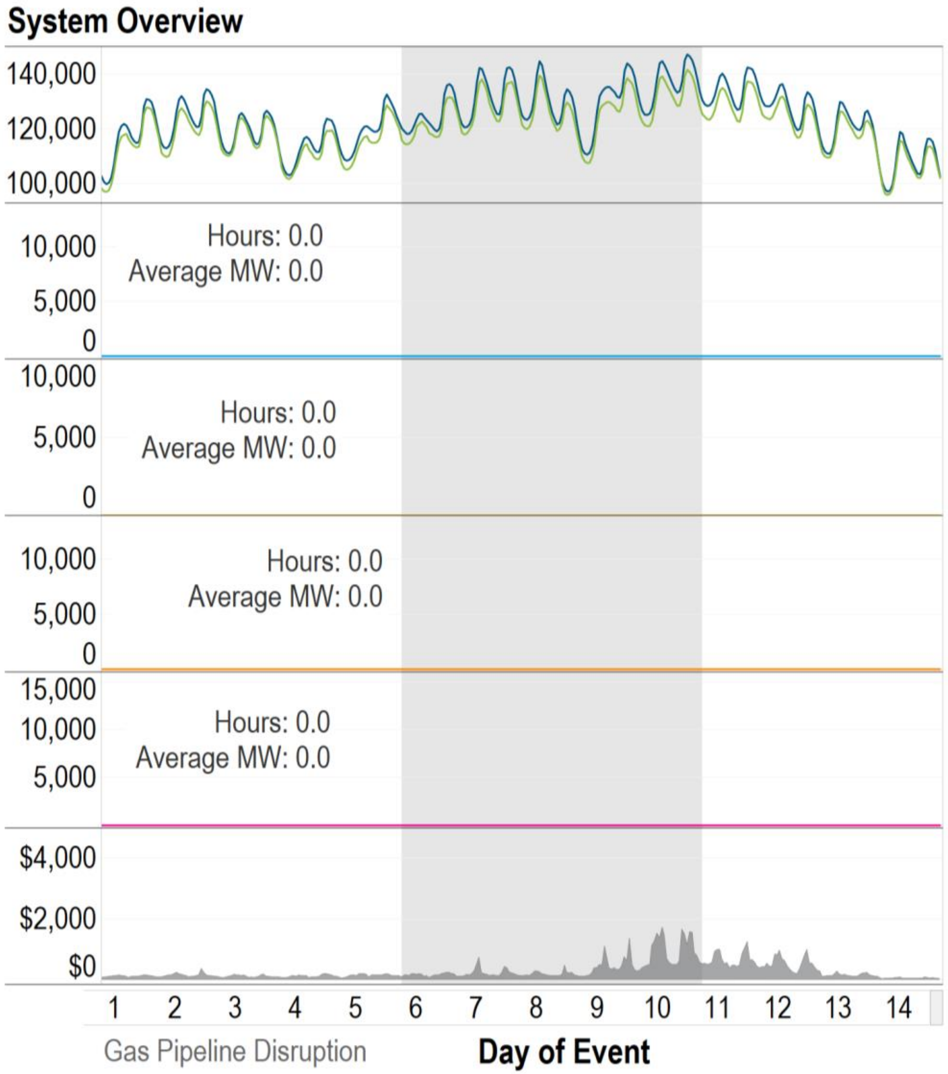
APPENDIX I – Phase 1 Sensitivities based on Stakeholder Feedback

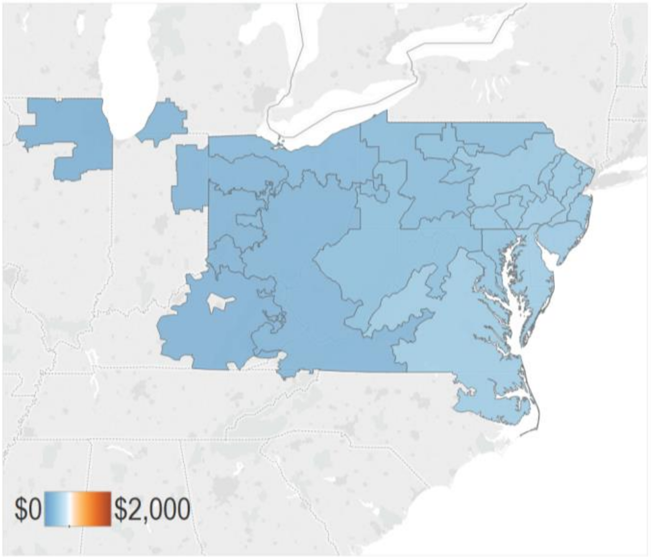
Pipeline Disruption Concurrent with Peak Load

Sensitivity 1



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]

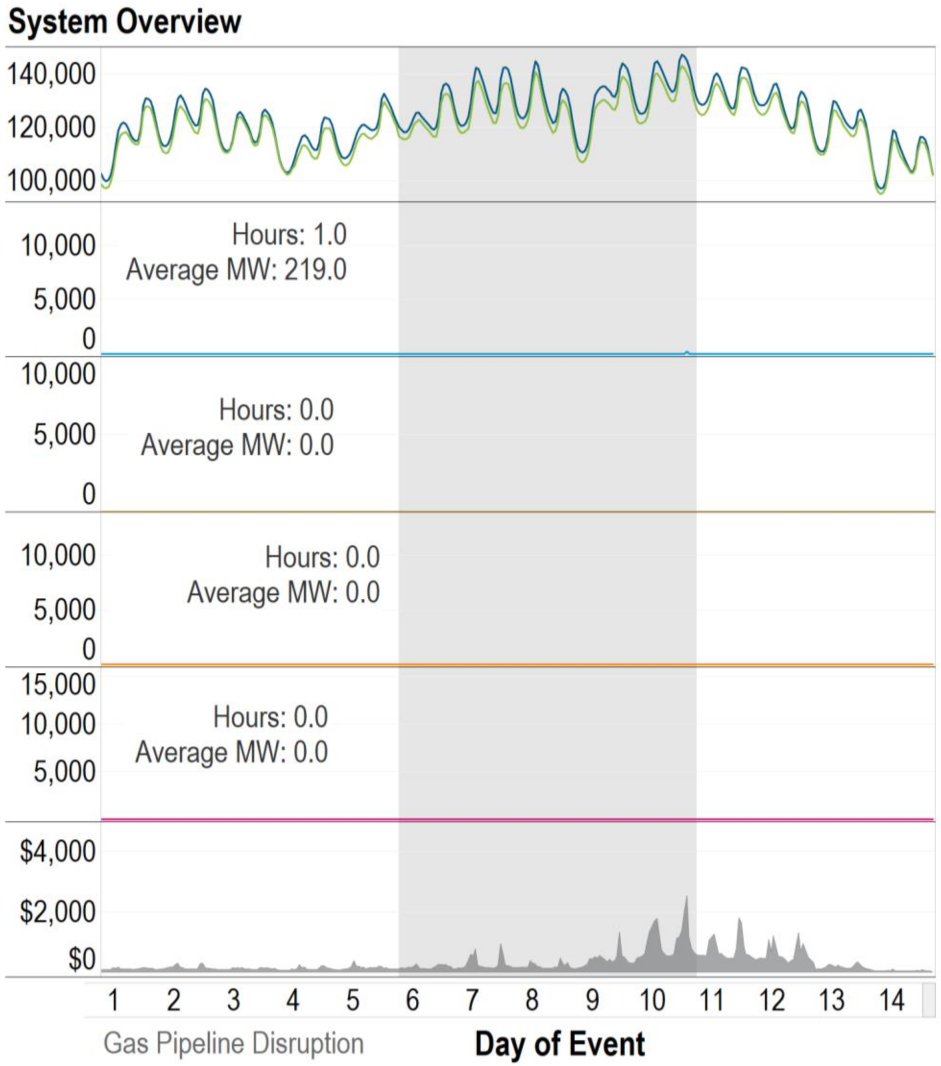


Sites Out of Oil **Oil Barrels Burned: 4.44M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	0	0	0	0	0	2	4	7	15	19	4	0

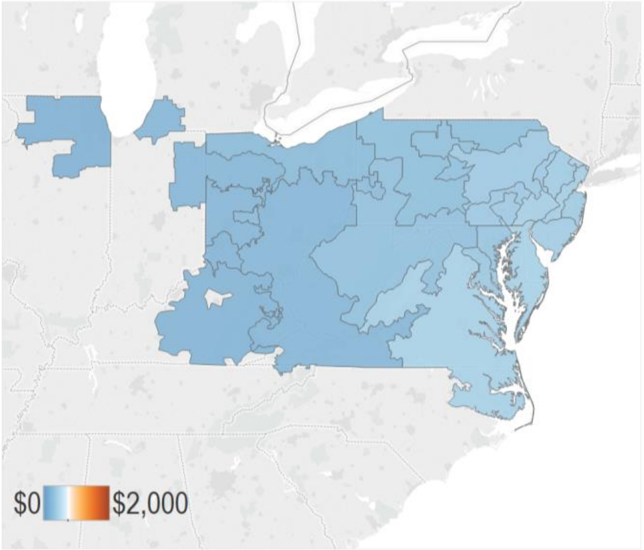
*141 Total Sites

Sensitivity 2



Load: Extreme
Refueling: Limited
Disruption: Looped 2 High
Non-Firm Avail: 62.50%
Retirement: Announced
Dispatch: Economic

Hourly Zonal Average LMP [$]

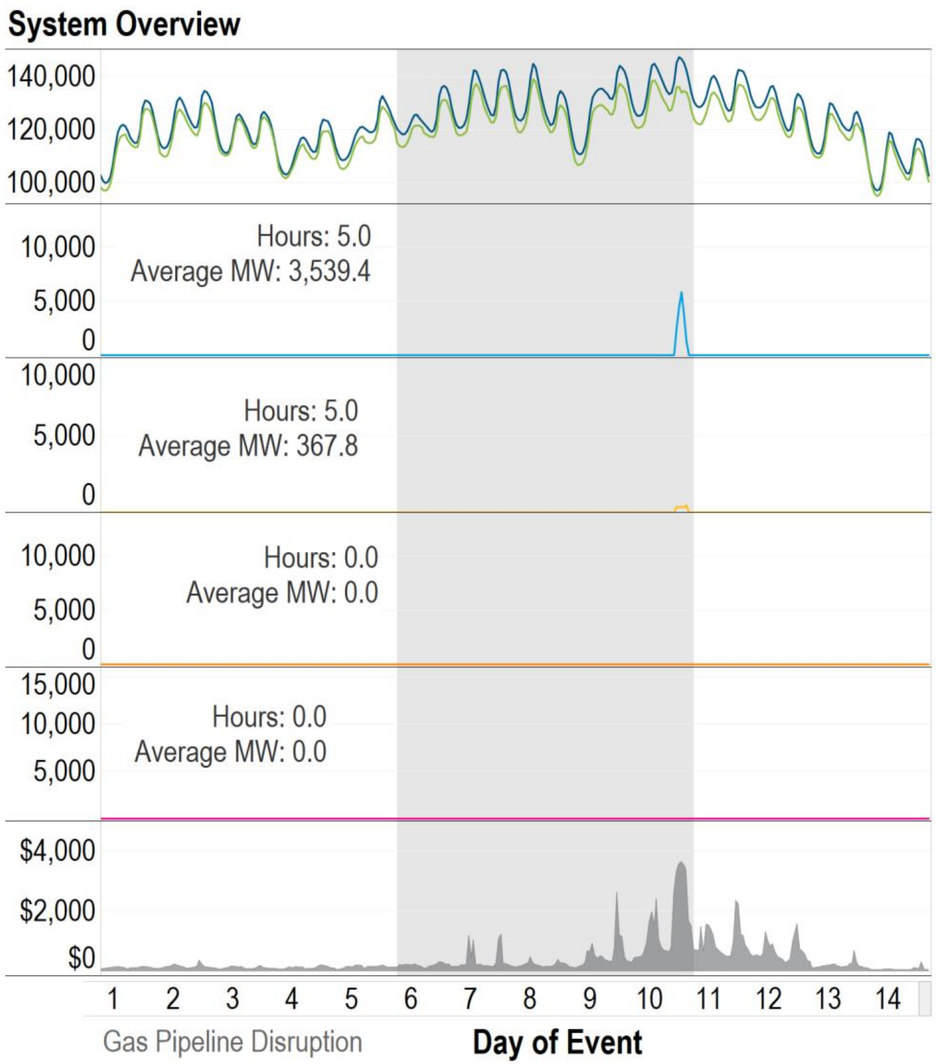


Sites Out of Oil **Oil Barrels Burned: 3.60M**

0	1	2	2	3	4	7	10	31	44	58	64	65	59
1	2	3	4	5	6	7	8	9	10	11	12	13	14

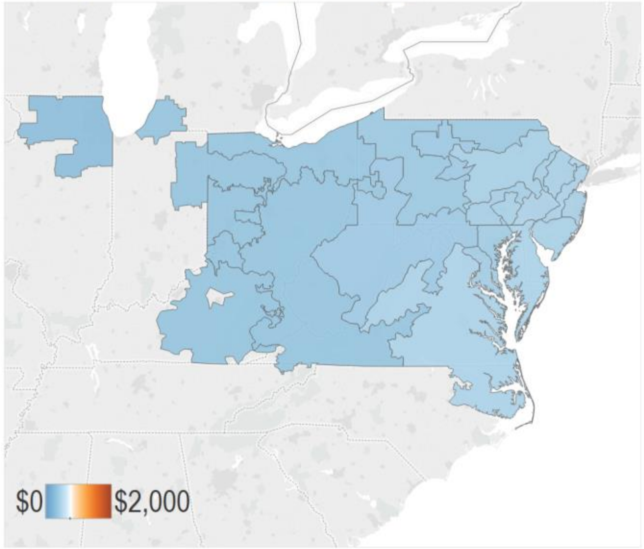
*141 Total Sites **Day of Event**

Sensitivity 3



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil — **Oil Barrels Burned: 4.90M**

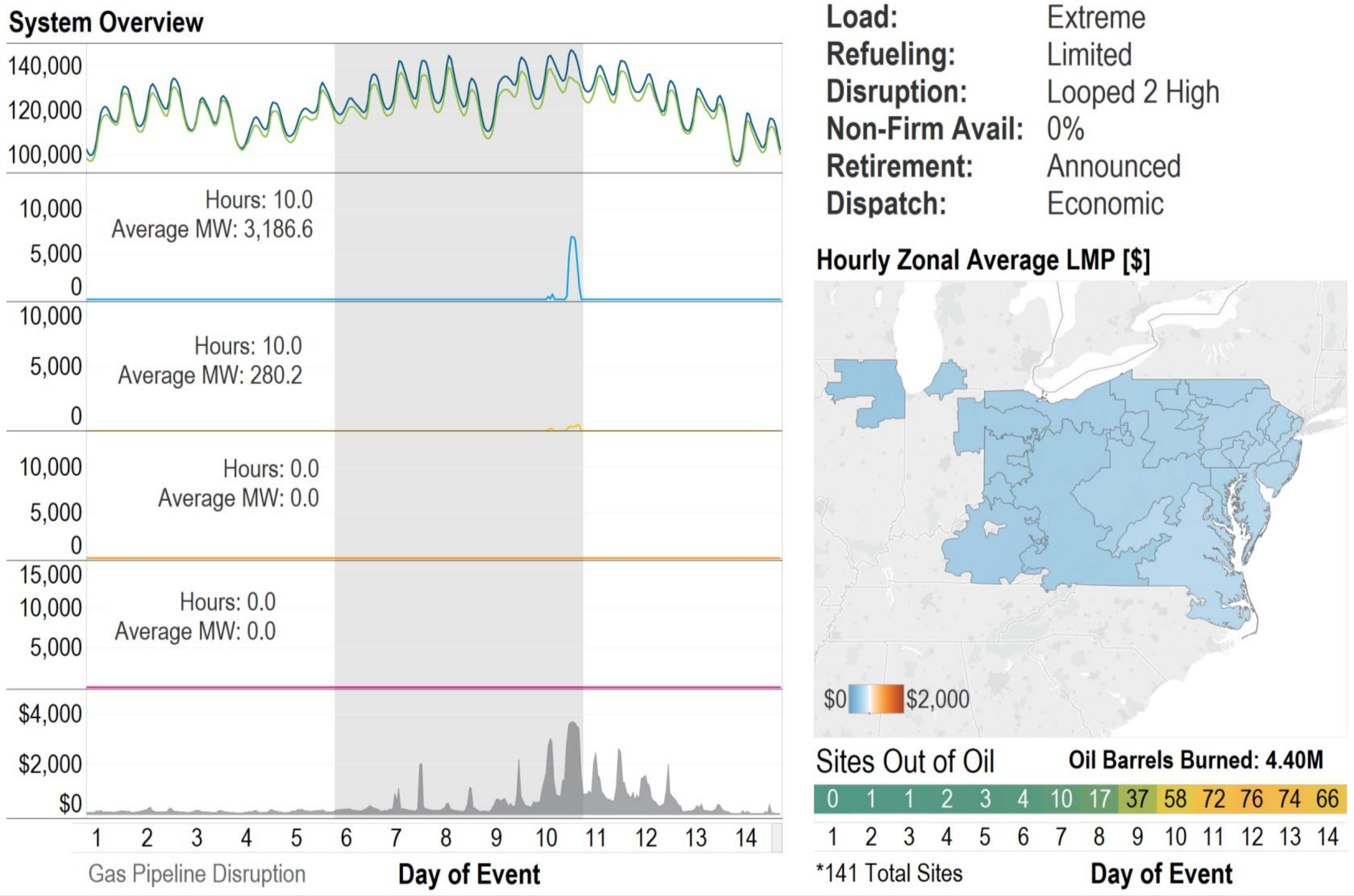
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	0	0	0	0	0	3	4	14	22	20	2	1

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:

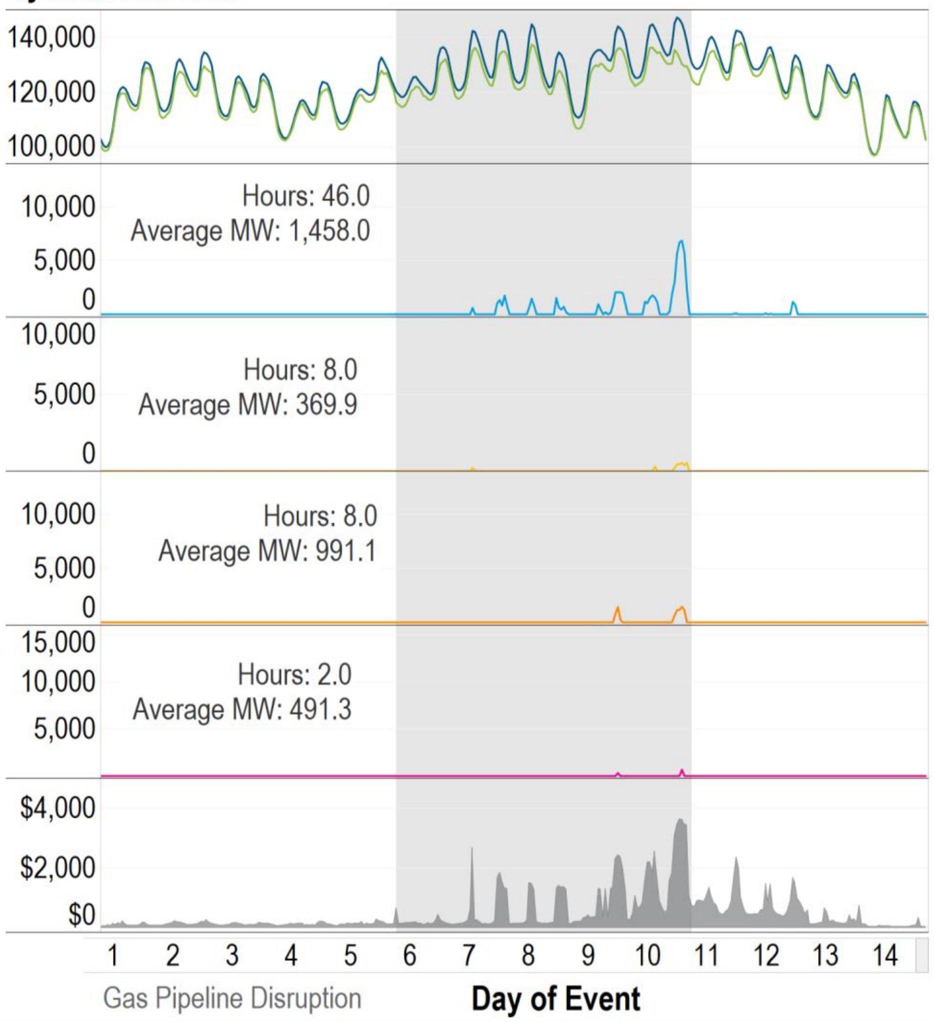
Pipeline Disruption Concurrent with Peak Load

Sensitivity 4



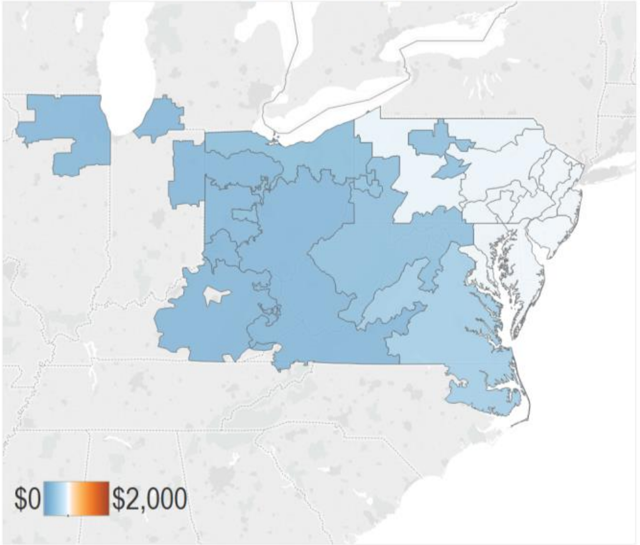
Phase 1 Sensitivities based on Stakeholder Feedback:
Pipeline Disruption Concurrent with Peak Load
Sensitivity 5

System Overview



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil **Oil Barrels Burned: 5.79M**

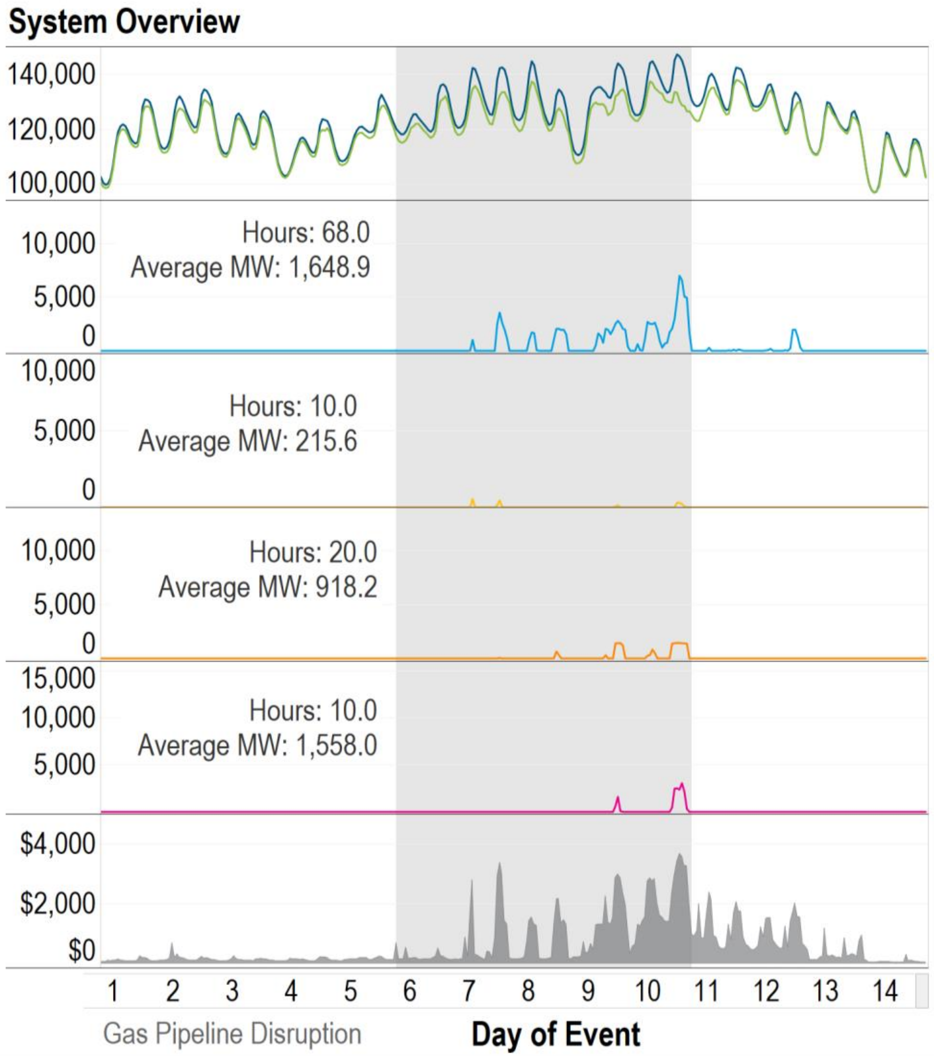
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	1	0	0	0	0	3	4	7	12	16	23	10	0

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:

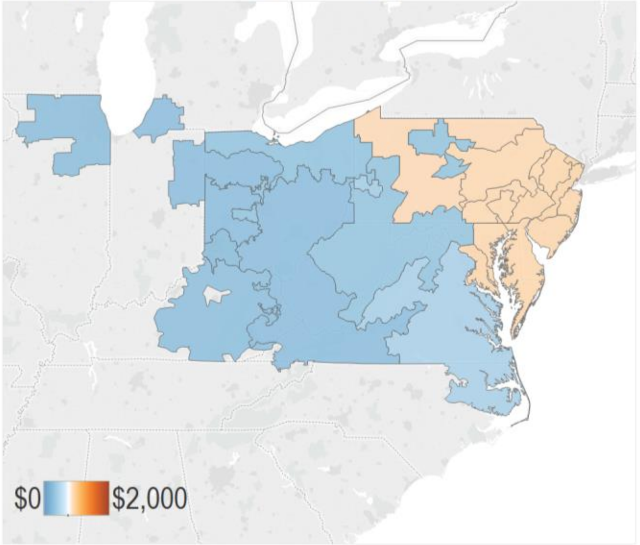
Pipeline Disruption Concurrent with Peak Load

Sensitivity 6



Load: Extreme
Refueling: Limited
Disruption: Looped 2 High
Non-Firm Avail: 62.50%
Retirement: Escalated 1
Dispatch: Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil — **Oil Barrels Burned: 4.86M**

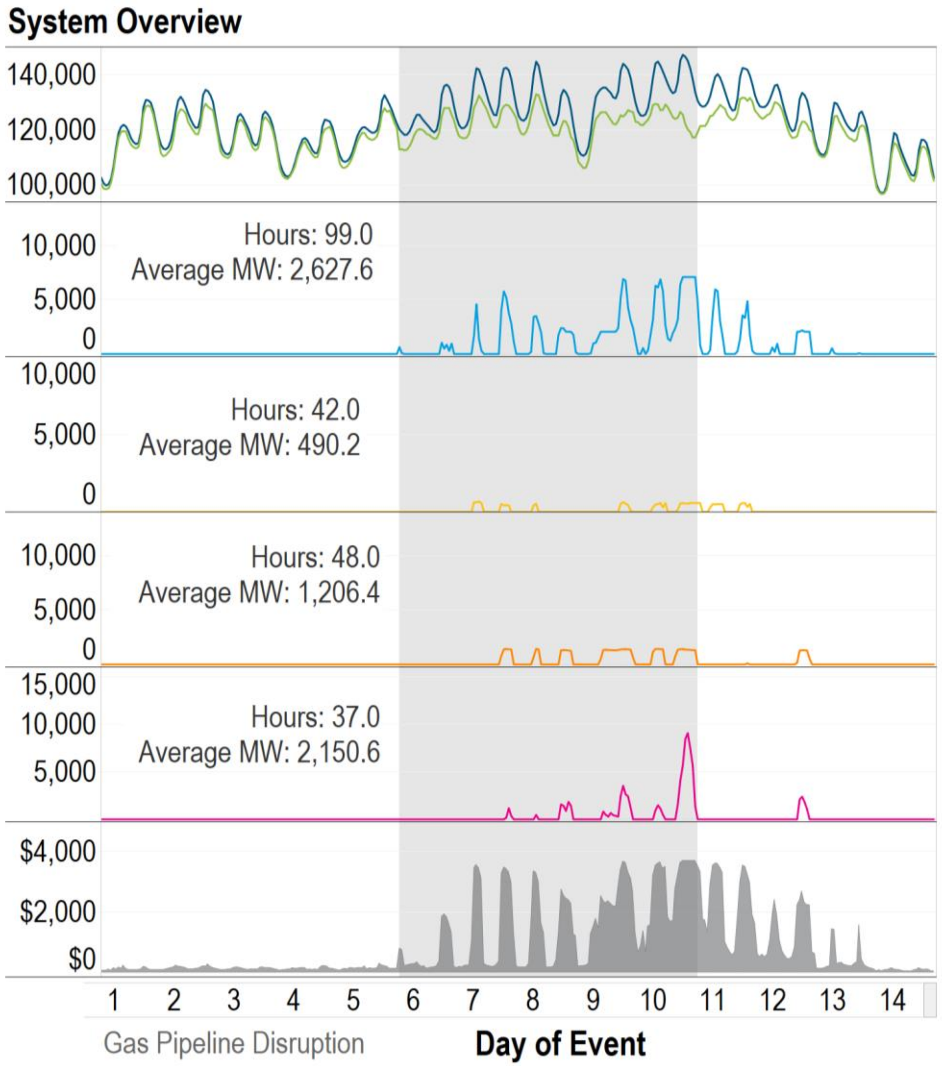
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	1	2	3	5	7	9	22	42	53	72	83	84	85	75

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:

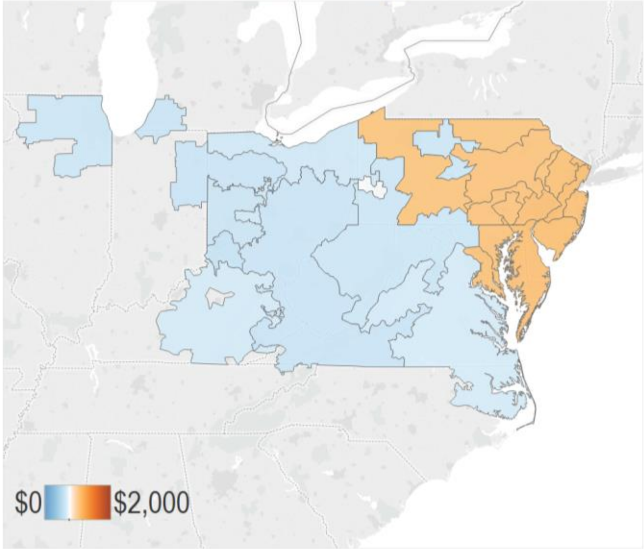
Pipeline Disruption Concurrent with Peak Load

Sensitivity 7



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]

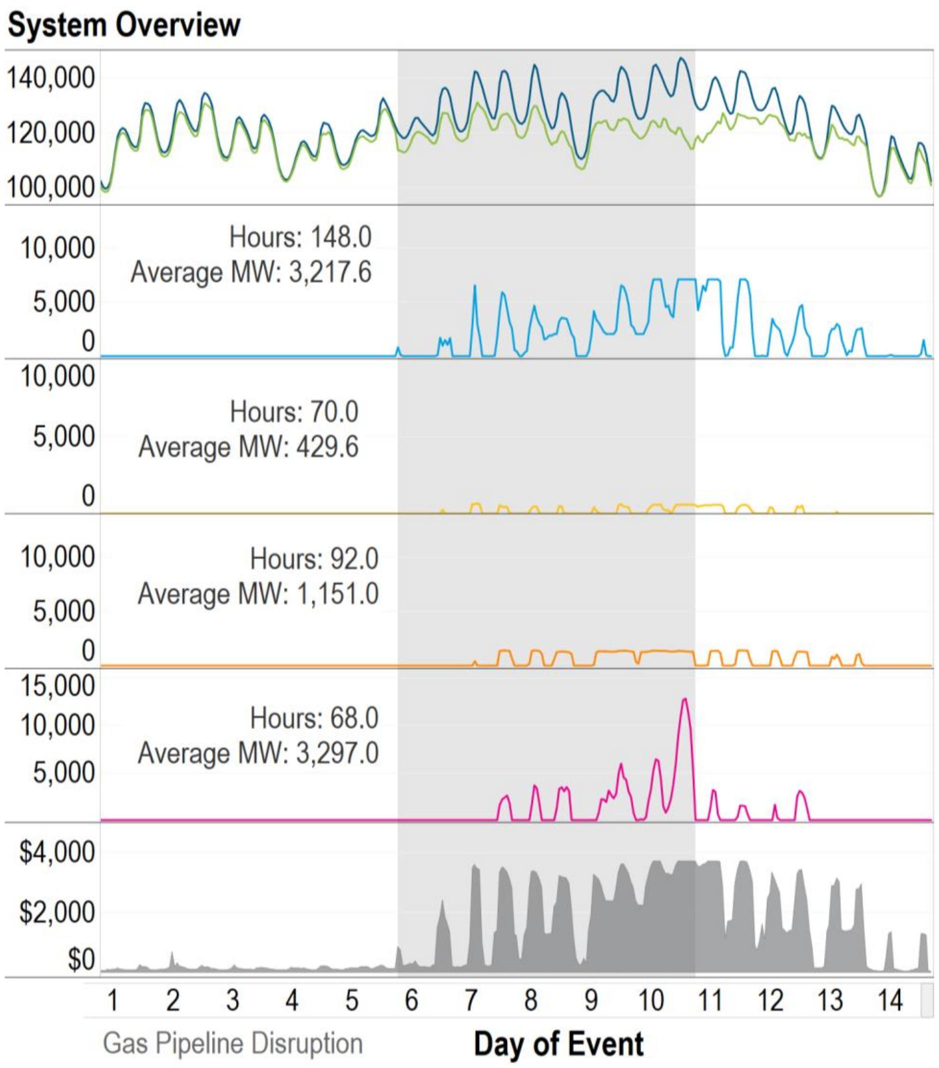


Sites Out of Oil **Oil Barrels Burned: 6.60M**

0	1	0	0	0	0	4	6	10	22	28	30	16	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14

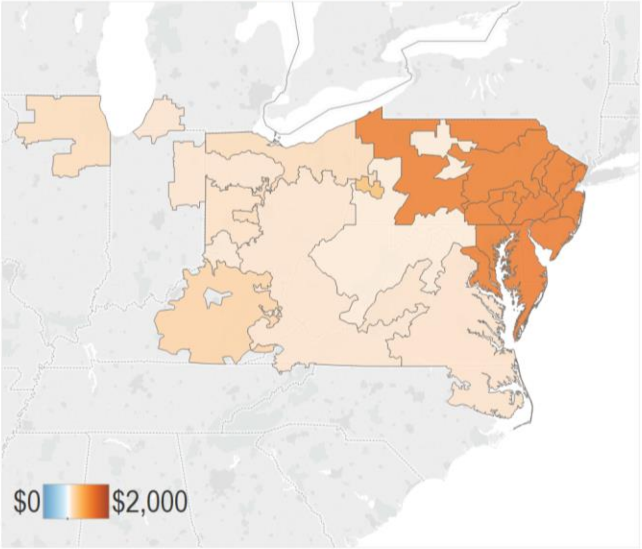
*141 Total Sites **Day of Event**

Sensitivity 8



Load: Extreme
Refueling: Limited
Disruption: Looped 2 High
Non-Firm Avail: 0%
Retirement: Escalated 1
Dispatch: Economic

Hourly Zonal Average LMP [$]



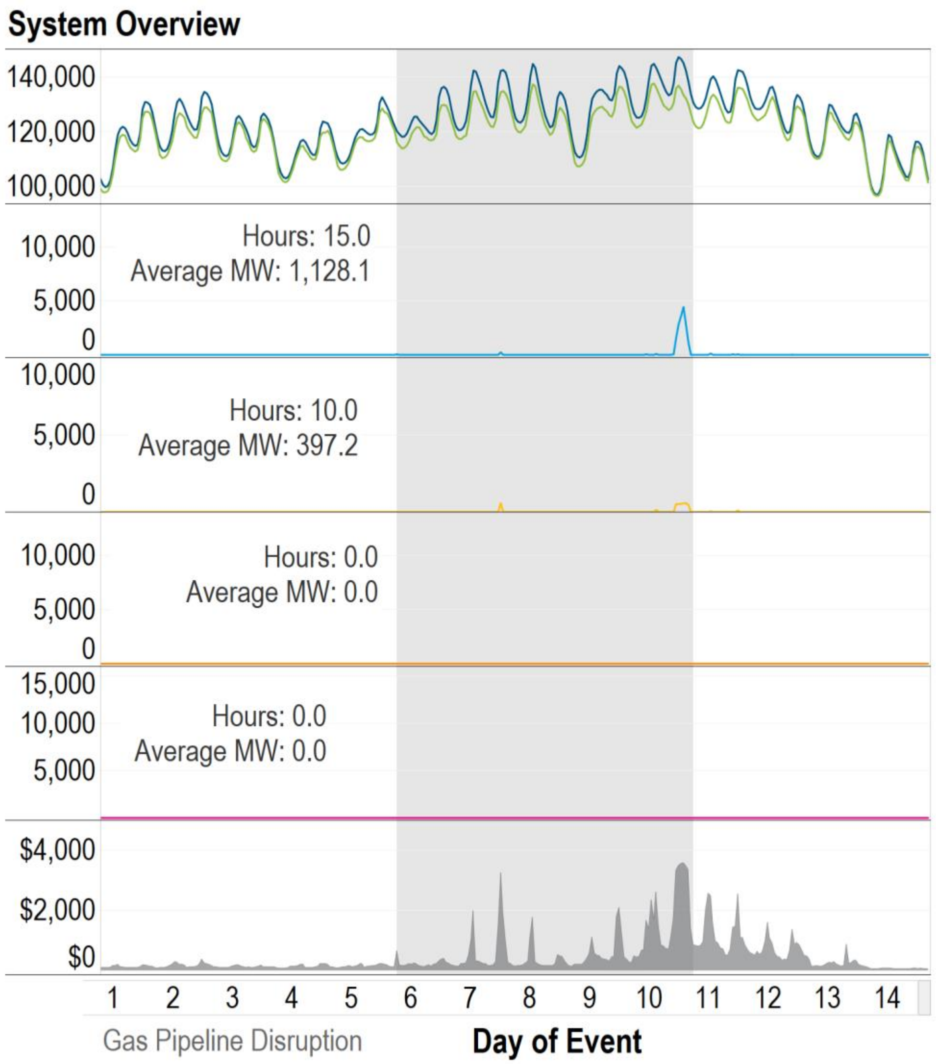
Sites Out of Oil **Oil Barrels Burned: 5.51M**

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

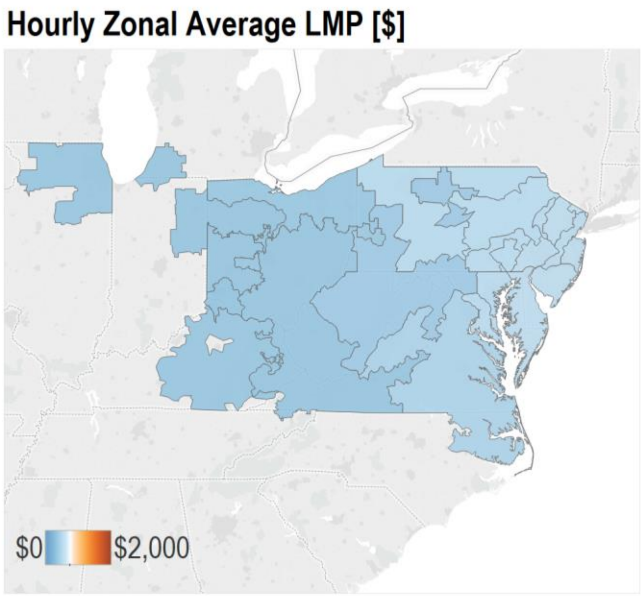
*141 Total Sites

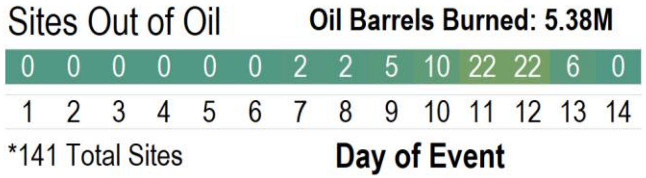
Pipeline Disruption Concurrent with Peak Load

Sensitivity 9

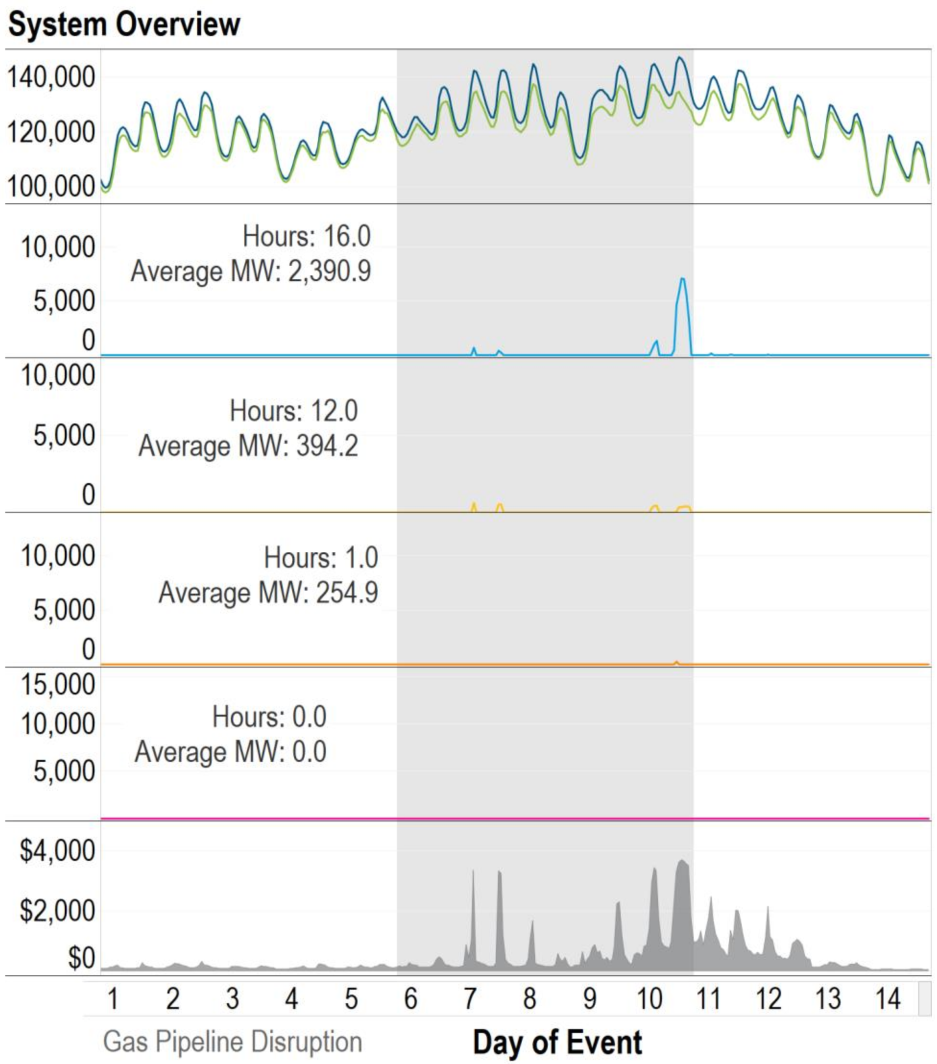


Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 2
Dispatch:	Economic



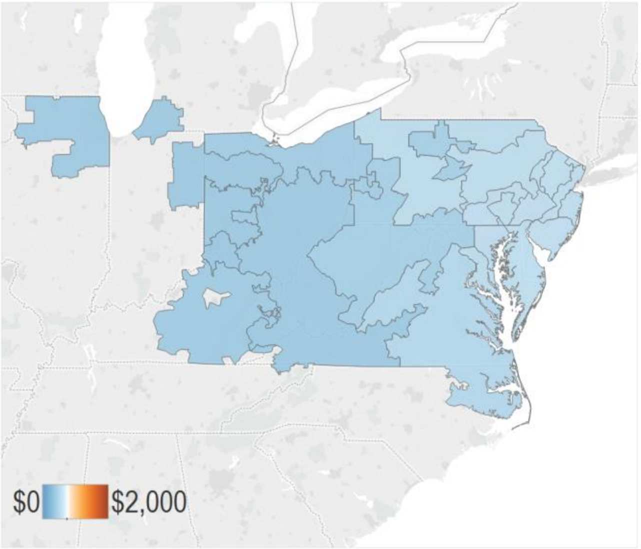


Phase 1 Sensitivities based on Stakeholder Feedback:
Pipeline Disruption Concurrent with Peak Load
Sensitivity 10



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 2
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil **Oil Barrels Burned: 4.60M**

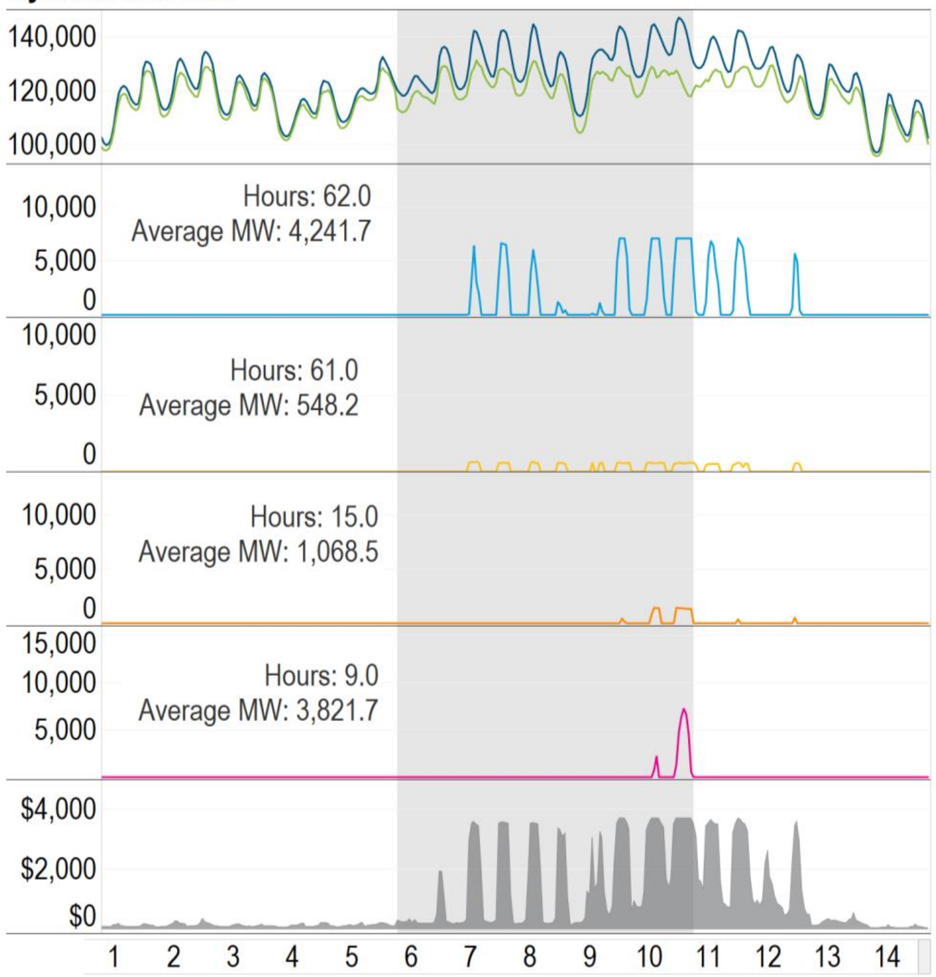
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	1	2	2	3	5	13	24	43	58	72	74	73	65

*141 Total Sites

Pipeline Disruption Concurrent with Peak Load

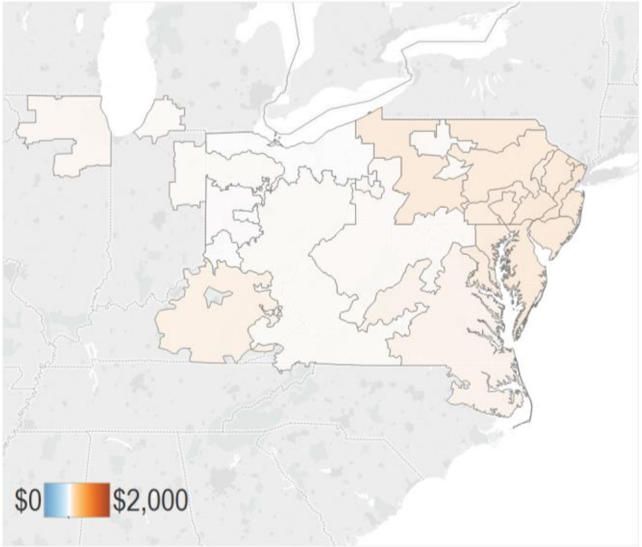
Sensitivity 11

System Overview



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 2
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil **Oil Barrels Burned: 6.12M**

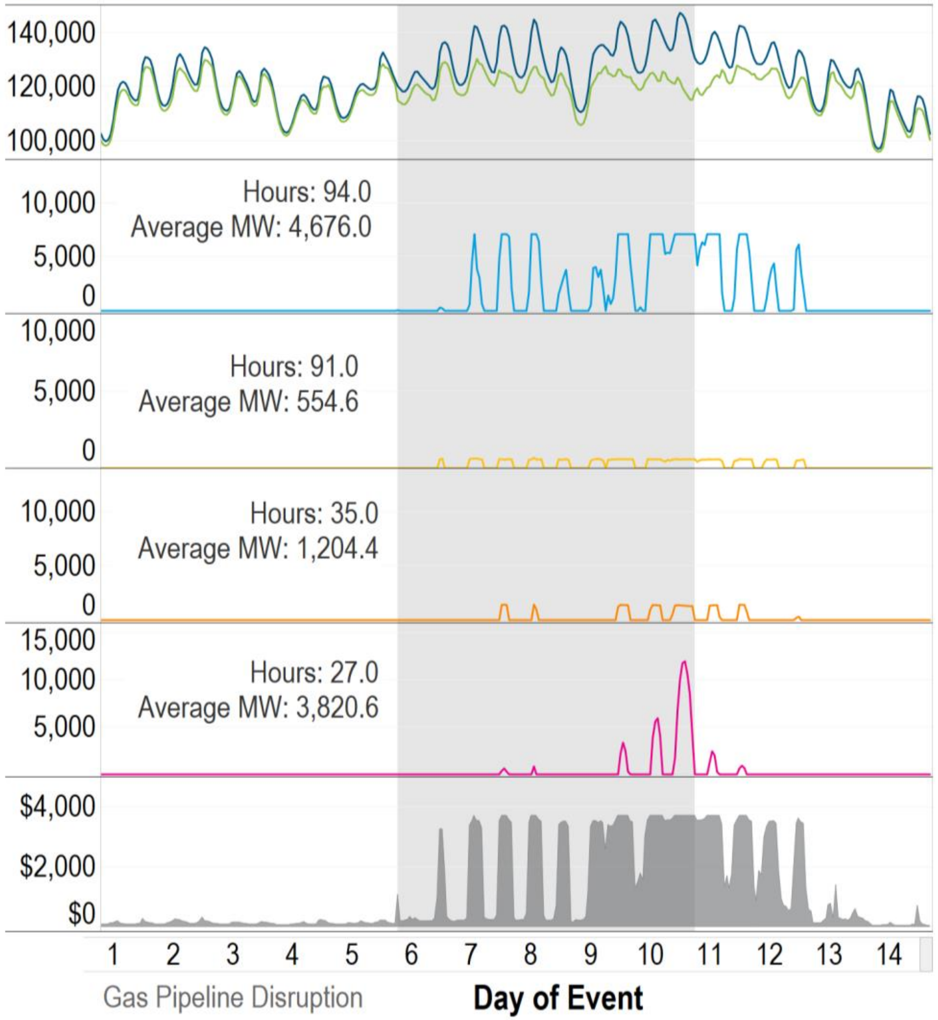
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	0	0	0	0	4	9	12	20	29	32	13	0

*141 Total Sites

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

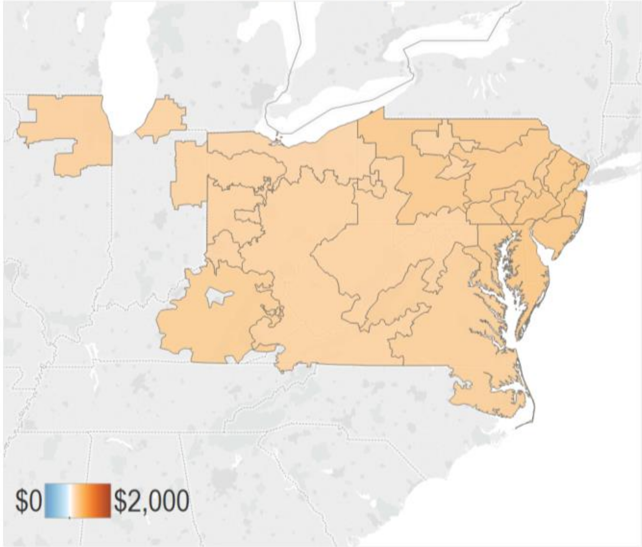
Sensitivity 12

System Overview



Load: Extreme
Refueling: Limited
Disruption: Looped 2 High
Non-Firm Avail: 0%
Retirement: Escalated 2
Dispatch: Economic

Hourly Zonal Average LMP [$]



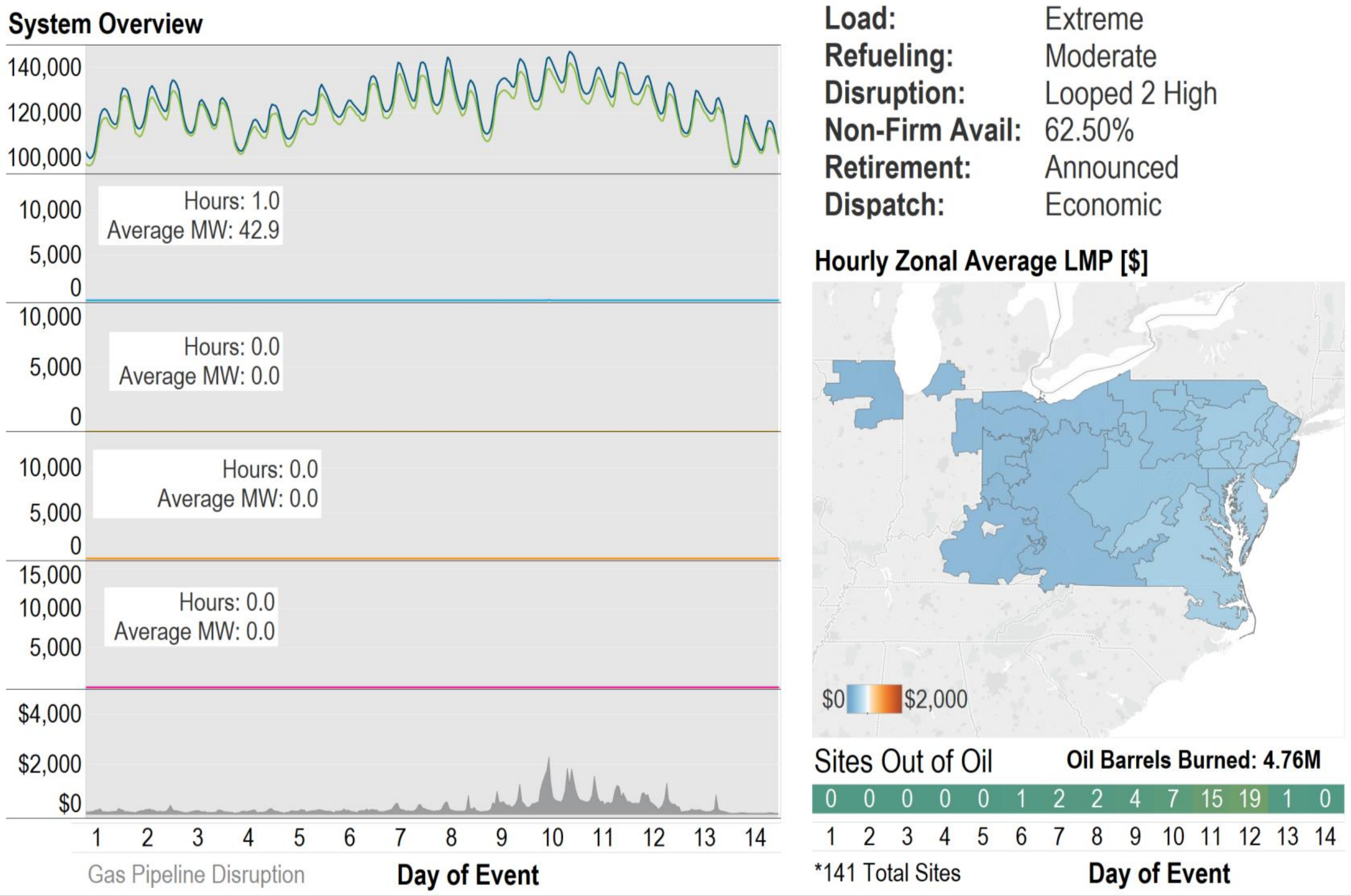
Sites Out of Oil — **Oil Barrels Burned: 5.07M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	1	2	2	3	7	23	48	63	75	85	88	88	69

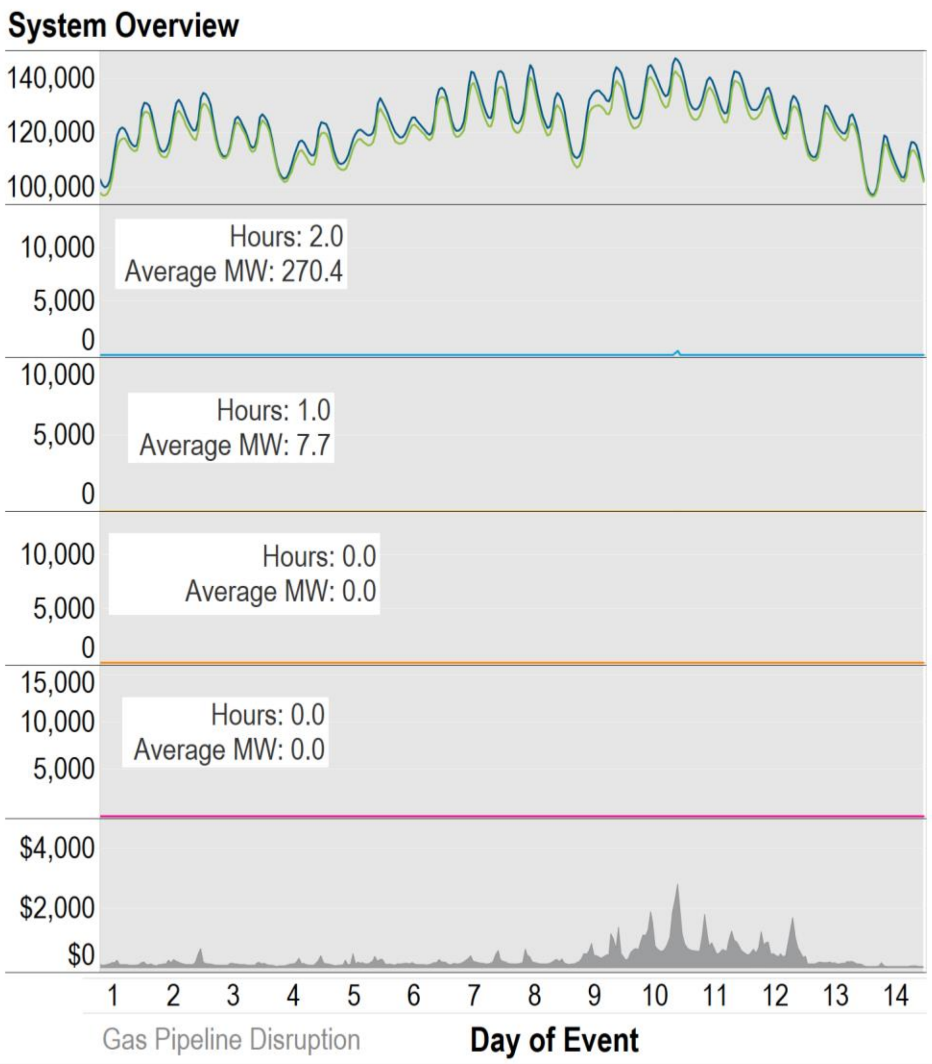
*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:
14-day Pipeline Disruption

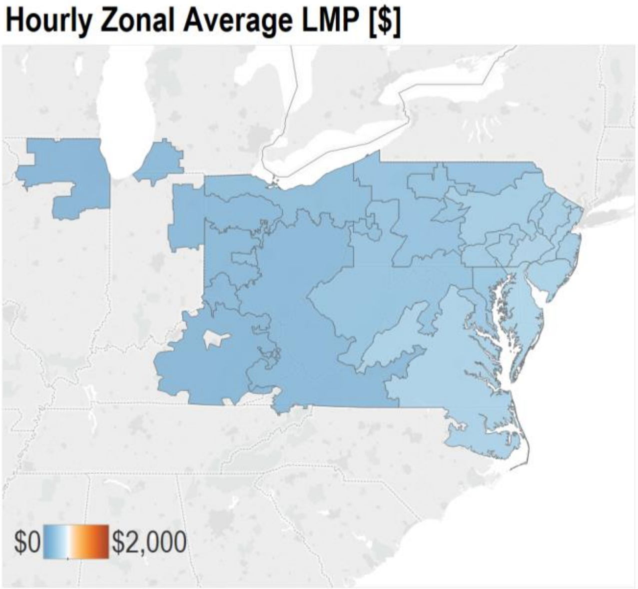
Sensitivity 13



Sensitivity 14



Load: Extreme
Refueling: Limited
Disruption: Looped 2 High
Non-Firm Avail: 62.50%
Retirement: Announced
Dispatch: Economic



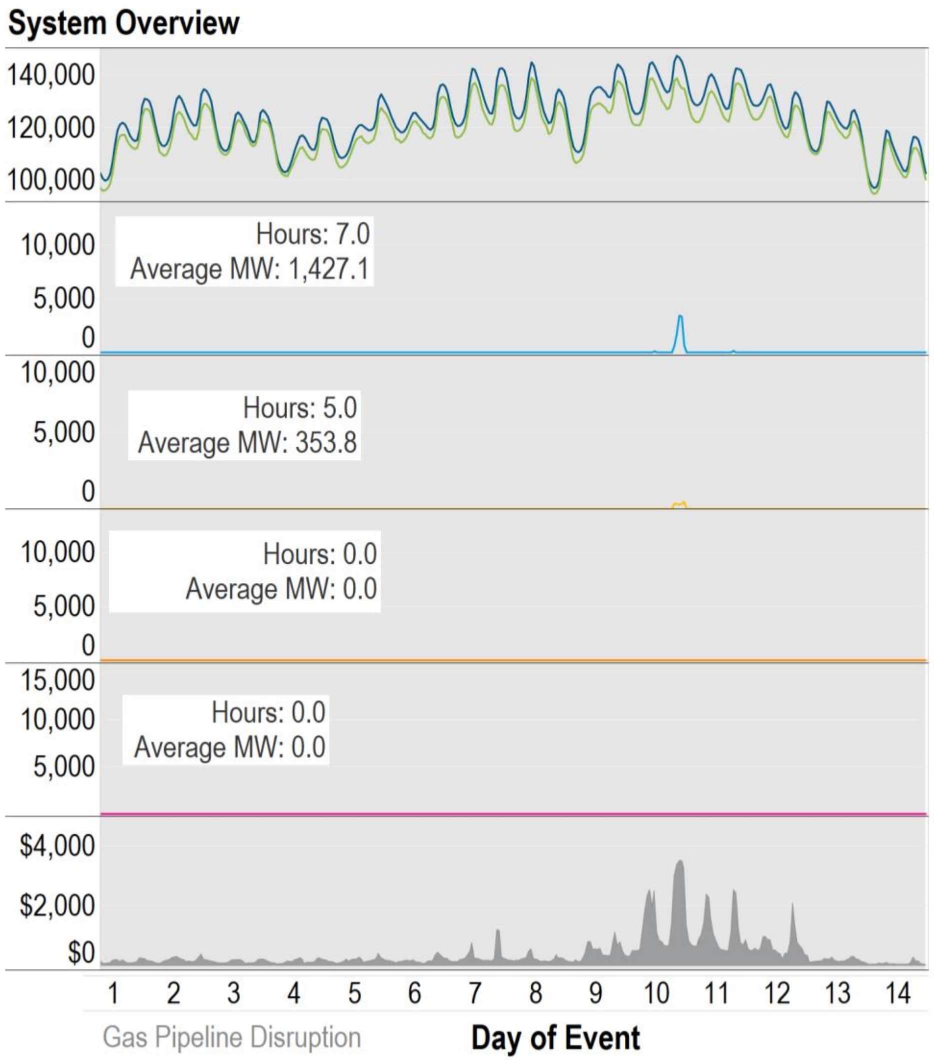
Sites Out of Oil **Oil Barrels Burned: 3.82M**

