Scenario Results – Part 1

FSSTF
10/25/2019
Overview – Scenario Results

Part 1 (October FSSTF)

1. Phase 1 sensitivities based on stakeholder feedback
   a. Pipeline disruption concurrent with event peak load
   b. 14-day pipeline disruption
   c. Initial oil inventory level at 50%
   d. Portfolio sensitivity with additional renewable replacement of retirements (Escalated 3)

2. RTO-wide scenarios using Relevant Risk data from Historical Cold Snap Events

Part 2 (November FSSTF)

3. Locational scenarios using Relevant Risk data from Historical Cold Snap Events

4. RTO-wide and locational scenarios using Relevant Risk data for summer event

3. Scenario with data from October 1, 2019 Operational Event

4. Address feedback from October FSSTF
## Goals of Scenario Analysis

<table>
<thead>
<tr>
<th>Inform stakeholders about:</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Potential impacts of fuel/energy/resource risk events</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>2. Factors that contribute to fuel/energy/resource security</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>3. Risk of occurrence of selected scenarios</td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>4. Analysis framework that could be applied to risks in other seasons and other resource portfolios</td>
<td>✔️</td>
<td>✔️</td>
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</tbody>
</table>
Phase 1 Sensitivities based on Stakeholder Feedback
## Scenario Analysis Approach

<table>
<thead>
<tr>
<th>Approach</th>
<th>Winter Load</th>
<th>Renewable Profiles</th>
<th>Relevant Risk Forced Outages</th>
<th>Other Forced Outages</th>
</tr>
</thead>
</table>
| **Phase 1 & Phase 1 Sensitivities based on Stakeholder Feedback (Phase 2)** | Typical  
• 50/50 peak (134,976 MW)  
• 2011/12 load profile  
Extreme Winter  
• 95/5 peak (147,721 MW)  
• 2017/18 load profile  
14 day study period | 2017/18 winter profiles, scaled to nameplate capacity in portfolio | Modeled sensitivities for fuel delivery risks: oil refueling, non-firm gas availability, pipeline disruptions | Forced outage rates using GADS cause codes not used in relevant risks or sensitivities |
| **Historical Relevant Risk Events (Phase 2)** | Load shapes consistent with selected cold snaps | Profile from cold snap, scaled to nameplate capacity in portfolio | Relevant Risk Forced Outages Rates from cold snap scaled to portfolio | Sensitivities for discrete occurrences of risks outside of historical forced outage dataset |

Portfolios: Announced (25.8% IRM), Escalated 1 (15.8% IRM), Escalated 2 (15.8% IRM), Escalated 3 (15.8% IRM)
## Review: Phase 1 Scenarios

<table>
<thead>
<tr>
<th>Dispatch</th>
<th>Retirement</th>
<th>Winter Load</th>
<th>Non-Firm Gas</th>
<th>Refueling</th>
<th>Pipeline Disruption (med. impact)</th>
<th>Pipeline Disruption (high impact)</th>
<th>Forced Outages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>Announced</td>
<td>Typical 50/50 134,976 MW</td>
<td>62.5% Avail.</td>
<td>Moderate</td>
<td>Looped 1</td>
<td>Looped 1</td>
<td>Five-Year Avg.</td>
</tr>
<tr>
<td>Max. Emergency</td>
<td>Escalated 1</td>
<td>Extreme 95/5 147,721 MW</td>
<td>0% Avail.</td>
<td>Limited</td>
<td>Looped 2</td>
<td>Looped 2</td>
<td>Modeled Outages</td>
</tr>
<tr>
<td>Escalated 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Single 1</td>
<td>Single 1</td>
<td></td>
</tr>
</tbody>
</table>

### Total Combinations

| 324 combinations |
Phase 1 Sensitivities based on Stakeholder Feedback

Adjust following **input assumptions**, one at a time, for selected scenarios:

1. Pipeline disruption concurrent with event peak load (days 6 - 10)
2. 14-day pipeline disruption
3. Initial oil inventory level at 50%
4. Portfolio sensitivity with additional renewable replacement of retirements (Escalated 3)

**Outputs** consistent with Phase 1 results presented for each scenario:

<table>
<thead>
<tr>
<th>Normal Operations</th>
<th>No Emergency Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal economic dispatch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Demand Response Deployed</th>
<th>Pre-Emergency Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demand response deployment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reserve Shortage</th>
<th>Emergency Warning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>An operational reserve shortage is triggered when 10-minute Synchronized Reserves are less than the largest generator in PJM. Depending on system conditions, a reserve shortage will trigger additional emergency procedures such as voltage reduction warnings and manual load shed warnings.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Voltage Reduction</th>
<th>Emergency Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Voltage reduction action enables load reductions by reducing voltages at the distribution level. PJM estimates a 1-2% load reduction resulting from a 5% load reduction in transmission zones capable of performing a voltage reduction.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load Shed</th>
<th>Emergency Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual load shed action enables zonal or system-wide load shed. This is the last step of all emergency procedure actions.</td>
</tr>
</tbody>
</table>

56 sensitivities
Phase 1 Announced Retirement Models for Sensitivities

- Phase 1 Scenarios used in sensitivities
### Phase 1 Escalated Retirement Models for Sensitivities

