

1. PJM Cold Weather Alerts vs Cold Snaps

Cold Weather Alert data was available only after May of 2004. The following Cold Weather Alerts were issued by PJM during the Cold Snaps presented at the July FSSTF:

Cold Snap 12/26/2017 – 01/07/2018 (13 days)

messageType	effectiveStartTime	effectiveEndTime	Region
Cold Weather Alert	2018-01-04T13:00:00	2018-01-08T01:56:00	PJM-RTO
Cold Weather Alert	2018-01-03T13:00:00	2018-01-06T05:00:00	PJM-RTO
Cold Weather Alert	2018-01-03T13:00:00	2018-01-07T04:59:00	PJM-RTO
Cold Weather Alert	2018-01-02T14:15:00	2018-01-05T04:59:00	DUQ, EKPC, DEOK, FE-ATSI, AEP, CPP, WESTERN, COMED, FE-AP, DAY, ITCI
Cold Weather Alert	2018-01-02T14:10:00	2018-01-04T04:56:00	ITCI, EKPC, DEOK, DAY, FE-AP, FE-ATSI, COMED, AEP, CPP, WESTERN, DUQ
Cold Weather Alert	2017-12-27T16:13:00	2018-01-03T03:25:00	PJM-RTO
Cold Weather Alert	2017-12-27T16:12:00	2018-01-01T03:19:00	WESTERN
Cold Weather Alert	2017-12-27T16:09:00	2017-12-31T03:09:00	DAY, COMED, DEOK

Cold Snap 01/21/2014 – 01/30/2014 (10 days)

messageType	effectiveStartTime	effectiveEndTime	Region
Cold Weather Alert	2014-01-27T14:02:00	2014-01-30T15:49:00	PJM-RTO
Cold Weather Alert	2014-01-23T14:49:00	2014-01-29T05:06:00	PJM-RTO
Cold Weather Alert	2014-01-23T14:49:00	2014-01-28T20:03:00	PJM-RTO
Cold Weather Alert	2014-01-21T17:01:00	2014-01-25T06:36:00	PJM-RTO
Cold Weather Alert	2014-01-21T17:01:00	2014-01-24T05:14:00	PJM-RTO

Cold Snap 02/03/2007 – 02/11/2007 (9 days)

messageType	effectiveStartTime	effectiveEndTime	Region
Cold Weather Alert	2007-02-06T19:57:00	2007-02-07T05:48:00	PJM-RTO
Cold Weather Alert	2007-02-06T19:55:00	2007-02-08T02:09:00	PJM-RTO

Cold Snap 02/13/2015 – 02/20/2015 (8 days)

messageType	effectiveStartTime	effectiveEndTime	Region
Cold Weather Alert	2015-02-20T14:01:00	2015-02-24T05:00:00	WESTERN
Cold Weather Alert	2015-02-17T14:11:00	2015-02-21T05:44:00	PJM-RTO
Cold Weather Alert	2015-02-16T14:08:00	2015-02-20T05:41:00	PJM-RTO
Cold Weather Alert	2015-02-16T14:08:00	2015-02-19T05:19:00	EKPC, FE-ATSI, WESTERN, DUQ, AEP, DEOK, COMED, CPP, DAY, FE-AP

Cold Snap 01/06/2015 – 01/10/2015 (5 days)

messageType	effectiveStartTime	effectiveEndTime	Region
Cold Weather Alert	2015-01-08T13:21:00	2015-01-11T05:58:00	WESTERN
Cold Weather Alert	2015-01-08T13:21:00	2015-01-10T09:36:00	WESTERN
Cold Weather Alert	2015-01-07T14:15:00	2015-01-09T04:43:00	PJM-RTO
Cold Weather Alert	2015-01-06T12:44:00	2015-01-07T14:15:00	EKPC, COMED, WESTERN, DAY, FE-ATSI, AEP, DEOK, CPP, FE-AP, DUQ
Cold Weather Alert	2015-01-06T12:43:00	2015-01-08T05:35:00	COMED, EKPC, FE-ATSI, CPP, WESTERN, DUQ, FE-AP, DEOK, AEP, DAY