0	1	3	3	4	7	9	14	34	47	60	68	67	59
1	2	3	4	5	6	7	8	9	10	11	12	13	14

*141 Total Sites **Day of Event**

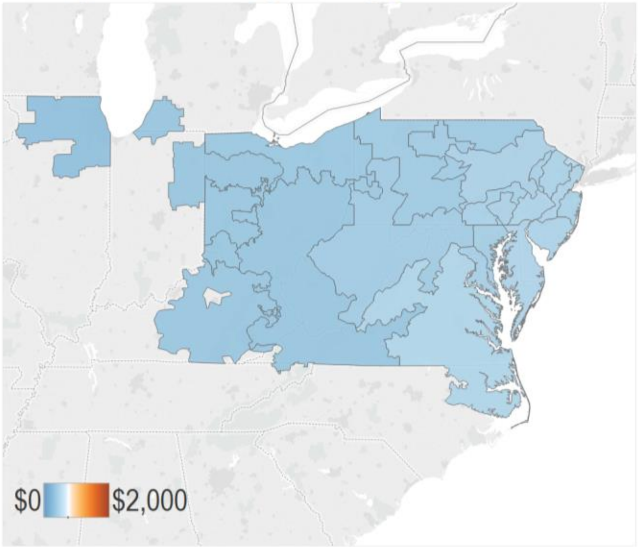
14-day Pipeline Disruption

Sensitivity 15



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil — **Oil Barrels Burned: 5.39M**

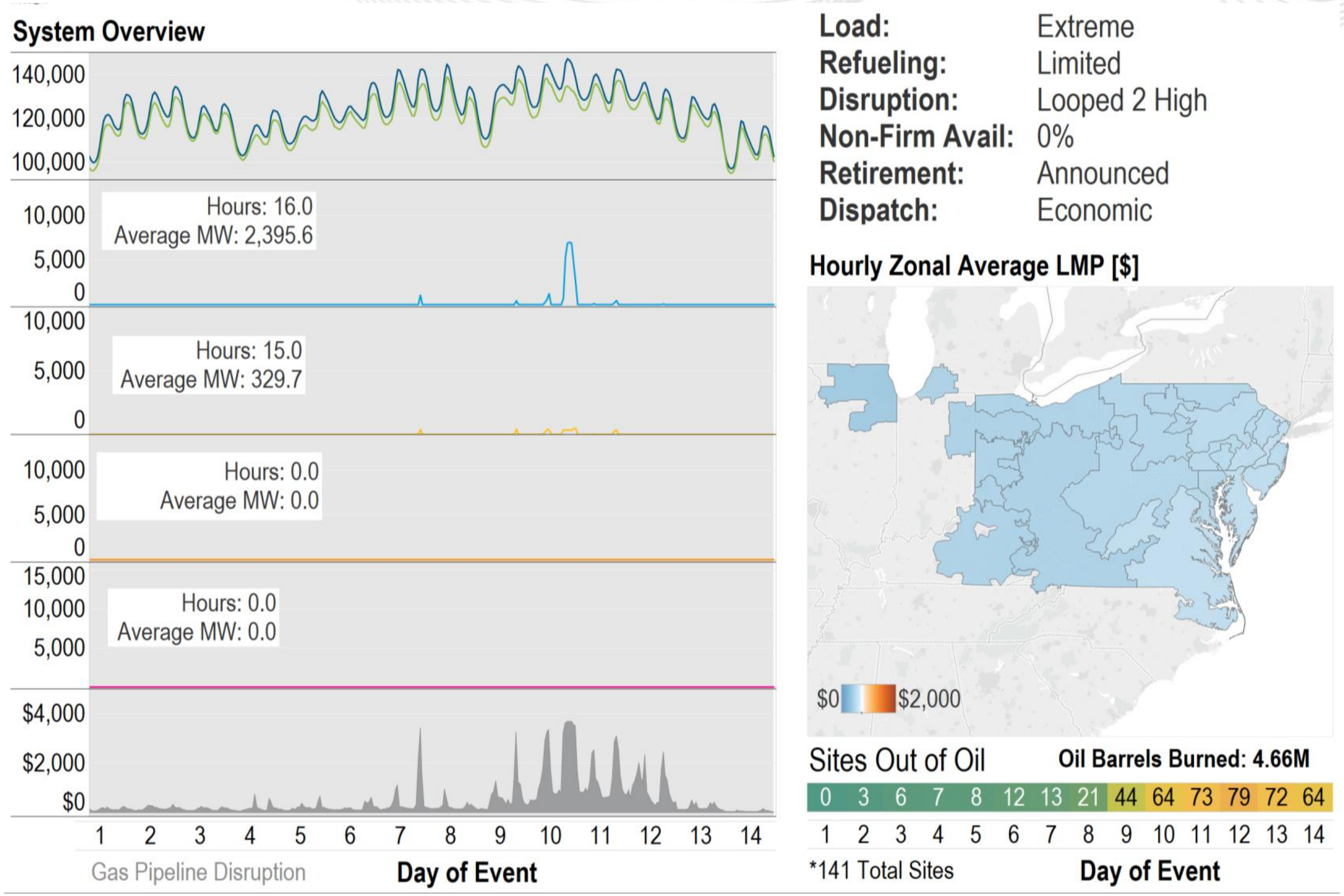
0	0	0	0	1	2	2	3	4	11	22	22	3	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14

*141 Total Sites — **Day of Event**

Phase 1 Sensitivities based on Stakeholder Feedback:

14-day Pipeline Disruption

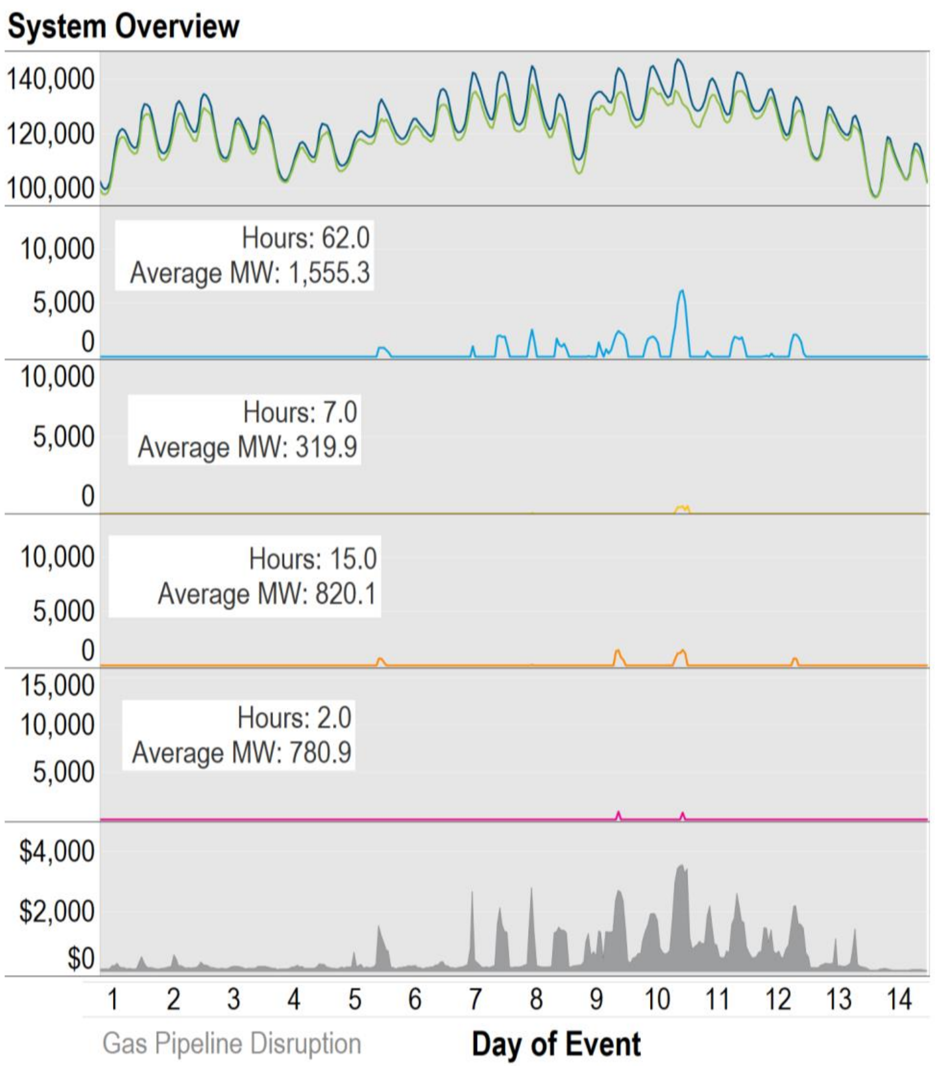
Sensitivity 16



Phase 1 Sensitivities based on Stakeholder Feedback:

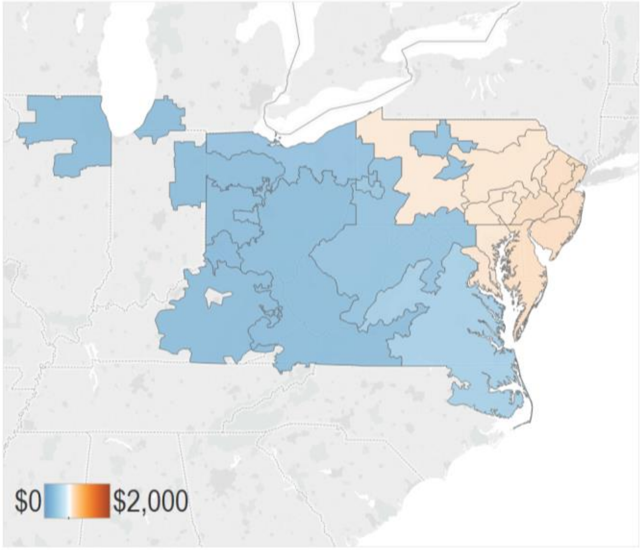
14-day Pipeline Disruption

Sensitivity 17



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]



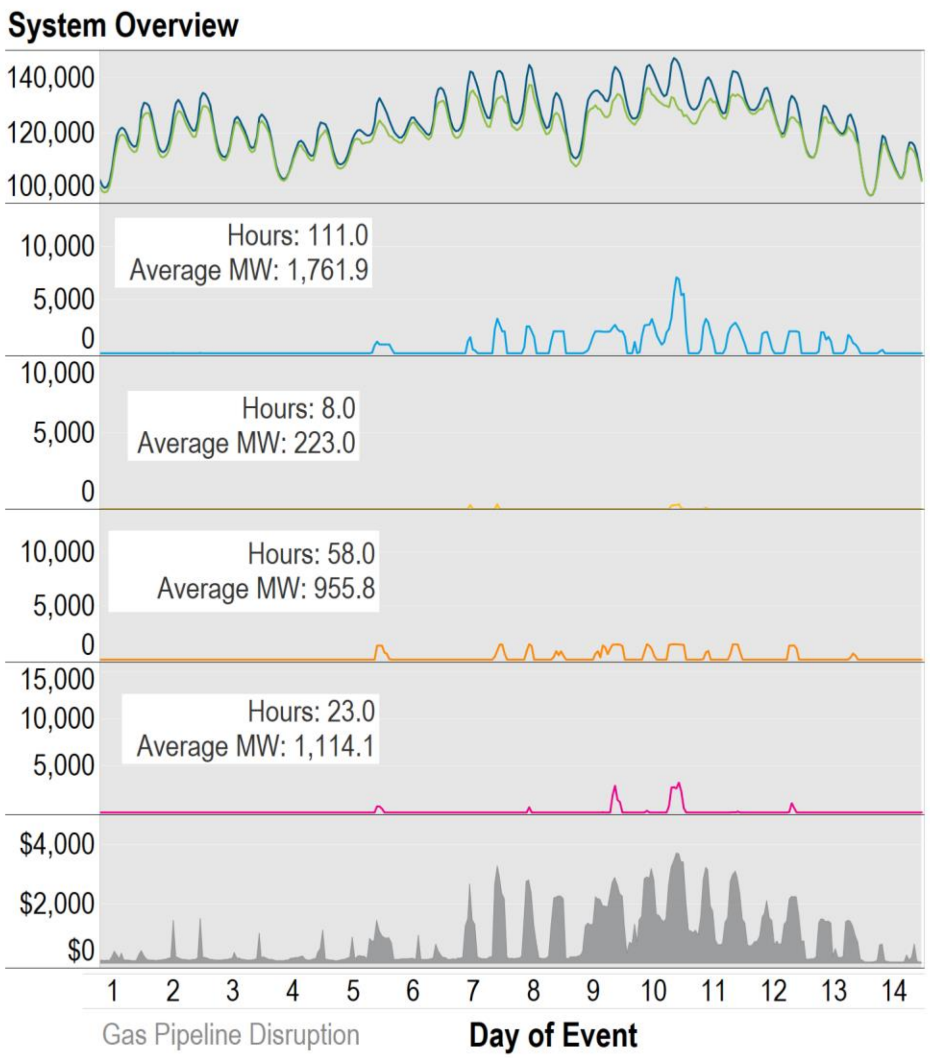
Sites Out of Oil **Oil Barrels Burned: 6.46M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	2	2	1	3	4	4	5	7	13	19	23	11	0

*141 Total Sites

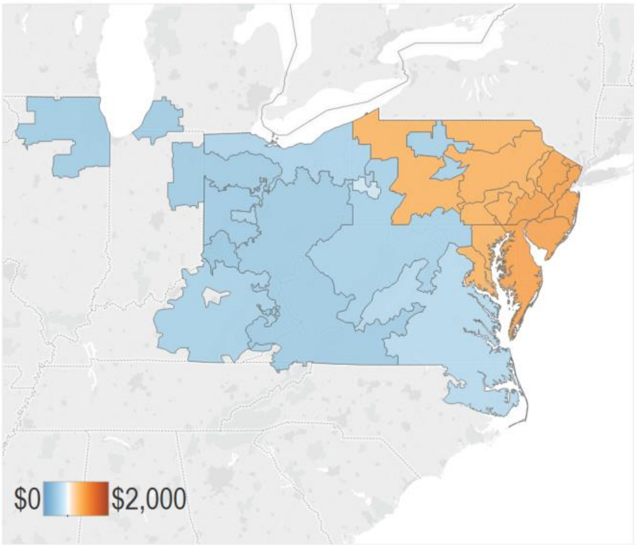
14-day Pipeline Disruption

Sensitivity 18



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]

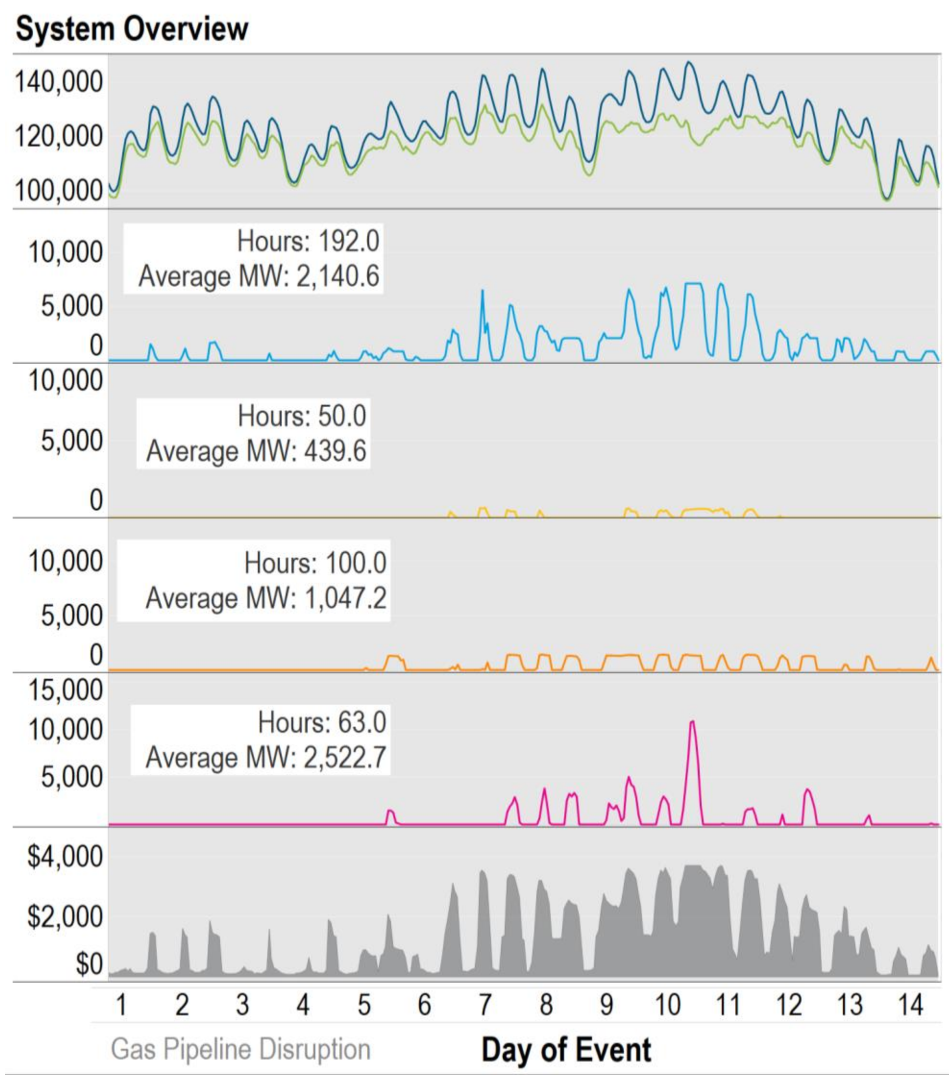


Sites Out of Oil **Oil Barrels Burned: 5.57M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	1	5	8	13	19	26	44	61	69	80	91	93	92	82

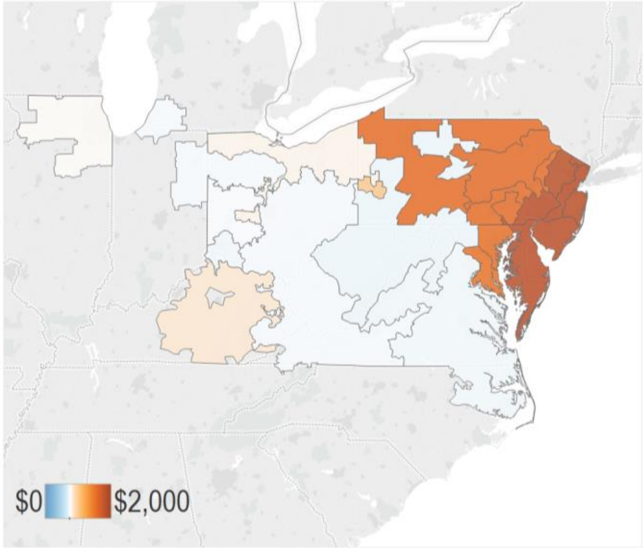
*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:
14-day Pipeline Disruption
Sensitivity 19



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]

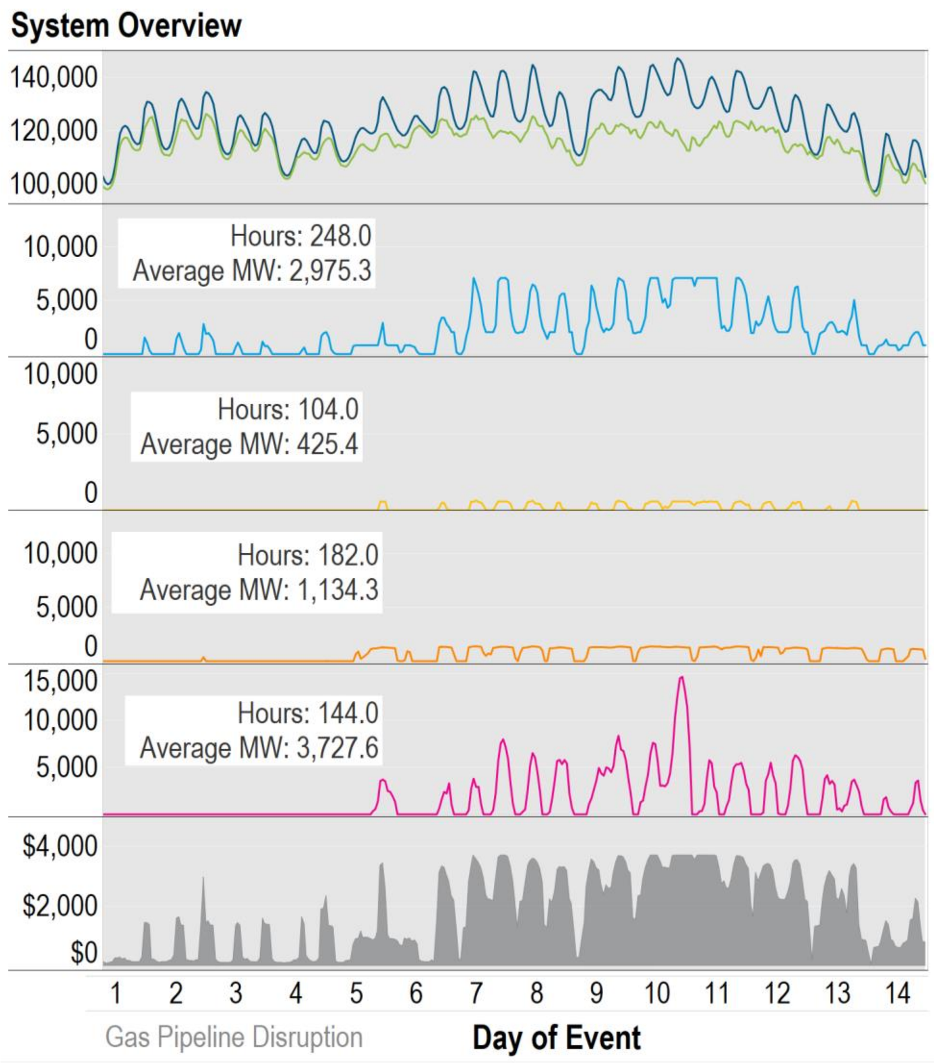


Sites Out of Oil — **Oil Barrels Burned: 8.11M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	2	1	3	4	6	8	12	19	27	31	34	24	8

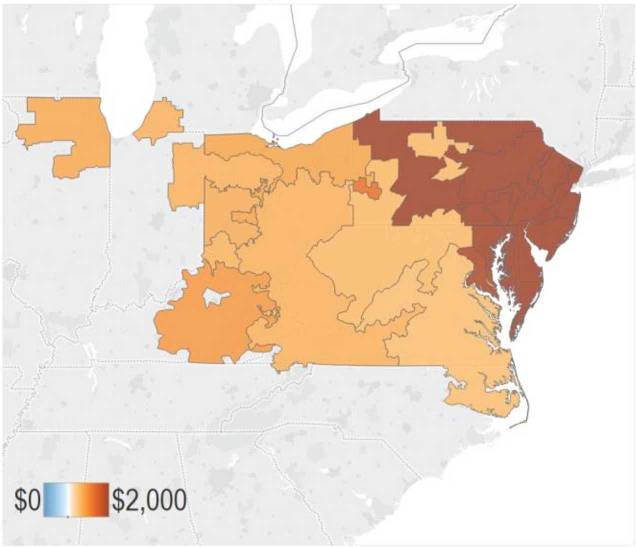
*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:
14-day Pipeline Disruption
Sensitivity 20



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]



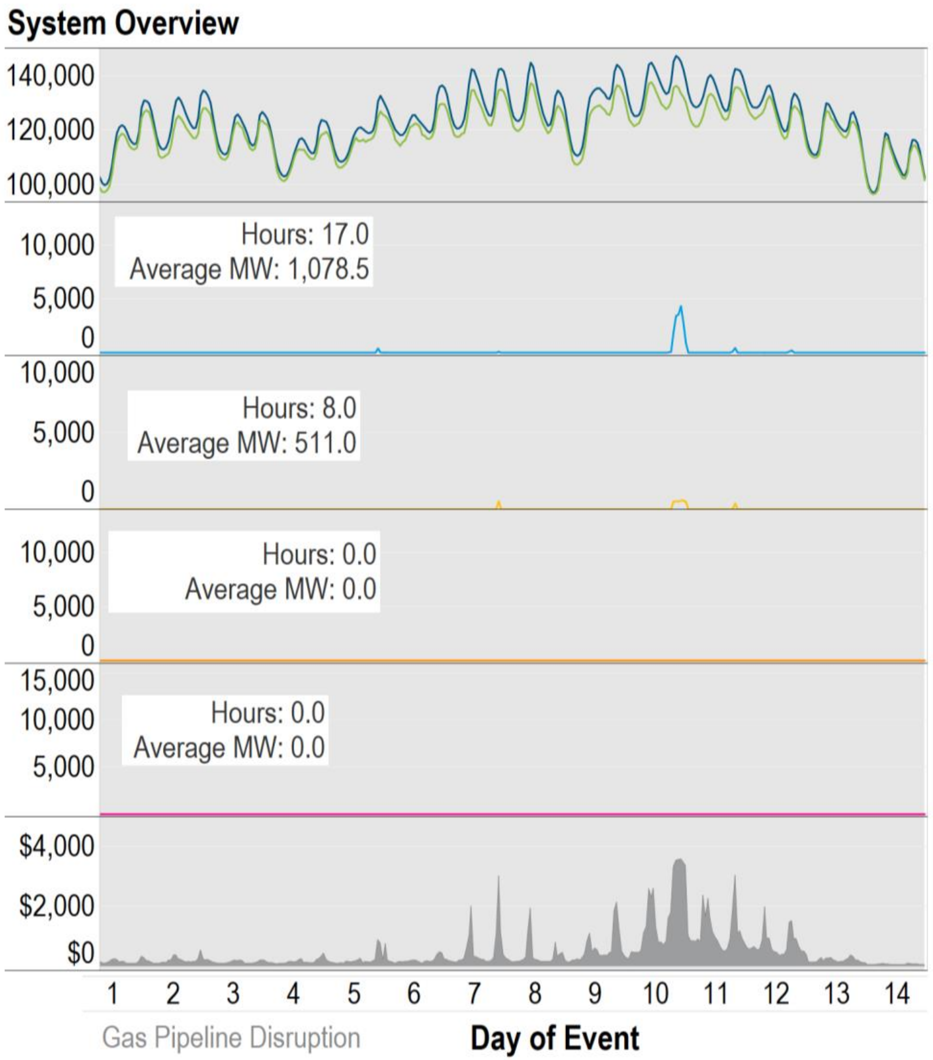
Sites Out of Oil

Oil Barrels Burned: 6.67M

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	3	15	24	36	48	63	77	97	99	100	109	108	108	102

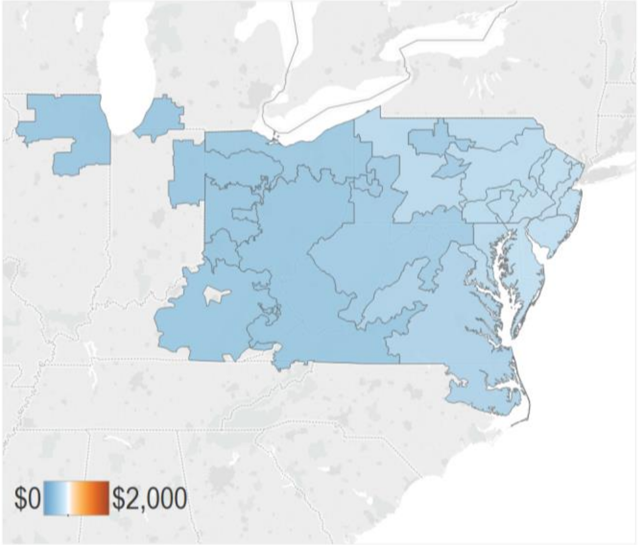
*141 Total Sites

Sensitivity 21



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 2
Dispatch:	Economic

Hourly Zonal Average LMP [$]

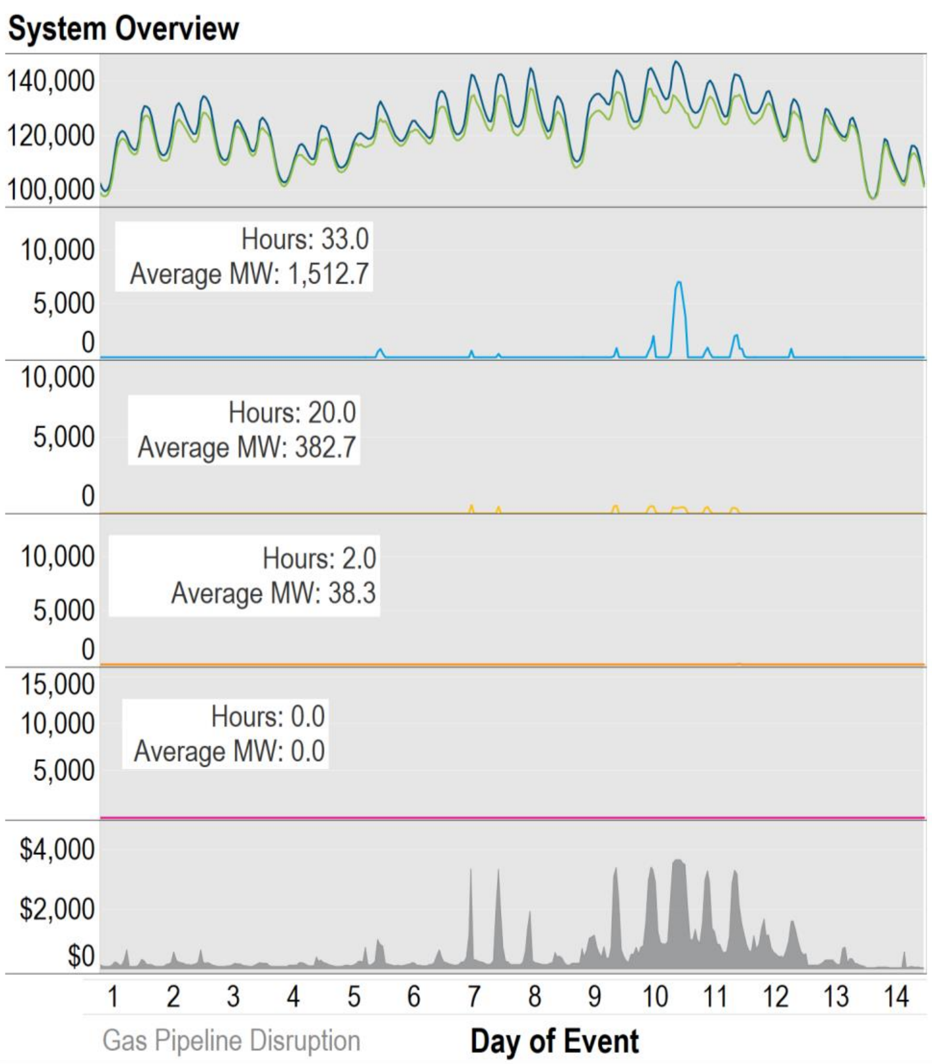


Sites Out of Oil — **Oil Barrels Burned: 5.85M**

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

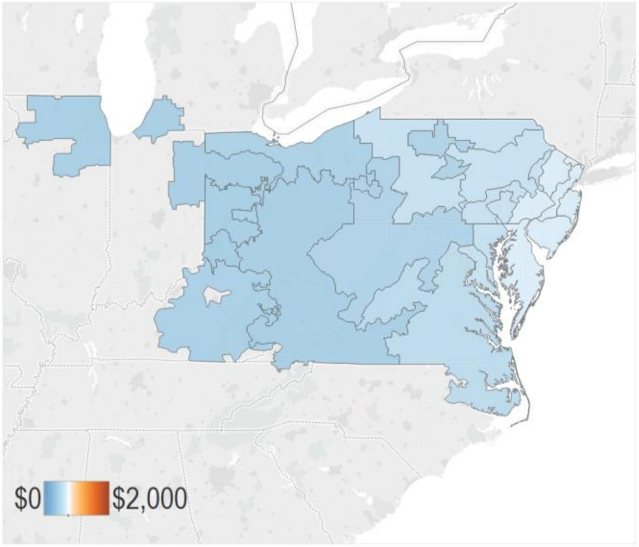
*141 Total Sites

Sensitivity 22



Load: Extreme
Refueling: Limited
Disruption: Looped 2 High
Non-Firm Avail: 62.50%
Retirement: Escalated 2
Dispatch: Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil — **Oil Barrels Burned: 4.94M**

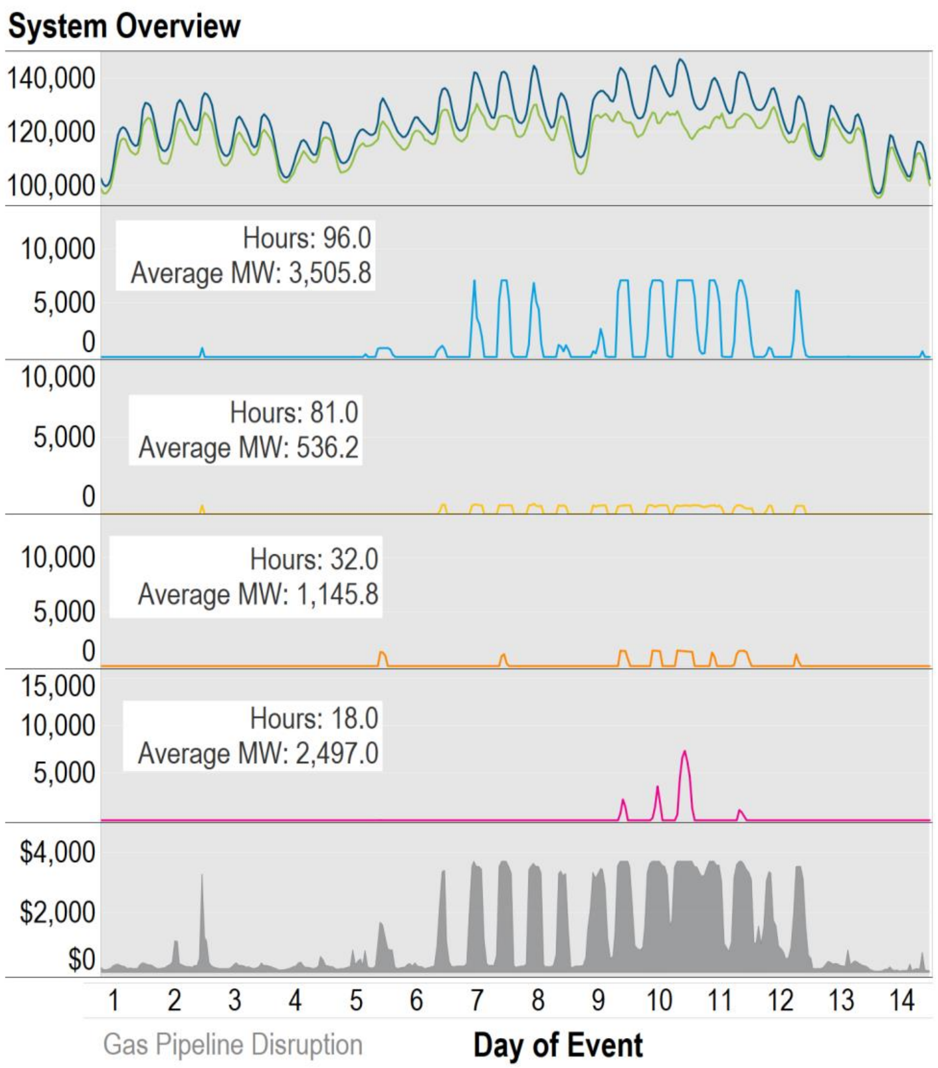
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	3	2	3	6	9	22	35	48	64	74	82	75	65

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:

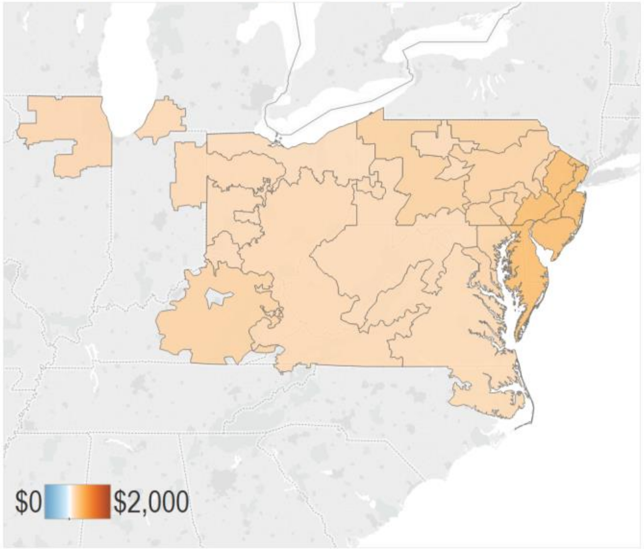
14-day Pipeline Disruption

Sensitivity 23



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 2
Dispatch:	Economic

Hourly Zonal Average LMP [$]



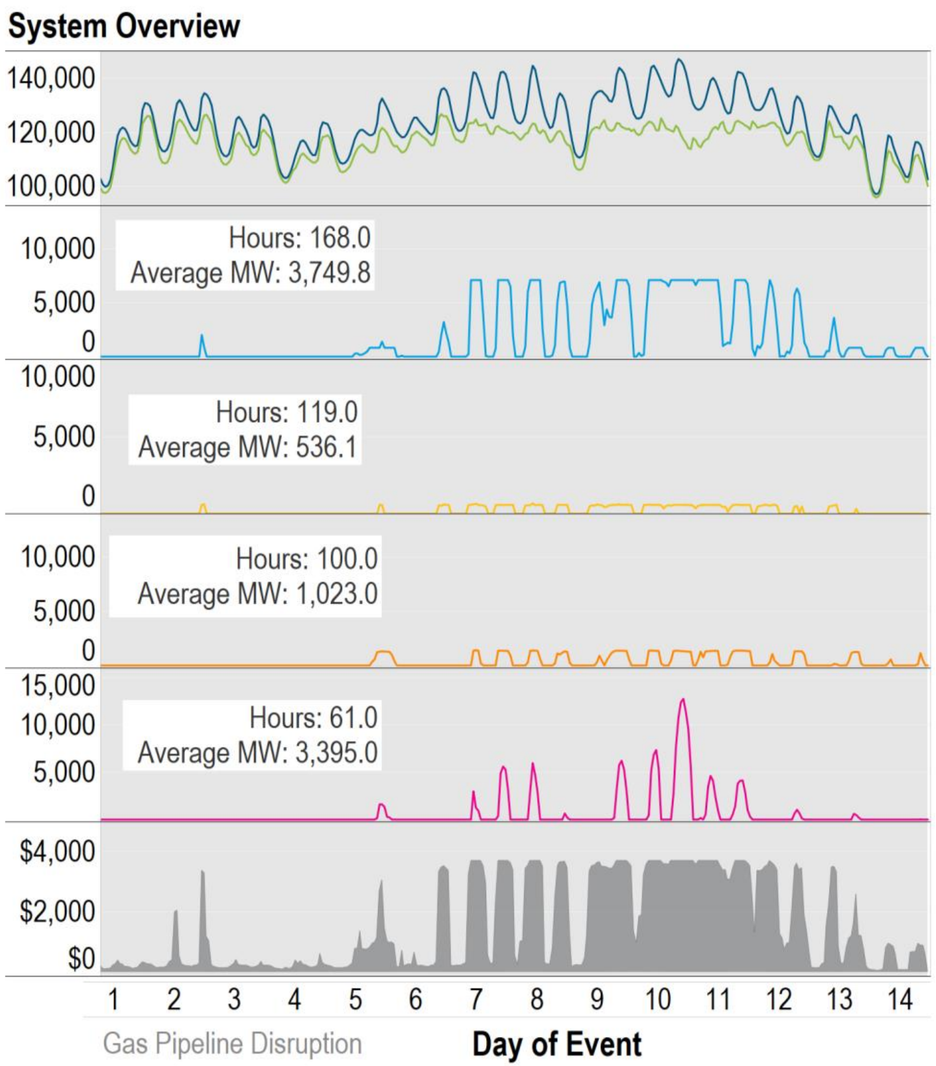
Sites Out of Oil — **Oil Barrels Burned: 7.27M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	1	1	2	3	4	5	10	17	24	28	32	14	3

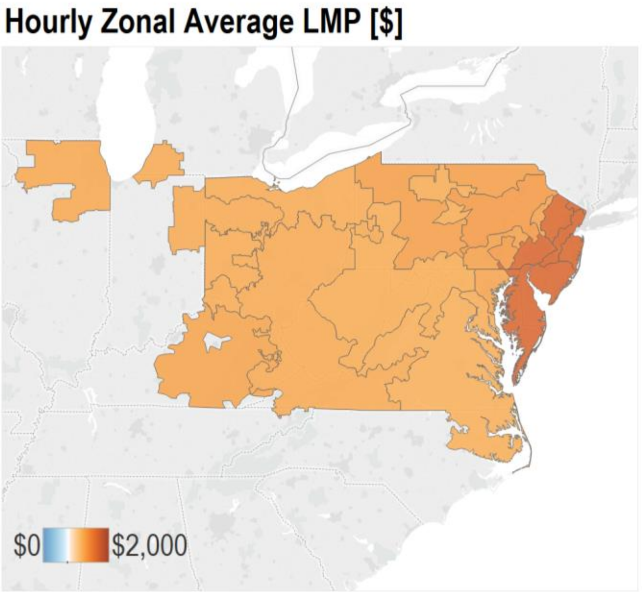
*141 Total Sites

14-day Pipeline Disruption

Sensitivity 24



Load: Extreme
Refueling: Limited
Disruption: Looped 2 High
Non-Firm Avail: 0%
Retirement: Escalated 2
Dispatch: Economic



Sites Out of Oil — **Oil Barrels Burned: 6.00M**

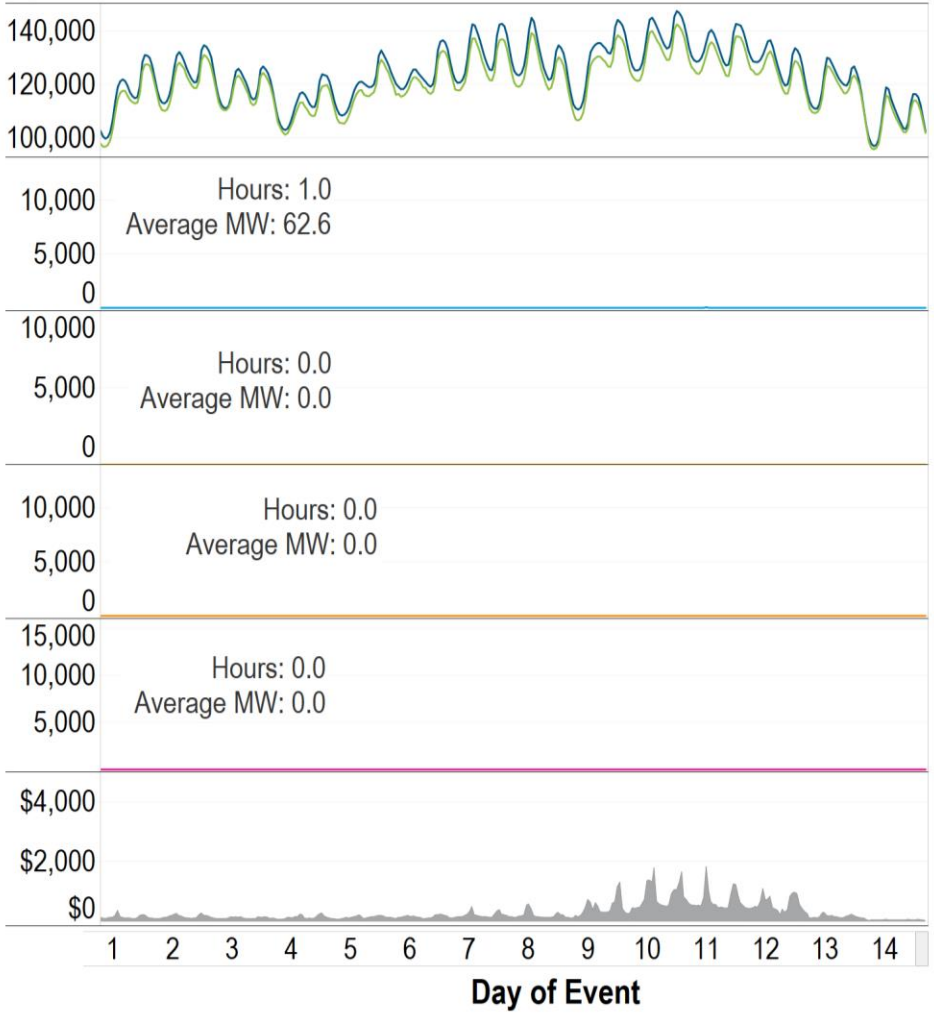
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	9	10	17	30	45	65	76	82	87	94	96	95	87

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%

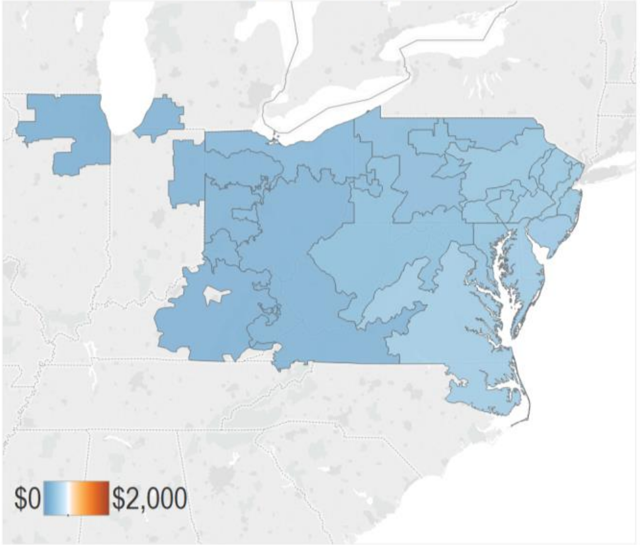
Sensitivity 25

System Overview



Load:	Extreme
Refueling:	Moderate
Disruption:	None
Non-Firm Avail:	62.50%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]



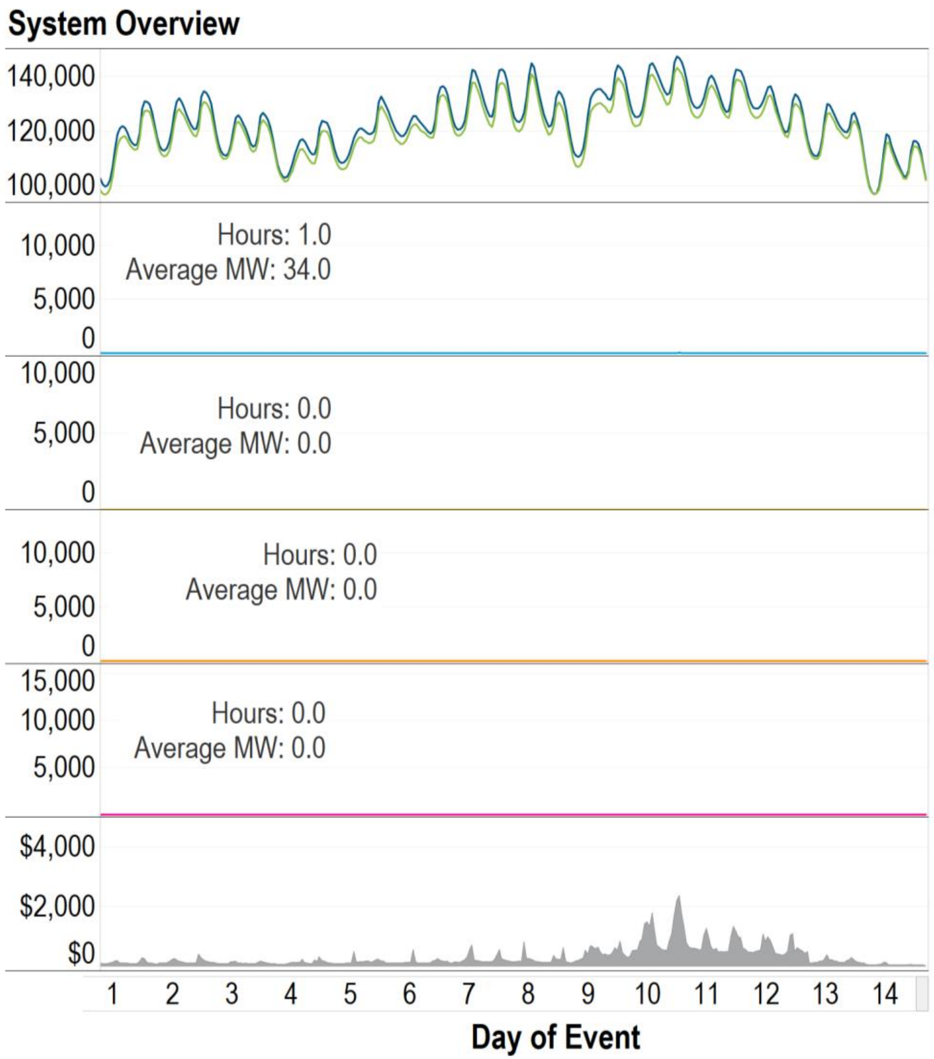
Sites Out of Oil **Oil Barrels Burned: 4.04M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	1	1	1	1	1	2	4	6	17	18	2	0

*141 Total Sites

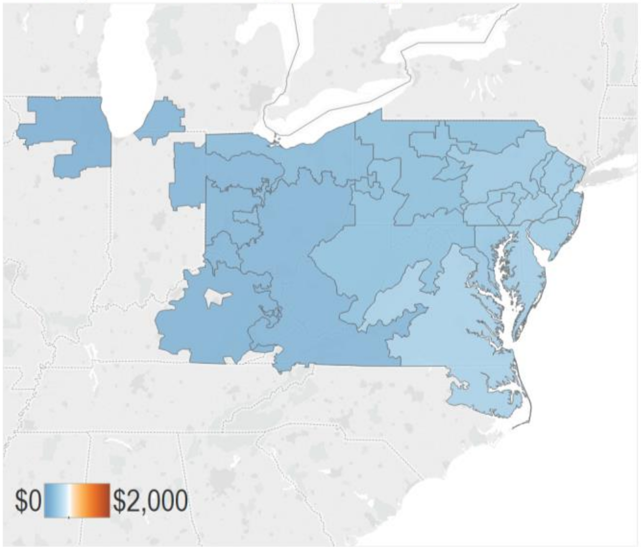
Initial Oil Inventory Level at 50%

Sensitivity 26



Load: Extreme
Refueling: Limited
Disruption: None
Non-Firm Avail: 62.50%
Retirement: Announced
Dispatch: Economic

Hourly Zonal Average LMP [$]



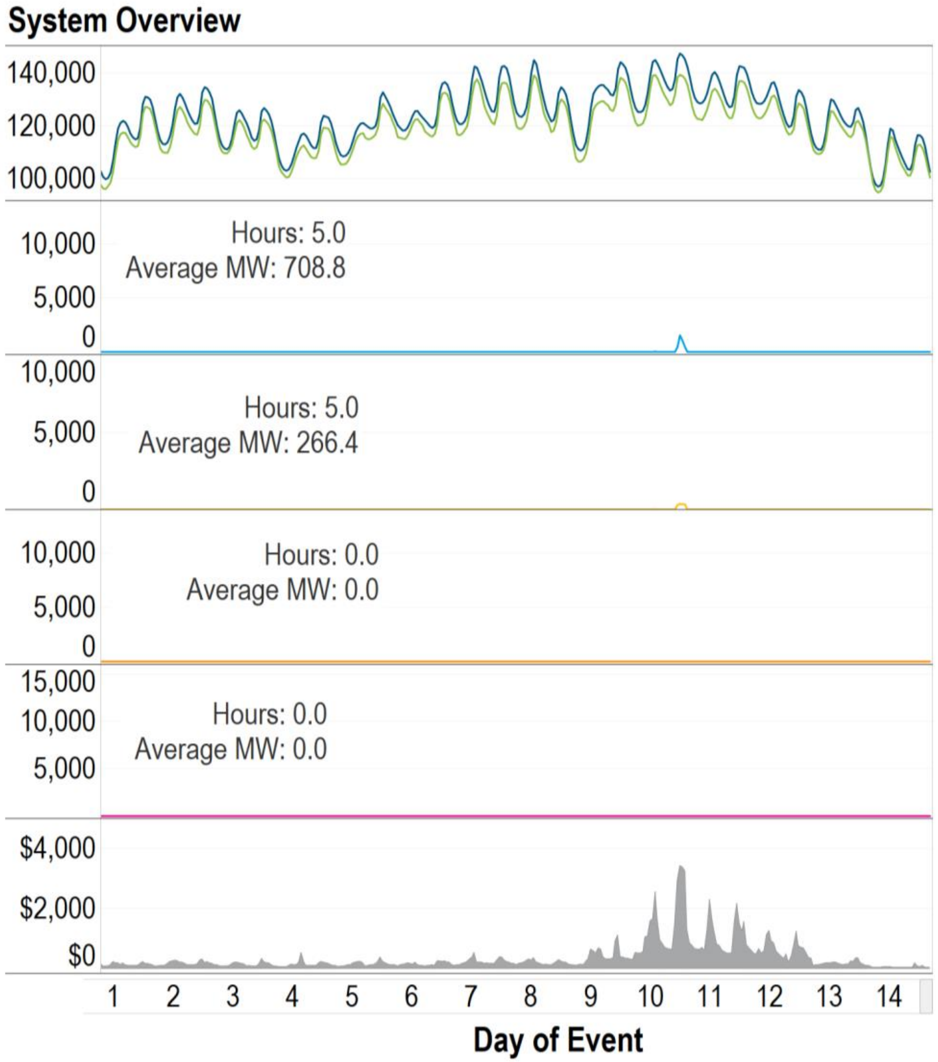
Sites Out of Oil — **Oil Barrels Burned: 3.25M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	5	7	8	7	8	16	17	47	62	71	75	71	64

*141 Total Sites

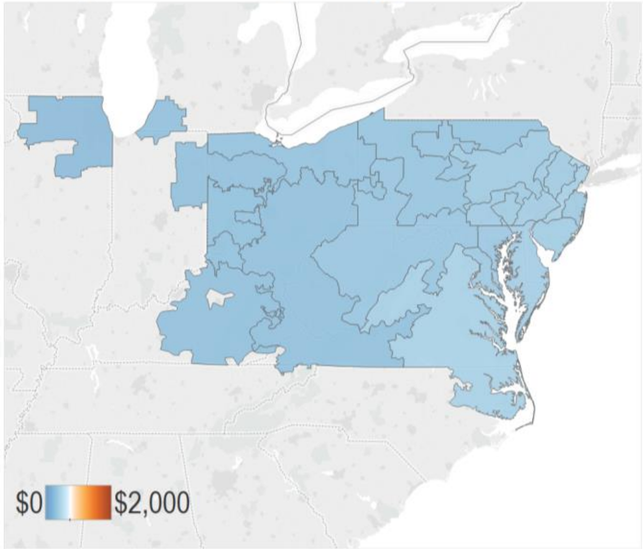
Initial Oil Inventory Level at 50%

Sensitivity 27



Load:	Extreme
Refueling:	Moderate
Disruption:	None
Non-Firm Avail:	0%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]



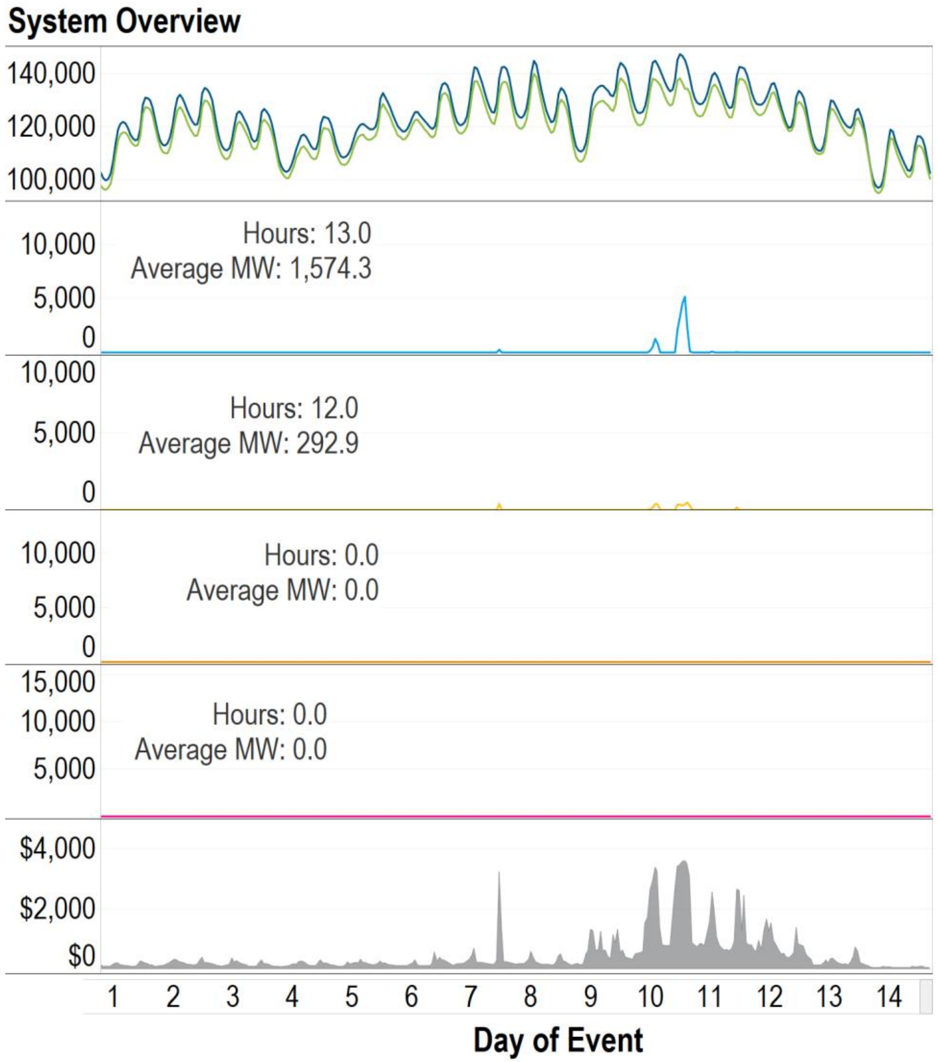
Sites Out of Oil **Oil Barrels Burned: 4.83M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	1	0	0	1	1	2	5	10	23	24	3	1

*141 Total Sites

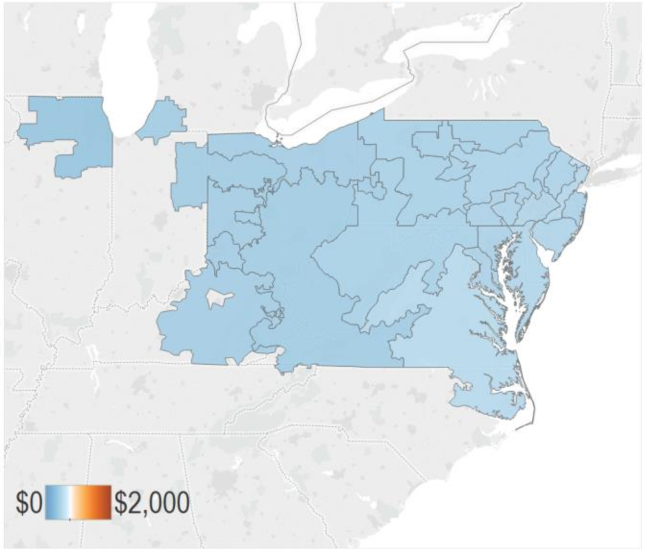
Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%

Sensitivity 28



Load:	Extreme
Refueling:	Limited
Disruption:	None
Non-Firm Avail:	0%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]



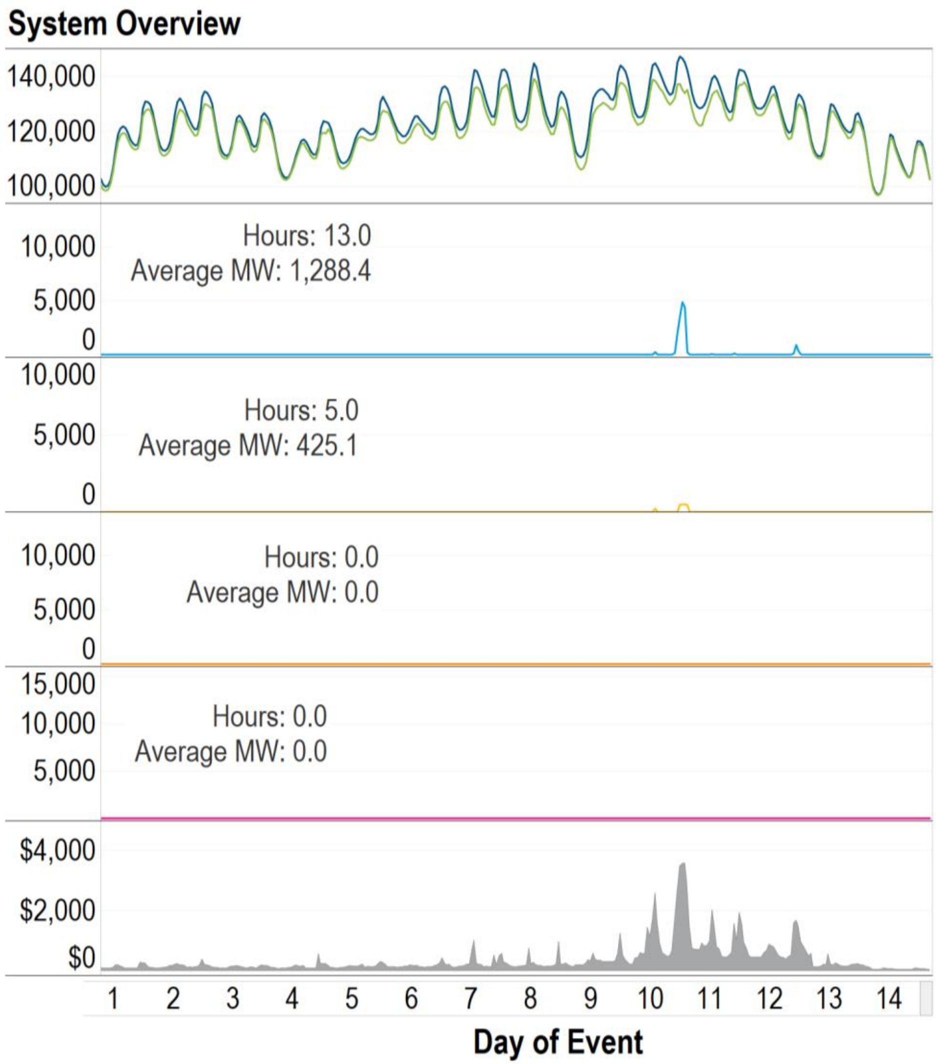
Sites Out of Oil — **Oil Barrels Burned: 4.07M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	7	8	11	13	13	23	32	62	78	90	91	84	72

