

APPENDIX S. IMPACT OF EXTREME COLD CONDITIONS: S31, S33 AND S36

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1 S31: VERY COLD SNAP WITH 90/10 ELECTRIC AND RCI GAS DEMANDS

Sensitivity 31 envisions a Study Region-wide cold-weather event when all PPAs coincidentally experience an extreme winter peak electric load and RCI gas demand.

1.1 RGDS S31 WINTER 2018

Figure S1 summarizes the affected generation during the Winter 2018 peak hour by PPA. The amount of affected generation decreases significantly in NYISO and is eliminated entirely in ISO-NE, as oil and coal are in merit and substitute for gas-fired generation. In PJM, increases in gas demand resulting from forced outages and higher electric load were roughly offset by substitution of oil and coal-fired generation in response to higher gas prices, while affected generation increased due to higher RCI gas demand. In IESO, generation gas demand and affected generation increased because gas prices for Ontario generators did not increase much and energy exports to other PPAs were higher. Affected generation in IESO did not increase proportionally with total generation because of the firm transportation rights held by many IESO generators.

Figure S1. RGDS S31 Winter 2018: Peak Hour Affected Generation

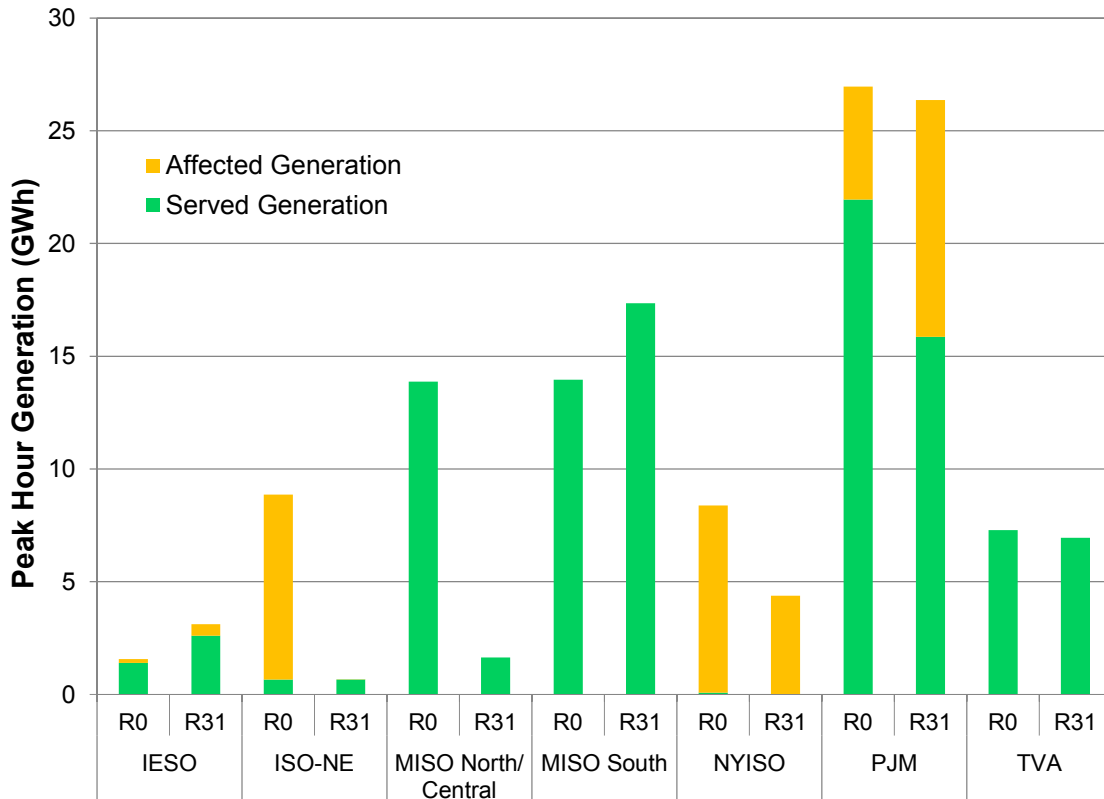


Figure S2 summarizes the unserved demand by GPCM location. The unserved demand and affected generation by location are quantified in Table S1. While much of IESO is shaded orange, the quantities of unserved demand and affected generation are relatively small. The green shading in New England and in Delaware indicating that there is no affected generation is a result of the relative fuel prices putting generation in those locations out of merit.

