships made of gas producers and local pipeline marketing companies. Once complete, these projects will help with the overall improvement in gas availability and reduce winter price volatility, especially in the eastern portions of PJM.

Liquefied Natural Gas

On-site liquefied natural gas (LNG) storage represents a potential option as a backup and/or supplemental fuel alternative for gas-fired generation. LNG storage is capable of supplementing gas delivered from the pipeline without having to take the unit offline. LNG storage companies have met with PJM staff to discuss applicability and have identified the potential opportunity Capacity Performance offers to help generators firm up their supply via LNG. PJM staff will continue to monitor onsite LNG options to gain a better understanding of its potential to improve unit reliability.

Compressed Natural Gas Delivery

Similar to LNG, compressed natural gas (CNG) can supplement gas delivered from the pipeline or be an alternative source of fuel when interstate pipeline capacity is unavailable. CNG can be delivered with short notice, such as day-ahead or intraday, to accommodate the electric demand on extreme days. CNG is currently being used by industrial manufacturers throughout the country who do not have access to gas pipeline connections.

Insurance

In the course of its research on Capacity Performance, PJM discovered that some generation owners had purchased insurance against non-performance penalties for their resources. PJM sought out and interviewed a brokerage firm that offered this product in order to learn more. The broker confirmed that some resources in PJM's footprint have purchased insurance policies that would cover non-performance penalty charges in certain circumstances.

The broker indicated that these policies are limited to covering forced outages due to plant equipment failures and do not include interruptions in fuel delivery and other outside forces. Policy premiums are based on historical forced outage rates, and generators with improved reliability will get a better price on the insurance at renewal. This is an indication that such policies serve as their own incentive for resources to improve their performance from the standpoint of reducing forced outages. The premium structure of these policies provides an indication that these policies are working to complement, not completely supplant, investment in the plant improvements designed to improve unit performance, which Capacity Performance was intended to incentivize. As part of its continuing review of Capacity Performance, PJM will continue to look into the interrelationship of insurance products (such as those described above) to the incentive structure built into the market design intended to drive investment in plant improvements.

Analysis: Cold Snap Performance (Dec. 28, 2017–Jan. 7, 2018)

The first year that capacity performance was in place, the weather was very mild with few Emergency Procedures issued, thus minimizing the opportunities for analysis. Since that time, the cold snap of Dec. 2017–Jan. 2018 provided a more rigorous test of the value of Capacity Performance. Though no PAI were called during this time, conditions on the system were stressed for a significant period of time.

This analysis draws heavily on the paper "PJM Cold Snap Performance,"[8] which was released on Feb. 26, 2018. That paper used preliminary data from PJM's eDART outage system to draw initial conclusions about the performance of Capacity Performance resources during the cold snap. Since the release of that paper, final Generator Availability Data System (GADS) data has become available; [9] this analysis uses that updated data for its reporting and conclusions and takes a closer look at the resources that were in forced outage in both the 2014 Polar Vortex and the 2018 cold snap, specifically those that are now Capacity Performance resources.

Cold Snap Weather Conditions

During the recent cold snap, while individual cities in PJM's footprint set low temperature records for days between Dec. 27 and Jan. 8, the average temperature did not reach the extreme lows that were experienced during the coldest days of 2014. On the day with the coldest average temperature during the Polar Vortex (Jan. 7, 2014), the minimum temperature dipped below 0 degrees Fahrenheit. During the recent cold snap, the average temperature was lowest on the morning of Jan. 1, 2018, dropping to 2.9 degrees.

Figure 9 shows that between the Polar Vortex and the recent cold snap, the difference in wind chill was even greater than that in temperature. The morning of Jan. 7, 2014, was by far the coldest, with the average wind chill across the PJM footprint dropping below -20 degrees, as compared to the lowest wind chill during the recent cold snap, which was -8.4 degrees. While the cold snap was a significant cold weather event, the temperature was not as low and the wind chill was not nearly as low as in the 2014 Polar Vortex.