*141 Total Sites

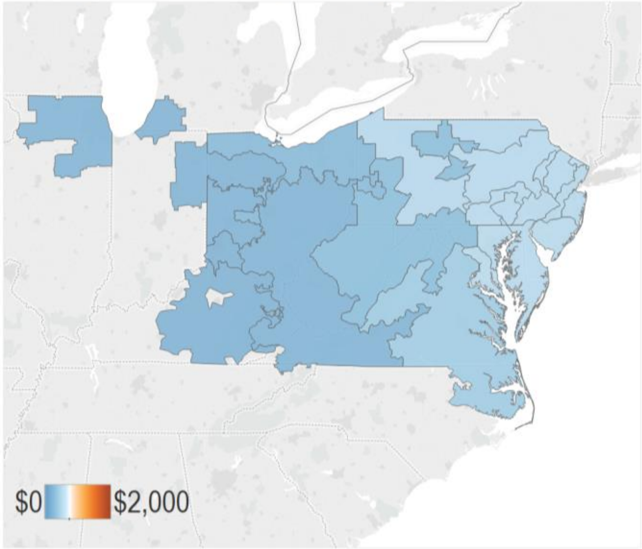
Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%

Sensitivity 29



Load: Extreme
Refueling: Moderate
Disruption: None
Non-Firm Avail: 62.50%
Retirement: Escalated 1
Dispatch: Economic

Hourly Zonal Average LMP [$]



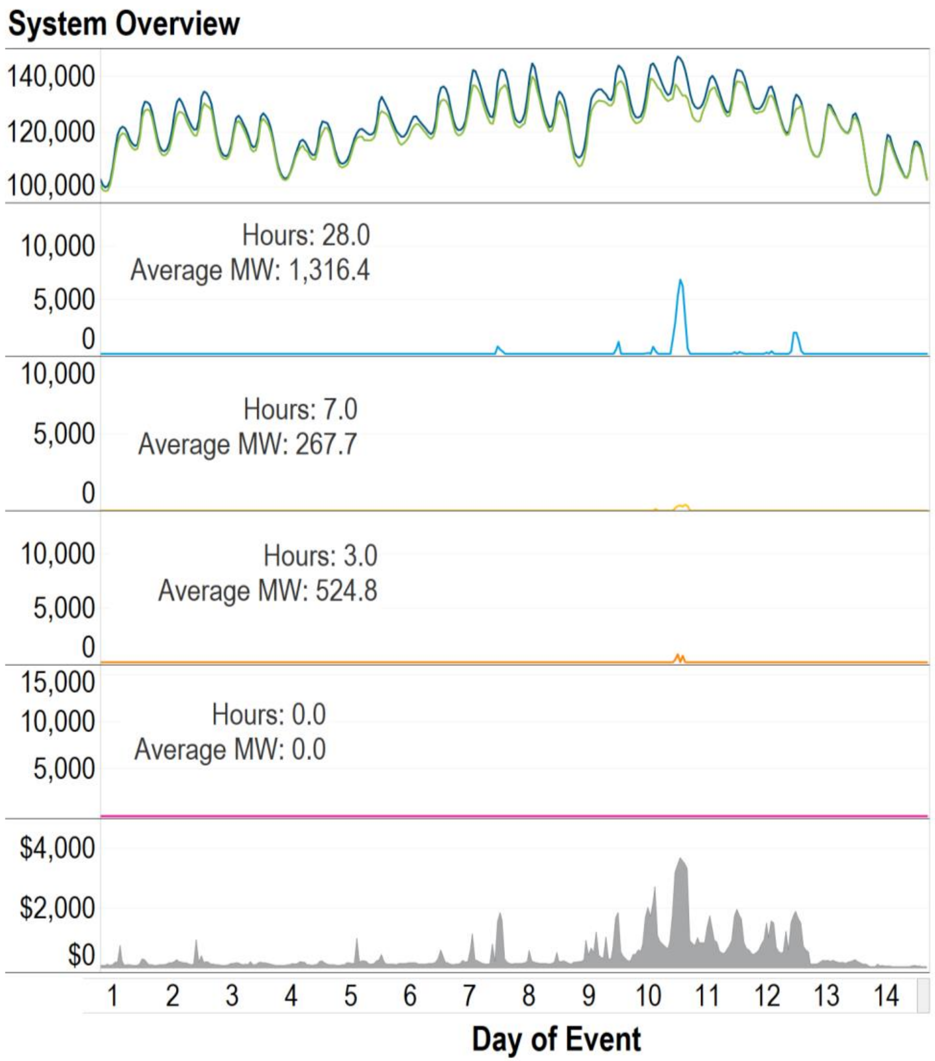
Sites Out of Oil **Oil Barrels Burned: 5.54M**

Sites Out of Oil	0	0	2	1	2	1	2	4	9	13	18	21	11	0
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14

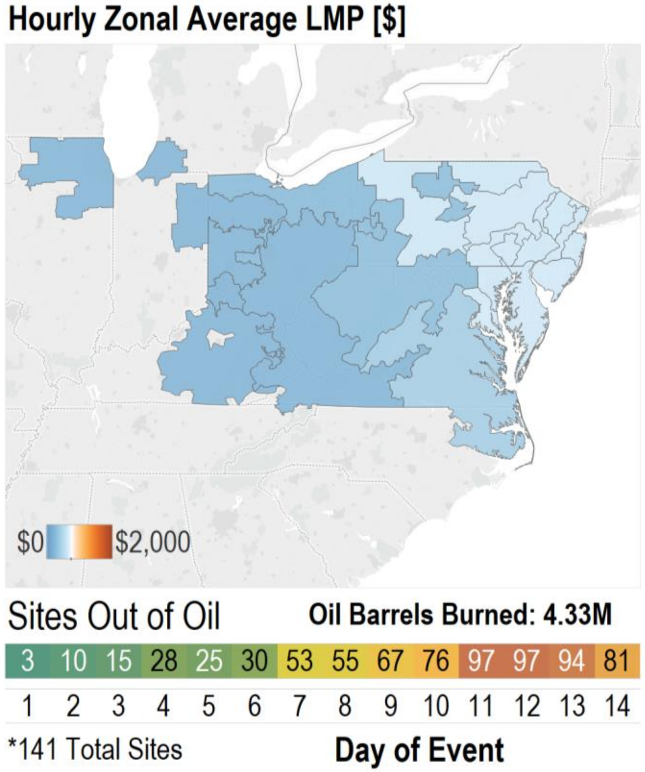
*141 Total Sites

Initial Oil Inventory Level at 50%

Sensitivity 30

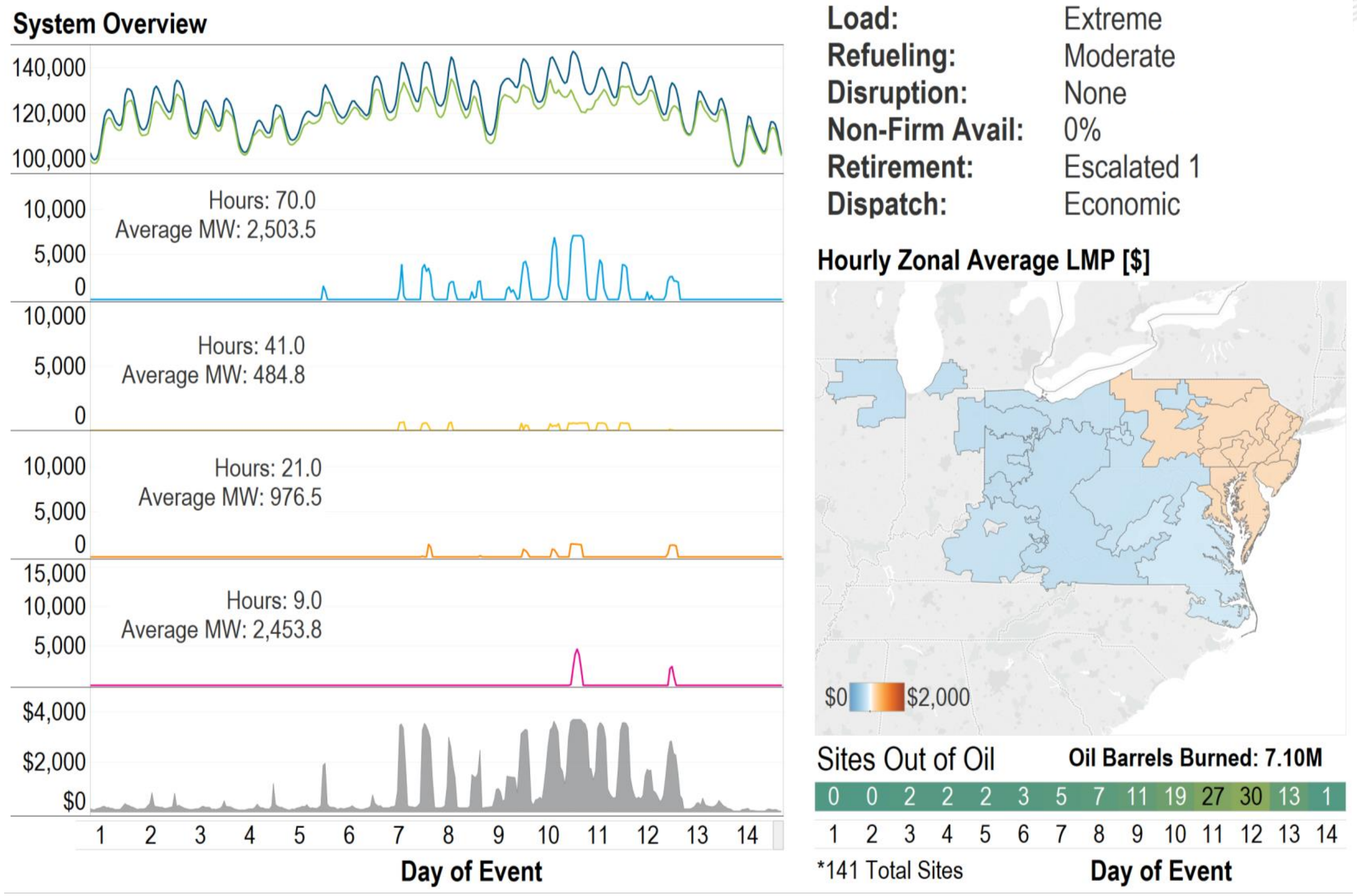


Load:	Extreme
Refueling:	Limited
Disruption:	None
Non-Firm Avail:	62.50%
Retirement:	Escalated 1
Dispatch:	Economic



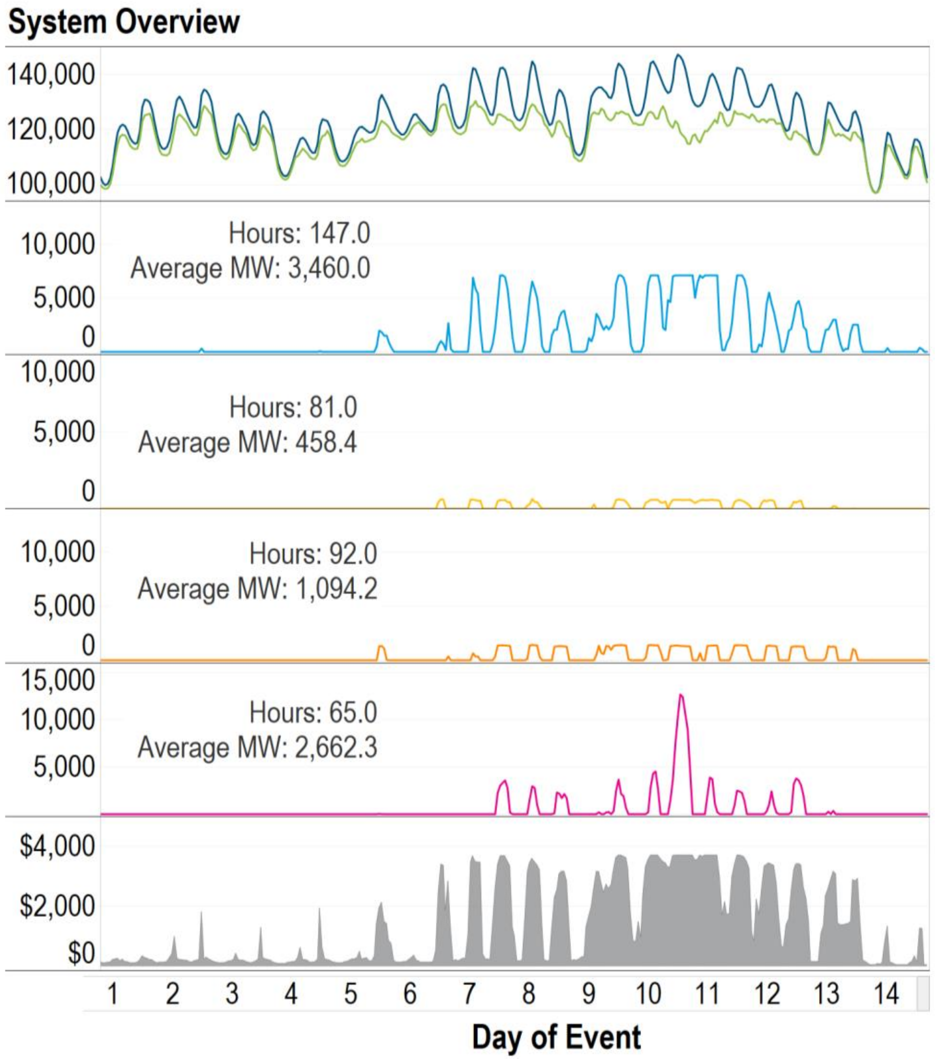
Initial Oil Inventory Level at 50%

Sensitivity 31



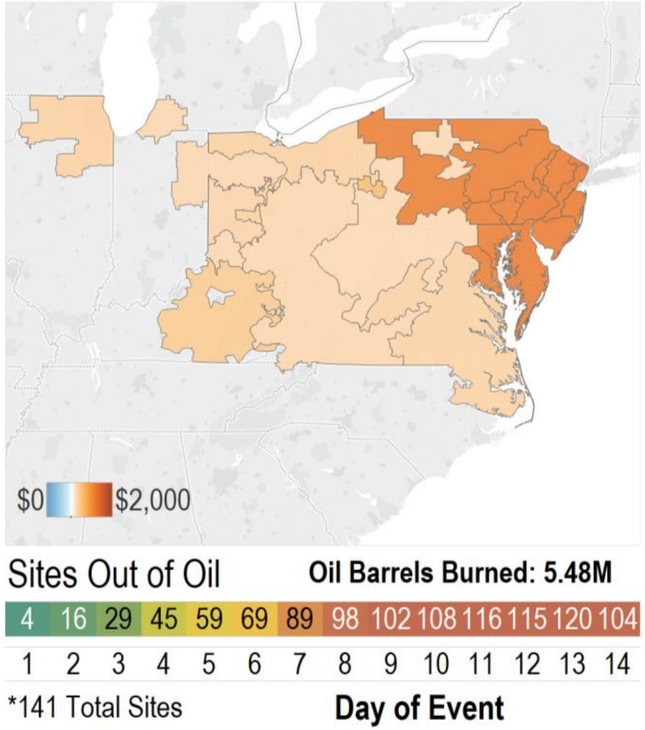
Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%

Sensitivity 32



Load:	Extreme
Refueling:	Limited
Disruption:	None
Non-Firm Avail:	0%
Retirement:	Escalated 1
Dispatch:	Economic

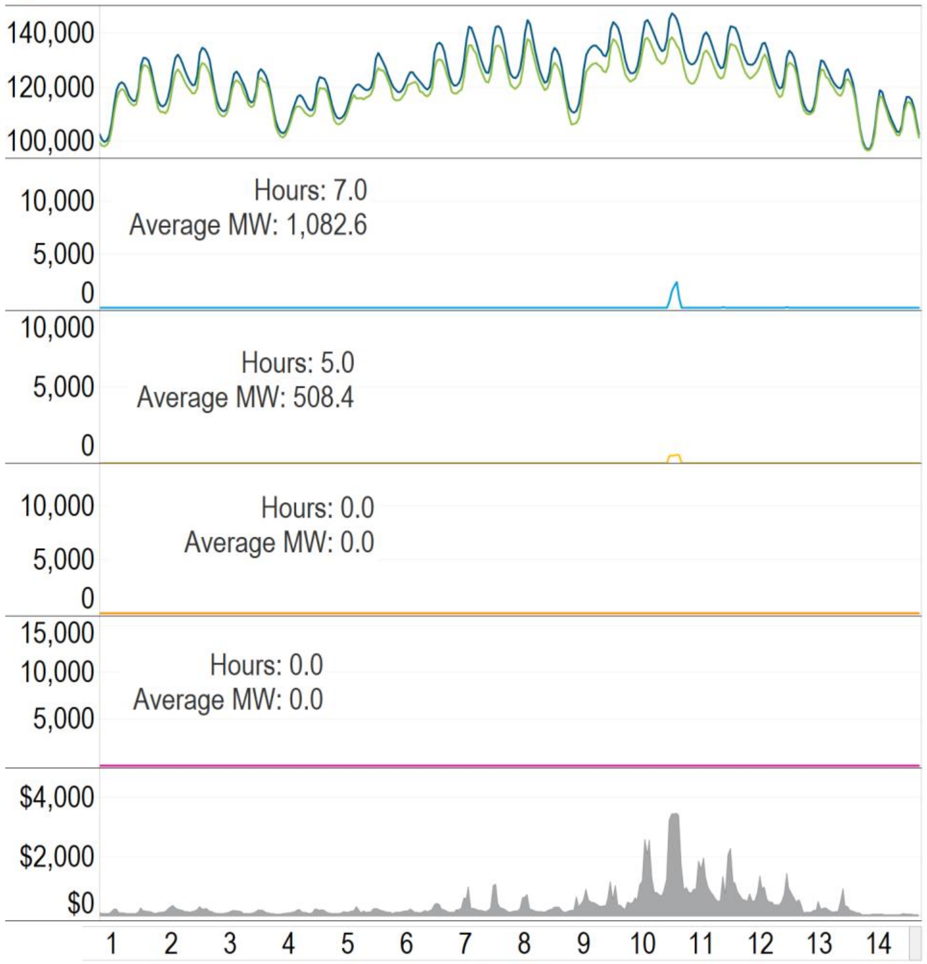
Hourly Zonal Average LMP [$]



Initial Oil Inventory Level at 50%

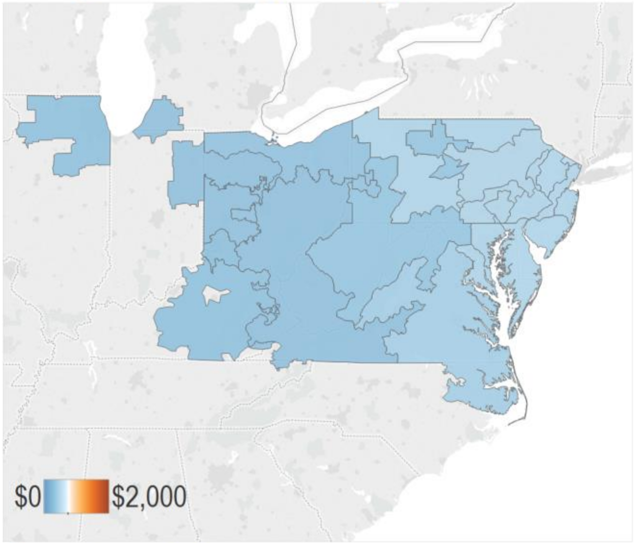
Sensitivity 33

System Overview



Load: Extreme
Refueling: Moderate
Disruption: None
Non-Firm Avail: 62.50%
Retirement: Escalated 2
Dispatch: Economic

Hourly Zonal Average LMP [$]



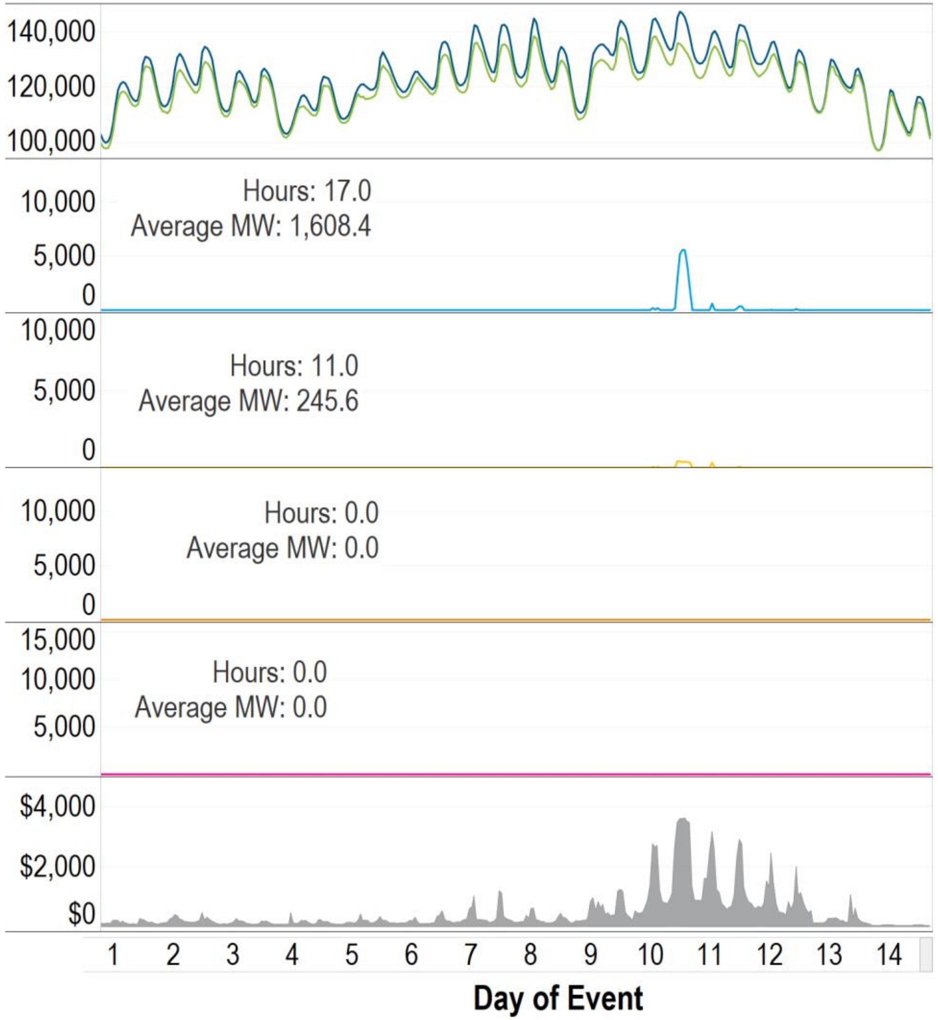
Sites Out of Oil — **Oil Barrels Burned: 4.77M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	1	0	2	1	2	2	5	12	23	19	7	0

*141 Total Sites

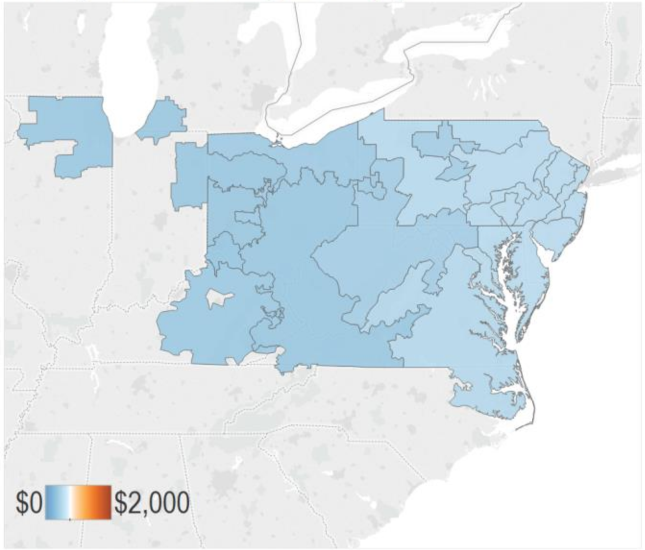
Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%
Sensitivity 34

System Overview



Load:	Extreme
Refueling:	Limited
Disruption:	None
Non-Firm Avail:	62.50%
Retirement:	Escalated 2
Dispatch:	Economic

Hourly Zonal Average LMP [$]



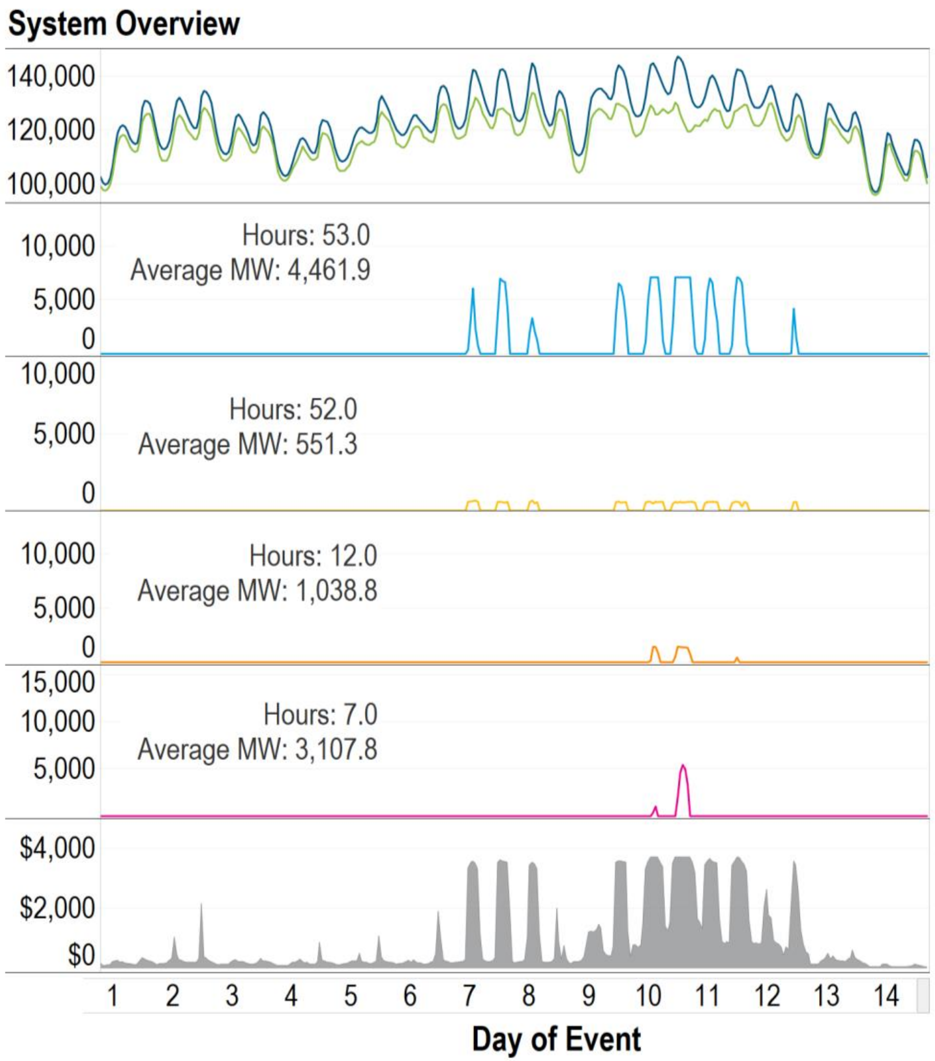
Sites Out of Oil **Oil Barrels Burned: 4.11M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	1	6	7	10	11	16	27	40	59	74	86	86	82	72

*141 Total Sites

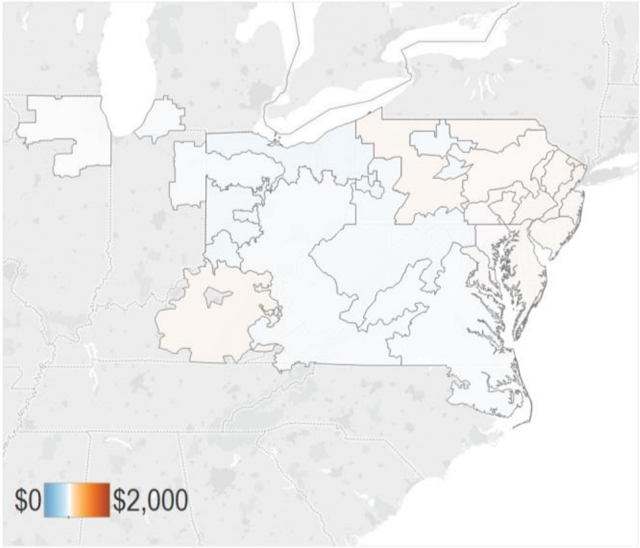
Initial Oil Inventory Level at 50%

Sensitivity 35



Load:	Extreme
Refueling:	Moderate
Disruption:	None
Non-Firm Avail:	0%
Retirement:	Escalated 2
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil

Oil Barrels Burned: 6.43M

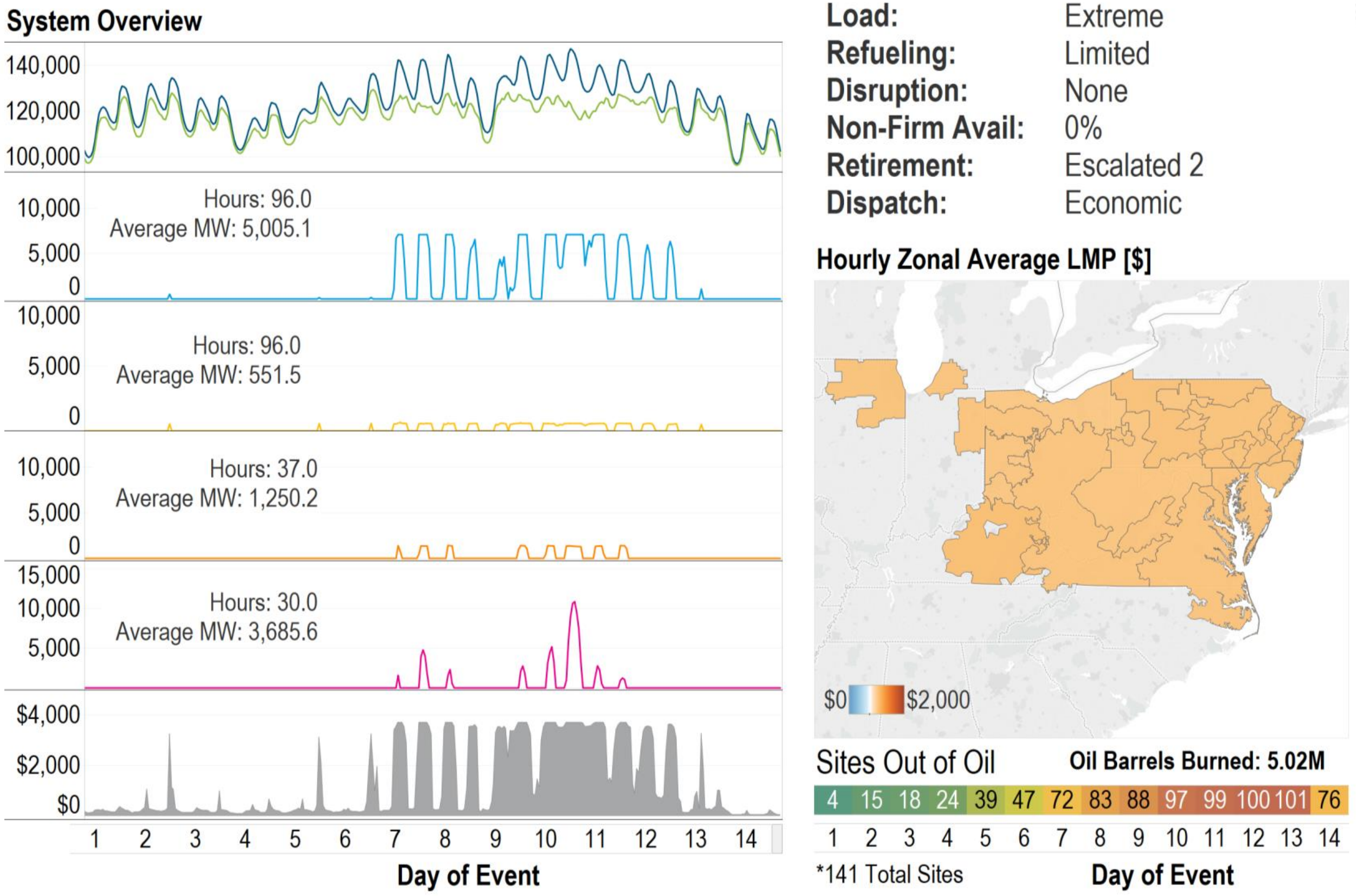
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	1	3	3	3	2	5	11	14	24	28	33	13	0

*141 Total Sites

Initial Oil Inventory Level at 50%

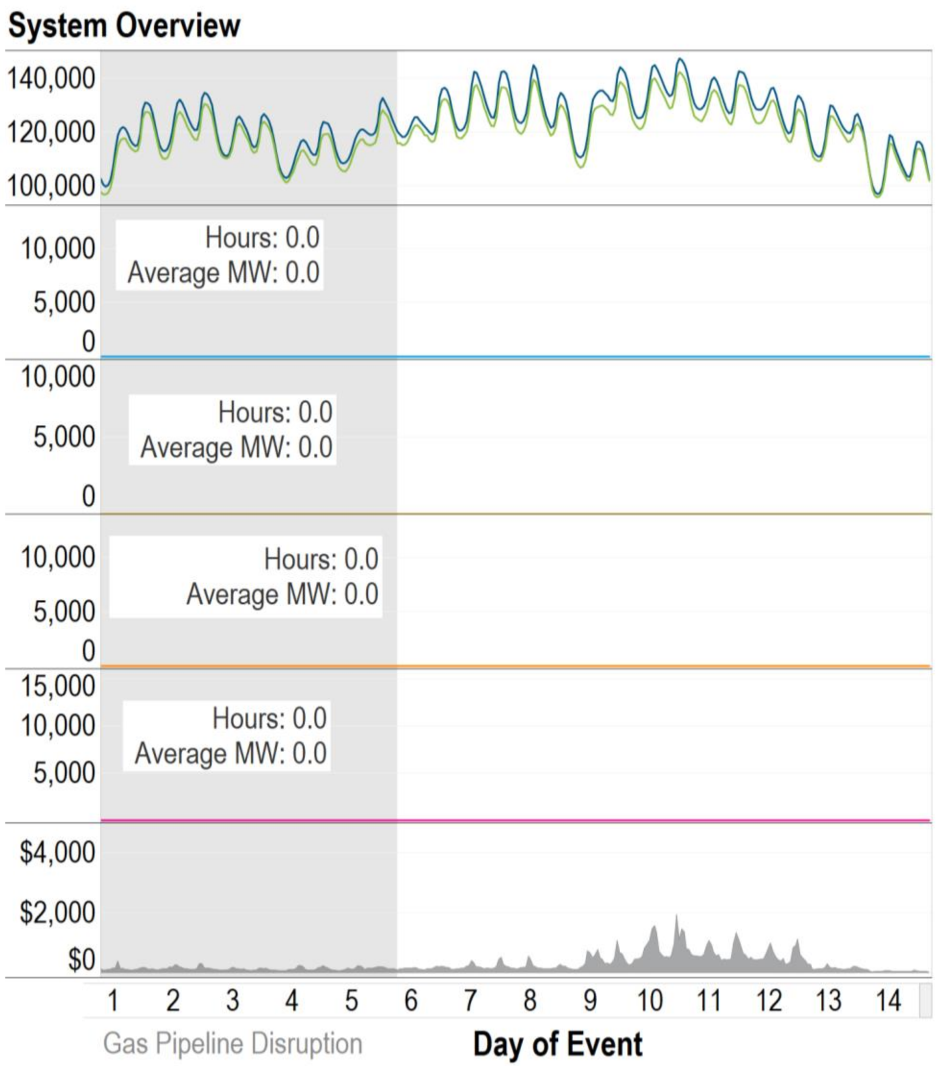
Sensitivity 36

Load:	Extreme
Refueling:	Limited
Disruption:	None
Non-Firm Avail:	0%
Retirement:	Escalated 2
Dispatch:	Economic



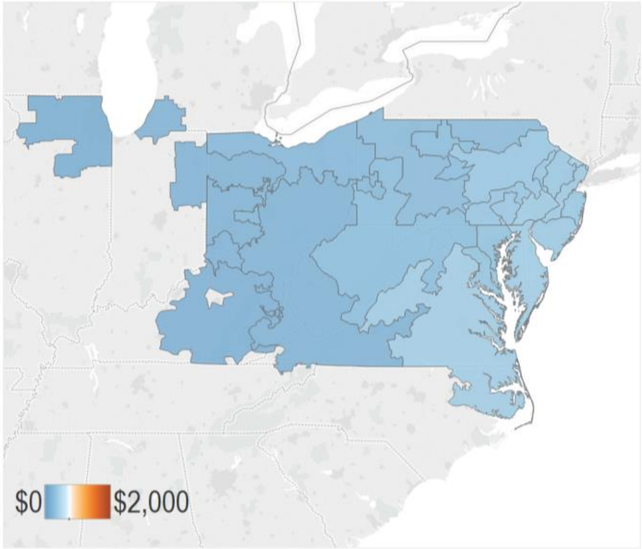
Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%

Sensitivity 37



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]



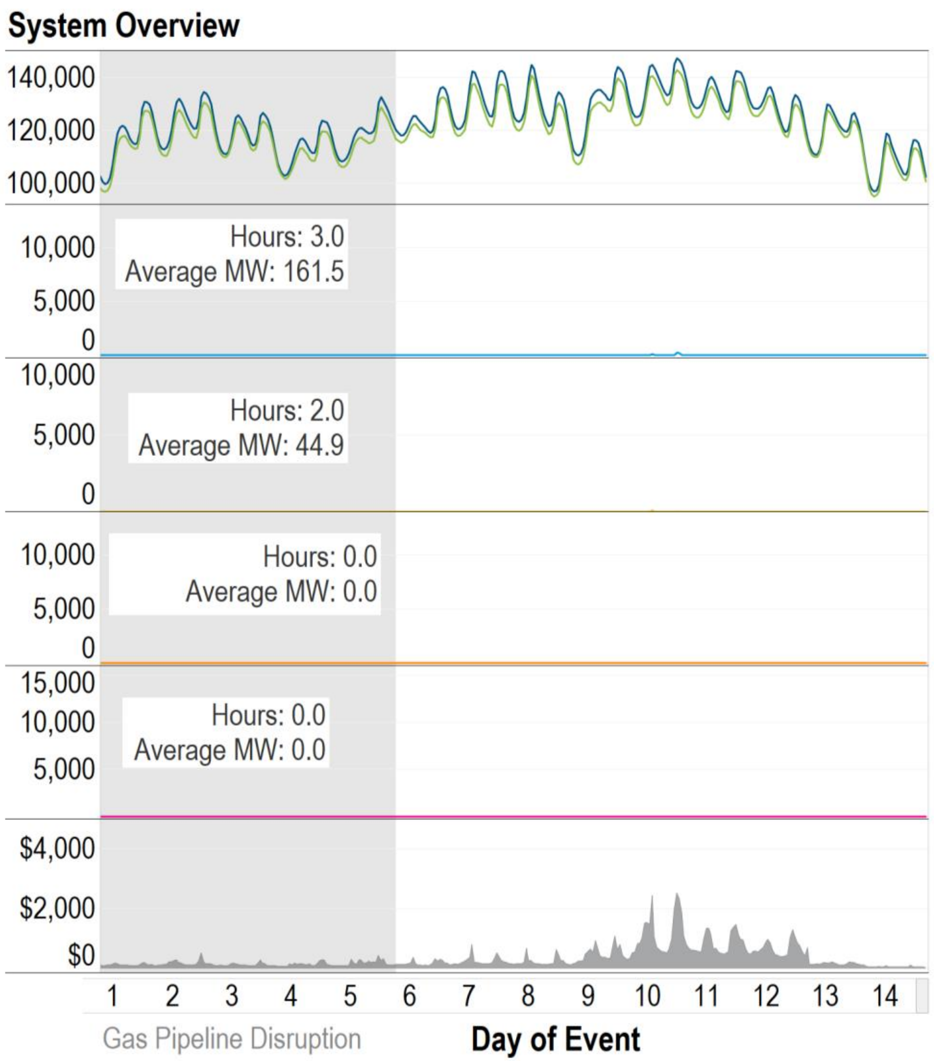
Sites Out of Oil **Oil Barrels Burned: 4.28M**

0	1	2	1	2	2	2	2	6	7	15	18	3	0
1	2	3	4	5	6	7	8	9	10	11	12	13	14

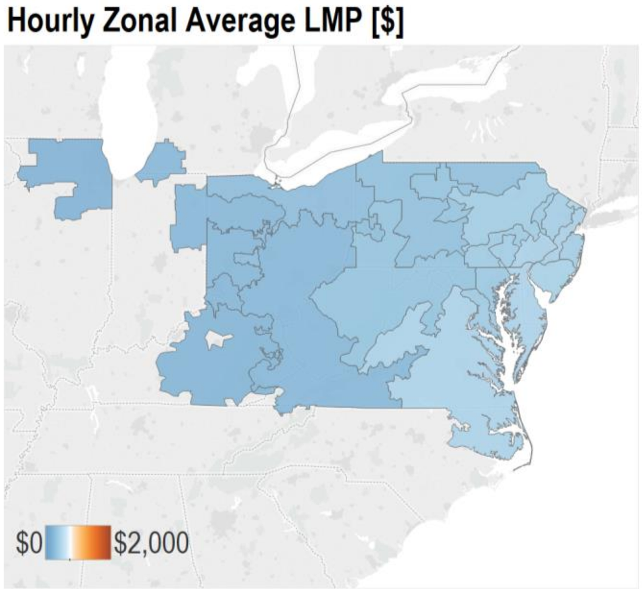
*141 Total Sites **Day of Event**

Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%

Sensitivity 38



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Announced
Dispatch:	Economic



Sites Out of Oil — **Oil Barrels Burned: 3.31M**

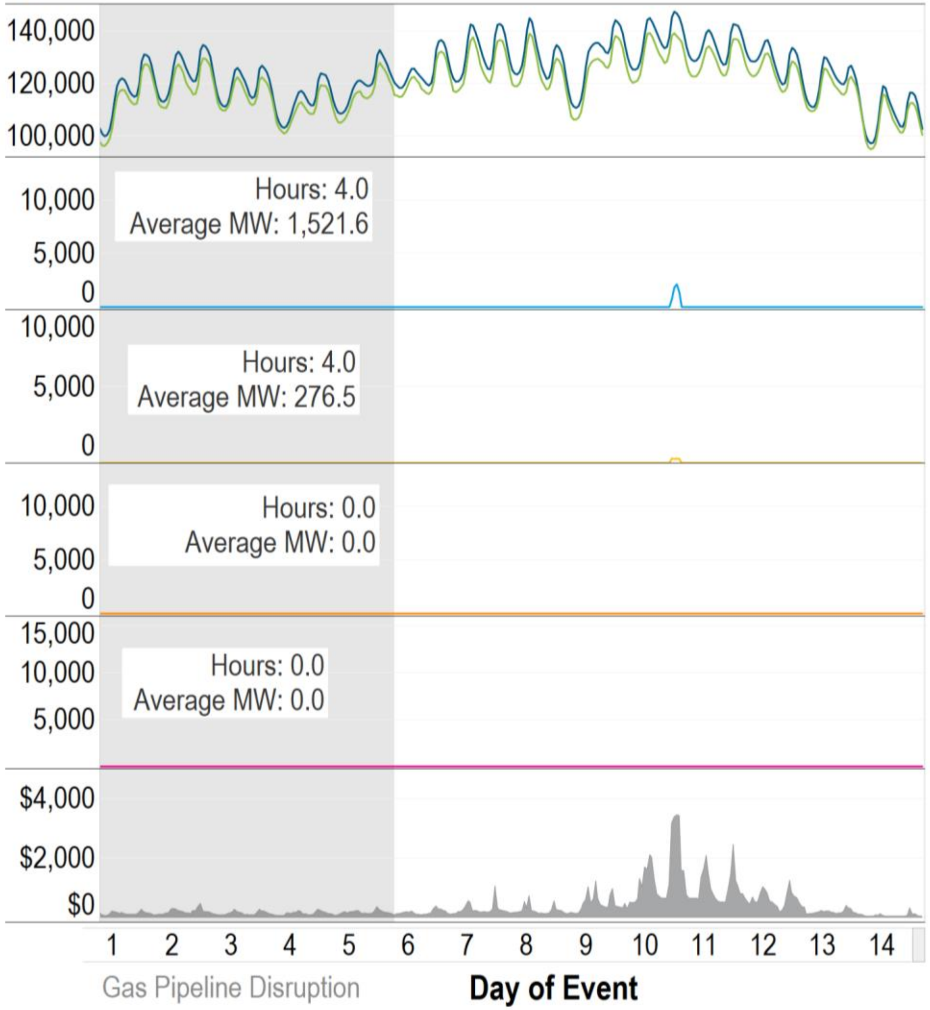
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	7	8	9	11	12	21	24	49	63	73	76	71	63

*141 Total Sites

Initial Oil Inventory Level at 50%

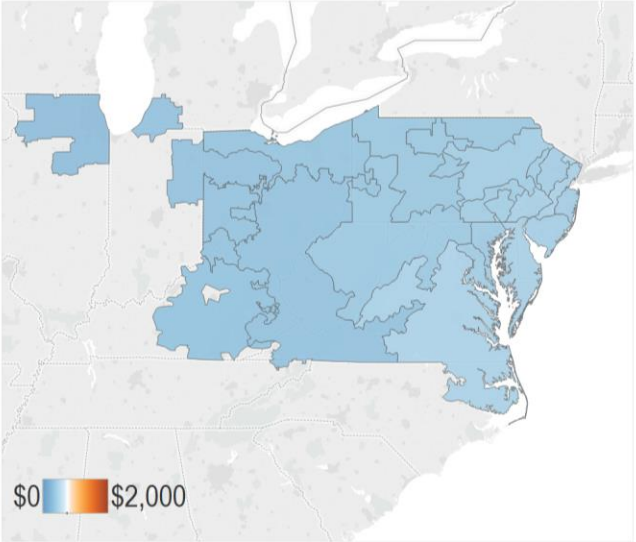
Sensitivity 39

System Overview



Load: Extreme
Refueling: Moderate
Disruption: Looped 2 High
Non-Firm Avail: 0%
Retirement: Announced
Dispatch: Economic

Hourly Zonal Average LMP [$]



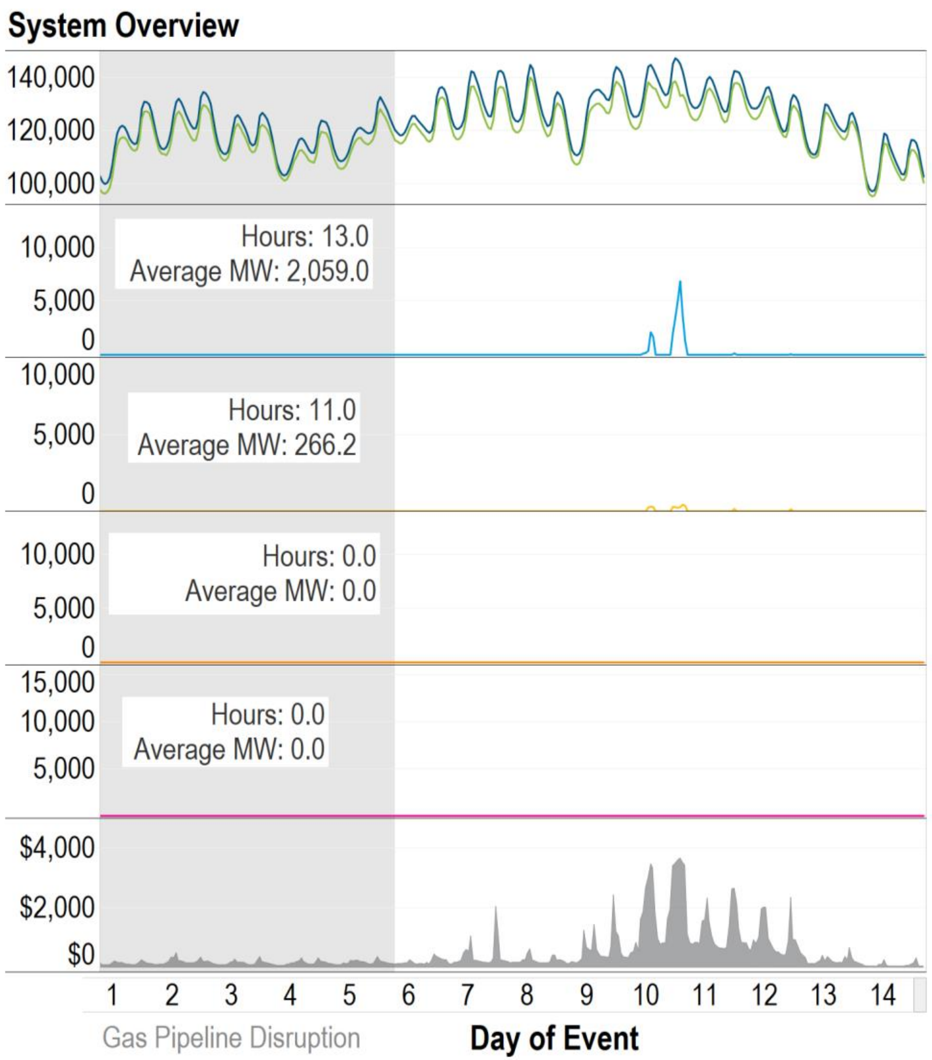
Sites Out of Oil **Oil Barrels Burned: 4.95M**

Sites Out of Oil	0	0	1	1	1	2	4	2	4	12	25	25	3	1
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14

*141 Total Sites

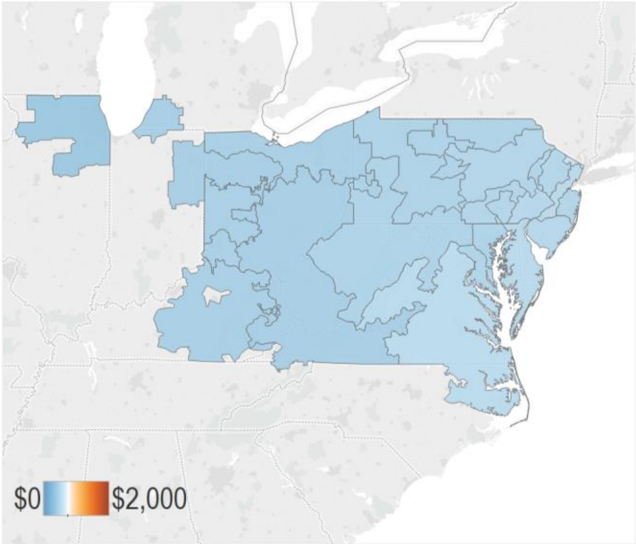
Initial Oil Inventory Level at 50%

Sensitivity 40



Load: Extreme
Refueling: Limited
Disruption: Looped 2 High
Non-Firm Avail: 0%
Retirement: Announced
Dispatch: Economic

Hourly Zonal Average LMP [$]



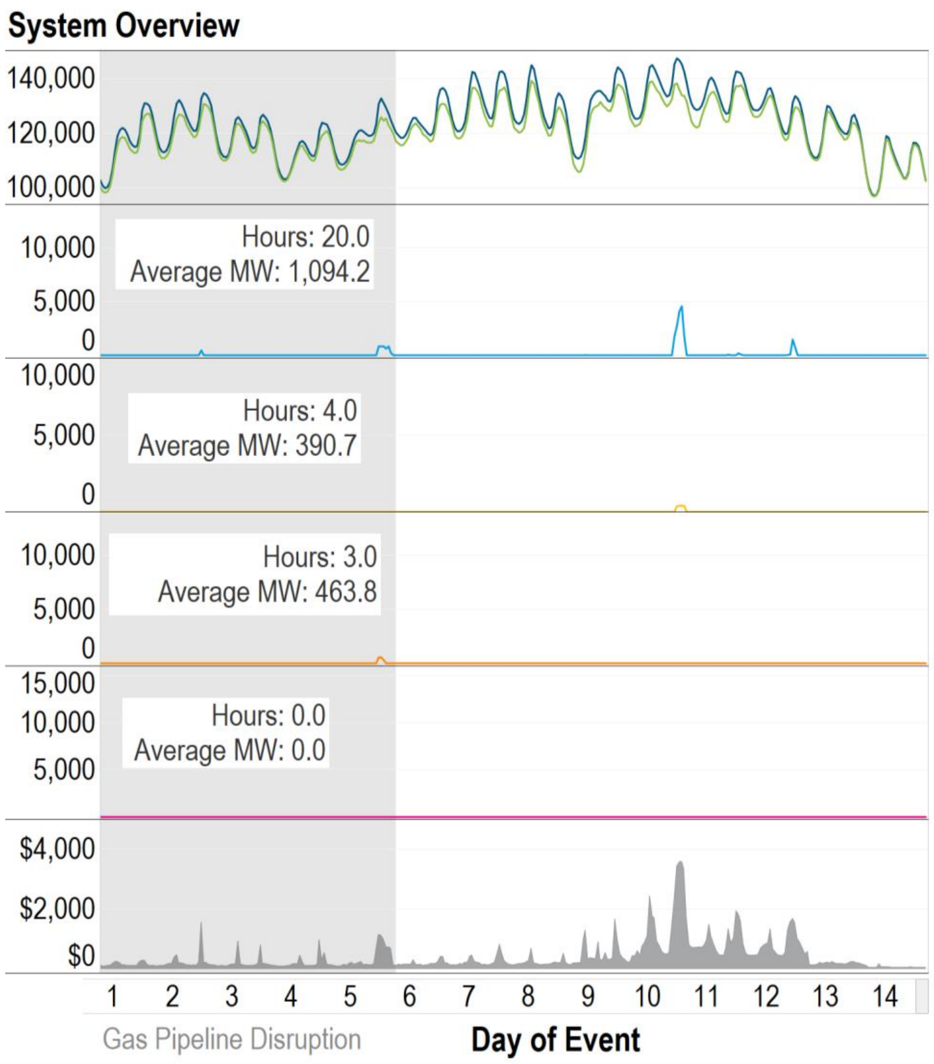
Sites Out of Oil — **Oil Barrels Burned: 4.19M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	1	8	8	13	16	19	28	40	63	78	90	89	83	70

*141 Total Sites

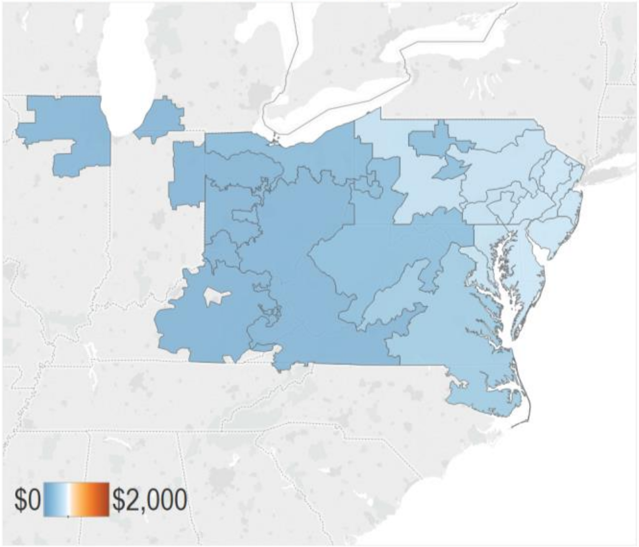
Initial Oil Inventory Level at 50%

Sensitivity 41



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]

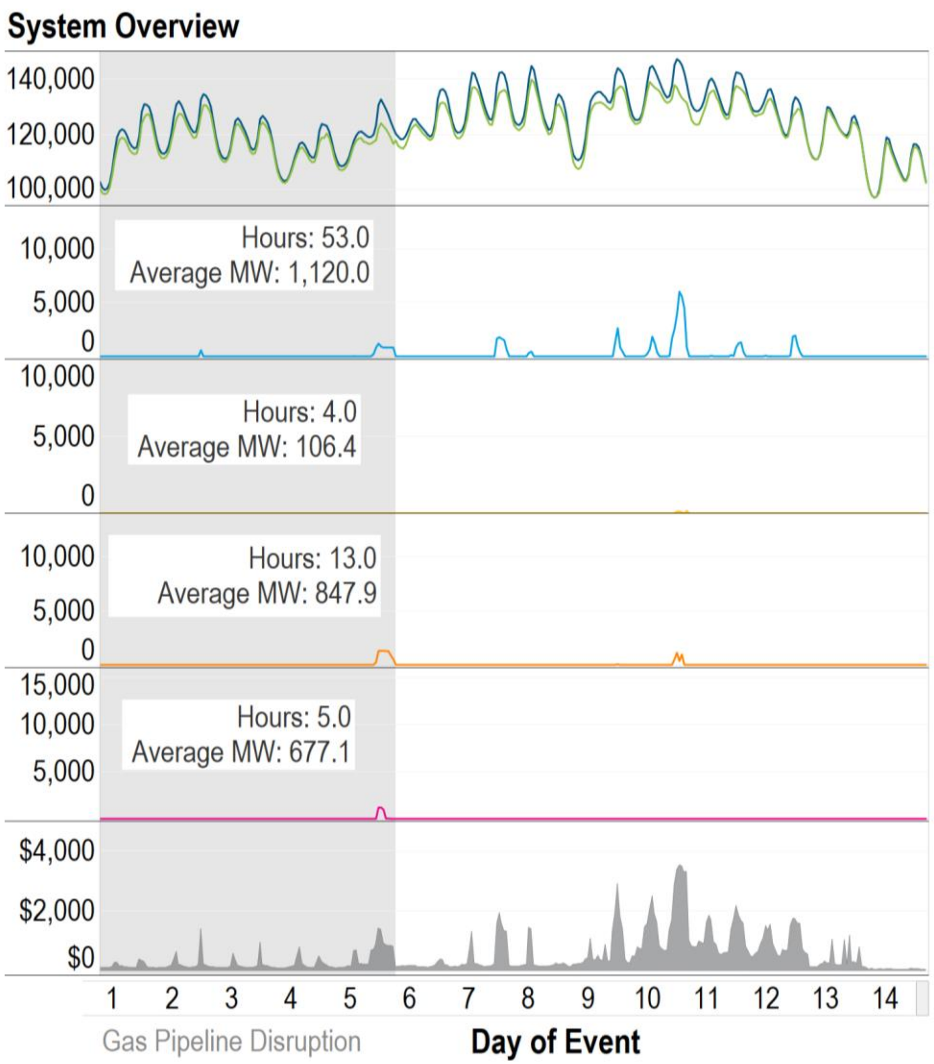


Sites Out of Oil — **Oil Barrels Burned: 6.03M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	2	4	4	3	3	4	5	9	13	18	22	9	0

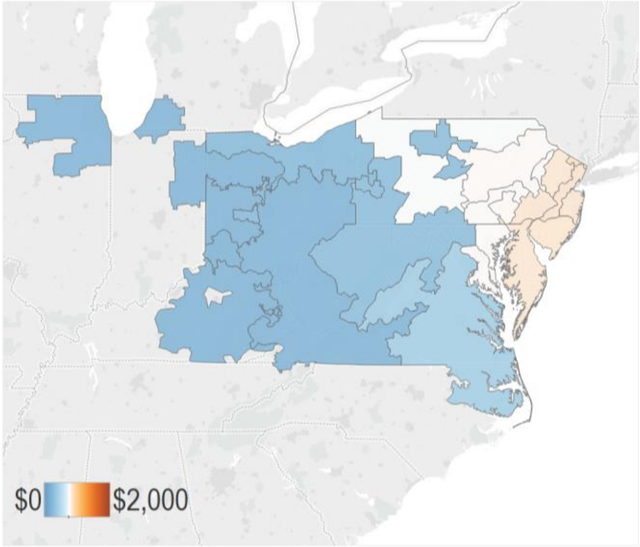
*141 Total Sites

Sensitivity 42



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]



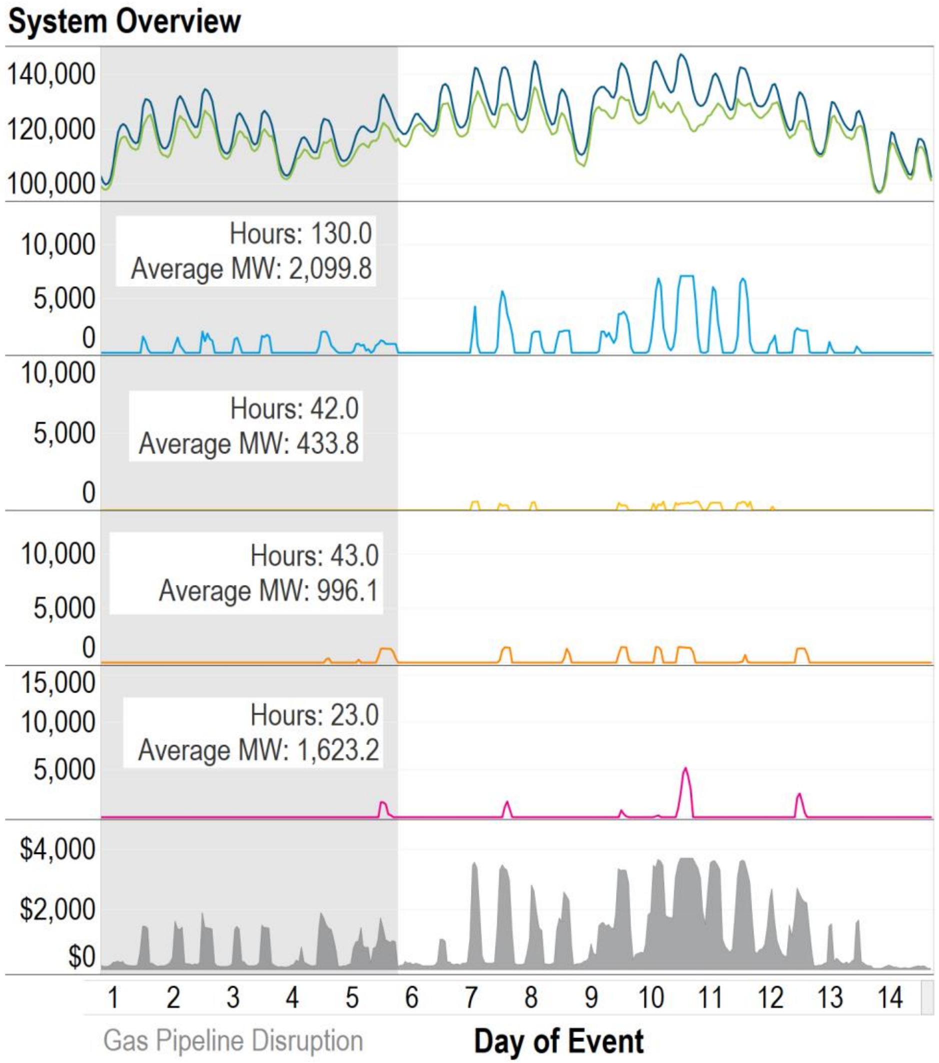
Sites Out of Oil **Oil Barrels Burned: 4.85M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	4	15	28	41	54	55	70	73	79	86	101	99	96	84

*141 Total Sites

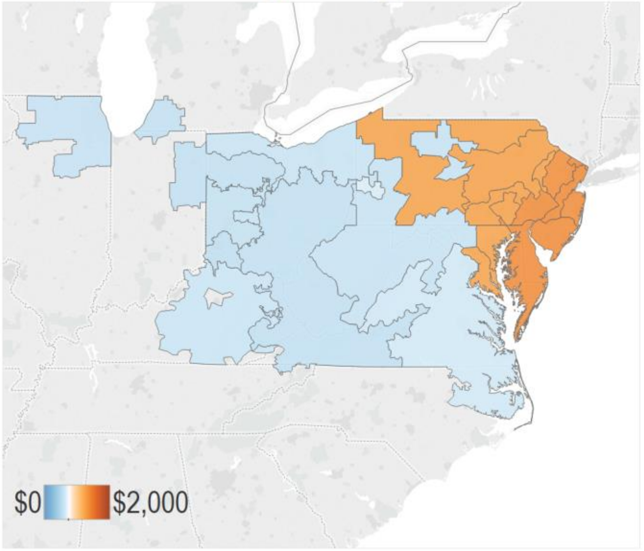
Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%