Figure S2. RGDS S31 Winter 2018: GPCM Locations with Peak Hour Affected Generation

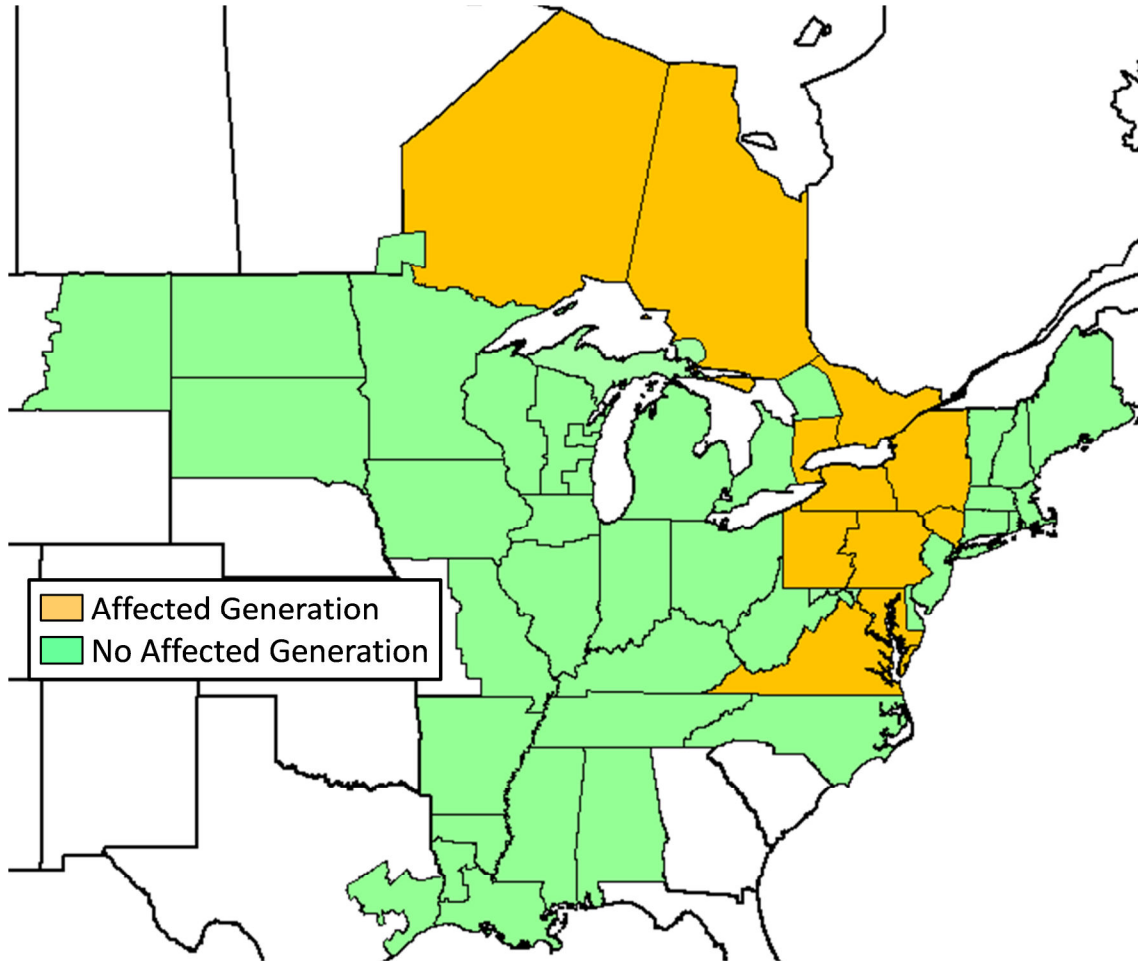


Table S1. RGDS S31 Winter 2018: Peak Hour Unserved Generator Gas Demand and Affected Generation

GPCM Location	Unserved Generation Gas Demand (MDth)	Affected Generation (MWh)
Maryland Eastern	3.3	315
New York Central Northern	25.8	2,634
New York Southern	14.3	1,537
New York Western	1.9	216
Ontario (CDA)	0.5	55
Ontario (EDA)	2.1	249
Ontario (NDA)	1.5	186
Ontario (WDA)	0.4	38
Pennsylvania Eastern	43.8	5,557
Pennsylvania Western	4.1	393
Virginia	35.4	4,237

Figure S3 shows the constrained pipeline segments, in red, that result in the affected generation shown in Figure S1 during the Winter 2018 peak hour. Relative to the constraints seen in RGDS S0, Eastern Shore, NB/NS Supply, and TransCanada Quebec are not shown here, because although the segments are still highly utilized serving RCI demand, the reduced generator dispatch in New England and Delaware means that no generation is affected. The NFG mainline, which is not constrained in RGDS S0, serves incremental generation in RGDS S31 because of relative gas price changes. Although the Transco Z5 segment is still highly utilized in RGDS S31, it does not appear as a constraint because the two segments which deliver gas into it, Transco Z4 and Transco Z6, and 100% utilized and therefore constrained.