<table>
<thead>
<tr>
<th>Winter Load</th>
<th>Retirement</th>
<th>Non-Firm Gas Avail.</th>
<th>Dispatch</th>
<th>Pipeline Disruption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>None</td>
<td>Single 1</td>
</tr>
<tr>
<td>Escalated 1</td>
<td>62.5%</td>
<td>Economic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Escalated 2</td>
<td>62.5%</td>
<td>Economic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Escalated 1</td>
<td>62.5%</td>
<td>Max Emerg</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Max Emerg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Escalated 2</td>
<td>62.5%</td>
<td>Max Emerg</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Max Emerg</td>
<td></td>
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</tbody>
</table>

- Phase 1 Scenarios used in sensitivities
Phase 1 Sensitivities based on Stakeholder Feedback: Pipeline Disruption Concurrent with Peak Load*  

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Related Phase 1 Scenario #</th>
<th>Portfolio</th>
<th>IRM</th>
<th>Dispatch</th>
<th>Winter Load</th>
<th>Non-Firm Gas Availability</th>
<th>Infrastructure Disruption</th>
<th>Disruption Severity</th>
<th>Disruption Duration</th>
<th>Refueling</th>
<th>Initial Oil Inventory Level</th>
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<tbody>
<tr>
<td>1</td>
<td>45</td>
<td>Announced</td>
<td>28.5%</td>
<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D6-10</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
<td>2</td>
<td>54</td>
<td>Announced</td>
<td>28.5%</td>
<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D6-10</td>
<td>Limited</td>
<td>85%</td>
</tr>
<tr>
<td>3</td>
<td>63</td>
<td>Announced</td>
<td>28.5%</td>
<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
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<td>D6-10</td>
<td>Moderate</td>
<td>85%</td>
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<tr>
<td>4</td>
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<td>Economic</td>
<td>Extreme</td>
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<td>Pipeline (L2)</td>
<td>High</td>
<td>D6-10</td>
<td>Limited</td>
<td>85%</td>
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<tr>
<td>5</td>
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<td>Economic</td>
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<td>62.5%</td>
<td>Pipeline (L2)</td>
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<td>85%</td>
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<tr>
<td>6</td>
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<td>62.5%</td>
<td>Pipeline (L2)</td>
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<td>D6-10</td>
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<td>85%</td>
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<tr>
<td>7</td>
<td>171</td>
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<td>Extreme</td>
<td>0%</td>
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<td>D6-10</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
<td>8</td>
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<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
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<td>D6-10</td>
<td>Limited</td>
<td>85%</td>
</tr>
<tr>
<td>9</td>
<td>261</td>
<td>Escalated 2</td>
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<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D6-10</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
<td>10</td>
<td>270</td>
<td>Escalated 2</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D6-10</td>
<td>Limited</td>
<td>85%</td>
</tr>
<tr>
<td>11</td>
<td>279</td>
<td>Escalated 2</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D6-10</td>
<td>Moderate</td>
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<tr>
<td>12</td>
<td>288</td>
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<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D6-10</td>
<td>Limited</td>
<td>85%</td>
</tr>
</tbody>
</table>

*Peak of 147,721 MW occurs on Day 10 with Extreme Winter load shape
### Phase 1: Pipeline Disruption D1-5

<table>
<thead>
<tr>
<th>Winter Load</th>
<th>Retirement</th>
<th>Non-Firm Gas Avail.</th>
<th>Dispatch</th>
<th>Limited Refueling</th>
<th>Moderate Refueling</th>
<th>Looped 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme (95/5)</td>
<td>Announced</td>
<td>62.5%</td>
<td>Economic</td>
<td>22</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Escalated 1</td>
<td>62.5%</td>
<td>Economic</td>
<td>7</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Escalated 2</td>
<td>62.5%</td>
<td>Economic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td></td>
<td></td>
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</table>

### Sensitivity #1-12: Pipeline Disruption D6-10

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<th>Non-Firm Gas Avail.</th>
<th>Dispatch</th>
<th>Limited Refueling</th>
<th>Moderate Refueling</th>
<th>Looped 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme (95/5)</td>
<td>Announced</td>
<td>62.5%</td>
<td>Economic</td>
<td>2</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Escalated 1</td>
<td>62.5%</td>
<td>Economic</td>
<td>37</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Escalated 2</td>
<td>62.5%</td>
<td>Economic</td>
<td>9</td>
<td>27</td>
<td></td>
</tr>
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</table>

- No increase in emergency procedures in sensitivities with Announced Retirement portfolio
- Some increase in emergency procedure hours in sensitivities with Escalated Retirement portfolios
Phase 1: Pipeline Disruption D1-5

<table>
<thead>
<tr>
<th>Winter Load</th>
<th>Retirement</th>
<th>Non-Firm Gas Avail.</th>
<th>Dispatch</th>
<th>Looped 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme (95/5)</td>
<td>Announced</td>
<td>62.5% Economic</td>
<td>62.5% Economic</td>
<td>0% Economic</td>
</tr>
<tr>
<td></td>
<td>Escalated 1</td>
<td>62.5% Economic</td>
<td>30 High</td>
<td>2 High</td>
</tr>
<tr>
<td></td>
<td>Escalated 2</td>
<td>62.5% Economic</td>
<td>21 High</td>
<td>104 High</td>
</tr>
</tbody>
</table>