A total of 123 additional Cold Weather Alerts PJM has issued that do not overlap with a Cold Snap. The table below shows the count by Year and Month. Some of these alerts were declared on days surrounding a Cold Snap or on cold snaps shorter than 5 days long. A few were declared on days outside of the winter period (in November or March)

Year	Month	Count
2004	5	1
2004	12	4
2005	1	7
2007	2	10
2008	1	7
2008	2	2
2008	12	1
2009	1	4
2009	2	1
2009	3	2
2009	12	2
2010	12	1
2011	1	2
2011	2	3
2012	11	1
2013	1	4
2013	11	1
2013	12	8
2014	1	5
2014	2	9
2014	3	2
2014	11	1
2015	1	8
2015	2	10
2015	3	2
2015	11	1
2016	1	2
2016	2	2
2016	11	1
2016	12	2
2017	11	1
2017	12	2
2018	1	3
2018	2	1
2018	11	1
2019	1	8
2019	3	1

2. PJM Emergency Procedures during Cold Snaps

Emergency Procedure data was available only after May of 2004. The following Emergency Procedures were implemented by PJM during the Cold Snaps presented at the July FSSTF:

Cold Snap 12/26/2017 – 01/07/2018 (13 days)

No Emergency Procedures were implemented

Cold Snap 01/21/2014 – 01/30/2014 (10 days)

messageType	effectiveStartTime	effectiveEndTime	Region
Voltage Reduction Warning/Reduction of NCPL	2014-01-30T11:57:00	2014-01-30T12:34:00	PJM-RTO
Maximum Generation Emergency Action	2014-01-30T10:59:00	2014-01-30T14:06:00	MIDATL, SOUTHERN
Voltage Reduction Warning/Reduction of NCPL	2014-01-24T12:26:00	2014-01-24T14:37:00	BGE, PEPCO
Maximum Generation Emergency Action	2014-01-24T09:28:00	2014-01-24T13:45:00	DOM, MIDATL, FE-AP
Emerg Load Mgmt Short Lead Time < 1Hr (Retired)	2014-01-24T09:24:00	2014-01-24T13:45:00	DOM, FE-AP, MIDATL
Emerg Load Mgmt Long Lead Time 1-2 hrs (Retired)	2014-01-24T09:23:00	2014-01-24T13:45:00	DOM, FE-AP, MIDATL
Maximum Generation Emergency Action Trans (Retired)	2014-01-23T18:58:00	2014-01-24T00:00:00	FE-AP, DOM, MIDATL
Emerg Load Mgmt Long Lead Time 1-2 hrs (Retired)	2014-01-23T18:58:00	2014-01-24T00:00:00	FE-AP, DOM, MIDATL
Emerg Load Mgmt Short Lead Time < 1Hr (Retired)	2014-01-23T18:58:00	2014-01-24T00:00:00	DOM, FE-AP, MIDATL
Emerg Load Mgmt Short Lead Time < 1Hr (Retired)	2014-01-23T09:42:00	2014-01-23T09:58:00	FE-AP, DOM, MIDATL
Emerg Load Mgmt Short Lead Time < 1Hr (Retired)	2014-01-23T09:41:00	2014-01-23T13:29:00	MIDATL
Emerg Load Mgmt Long Lead Time 1-2 hrs (Retired)	2014-01-23T09:41:00	2014-01-23T09:58:00	DOM, FE-AP, MIDATL
Emerg Load Mgmt Short Lead Time < 1Hr (Retired)	2014-01-23T09:39:00	2014-01-23T13:29:00	FE-AP
Emerg Load Mgmt Short Lead Time < 1Hr (Retired)	2014-01-23T09:39:00	2014-01-23T13:29:00	DOM
Maximum Generation Emergency Action	2014-01-23T09:39:00	2014-01-23T13:29:00	DOM, FE-AP, MIDATL
Emerg Load Mgmt Long Lead Time 1-2 hrs (Retired)	2014-01-23T09:38:00	2014-01-23T13:29:00	FE-AP
Emerg Load Mgmt Long Lead Time 1-2 hrs (Retired)	2014-01-23T09:38:00	2014-01-23T13:29:00	DOM
Emerg Load Mgmt Long Lead Time 1-2 hrs (Retired)	2014-01-23T09:37:00	2014-01-23T13:29:00	Mid-Atlantic
Maximum Generation Emergency Action Trans (Retired)	2014-01-22T22:28:00	2014-01-23T02:00:00	PEPCO, BGE
Emerg Load Mgmt Short Lead Time < 1Hr (Retired)	2014-01-22T19:00:00	2014-01-23T02:00:00	BGE, PEPCO
Emerg Load Mgmt Long Lead Time 1-2 hrs (Retired)	2014-01-22T19:00:00	2014-01-23T02:00:00	BGE, PEPCO
Maximum Generation Emergency Action	2014-01-22T18:59:00	2014-01-23T02:00:00	PEPCO, BGE