Figure S3. RGDS S31 Winter 2018: Peak Hour Constraints

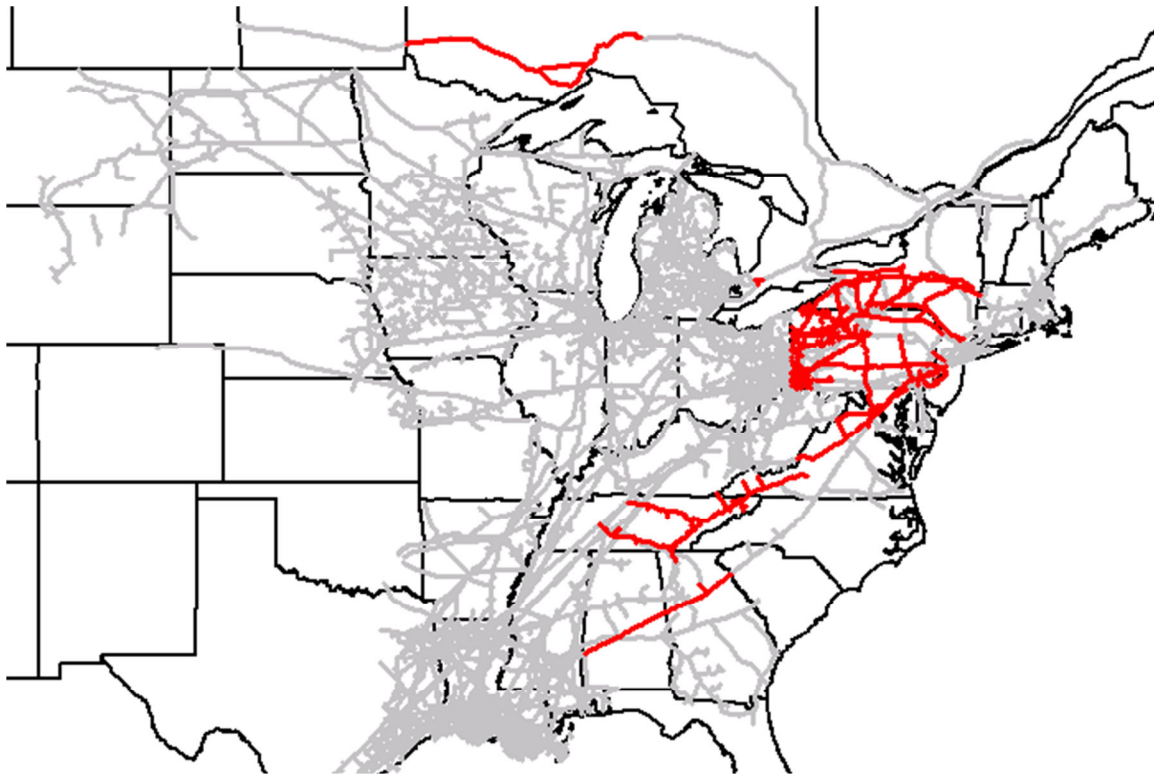


Table S2 lists the segments that are constrained during the peak hour.

Table S2. RGDS S31 Winter 2018: Peak Hour Constraints

Columbia Gas VA/MD	Empire Mainline	TransCanada Ontario West
Columbia Gas W PA/NY	Millennium	Transco Leidy Atlantic
Constitution	NFG Mainline	Transco Z4
Dominion Eastern NY	Tennessee Z4 PA	Transco Z6
Dominion Western NY	Tennessee Z5 NY	Transco Z6 Leidy to 210
Dominion Southeast	Texas Eastern M2 PA South	Union Gas Dawn
East Tennessee Mainline	Texas Eastern M3 North	

1.2 RGDS S31 WINTER 2023

Figure S4 summarizes the affected generation during the Winter 2023 peak hour by PPA. Changes in affected generation relative to RGDS S0 are similar to those seen in Winter 2018, with the exception of PJM, the quantity of affected generation in RGDS S31 has not changed significantly from Winter 2018, but is now less than the amount of affected generation in RGDS S0. This shift is because to the large increase in affected generation in Pennsylvania Eastern between Winter 2018 and Winter 2023 in RGDS S0 does not occur in RGDS S31. In RGDS S31, affected generation in Pennsylvania Eastern is already at a similar level in Winter 2018 to the Winter 2023 level in RGDS S0 because of the changes to the relative fuel prices.