Sensitivity 43



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]



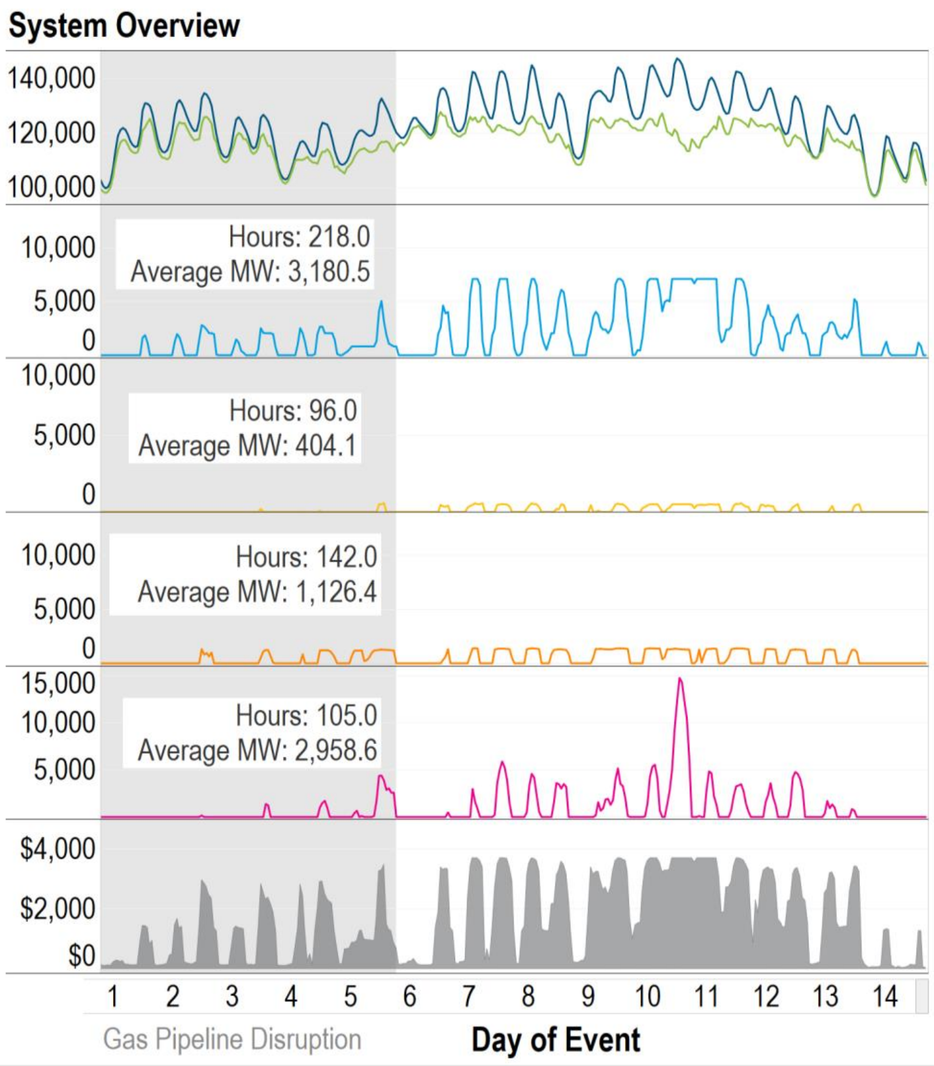
Sites Out of Oil **Oil Barrels Burned: 7.63M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	4	6	5	4	4	8	9	13	26	34	33	19	1

*141 Total Sites

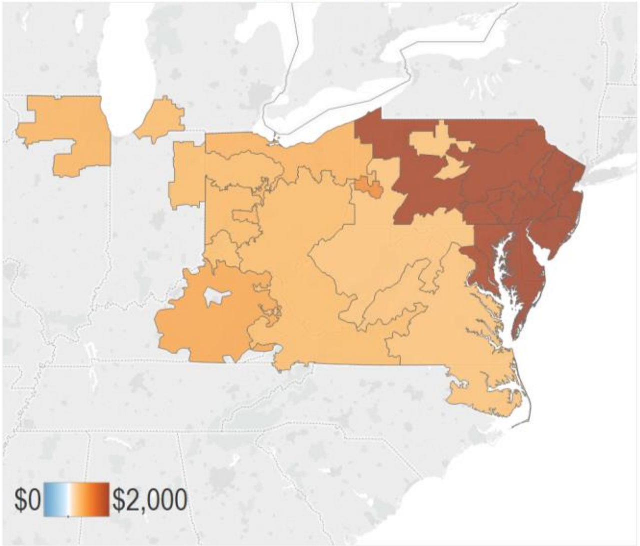
Initial Oil Inventory Level at 50%

Sensitivity 44



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 1
Dispatch:	Economic

Hourly Zonal Average LMP [$]



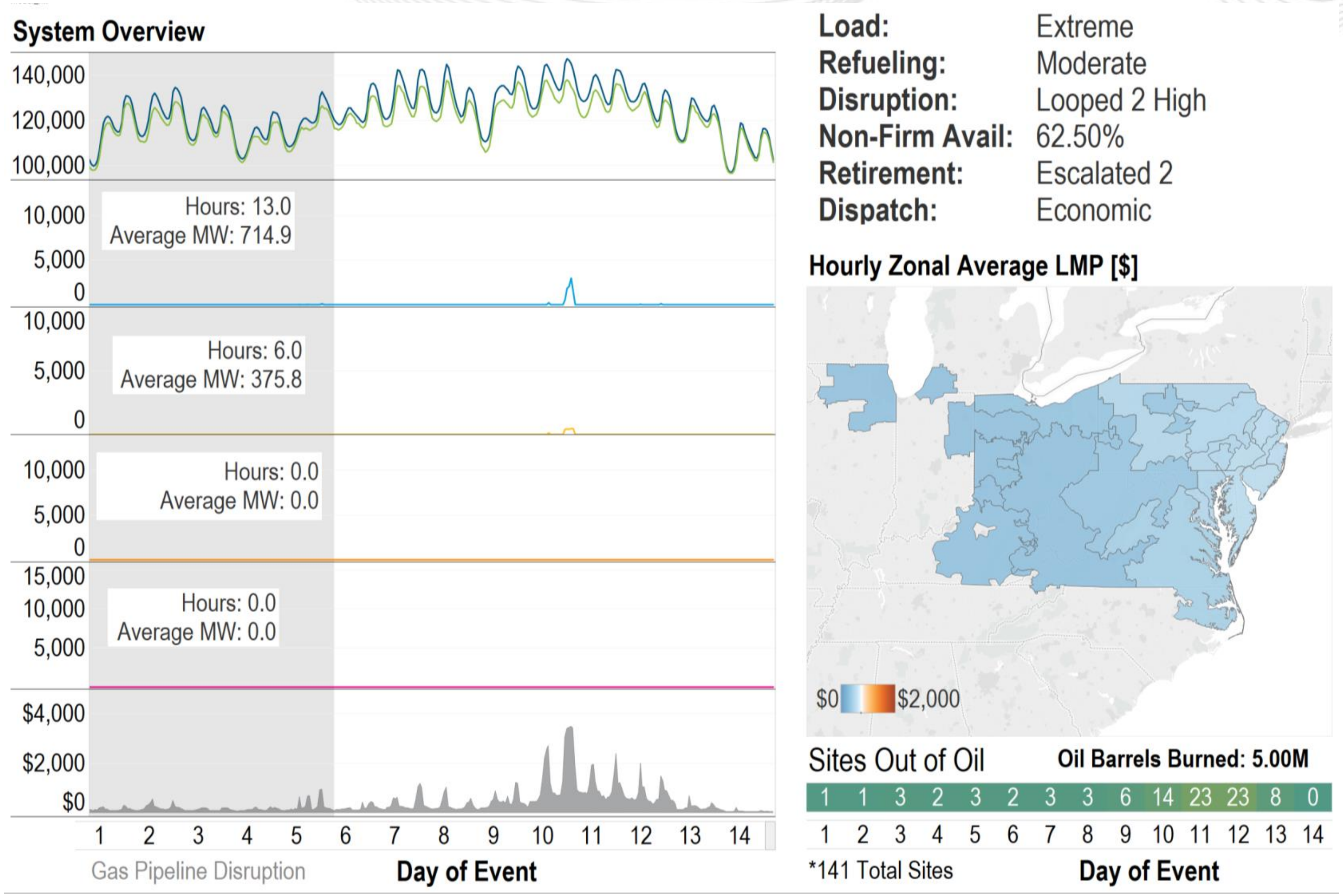
Sites Out of Oil — **Oil Barrels Burned: 5.85M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	12	40	60	81	91	96	105	109	108	113	124	120	123	108

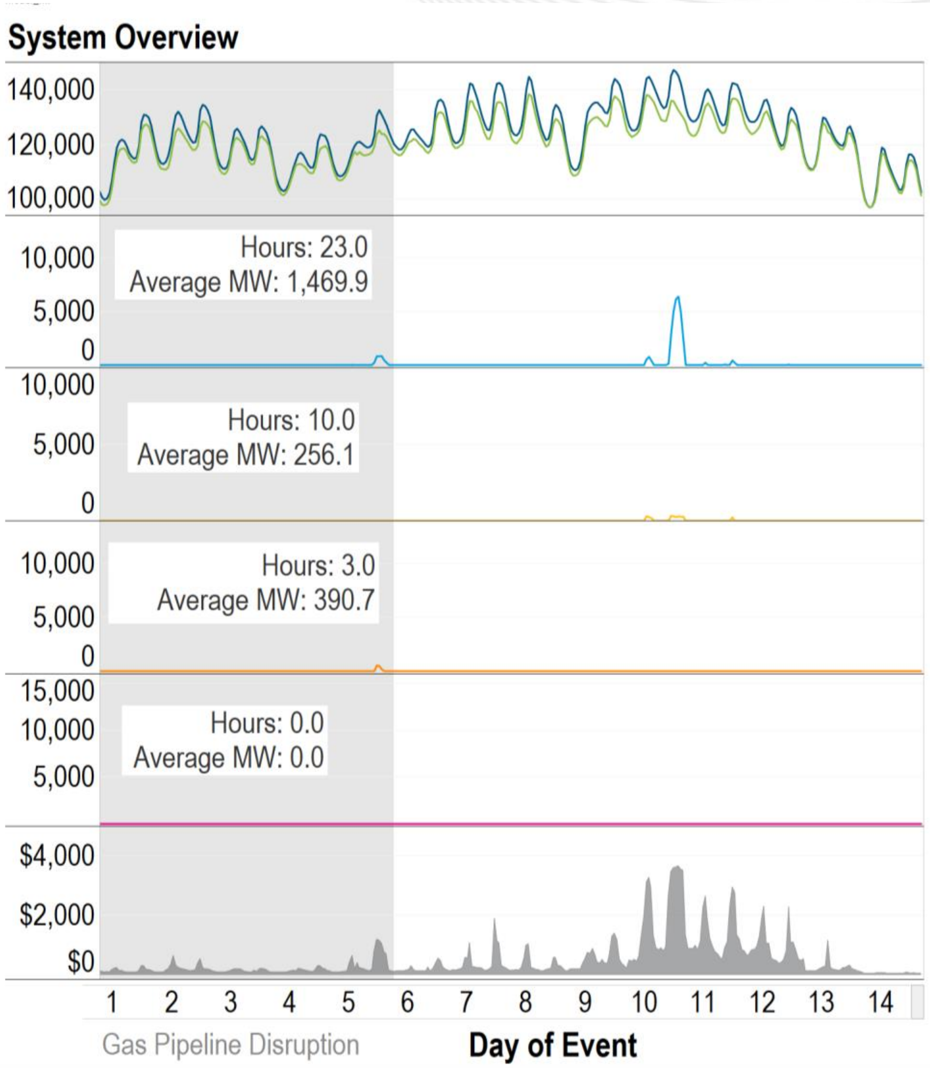
*141 Total Sites

Initial Oil Inventory Level at 50%

Sensitivity 45

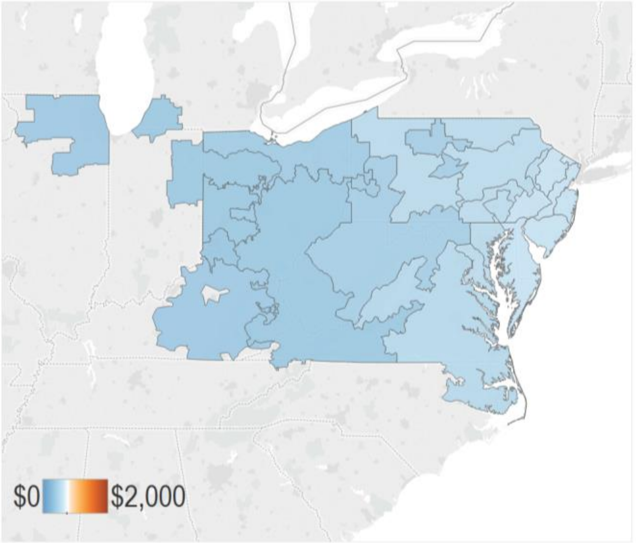


Phase 1 Sensitivities based on Stakeholder Feedback:
Initial Oil Inventory Level at 50%
Sensitivity 46



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 2
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil **Oil Barrels Burned: 4.34M**

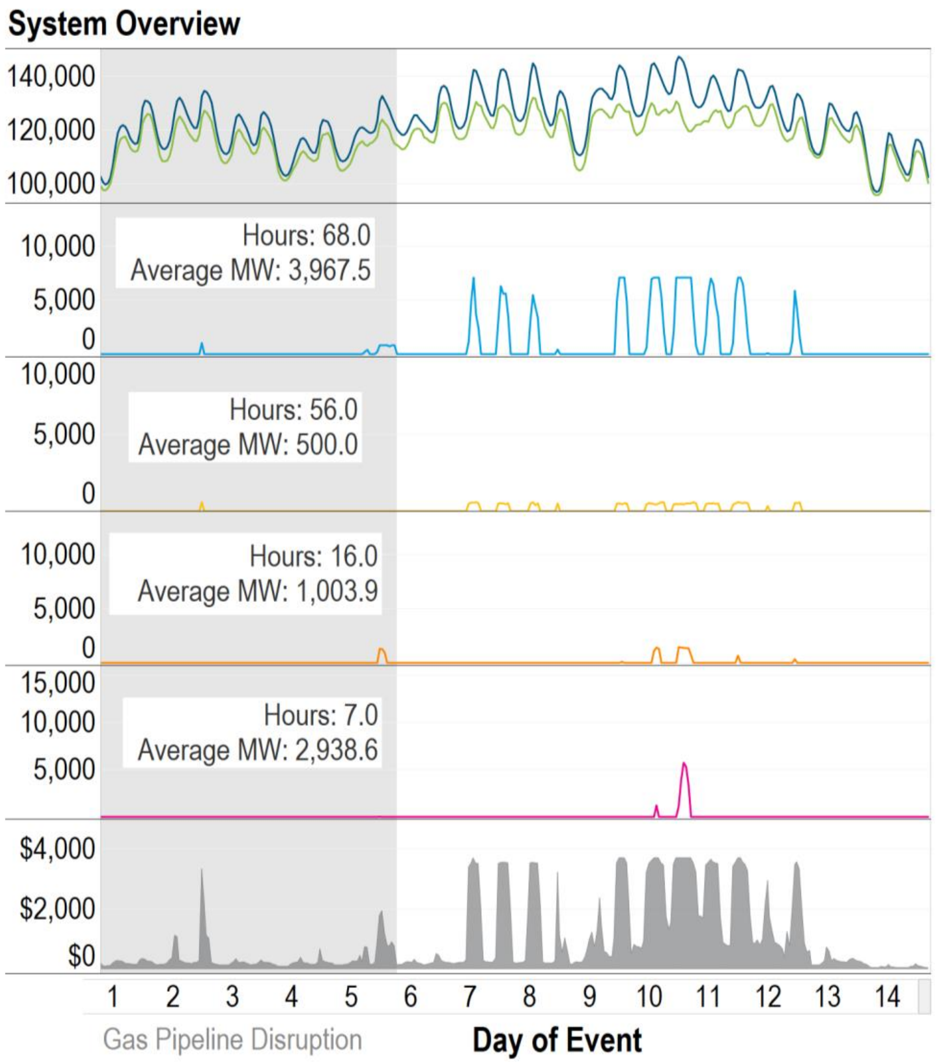
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	3	5	9	15	17	21	42	50	68	76	91	87	79	71

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:

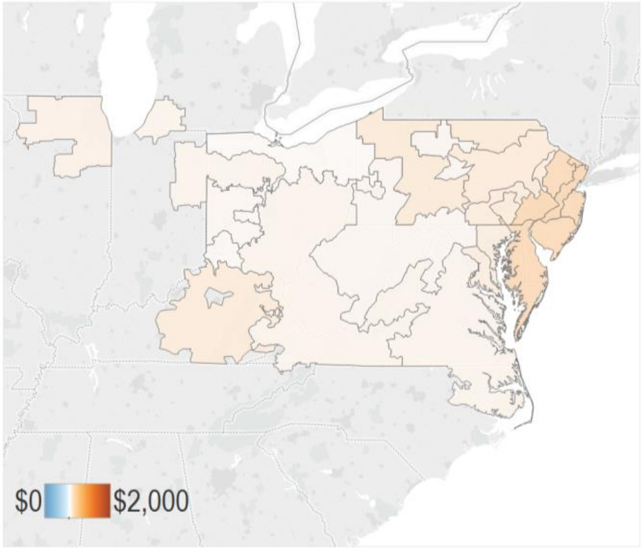
Initial Oil Inventory Level at 50%

Sensitivity 47



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 2
Dispatch:	Economic

Hourly Zonal Average LMP [$]

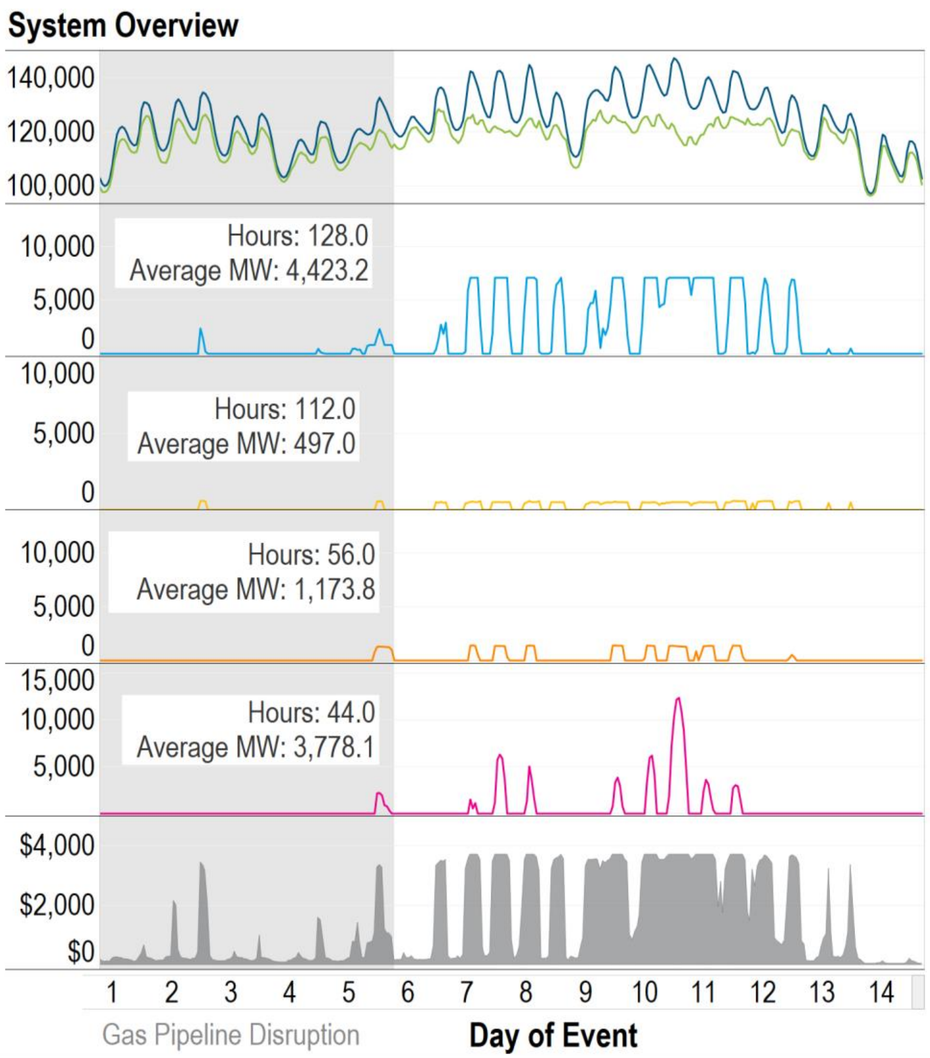


Sites Out of Oil **Oil Barrels Burned: 6.91M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	2	4	4	4	4	9	13	15	23	28	32	12	0

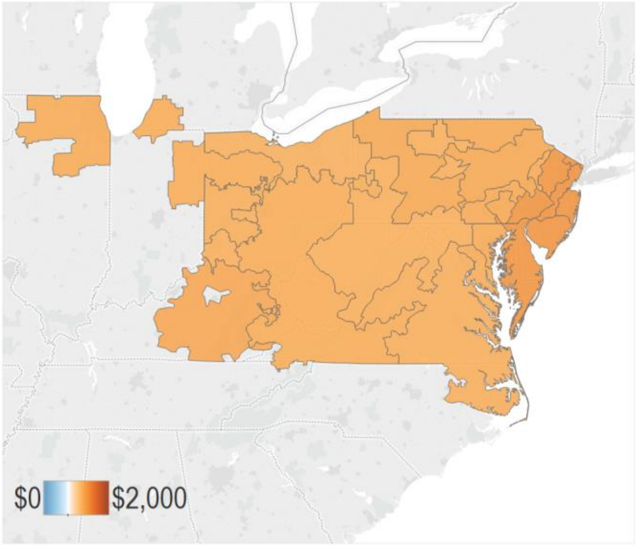
*141 Total Sites

Sensitivity 48



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 2
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil **Oil Barrels Burned: 5.31M**

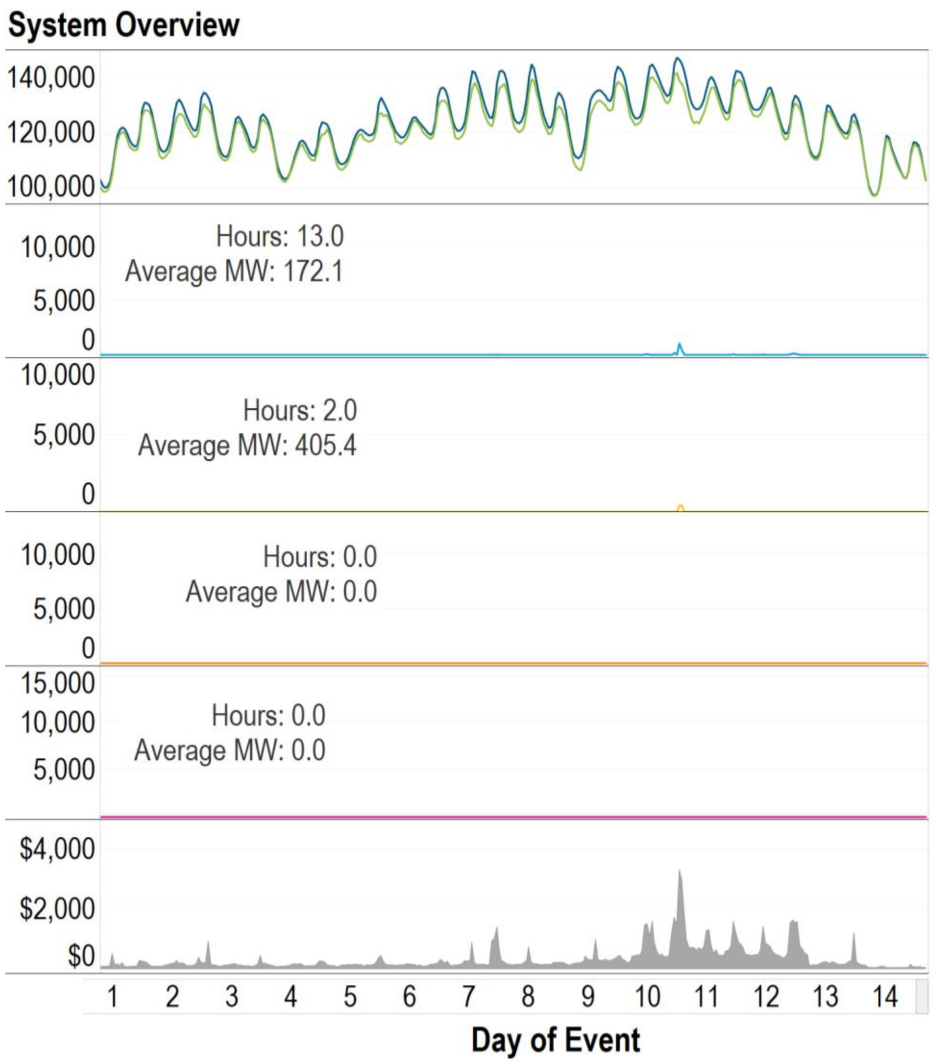
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	6	21	31	41	58	69	82	89	93	98	102	101	103	79

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:

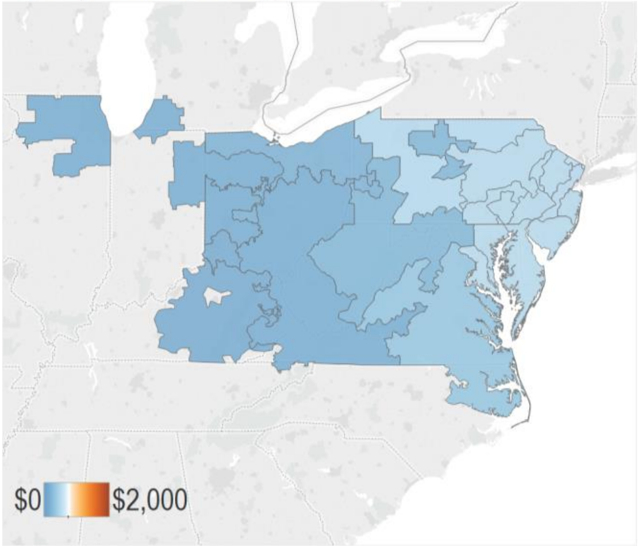
“Escalated 3” Portfolio

Sensitivity 49



Load:	Extreme
Refueling:	Moderate
Disruption:	None
Non-Firm Avail:	62.50%
Retirement:	Escalated 3
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil — **Oil Barrels Burned: 5.31M**

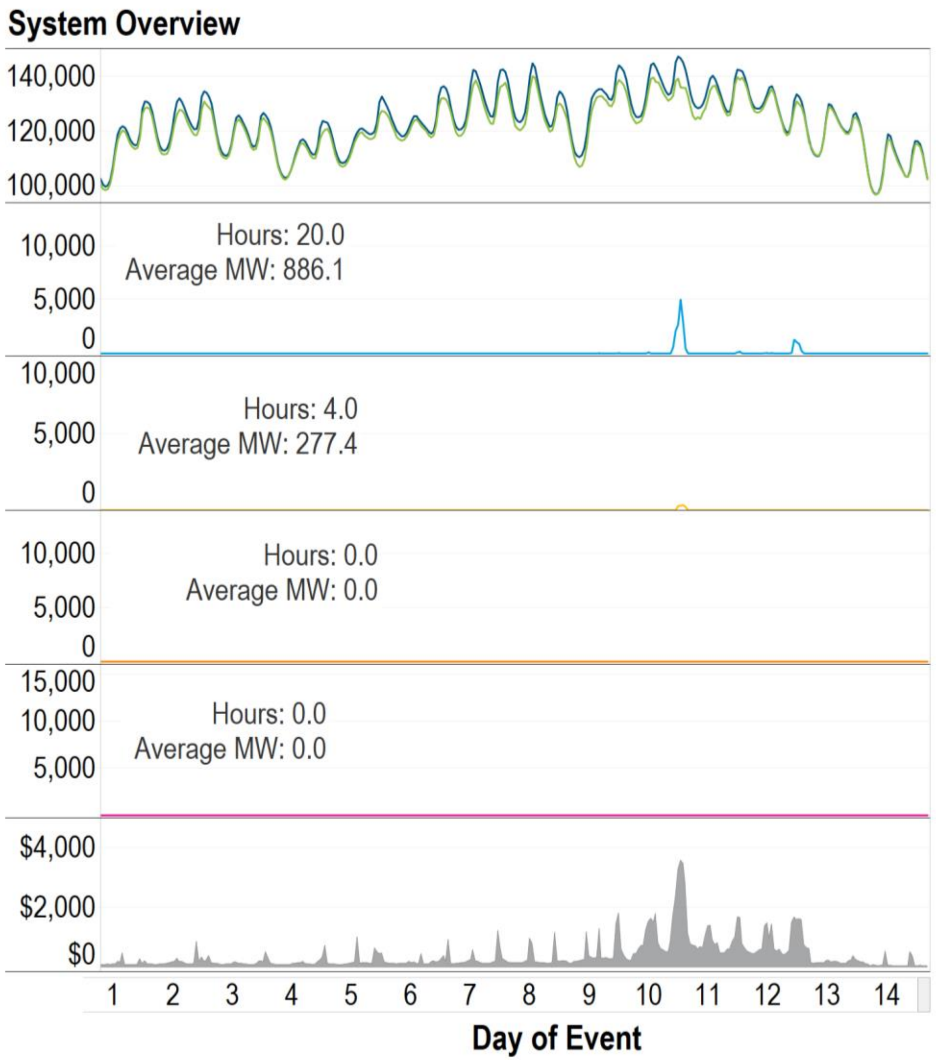
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	1	0	1	1	2	2	3	7	9	19	20	10	0

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:

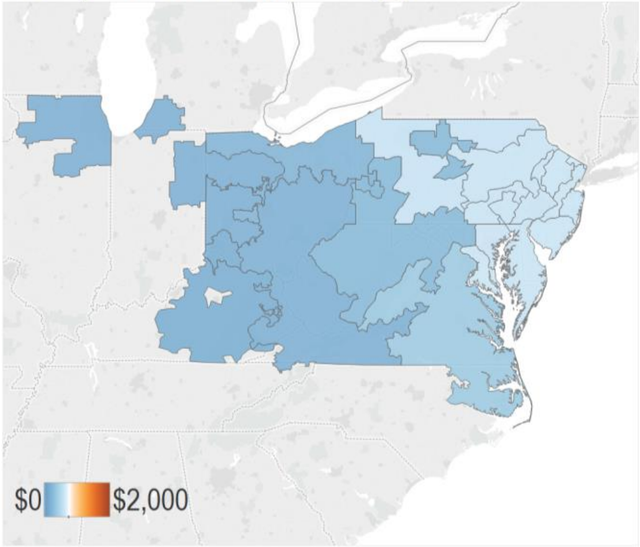
“Escalated 3” Portfolio

Sensitivity 50



Load:	Extreme
Refueling:	Limited
Disruption:	None
Non-Firm Avail:	62.50%
Retirement:	Escalated 3
Dispatch:	Economic

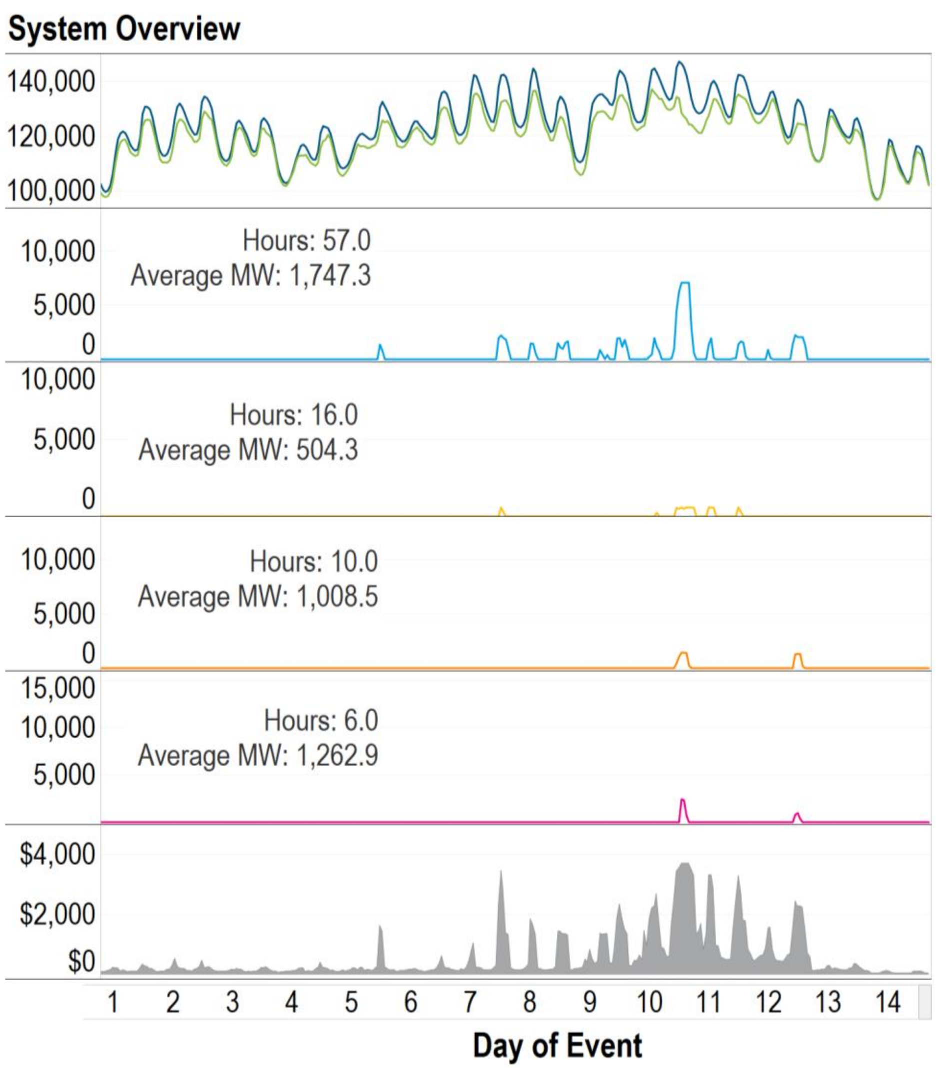
Hourly Zonal Average LMP [$]



Sites Out of Oil **Oil Barrels Burned: 4.19M**

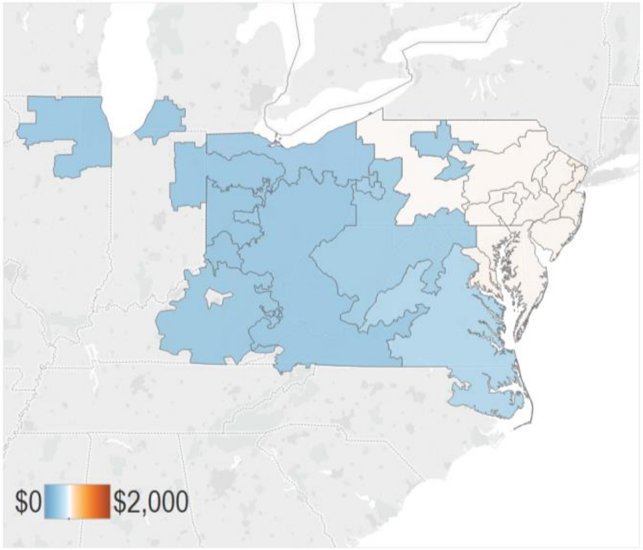
*141 Total Sites **Day of Event**

Sensitivity 51



Load: Extreme
Refueling: Moderate
Disruption: None
Non-Firm Avail: 0%
Retirement: Escalated 3
Dispatch: Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil — **Oil Barrels Burned: 6.49M**

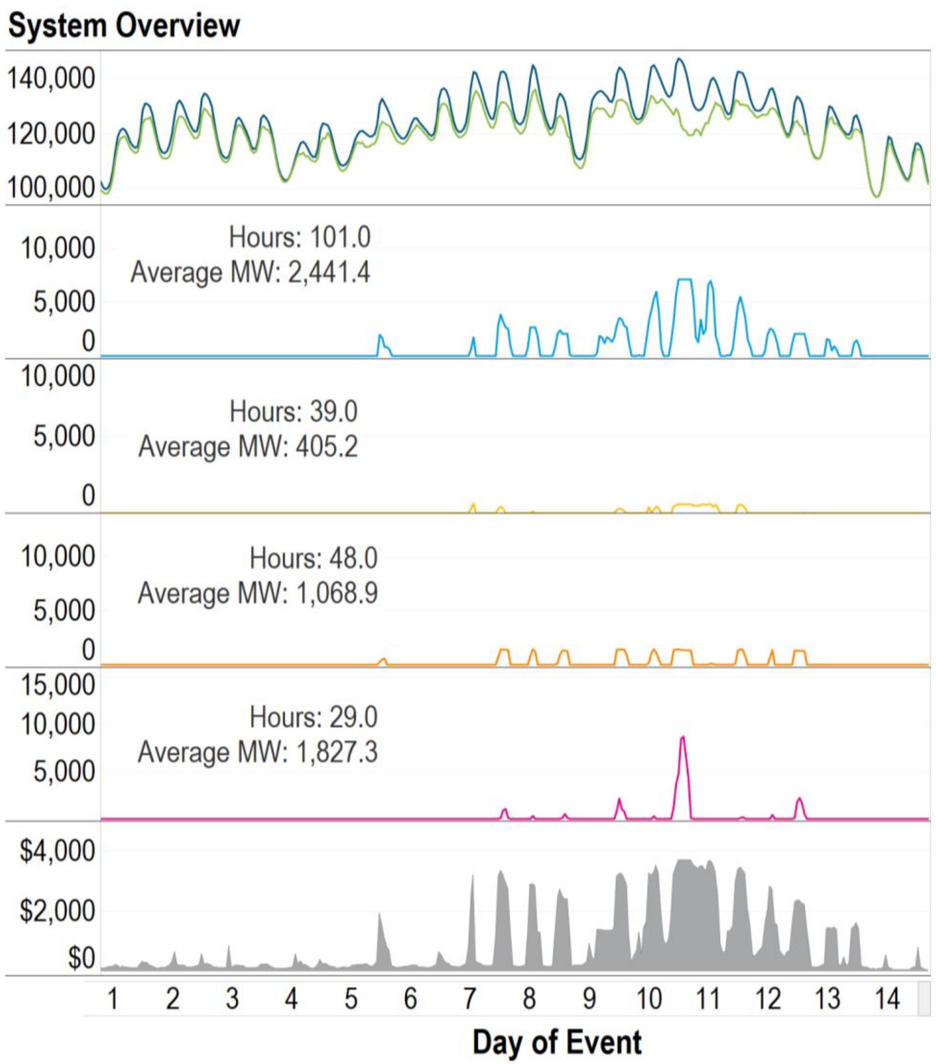
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	0	1	2	2	3	5	8	14	25	22	8	0

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:

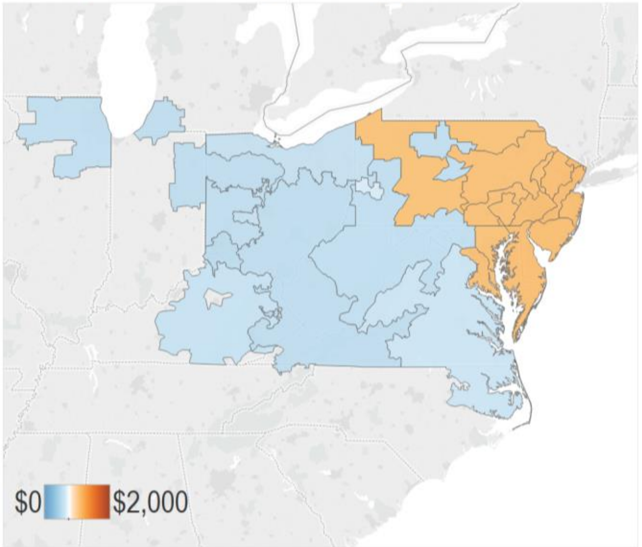
“Escalated 3” Portfolio

Sensitivity 52



Load:	Extreme
Refueling:	Limited
Disruption:	None
Non-Firm Avail:	0%
Retirement:	Escalated 3
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Sites Out of Oil

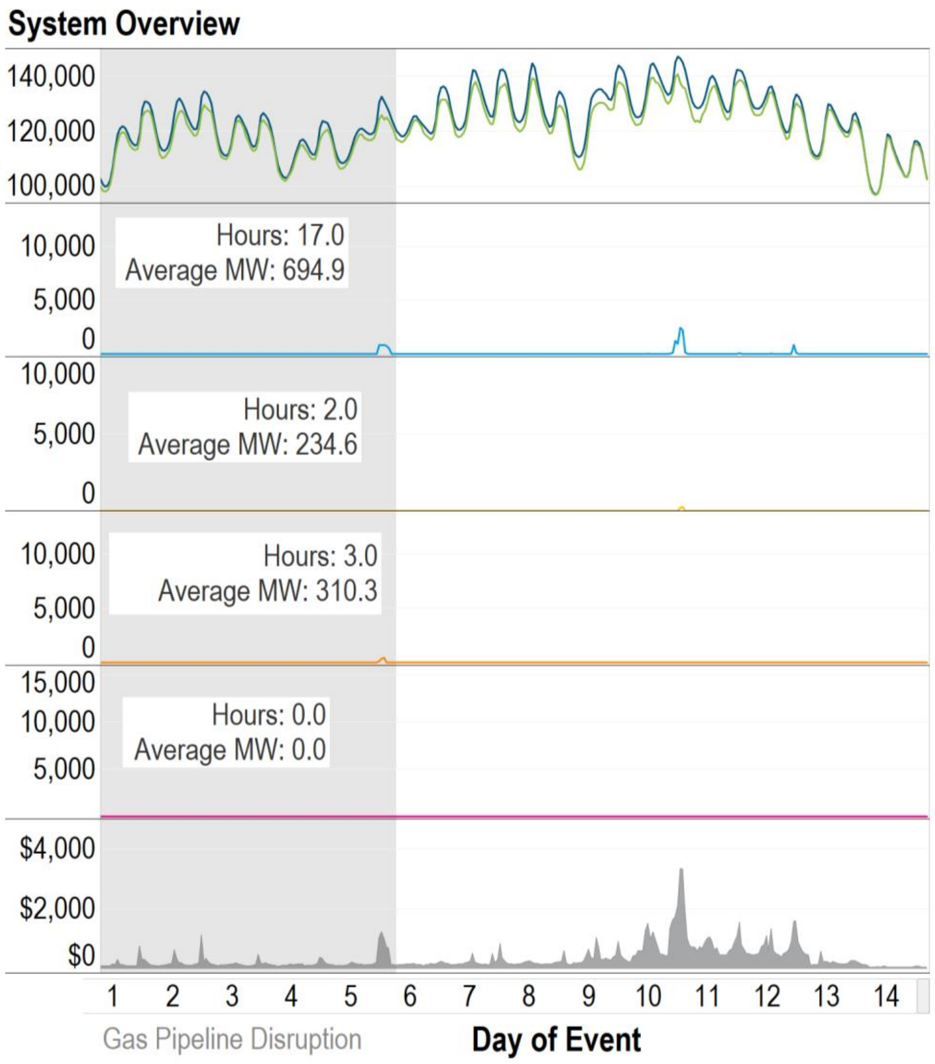
Oil Barrels Burned: 5.47M

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	4	8	11	13	18	40	50	61	74	83	87	84	75

*141 Total Sites

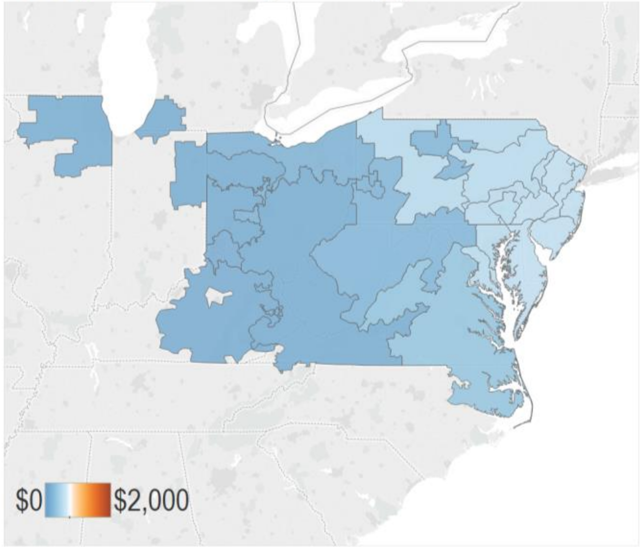
Phase 1 Sensitivities based on Stakeholder Feedback:
“Escalated 3” Portfolio

Sensitivity 53



Load: Extreme
Refueling: Moderate
Disruption: Looped 2 High
Non-Firm Avail: 62.50%
Retirement: Escalated 3
Dispatch: Economic

Hourly Zonal Average LMP [$]



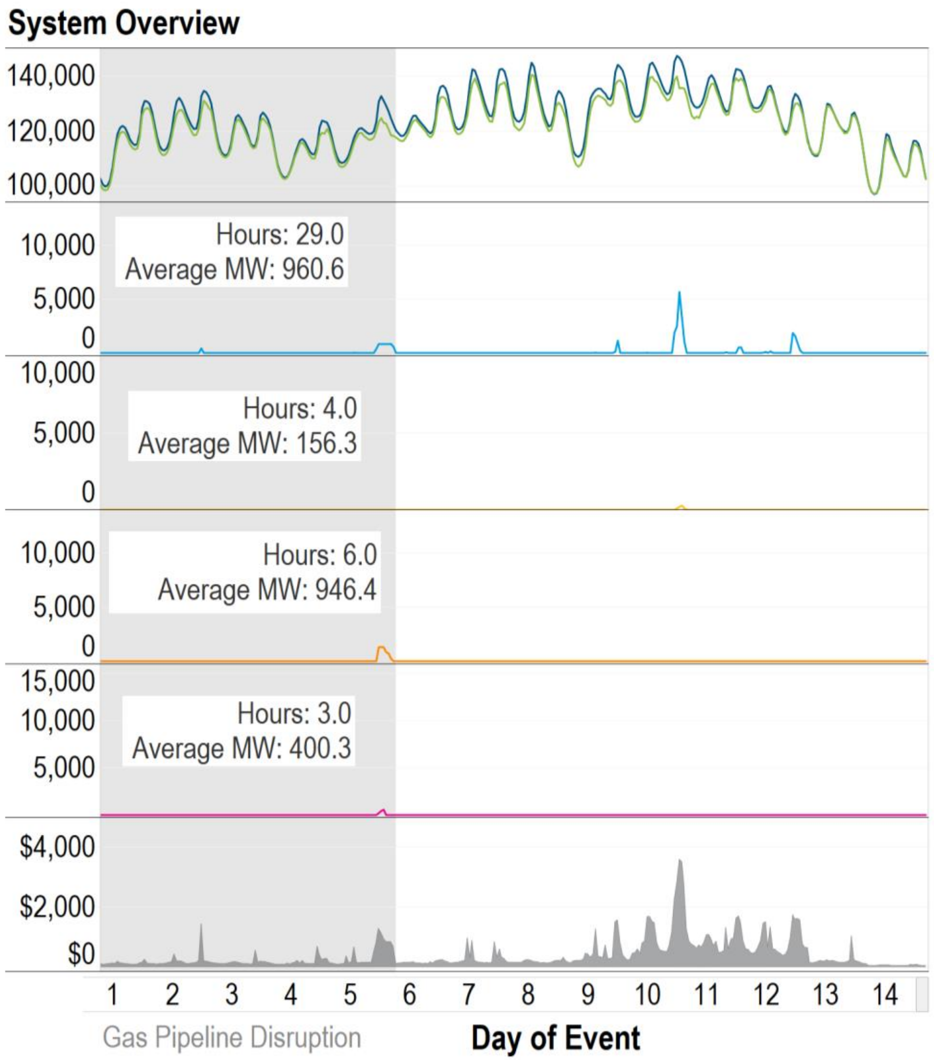
Sites Out of Oil — **Oil Barrels Burned: 5.69M**

Sites Out of Oil	0	2	1	1	3	2	3	3	8	12	18	21	8	0
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14

*141 Total Sites

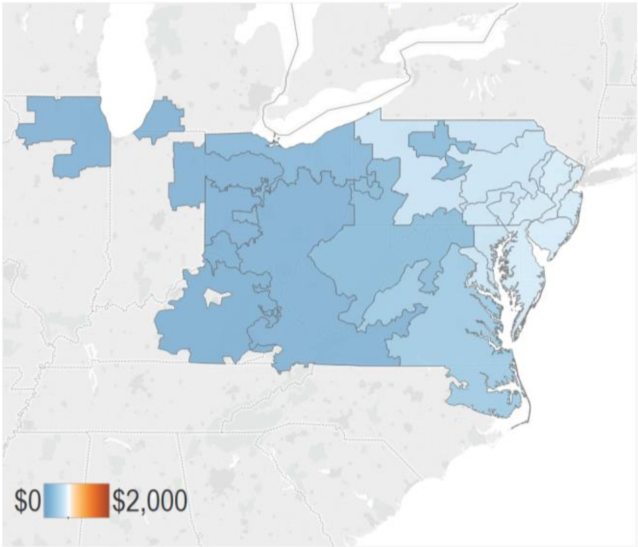
“Escalated 3” Portfolio

Sensitivity 54



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 3
Dispatch:	Economic

Hourly Zonal Average LMP [$]

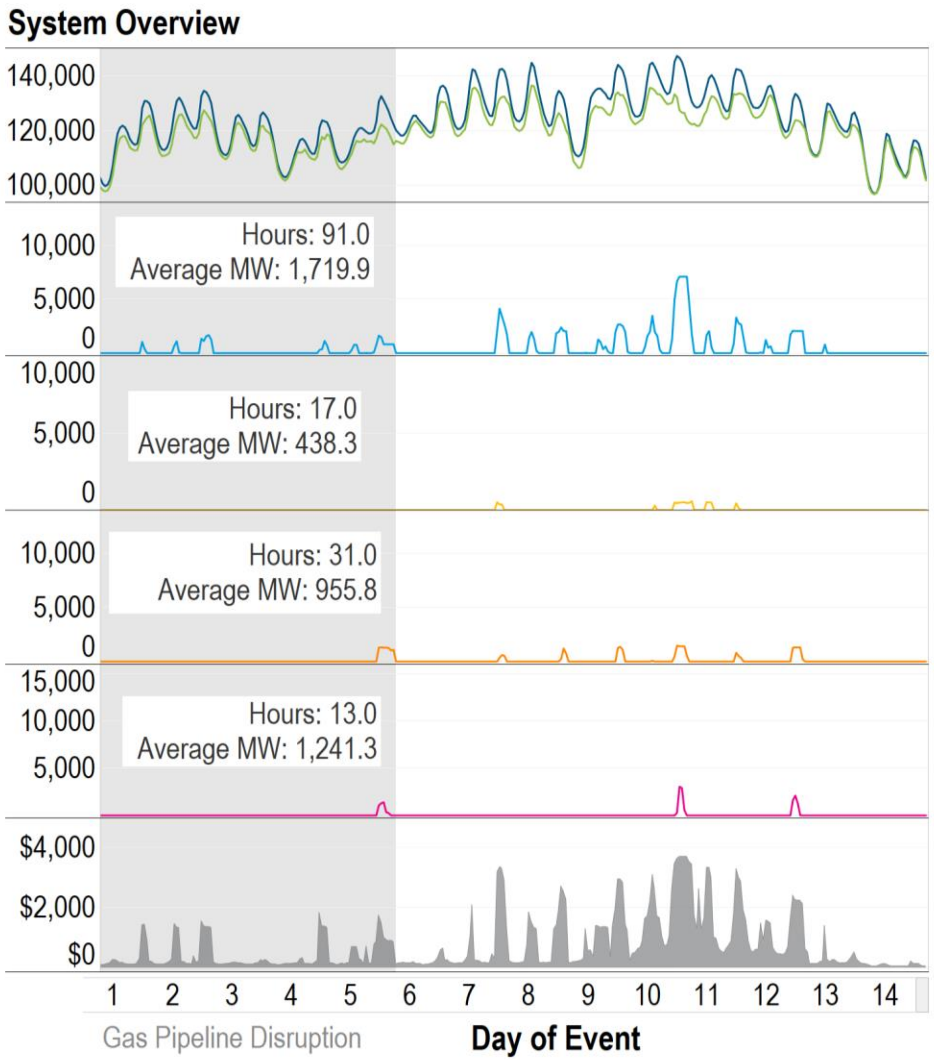


Sites Out of Oil — **Oil Barrels Burned: 4.77M**

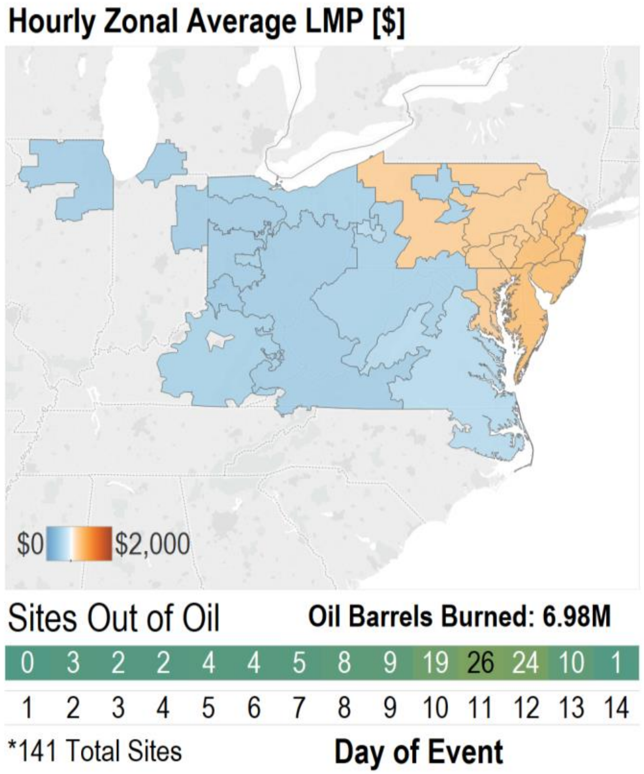
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	3	4	7	13	16	30	36	46	54	70	73	70	60

*141 Total Sites

Phase 1 Sensitivities based on Stakeholder Feedback:
"Escalated 3" Portfolio
Sensitivity 55

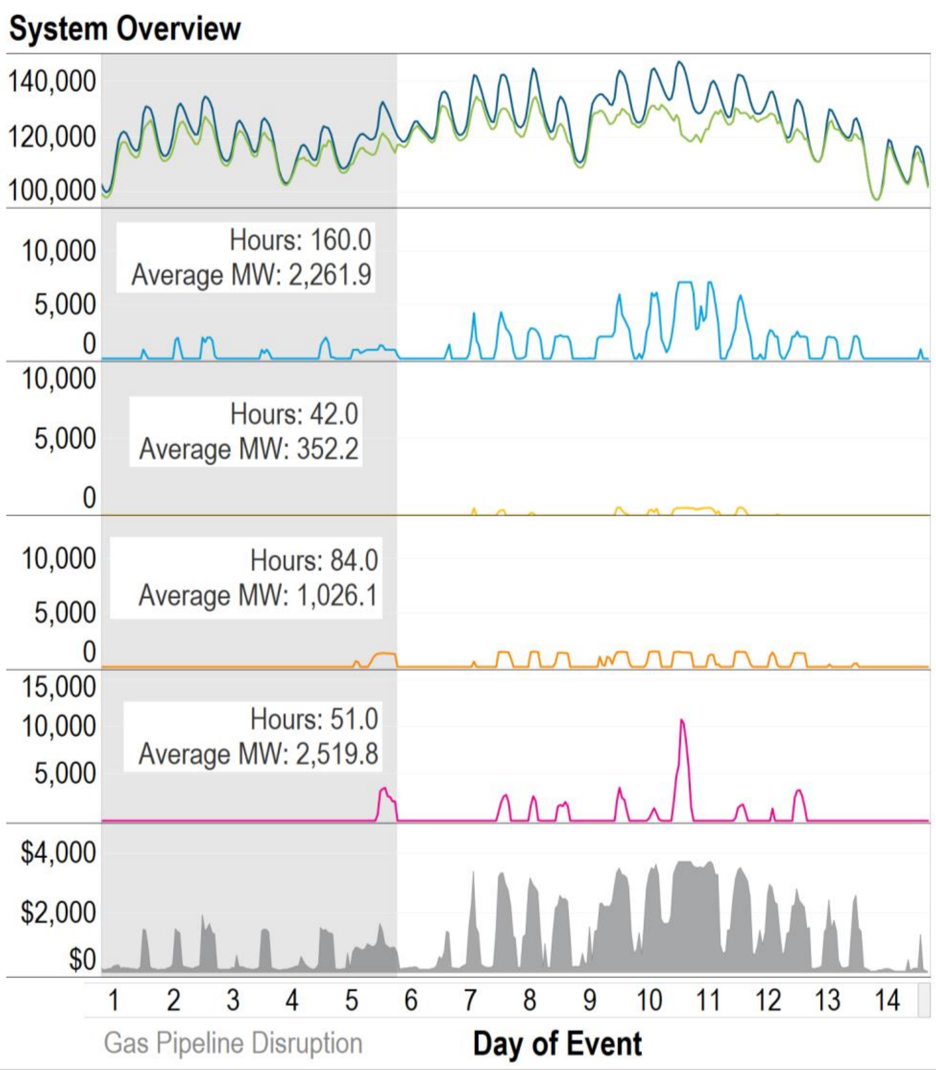


Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 3
Dispatch:	Economic



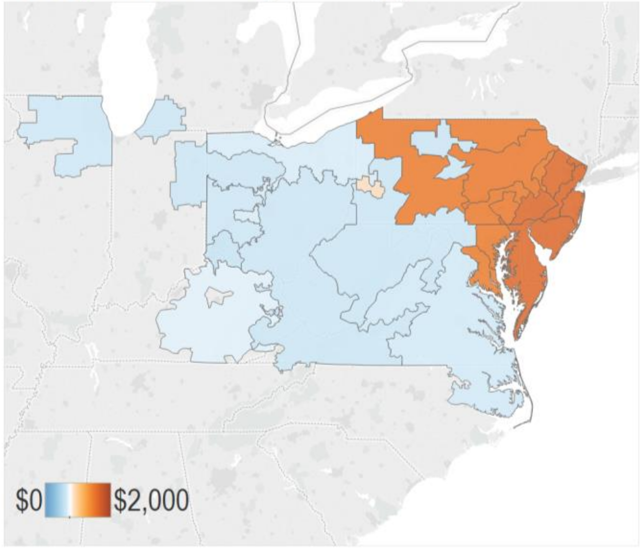
"Escalated 3" Portfolio

Sensitivity 56



Load: Extreme
Refueling: Limited
Disruption: Looped 2 High
Non-Firm Avail: 0%
Retirement: Escalated 3
Dispatch: Economic

Hourly Zonal Average LMP [$]



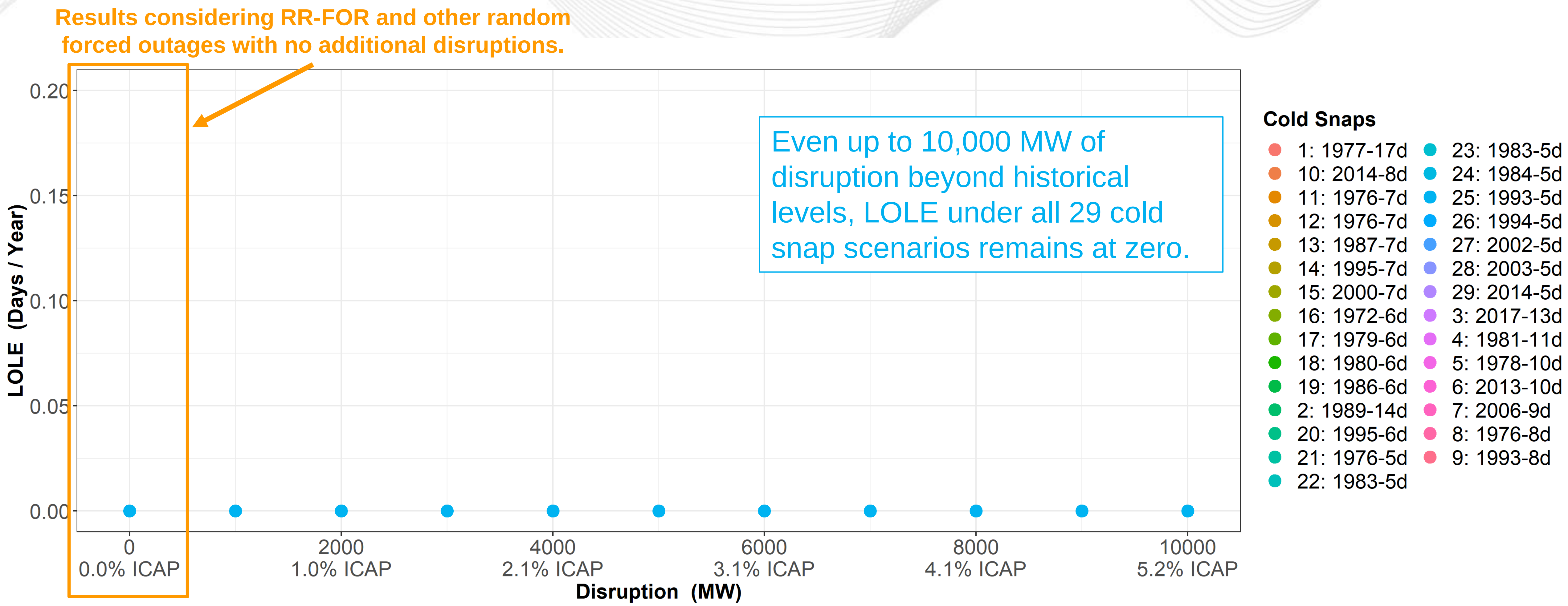
Sites Out of Oil — **Oil Barrels Burned: 5.93M**

Sites Out of Oil	3	14	22	33	39	49	60	68	77	85	92	93	91	81
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14

*141 Total Sites

APPENDIX II – Scenarios using Relevant Risk data from Historical Cold Snap Events

LOLE vs Disruption for each Cold Snap - Announced Retirements



Note: Only Cold Snaps with LOLE > 0 are labeled in the graph

LOLE vs Disruption for each Cold Snap (CS) - Announced Retirements

Disruption	CS1.1977.17d	CS2.1989.14d	CS3.2017.13d	CS4.1981.11d	CS5.1978.10d	CS6.2013.10d	CS7.2006.9d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0
5000	0	0	0	0	0	0	0
6000	0	0	0	0	0	0	0
7000	0	0	0	0	0	0	0
8000	0	0	0	0	0	0	0
9000	0	0	0	0	0	0	0
10000	0	0	0	0	0	0	0

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap (CS) - Announced Retirements

Disruption	CS8.1976.8d	CS9.1993.8d	CS10.2014.8d	CS11.1976.7d	CS12.1976.7d	CS13.1987.7d	CS14.1995.7d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0
5000	0	0	0	0	0	0	0
6000	0	0	0	0	0	0	0
7000	0	0	0	0	0	0	0
8000	0	0	0	0	0	0	0
9000	0	0	0	0	0	0	0
10000	0	0	0	0	0	0	0

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap (CS) - Announced Retirements

Disruption	CS15.2000.7d	CS16.1972.6d	CS17.1979.6d	CS18.1980.6d	CS19.1986.6d	CS20.1995.6d	CS21.1976.5d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0
5000	0	0	0	0	0	0	0
6000	0	0	0	0	0	0	0
7000	0	0	0	0	0	0	0
8000	0	0	0	0	0	0	0
9000	0	0	0	0	0	0	0
10000	0	0	0	0	0	0	0