Cold Snap 02/03/2007 – 02/11/2007 (9 days)

No Emergency Procedures were implemented

Cold Snap 02/13/2015 – 02/20/2015 (8 days)

No Emergency Procedures were implemented

Cold Snap 01/06/2015 – 01/10/2015 (5 days)

No Emergency Procedures were implemented

3. Cold Snap Information at Zonal Level

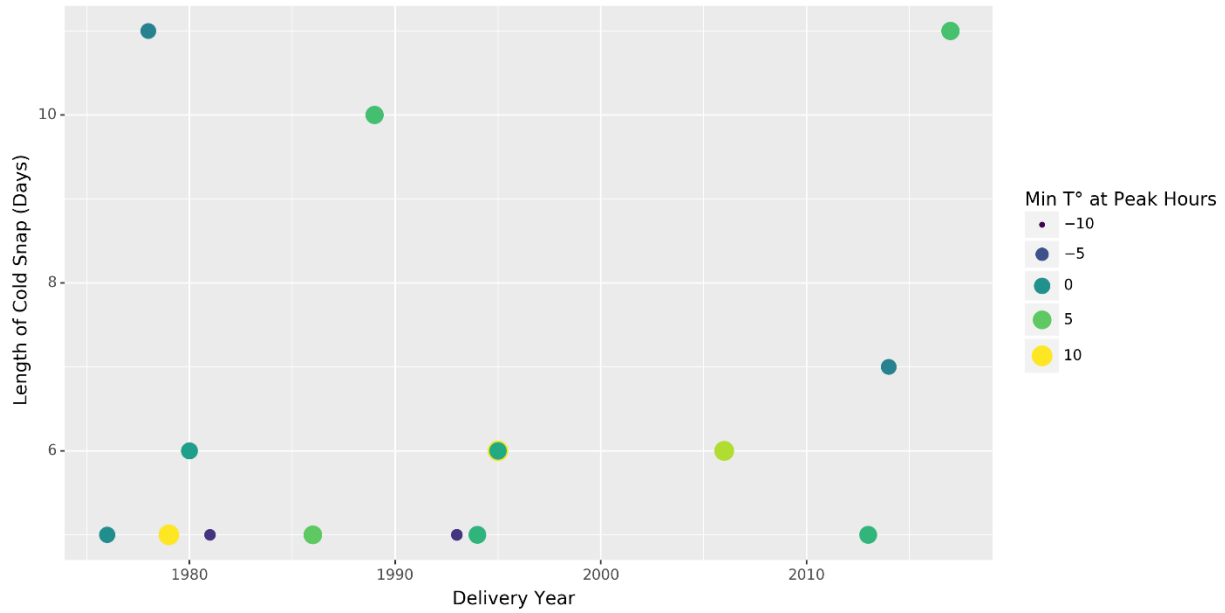
The Cold Snaps at the zonal level were identified using the definition presented at the July FSSTF (“A series of 5 or more contiguous days where the average RTO wind-adjusted temperature (WWP) in each of such days is less than 21.5°F”)

For the Mid-Atlantic region:

A total of 15 Cold Snaps are identified:

Number of Days	Delivery Year	Start	End
11	1978	9-Feb-79	19-Feb-79
11	2017	28-Dec-17	7-Jan-18
10	1989	16-Dec-89	25-Dec-89
7	2014	15-Feb-15	21-Feb-15
6	1980	8-Jan-81	13-Jan-81
6	1995	4-Jan-96	9-Jan-96
6	1995	3-Feb-96	8-Feb-96
6	2006	4-Feb-07	9-Feb-07
5	1976	28-Jan-77	1-Feb-77
5	1979	30-Jan-80	3-Feb-80
5	1981	15-Jan-82	19-Jan-82
5	1986	24-Jan-87	28-Jan-87
5	1993	18-Jan-94	22-Jan-94
5	1994	5-Feb-95	9-Feb-95
5	2013	21-Jan-14	25-Jan-14

The following graph provides information about the severity of the cold snap at Peak Hours (hours ending 7 and 19)



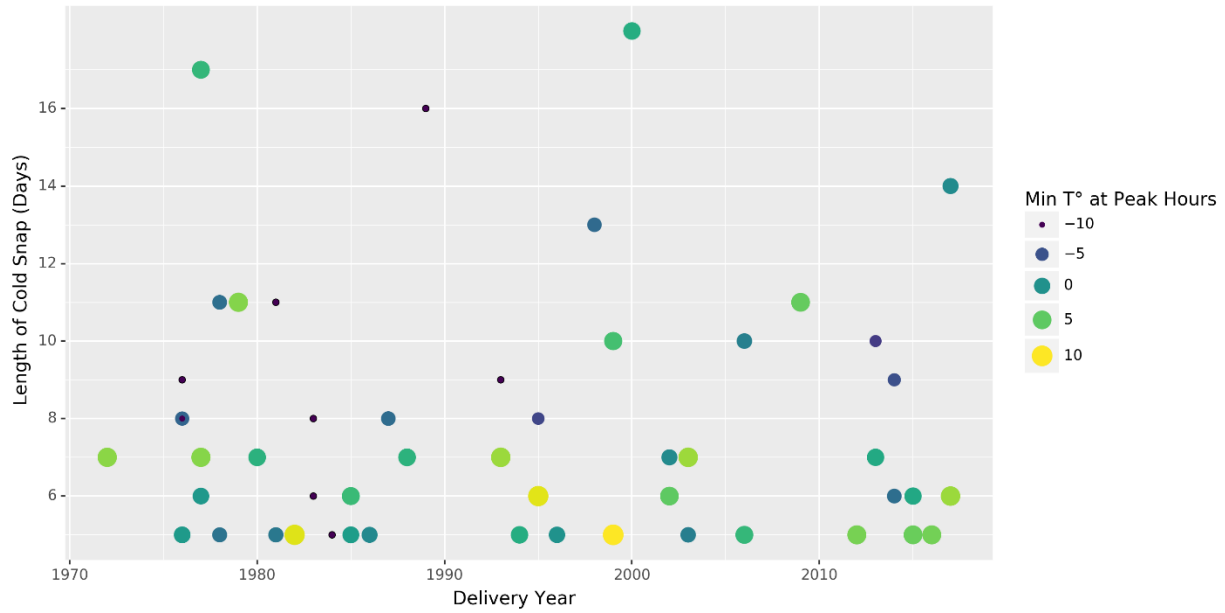
For the PJM West region:

A total of 52 Cold Snaps are identified:

Number of Days	Delivery Year	Start	End
18	2000	17-Dec-00	3-Jan-01
17	1977	26-Jan-78	11-Feb-78
16	1989	12-Dec-89	27-Dec-89
14	2017	25-Dec-17	7-Jan-18
13	1998	30-Dec-98	11-Jan-99
11	1978	2-Jan-79	12-Jan-79
11	1978	4-Feb-79	14-Feb-79
11	1979	26-Jan-80	5-Feb-80
11	1981	8-Jan-82	18-Jan-82
11	2009	1-Jan-10	11-Jan-10
10	1999	20-Jan-00	29-Jan-00
10	2006	2-Feb-07	11-Feb-07
10	2013	21-Jan-14	30-Jan-14
9	1976	15-Jan-77	23-Jan-77
9	1993	14-Jan-94	22-Jan-94
9	2014	12-Feb-15	20-Feb-15
8	1976	6-Jan-77	13-Jan-77
8	1976	26-Jan-77	2-Feb-77
8	1983	15-Jan-84	22-Jan-84
8	1987	4-Jan-88	11-Jan-88