Figure S4. RGDS S31 Winter 2023: Peak Hour Affected Generation

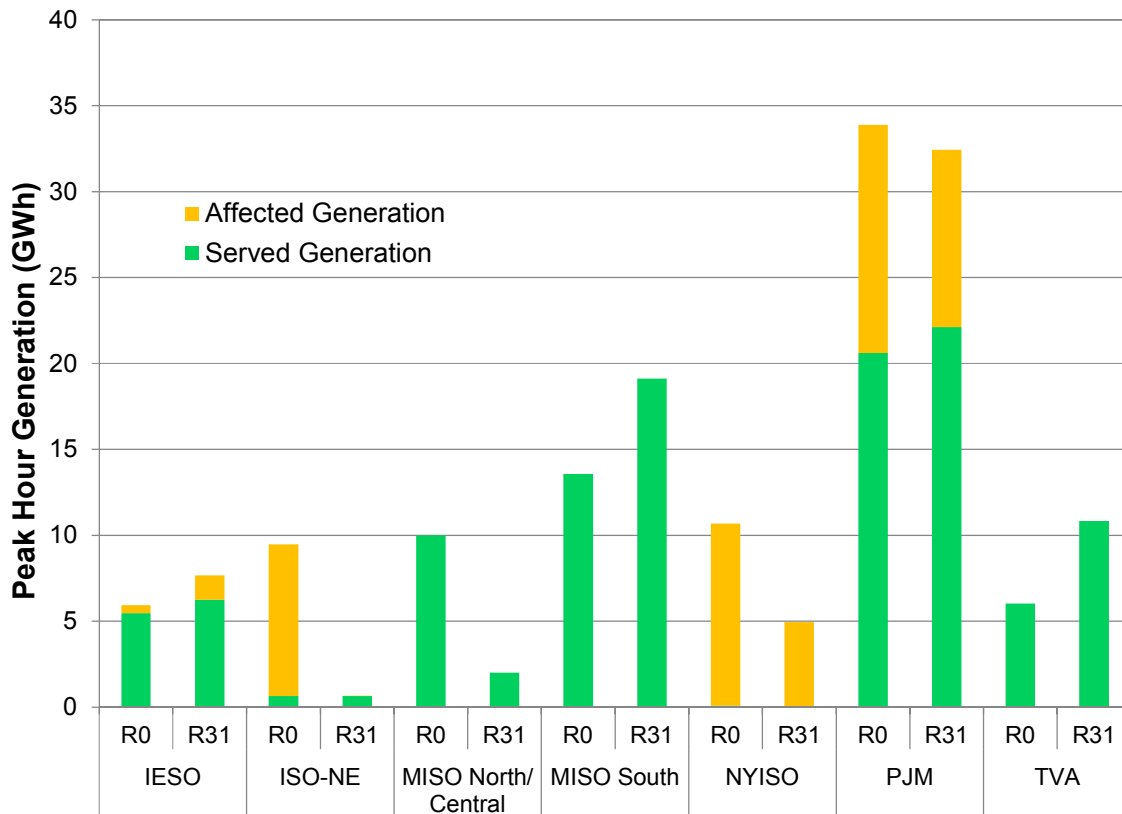


Figure S5 summarizes the unserved demand by GPCM location. The unserved demand and affected generation by location are quantified in Table S3. The locations with affected generation and the relative amounts of affected generation in each location are largely unchanged from Winter 2018, with the exception of New Jersey, which has a small amount of affected generation in Winter 2023.

Figure S5. RGDS S31 Winter 2023: GPCM Locations with Peak Hour Affected Generation

