Executive Summary

This Addendum to our white paper on the polar vortex1 is largely based on additional information on system conditions during the polar vortex event provided by PJM and other ISOs, subsequent to the release of ICF’s original white paper. This information reinforces our conclusions: (1) a number of factors, including gas infrastructure and contracting constraints, seasonality of resource availability, and untested reliance on resources with limited testing, all contributed to the wholesale price spikes; understanding these drivers of the power price increases can position investors to take advantage of opportunities that cold snaps provide and (2) a full forensic review of reliability is needed that focuses not only on operational problems, but also on implications for planning, policy, operations, and market structure. Put another way, the grid successfully avoided disaster, but did we need to “skate so close to the edge”? The focus of this Addendum is on reliability, but we emphasize that reliability is closely related to generation profitability, and hence, commercial endeavors need to be properly structured based on anticipation of the market implications of reliability trends.

PJM Outage Information

PJM has provided additional outage information subsequent to the release of ICF’s original white paper (see Figure 1). Figure 2 expresses the same information on a percentage basis relative to total capacity by type.

Figure 1. Generation Forced Outages for January 6–8, 2014

<table>
<thead>
<tr>
<th>RTO</th>
<th>Diesel/CTs</th>
<th>Steam/Fossil</th>
<th>Nuclear</th>
<th>Combined Cycle</th>
<th>Hydro</th>
<th>Wind</th>
<th>Other</th>
<th>Confirmed Gas Curtailments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday 1/6/2014</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>8:00 PM</td>
<td>30,239</td>
<td>8,120</td>
<td>16,116</td>
<td>2,047</td>
<td>1,665</td>
<td>59</td>
<td>1,200</td>
<td>1,032</td>
</tr>
<tr>
<td>Tuesday 1/7/2014</td>
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<tr>
<td>8:00 AM</td>
<td>35,069</td>
<td>11,238</td>
<td>16,910</td>
<td>1,605</td>
<td>2,299</td>
<td>63</td>
<td>1,313</td>
<td>1,641</td>
</tr>
<tr>
<td>7:00 PM</td>
<td>38,033</td>
<td>12,374</td>
<td>18,784</td>
<td>1,605</td>
<td>2,358</td>
<td>61</td>
<td>1,554</td>
<td>1,297</td>
</tr>
<tr>
<td>Wednesday 1/8/2014</td>
<td></td>
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<td></td>
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<tr>
<td>8:00 AM</td>
<td>39,520</td>
<td>13,962</td>
<td>19,114</td>
<td>1,605</td>
<td>2,294</td>
<td>67</td>
<td>1,491</td>
<td>987</td>
</tr>
<tr>
<td>8:00 PM</td>
<td>27,044</td>
<td>9,050</td>
<td>14,281</td>
<td>892</td>
<td>889</td>
<td>53</td>
<td>1,152</td>
<td>727</td>
</tr>
</tbody>
</table>

Source: Source: PJM²

Published Monday Jan 13, 2014
The amount of generator outages during this cold snap was unprecedented. On January 13, 2014, PJM ISO stated that during the top winter demand days of the past five years, no more than 16,127 MW was ever forced off-line (see Figures 3 and 4). As a percentage of total capacity, the previous high for forced outage rate was only 9 percent, compared to a stunning 20 percent during the polar vortex.

### Figure 3. Historical Comparison of Generation Outages in PJM over Past Five Winters

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>ISO Capacity (MW)</td>
<td>174,586</td>
<td>174,586</td>
<td>174,710</td>
<td>174,710</td>
<td>190,700</td>
<td>193,013</td>
<td>189,658</td>
</tr>
<tr>
<td>Peak Load (MW)</td>
<td>132,493</td>
<td>133,844</td>
<td>129,246</td>
<td>132,073</td>
<td>124,273</td>
<td>128,593</td>
<td>141,312</td>
</tr>
<tr>
<td>Forced Outages (MW)</td>
<td>9,664</td>
<td>12,204</td>
<td>13,056</td>
<td>16,127</td>
<td>9,258</td>
<td>15,794</td>
<td>38,309</td>
</tr>
<tr>
<td>Forced Outages (% of ICAP)</td>
<td>6%</td>
<td>7%</td>
<td>7%</td>
<td>9%</td>
<td>5%</td>
<td>8%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Source: PJM³, SNL