8	1995	30-Jan-96	6-Feb-96
7	1972	6-Jan-73	12-Jan-73
7	1977	17-Feb-78	23-Feb-78
7	1980	7-Jan-81	13-Jan-81
7	1988	4-Feb-89	10-Feb-89
7	1993	24-Dec-93	30-Dec-93
7	2002	21-Jan-03	27-Jan-03
7	2003	19-Jan-04	25-Jan-04
7	2013	6-Feb-14	12-Feb-14
6	1977	6-Dec-77	11-Dec-77
6	1983	22-Dec-83	27-Dec-83
6	1985	10-Feb-86	15-Feb-86
6	1995	3-Jan-96	8-Jan-96
6	2002	14-Jan-03	19-Jan-03
6	2014	5-Jan-15	10-Jan-15
6	2015	17-Jan-16	22-Jan-16
6	2017	13-Jan-18	18-Jan-18
5	1976	29-Dec-76	2-Jan-77
5	1978	16-Feb-79	20-Feb-79
5	1981	9-Feb-82	13-Feb-82
5	1982	16-Jan-83	20-Jan-83
5	1984	19-Jan-85	23-Jan-85
5	1985	17-Dec-85	21-Dec-85
5	1986	23-Jan-87	27-Jan-87
5	1994	5-Feb-95	9-Feb-95
5	1996	10-Jan-97	14-Jan-97
5	1999	21-Dec-99	25-Dec-99
5	2003	28-Jan-04	1-Feb-04
5	2006	14-Feb-07	18-Feb-07
5	2012	21-Jan-13	25-Jan-13
5	2015	10-Feb-16	14-Feb-16
5	2016	5-Jan-17	9-Jan-17

The following graph provides information about the severity of the cold snap at Peak Hours (hours ending 7 and 19)

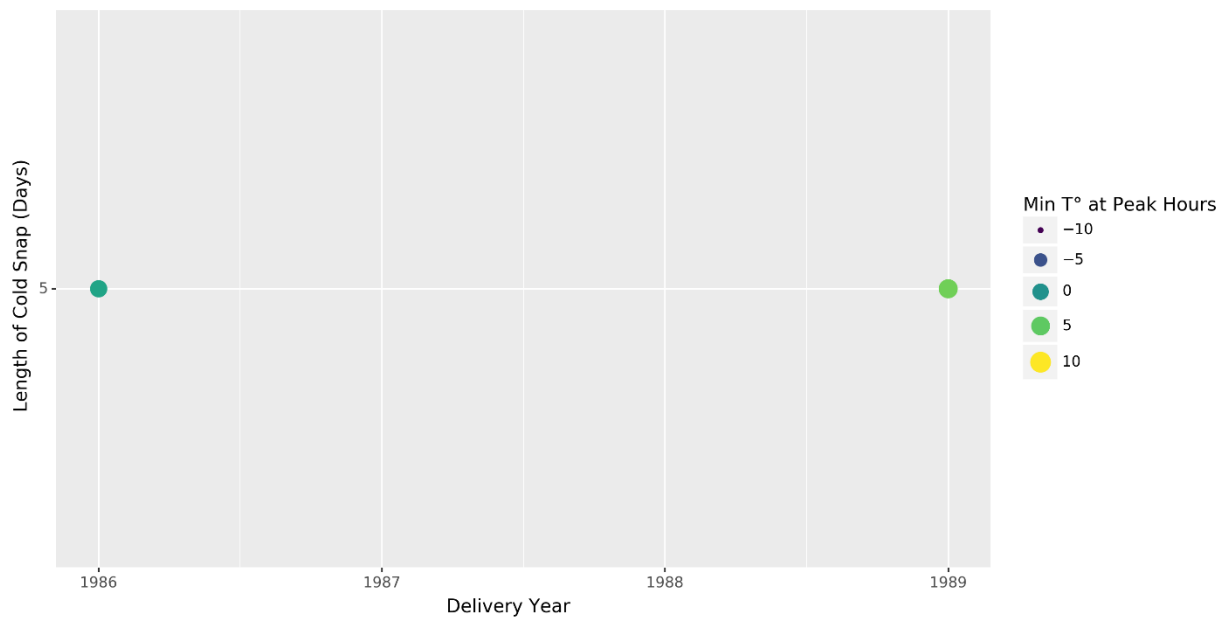


For the Dominion region:

A total of 2 Cold Snaps are identified:

Number of Days	Delivery Year	Start	End
5	1986	24-Jan-87	28-Jan-87
5	1989	21-Dec-89	25-Dec-89

The following graph provides information about the severity of the cold snap at Peak Hours (hours ending 7 and 19)



4. Natural Gas Pipeline Disruption data

The data is available at the Pipeline and Hazardous Materials Safety Administration (PHMSA) website at: https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/data_statistics/pipeline/incident_gas_transmission_gathering_jan2010_present.zip

5. Agencies predicting Weather in the long-term

PJM is not aware of agencies making weather predictions for the long-term at a granular level. The Climate Prediction Center at the National Weather Service provides a weather outlook but it is only limited to the next 12 months (<https://www.cpc.ncep.noaa.gov/products/predictions/90day/>)

6. Explanation of Heatmap in Slide 6 of Gap Analysis – Relevant Risks vs Products presentation

The content below provides background information for the development of the heatmap in Slide 6 of the Gap Analysis – Relevant Risks vs Products presentation. The information is provided for each cell in the heatmap, where each “cell” is described as a row/column.

Cell: Capacity Performance / Long Duration Cold Snap; **Result:** Not Addressed

The Capacity Performance requirement (the FPR) is calculated via the Reserve Requirement Study (aka, the IRM Study). Such study does not consider all hours of the year, only the peak hour of each weekday. When dealing with a Cold Snap, during which forced outages and solar unavailability are significant and can vary greatly by hour, it is important to consider the loss of load risk at all hours, not just the peak hour. In addition, the RRS considers an average relationship between the peaks of two contiguous weeks (for instance, the peak of the second week in January is X% of the peak of the third week in January, where X is an average value from history). In a long Cold Snap encompassing two weeks or more, the relationship between the weekly peaks is likely to be much different from what has occurred on average historically.

Cell: Capacity Performance / Short Duration Cold Snap; **Result:** Partially Addressed

The RRS does not consider all hours of the year, only the peak hour of each weekday (see first half of paragraph above).

Cell: Capacity Performance / NG Pipeline Disruption; **Result:** Partially Addressed

For 51 weeks of the delivery year, the RRS uses a capacity model based on each unit’s most recent 5 years of generation performance data reported via eGADS. Furthermore, forced outages are assumed to be random and independent.

For the winter peak week, the RRS uses a capacity model based on the most recent 11 years of system-wide aggregate generation performance data reported via eGADS. For this week, forced outages are not assumed to be independent.

To the extent that NG Pipeline disruptions have impacted PJM generation during winter peak weeks of the last 11 years, then the RRS winter peak week capacity model will capture such outages. However, if the disruptions have occurred on a week other than the winter peak week, then the RRS capacity model will not fully capture the impact of such disruption on forced outages (this will be the case if the disruption occurred during the most recent 5 years or prior to that).

The impact on PJM generation of potential future pipeline disruptions, of different characteristics than those that have occurred in recent years, is not accounted for in the RRS.

Cell: Capacity Performance / Renewable Intermittency RR; **Result:** Partially Addressed

As mentioned above, the RRS models only the peak hour of each weekday, therefore missing all the hourly variability exhibited by renewable generation. Moreover, at the peak hour of each day, the RRS models wind and solar resources as always producing at their capacity credit during a cold snap (13% of nameplate on average for wind, 38% of nameplate on average for solar). This is likely to be inaccurate for both wind and solar resources: wind resources are likely to produce more than their capacity credit while solar resources are likely to produce less.

Cell: Capacity Performance / Forced Outages RR; **Result:** Partially Addressed

For 51 weeks of the delivery year, the RRS uses a capacity model based on each unit's most recent 5 years of generation performance data reported via eGADS. Furthermore, forced outages are assumed to be random and independent.