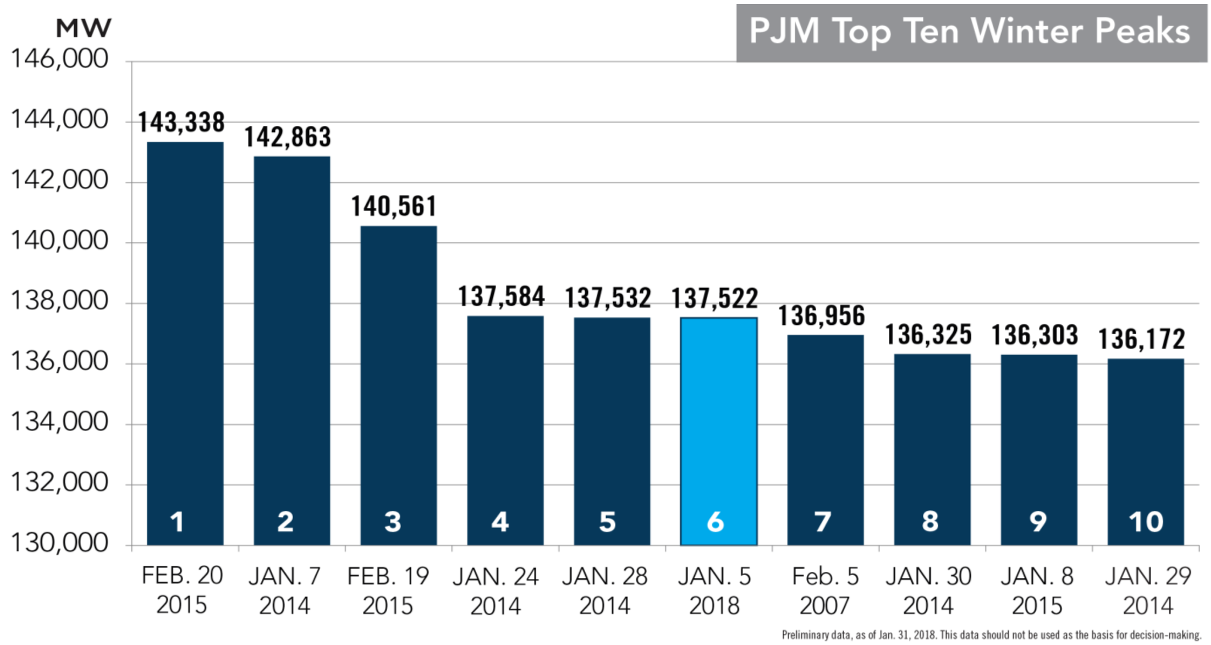
[8] http://www.pjm.com/-/media/library/reports-notices/weather-related/20180226-january-2018-cold-weather-event-report.ashx

[9] The PJM eDART system is an online portal that is used in real-time operations to track generating unit capabilities on a minute-by-minute basis. PJM generation owners (GOs) submit unit forced/unplanned outages and reductions through this portal during the current operating period so that PJM dispatch can assess unit availability and maintain adequate reserves to ensure system reliability. When a GO submits an unplanned reduction or outage, the actual cause of a reduction, trip or start failure may not be known until much later and indeed may be different from the cause reported on the eDART ticket. This is reconciled at the earliest by the 20th of the month following the month in which the outage occurred, using the Generator Availability Data System (GADS).

Figure 9. PJM Average Temperature and Wind Chill (Hourly)

While no individual hour of the 2017–18 winter compared to the severity experienced during previous cold weather events, the duration of the cold contributed to high demand conditions. Jan. 5, 2018, Hour Ending (HE) 19 had a peak demand of 137,522 MW (see Figure 10), which now ranks as the sixth highest PJM winter peak. This peak occurred on the day with the lowest wind chill.

Figure 10. PJM Top 10 Winter Peaks



Generator Performance during the Cold Snap

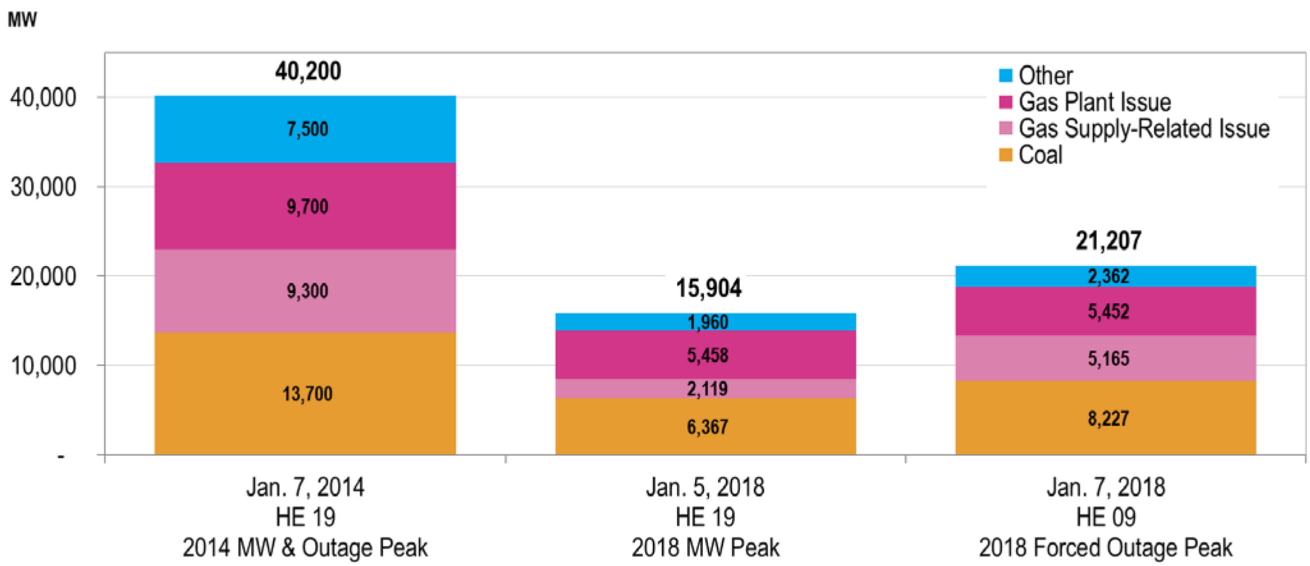
During the Polar Vortex, the peak outage and peak demand day was the same: Jan. 7, 2014. During the 2018 cold snap, the peak demand was on Jan. 5, 2018, at HE19, while the peak outage day was Jan. 7, 2018 at HE9.