Column names include Cold Snap number, delivery year and duration

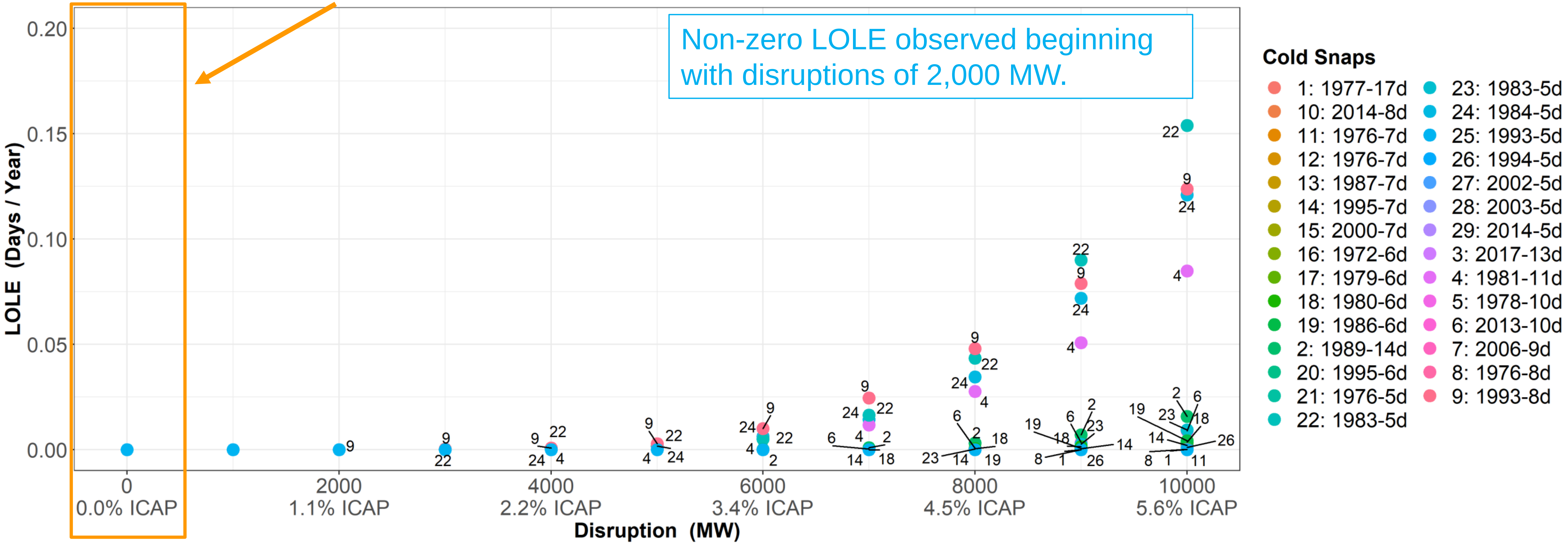
LOLE vs Disruption for each Cold Snap (CS) - Announced Retirements

Disruption	CS22.1983.5d	CS23.1983.5d	CS24.1984.5d	CS25.1993.5d	CS26.1994.5d	CS27.2002.5d	CS28.2003.5d	CS29.2014.5d
0	0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0	0
5000	0	0	0	0	0	0	0	0
6000	0	0	0	0	0	0	0	0
7000	0	0	0	0	0	0	0	0
8000	0	0	0	0	0	0	0	0
9000	0	0	0	0	0	0	0	0
10000	0	0	0	0	0	0	0	0

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #1

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



Note: Only Cold Snaps with LOLE > 0 are labeled in the graph

LOLE vs Disruption for each Cold Snap - Escalated Retirements #1

Disruption	CS1.1977.17d	CS2.1989.14d	CS3.2017.13d	CS4.1981.11d	CS5.1978.10d	CS6.2013.10d	CS7.2006.9d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0	0	0.00025	0	0	0
5000	0	0	0	0.0015	0	0	0
6000	0	0.00021	0	0.0052	0	0	0
7000	0	0.001	0	0.012	0	0.00036	0
8000	0	0.0032	0	0.028	0	0.00071	0
9000	6e-05	0.007	0	0.051	0	0.0036	0
10000	0.00018	0.016	0	0.085	0	0.0089	0

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #1

Disruption	CS8.1976.8d	CS9.1993.8d	CS10.2014.8d	CS11.1976.7d	CS12.1976.7d	CS13.1987.7d	CS14.1995.7d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0.0001	0	0	0	0	0
3000	0	0.00042	0	0	0	0	0
4000	0	0.00083	0	0	0	0	0
5000	0	0.0029	0	0	0	0	0
6000	0	0.01	0	0	0	0	0
7000	0	0.025	0	0	0	0	0.00011
8000	0	0.048	0	0	0	0	0.00011
9000	0.0001	0.079	0	0	0	0	0.00045
10000	0.00021	0.12	0	0.00045	0	0	0.002

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #1

Disruption	CS15.2000.7d	CS16.1972.6d	CS17.1979.6d	CS18.1980.6d	CS19.1986.6d	CS20.1995.6d	CS21.1976.5d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0
5000	0	0	0	0	0	0	0
6000	0	0	0	0	0	0	0
7000	0	0	0	0.00012	0	0	0
8000	0	0	0	0.0005	0.00012	0	0
9000	0	0	0	0.0015	0.00075	0	0
10000	0	0	0	0.0036	0.0042	0	0

Column names include Cold Snap number, delivery year and duration

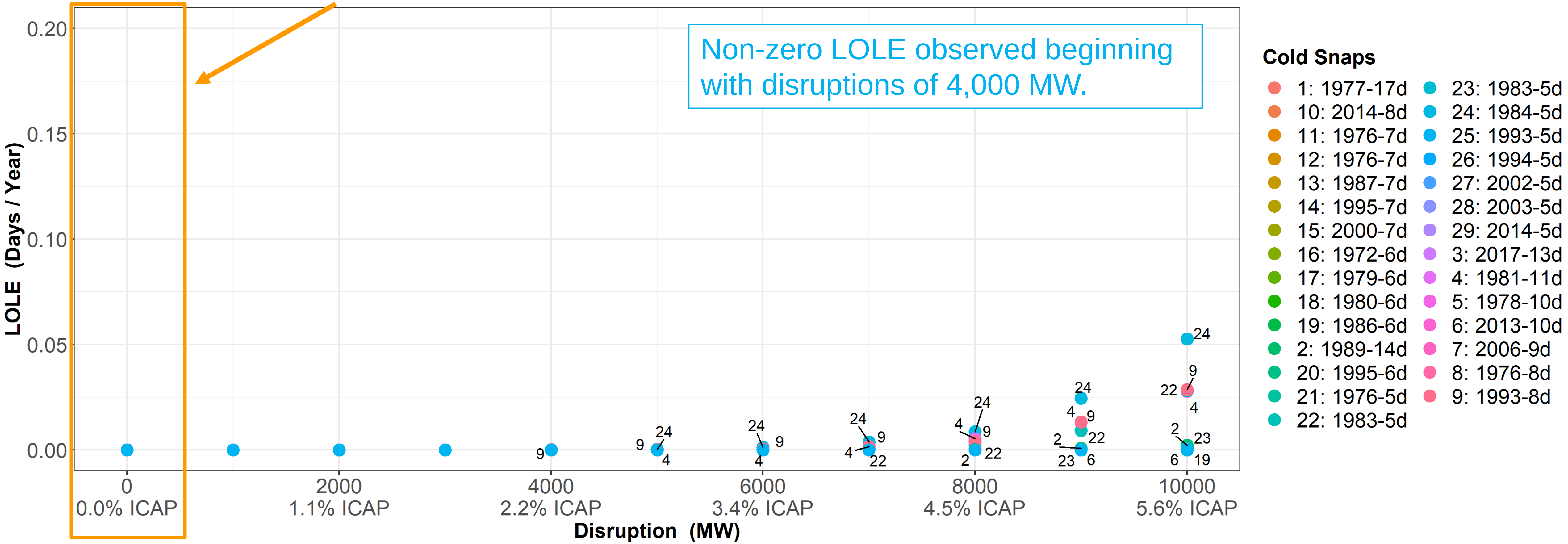
LOLE vs Disruption for each Cold Snap - Escalated Retirements #1

Disruption	CS22.1983.5d	CS23.1983.5d	CS24.1984.5d	CS25.1993.5d	CS26.1994.5d	CS27.2002.5d	CS28.2003.5d	CS29.2014.5d
0	0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
3000	0.00028	0	0	0	0	0	0	0
4000	0.00069	0	0.00014	0	0	0	0	0
5000	0.0019	0	0.0018	0	0	0	0	0
6000	0.005	0	0.0062	0	0	0	0	0
7000	0.017	0	0.014	0	0	0	0	0
8000	0.043	0.00042	0.035	0	0	0	0	0
9000	0.09	0.0028	0.072	0	0.00042	0	0	0
10000	0.15	0.0094	0.12	0	0.0011	0	0	0

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #2

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



Note: Only Cold Snaps with LOLE > 0 are labeled in the graph

LOLE vs Disruption for each Cold Snap - Escalated Retirements #2

Disruption	CS1.1977.17d	CS2.1989.14d	CS3.2017.13d	CS4.1981.11d	CS5.1978.10d	CS6.2013.10d	CS7.2006.9d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0
5000	0	0	0	8e-05	0	0	0
6000	0	0	0	0.00033	0	0	0
7000	0	0	0	0.0017	0	0	0
8000	0	0.00028	0	0.0053	0	0	0
9000	0	0.00076	0	0.013	0	0.00036	0
10000	0	0.0023	0	0.028	0	0.00036	0

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #2

Disruption	CS8.1976.8d	CS9.1993.8d	CS10.2014.8d	CS11.1976.7d	CS12.1976.7d	CS13.1987.7d	CS14.1995.7d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0.00021	0	0	0	0	0
5000	0	0.00021	0	0	0	0	0
6000	0	0.00052	0	0	0	0	0
7000	0	0.0017	0	0	0	0	0
8000	0	0.004	0	0	0	0	0
9000	0	0.013	0	0	0	0	0
10000	0	0.029	0	0	0	0	0

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #2

Disruption	CS15.2000.7d	CS16.1972.6d	CS17.1979.6d	CS18.1980.6d	CS19.1986.6d	CS20.1995.6d	CS21.1976.5d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0
5000	0	0	0	0	0	0	0
6000	0	0	0	0	0	0	0
7000	0	0	0	0	0	0	0
8000	0	0	0	0	0	0	0
9000	0	0	0	0	0	0	0
10000	0	0	0	0	0.00012	0	0

Column names include Cold Snap number, delivery year and duration

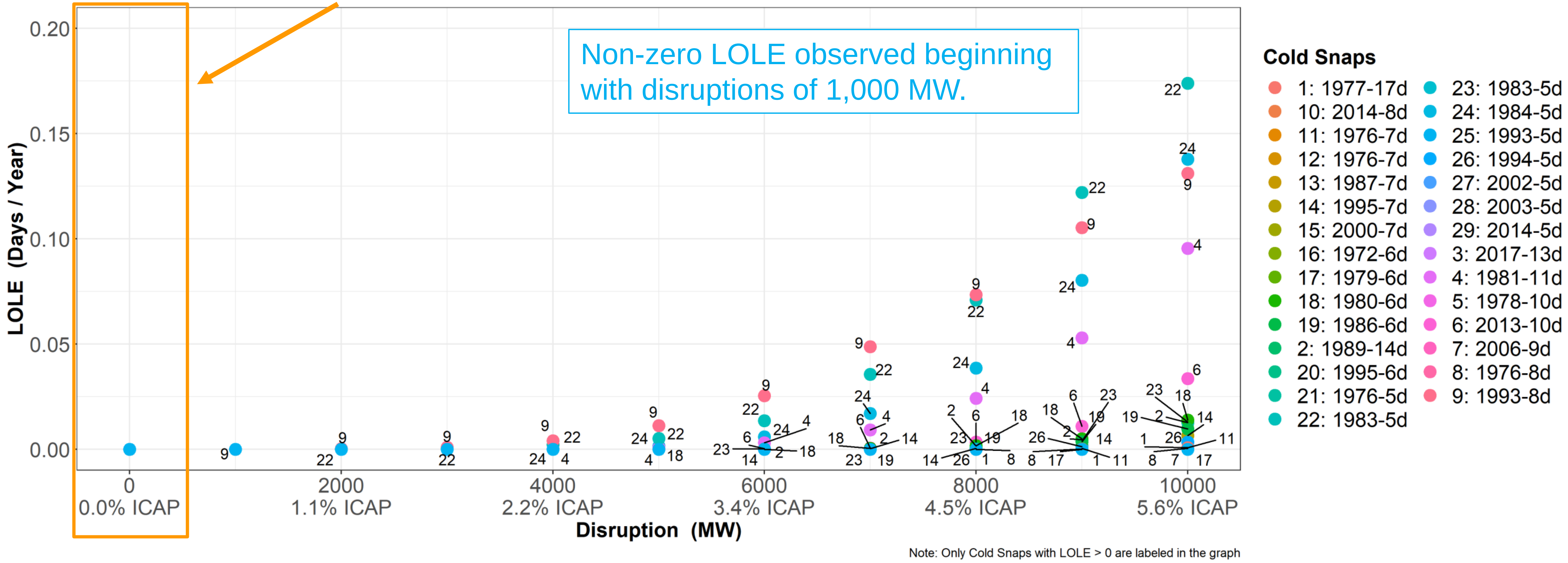
LOLE vs Disruption for each Cold Snap - Escalated Retirements #2

Disruption	CS22.1983.5d	CS23.1983.5d	CS24.1984.5d	CS25.1993.5d	CS26.1994.5d	CS27.2002.5d	CS28.2003.5d	CS29.2014.5d
0	0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0	0
5000	0	0	0.00042	0	0	0	0	0
6000	0	0	0.0012	0	0	0	0	0
7000	0.00042	0	0.0037	0	0	0	0	0
8000	0.0024	0	0.0086	0	0	0	0	0
9000	0.0093	0.00028	0.025	0	0	0	0	0
10000	0.028	0.00069	0.053	0	0	0	0	0

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #3

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



Note: Only Cold Snaps with LOLE > 0 are labeled in the graph

LOLE vs Disruption for each Cold Snap - Escalated Retirements #3

Disruption	CS1.1977.17d	CS2.1989.14d	CS3.2017.13d	CS4.1981.11d	CS5.1978.10d	CS6.2013.10d	CS7.2006.9d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0	0	0.00017	0	0	0
5000	0	0	0	0.00083	0	0	0
6000	0	7e-05	0	0.0032	0	0.00036	0
7000	0	0.00056	0	0.0093	0	0.00071	0
8000	6e-05	0.0017	0	0.024	0	0.0036	0
9000	0.00024	0.0046	0	0.053	0	0.011	0
10000	0.00077	0.013	0	0.096	0	0.034	0.0001

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #3

Disruption	CS8.1976.8d	CS9.1993.8d	CS10.2014.8d	CS11.1976.7d	CS12.1976.7d	CS13.1987.7d	CS14.1995.7d
0	0	0	0	0	0	0	0
1000	0	0.0001	0	0	0	0	0
2000	0	0.00042	0	0	0	0	0
3000	0	0.00094	0	0	0	0	0
4000	0	0.0041	0	0	0	0	0
5000	0	0.011	0	0	0	0	0
6000	0	0.026	0	0	0	0	0.00011
7000	0	0.049	0	0	0	0	0.00034
8000	0.0001	0.074	0	0	0	0	0.00057
9000	0.00021	0.11	0	0.00045	0	0	0.0018
10000	0.00052	0.13	0	0.00091	0	0	0.0066

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #3

Disruption	CS15.2000.7d	CS16.1972.6d	CS17.1979.6d	CS18.1980.6d	CS19.1986.6d	CS20.1995.6d	CS21.1976.5d
0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0
5000	0	0	0	0.00012	0	0	0
6000	0	0	0	0.00012	0	0	0
7000	0	0	0	0.0005	0.00012	0	0
8000	0	0	0	0.0018	0.00075	0	0
9000	0	0	0.00012	0.005	0.0036	0	0
10000	0	0	0.00012	0.014	0.0097	0	0

Column names include Cold Snap number, delivery year and duration

LOLE vs Disruption for each Cold Snap - Escalated Retirements #3

Disruption	CS22.1983.5d	CS23.1983.5d	CS24.1984.5d	CS25.1993.5d	CS26.1994.5d	CS27.2002.5d	CS28.2003.5d	CS29.2014.5d
0	0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0	0
2000	0.00014	0	0	0	0	0	0	0
3000	0.00056	0	0	0	0	0	0	0
4000	0.0022	0	0.00028	0	0	0	0	0
5000	0.0053	0	0.0017	0	0	0	0	0
6000	0.014	0.00014	0.006	0	0	0	0	0
7000	0.036	0.00042	0.017	0	0	0	0	0
8000	0.071	0.00083	0.039	0	0.00042	0	0	0
9000	0.12	0.0039	0.08	0	0.0012	0	0	0
10000	0.17	0.013	0.14	0	0.0035	0	0	0

Column names include Cold Snap number, delivery year and duration

APPENDIX III – Description of Monte Carlo Methodology to model Random Forced Outages

- For each thermal unit (and hydro units), it is assumed that there are two states:
  – On (unit is online producing its maximum output)
  – Off (unit is offline, on a forced outage, producing zero output)
- The time a unit spends in either of the above two states is assumed to be a random variable with an exponential distribution (this is a standard reliability assumption). The cumulative density function (CDF) of the exponential distribution is

$$F(x) = 1 - e^{\frac{-x}{\alpha}}$$

where α is the mean of the distribution (i.e., the mean time a unit is online or the mean time a unit is offline)

- The mean time a unit is online (or mean time to failure) and the mean time a unit is offline (or mean time to repair) can be estimated from the GADS data.
- If a random number R is drawn, then the time-in-state, T, can be computed using the CDF of the exponential distribution

$$T = -\ln(R) * \alpha$$

- For instance, for a given unit the mean time to failure is 1,111 hours while the mean time to repair is 84 hours
- Let's assume that in the first replication of the Monte Carlo, the unit starts online

Monte Carlo for Random Forced Outages

- To determine for how long the unit is online, we draw a random number R. Let's assume the first random number is 0.59. Therefore,

$$T_1 = -\ln(0.59) * 1{,}111 = 586.2\ hrs$$

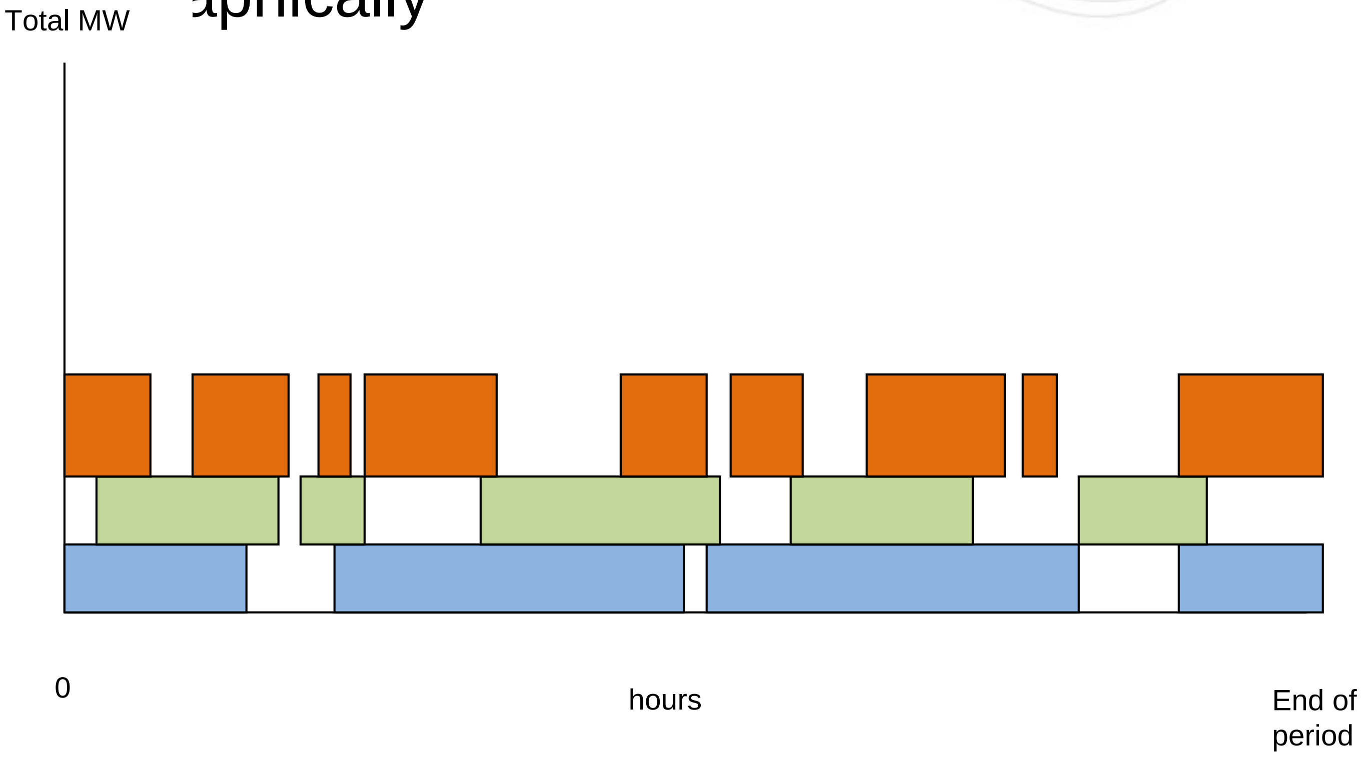
- When the simulation clock hits 586.2 hrs, the unit transitions to the offline state. To determine for how long the unit is offline, we use a second random number, say 0.43. Therefore,

$$T_2 = -\ln(0.43) * 84 = 70.9\ hrs$$

- After the forced outage, the simulation clock hits 586.2 + 70.9 = 657.1 hrs. At this time, the unit transitions to the online state and a new random number is generated. This sequence is repeated until reaching the end of the simulation period.

Monte Carlo for Random Forced Outages

- Graphically

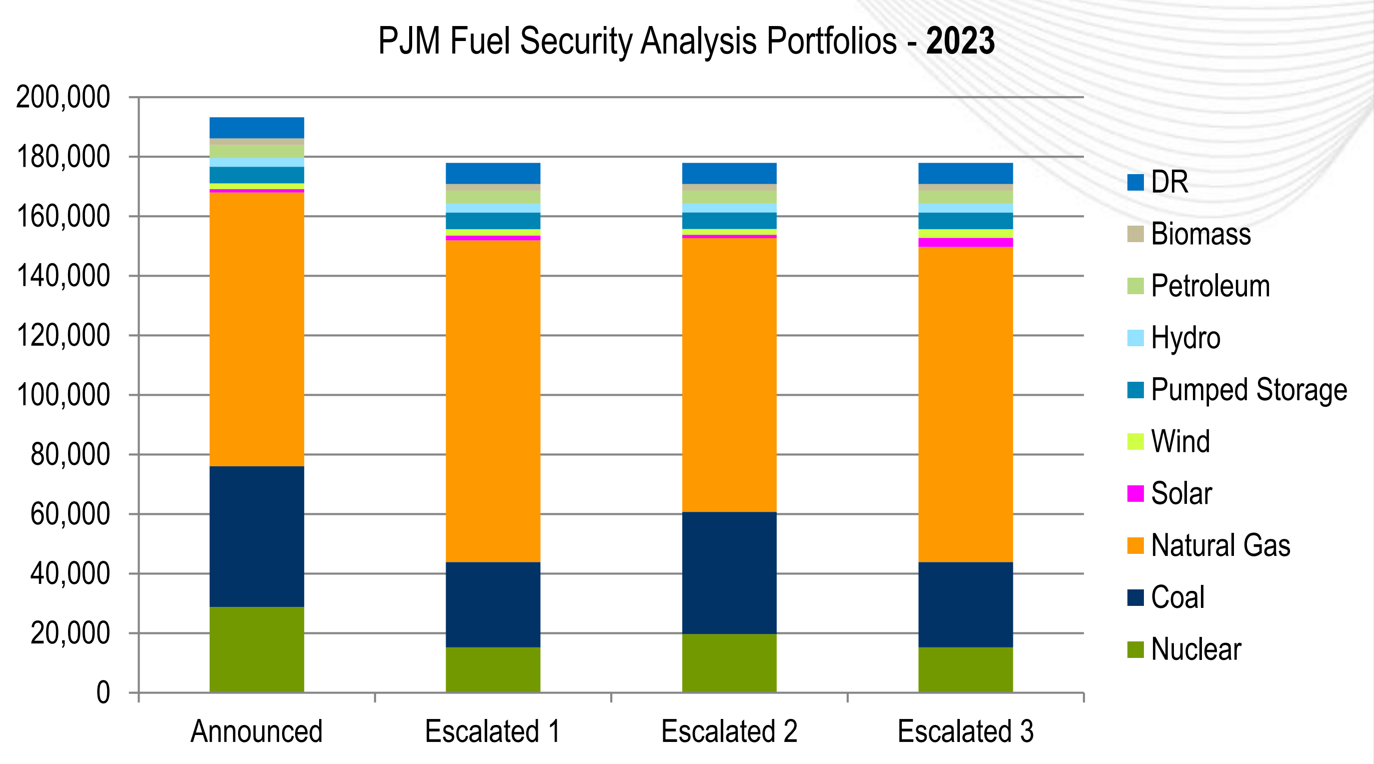


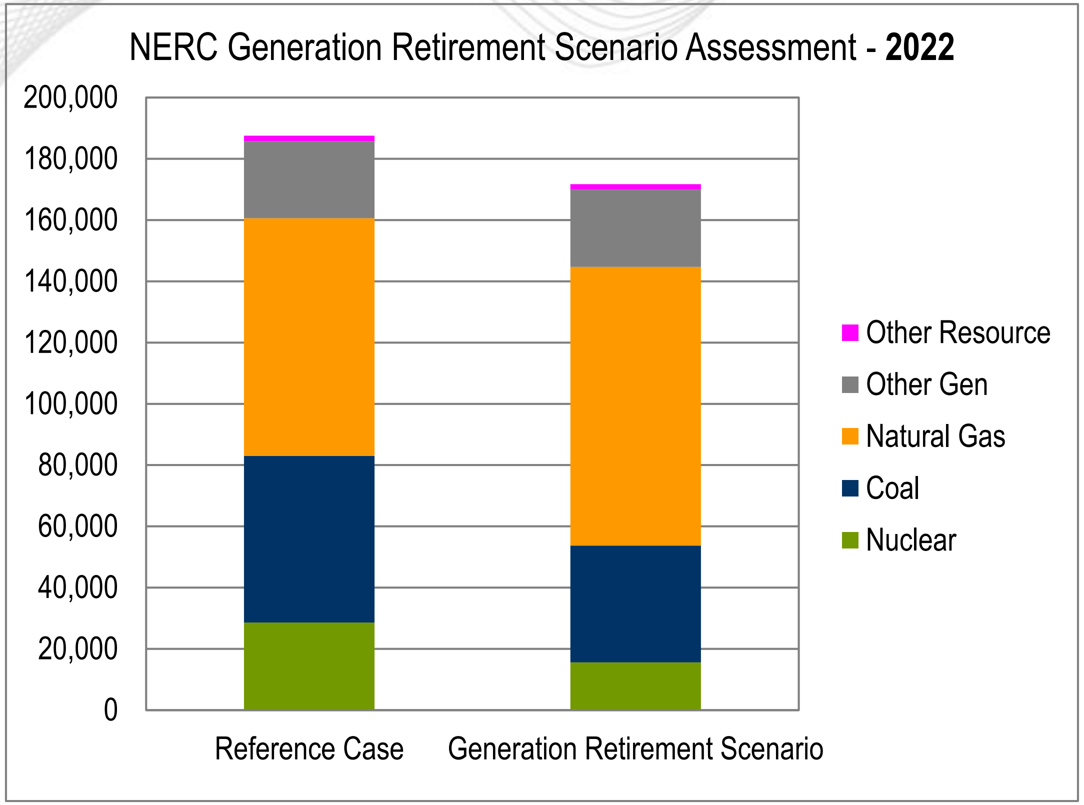
In this graph, only 3 units are considered (each one represented by a different color)
Each colored block represents the time a unit is online whereas the white spaces in between represent the time a unit is offline (on a forced outage).
More units can be stacked up in the plot.
A plot such as this one is useful to determine the total amount of capacity available at each hour of the period studied.

This plot represents 1 simulation run.
In the analysis, a total of 1,000 simulations are run.
The random numbers generated by the program change between runs.
Thus, each simulation is likely to result in a different graph.

APPENDIX IV

Portfolio Comparison with NERC Retirement Assessment





	PJM Fuel Security Analysis Portfolios (2023)				NERC Generation Retirement Scenario Assessment (2022)	
	Announced	*Escalated 1*	*Escalated 2*	*Escalated 3*	*Reference Case*	*Generation Retirement Scenario*
Natural Gas	91,896	108,013	91,896	105,826	77,523	91,007
Coal	47,241	28,643	41,051	28,643	54,432	38,103
Nuclear	28,800	15,233	19,672	15,233	28,620	15,602
Portfolio IRM	25.80%	15.8%	15.8%	15.8%	27.4%	16.6%

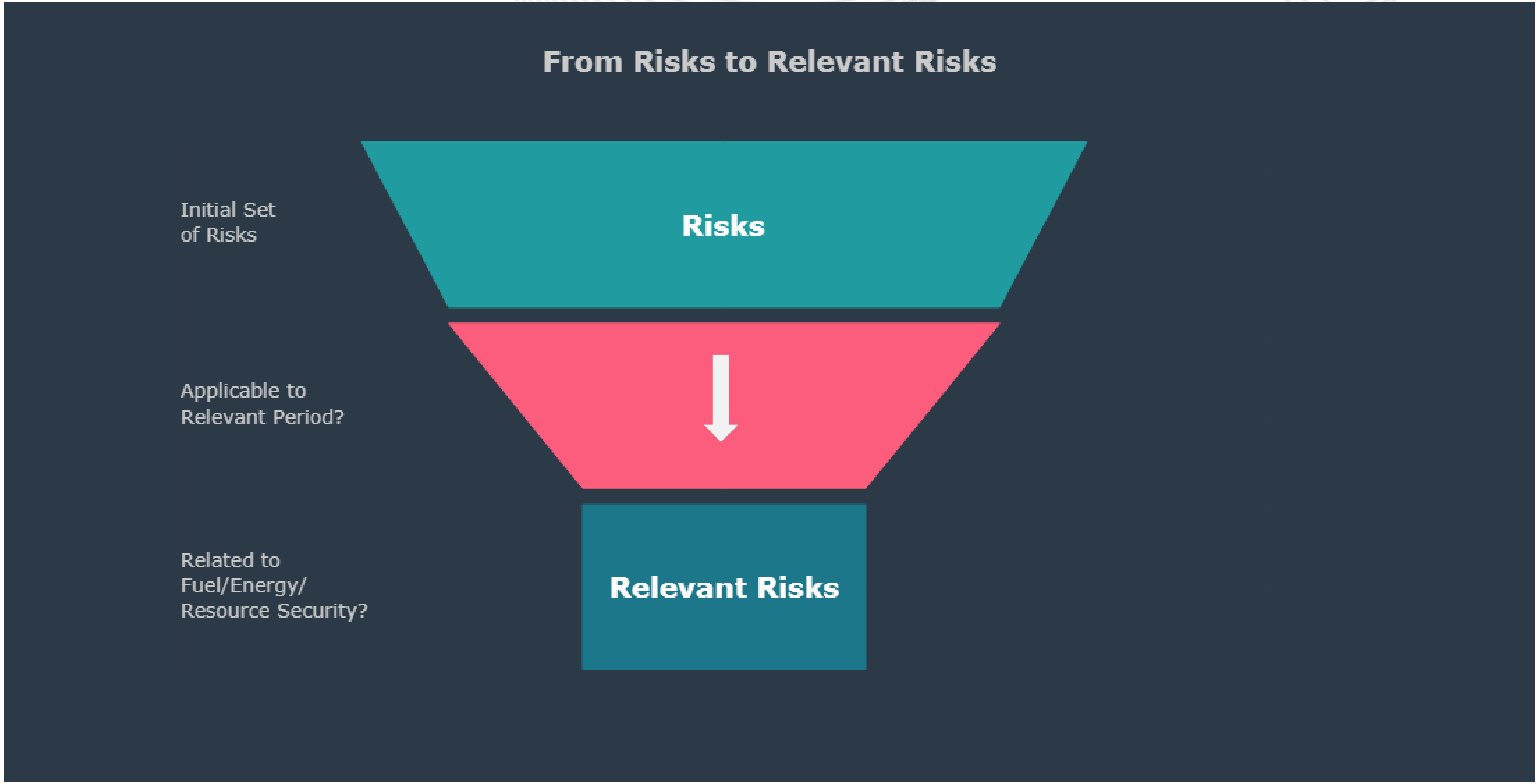
https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_Retirements_Report_2018_Final.pdf

Education

FSSTF
June 26, 2019

Patricio Rocha Garrido, Resource Adequacy Planning
Daniel Bennett, Generation
Natalie Tacka, Applied Innovation
Patrick Bruno, Capacity Market Operations

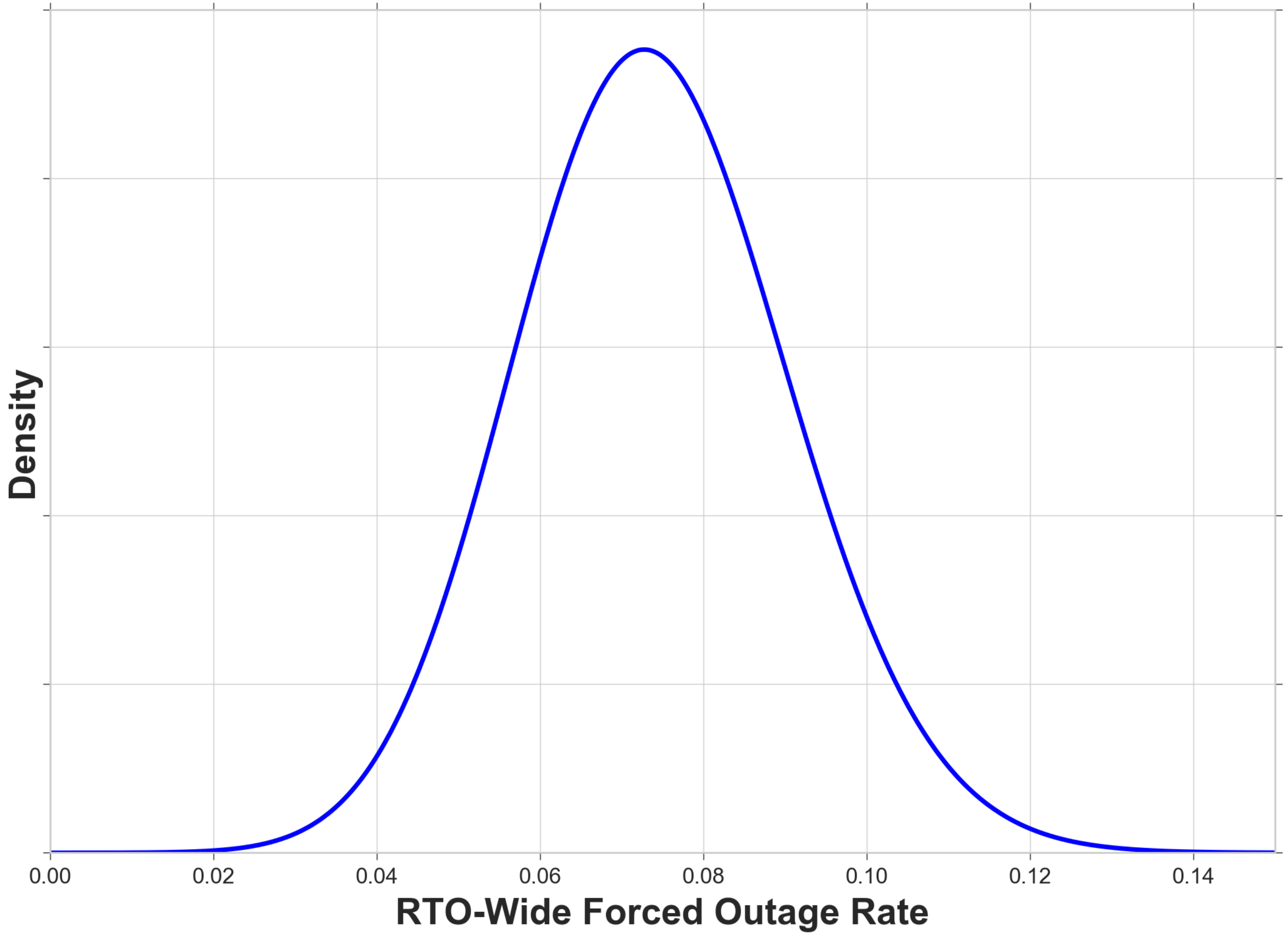
- At the previous FSSTF, PJM presented the approach to filter the Relevant Risks
  - This entailed determining a Relevant Period


From Risks to Relevant Risks
Initial Set
of Risks
Risks
Applicable to
Relevant Period?
Related to
Fuel/Energy/
Resource Security?
Relevant Risks

- At today's FSSTF, PJM will make presentations
  - Supporting Winter as the Relevant Period
  - Showing a preliminary version of the Relevant Risks filtering process
  - Showing more information about current Products/Mechanisms that address the most typical uncertainties/risks
- At the July FSSTF, as part of the Gap Analysis, PJM will examine if the identified Relevant Risks are addressed by the current Products/Mechanisms

Relevant Period Identification and Methodology

Theoretical RTO-wide Forced Outage Rate



If individual forced outages are random and independent

Mean: ~7.0%
StDev: ~1.4%
90^{th} Perc: ~9.2%

Development of Empirical RTO-wide Forced Outage Rates

- For the last 11 years, the top 3 peak-load weeks of each season are identified
- The RTO-wide Forced Outage Rate at the peak hour of each weekday within each of the above weeks is recorded
- Therefore, for instance, for Winter Week 1
  - There are 11 winter peak weeks (one for each year)
  - There are 5 peak hours within each of the above weeks (one for each weekday)
  - We end up with 55 RTO-wide forced outage observations

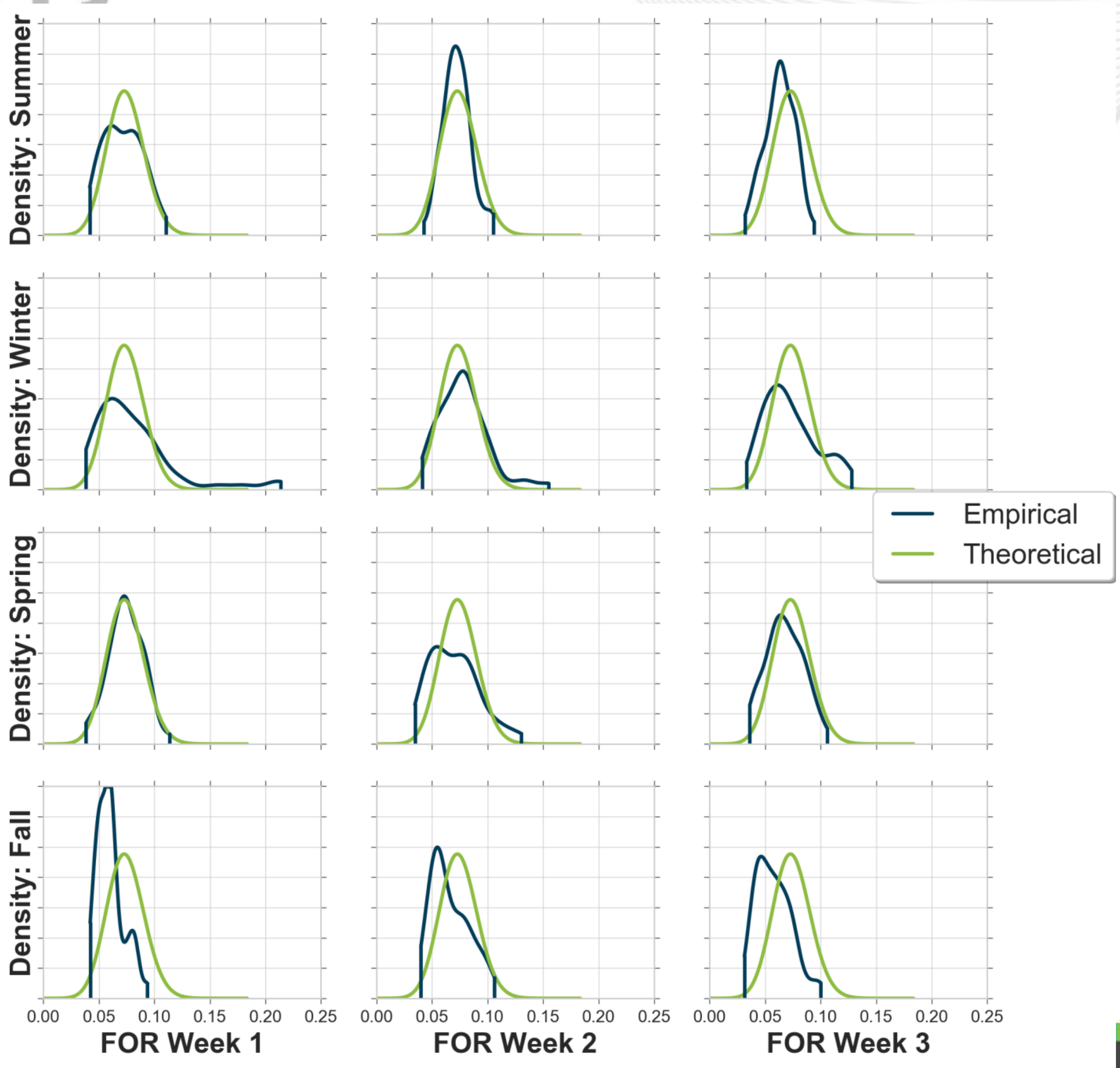
Empirical RTO-wide Forced Outage Rates

		RTO-Wide Forced Outage Rate		
Season	**Load-Magnitude Ordered Week**	**Mean**	**StDev**	**90th perc**
Summer	1	7.1%	1.8%	9.3%
Summer	2	7.2%	1.3%	8.5%
Summer	3	6.3%	1.3%	7.9%
Winter	1	8.2%	3.8%	11.8%
Winter	2	7.8%	2.3%	10.2%
Winter	3	7.3%	2.4%	11.3%
Spring	1	7.4%	1.6%	9.2%
Spring	2	7.0%	2.3%	10.1%
Spring	3	6.7%	1.7%	8.8%
Fall	1	6.0%	1.2%	8.0%
Fall	2	6.6%	1.7%	9.3%
Fall	3	5.8%	1.6%	7.6%

For comparison, the Theoretical distribution has the following statistics:

Mean: ~7.0%
StDev: ~1.4%
90^{th} Perc: ~9.2%

Empirical vs Theoretical Distributions



Height of line represents how often forced outage rates in x-axis have occurred in the last 11 years for each of the season-week combinations.

In the Top 3 winter weeks, the empirical forced outage distribution (blue line) has a longer right-hand side tail than the theoretical forced outage distribution (green line).

Observations

- The previous slide shows that historical RTO-wide Forced Outage Rates during the Top 3 Winter weeks do not comport with the independence assumption
  - For the Top 3 weeks of the rest of the seasons the independence assumption seems to hold
- Why have RTO-wide forced outage rates been historically greater during the Top 3 Winter weeks?

Forced Outages due to Lack Of Fuel

- Using the Empirical RTO-wide Forced Outage Rate data, but only considering those forced outages with cause codes related to lack of fuel yields the following table

		RTO-Wide Forced Outage MW due to Lack of Fuel		
Season	**Load-Magnitude Ordered Week**	**Mean**	**StDev**	**90th perc**
Winter	1	2,310	2,670	6,649
Winter	3	1,744	2,307	4,572
Winter	2	1,600	1,640	3,404
Spring	2	794	1,448	1,648
Spring	1	570	651	1,284
Spring	3	563	516	1,351
Fall	3	476	497	1,219
Fall	2	307	486	1,170
Summer	3	194	368	871
Fall	1	172	307	654
Summer	1	131	300	339
Summer	2	113	308	317

The weeks showing the highest volume of forced outages due to lack of fuel (Winter 1, Winter 3, Winter 2, Spring 2) are the same weeks showing a longer right-hand side tail for the empirical forced outage distribution in Slide 5.

The top 3 Winter weeks are by far the weeks with the highest volume of forced outages due to lack of fuel

- In addition, Winter is the season with the second highest peak loads. For instance, according to the 2019 PJM Load Forecast for Delivery Year 2023

Forecasted 50/50 Seasonal Peaks:

- Summer: 152,854 MW
- Winter: 133,882 MW
- Spring: 120,617 MW
- Fall: 130,255 MW

Conclusion

- Putting together the above Forced Outages and Seasonal Peak Load considerations, the Winter Peak Period is the most concerning period from a Fuel/Resource Security perspective given the potential for high forced outage levels and high peak loads that may result in loss-of-load events
  - This supports the approach taken in Phase 1 whose results show loss-of-load events during a Winter cold snap under a high volume of forced outages

Risk Filtering Process and Scenario Review

Definitions

Risk

- Any event that may pose a resource adequacy issue for the PJM system

Relevant Period(s)

- Period(s) of the year in which Fuel/Energy/Resource Security issues may result in potential resource adequacy issues

Relevant Risk

- A subset of the identified Risks relevant to Fuel/Energy/Resource Security scope and that may occur during the determined Relevant Period

Relevant Scenarios

- Combination of potential realizations of Relevant Risks that create a set of conditions to be evaluated

Objectives and Process

Identify Risks

- Review historical data and solicit input from stakeholders and area experts to list Risks to the PJM system

Narrow to Relevant Risks

- Analyze the Risks identified to develop a list of risks within the Fuel/Energy/Resource Security scope and the identified Relevant Period

Collect Data on Study Risks

- Collect data on the frequency of occurrence, generation impact, locational nature, and other factors necessary to model the Study Risks and their affect of Fuel/Energy/Resource Security

Define Relevant Scenarios

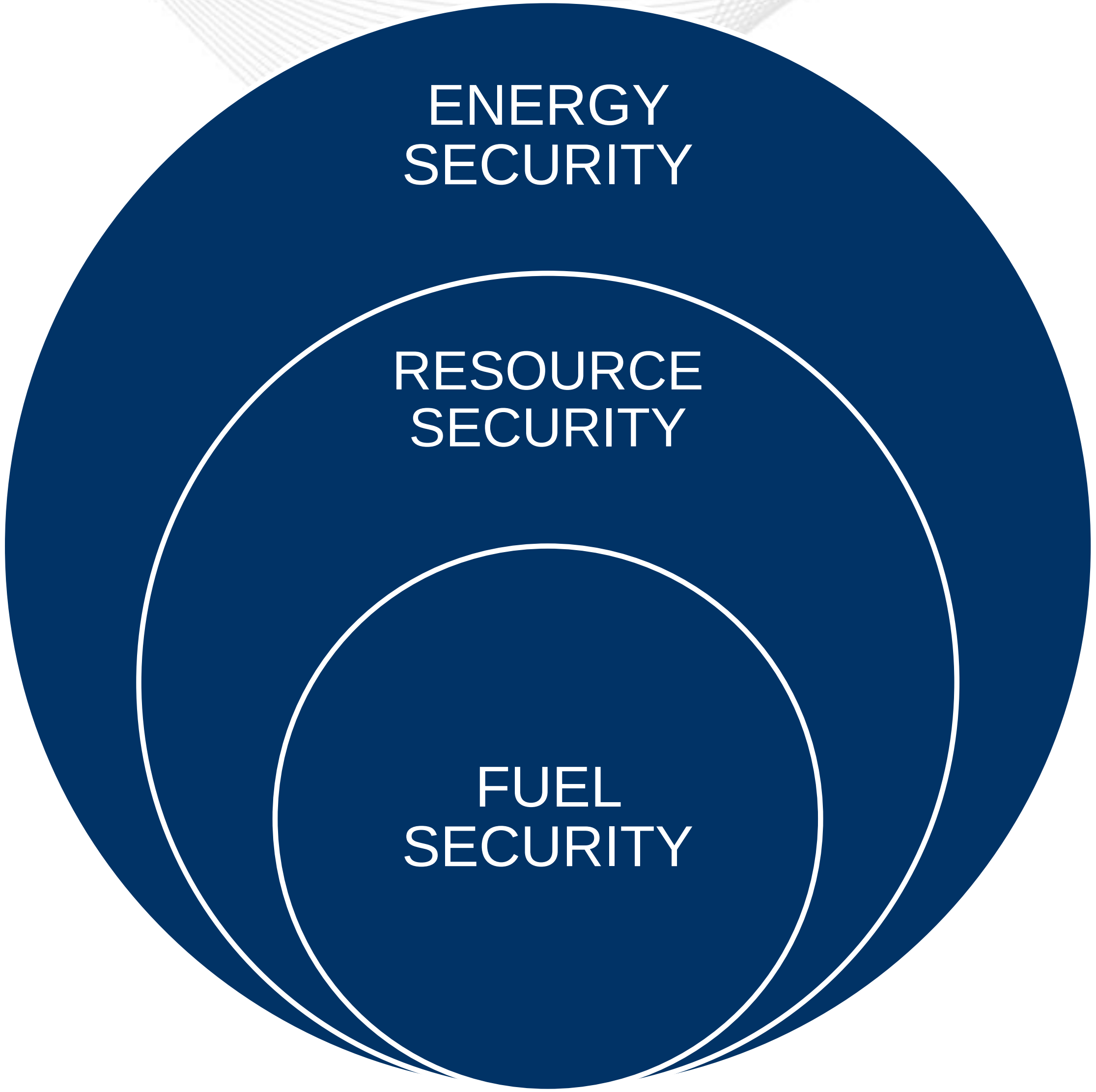
- Combine the Relevant Risks into event scenarios and identify any significant gaps from Phase 1 scenarios

Evaluate Relevant Scenarios

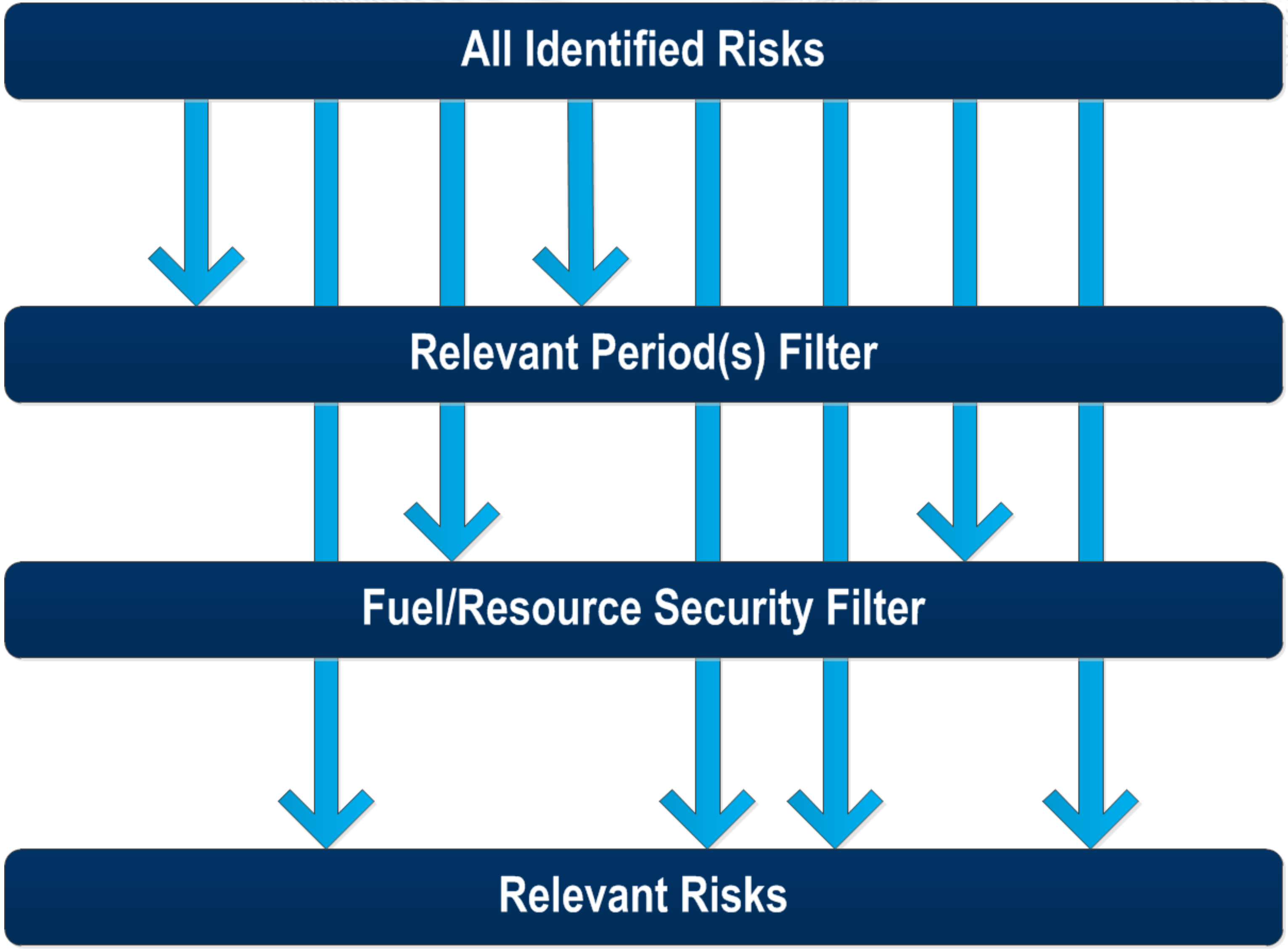
- Identify Relevant Scenarios with high loss of load impact to the PJM system

Senior Task Force Charter Terms

Fuel Security:
This can be categorized as the availability of fuel both on-site and assessed from delivery systems required for a unit to generate consistent with dispatch signals or operating instructions. This includes all resource types



Resource Security:
Availability of a set of resources with the same fuel type associated with different types of common vulnerabilities. Includes all resource types.


All Identified Risks
Relevant Period(s) Filter
Fuel/Resource Security Filter
Relevant Risks

Identified Risks (1 of 3)

INDEX	RISK	DESCRIPTION
1	Long Duration Cold Snap	Consecutive days below a temperature threshold greater than a set duration
2	Short Duration Cold Snap	Consecutive days below a temperature threshold less than a set duration
3	Long Duration Heat Wave	Consecutive days above a temperature threshold greater than a set duration
4	Short Duration Heat Wave	Consecutive days above a temperature threshold less than a set duration
5	Coal Refueling (Bridge Failure)	Reduced coal refueling capacity due to a bridge failure
6	Coal Refueling (Lock and Dam Failure)	Reduced coal refueling capacity due to a lock and dam failure
7	Coal Refueling (Rail Failure)	Reduced coal refueling capacity due to a failure of the rail infrastructure
8	Coal Refueling (River Freezing)	Reduced coal refueling capacity due to freezing rivers impacting barge traffic
9	Coal Unavailability (Coal Quality)	The unavailability of coal fired units due to poor fuel quality (wet coal, low quality coal, etc.)