For the winter peak week, the RRS uses a capacity model based on the most recent 11 years of system-wide aggregate generation performance data reported via eGADS. For this week, forced outages are not assumed to be independent.

To the extent that Forced Outages RR have occurred during winter peak weeks of the last 11 years, then the RRS winter peak week capacity model will capture such outages. However, if the outages have occurred on a week other than the winter peak week, then the RRS capacity model will not fully capture such outages (this will be the case if the outages occurred during the most recent 5 years or prior to that).

Multiple Cells: Energy Market; **Result:** Not Addressed

The Energy Market (real-time and day-ahead) procures MWs to exactly meet a targeted demand value. The Energy Market, thus, does not procure additional MWs to address uncertainties.

Multiple Cells: Contingency Reserves Current; **Result:** Not Addressed (for all the relevant risks except Forced Outages RR, which is Partially Addressed)

The requirement for the real-time contingency reserves is based on the single-largest contingency in the system plus 190 MW. Therefore, such requirement does not address any of the identified uncertainties (relevant risks).

The requirement for the day-ahead contingency reserves partially accounts for Forced Outages RR because it is based on historical forced outage rates (as well as historical load forecast error)

Multiple Cells: Contingency Reserves Reserve Price Formation / NG Pipeline Disruption, Contingency Reserves Reserve Price Formation / Forced Outages RR; **Result:** Partially Addressed

The recently filed Contingency Reserves changes propose a requirement that is based on several uncertainties. One of those uncertainties is the amount of 30-min and 60-min forced outages during the most recent 3 years. Therefore, if NG pipeline disruptions or Forced Outages RR have occurred in the most recent 3 years, then the proposed contingency reserve requirement will include these disruptions/outages.

Multiple Cells: Contingency Reserves Reserve Price Formation / Long Duration Cold Snap, Contingency Reserves Reserve Price Formation / Short Duration Cold Snap, Contingency Reserves Reserve Price Formation / Renewable Intermittency RR; **Result:** Not Addressed

The recently filed Contingency Reserves changes propose a requirement based on several uncertainties. Some of these uncertainties are related to load and renewables' performance. However, these uncertainties are calculated relative to the 30-min and 60-min forecast for load and renewable output. Therefore, the requirement does not address the multi-hour variability that load and renewable output exhibit during a cold snap.

Multiple Cells: Regulation Market; **Result:** Not Addressed

The regulation market requirement is either 525 MW (for non-ramping hours) or 800 MW (for ramping hours). The requirement does not account for any of the relevant risks.

Multiple Cells: Gas Contingency Procedure / NG Pipeline Disruption, Gas Contingency Procedure / Forced Outages RR; **Result:** Partially Addressed

If a gas contingency occurs then the day-ahead contingency reserve requirement can be increased to account for the MWs impacted by the gas contingency. However, this is a reactive increase in the requirement, not proactive.

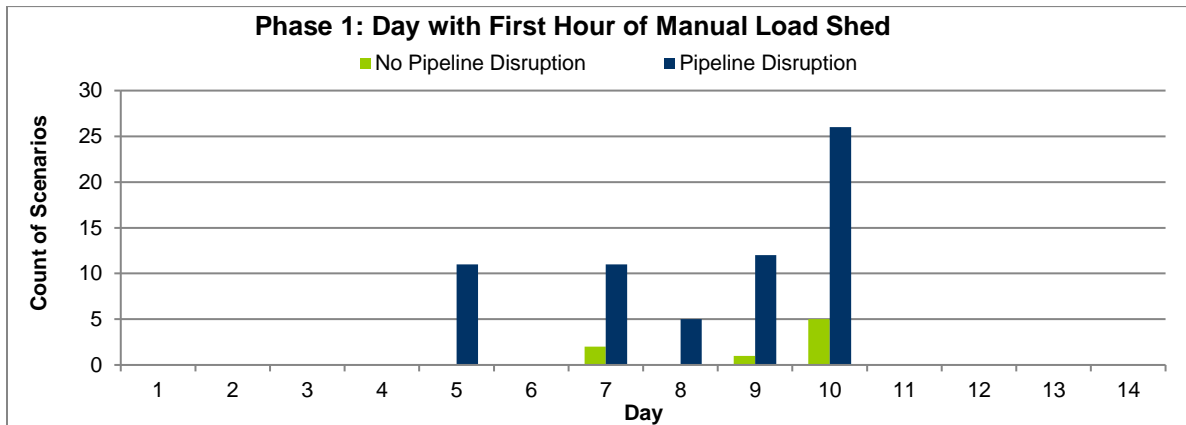
Multiple Cells: Gas Contingency Procedure / Long Duration Cold Snap, Gas Contingency Procedure / Short Duration Cold Snap, Gas Contingency Procedure / Renewable Intermittency RR; **Result:** Not Addressed