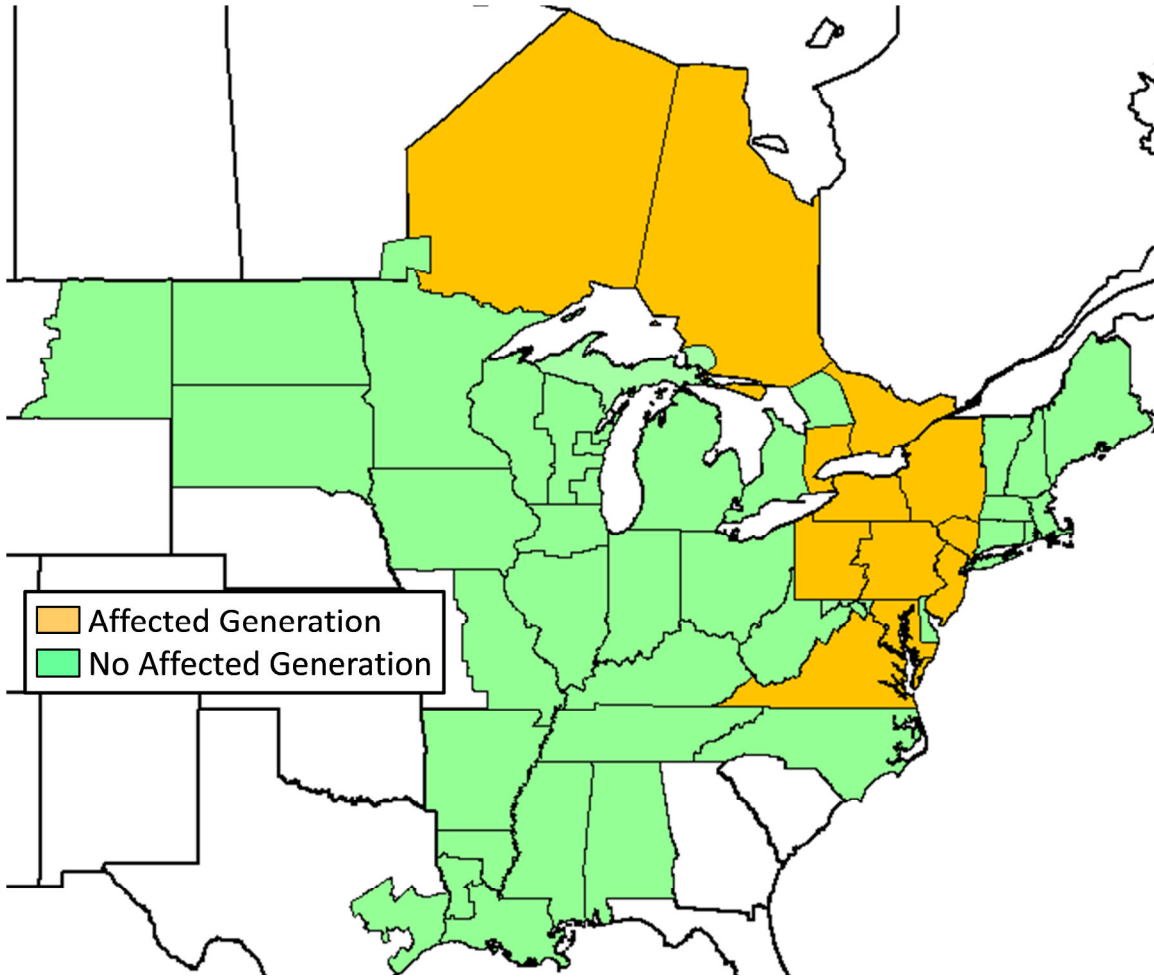


Table S3. RGDS S31 Winter 2023: Peak Hour Unserved Generator Gas Demand and Affected Generation

GPCM Location	Unserved Generation Gas Demand (MDth)	Affected Generation (MWh)
Maryland Eastern	3.3	315
New Jersey	0.3	46
New York Central Northern	30.0	3,199
New York Southern	14.3	1,537
New York Western	1.9	216
Ontario (CDA)	0.5	55
Ontario (EDA)	8.5	1,133
Ontario (NDA)	1.5	186
Ontario (WDA)	0.4	38
Pennsylvania Eastern	43.8	5,557
Pennsylvania Western	1.1	119
Virginia	36.2	4,285

Figure S6 shows the constrained pipeline segments, in red, that result in the affected generation shown in Figure S4 during the Winter 2023 peak hour. The constraint on Transco is shifted from Transco Z4 and Transco Z6 to Transco Z5, relative to Winter 2018.