Sensitivity #1-12: Pipeline Disruption D6-10

<table>
<thead>
<tr>
<th>Winter Load</th>
<th>Retirement</th>
<th>Non-Firm Gas Avail.</th>
<th>Dispatch</th>
<th>Looped 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme (95/5)</td>
<td>Announced</td>
<td>62.5% Economic</td>
<td>62.5% Economic</td>
<td>0% Economic</td>
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<tr>
<td></td>
<td>Escalated 1</td>
<td>62.5% Economic</td>
<td>1 High</td>
<td>16 High</td>
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<tr>
<td></td>
<td>Escalated 2</td>
<td>62.5% Economic</td>
<td>34 High</td>
<td>103 High</td>
</tr>
</tbody>
</table>

- No increase in emergency procedures in sensitivities with Announced Retirement portfolio
- Some increase in emergency procedure GWh in sensitivities with Escalated Retirement portfolios

Sensitivity Scenario Summaries in Appendix I
Phase 1: Pipeline Disruption D1-5

**Moderate Refueling**

- Sites Out of Oil: 0 2 1 3 4 4 6 7 12 21 29 26 17 1
- Day of Event: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

**Limited Refueling**

- Sites Out of Oil: 3 15 24 36 48 56 70 90 97 98 109 107 108 95
- Day of Event: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Scenario 171

Scenario 180

Onsite inventories depleted during pipeline disruption, before peak load of scenario

**Sensitivity #1-12: Pipeline Disruption D6-10**

**Moderate Refueling**

- Sites Out of Oil: 0 1 0 0 0 1 4 6 10 22 28 30 16 1
- Day of Event: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

**Limited Refueling**

- Sites Out of Oil: 1 2 3 5 7 12 35 66 74 88 100 103 107 94
- Day of Event: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Sensitivity 7

Sensitivity 8

Onsite inventory depletion occurs later in scenario with pipeline disruption + peak load

Phase 1 Sensitivities based on Stakeholder Feedback: Pipeline Disruption Concurrent with Peak Load*

www.pjm.com
# Phase 1 Sensitivities based on Stakeholder Feedback:
## 14-day Pipeline Disruption

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Related Phase 1 Scenario #</th>
<th>Portfolio</th>
<th>IRM</th>
<th>Dispatch</th>
<th>Winter Load</th>
<th>Non-Firm Gas Availability</th>
<th>Infrastructure Disruption</th>
<th>Disruption Severity</th>
<th>Disruption Duration</th>
<th>Refueling</th>
<th>Initial Oil Inventory Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>45</td>
<td>Announced</td>
<td>28.5%</td>
<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
<td>14</td>
<td>54</td>
<td>Announced</td>
<td>28.5%</td>
<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Limited</td>
<td>85%</td>
</tr>
<tr>
<td>15</td>
<td>63</td>
<td>Announced</td>
<td>28.5%</td>
<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
<td>16</td>
<td>72</td>
<td>Announced</td>
<td>28.5%</td>
<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Limited</td>
<td>85%</td>
</tr>
<tr>
<td>17</td>
<td>153</td>
<td>Escalated 1</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
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<td>162</td>
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<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Limited</td>
<td>85%</td>
</tr>
<tr>
<td>19</td>
<td>171</td>
<td>Escalated 1</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
<td>20</td>
<td>180</td>
<td>Escalated 1</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Limited</td>
<td>85%</td>
</tr>
<tr>
<td>21</td>
<td>261</td>
<td>Escalated 2</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
<td>22</td>
<td>270</td>
<td>Escalated 2</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Limited</td>
<td>85%</td>
</tr>
<tr>
<td>23</td>
<td>279</td>
<td>Escalated 2</td>
<td>15.8%</td>
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<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
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<td>D1-14</td>
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<td>85%</td>
</tr>
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<td>24</td>
<td>288</td>
<td>Escalated 2</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-14</td>
<td>Limited</td>
<td>85%</td>
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</table>
Phase 1 Sensitivities based on Stakeholder Feedback:
14-day Pipeline Disruption Emergency Procedure Hours

### Phase 1: Pipeline Disruption D1-5

<table>
<thead>
<tr>
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<th>Retirement</th>
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<th>Dispatch</th>
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<td>Escalated 2</td>
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- Increase in pre-emergency procedures in sensitivities with Announced Retirement portfolio
- Increase in emergency procedure hours in sensitivities with Escalated Retirement portfolios

### Sensitivity #13-24: Pipeline Disruption D1-14

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Sensitivity Scenario Summaries in Appendix I
Phase 1: Pipeline Disruption D1-5

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<th>Moderate Refueling</th>
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<tr>
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Sensitivity Scenario Summaries in Appendix I

- Increase in pre-emergency procedures in sensitivities with Announced Retirement portfolio
- Increase in emergency procedure GWh in sensitivities with Escalated Retirement portfolios
**Phase 1 Sensitivities based on Stakeholder Feedback:**