Identified Risks (2 of 3)

INDEX	RISK	DESCRIPTION
10	Natural Gas Pipeline Disruptions	Any disruption to the natural gas pipeline infrastructure (pipe, gas compressor, etc.) that impacts the ability to transport natural gas, excluding malicious causes (to be included in Phase 3)
11	Natural Gas Unavailability Non-Firm Units	The curtailment or unavailability of natural gas delivery to units with interruptible transportation for any reason
12	Oil Refueling (Oil Terminal)	Reduced oil refueling capacity due to limitations at oil terminals or other oil supply centers
13	Oil Refueling (Truck Restrictions)	Reduced oil refueling capacity due to truck transportation limitations
14	Nuclear Regulatory Shutdown (Fuel Related)	A mandated shutdown or power reduction of nuclear units for reasons related to fuel issues
15	Nuclear Regulatory Shutdown (Non-Fuel Related)	A mandated shutdown or power reduction of nuclear units for reasons not related to fuel issues
16	Nuclear Unavailability (High Winds)	The preemptive shutdown or power reduction of nuclear units due to high wind speeds

Identified Risks (3 of 3)

INDEX	RISK	DESCRIPTION
17	Hydro Unavailability (Drought / Low Water Level)	Reduced hydro availability due to low water levels or droughts
18	Hydro Unavailability (Freezing Rivers)	Reduced hydro availability due to river freezing
19	Solar Intermittency	The inherent intermittency of solar resources throughout the year
20	Wind Intermittency	The inherent intermittency of wind resources throughout the year; Temperature-triggered shutdown based on turbine settings
21	High River Temperatures / Drought (Cooling Water Impacts)	Plant efficiency impacts caused high river water temperatures reducing cooling capabilities
22	River Freezing (Cooling Water Impacts)	Plant efficiency impacts caused by river freezing (ice on screens, reduced water intake capabilities, etc.)
23	Earthquake	An earthquake that affects the PJM footprint
24	Hurricane / Tropical Storms	A hurricane or tropical storm that affects the PJM footprint
25	Ice Storm (Transportation Impacts)	An ice storm that affects the PJM footprint and adversely impacts the transportation of fuel or other commodities

INDEX	RISK	SPRING	SUMMER	FALL	WINTER
1	Long Duration Cold Snap				
2	Short Duration Cold Snap				
3	Long Duration Heat Wave				
4	Short Duration Heat Wave				
5	Coal Refueling (Bridge Failure)				
6	Coal Refueling (Lock and Dam Failure)				
7	Coal Refueling (Rail Failure)				
8	Coal Refueling (River Freezing)				
9	Coal Unavailability (Coal Quality)				
10	Natural Gas Pipeline Disruptions				
11	Natural Gas Unavailability Non-Firm Units				
12	Oil Refueling (Oil Terminal)				
13	Oil Refueling (Truck Restrictions)				
14	Nuclear Regulatory Shutdown (Fuel Related)				
15	Nuclear Regulatory Shutdown (Non-Fuel Related)				
16	Nuclear Unavailability (High Winds)				
17	Hydro Unavailability (Drought / Low Water Level)				
18	Hydro Unavailability (Freezing Rivers)				
19	Solar Intermittency				
20	Wind Intermittency				
21	High River Temperatures / Drought (Cooling Water Impacts)				
22	River Freezing (Cooling Water Impacts)				
23	Earthquake				
24	Hurricane / Tropical Storms				
25	Ice Storm (Transportation Impacts)				

INDEX	RISK	SPRING	SUMMER	FALL	WINTER
1	Long Duration Cold Snap				
2	Short Duration Cold Snap				
5	Coal Refueling (Bridge Failure)				
6	Coal Refueling (Lock and Dam Failure)				
7	Coal Refueling (Rail Failure)				
8	Coal Refueling (River Freezing)				
9	Coal Unavailability (Coal Quality)				
10	Natural Gas Pipeline Disruptions				
11	Natural Gas Unavailability Non-Firm Units				
12	Oil Refueling (Oil Terminal)				
13	Oil Refueling (Truck Restrictions)				
14	Nuclear Regulatory Shutdown (Fuel Related)				
15	Nuclear Regulatory Shutdown (Non-Fuel Related)				
16	Nuclear Unavailability (High Winds)				
18	Hydro Unavailability (Freezing Rivers)				
19	Solar Intermittency				
20	Wind Intermittency				
22	River Freezing (Cooling Water Impacts)				
23	Earthquake				
25	Ice Storm (Transportation Impacts)				

INDEX	RISK	FUEL SECURITY	RESOURCE SECURITY	Explicitly Modeled PHASE 1
1	Long Duration Cold Snap			
2	Short Duration Cold Snap			
5	Coal Refueling (Bridge Failure)			
6	Coal Refueling (Lock and Dam Failure)			
7	Coal Refueling (Rail Failure)			
8	Coal Refueling (River Freezing)			
9	Coal Unavailability (Coal Quality)			
10	Natural Gas Pipeline Disruptions			
11	Natural Gas Unavailability Non-Firm Units			
12	Oil Refueling (Oil Terminal)			
13	Oil Refueling (Truck Restrictions)			
14	Nuclear Regulatory Shutdown (Fuel Related)			
15	Nuclear Regulatory Shutdown (Non-Fuel Related)			
16	Nuclear Unavailability (High Winds)			
18	Hydro Unavailability (Freezing Rivers)			
19	Solar Intermittency			
20	Wind Intermittency			
22	River Freezing (Cooling Water Impacts)			
23	Earthquake			
25	Ice Storm (Transportation Impacts)			

INDEX	RISK	FUEL SECURITY	RESOURCE SECURITY	Explicitly Modeled PHASE 1
1	Long Duration Cold Snap			
2	Short Duration Cold Snap			
5	Coal Refueling (Bridge Failure)			
6	Coal Refueling (Lock and Dam Failure)			
7	Coal Refueling (Rail Failure)			
8	Coal Refueling (River Freezing)			
9	Coal Unavailability (Coal Quality)			
10	Natural Gas Pipeline Disruptions			
11	Natural Gas Unavailability Non-Firm Units			
12	Oil Refueling (Oil Terminal)			
13	Oil Refueling (Truck Restrictions)			
14	Nuclear Regulatory Shutdown (Fuel Related)			
15	Nuclear Regulatory Shutdown (Non-Fuel Related)			
16	Nuclear Unavailability (High Winds)			
18	Hydro Unavailability (Freezing Rivers)			
19	Solar Intermittency			
20	Wind Intermittency			
22	River Freezing (Cooling Water Impacts)			
25	Ice Storm (Transportation Impacts)			

Scenario Feedback Mapped to Identified Risks

- A matrix combining feedback on risks/scenarios submitted by stakeholders with a mapping to the identified risks is located on the FSSTF webpage:
  - https://www.pjm.com/committees-and-groups/task-forces/fsstf.aspx

Next Steps

Identify Risks

- Review historical data and solicit input from stakeholders and area experts to list Risks to the PJM system

Narrow to Relevant Risks

- Analyze the Risks identified to develop a list of risks within the Fuel/Energy/Resource Security scope and the identified Relevant Period

Collect Data on Study Risks

- Collect data on the frequency of occurrence, generation impact, locational nature, and other factors necessary to model the Study Risks and their affect of Fuel/Energy/Resource Security

Define Relevant Scenarios

- Combine the Relevant Risks into event scenarios and identify any significant gaps from Phase 1 scenarios

Evaluate Relevant Scenarios

- Identify Relevant Scenarios with high loss of load impact to the PJM system

Cold Snaps and Pipeline Disruptions – Historical Data

Patricio Rocha Garrido

FSSTF

07/16/2019

- At the May FSSTF, PJM presented the Risk Assessment Approach which included:
  - Identifying the Relevant Risks (this was covered at the June FSSTF meeting)
  - Identifying the potential realizations of each Relevant Risk.
    - To accomplish this, historical data on each Relevant Risk will be analyzed
- At today's FSSTF, PJM will present historical data on two such Relevant Risks: Cold Snap and Pipeline Disruptions
- At the August FSSTF, PJM will present historical data on the remaining Relevant Risks as well as the impact of the Relevant Risks on PJM generation

Relevant Risks Identified at June FSSTF Meeting

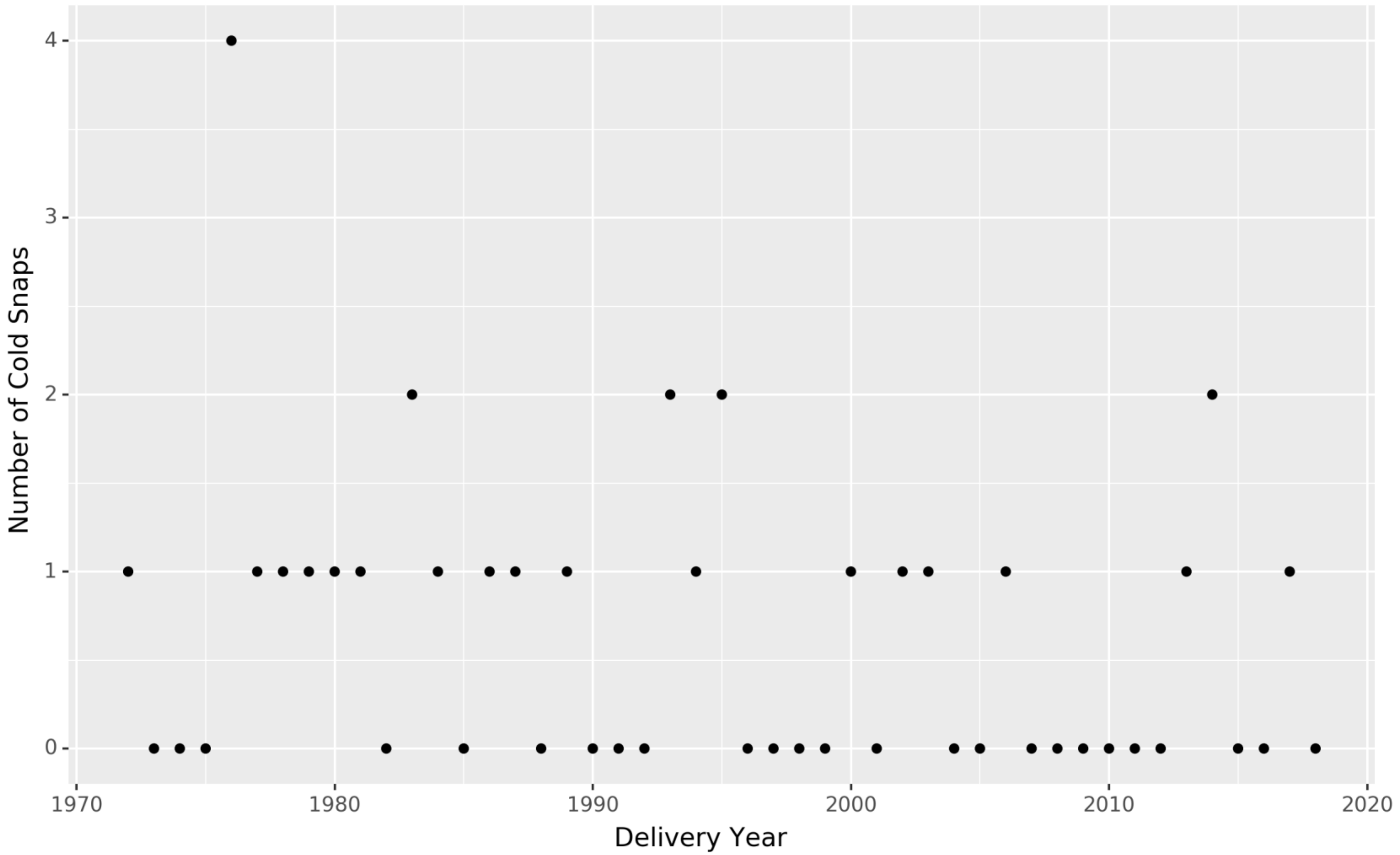
Relevant Risks
Long Duration Cold Snap
Short Duration Cold Snap
Natural Gas Pipeline Disruptions
Solar Intermittency
Wind Intermittency
Coal Refueling (Bridge Failure)
Coal Refueling (Lock and Dam Failure)
Coal Refueling (Rail Failure)
Coal Refueling (River Freezing)
Coal Unavailability (Coal Quality)
Natural Gas Unavailability Non-Firm Units
Oil Refueling (Oil Terminal)
Oil Refueling (Truck Restrictions)
Nuclear Regulatory Shutdown (Fuel Related)
Nuclear Regulatory Shutdown (Non-Fuel Related)
Nuclear Unavailability (High Winds)
Hydro Unavailability (Freezing Rivers)
River Freezing (Cooling Water Impacts)
Ice Storm (Transportation Impacts)

Cold Snap – Definition

- 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
  - The RTO WWP for a given day is calculated as a load-weighted average across 30+ weather stations in the current PJM footprint, and across the 24 hour readings of each day
  - The 21.5°F threshold corresponds to an estimate of the 90^{th} percentile value of historical daily RTO average WWP values

- Weather data from period DY1972 - DY2018 (47 winter periods)
- Average RTO wind-adjusted temperature (WWP) is calculated for each of the winter days

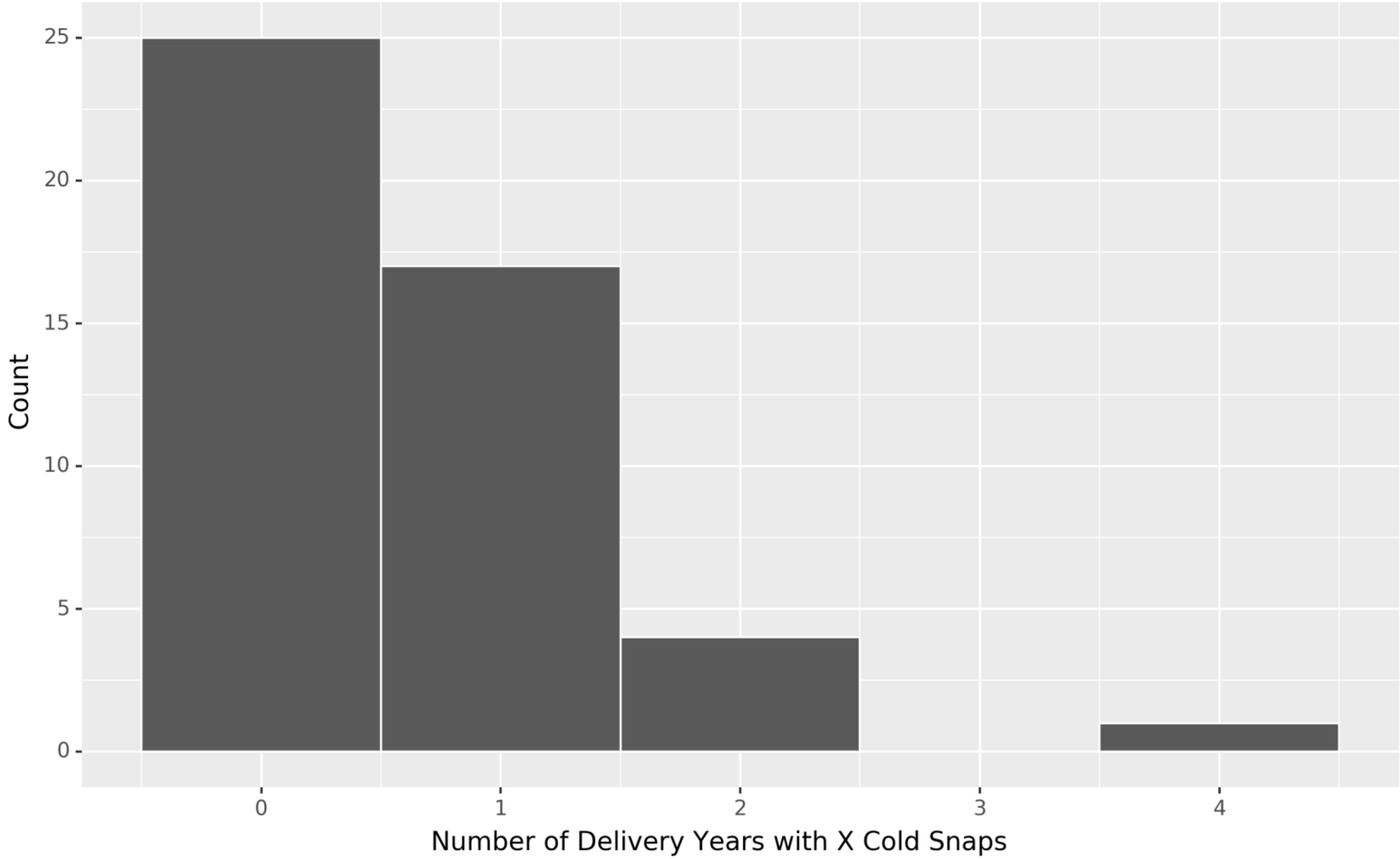
Cold Snaps – Delivery Year vs Number of Cold Snaps



A total of 29 cold snaps in 47 winter periods are identified

Average: 0.6 Cold Snaps per Delivery Year (Winter)

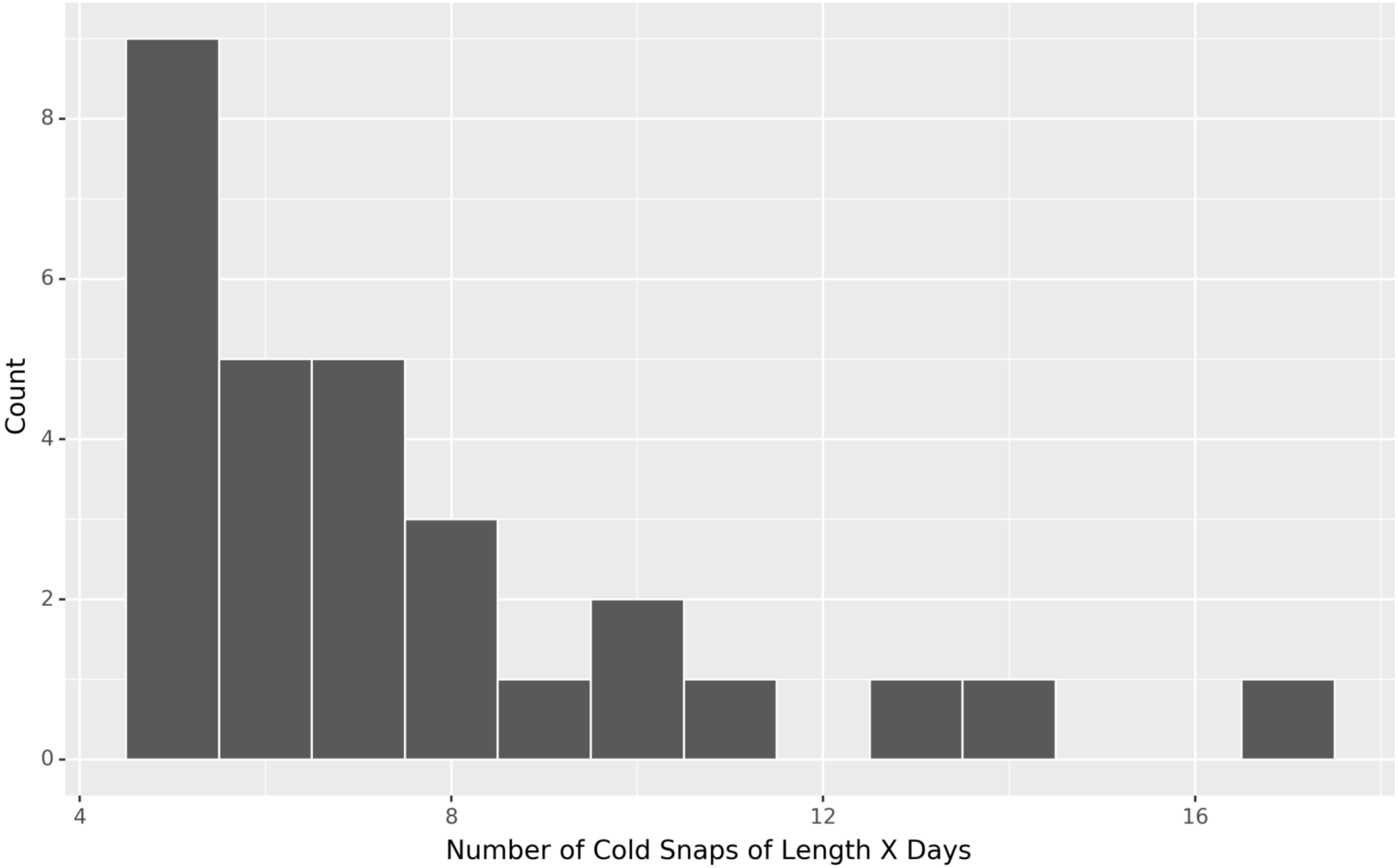
Cold Snaps – Number of DYs with X Cold Snaps



A total of 29 cold snaps in 47 winter periods are identified

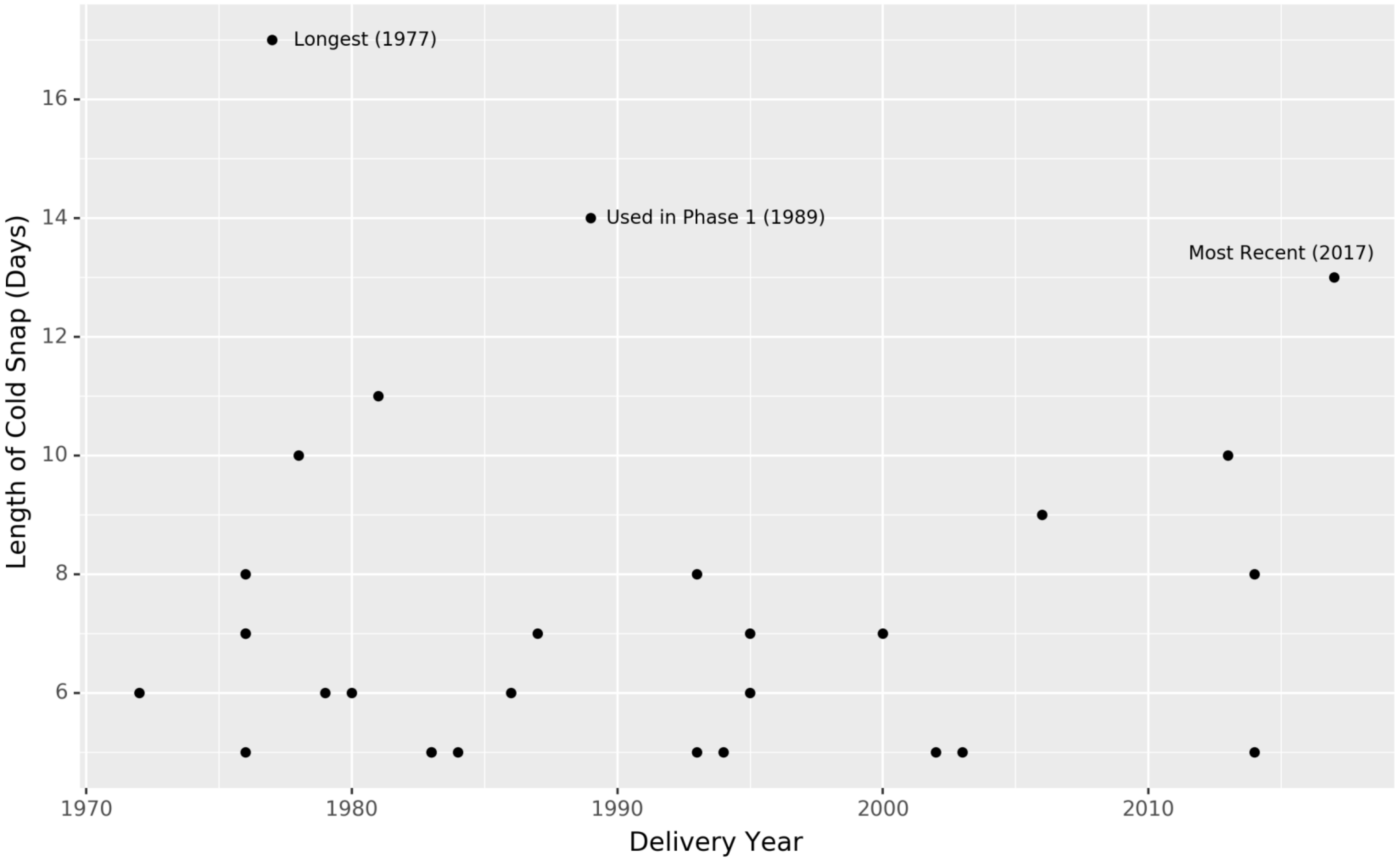
Average: 0.6 Cold Snaps per Delivery Year (Winter)

Cold Snaps – Number of Cold Snaps of Length X Days

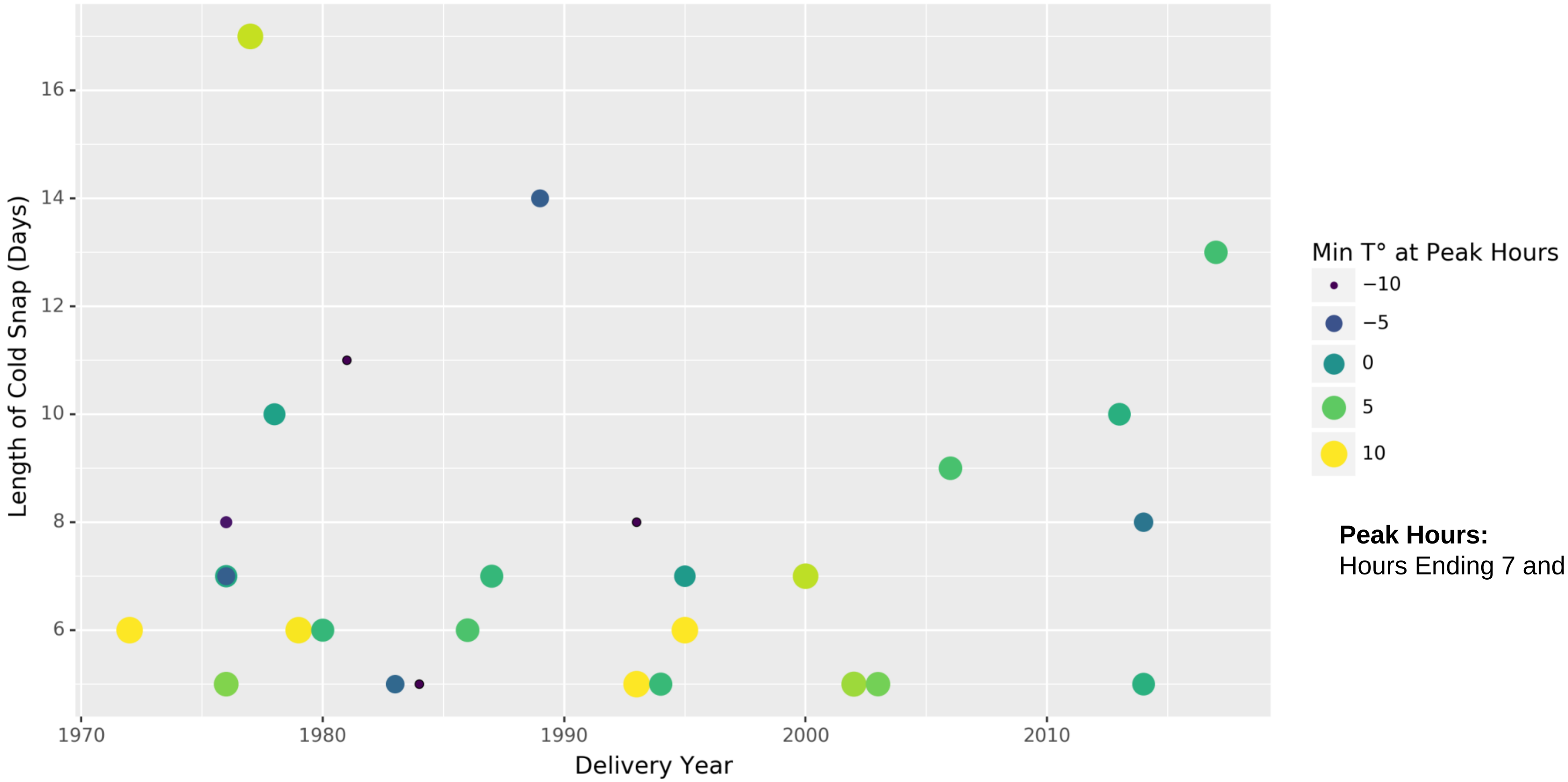


Average Length: 7.5 days

Cold Snaps – Delivery Year vs Length of Cold Snap



Cold Snaps – Delivery Year vs Length of Cold Snap (and Min T at Peak Hours)



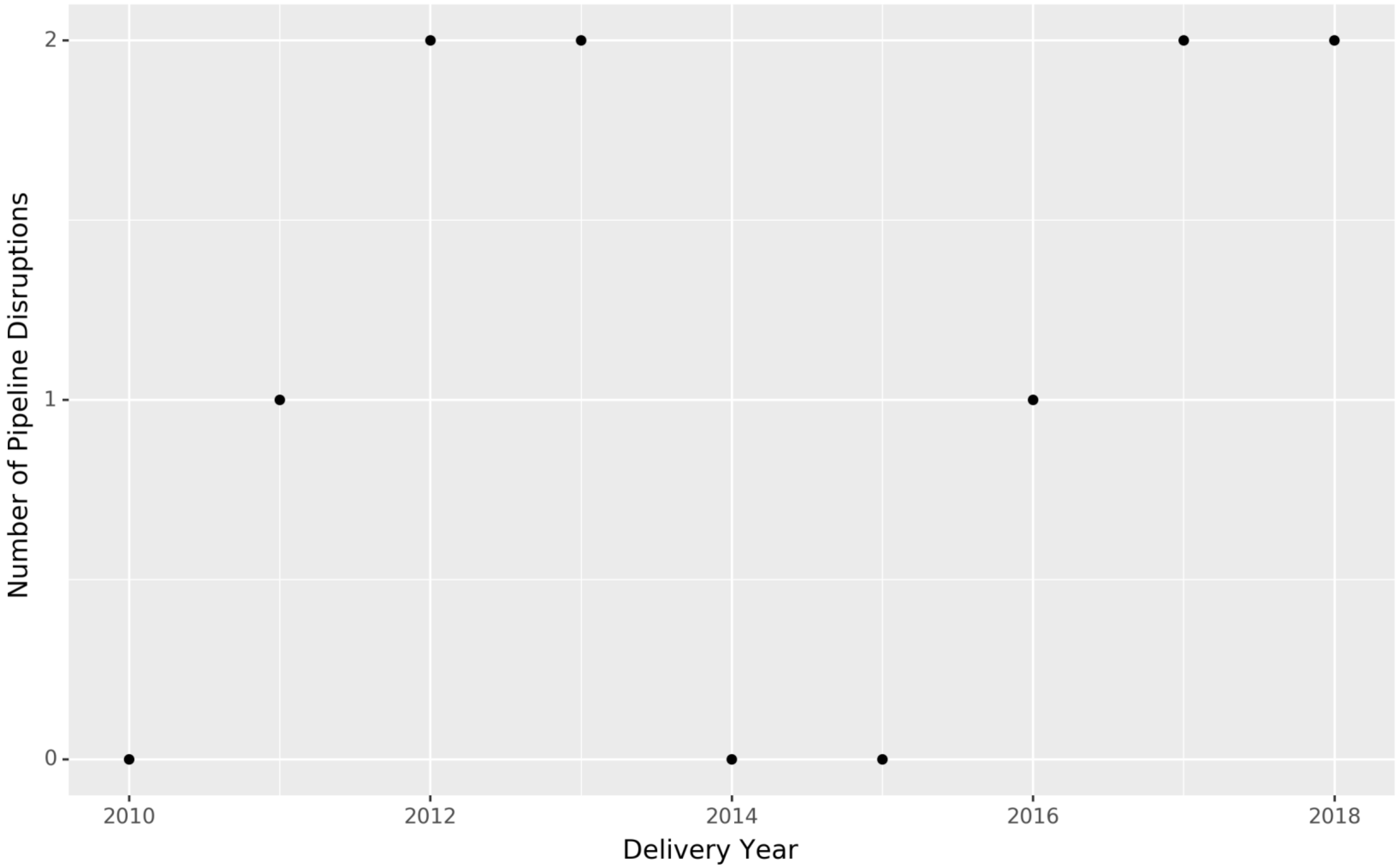
Peak Hours:
Hours Ending 7 and 19

- Pipeline failure event impacting the onshore gas transmission system where the reported failure mode is classified as either a Rupture or a Mechanical Puncture
  - Events where the reported failure mode is classified as a Leak or Other are not included as Pipeline Disruptions because they are deemed to be less impactful

Pipeline Disruptions – Data

- Event data collected by the Pipeline and Hazardous Material Safety Administration (PHMSA) of the United States Department of Transportation in the period 2010 – 2019 Q2
- Events with a start date in Winter time (Dec – Feb) are included
- Events reported by Pipelines or Local Distribution Companies (LDCs) to which PJM generators are connected are included
- Events that have occurred within a PJM State are included

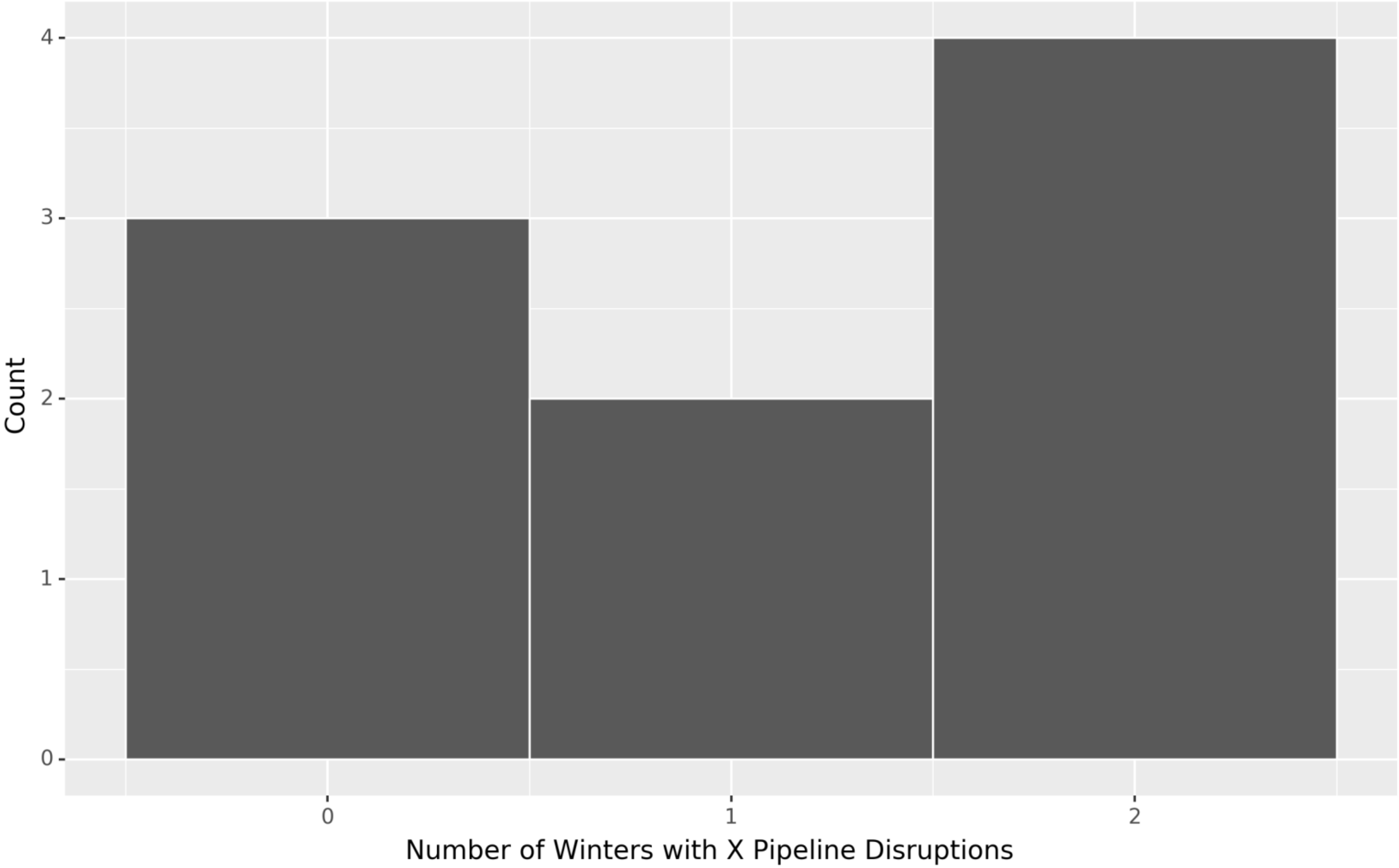
Delivery Year (Winter) vs Number of Pipeline Disruptions



A total of 10 disruptions in 9 winter periods are identified

Average: 1.1 Pipeline Disruptions per Delivery Year (Winter)

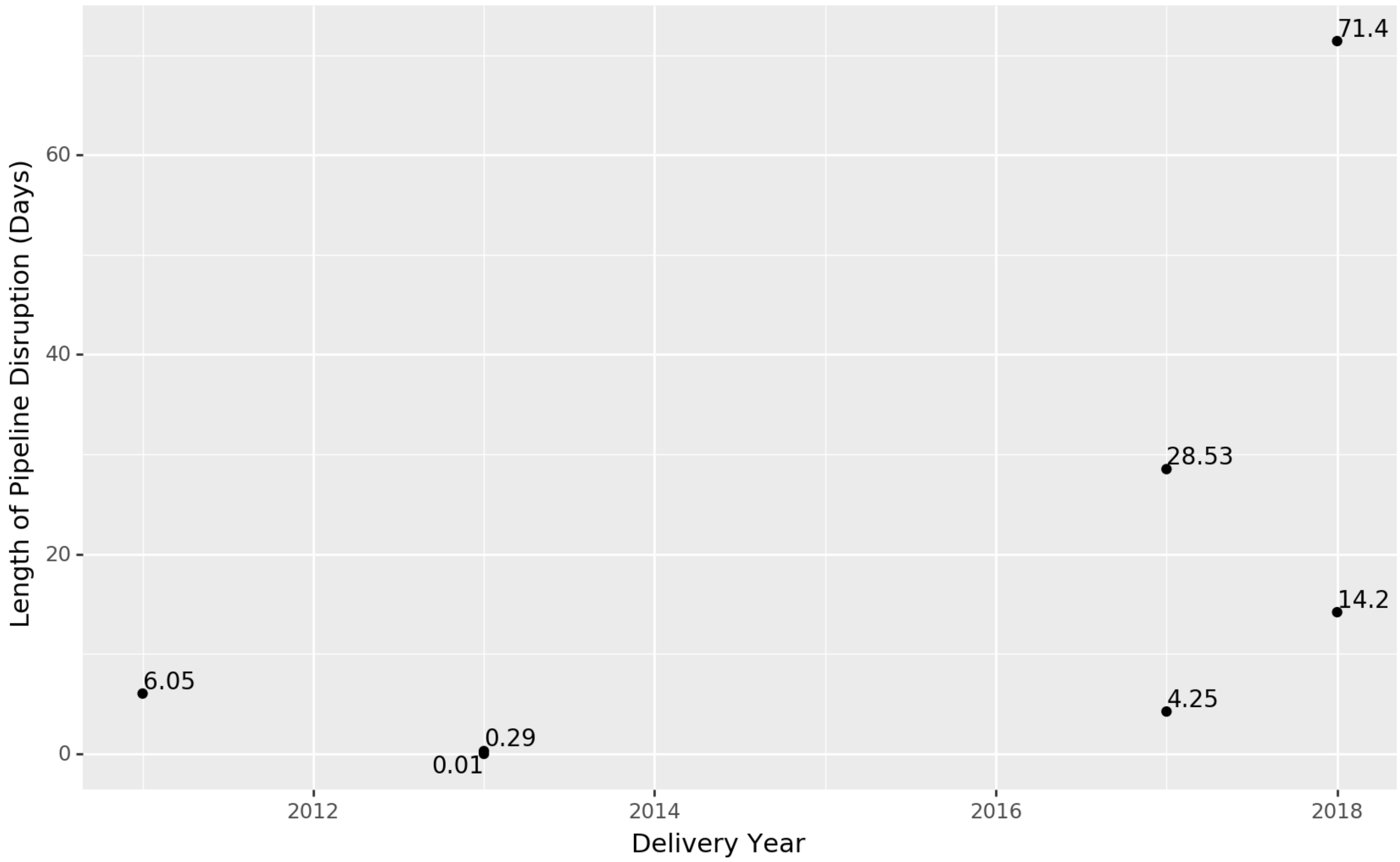
Number of DYs (Winters) with X Pipeline Disruptions



A total of 10 disruptions in 9 winter periods are identified

Average: 1.1 Pipeline Disruptions per Delivery Year (Winter)

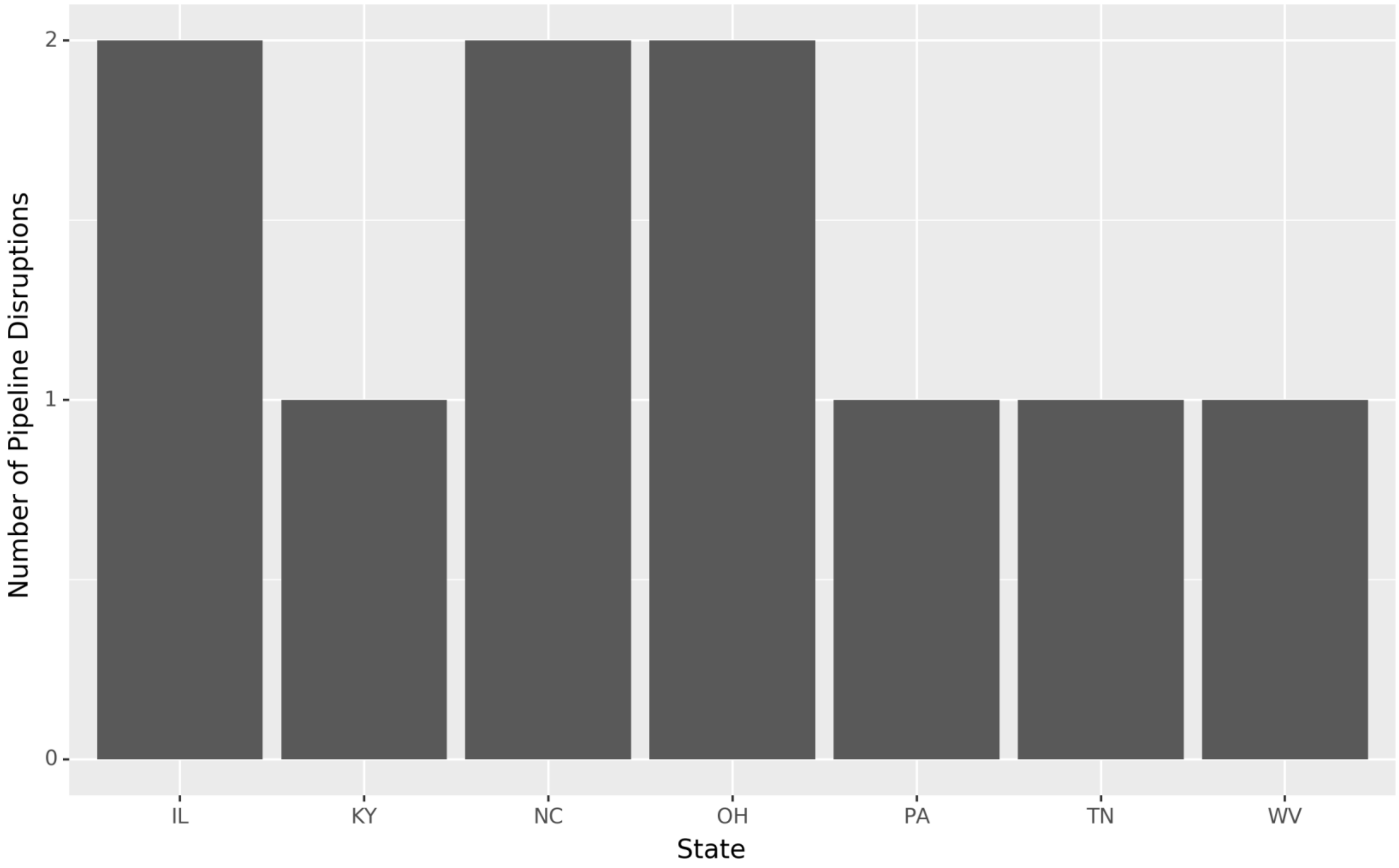
Delivery Year (Winter) vs Duration of Pipeline Disruptions



Duration shown for 7 events only.

Outliers and events with missing data are not shown

State vs Number of Pipeline Disruptions



Historical Data on Relevant Risks

FSSTF

08/12/2019

Risk Assessment Review

June

- 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

Relevant Risks

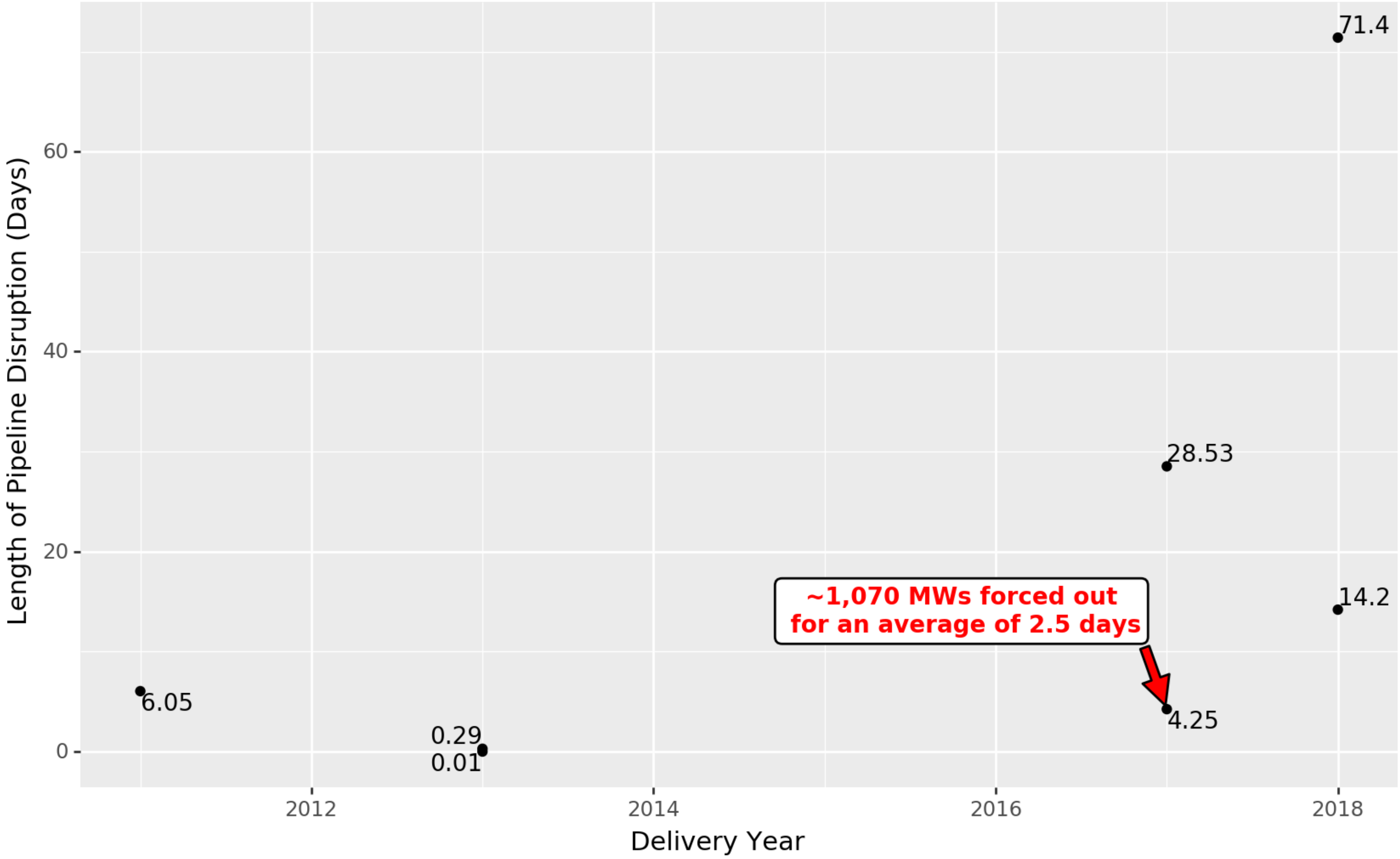
Relevant Risks	
Long Duration Cold Snap	Covered in July
Short Duration Cold Snap	
Natural Gas Pipeline Disruptions	Covered in July and to be continued today
Solar Intermittency	To be covered today
Wind Intermittency	
Coal Refueling (Bridge Failure)	To be covered today
Coal Refueling (Lock and Dam Failure)	
Coal Refueling (Rail Failure)	
Coal Refueling (River Freezing)	
Coal Unavailability (Coal Quality)	
Natural Gas Unavailability Non-Firm Units	
Oil Refueling (Oil Terminal)	
Oil Refueling (Truck Restrictions)	
Nuclear Regulatory Shutdown (Fuel Related)	
Nuclear Regulatory Shutdown (Non-Fuel Related)	
Nuclear Unavailability (High Winds)	
Hydro Unavailability (Freezing Rivers)	
River Freezing (Cooling Water Impacts)	
Ice Storm (Transportation Impacts)	

Relevant Risk:
Pipeline Disruptions

Frequency of Pipeline Disruptions

Based on Pipeline and Hazardous Material Safety Administration (PHMSA) data:

Historical Impact of Pipeline Disruptions



Duration shown for 7 events only. Outliers and events with missing data are not shown

Only the December 2017 disruption impacted PJM generation (approximately 1,070 MW of forced outages)

The rest of the pipeline disruptions that have occurred during Winter in the PJM footprint since 2010 have not impacted PJM generation

Impact of Pipeline Disruptions

- It is difficult to establish the impact of a pipeline disruption on PJM generation based on GADS data because there are no specific cause codes referencing pipeline disruptions
- The limited impact that PJM generation has experienced due to recent pipeline disruptions is not necessarily an indicator of future impact levels
- Had some of the past disruptions occurred at different geographic locations or other times of the year under more stressful conditions, the impact on PJM generation could have been more significant

Relevant Risk:
Wind and Solar Intermittency

Cold Snaps Analyzed:

Cold Snap	Start	Stop	Duration
1	Jan. 21, 2014	Jan. 30 2014	10 Days
2	Jan. 6, 2015	Jan. 10, 2015	5 Days
3	Feb. 13, 2015	Feb. 20, 2015	8 Days
4	Dec. 26, 2017	Jan. 7, 2018	13 Days

Winter Peak Hours:

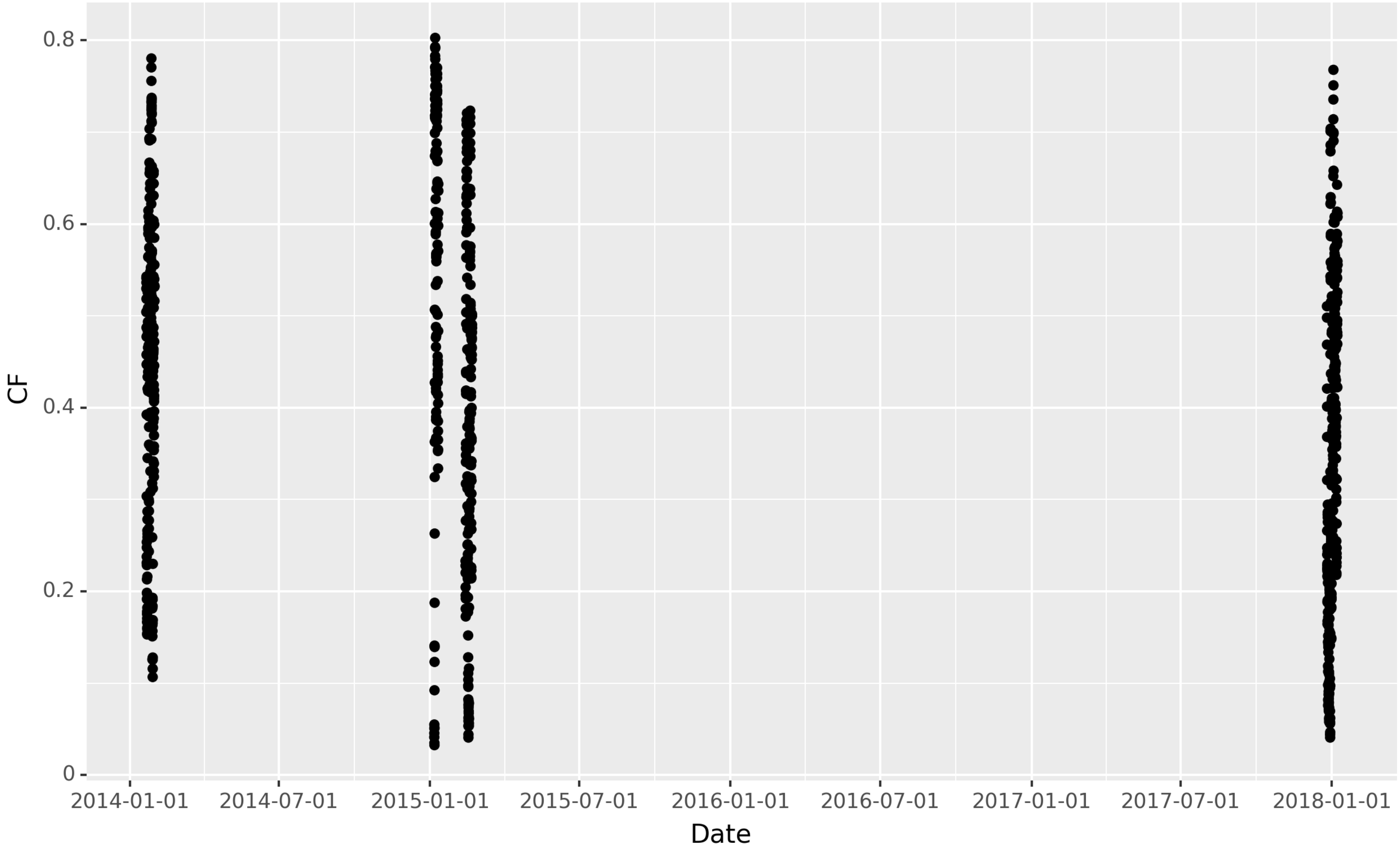
AM Peak	PM Peak
HE08 & HE09	HE19 & HE20

Capacity Factor:

$$\mathrm{CF} = \frac{\text{Actual Hourly Output}}{\text{Total Installed Nameplate}}$$

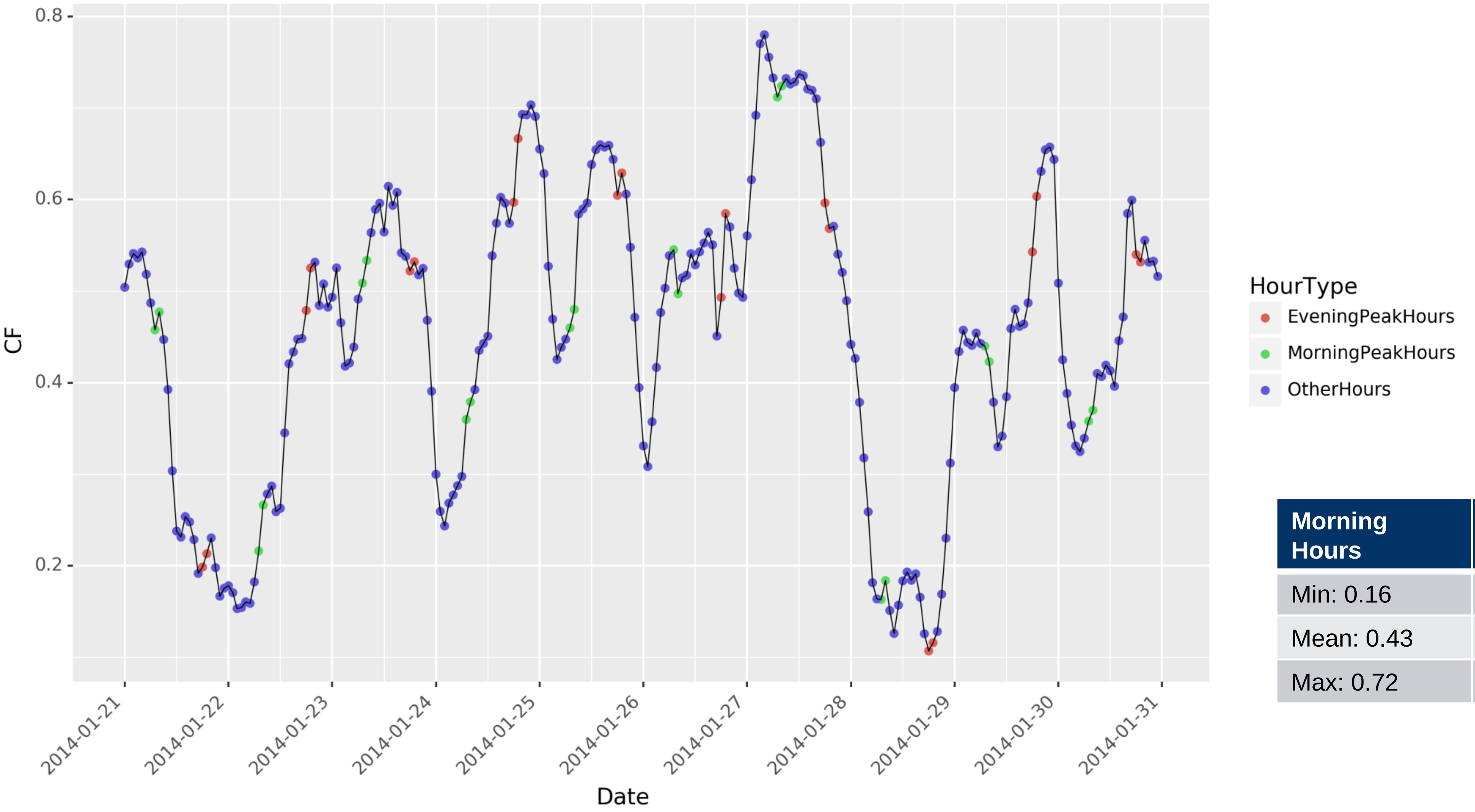
For solar and wind resources, capacity factor serves as an indicator of how effectively the resources are performing

Wind Hourly Capacity Factors



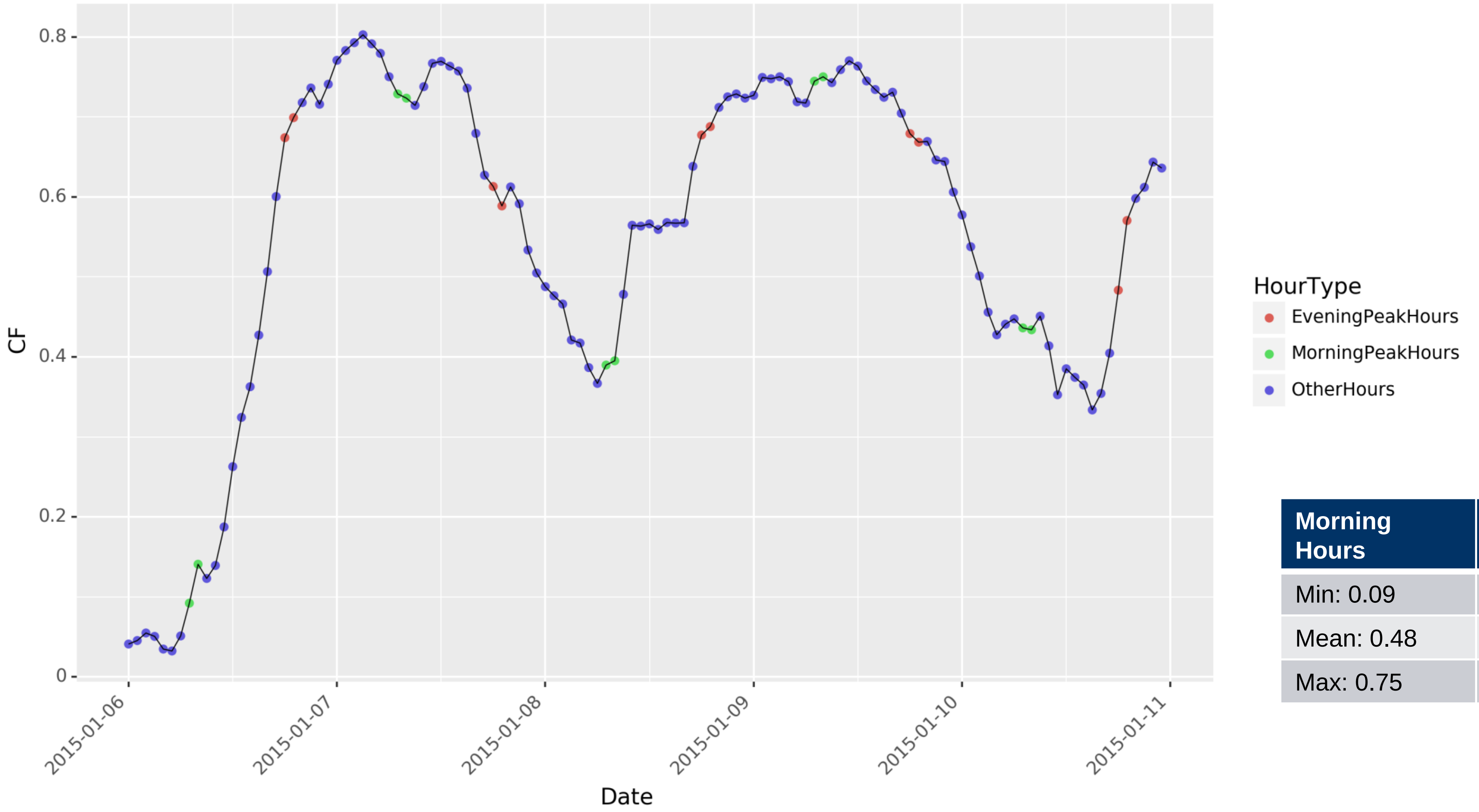
- Wide CF distribution
- All CFs > 0.00
- Many hours are much higher than the anticipated 0.13 CF

Wind Hourly Capacity Factor (01/21/14 – 01/30/14)



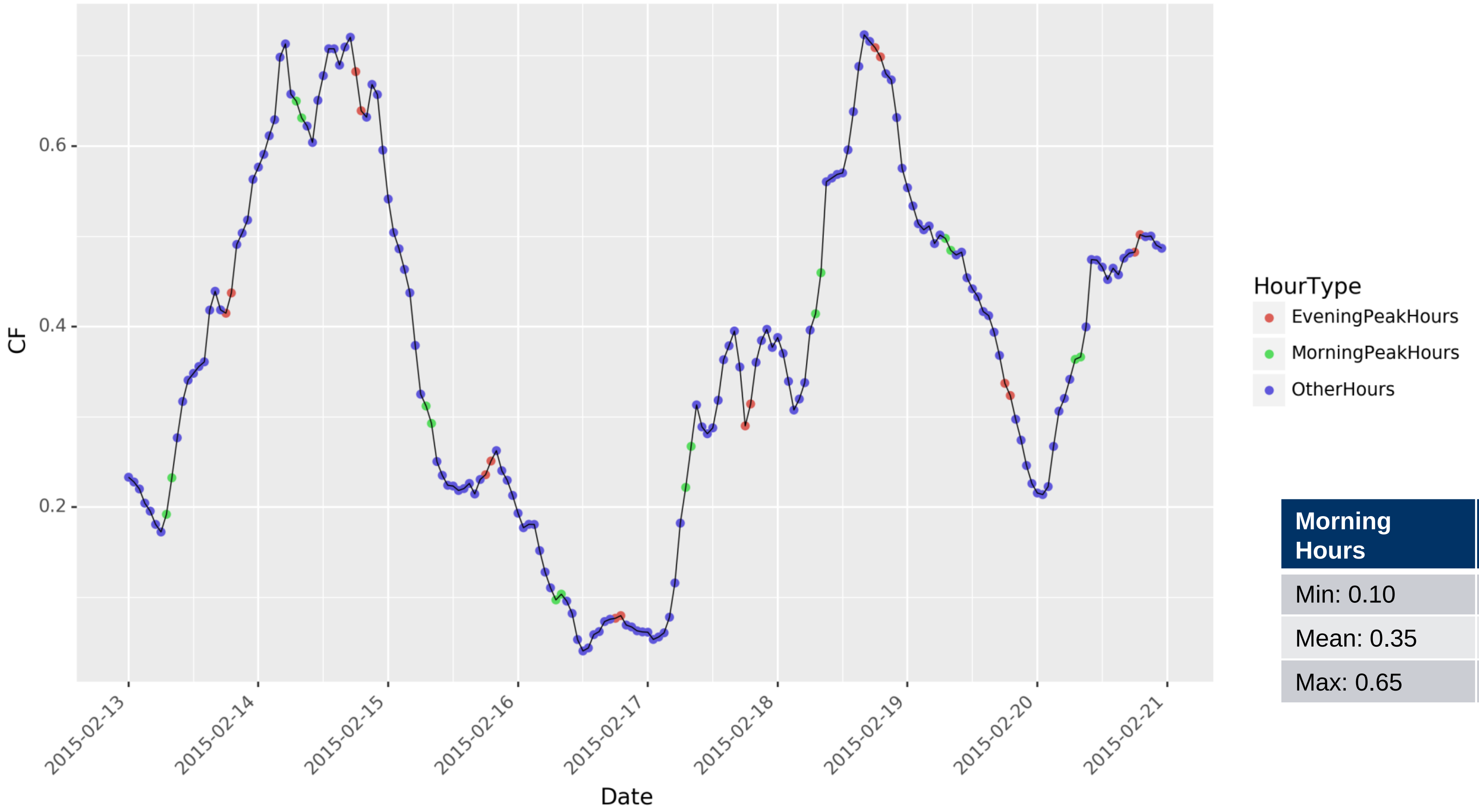
Morning Hours	Evening Hours
Min: 0.16	Min: 0.11
Mean: 0.43	Mean: 0.48
Max: 0.72	Max: 0.67

Wind Hourly Capacity Factor (01/06/15 – 01/10/15)



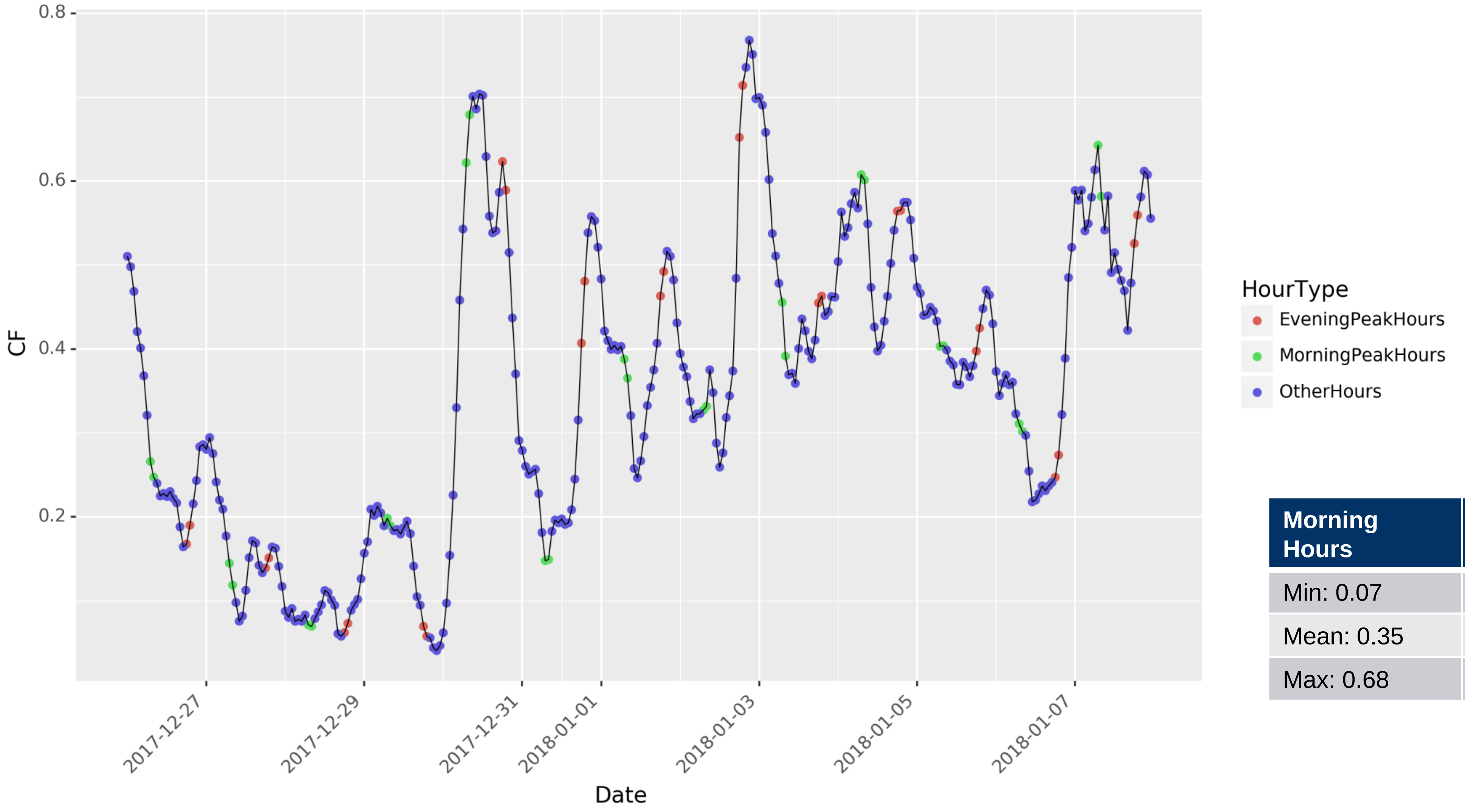
Morning Hours	Evening Hours
Min: 0.09	Min: 0.48
Mean: 0.48	Mean: 0.63
Max: 0.75	Max: 0.70

Wind Hourly Capacity Factor (02/13/15 – 02/20/15)



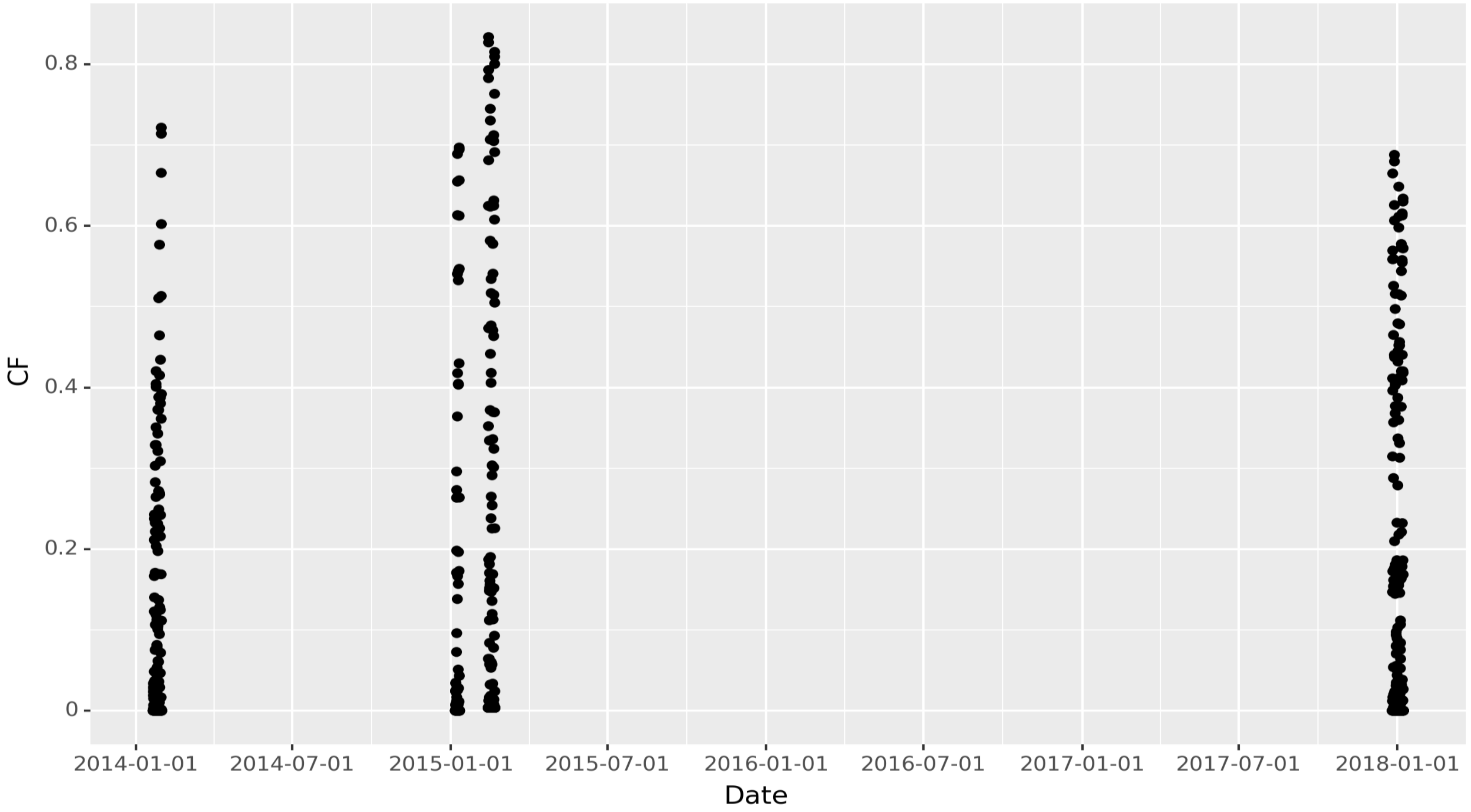
Morning Hours	Evening Hours
Min: 0.10	Min: 0.08
Mean: 0.35	Mean: 0.40
Max: 0.65	Max: 0.71