Forced Outages: Polar Vortex vs. Cold Snap

As shown in Figure 11, during the peak demand of the cold snap, forced outages made up only 15,904 MW (8 percent of total PJM capacity). Even on PJM's peak outage day, forced outages were only 21,207 MW (11 percent of total PJM capacity). This is a 47 percent improvement over the 2014 Polar Vortex, when forced outages reached 40,200 MW (22 percent of total PJM capacity).

As noted earlier, the temperature and wind chill differences between the two events played a role in the decrease of outages. However, PJM's resources may also have been better prepared for the cold snap due to enhancements incented by Capacity Performance in the intervening years, such as investment in testing and inspecting equipment and equipment upgrades.

Figure 11. Polar Vortex vs. Cold Snap: Forced Outages at Outage and Demand Peaks[10]

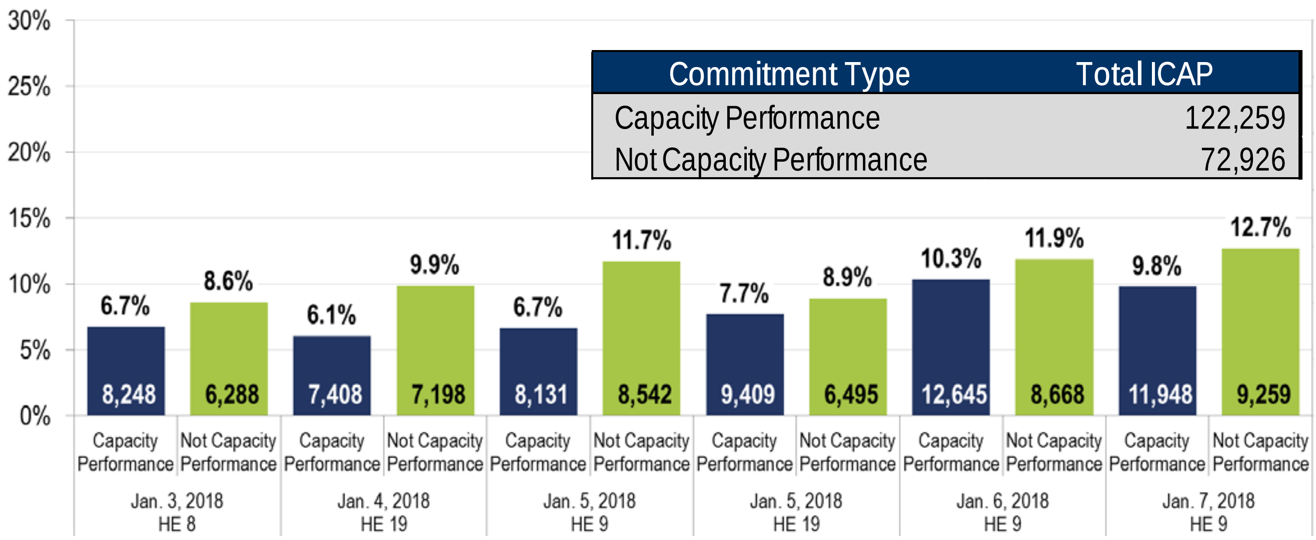


[10]The forced outage data for Jan. 5, 2018, and Jan. 7, 2018, in Fig. 12 includes notable differences for coal and gas plant outages compared to the eDART-based outage amounts previously published in the report "PJM Cold Snap Performance Dec. 28, 2017 to Jan. 7, 2018." GADS installed capacity for pseudo-tied units is based on full unit installed megawatt capacity, while eDART is based only on the pseudo-tied amount of megawatts. The outage data for the dates in this report reflect GADS data adjusted to include only corresponding reductions from pseudo-tied amounts into PJM. Other differences in the megawatt amounts are attributed to differences in the aggregation of the data in the two systems. eDART looks at a minute snapshot in time, while GADS integrates data over the hour. Finally, eDART and GADS are independent tools that are not integrated and require generators to submit information into each tool separately.