Figure S6. RGDS S31 Winter 2023: Peak Hour Constraints

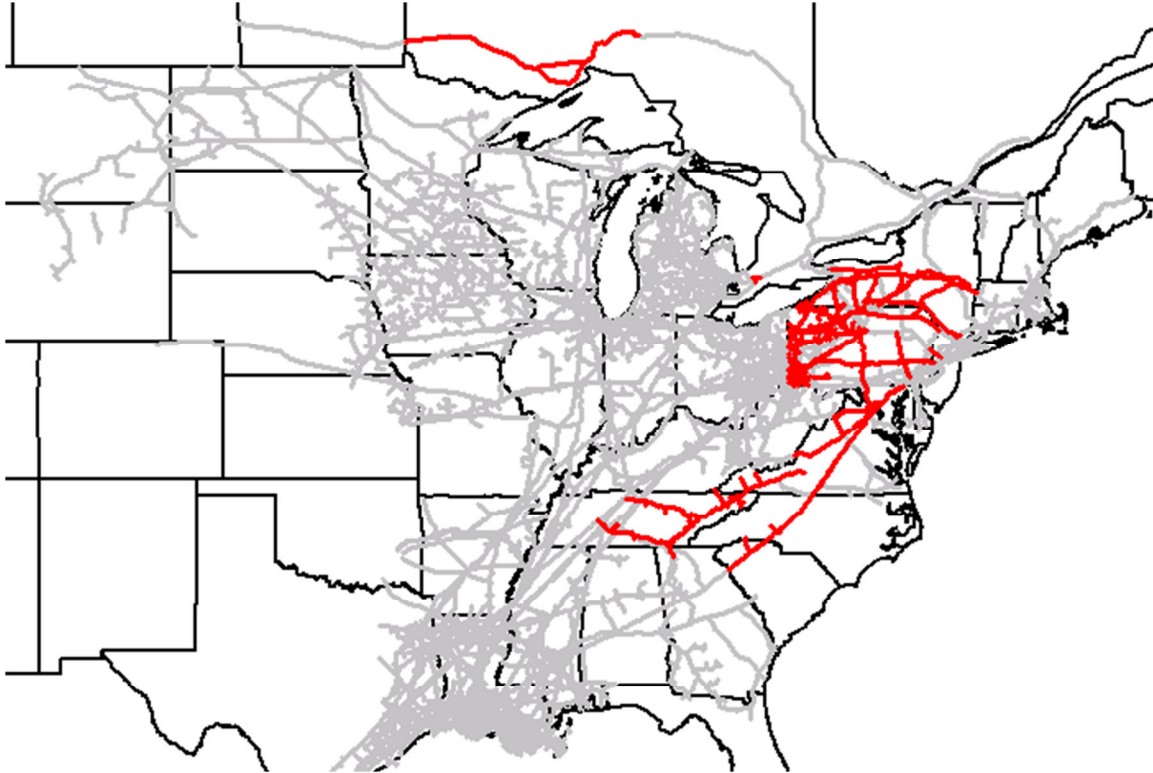


Table S4 lists the segments that are constrained during the peak hour.

Table S4. RGDS S31 Winter 2023: Peak Hour Constraints

Columbia Gas VA/MD	Empire Mainline	Texas Eastern M3 North
Columbia Gas W PA/NY	Millennium	TransCanada Ontario West
Constitution	NFG Mainline	Transco Leidy Atlantic
Dominion Eastern NY	Tennessee Z4 PA	Transco Z5
Dominion Western NY	Tennessee Z5 NY	Transco Z6 Leidy to 210
Dominion Southeast	Texas Eastern M2 PA South	Union Gas Dawn
East Tennessee Mainline		

2 S33: S31 + HIGH FORCED OUTAGE RATE FOR COAL AND OIL UNITS

Sensitivity 33 tested the ability to compensate for unavailable coal and oil-fired capacity during the cold weather event modeled in Sensitivity 31.

2.1 RGDS S33 WINTER 2018

Figure S7 summarizes the affected generation during the Winter 2018 peak hour by PPA. The changes in affected generation relative to RGDS S0 are very similar to those seen in RGDS S31 above, with slightly higher total generation in most PPAs due to forced outages of coal- and oil-fired units.