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MISO, which was also hit hard by the cold weather, experienced a similar proportion of outages to PJM, losing 28,736 MW (or 22 percent of its total generation). The high forced outage rates seen in PJM and MISO contrast to much lower reported forced outage rates in other ISOs during the polar vortex. NYISO lost 4,135 MW of capacity over the cold snap, or around 10 percent of its installed capacity, close to its average outage rate. Of the 4,135 MW, only around 1,500 MW was directly attributable to cold weather, with 992 MW due to fuel outages (either of natural gas or of coal), and the remainder neither fuel nor weather related. Most of the remaining capacity was the Indian Point 3 nuclear facility, which tripped on January 6. ISO-NE lost only around 1,500 MW of its generation, or around 5 percent of total, but as discussed below, many units successfully switched to generating using stored oil when natural gas supplies became scarce. ERCOT also lost only around 5 percent of its capacity to forced outages during this period. Figure 5 below depicts MISO and PJM’s significantly higher forced outages than usual, especially when compared with ISO-NE and ERCOT.

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7 Communications with NYISO.
9 http://www.reuters.com/article/2014/01/07/utilities-ercot-cold-idUSL2N0KG10G20140107
The key implications of this new information include:

- **Weatherization**—The failure of nearly 40 GW of PJM generation capacity on Wednesday, January 8, 2014 at 8 a.m.—a full 20-to-24 percent of PJM generation capacity in PJM¹⁰—highlights the need to provide more incentives for performance generally, and especially during the winter. Up to 88 percent of forced outage capacity is from oil- and gas-fired generation—e.g., diesels, combustion turbines, steam/fossil (which can be coal or oil and natural gas), and combined cycles. This highlights the need for weatherization and other steps to provide for generation availability and appropriate fuel supply during extreme cold events. Incentives such as high hourly energy prices and other market rules should be reevaluated to ensure they are appropriate to address the need. Of particular concern is the recent change in market structures that favor summer-only resources. An additional concern is the increasing reliance on natural gas generation with interruptible gas service that is more likely to be interrupted during critical winter periods. These issues are discussed further below.

- **Firm Natural Gas Delivery**—While the natural gas pipelines were able to meet all their obligations to firm transportation customers, there was no interruptible capacity available due to the high level of firm demand. Up to one-third of the outages in PJM (see Figure 1, 8 PM Wednesday) were due to lack of natural gas delivery capability to generators that rely on interruptible capacity. Firm gas transportation capacity and/or adequately tested backup (e.g., oil) is not a requirement in any capacity market. Thus, the costs of firm natural gas transportation are not included in the Cost of New Entrants (CONE). By comparison, ISO-NE experienced fewer than 1,500 MW of forced outages on January 7, due to a lack of gas supplies. As a short-term solution to New England generators’ lack of firm fuel supplies,  

¹⁰ PJM contracted (via RPM forward capacity markets) local generation and FRR generation in PJM is 168,600 MW. Total PJM generation as of June 2013 was 183,300 MW. This includes units that are in the process of retiring due to low capacity prices, tightened environmental standards and other factors. Thus, forced outages were 20 percent of total generation, and 24 percent of total PJM contracted supply generation.
last fall ISO-NE procured nearly 2 million MWh for this winter from a combination of oil- and dual-fuel generators. In exchange for their commitment to maintain oil inventories needed to provide power when called upon, the selected oil- and dual-fuel generators receive monthly payments regardless of whether they are actually dispatched. This policy worked well for ISO-NE during the cold snap. Oil provided 25 percent of total generation across the entire ISO during the afternoon of January 7, 2014, as units typical running on natural gas switched over to oil for a short period of time. Over the month of January 2013, oil provided only 7 percent of total generation in New England. NERC, FERC, RTOs, and others are addressing long-term solutions to this issue, but the outcome is uncertain.