**Initial Oil Inventory Level at 50%**

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Related Phase 1 Scenario #</th>
<th>Portfolio</th>
<th>IRM</th>
<th>Dispatch</th>
<th>Winter Load</th>
<th>Non-Firm Gas Availability</th>
<th>Infrastructure Disruption</th>
<th>Disruption Severity</th>
<th>Disruption Duration</th>
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<td>None</td>
<td>None</td>
<td>Limited</td>
<td>50%</td>
</tr>
<tr>
<td>26</td>
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<td>Extreme</td>
<td>62.5%</td>
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<td>None</td>
<td>None</td>
<td>Limited</td>
<td>50%</td>
</tr>
<tr>
<td>27</td>
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<td>Economic</td>
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<td>Limited</td>
<td>50%</td>
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<td>Pipeline (L2)</td>
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<td>D1-5</td>
<td>Moderate</td>
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<td>Pipeline (L2)</td>
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<td>D1-5</td>
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<td>Pipeline (L2)</td>
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<td>D1-5</td>
<td>Limited</td>
<td>50%</td>
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<td>Pipeline (L2)</td>
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<td>D1-5</td>
<td>Limited</td>
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<td>Pipeline (L2)</td>
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<td>D1-5</td>
<td>Limited</td>
<td>50%</td>
</tr>
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<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
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<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-5</td>
<td>Limited</td>
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<td>279</td>
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<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
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<td>Economic</td>
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<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-5</td>
<td>Limited</td>
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</table>
Phase 1 Sensitivities based on Stakeholder Feedback: Initial Oil Inventory Level at 50% Emergency Procedure Hours

### Phase 1: Initial Oil Inventory Level at 85%

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<th>Dispatch</th>
<th>Moderate Refueling</th>
<th>Limited Refueling</th>
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<td>Green</td>
<td>Blue</td>
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<td>Extreme (95/5)</td>
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<td>Green</td>
<td>Blue</td>
</tr>
<tr>
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<td>Economic</td>
<td>High</td>
<td>Yellow</td>
<td>Yellow</td>
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<tr>
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<td>62.5% Economic</td>
<td>None</td>
<td>Green</td>
<td>Blue</td>
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<tr>
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<td>0%</td>
<td>Economic</td>
<td>High</td>
<td>Yellow</td>
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<td>High</td>
<td>Yellow</td>
<td>Yellow</td>
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</table>

### Sensitivity #25-48: Initial Oil Inventory Level at 50%

- Some increase in pre-emergency procedures in sensitivities with Announced Retirement portfolio
- Some increase in emergency procedure hours in sensitivities with Escalated Retirement portfolios

- Scenarios to be compared in following slides

*Sensitivity Scenario Summaries in Appendix I*
Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%
Emergency Procedure GWh

**Phase 1: Initial Oil Inventory Level at 85%**

<table>
<thead>
<tr>
<th>Winter Load</th>
<th>Retirement</th>
<th>Non-Firm Gas Avail.</th>
<th>Dispatch</th>
<th>Moderate Refueling</th>
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**Sensitivity #25-48: Initial Oil Inventory Level at 50%**

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<th>Moderate Refueling</th>
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<td>62.5% Economic</td>
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<td>Looped 2</td>
<td>None</td>
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</table>

- Some increase in pre-emergency procedures in sensitivities with Announced Retirement portfolio
- Some increase in emergency procedure GWh in sensitivities with Escalated Retirement portfolios

Scenarios to be compared in following slides

Sensitivity Scenario Summaries in Appendix I
Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%

Phase 1: Initial Oil Inventory Level at 85%

Moderate Refueling

Limited Refueling

Sensitivity #25-48: Initial Oil Inventory Level at 50%

Moderate Refueling

Limited Refueling

More rapid onsite fuel depletion in sensitivities with lower initial inventory levels
Addition of Escalated 3 Portfolio for Sensitivity

Note: Appendix IV includes comparison of portfolios used in PJM analysis to portfolios used in 2018 NERC Generation Retirement Scenario Assessment
### Phase 1 Sensitivities based on Stakeholder Feedback:
**“Escalated 3” Portfolio**

<table>
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<th>Related Phase 1 Scenario #</th>
<th>Portfolio</th>
<th>IRM</th>
<th>Dispatch</th>
<th>Winter Load</th>
<th>Non-Firm Gas Availability</th>
<th>Infrastructure Disruption</th>
<th>Disruption Severity</th>
<th>Disruption Duration</th>
<th>Refueling</th>
<th>Initial Oil Inventory Level</th>
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<tbody>
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<td>Extreme</td>
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<td>None</td>
<td>Moderate</td>
<td>85%</td>
</tr>
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<td>None</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
<td>52</td>
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<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>None</td>
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<td>None</td>
<td>Limited</td>
<td>85%</td>
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<tr>
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<td>153</td>
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<td>Economic</td>
<td>Extreme</td>
<td>62.5%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-5</td>
<td>Moderate</td>
<td>85%</td>
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<tr>
<td>54</td>
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<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-5</td>
<td>Limited</td>
<td>85%</td>
</tr>
<tr>
<td>55</td>
<td>171</td>
<td>Escalated 3</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-5</td>
<td>Moderate</td>
<td>85%</td>
</tr>
<tr>
<td>56</td>
<td>180</td>
<td>Escalated 3</td>
<td>15.8%</td>
<td>Economic</td>
<td>Extreme</td>
<td>0%</td>
<td>Pipeline (L2)</td>
<td>High</td>
<td>D1-5</td>
<td>Limited</td>
<td>85%</td>
</tr>
</tbody>
</table>
Phase 1 Sensitivities based on Stakeholder Feedback: “Escalated 3” Portfolio Emergency Procedure Hours