Figure S7. RGDS S33 Winter 2018: Peak Hour Affected Generation

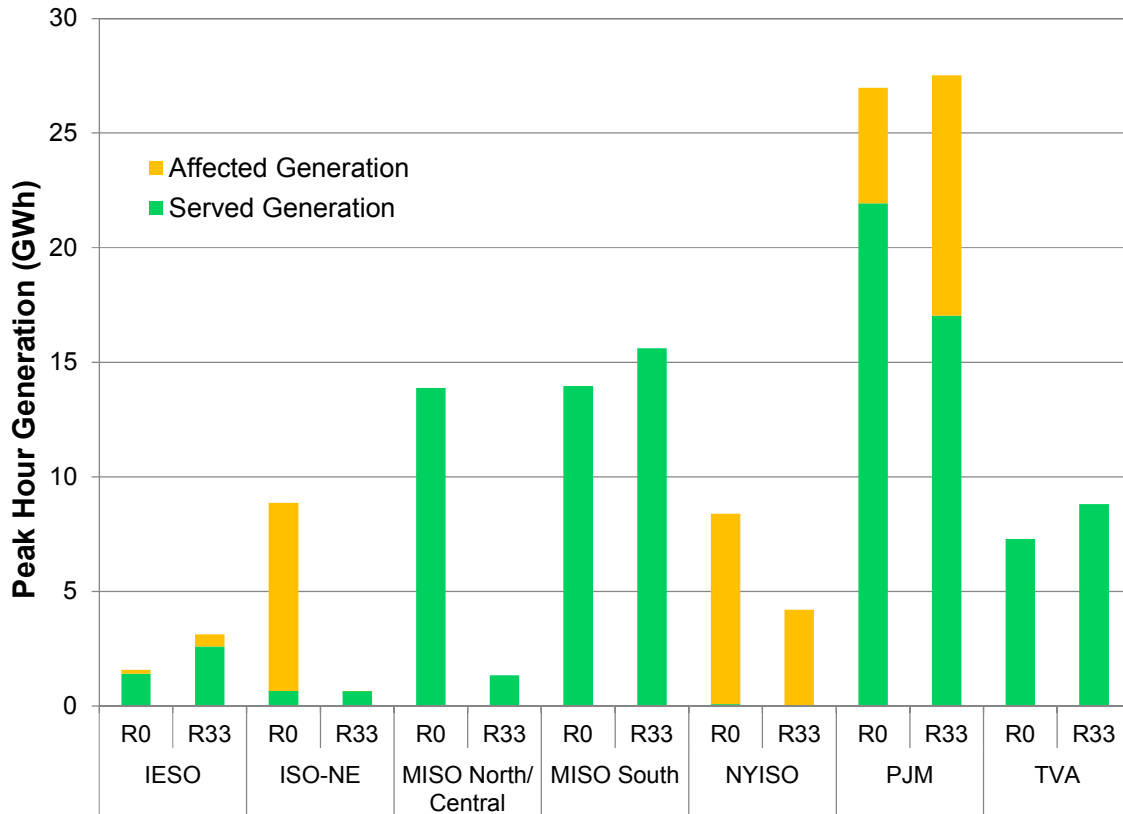


Figure S8 summarizes the unserved demand by GPCM location. The unserved demand and affected generation by location are quantified in Table S5. These results are again very similar to the RGDS 31 results, with affected generation in the same locations.

Figure S8. RGDS S33 Winter 2018: GPCM Locations with Peak Hour Affected Generation

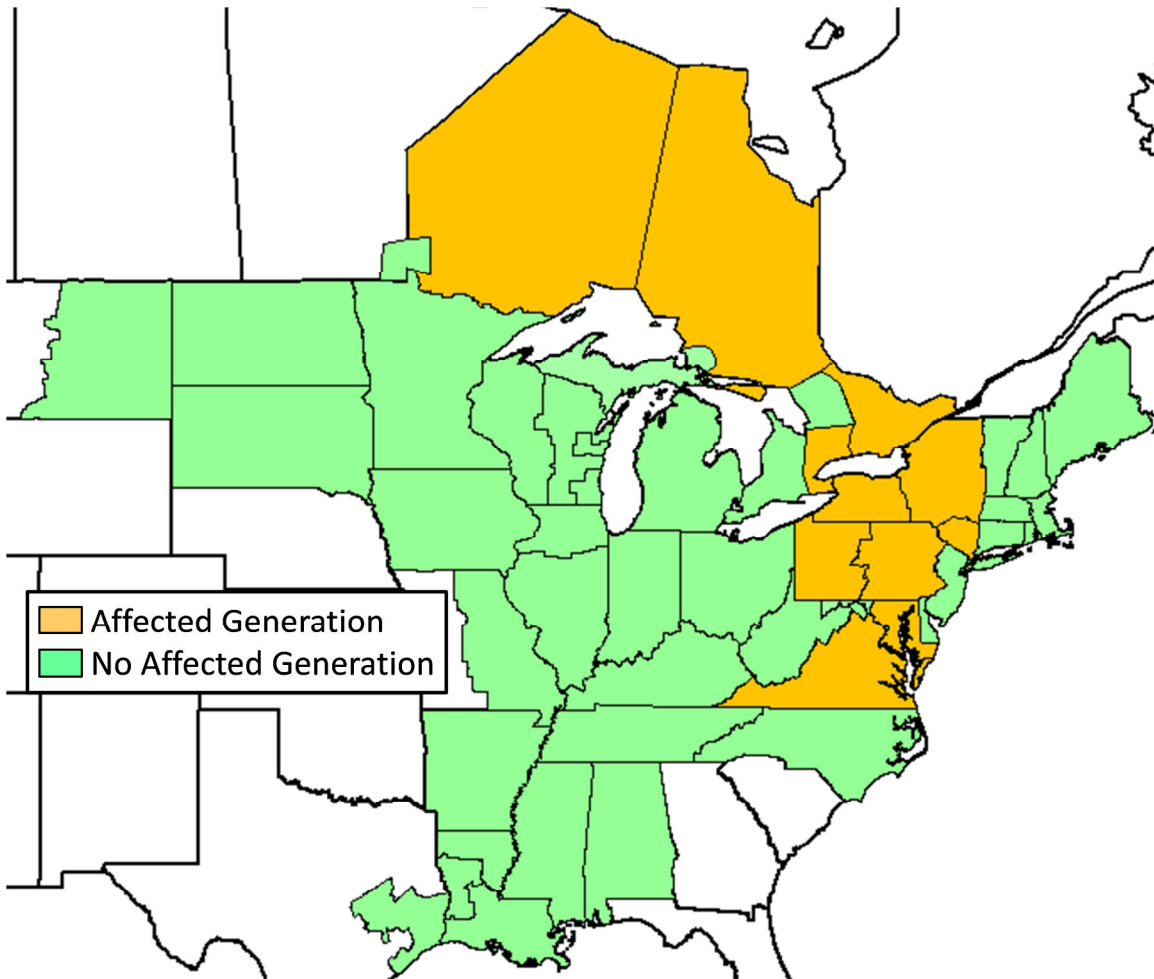


Table S5. RGDS S33 Winter 2018: Peak Hour Unserved Generator Gas Demand and Affected Generation