- **Retirements and Environmental Standards**—The federal environmental standards known as MATS become effective over the April 2015 to April 2016 period. MATS and other environmental regulations are a key reason (but not the only reason) why PJM has approximately 15,000 MW of very recent and forthcoming coal power plant retirements. This large and growing amount of coal plant retirements will further increase the reliance on natural gas and oil units, and this coal generation capacity will likely not be available for the next polar vortex. There is little doubt that if these retirements had all already occurred without other offsetting changes such as lower forced outage rates at oil and natural gas and other plants, and the construction of alternative resources, the results would have been more dire. Rather than PJM instituting voltage reductions, there would likely have been rolling blackouts threatening space heating, and hence, public health and safety.

- **Renewables**—Outages at renewables did not appear to play a large role in PJM’s situation. However, to the extent that capacity credit was given based on summer availability, this may have overstated the contribution of solar or other intermittent renewables. Also, the level of operating reserve (i.e., quick start or on-line generation) requirements given renewable capacity may have been understated.

- **Interruptible Load**—Interruptible load participation in the markets is a new phenomenon that has grown very rapidly, and the structures in place may have inadvertently played a role in exposing the grid to winter reliability problems and price spikes. Interruptible load accounts for half of PJM’s planning reserve capacity, much of which is contracted for summer only service. Competition from interruptible load is also lowering capacity prices and contributing to the retirements of generators. However, this resource is inherently more easily withdrawn from the market than generating stations. For example, in ISO-NE, only approximately 30 percent of interruptible load contracted for in ISO-NE’s forward capacity auction (FCM) is available during the contract delivery period. Recently, the amounts of interruptible load clearing PJM and ISO-NE’s auctions have also decreased (see Figure 4), but they remain at high levels. Generation is also increasingly focused on summer-only delivery due to the similarity in payments for summer only interruptible load and annual resources. FERC proceedings are addressing this issue, but the outcome is uncertain.

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11 PJM has three types of DR: Limited DR, which can only be dispatched up to 10 times in the summer for 6 hours at a time; extended DR, which can be dispatched an unlimited amount of times for 10 hours at a time from the spring to the fall; and annual DR, which can be called an unlimited amount of times for 10 hours at a time year-round. In the most recent RPM auction (2016/2017), of the nearly 10 GW of DR that cleared, 4.7 GW was limited DR, 3.4 GW was extended DR and only 1.8 GW was annual DR.
Winter Outage Rates and Planning Reserve Margins—A key driver for determination of the planning reserve margin target is the assumed forced outage rate by plant. Current planning assumes individual power plant outage rates are independent of one another. However, the evidence is clear that during extreme winter events, forced outages are not independent (i.e., individual plant outages are highly correlated in that they occur simultaneously), and to the extent PJM and other grid planners continue to make the standard assumption that outages are independent during extreme winter events (i.e., regardless of whether plant X is out, the probability plant Y is also out is unchanged), they are greatly understating the need for resources during the winter. An adjustment based on the recent cold snap, and the 2011 ERCOT cold snap, will result in greater emphasis on winter supply. In light of forthcoming retirements, this adjustment is urgently needed.

Importance of Price Spikes—U.S. policy on price spikes is very diverse and it is very unlikely that all of the prevailing approaches are appropriate. Rather, it is indicative of the need for greater attention to this critical tool for providing incentives for actual operation during critical periods. For example, during shortage events, ERCOT sets a $5,000/MWh level, PJM sets a $2,200/MWh level, and ISO-NE sets a $1,000/MWh level. While there are other differences between these markets, compensation must be highly focused on encouraging operational capability during system extremes, i.e., during the actual need. In light of the growing complexity of the resource mix and demand condition, administrative mechanisms cannot fully keep up with the very dynamic need for action, even under the best of circumstances. Price spikes allow the market to efficiently send signals that resources are needed. Price caps are being raised in some markets, but in light of the critical need to ensure public health and safety, more attention is required on the impacts of energy market price caps on reliability. Thus, while some steps will alleviate the price increases (e.g., firm fuel supply and changes in the resource mix that favor availability year round as opposed to summer only), others may raise prices (e.g. raising the price cap during shortage events to ensure that power plants have the appropriate incentive to be available when needed, regardless of season and hour of the day). However, these changes are needed to prevent worse reliability problems during the next cold snap.
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