Wind Hourly Capacity Factor (12/26/17 – 01/07/18)



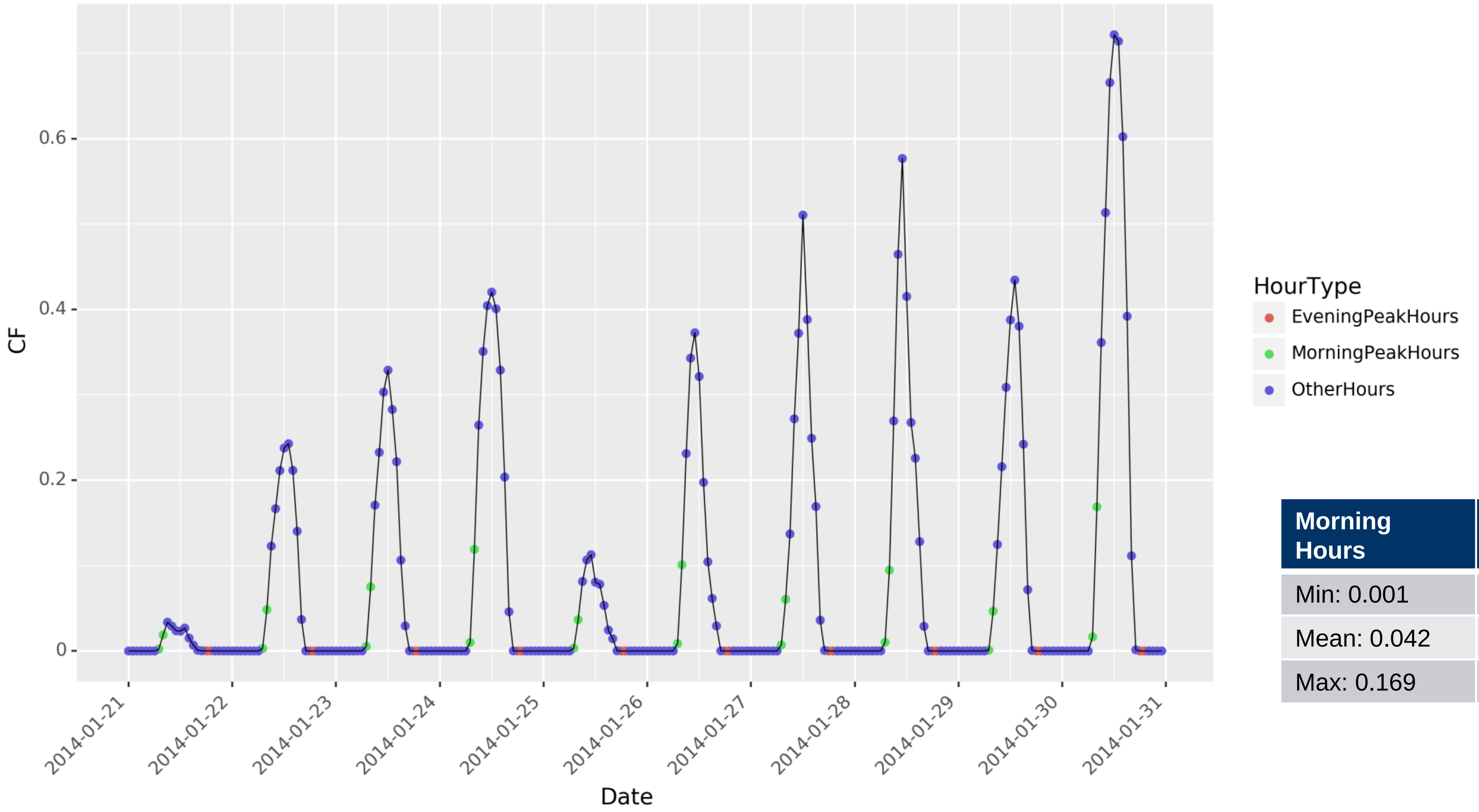
Morning Hours	Evening Hours
Min: 0.07	Min: 0.06
Mean: 0.35	Mean: 0.38
Max: 0.68	Max: 0.71

Solar Hourly Capacity Factors



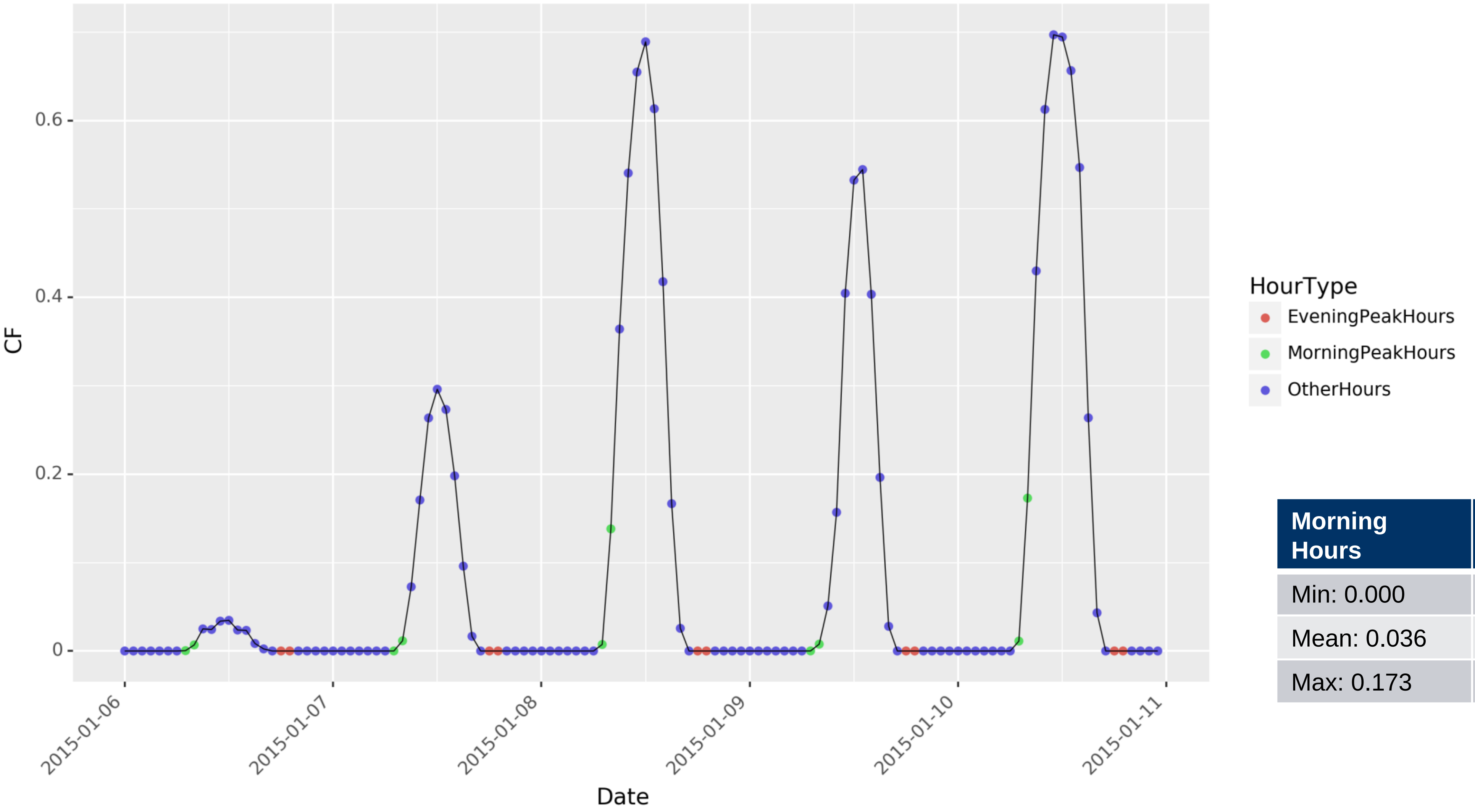
- Wide CF distribution
- Many CFs = 0.00
- Overall average is lower than the anticipated 0.38 CF

Solar Hourly Capacity (01/21/14 – 01/30/14)



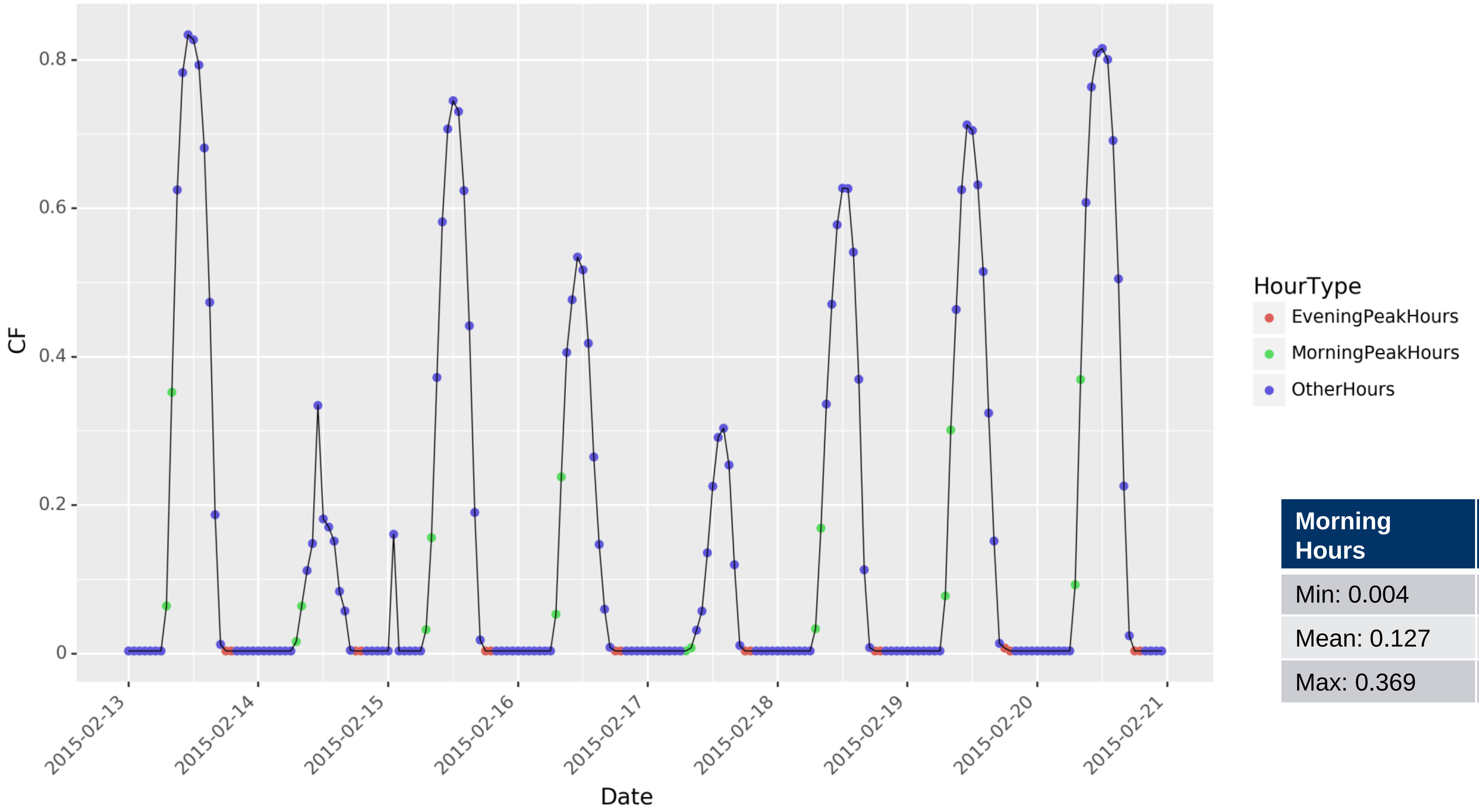
Morning Hours	Evening Hours
Min: 0.001	Min: 0.000
Mean: 0.042	Mean: 0.000
Max: 0.169	Max: 0.000

Solar Hourly Capacity Factor (01/06/15 – 01/10/15)



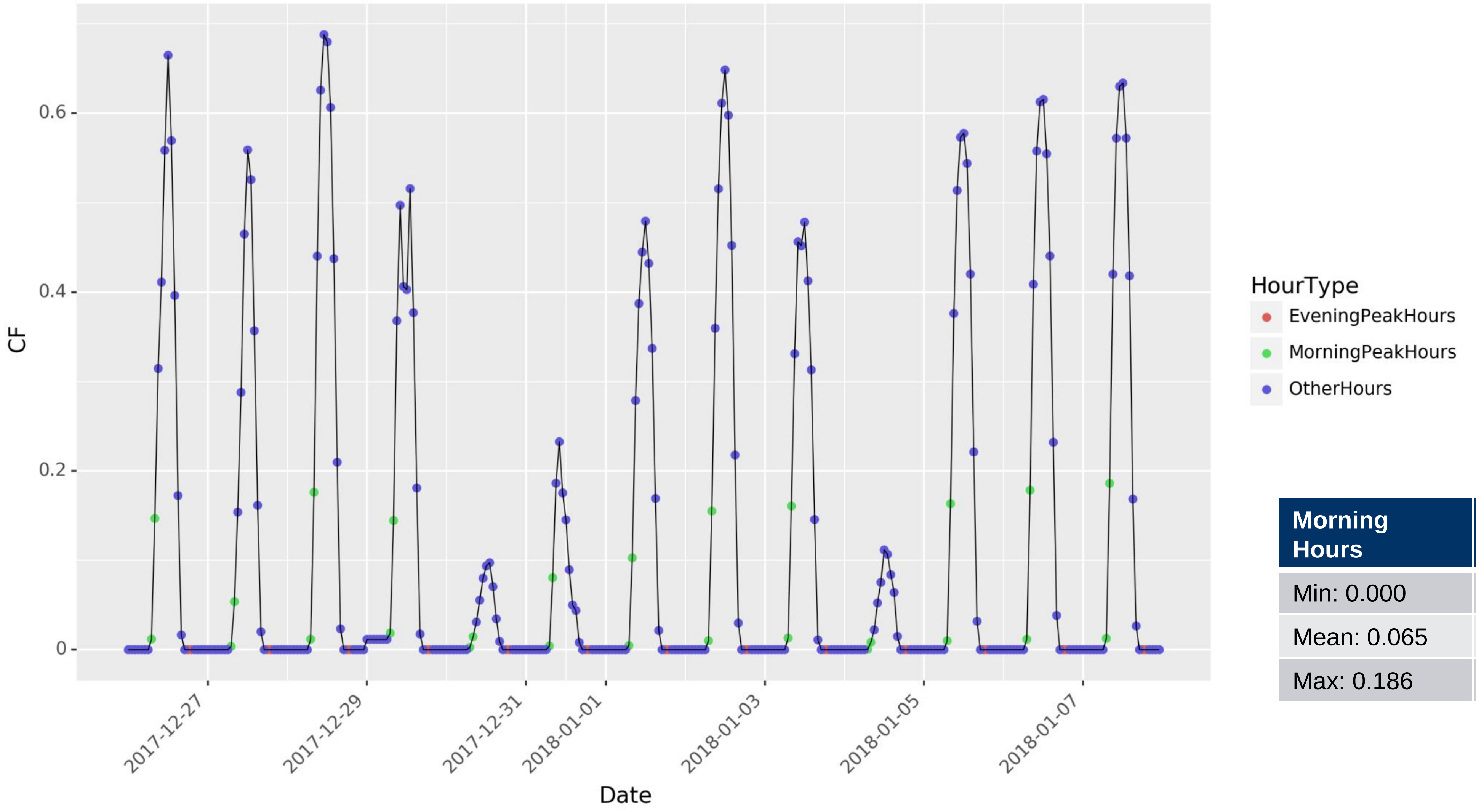
Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.036	Mean: 0.000
Max: 0.173	Max: 0.000

Solar Hourly Capacity Factor (02/13/15 – 02/20/15)



Morning Hours	Evening Hours
Min: 0.004	Min: 0.004
Mean: 0.127	Mean: 0.004
Max: 0.369	Max: 0.007

Solar Hourly Capacity Factor (12/26/17 – 01/07/18)



Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.065	Mean: 0.000
Max: 0.186	Max: 0.000

Wind and Solar Intermittency Summary

Wind:

- Wide distribution of capacity factors during all four cold snaps
- Capacity factors generally outperform the anticipated capacity factor of 0.13 during both peak and non-peak hours

Solar:

- Wide distribution of capacity factors during all four cold snaps
- Capacity factors never reach the anticipated capacity factor of 0.38 during peak hours
- Shorter winter days translate to a small number of daily hours at or above the anticipated capacity factor of 0.38

Relevant Risk:
Fuel Specific Risks

Generating Availability Data System (GADS)

- NERC established data collection system with required data submission for conventional generators 20 MW and greater
- Each event is unique and has an event type that describes the outage/derate and a cause code that describes the mechanism triggering the event

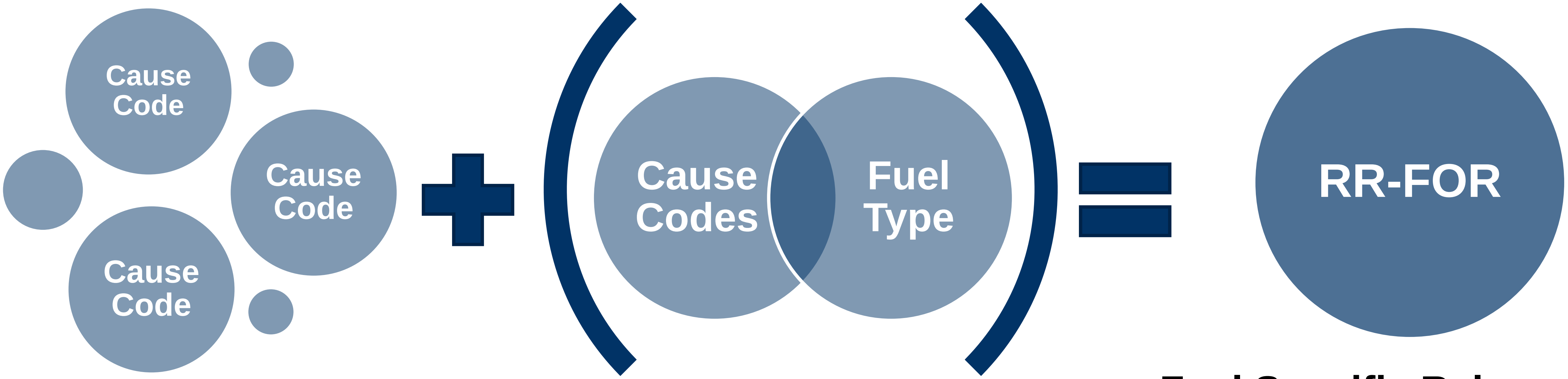
NERC GADS Website:
https://www.nerc.com/pa/RAPA/gads/Pages/GeneratingAvailabilityDataSystem-(GADS).aspx

2019 GADS Cause Codes:
https://www.nerc.com/pa/RAPA/gads/DataReportingInstructions/2019_GADS_Cause_Codes.xlsx

Relevant Risks

Relevant Risks
Long Duration Cold Snap
Short Duration Cold Snap
Natural Gas Pipeline Disruptions
Solar Intermittency
Wind Intermittency
Coal Refueling (Bridge Failure)
Coal Refueling (Lock and Dam Failure)
Coal Refueling (Rail Failure)
Coal Refueling (River Freezing)
Coal Unavailability (Coal Quality)
Natural Gas Unavailability Non-Firm Units
Oil Refueling (Oil Terminal)
Oil Refueling (Truck Restrictions)
Nuclear Regulatory Shutdown (Fuel Related)
Nuclear Regulatory Shutdown (Non-Fuel Related)
Nuclear Unavailability (High Winds)
Hydro Unavailability (Freezing Rivers)
River Freezing (Cooling Water Impacts)
Ice Storm (Transportation Impacts)

Fuel Specific Relevant Risk Forced Outage Rate (RR-FOR)

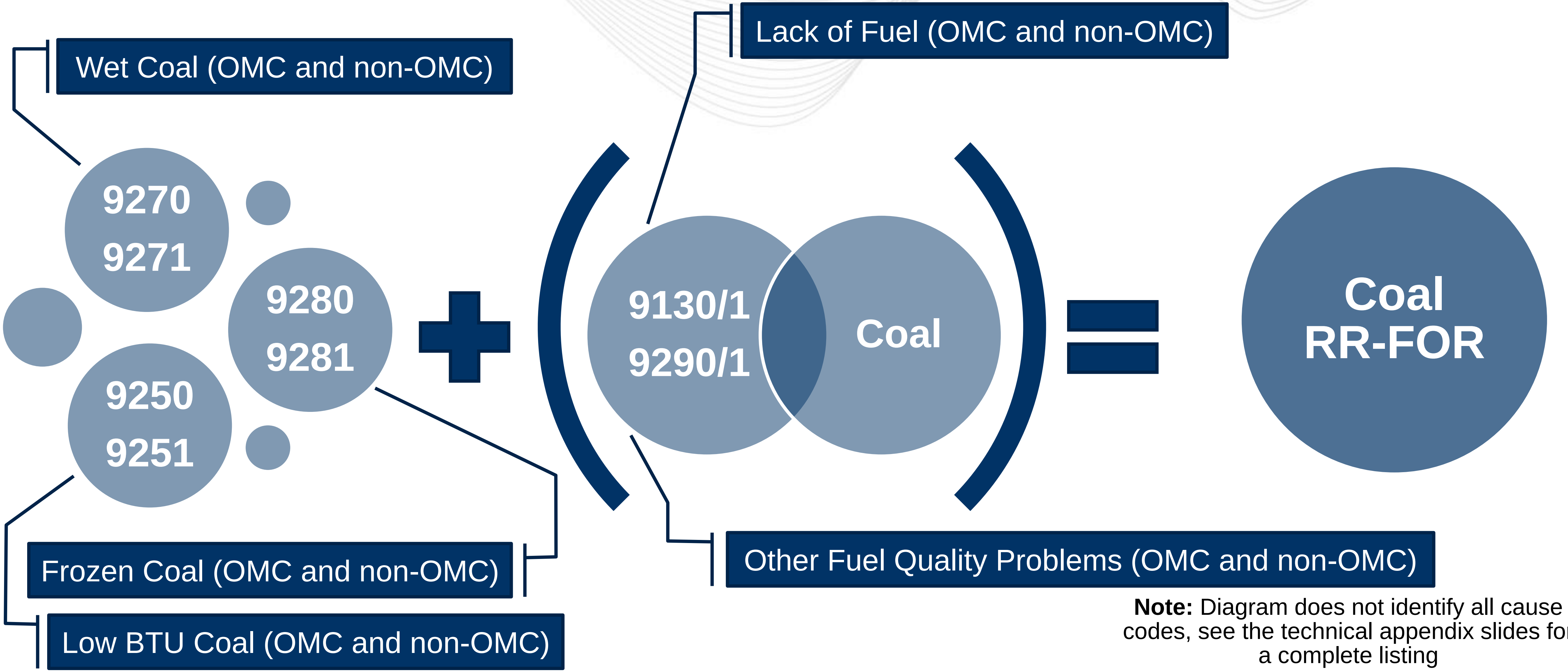


Fuel Specific Cause Codes

Common Cause Codes

Fuel Specific Relevant Risk Forced Outage Rate

Example



Note: Diagram does not identify all cause codes, see the technical appendix slides for a complete listing

Cold Snaps Analyzed:

Cold Snap	Start	Stop	Duration
1	Jan. 21, 2014	Jan. 30 2014	10 Days
2	Jan. 6, 2015	Jan. 10, 2015	5 Days
3	Feb. 13, 2015	Feb. 20, 2015	8 Days
4	Dec. 26, 2017	Jan. 7, 2018	13 Days

Winter Peak Hours:

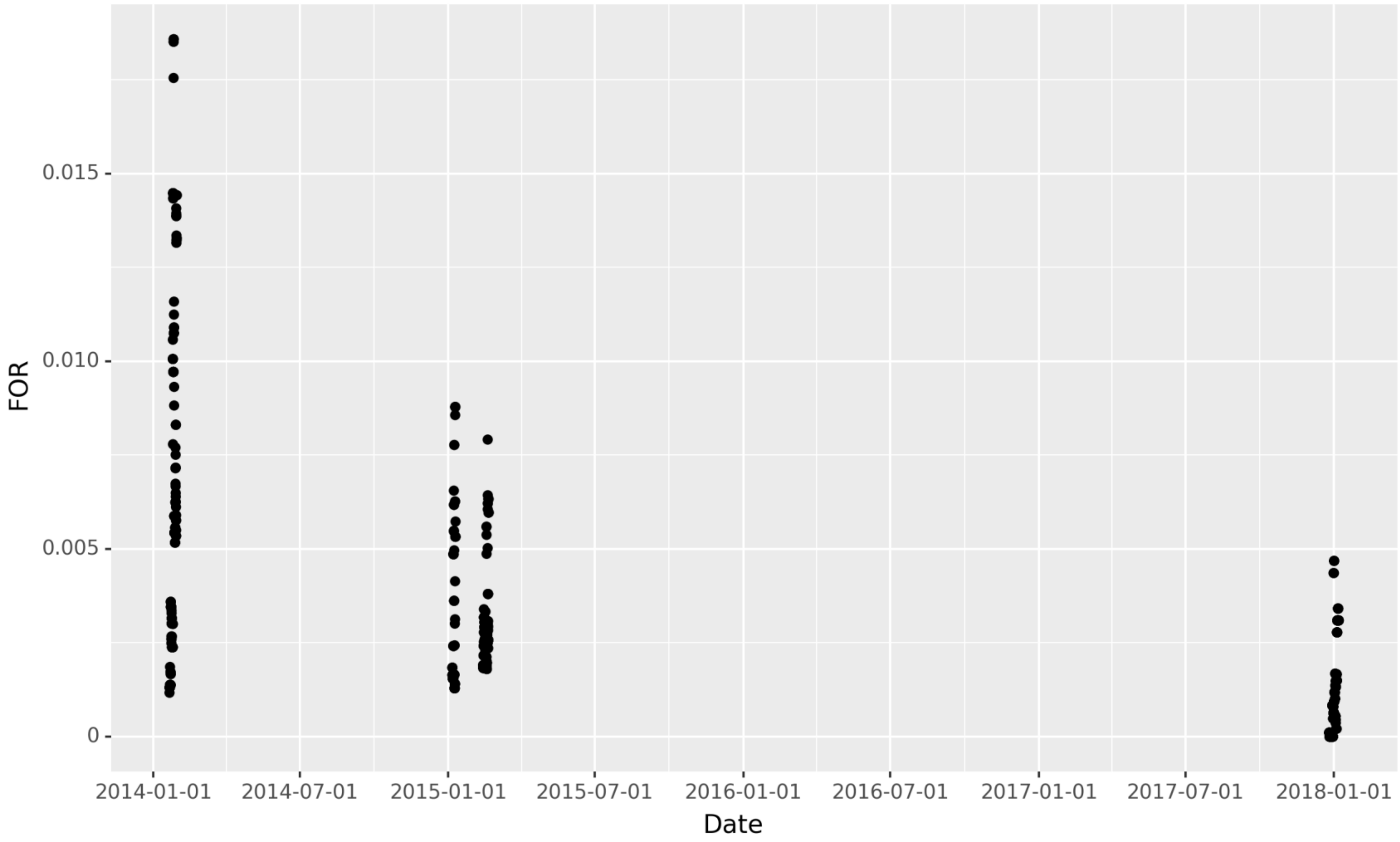
AM Peak	PM Peak
HE08 & HE09	HE19 & HE20

Forced Outage Rate:

$$\mathrm{FOR} = \frac{\text{MW Forced Out}}{\text{Total Installed Nameplate}}$$

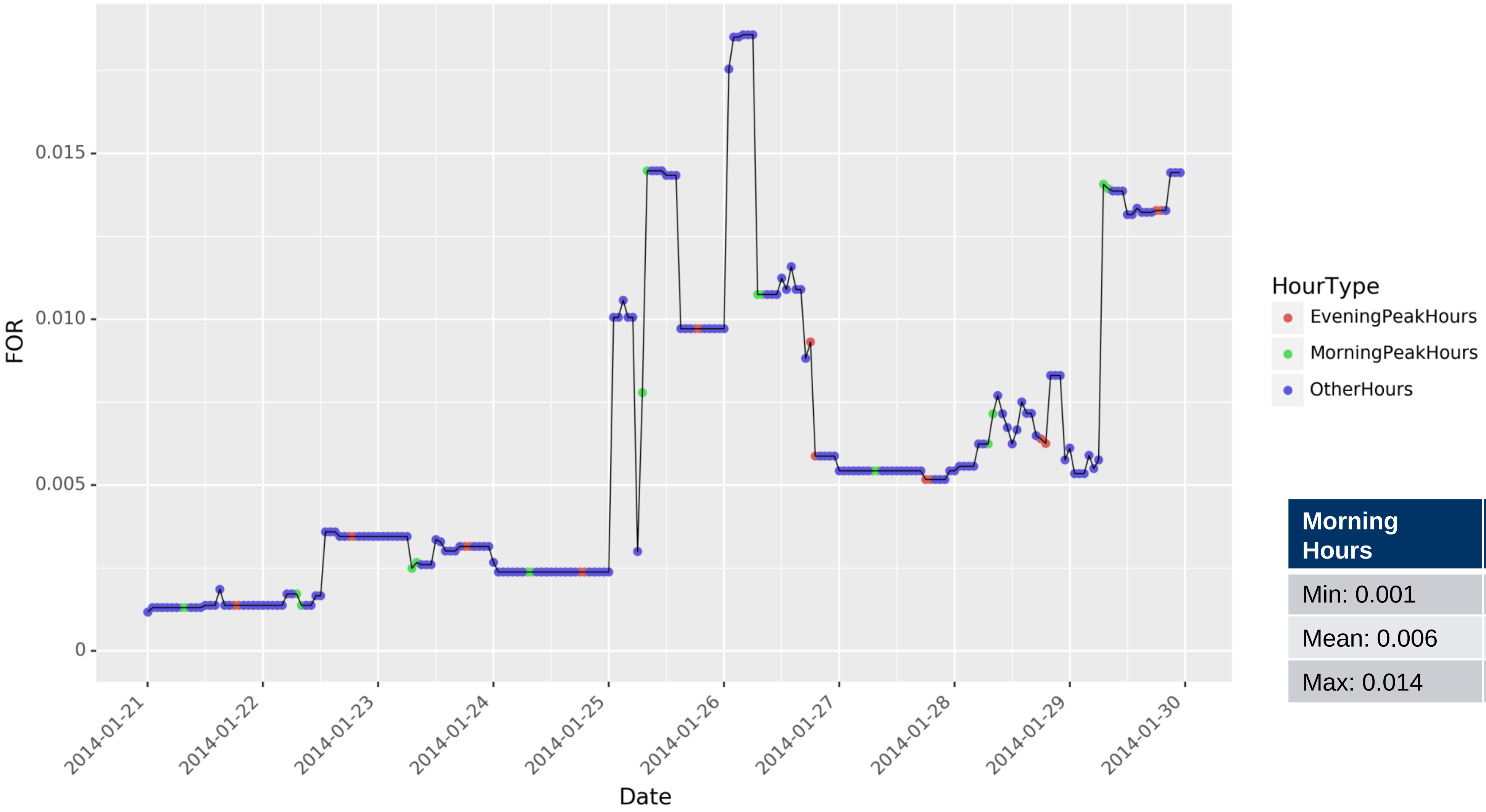
For coal, natural gas, nuclear, hydro, and oil resources, the forced outage rate serves as an indicator of the degree of unavailability for a set of resources

Coal RR-FOR



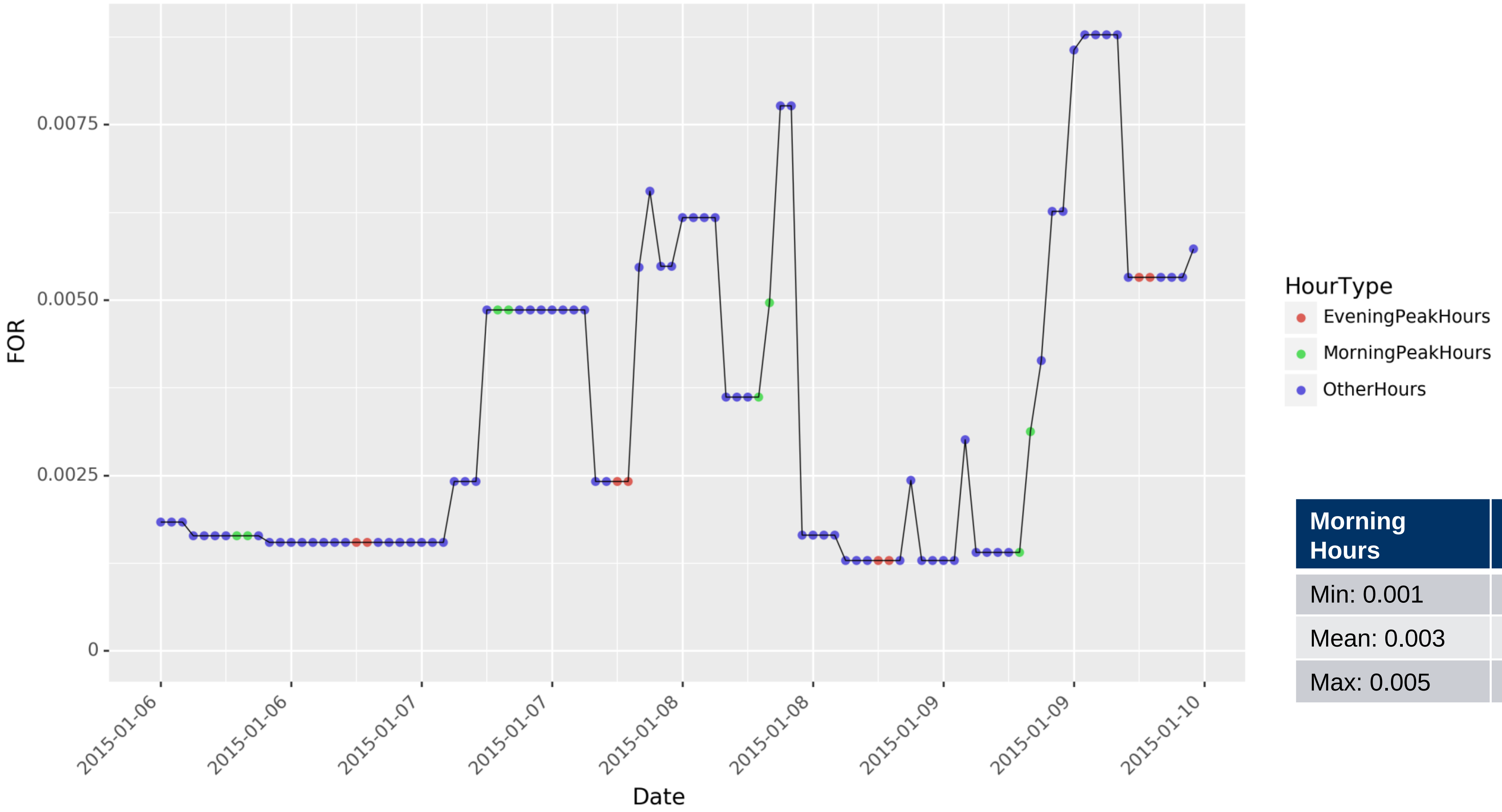
FOR
0.015
0.010
0.005
0
2014-01-01
2014-07-01
2015-01-01
2015-07-01
2016-01-01
2016-07-01
2017-01-01
2017-07-01
2018-01-01
Date

Coal RR-FOR (01/21/14 – 01/30/14)



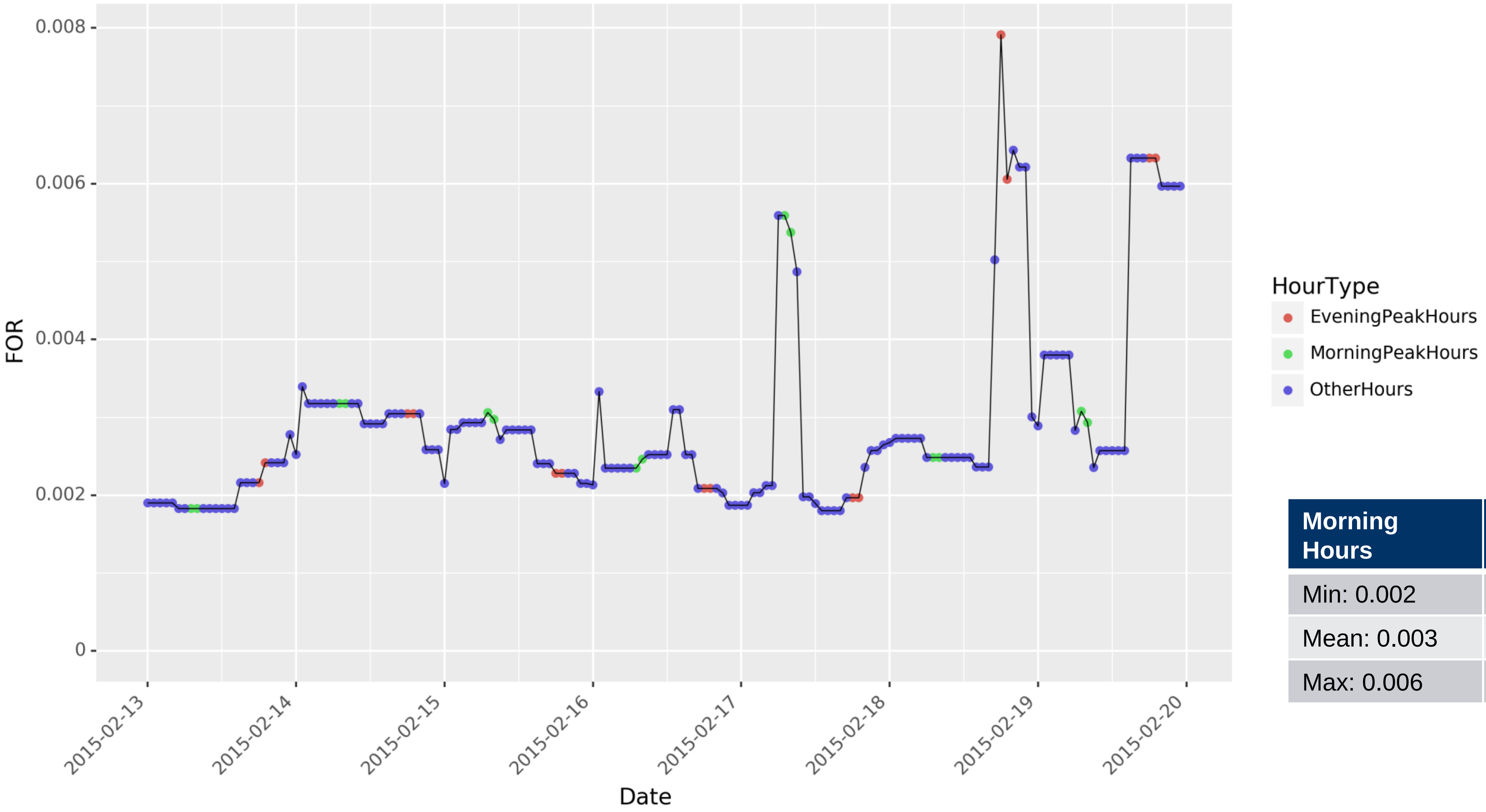
Morning Hours	Evening Hours
Min: 0.001	Min: 0.001
Mean: 0.006	Mean: 0.006
Max: 0.014	Max: 0.013

Coal RR-FOR (01/06/15 – 01/10/15)



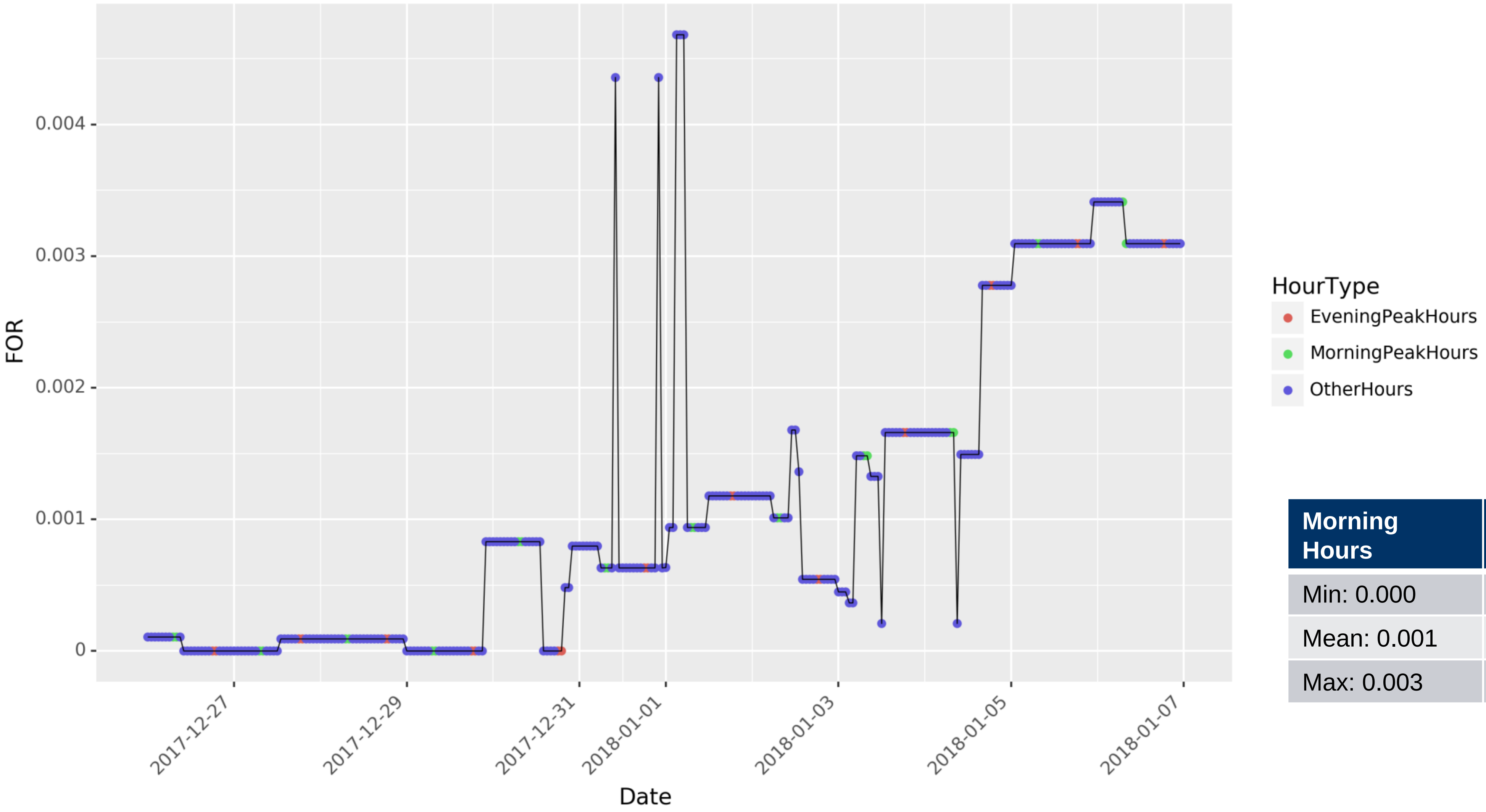
Morning Hours	Evening Hours
Min: 0.001	Min: 0.001
Mean: 0.003	Mean: 0.003
Max: 0.005	Max: 0.005

Coal RR-FOR (02/13/15 – 02/20/15)



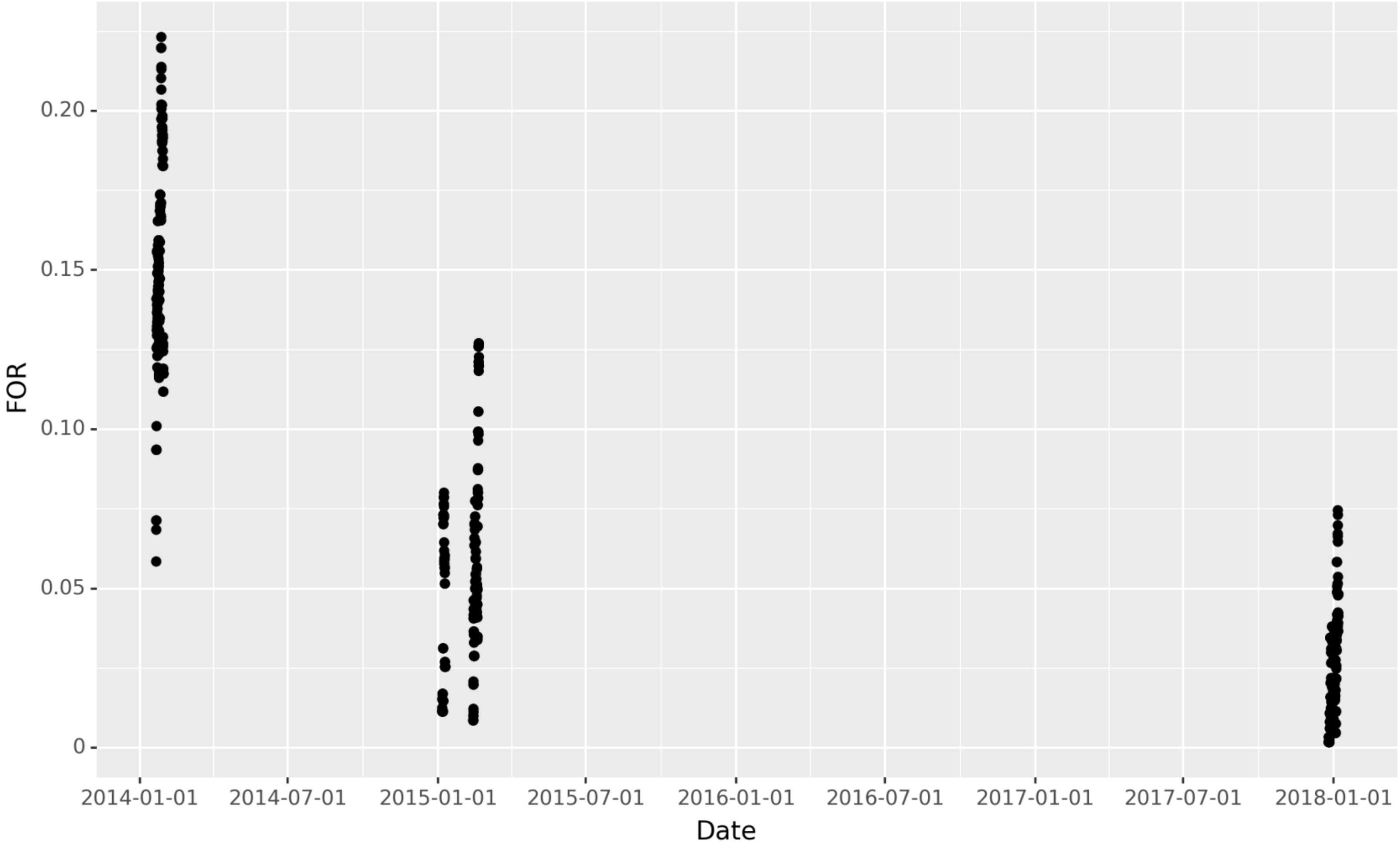
Morning Hours	Evening Hours
Min: 0.002	Min: 0.002
Mean: 0.003	Mean: 0.004
Max: 0.006	Max: 0.008

Coal RR-FOR (12/26/17 – 01/07/18)

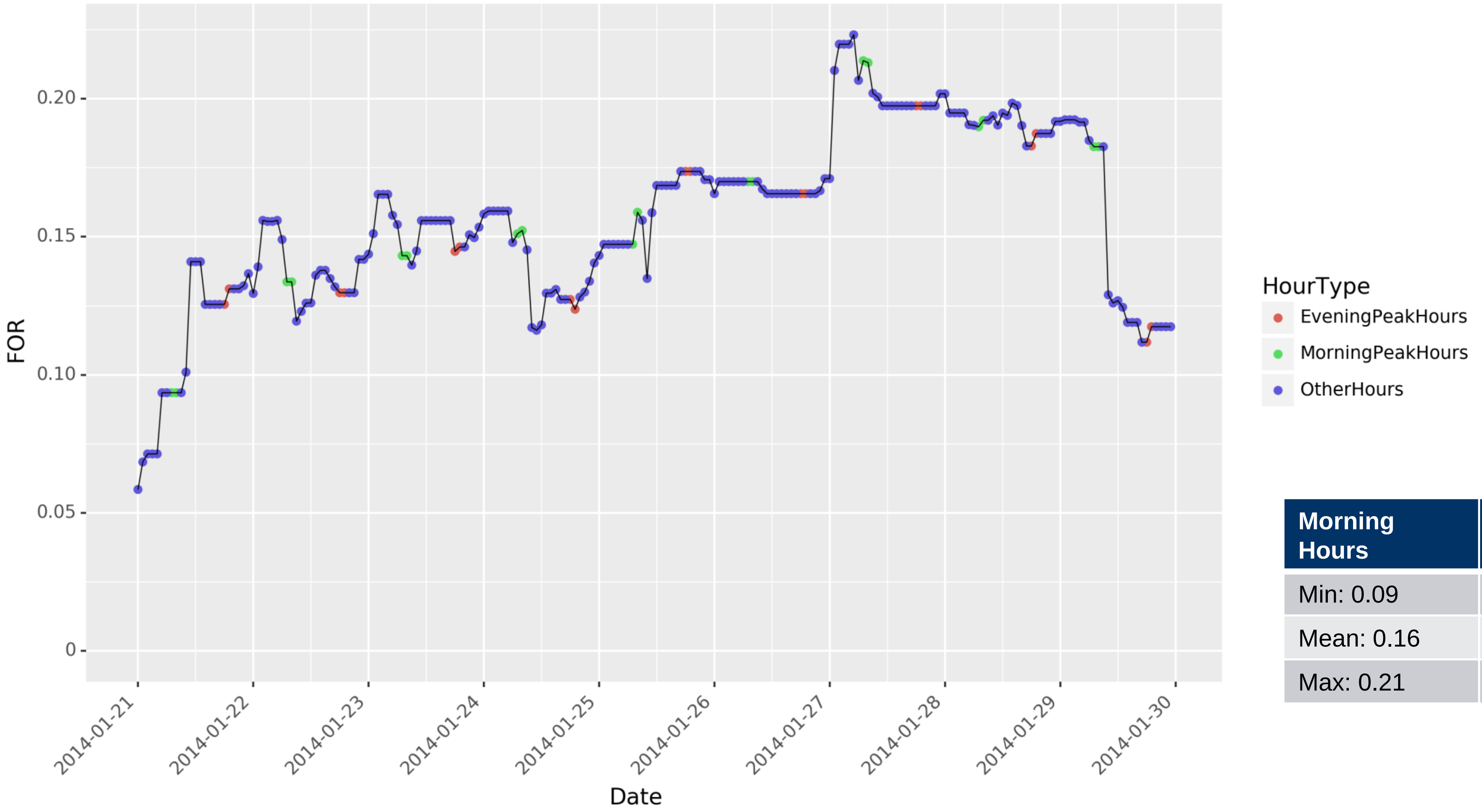


Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.001	Mean: 0.001
Max: 0.003	Max: 0.003

Natural Gas RR-FOR

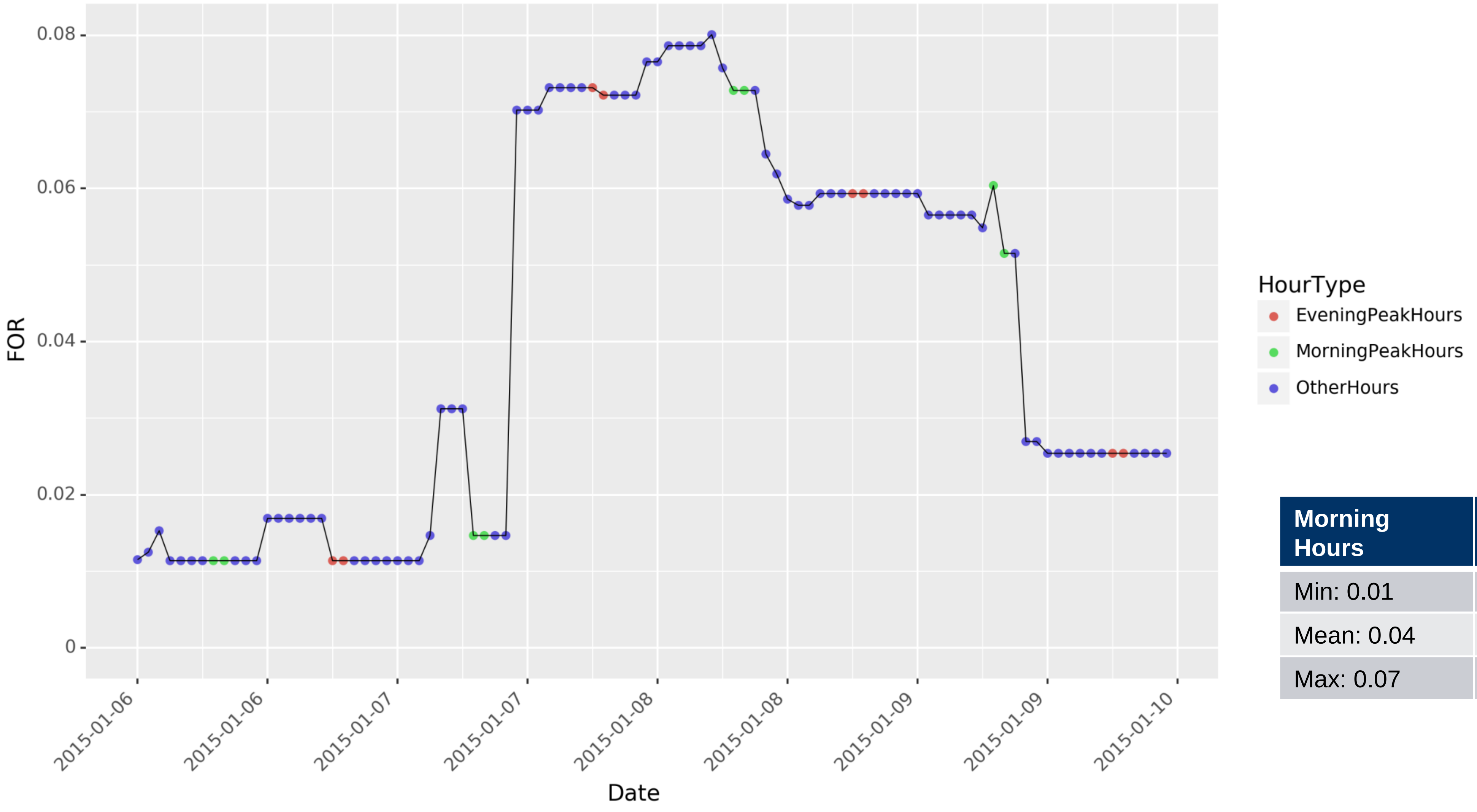


Natural Gas RR-FOR (01/21/14 – 01/30/14)



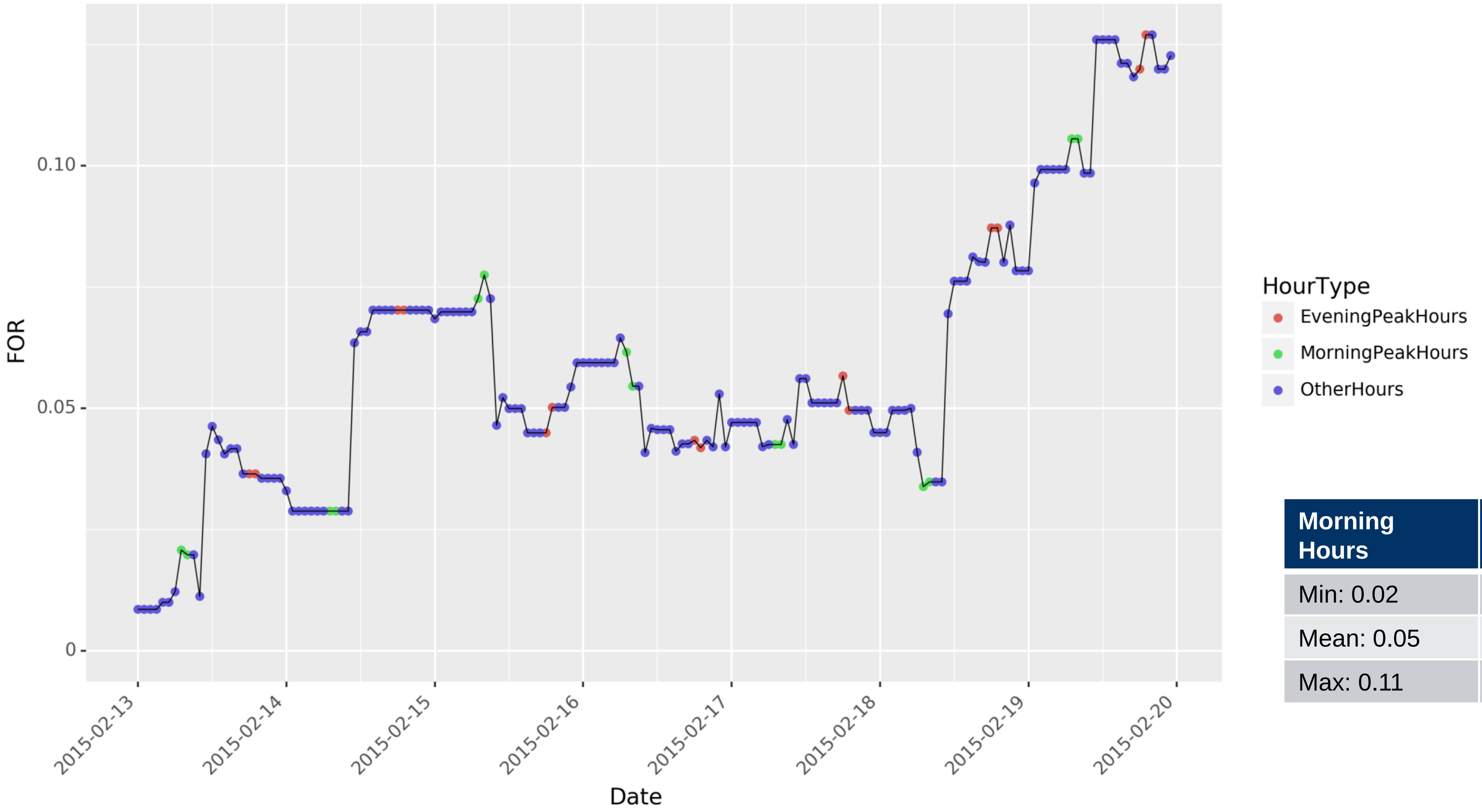
Morning Hours	Evening Hours
Min: 0.09	Min: 0.11
Mean: 0.16	Mean: 0.15
Max: 0.21	Max: 0.20

Natural Gas RR-FOR (01/06/15 – 01/10/15)



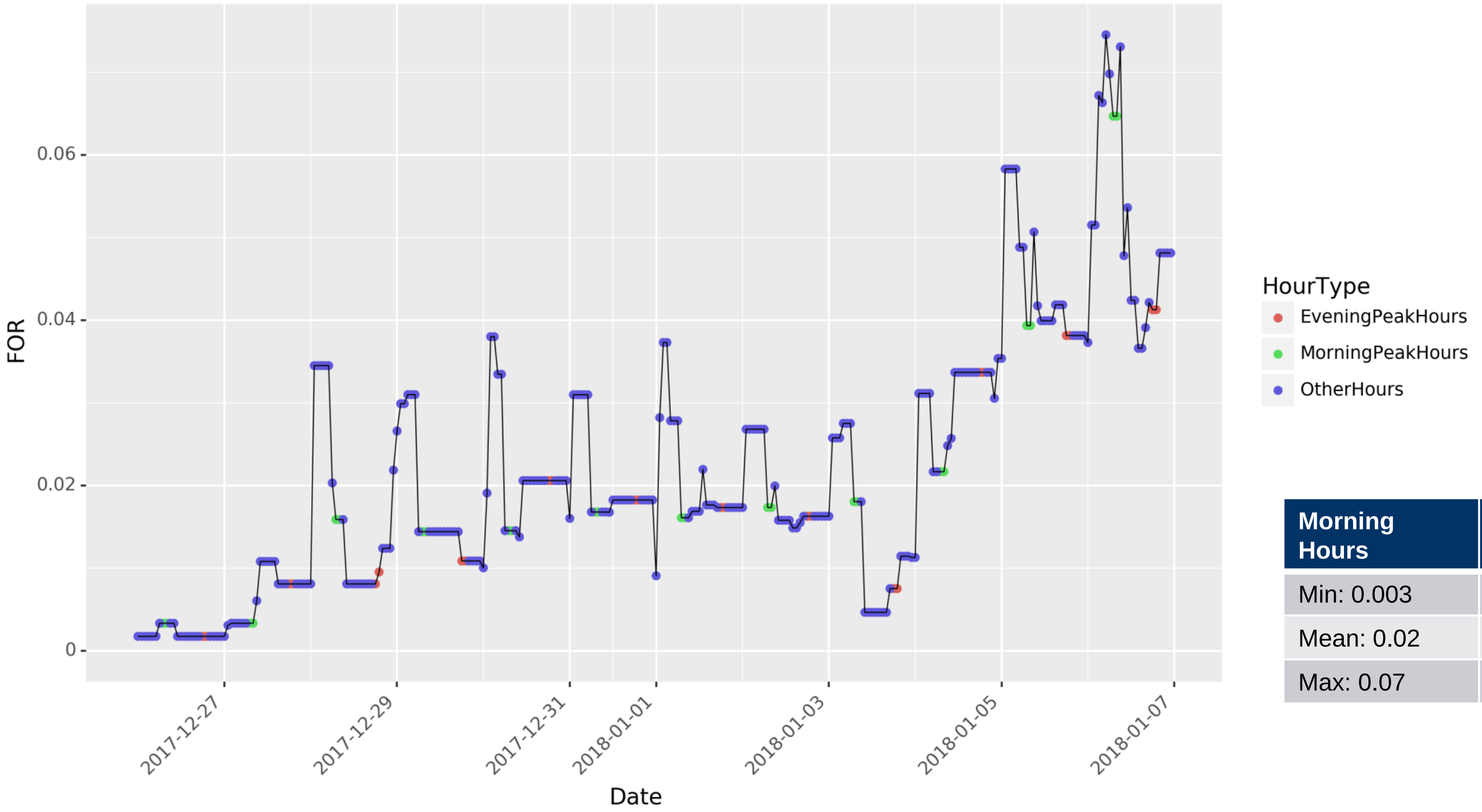
Morning Hours	Evening Hours
Min: 0.01	Min: 0.01
Mean: 0.04	Mean: 0.04
Max: 0.07	Max: 0.07