<table>
<thead>
<tr>
<th>Winter Load</th>
<th>Retirement</th>
<th>Non-Firm Gas Avail.</th>
<th>Dispatch</th>
<th>Moderate Refueling</th>
<th>Limited Refueling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>None</td>
<td>Looped 2</td>
<td>None</td>
</tr>
<tr>
<td>Announced</td>
<td>62.5%</td>
<td>Economic</td>
<td>None</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td>Looped 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme (95/5) Escalated 1</td>
<td>62.5%</td>
<td>Economic</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td>Looped 2</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>Escalated 2</td>
<td>62.5%</td>
<td>Economic</td>
<td>None</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td>Looped 2</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

### Sensitivity #49-56: Escalated 3 Portfolio

<table>
<thead>
<tr>
<th>Winter Load</th>
<th>Retirement</th>
<th>Non-Firm Gas Avail.</th>
<th>Dispatch</th>
<th>Moderate Refueling</th>
<th>Limited Refueling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>None</td>
<td>Looped 2</td>
<td>None</td>
</tr>
<tr>
<td>Announced</td>
<td></td>
<td></td>
<td>None</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Looped 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme (95/5) Escalated 3</td>
<td>62.5%</td>
<td>Economic</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>Economic</td>
<td>Looped 2</td>
<td>6</td>
<td>13</td>
</tr>
</tbody>
</table>

Renewable ICAP in portfolios and renewable profiles (scaled to nameplate MW) contributed to the reduced severity observed between scenarios with Escalated 1 and Escalated 3 portfolios, which include the same numbers of retirements with a different mix of replacement resources.

Sensitivity Scenario Summaries in Appendix I
Phase 1 Sensitivities based on Stakeholder Feedback: “Escalated 3” Portfolio Emergency Procedure GWh

Renewable ICAP in portfolios and renewable profiles (scaled to nameplate MW) contributed to the reduced severity observed between scenarios with Escalated 1 and Escalated 3 portfolios, which include the same numbers of retirements with a different mix of replacement resources.

*Sensitivity Scenario Summaries in Appendix I*
Part 1 (October FSSTF)

1. Phase 1 sensitivities based on stakeholder feedback
   a. Pipeline disruption concurrent with event peak load
   b. 14-day pipeline disruption
   c. Initial oil inventory level at 50%
   d. Portfolio sensitivity with additional renewable replacement of retirements (Escalated 3)

2. RTO-wide scenarios using Relevant Risk data from Historical Cold Snap Events

Part 2 (November FSSTF)

3. Locational scenarios using Relevant Risk data from Historical Cold Snap Events

4. RTO-wide and locational scenarios using Relevant Risk data for summer event

3. Scenario with data from October 1, 2019 Operational Event

4. Address feedback from October FSSTF
Scenarios using Relevant Risk data from Historical Cold Snap Events
Risk Assessment Review

June
- Why current focus on winter?
- Relevant Risk filtering and identification

July
- Historical Cold Snap data
- Historical Pipeline Disruption frequency data

August
- Historical Pipeline Disruption impact data
- Historical Wind and Solar Intermittency
- Historical Relevant Risk data
- Discussion of scenario analysis approach

September
- Review of Relevant Risk data as input to scenario analysis

October
Preliminary results
## Relevant Risks for Winter Scenarios

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Covered in July</th>
<th>Covered in July / August</th>
<th>Covered in August</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Duration Cold Snap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short Duration Cold Snap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas Pipeline Disruptions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar Intermittency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Intermittency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal Refueling (Bridge Failure)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal Refueling (Lock and Dam Failure)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal Refueling (Rail Failure)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal Refueling (River Freezing)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal Unavailability (Coal Quality)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas Unavailability Non-Firm Units</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil Refueling (Oil Terminal)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil Refueling (Truck Restrictions)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear Regulatory Shutdown (Fuel Related)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear Regulatory Shutdown (Non-Fuel Related)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear Unavailability (High Winds)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydro Unavailability (Freezing Rivers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>River Freezing (Cooling Water Impacts)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice Storm (Transportation Impacts)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cold Snaps

29 identified cold snaps in 47 winter periods (1972 – 2018)
- Definition: 5 or more contiguous days where average RTO wind-adjusted temperature (WWP) in each day is less than 21.5°F
- Average occurrence: 0.6 Cold Snaps per Delivery Year (Winter)
- Average Length: 7.5 days

4 Cold Snaps with available data for calculating:
- Fuel specific Relevant Risk Forced Outage Rates (RR-FOR)
- Wind & Solar capacity factor profiles
Cold Snaps Analyzed:

<table>
<thead>
<tr>
<th>Cold Snap</th>
<th>Start</th>
<th>Stop</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Jan. 6, 2015</td>
<td>Jan. 10, 2015</td>
<td>5 Days</td>
</tr>
</tbody>
</table>

Forced Outage Rate:

\[
\text{FOR} = \frac{\text{MW Forced Out}}{\text{Total Installed Nameplate}}
\]

For coal, natural gas, nuclear, hydro, and oil resources, the forced outage rate serves as an indicator of the degree of unavailability for a set of resources.