Cold Snap Capacity Performance vs. Non-Capacity Performance

In order to obtain an assessment of Capacity Performance resources and non-Capacity Performance resources, PJM reviewed GADS forced outage data for all generation resources based on commitment type and installed capacity (ICAP) within each commitment type across the cold snap. Overall, the performance of Capacity Performance resources was better than performance of non-Capacity Performance resources between Jan. 3 and Jan. 7, the coldest days of the recent cold snap (see Figure 12).

Figure 12. CP vs. Non-CP Forced Outage Rates – Cold Snap[11]



Similarly, PJM compared Capacity Performance and non-Capacity Performance forced outages by fuel type in the peak hours of the cold snap and the 2014 Polar Vortex (Figure 13). Forced outage rates for each generation fuel type were lower during the cold snap than during the Polar Vortex peak for both Capacity Performance and non-Capacity Performance resources. The nuclear resources performed well during the cold snap, just short of their full capability due to several partial outages. However, coal and oil Capacity Performance resources did not perform as well as their non-Capacity Performance counterparts during the cold snap. Understanding the source of this issue requires some additional analysis.

[11] As a percentage of total CP and non-CP ICAP.

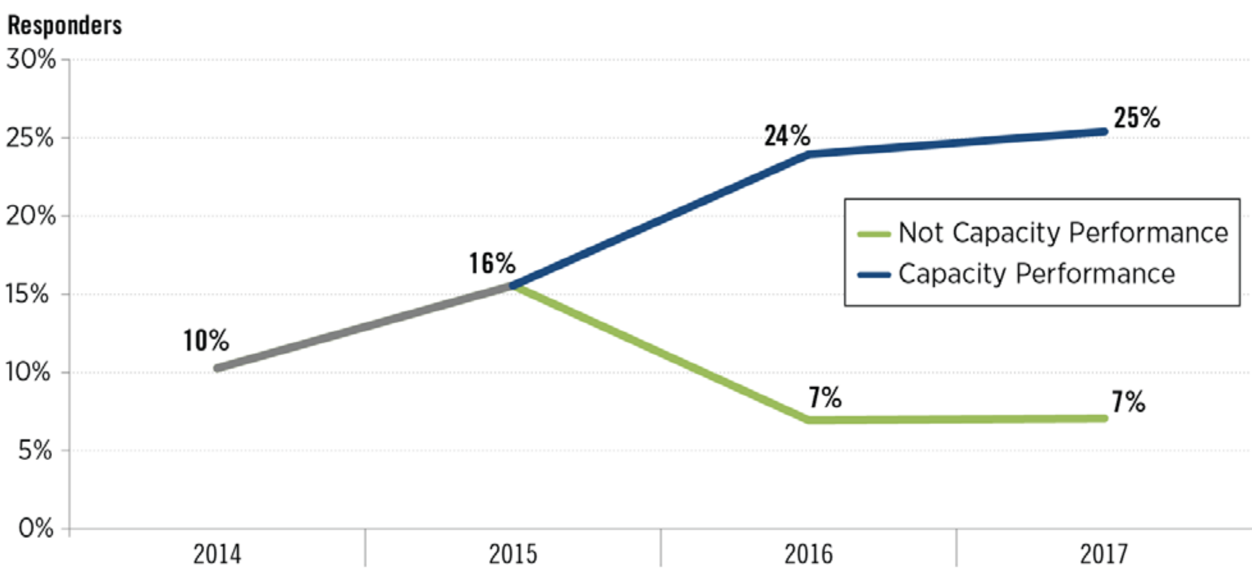
Figure 13. CP vs. Non-CP Forced Outages by Fuel Type – Cold Snap and Polar Vortex[12]

Jan. 7, 2014 HE 8			Jan. 3, 2018 HE 8	Jan. 4, 2018 HE 19	Jan. 5, 2018 HE 9	Jan. 5, 2018 HE 19	Jan. 6, 2018 HE 9	Jan. 7, 2018 HE 9
Coal	18.6%	CP	12.7%	12.0%	11.6%	11.9%	12.3%	15.0%
		Non-CP	9.3%	5.3%	6.8%	6.7%	10.0%	9.5%
Gas	32.7%	CP	4.0%	5.0%	5.8%	8.7%	15.3%	11.1%
		Non-CP	9.4%	16.7%	18.7%	13.0%	17.1%	19.7%
Oil	27.3%	CP	27.3%	N/A	17.0%	17.1%	19.0%	16.3%
		Non-CP	15.9%	8.2%	14.8%	15.0%	18.4%	20.2%
Other	15.2%	CP	1.0%	0.9%	0.9%	0.8%	1.6%	1.6%
		Non-CP	5.3%	3.9%	4.8%	3.6%	4.2%	3.5%

The lower outage rate in natural gas Capacity Performance resources compared to non-Capacity Performance resources could be an indication that those resources had prepared better for weather events through increased firmness of transportation capacity and supply, along with a greater diversity of natural gas supply resources and delivery options.