Natural Gas RR-FOR (02/13/15 – 02/20/15)



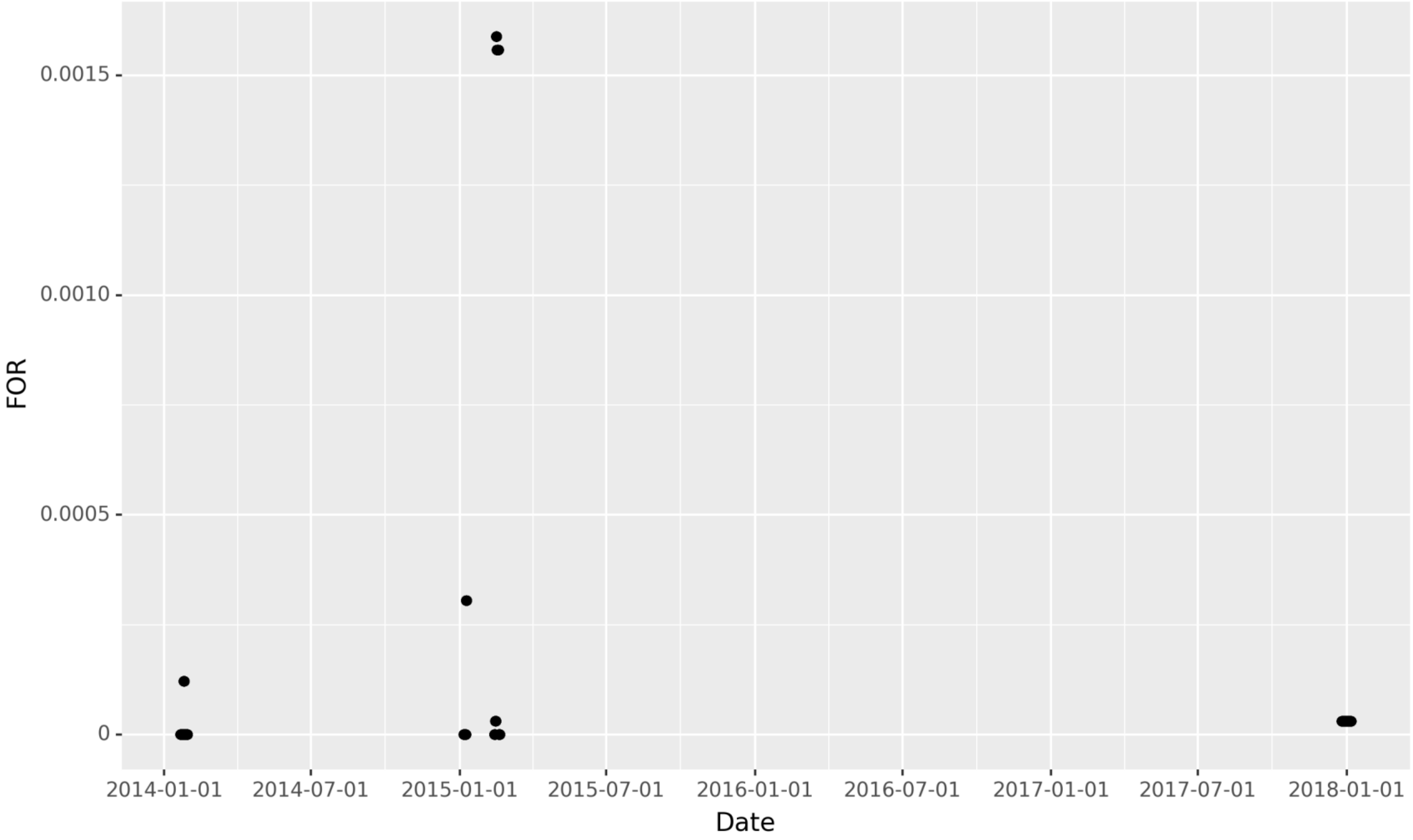
Morning Hours	Evening Hours
Min: 0.02	Min: 0.04
Mean: 0.05	Mean: 0.07
Max: 0.11	Max: 0.13

Natural Gas RR-FOR (12/26/17 – 01/07/18)

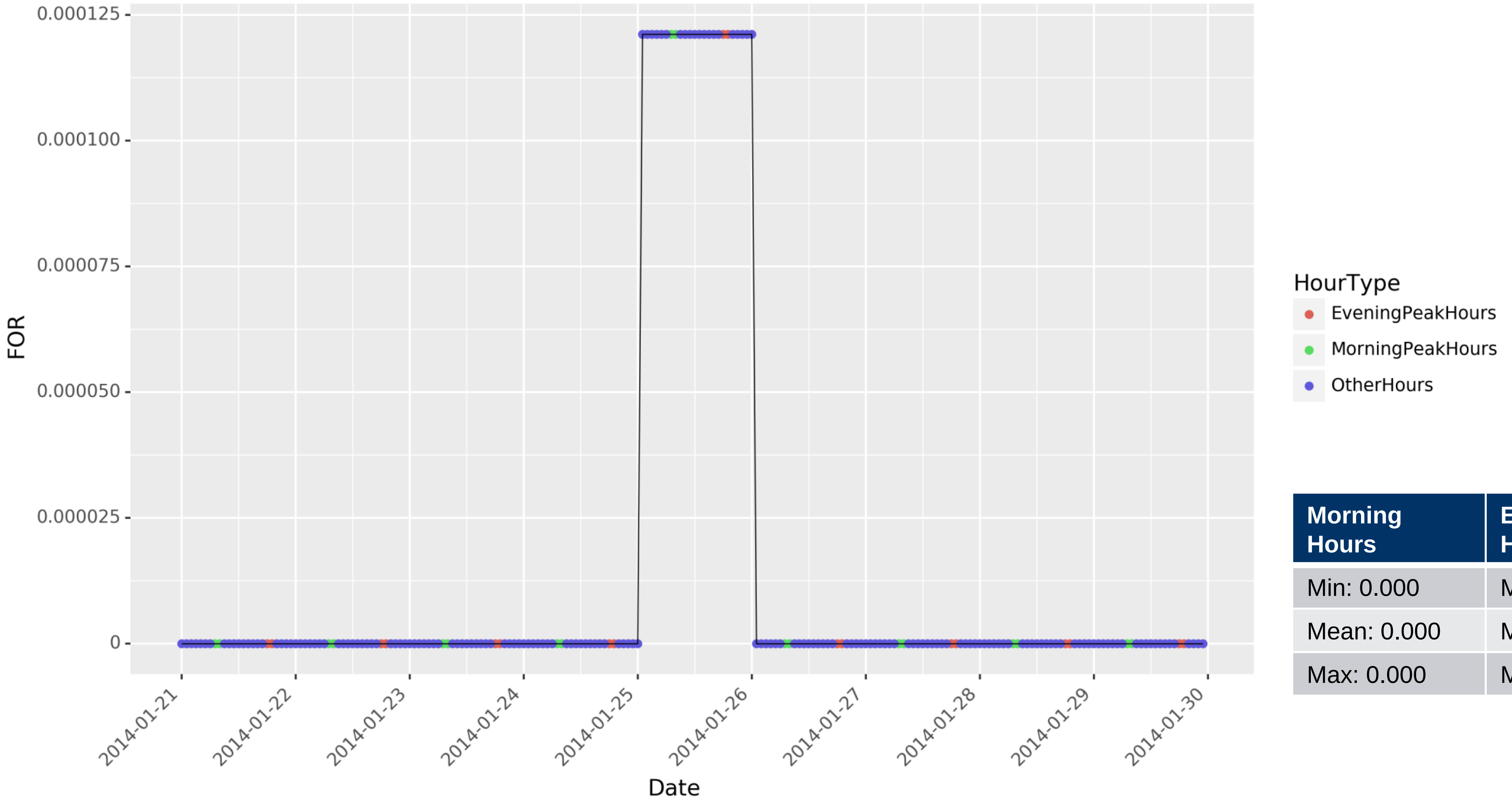


Morning Hours	Evening Hours
Min: 0.003	Min: 0.002
Mean: 0.02	Mean: 0.02
Max: 0.07	Max: 0.04

Nuclear RR-FOR

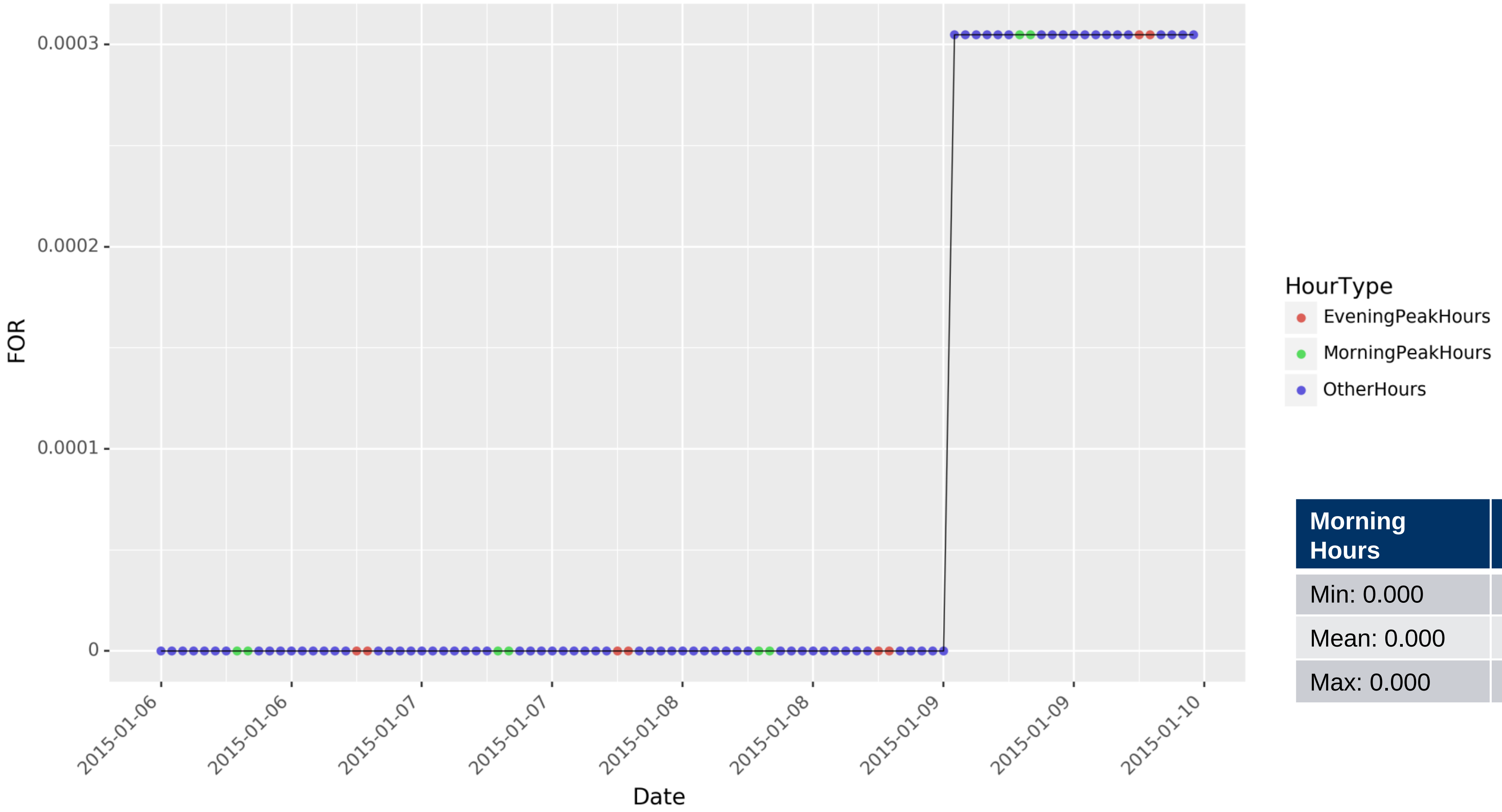


Nuclear RR-FOR (01/21/14 – 01/30/14)



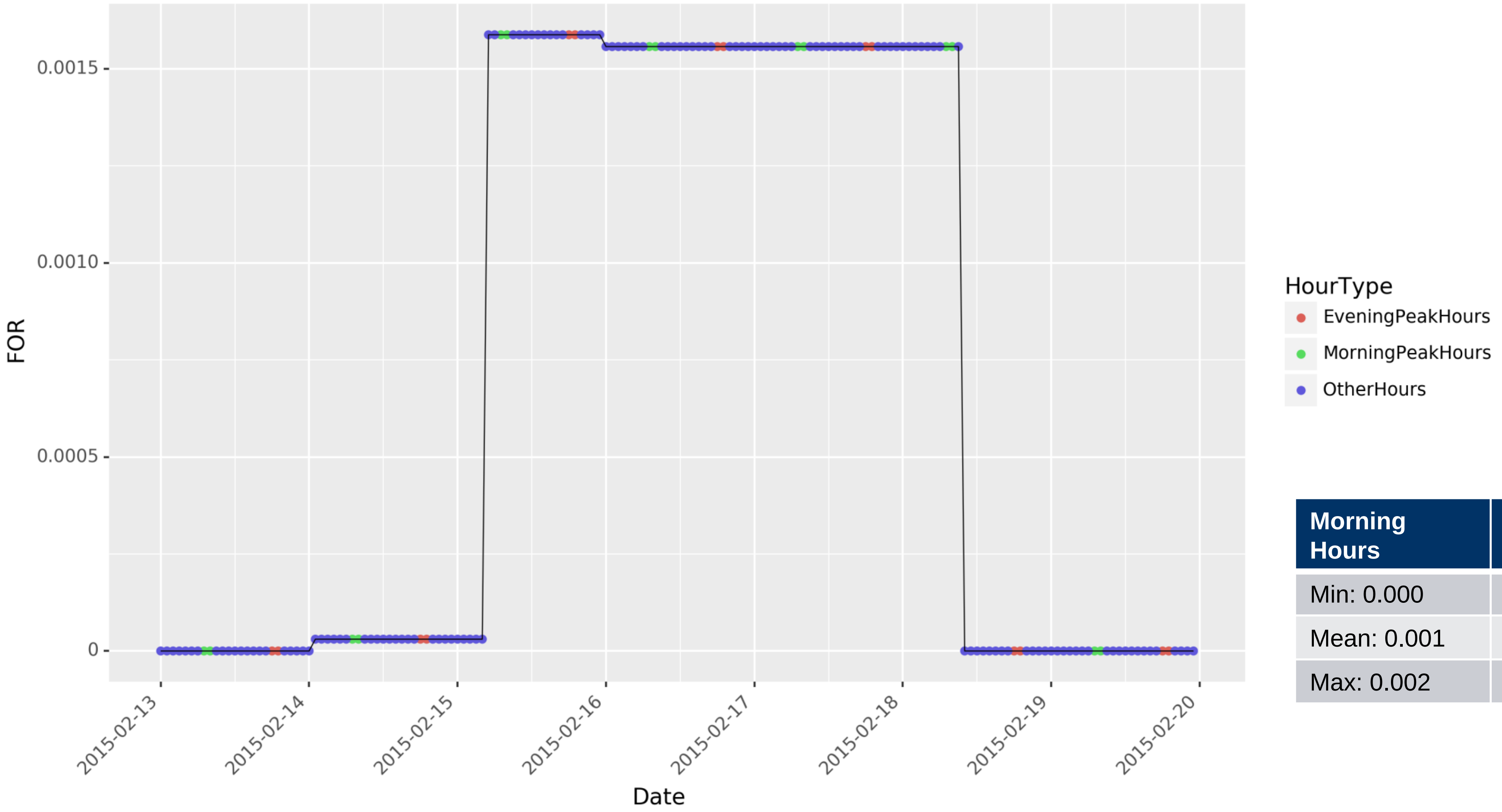
Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.000	Mean: 0.000
Max: 0.000	Max: 0.000

Nuclear RR-FOR (01/06/15 – 01/10/15)



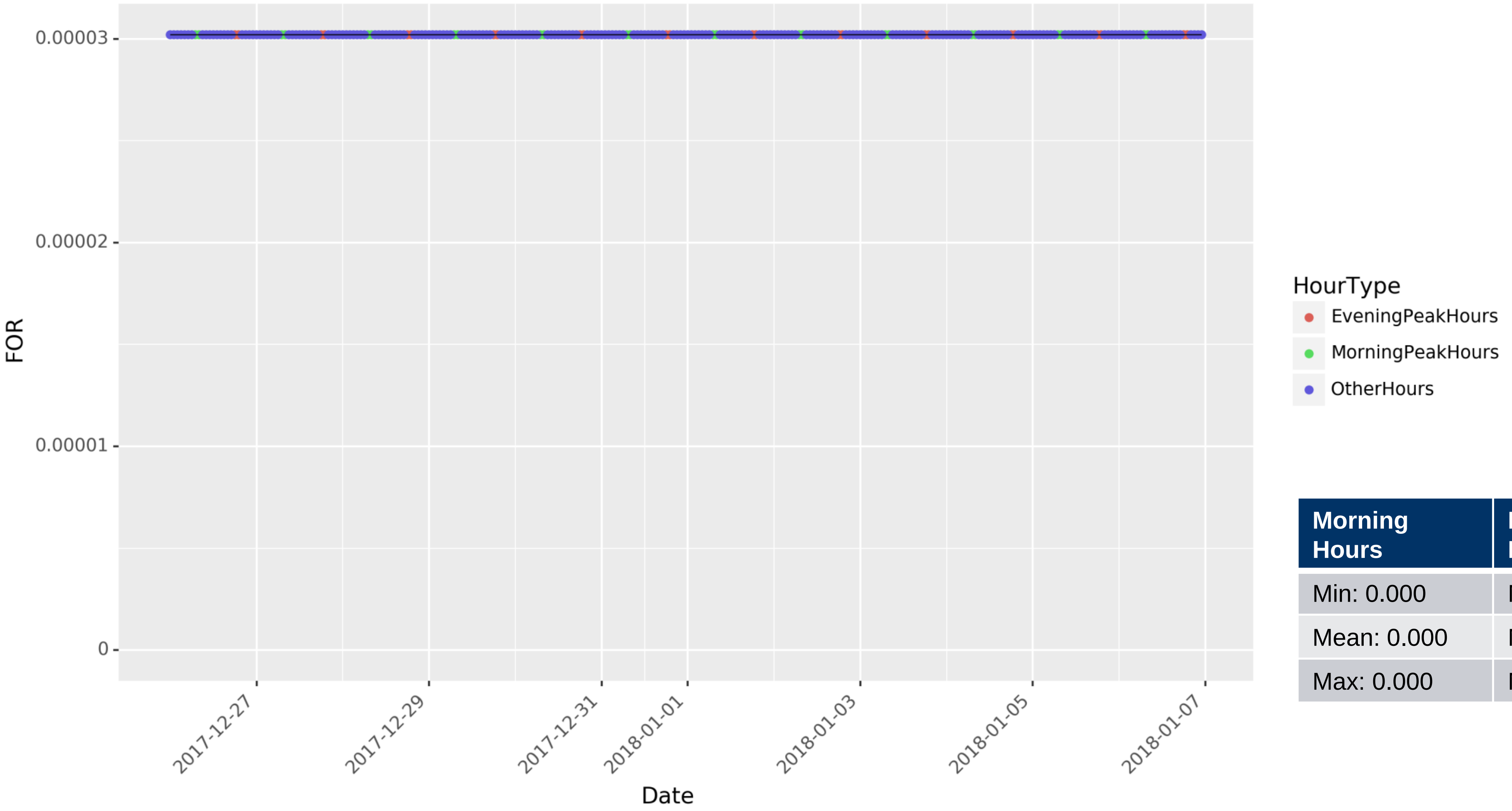
Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.000	Mean: 0.000
Max: 0.000	Max: 0.000

Nuclear RR-FOR (02/13/15 – 02/20/15)



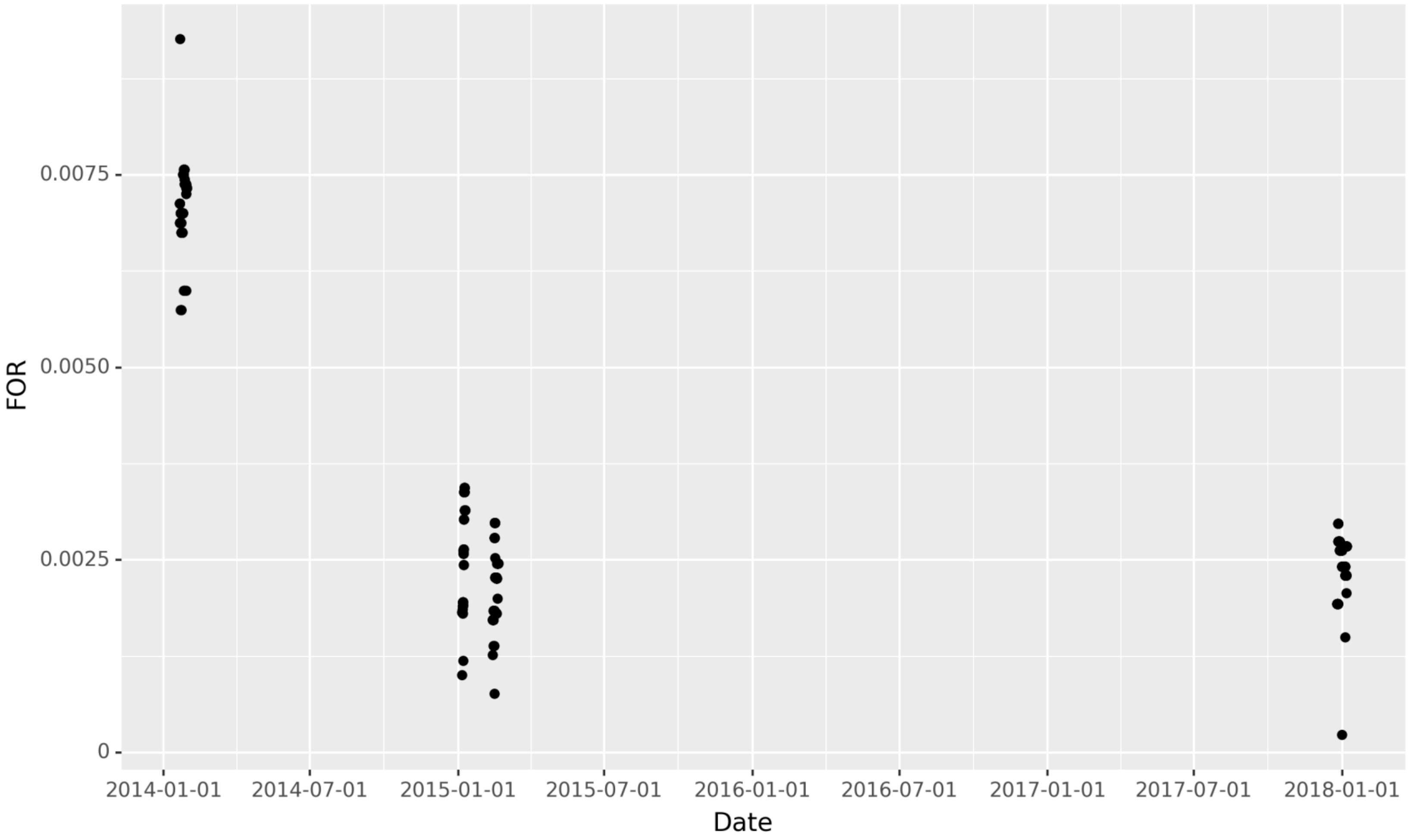
Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.001	Mean: 0.001
Max: 0.002	Max: 0.002

Nuclear RR-FOR (12/26/17 – 01/07/18)



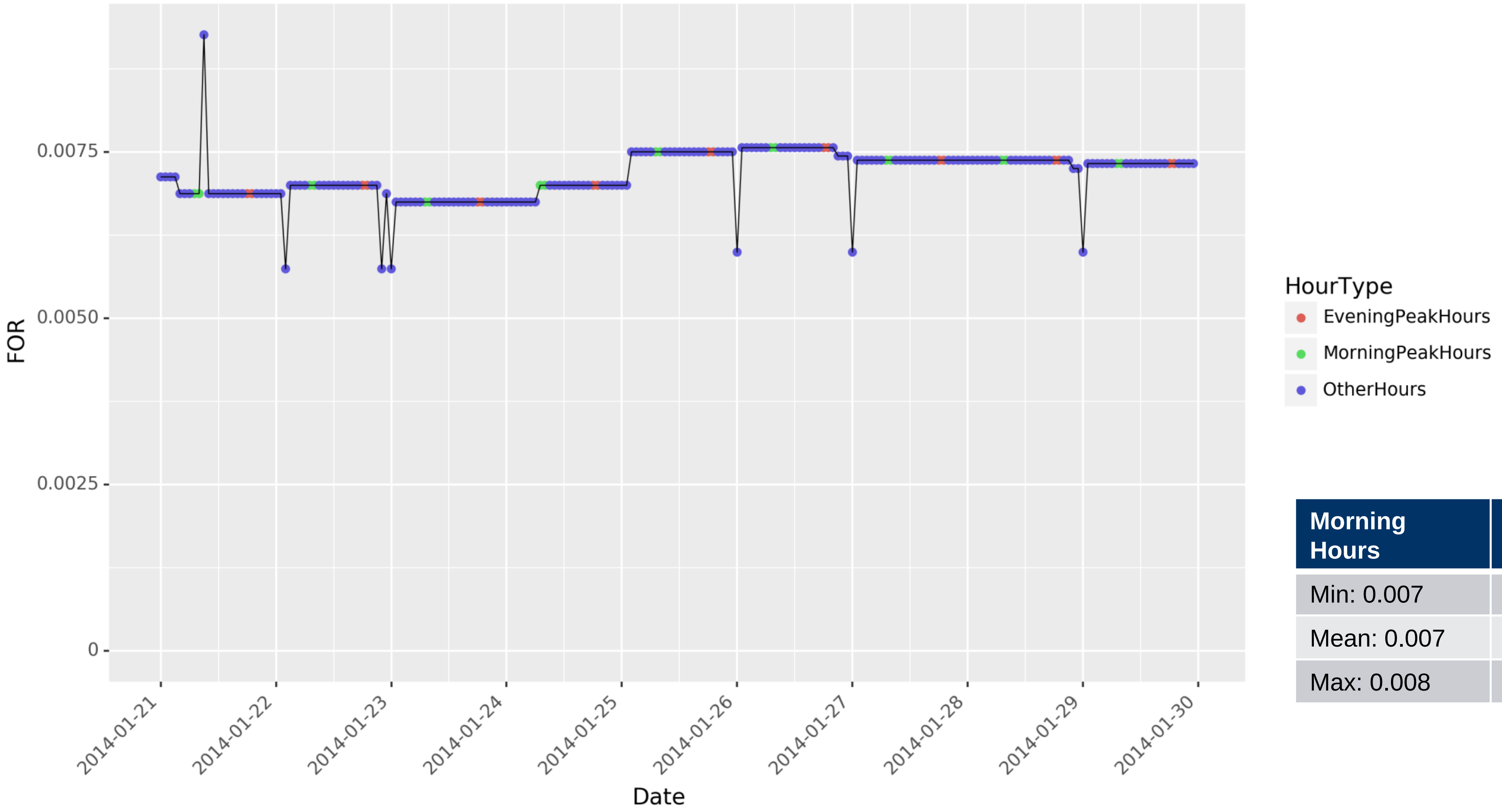
Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.000	Mean: 0.000
Max: 0.000	Max: 0.000

Hydro RR-FOR



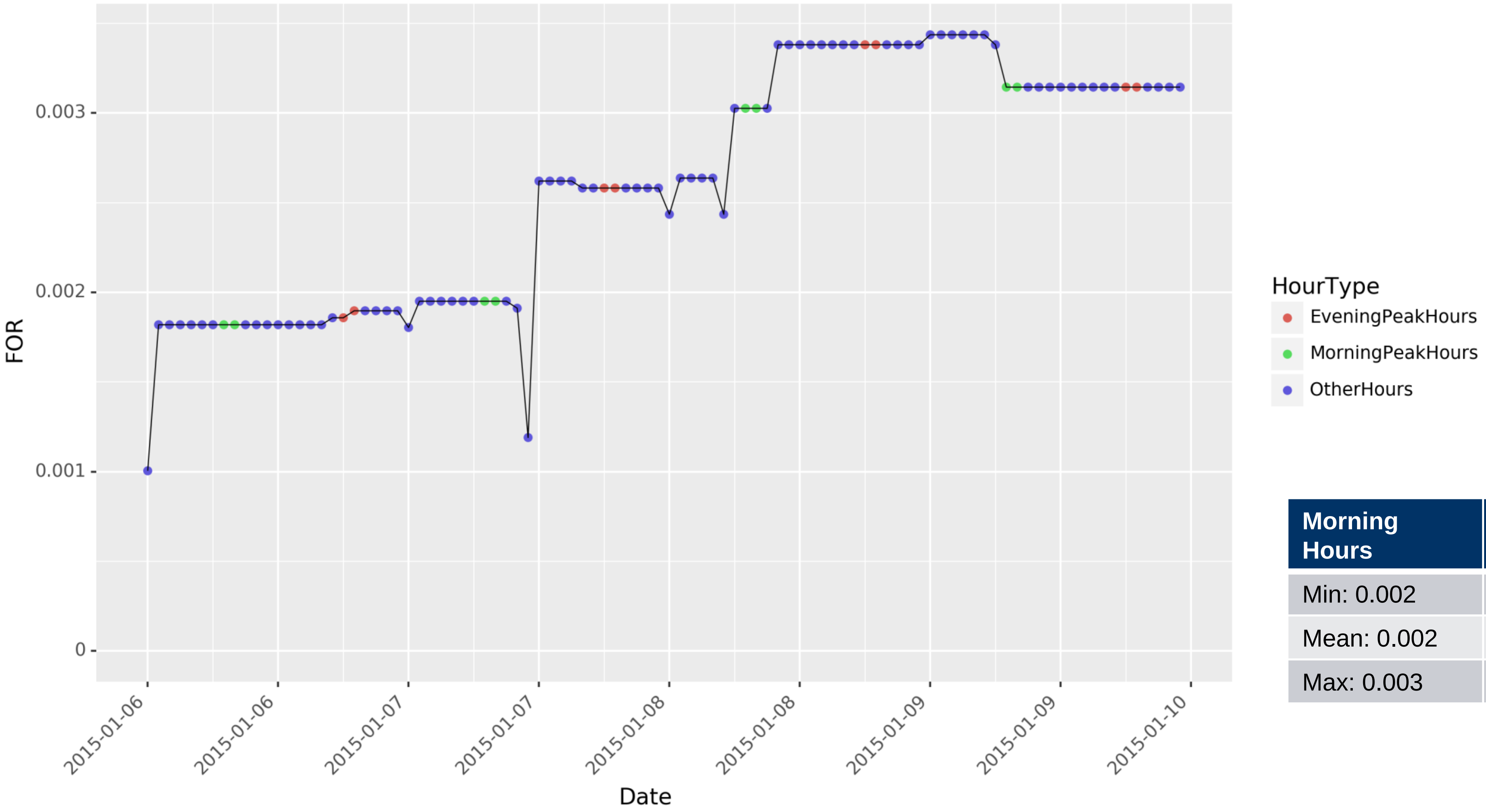
FOR
0.0075
0.0050
0.0025
0
2014-01-01
2014-07-01
2015-01-01
2015-07-01
2016-01-01
2016-07-01
2017-01-01
2017-07-01
2018-01-01
Date

Hydro RR-FOR (01/21/14 – 01/30/14)



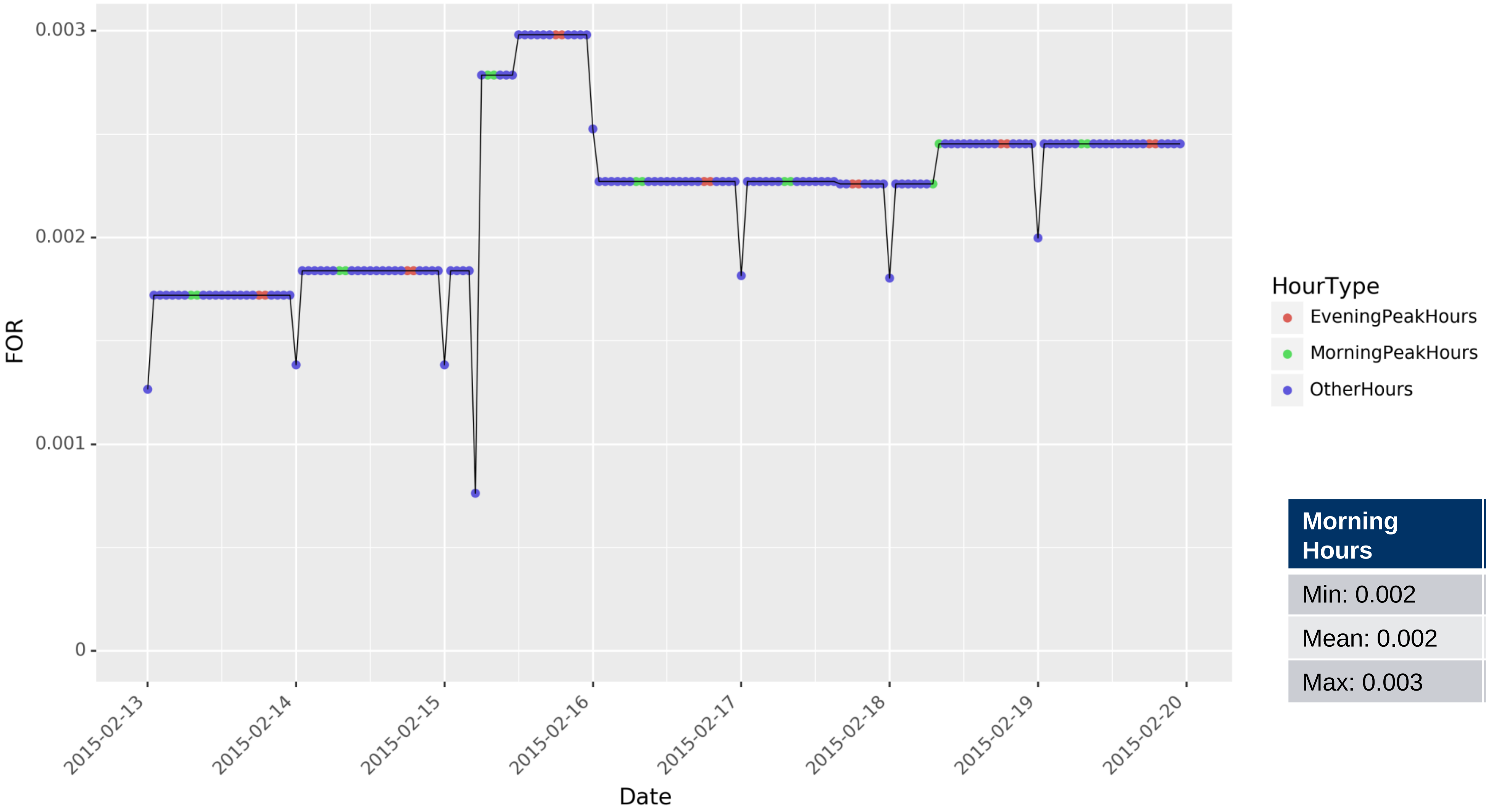
Morning Hours	Evening Hours
Min: 0.007	Min: 0.007
Mean: 0.007	Mean: 0.007
Max: 0.008	Max: 0.008

Hydro RR-FOR (01/06/15 – 01/10/15)



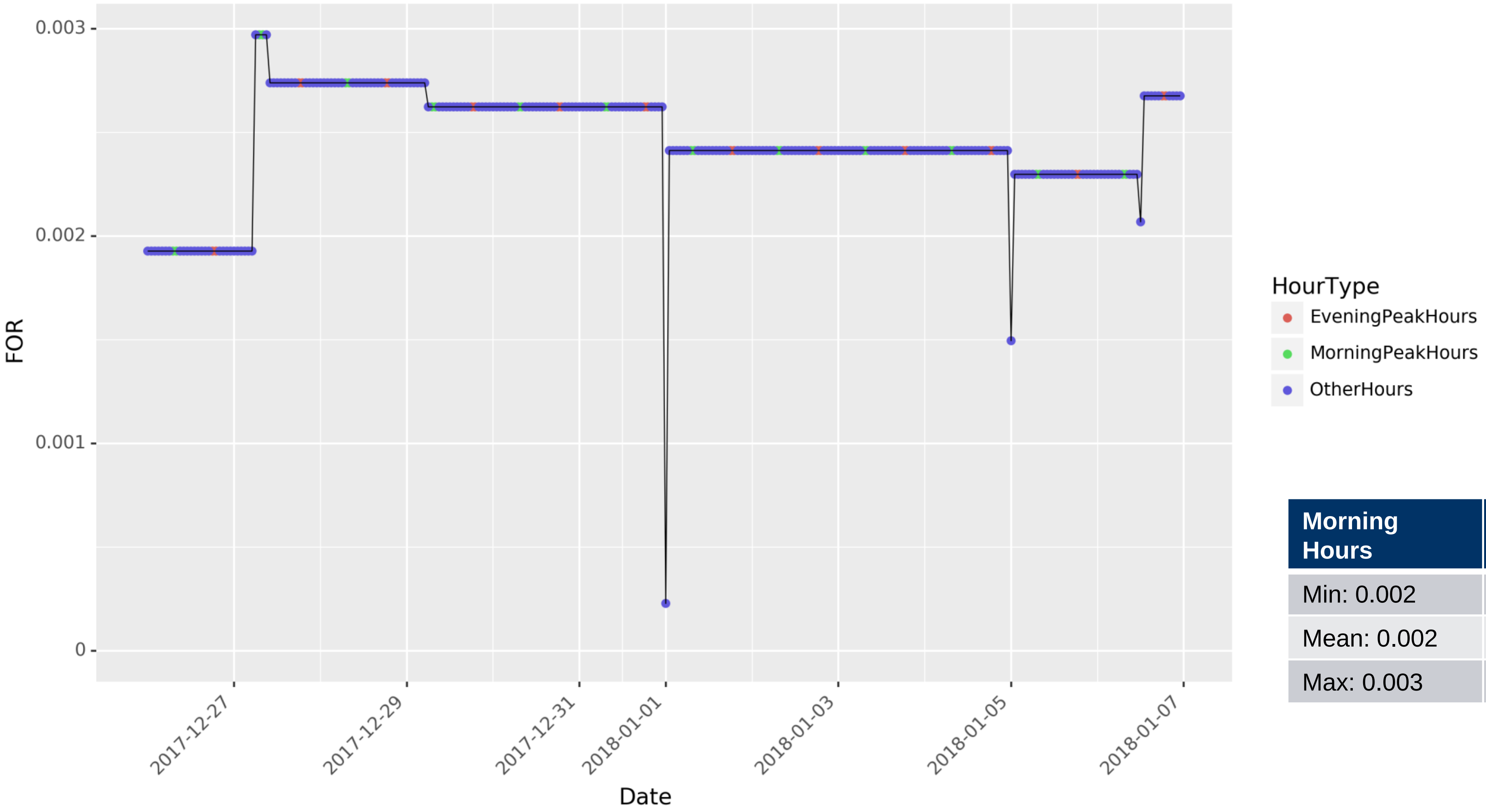
Morning Hours	Evening Hours
Min: 0.002	Min: 0.002
Mean: 0.002	Mean: 0.003
Max: 0.003	Max: 0.003

Hydro RR-FOR (02/13/15 – 02/20/15)



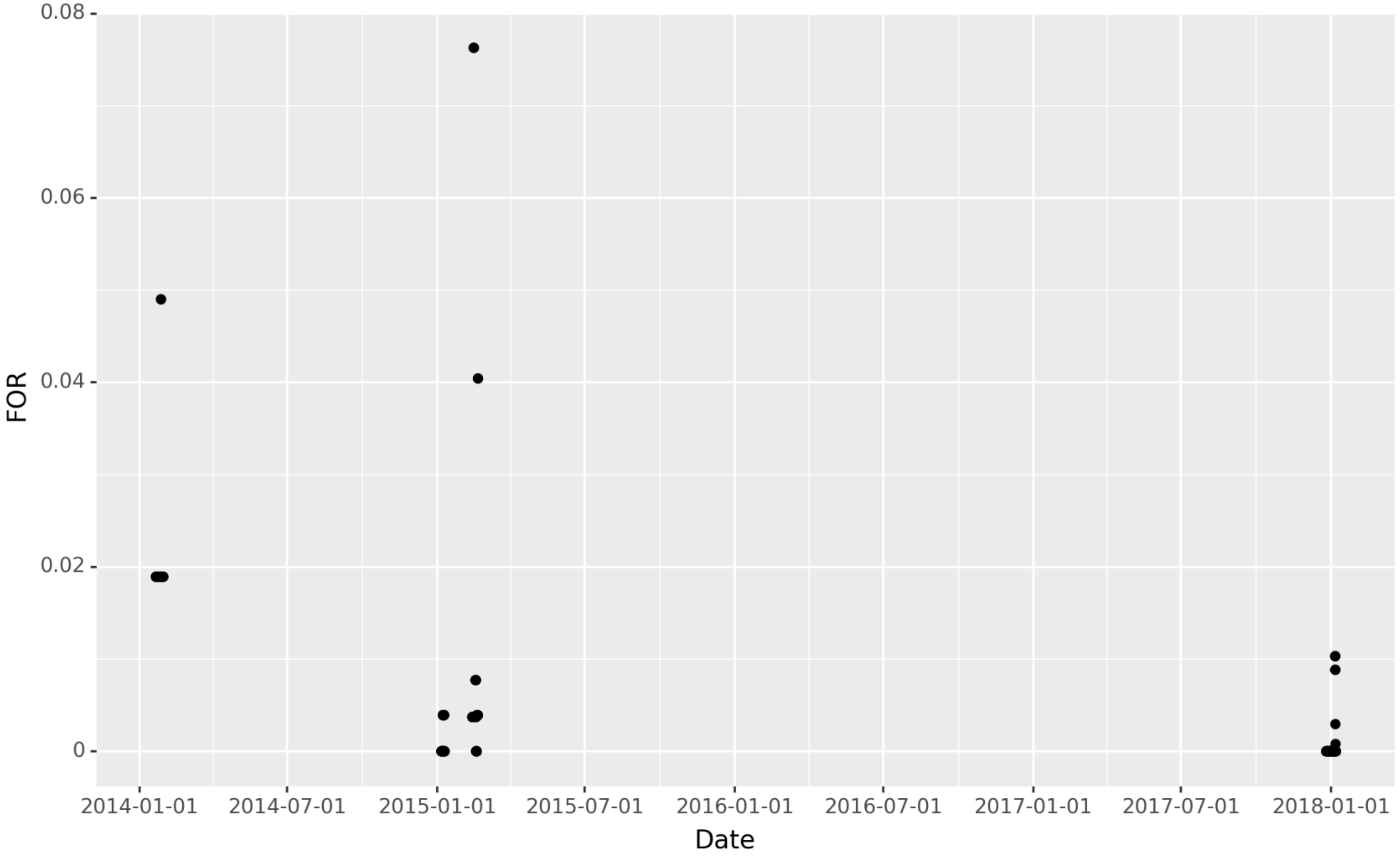
Morning Hours	Evening Hours
Min: 0.002	Min: 0.002
Mean: 0.002	Mean: 0.002
Max: 0.003	Max: 0.003

Hydro RR-FOR (12/26/17 – 01/07/18)



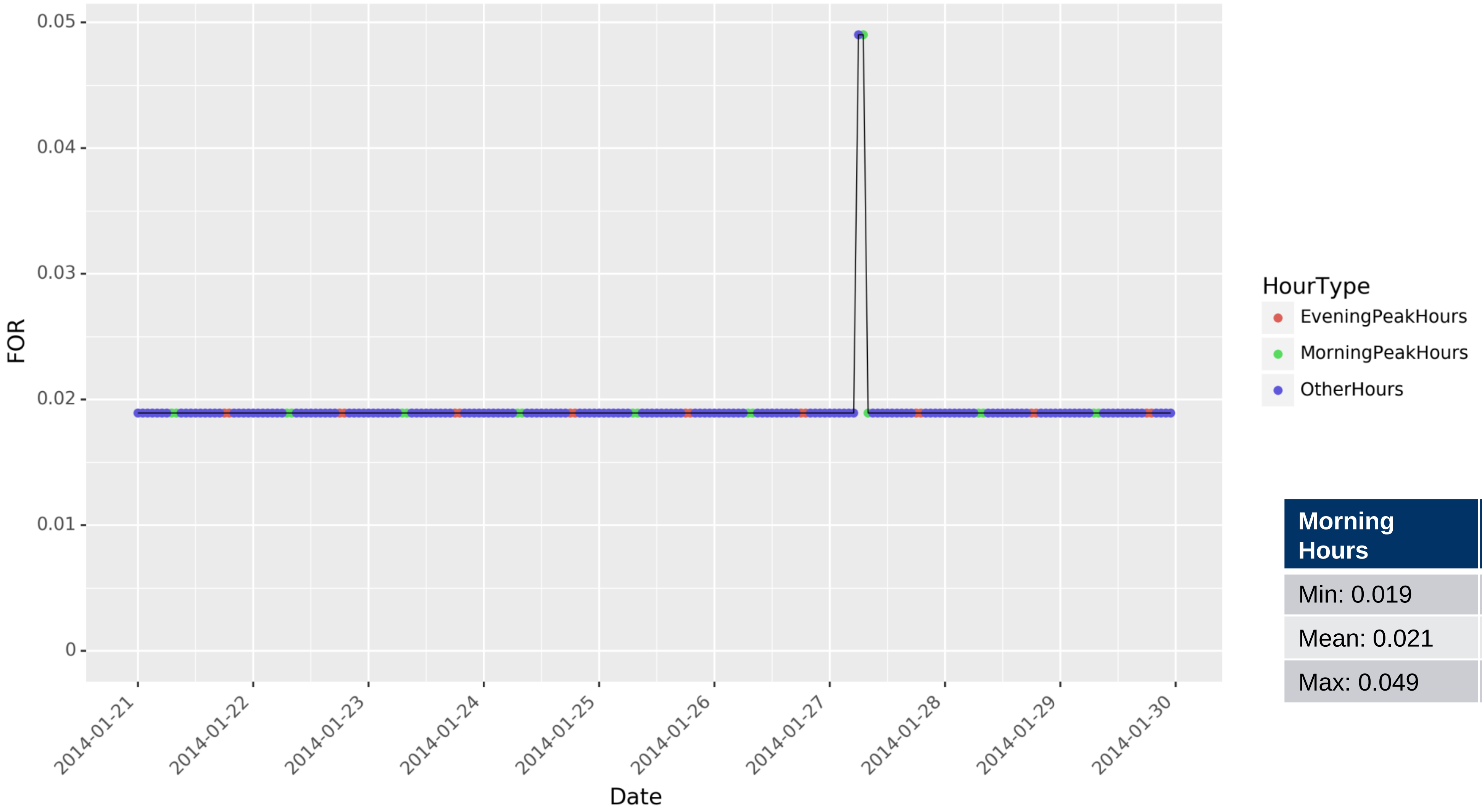
Morning Hours	Evening Hours
Min: 0.002	Min: 0.002
Mean: 0.002	Mean: 0.002
Max: 0.003	Max: 0.003

Oil RR-FOR



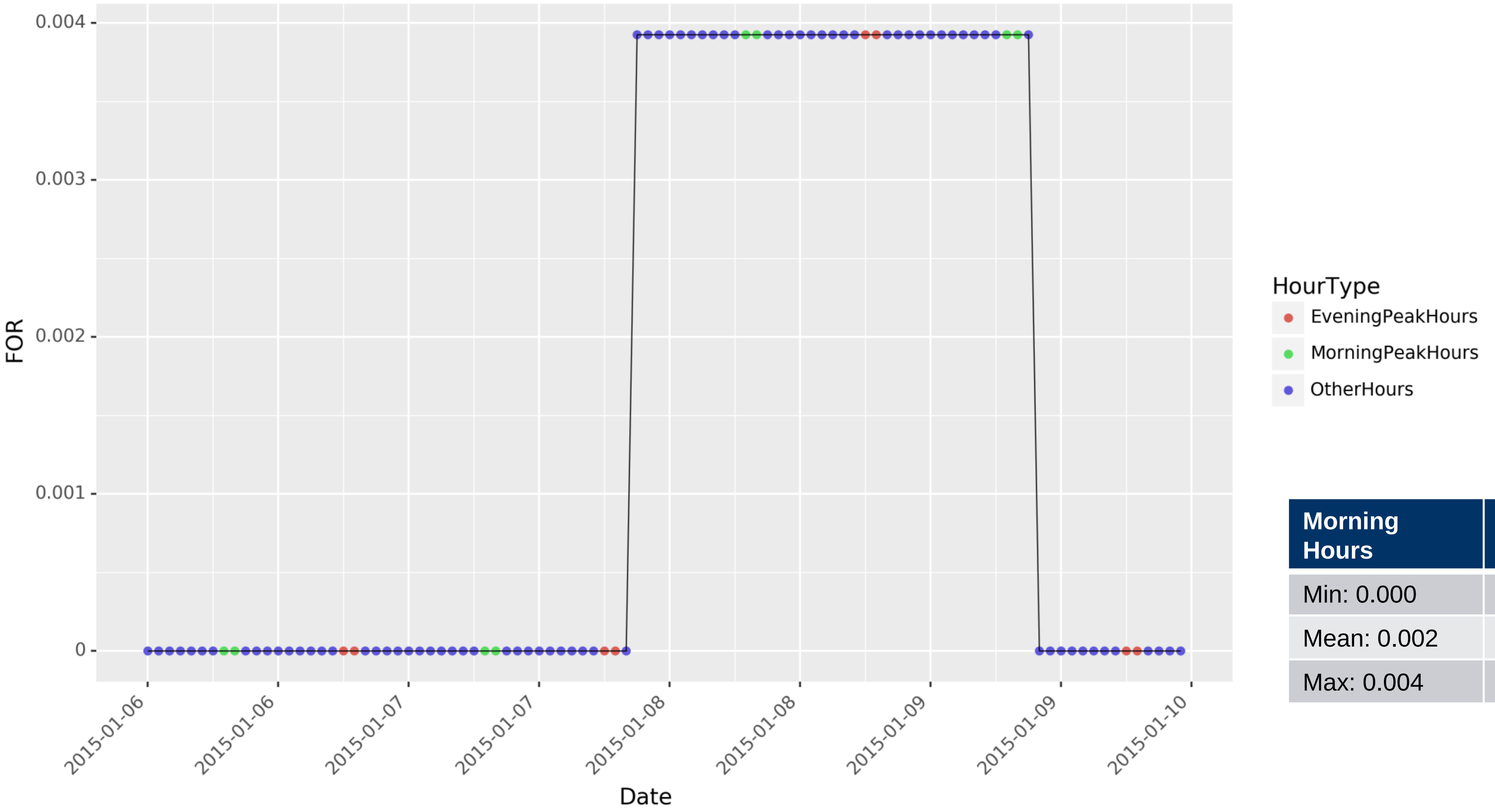
0.08
0.06
0.04
0.02
0
FOR
2014-01-01
2014-07-01
2015-01-01
2015-07-01
2016-01-01
2016-07-01
2017-01-01
2017-07-01
2018-01-01
Date

Oil RR-FOR (01/21/14 – 01/30/14)



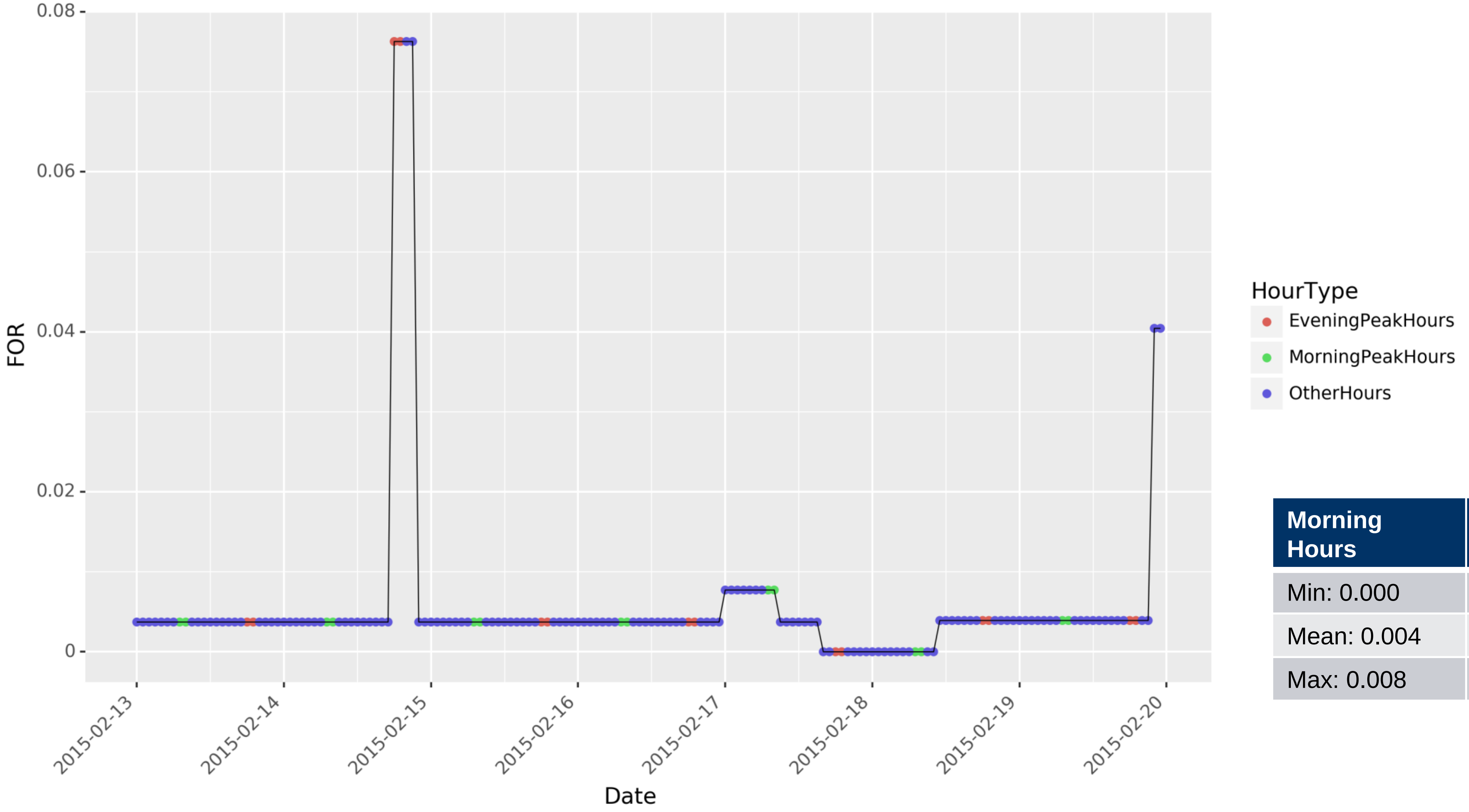
Morning Hours	Evening Hours
Min: 0.019	Min: 0.019
Mean: 0.021	Mean: 0.019
Max: 0.049	Max: 0.019

Oil RR-FOR (01/06/15 – 01/10/15)



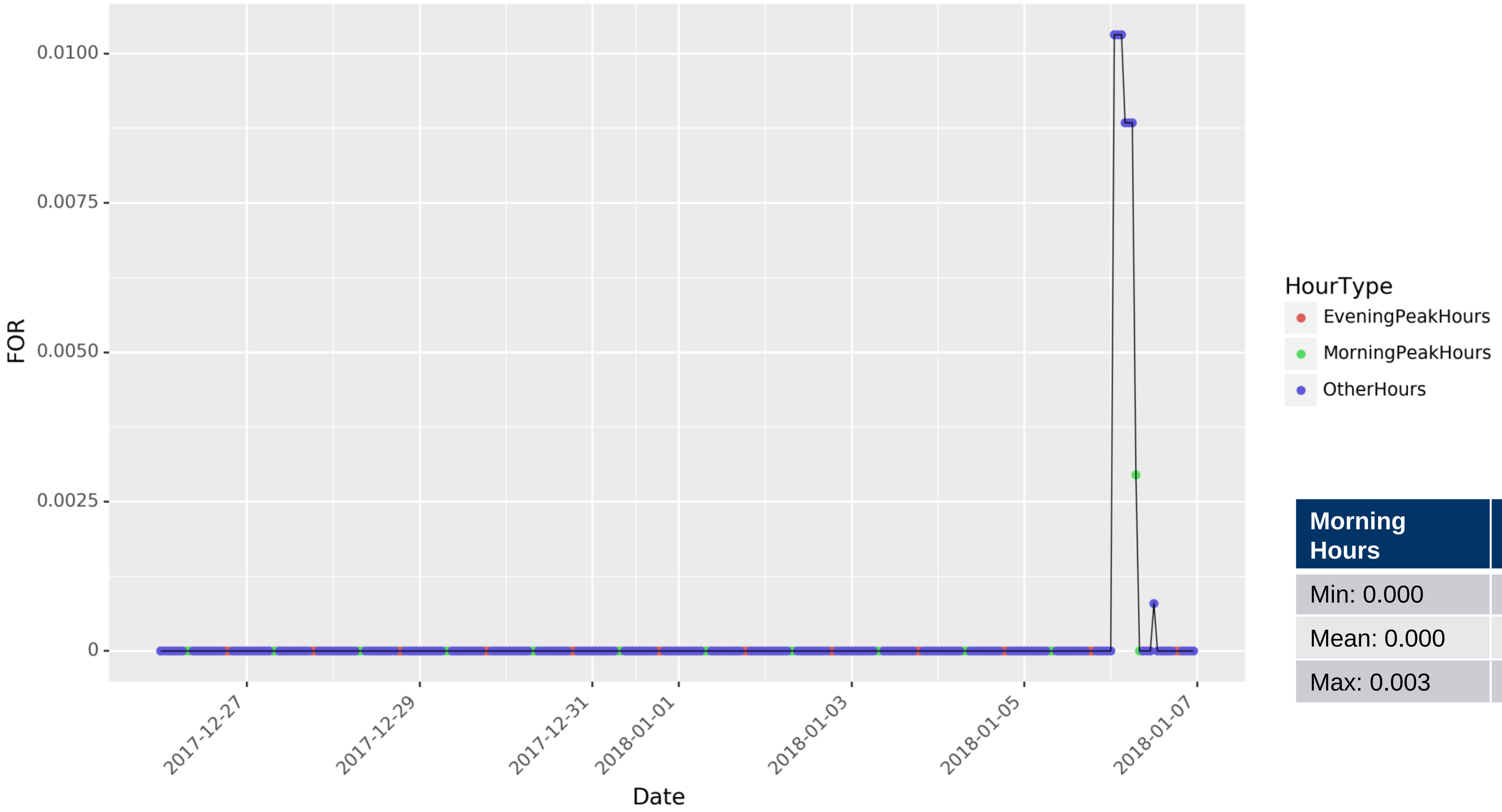
Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.002	Mean: 0.001
Max: 0.004	Max: 0.004

Oil RR-FOR (02/13/15 – 02/20/15)



Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.004	Mean: 0.014
Max: 0.008	Max: 0.076

Oil RR-FOR (12/26/17 – 01/07/18)



Morning Hours	Evening Hours
Min: 0.000	Min: 0.000
Mean: 0.000	Mean: 0.000
Max: 0.003	Max: 0.000

Scenario Development

Scenario Analysis

<table>
<tr><th>Scenario Analysis</th><th>Winter Load</th><th>Renewable Profiles</th><th>Relevant Risk Forced Outages</th><th>Other Forced Outages</th></tr>
<tr><td>Phase 1</td><td>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</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 rowspan="3">Forced outage rates using GADS cause codes not used in relevant risks or sensitivities</td></tr>
<tr><td rowspan="2">Phase 2</td><td rowspan="2">Load shapes consistent with selected cold snaps</td><td rowspan="2">Profile from cold snap, scaled to nameplate capacity in portfolio</td><td>Relevant Risk Forced Outages Rates from cold snap scaled to portfolio</td></tr>
<tr><td>Sensitivities for discrete occurrences of risks outside of historical forced outage dataset</td></tr>
</table>

Phase 1 portfolios for all scenarios: Announced (25.8% IRM), Escalated 1 (15.8% IRM), Escalated 2 (15.8% IRM)

Approach for Phase 2 Scenarios Using Relevant Risk Data

1. Selected cold snaps from analysis of winter weather:
   - Jan 21, 2014 through Jan 30, 2014 (10 days)
   - Jan 6, 2015 through Jan 10, 2015 (5 days)
   - Feb 13, 2015 through Feb 20, 2015 (8 days)
   - Dec 26, 2017 though Jan 7, 2018 (13 days)

2. For each cold snap, will use associated:
   a) Resource-Type Specific Forced Outage profiles to address the relevant risks
   b) Renewable output profiles
   c) Forced outage rates using GADS cause codes not used in relevant risks or sensitivities

3. Sensitivities to model discrete occurrences of risks outside of historical forced outage dataset (pipeline disruptions, rail disruption, nuclear regulatory shutdown, etc.)

Technical Appendix: Fuel Specific Cause Code Combinations

Coal Specific Cause Codes

Cause Code	Description
9200 & 9201	High Ash Content (OMC & non-OMC)
9210 & 9211	Low Grindability (OMC & non-OMC)
9220 & 9221	High Sulfur Content (OMC & non-OMC)
9230 & 9231	High Vanadium Content (OMC & non-OMC)
9240 & 9241	High Sodium Content (OMC & non-OMC)
9250 & 9251	Low BTU Coal (OMC & non-OMC)
9270 & 9271	Wet Coal (OMC & non-OMC)
9280 & 9281	Frozen Coal (OMC & non-OMC)

Coal Applicable Common Cause Codes

Cause Code	Description
9130	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Other Fuel Quality Problems (OMC & non-OMC)
7112 & 3274	Ice blockages at intake structures
7199	Other water supply/discharge problems
9135	Lack of Water
3273	Debris in circulating water from outside sources
3280	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Fuel Conservation

Natural Gas Specific Cause Codes

Cause Code	Description
9205	Poor quality natural gas fuel, low heat content

Natural Gas Applicable Common Cause Codes

Cause Code	Description
9130	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Other Fuel Quality Problems (OMC & non-OMC)
7112 & 3274	Ice blockages at intake structures
7199	Other water supply/discharge problems
9135	Lack of Water
3273	Debris in circulating water from outside sources
3280	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Fuel Conservation

Nuclear Specific Cause Codes

Cause Code	Description
9500	Regulatory (nuclear) proceedings and hearings – regulatory agency initiated
9502	Regulatory (nuclear) proceedings and hearings – intervenor initiated
9710	Investigation of possible nuclear safety problems
2010	Fuel failure, including high activity in Reactor Coolant System or off-gas system
2030	Fuel limits – peaking factors
2032	Fuel limits – minimum critical power ratio (BWR units only)
2033	Fuel limits – maximum average planar linear heat generation rate (BWR units only)
2037	Other fuel limits (excluding core coast down, conservation, or stretch)

Nuclear Applicable Common Cause Codes

Cause Code	Description
9130	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Other Fuel Quality Problems (OMC & non-OMC)
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3280	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Fuel Conservation

Hydro Specific Cause Codes

Cause Code	Description
7100	Upper reservoir dams and dikes
7101	Lower reservoir dams and dikes
7102	Auxiliary reservoir dams and dikes
7110	Intake channel or flume (excluding trash racks)
7111	Intake tunnel

Hydro Applicable Common Cause Codes

Cause Code	Description
9130	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Other Fuel Quality Problems (OMC & non-OMC)
7112 & 3274	Ice blockages at intake structures
7199	Other water supply/discharge problems
9135	Lack of Water
3273	Debris in circulating water from outside sources
3280	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Fuel Conservation

Oil Specific Cause Codes

Cause Code	Description
9260 & 9261	Low BTU oil (OMC & non-OMC)

Oil Applicable Common Cause Codes

Cause Code	Description
9130	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Other Fuel Quality Problems (OMC & non-OMC)
7112 & 3274	Ice blockages at intake structures
7199	Other water supply/discharge problems
9135	Lack of Water
3273	Debris in circulating water from outside sources
3280	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Fuel Conservation