Winter Peak Hours:

<table>
<thead>
<tr>
<th>AM Peak</th>
<th>PM Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE08 &amp; HE09</td>
<td>HE19 &amp; HE20</td>
</tr>
</tbody>
</table>

* 2014 winter data is considered in this analysis. Forced outages from the peak week of the 2013/14 winter (which contained Jan. 6-8, 2014, Polar Vortex 1) are not included in the development of the Capacity Model in the Reserve Requirement Study. Note that Jan. 6-8, 2014 does not fall under the cold snap criteria defined for this analysis.
Fuel Specific Relevant Risk Forced Outage Rate (RR-FOR)

Fuel Specific Cause Codes + (Cause Codes ∩ Fuel Type) = RR-FOR

Common Cause Codes

Fuel Specific Relevant Risk Forced Outage Rate

www.pjm.com
### Relevant Risk Forced Outage Rate Summary by Fuel Type

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oil</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off Peak</td>
<td>1.909%</td>
<td>0.122%</td>
<td>0.957%</td>
<td>0.022%</td>
<td>0.768%</td>
</tr>
<tr>
<td>Peak</td>
<td>1.979%</td>
<td>0.118%</td>
<td>1.266%</td>
<td>0.006%</td>
<td>0.850%</td>
</tr>
<tr>
<td>All Hours</td>
<td>1.921%</td>
<td>0.121%</td>
<td>1.008%</td>
<td>0.020%</td>
<td>0.782%</td>
</tr>
<tr>
<td><strong>Nuclear</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off Peak</td>
<td>0.001%</td>
<td>0.012%</td>
<td>0.062%</td>
<td>0.003%</td>
<td>0.017%</td>
</tr>
<tr>
<td>Peak</td>
<td>0.001%</td>
<td>0.012%</td>
<td>0.069%</td>
<td>0.003%</td>
<td>0.018%</td>
</tr>
<tr>
<td>All Hours</td>
<td>0.001%</td>
<td>0.012%</td>
<td>0.063%</td>
<td>0.003%</td>
<td>0.017%</td>
</tr>
<tr>
<td><strong>Hydro</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off Peak</td>
<td>0.717%</td>
<td>0.273%</td>
<td>0.209%</td>
<td>0.246%</td>
<td>0.372%</td>
</tr>
<tr>
<td>Peak</td>
<td>0.721%</td>
<td>0.275%</td>
<td>0.215%</td>
<td>0.250%</td>
<td>0.377%</td>
</tr>
<tr>
<td>All Hours</td>
<td>0.718%</td>
<td>0.273%</td>
<td>0.210%</td>
<td>0.247%</td>
<td>0.373%</td>
</tr>
<tr>
<td><strong>Gas</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off Peak</td>
<td>15.101%</td>
<td>3.755%</td>
<td>6.466%</td>
<td>2.456%</td>
<td>7.040%</td>
</tr>
<tr>
<td>Peak</td>
<td>15.117%</td>
<td>3.576%</td>
<td>6.540%</td>
<td>2.306%</td>
<td>6.982%</td>
</tr>
<tr>
<td>All Hours</td>
<td>15.104%</td>
<td>3.725%</td>
<td>6.479%</td>
<td>2.431%</td>
<td>7.031%</td>
</tr>
<tr>
<td><strong>Coal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off Peak</td>
<td>0.684%</td>
<td>0.374%</td>
<td>0.461%</td>
<td>0.131%</td>
<td>0.392%</td>
</tr>
<tr>
<td>Peak</td>
<td>0.699%</td>
<td>0.334%</td>
<td>0.537%</td>
<td>0.125%</td>
<td>0.405%</td>
</tr>
<tr>
<td>All Hours</td>
<td>0.687%</td>
<td>0.367%</td>
<td>0.474%</td>
<td>0.130%</td>
<td>0.394%</td>
</tr>
</tbody>
</table>

* Does not include additional random forced outages generated by Monte Carlo simulation

** Gas forced outage MW from RR-FOR capped at MW of non-firm gas in portfolio
Cold Snaps Analyzed:

<table>
<thead>
<tr>
<th>Cold Snap</th>
<th>Start</th>
<th>Stop</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jan. 21, 2014</td>
<td>Jan. 30, 2014</td>
<td>10 Days</td>
</tr>
<tr>
<td>2</td>
<td>Jan. 6, 2015</td>
<td>Jan. 10, 2015</td>
<td>5 Days</td>
</tr>
</tbody>
</table>

Capacity Factor:

\[ CF = \frac{\text{Actual Hourly Output}}{\text{Total Installed Nameplate}} \]

For solar and wind resources, capacity factor serves as an indicator of how effectively the resources are performing.