Since 2014, PJM has conducted an annual Fuel and Emission Survey to collect operational and technical information about the generation units that operate within PJM, with a focus on each unit's fuel supply and procurement details. Based on the survey results from 2014–2017, more natural gas Capacity Performance resources have firm supply and firm transportation contracts[13] than in 2014, the year of the Polar Vortex (Figure 14). Additionally, fewer CP resources have neither firm supply nor firm transportation (Figure 15).

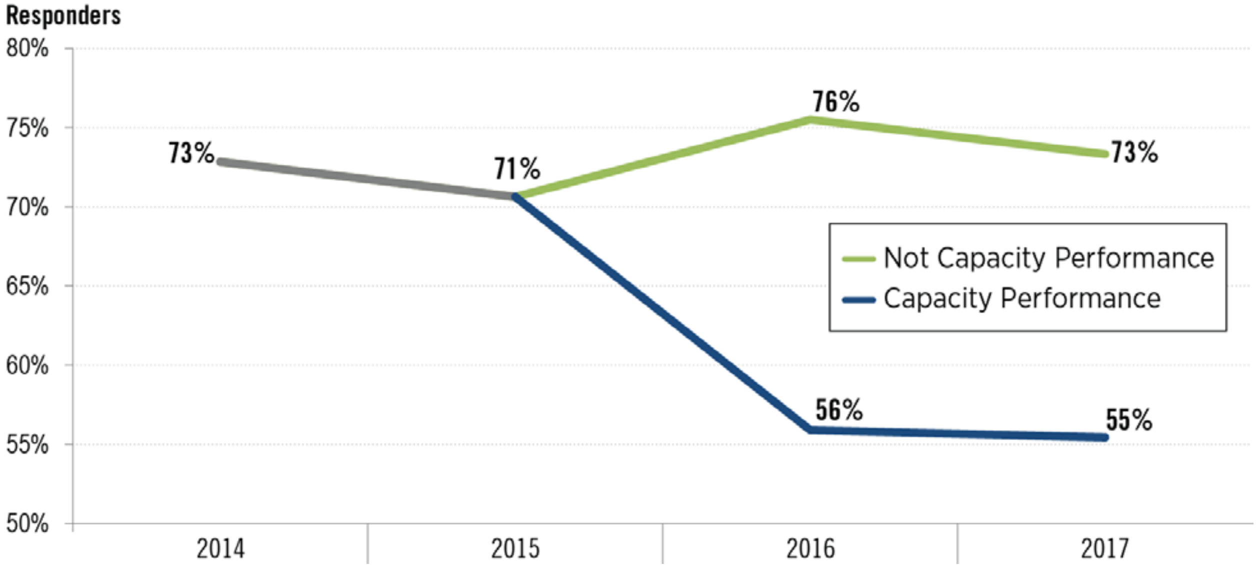
Figure 14. Gas Units with Both Firm Supply and Firm Transportation Contracts



[12] As a percentage of fuel-specific CP and non-CP ICAP.

[13] The term "firm" broadly refers to a contractual gas pipeline delivery path that provides a higher priority of service. Firm contracts are reported by generators in annual and periodic PJM surveys. In Figures 14 and 15, Percentage of Units with Both Firm Supply and Firm Transportation Contracts were derived from the 2018 Generator Survey, specifically, questions FQG-33: "Does the unit have a firm gas supply contract?" and FQG-34: "Does the unit own firm transportation on any of the following pipelines?"

Figure 15. Gas Units with neither Firm Supply nor Firm Transportation Contracts



Internal analysis supports the observation that gas supply was less of an issue for natural gas Capacity Performance resources during the cold snap than non-Capacity Performance gas resources. While detailed results cannot be shared due to confidentiality constraints, over the period of Jan. 3 through Jan. 7, during the peak hours examined in this analysis, outages due to gas supply issues for Capacity Performance resources averaged 2.2 percent of Gas Capacity Performance ICAP, whereas outages due to gas supply issues for non-Capacity Performance resources averaged 7.9 percent of Gas Non-Capacity Performance ICAP.