The gas contingency procedures do not address the Long Duration Cold Snap, Short Duration Cold Snap or Renewable Intermittency RR risks.

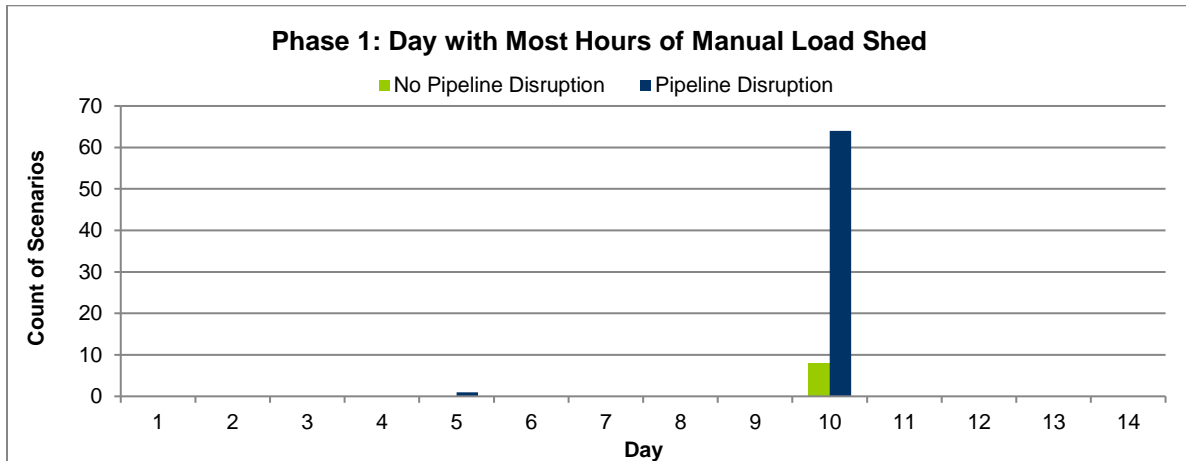
7. How many days into cold snap did load shed occur in Phase 1 scenarios?

In the Phase 1 analysis, manual load shed was observed in 8 of the 36 scenarios with *no* pipeline disruption, and in 65 of the 288 scenarios *with* a 5-day pipeline disruption beginning on Day 1. No manual load shed was observed in scenarios with the Announced Retirement portfolio. Manual load shed was observed in 37 of the 108 scenarios with the Escalated 1 Retirement portfolio, and in 34 of the 108 scenarios with the Escalated 2 Retirement portfolio. All load shed was observed in scenarios with the 'Extreme' winter load, in which a peak of 147,721 MW occurred on Day 10.

The bar graph below shows the day in each scenario in which the first hour of load shed occurred.



The bar graph below shows the day in each scenario in which the most hours of load shed occurred.



Related Fuel Security documentation:

- Scenarios Summaries: <https://pjm.com/-/media/library/reports-notice/fuel-security/20190116-fuel-security-analysis-scenario-summaries.ashx?la=en>
- Scenario Summaries Key: <https://pjm.com/-/media/library/reports-notice/fuel-security/20190314-fuel-security-analysis-scenario-summaries-key.ashx?la=en>
- Phase 1 Analysis Issue Tracking page: <https://pjm.com/committees-and-groups/issue-tracking/fuel-security.aspx>

- FSSTF Issue Details page: <https://pjm.com/committees-and-groups/issue-tracking/issue-tracking-details.aspx?Issue={FF552C36-048D-405A-A296-125FC8098915}>