Winter Peak Hours:

<table>
<thead>
<tr>
<th>AM Peak</th>
<th>PM Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE08 &amp; HE09</td>
<td>HE19 &amp; HE20</td>
</tr>
</tbody>
</table>
## Scenario Analysis Approach

<table>
<thead>
<tr>
<th>Approach</th>
<th>Winter Load</th>
<th>Renewable Profiles</th>
<th>Relevant Risk Forced Outages</th>
<th>Other Forced Outages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase 1</strong> &amp; Phase 1 Sensitivities based on Stakeholder Feedback (Phase 2)</td>
<td><strong>Typical</strong>&lt;br&gt;• 50/50 peak (134,976 MW)&lt;br&gt;• 2011/12 load profile</td>
<td>2017/18 winter profiles, scaled to nameplate capacity in portfolio</td>
<td>Explicitly modeled sensitivities for fuel delivery risks: oil refueling, non-firm gas availability, pipeline disruptions</td>
<td></td>
</tr>
<tr>
<td><strong>Extreme Winter</strong>&lt;br&gt;• 95/5 peak (147,721 MW)&lt;br&gt;• 2017/18 load profile</td>
<td>14 day study period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Historical Relevant Risk Events (Phase 2)</strong></td>
<td>Load shapes consistent with selected cold snaps</td>
<td>Profile from cold snap, scaled to nameplate capacity in portfolio</td>
<td>Relevant Risk Forced Outages Rates from cold snap scaled to portfolio</td>
<td>Forced outage rates using GADS cause codes not used in relevant risks or sensitivities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Portfolios:** Announced (25.8% IRM), Escalated 1 (15.8% IRM), Escalated 2 (15.8% IRM), Escalated 3 (15.8% IRM)
Load Shapes based on Historical Cold Snaps

• A 2023/2024 hourly load shape is derived based on the weather of each historical cold snaps
  – Therefore, 29 hourly load shapes are derived
• The procedure to derive the hourly load shapes is consistent with the PJM Load Forecast model and considers
  – A peak load forecast model employed to determine the “peak load” of each load shape
  – An hourly load forecast model employed to determine the relationship between the hourly loads (the “shape”) in each load shape
  – The forecasted “shape” is then adjusted so that the shape’s peak is equal to the forecasted “peak load”
Approach to Historical Cold Snap + Relevant Risk Scenarios

**Set 1:** Four most recent cold snaps with related RR-FOR and wind/solar capacity factor profiles from same period

**Set 2:** Scenarios for remaining 25 cold snaps paired with RR-FOR and wind/solar capacity factor profiles from each of the four cold snaps

<table>
<thead>
<tr>
<th>Cold Snap</th>
<th>Fuel Specific RR-FOR</th>
<th>Wind &amp; Solar Capacity Factor Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS-1</td>
<td>CS-1</td>
<td>CS-1</td>
</tr>
<tr>
<td>CS-2</td>
<td>CS-2</td>
<td>CS-2</td>
</tr>
<tr>
<td>CS-3</td>
<td>CS-3</td>
<td>CS-3</td>
</tr>
<tr>
<td>CS-4</td>
<td>CS-4</td>
<td>CS-4</td>
</tr>
<tr>
<td>Remaining 25</td>
<td></td>
<td>Remained 25</td>
</tr>
</tbody>
</table>

- Monte Carlo for other forced outages (non RR-FOR) in each scenario
- Approach could be applied to any portfolio – in this case will be using Phase 1 & Phase 1 sensitivity portfolios
- 0 MWs of Planned Outages are assumed in all scenarios
- Results: Loss of load expectation (LOLE) metric
Stochastic Elements in Simulation

- Load Shapes: technically, 47 winter load shapes (one for each year in the period 1972-2018) are examined. Each one of them is assumed to be equally likely.
  - For winters without Cold Snaps, the reported LOLE is assumed to be zero
  - For the rest of the winters, the reported LOLE is the sum of the LOLE for each of the Cold Snaps in the winter
- Random Forced Outages (excluding those associated with Relevant Risks)
  - Modeled using Monte Carlo (1,000 replications)
Stochastic Elements in Simulation

- Relevant Risks Forced Outages Rates (RR-FOR) / Renewables Capacity Factors (CF)
  - For the 4 most recent Cold Snaps, the corresponding hourly RR-FOR and CF patterns are used (e.g., for the 12/26/2017 – 01/07/2018 Cold Snap, the RR-FORs and CFs from the same period are used)
  - For the 25 older Cold Snaps, the hourly patterns from the 4 most recent Cold Snaps are used, with each one of them assumed to be equally likely.
- Daily Peaks are aligned to determine the positioning of the hourly patterns. Data from the most recent cold snaps is used on a rolling basis to fill up data gaps. For example:
Stochastic Elements in Simulation

• Disruption timing during Cold Snap:
  – Disruptions of size X MW (where X is varied from 0 MW to 10,000 MW) are also simulated
    • The size of the disruption is not stochastic
  – The duration of the disruption is assumed to be 5 days (not stochastic)
  – The timing of the disruption is modeled stochastically by considering all potential overlapping patterns between the disruption and the Cold Snap (with each potential overlapping pattern assumed equally likely)
Stochastic Elements in Simulation

• Disruption timing during Cold Snap:
  – For example, for a 10 day Cold Snap (in yellow below), PJM simulated all overlapping patterns

There are 14 potential overlapping patterns between the disruption (in green) and the Cold Snap (in yellow).