Common Fleet Comparison – Cold Snap and Polar Vortex

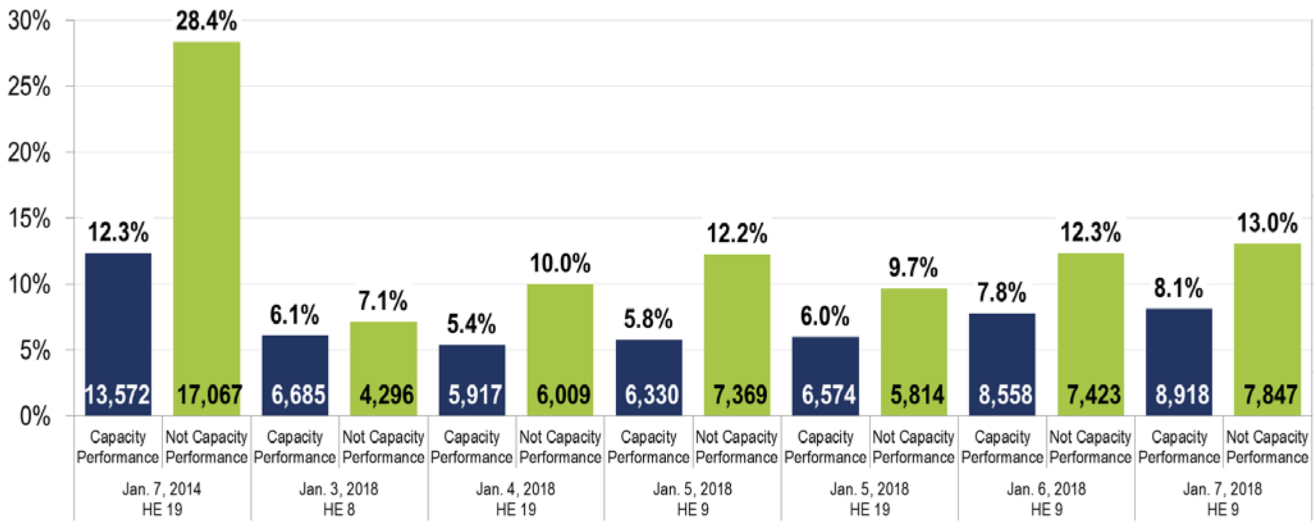
Forced Outages

In order to complete a fair comparison, PJM looked at outage rates among resources that were common to the generation fleet during both the 2014 Polar Vortex and the 2017–18 cold snap. Examining a set of resources common to both time periods was important for removing the influence of a dissimilar set of resources on the overall forced outage rates for both events (resources that have retired since the Polar Vortex may have skewed forced outage rates higher for the Polar Vortex, and new resources that have come online since then could have improved the outage rates during the cold snap). As noted in the Cold Snap Weather Conditions section of this paper, it is important to remember that weather conditions were not as extreme in the recent cold snap as they were during the Polar Vortex.

After adjusting for the changes in the generation fleet, outages rates for both Capacity Performance and non-Capacity Performance resources remained lower in the cold snap than in the Polar Vortex. On the peak load day of Jan. 5, 2018, outage rates for resources that are currently Capacity Performance improved from 12.3 percent in 2014 to 5.7 percent in 2018.

A key objective of Capacity Performance is to ensure that resources are available during peak demand. In the cold snap, Capacity Performance resources performed well during periods of high demand (Figure 16).

Figure 16. Forced Outage Rate for Resources Common to Polar Vortex and Cold Snap



Forced Outages by Fuel Type

As noted previously, overall, the forced outages of each fuel type were lower in the cold snap peaks than in the Polar Vortex peak. Looking at forced outage rates by fuel type (and in comparison to the 2014 Polar Vortex) (see Figure 17), Capacity Performance gas resources' forced outage rates improved. As compared to 2014, this could be an indication that gas Capacity Performance was better prepared through more resilient gas supply arrangements, as noted previously. However, both coal and oil Capacity Performance resources showed no improvement in forced outage rates from the Polar Vortex to the cold snap. Additionally, as was noted when looking at the overall fleet, coal and oil Capacity Performance resources did not perform as well as their non-Capacity Performance counterparts.

Figure 17. Forced Outage Rate by Fuel Type for Resources Common to Polar Vortex and Cold Snap[14]

		Jan. 7, 2014 HE 8	Jan. 3, 2018 HE 8	Jan. 4, 2018 HE 19	Jan. 5, 2018 HE 9	Jan. 5, 2018 HE 19	Jan. 6, 2018 HE 9	Jan. 7, 2018 HE 9
Coal	CP	10.1%	12.3%	11.5%	10.7%	10.8%	11.3%	11.8%
	Non-CP	23.7%	9.3%	5.3%	6.8%	6.7%	10.0%	9.5%
Gas	CP	22.3%	2.0%	3.4%	4.1%	4.7%	9.3%	10.2%
	Non-CP	41.9%	5.7%	16.6%	19.6%	14.0%	17.1%	18.8%
Oil	CP	17.0%	27.4%	N/A	17.1%	17.2%	19.1%	16.4%
	Non-CP	25.5%	16.1%	8.2%	16.1%	15.0%	18.4%	20.2%