The overlapping patterns include partial and full overlaps. They range from “first day of snap coincides with last day of disruption” to “last day of snap coincides with first day of disruption”.

```
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
```
• Therefore, the total number of scenarios examined for a Cold Snap of, for example, 10 days under a disruption of size X is
  – If the Cold Snap is one of the four most recent Cold Snaps:
    \[1,000 \times 1 \times 14 = 14,000\]
  – If the Cold Snap is one of the older Cold Snaps:
    \[1,000 \times 4 \times 14 = 56,000\]
LOLE Results

• First, LOLE is calculated for each of the Cold Snaps under a Disruption of size X MW (where X is varied from 0 MW to 10,000 MW)
  – These graphs and tables are shown in the Appendix

• The above results are then aggregated by year (if a year did not have a Cold Snap, the LOLE is assumed to be zero). A total of 47 LOLE values (one for each year in the period 1972-2018) are then averaged.
  – These are the results shown in the upcoming slides
• The LOLE results under a 0 MW Disruption capture the impact of Relevant Risk Forced Outages, Wind/Solar Capacity Factors, and random Forced Outages without any additional disruption.
Clarification of LOLE results

• The LOLE results are expressed in days/year
• The LOLE values reported for each portfolio in this analysis are in addition to the LOLE outside of the winter period
  – For instance, a portfolio with reserves at the IRM has an LOLE equal to 0.1 days/year (from the Summer period) plus the LOLE reported in this analysis.
LOLE vs Disruption - Announced Retirements (28.5% ICAP Reserves)

Even up to 10,000 MW of disruption beyond historical levels, average LOLE remains at zero.

Results considering RR-FOR and other random forced outages with no additional disruptions.
LOLE vs Disruption - Escalated Retirements #1 (15.8% ICAP Reserves)

Averaging across all winters, non-zero LOLE observed beginning with disruptions of 2,000 MW.
Results considering RR-FOR and other random forced outages with no additional disruptions.

Averaging across all winters, non-zero LOLE observed beginning with disruptions of 4,000 MW.
LOLE vs Disruption - Escalated Retirements #3 (15.8% ICAP Reserves)

Results considering RR-FOR and other random forced outages with no additional disruptions.

Averaging across all winters, non-zero LOLE observed beginning with disruptions of 1,000 MW.
## Example Disruptions

Intended to provide context for “Disruption (MW)” axis in LOLE results slides

<table>
<thead>
<tr>
<th>Disruption Type</th>
<th>Worst Case Potential Loss (MW)</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas Pipeline Contingency with Electric System Impact*</td>
<td>4,945</td>
<td>Worst case; units with dual fuel or alternate pipeline are not able to switch.</td>
</tr>
<tr>
<td>Regulatory Event Impacting Nuclear Generation</td>
<td>32,300</td>
<td>All nuclear units in the PJM footprint are required to come offline concurrently.</td>
</tr>
<tr>
<td>Regional Event Impacting Nuclear Generation</td>
<td>10,000 - 16,000</td>
<td>A localized event, such as severe weather pattern, requires nuclear generation in a localized region to come offline concurrently.</td>
</tr>
<tr>
<td>Coal Barge Disruption</td>
<td>12,800</td>
<td>River freezing, or similar, leads to fuel delivery issues impacting all coal units that rely exclusively on barge fuel deliveries. Assumes coal piles are already running low.</td>
</tr>
<tr>
<td>Coal Rail Disruption</td>
<td>9,600</td>
<td>Rail failure, or similar, leads to fuel delivery issues impacting all coal units that rely exclusively on rail fuel deliveries. Assumes coal piles are already running low.</td>
</tr>
<tr>
<td>Coal Truck Disruption</td>
<td>3,200</td>
<td>Trucking availability, or similar, leads to fuel delivery issues impacting all coal units that rely exclusively on truck fuel deliveries. Assumes coal piles are already running low.</td>
</tr>
<tr>
<td>Non-Coal Barge Disruption</td>
<td>2,800</td>
<td>River freezing, or similar, leads to fuel delivery issues impacting all non-coal units that rely exclusively on barge fuel deliveries.</td>
</tr>
<tr>
<td>Non-Coal Truck Disruption</td>
<td>3,800</td>
<td>Trucking availability, or similar, leads to fuel delivery issues impacting all non-coal units that rely exclusively on truck fuel deliveries.</td>
</tr>
<tr>
<td>Wind Turbine Shutdown Due to Operating Limits</td>
<td>3,800</td>
<td>Extreme low temperatures, or similar, requires wind turbines in a localized region being forced to come offline concurrently.</td>
</tr>
</tbody>
</table>

* Historical impact of pipeline disruptions on generation discussed at July FSSTF
Overview – Scenario Results

Part 1 (October FSSTF)

1. Phase 1 sensitivities based on stakeholder feedback
   a. Pipeline disruption concurrent with event peak load
   b. 14-day pipeline disruption
   c. Initial oil inventory level at 50%
   d. Portfolio sensitivity with additional renewable replacement of retirements (Escalated 3)

2. RTO-wide scenarios using Relevant Risk data from Historical Cold Snap Events

Part 2 (November FSSTF)

3. Locational scenarios using Relevant Risk data from Historical Cold Snap Events

4. RTO-wide and locational scenarios using Relevant Risk data for summer event

3. Scenario with data from October 1, 2019 Operational Event

4. Address feedback from October FSSTF