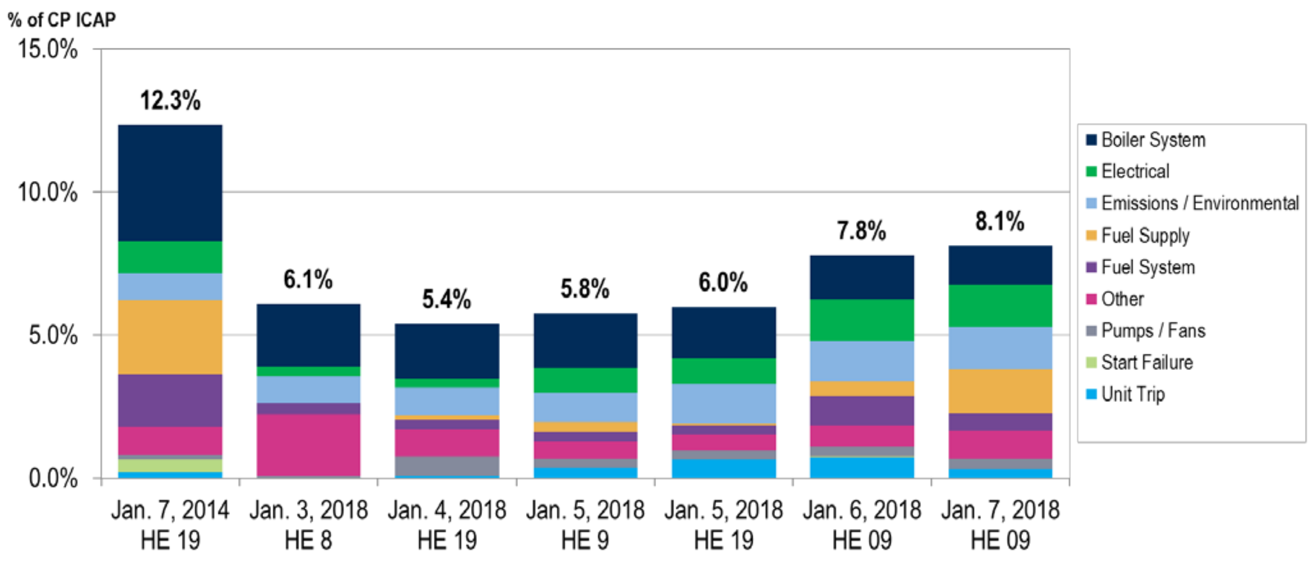
14 As a percentage of fuel-specific CP and non-CP ICAP.

Forced Outage Causes

On the peak load and outage day of the 2014 Polar Vortex, fuel supply issues were significant, accounting for nearly 40 percent of overall outage megawatts. By contrast, during the recent cold snap, fuel supply issues for Capacity Performance resources (including oil supply, replenishment and gas supply-related issues) were minimal, averaging around 3 percent of outage megawatts, until the last day of the cold snap, when they reached nearly 19 percent of outage megawatts (Figure 18). The extended period of cold weather may account for the increase, which still did not approach the level of fuel supply issues seen during the Polar Vortex.

Among Capacity Performance resources, boiler issues (including boiler and tube leaks, valve and feed water problems, water chemistry and any full or partial outage affecting plant primary systems not otherwise categorized in the report) were the largest cause of forced outages during the Polar Vortex. While boiler issues were also among the most frequently cited outage causes for these resources in the cold snap, there were fewer boiler-related outages, and they decreased over the course of the cold snap.

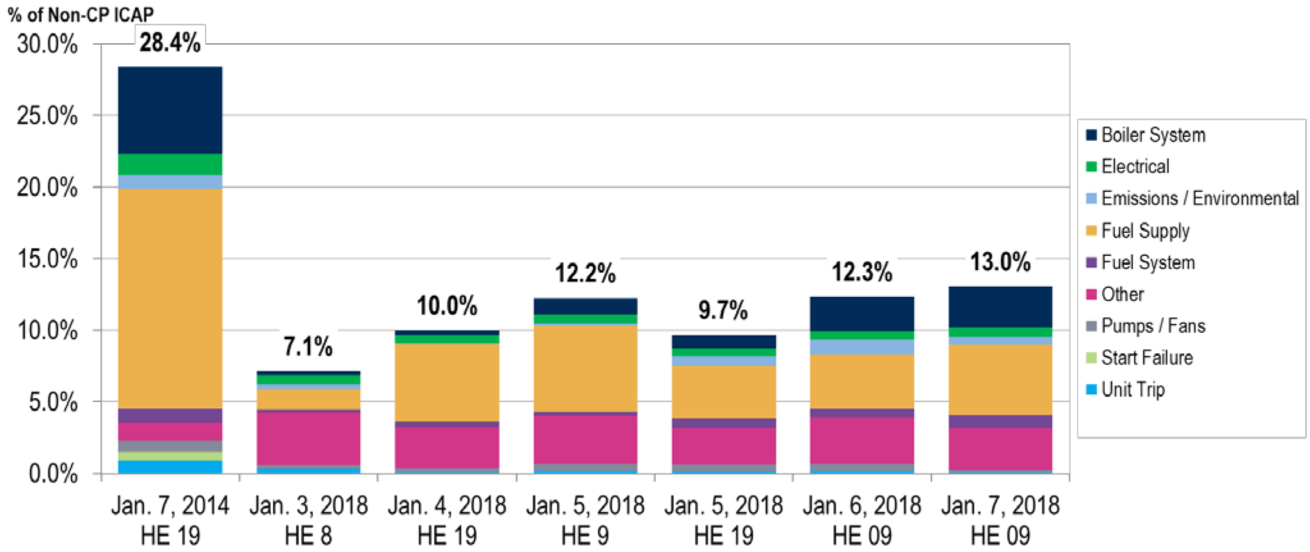
Figure 18. Outage Causes for CP Resources Common to Polar Vortex and Cold Snap [15]



Similarly to Capacity Performance resources, the percentage of fuel supply-related outages was significantly lower in 2018 compared to 2014 for non-Capacity Performance resources. However, fuel supply-related outages still accounted for an average of 36 percent of outages among the non-Capacity Performance resources in 2018 (Figure 19).

[15] As a percentage of CP ICAP.

Figure 19. Outage Causes for Non-CP Resources Common to Polar Vortex and Cold Snap [16]



Conclusion

Capacity Performance was created to incent resource owners to make increased investments in their generation fleets in order to ensure year-round deliverability and availability. Overall improved generator performance helps to ensure the grid reliability that is essential to the health and well-being of the consumers and businesses in the PJM footprint when extreme weather occurs.

Despite the lack of extreme weather and performance assessment intervals, PJM has found indicators of the positive impact of Capacity Performance. Resource owners report they are making investments in their resources, such as equipment overhauls and upgrades, and restrictive generator-operating parameters are decreasing. A decrease in forced outage rates, especially over the peak hours of the 2017–18 cold snap, is also a positive indicator that PJM's resources were available when they were needed most.

PJM recognizes that the data is limited and that there are notable differences in temperature extremes, wind chill and length of cold weather when comparing the cold snap in 2018 and the 2014 Polar Vortex. As a result, this report is indicative, but not intended to be conclusive, regarding the results of the implementation of Capacity Performance on improved generator performance. Nevertheless, the preliminary results reported above are, for the most part, positive. In coming years, when PAI do occur, PJM will provide additional analysis to report on performance and grid conditions.

[16] As a percentage of non-CP ICAP.

Appendix: Qualitative Analysis

Resource Investments

In order to learn more about resource investments while preserving confidentiality, PJM informally contacted generation owners within the PJM footprint to learn about the investments that they have made in existing generation to meet the Capacity Performance standards. PJM also reviewed information submitted by developers of new generation during the Generator Interconnection Process.

Existing Resources[17]

In informal conversations, some generation owners with aging resources told PJM they are investing in reliability upgrades (e.g., equipment overhauls and component and facility upgrades) to ensure the availability of their resources.

There appear to be some trends among the different resource types:

Combined Cycle and Combustion Turbine Resources

A number of the resources located in constrained areas of the gas pipeline system told PJM they were investing in dual-fuel capability. Some generation owners said that firm transportation contracts on the gas pipelines or with local distribution companies were unavailable or not feasible. They said this was primarily due to the physical inability to construct (or prohibitively high cost of constructing) additional pipeline infrastructure, so those resources chose to install fuel-oil tanks as a backup in order to ensure their availability throughout the year, regardless of pipeline or supply restrictions.

Other generation owners said they opted to invest in bundled (firm supply and firm transportation) gas contracts with natural gas marketing companies to ensure delivery of natural gas to their resources. Unfortunately, this market is relatively opaque, which makes it difficult to judge the degree of firm supply available for resources that are depending on this option during stressed grid conditions.

Some generation owners told PJM they have also implemented 24x7 staffing to ensure quick startup time in the event that they are called on to run by PJM.

Coal-Fired Resources

Many of the coal-fired resources in the PJM footprint are more than 20 years old. As mentioned above, some generation owners with aging resources told PJM that they are investing in major equipment overhauls and upgrades to ensure the longevity of these resources. These generation owners also said they are performing routine testing and inspections to ensure the quality of their equipment. Often, these coal generation owners noted that another major area of investment is winterization of equipment to prevent icing and freezing.

[17] See "Capacity Performance Driven Investments" for the type of information that generators have shared with PJM, which forms the basis of the information described. http://pjm.com/~/media/committees-groups/committees/mc/20161024-webinar/20161024-item-03-resource-investments-in-response-to-capacity-performance-requirements.ashx

New Resources Entering the Market

New resources entering the PJM energy market are required to meet the standards of Capacity Performance. Some of those resources opt to report contractual fuel procurement arrangements through the Generator Interconnection Process. Many of these new resources are natural gas-fired resources that need to ensure their fuel supply. These resources often have been strategically located in areas with multiple pipeline capacity options and highly liquid supply capability, and are ensuring their fuel supply reliability through a variety of options, including firm gas supply, firm transportation contracts and connecting to multiple pipelines.