GPCM Location	Unserved Generation Gas Demand (MDth)	Affected Generation (MWh)
Maryland Eastern	3.3	315
New York Central Northern	24.5	2,448
New York Southern	14.3	1,537
New York Western	1.9	216
Ontario (CDA)	0.5	55
Ontario (EDA)	2.1	249
Ontario (NDA)	1.5	186
Ontario (WDA)	0.4	38
Pennsylvania Eastern	43.8	5,557
Pennsylvania Western	4.1	393
Virginia	35.4	4,237

Figure S9 shows the constrained pipeline segments, in red, that result in the affected generation shown in Figure S7 during the Winter 2018 peak hour. Due to the similar gas demand patterns between RGDS S31 and RGDS S33, constraints are unchanged.

Figure S9. RGDS S33 Winter 2018: Peak Hour Constraints

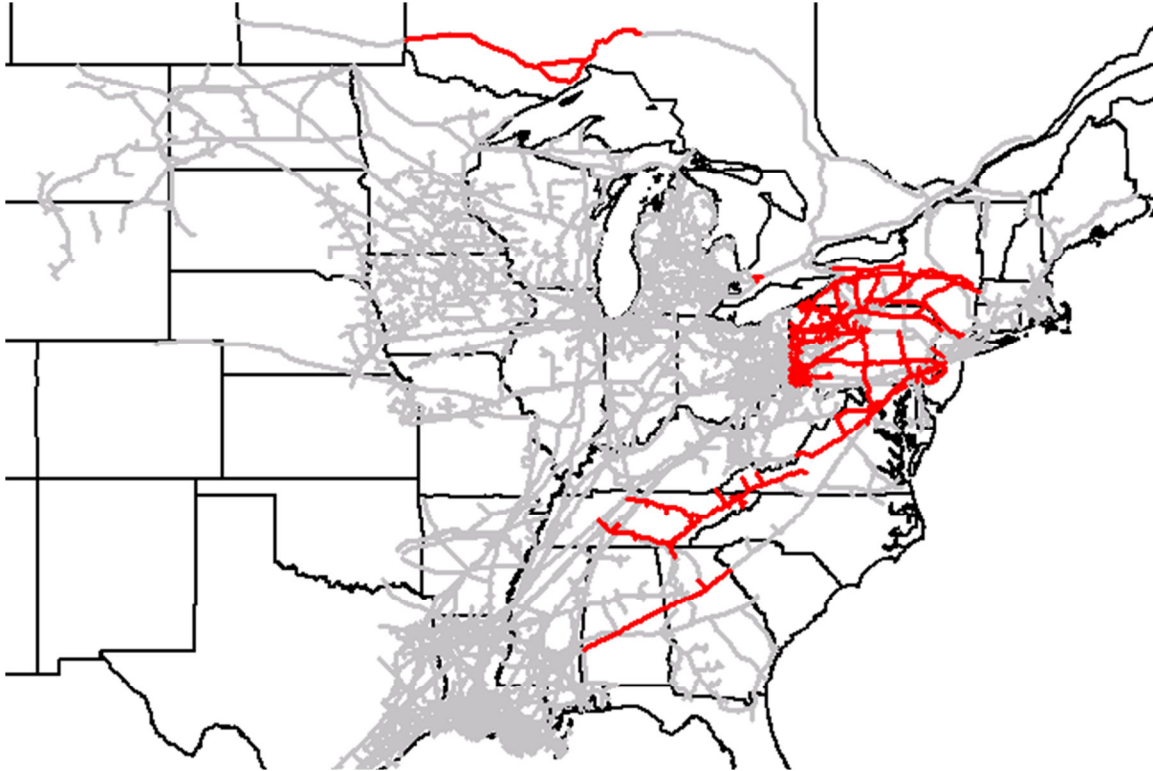


Table S6 lists the segments that are constrained during the peak hour.

Table S6. RGDS S33 Winter 2018: Peak Hour Constraints

Columbia Gas VA/MD	Empire Mainline	TransCanada Ontario West
Columbia Gas W PA/NY	Millennium	Transco Leidy Atlantic
Constitution	NFG Mainline	Transco Z4
Dominion Eastern NY	Tennessee Z4 PA	Transco Z6
Dominion Western NY	Tennessee Z5 NY	Transco Z6 Leidy to 210
Dominion Southeast	Texas Eastern M2 PA South	Union Gas Dawn
East Tennessee Mainline	Texas Eastern M3 North	

2.2 RGDS S33 WINTER 2023

The RGDS S33 Winter 2023 results are very similar to the RGDS S31 Winter 2023 results for the same reasons expressed regarding Winter 2018 in the previous section. Figure S10 summarizes the affected generation during the Winter 2023 peak hour by PPA.

Figure S10. RGDS S33 Winter 2023: Peak Hour Affected Generation

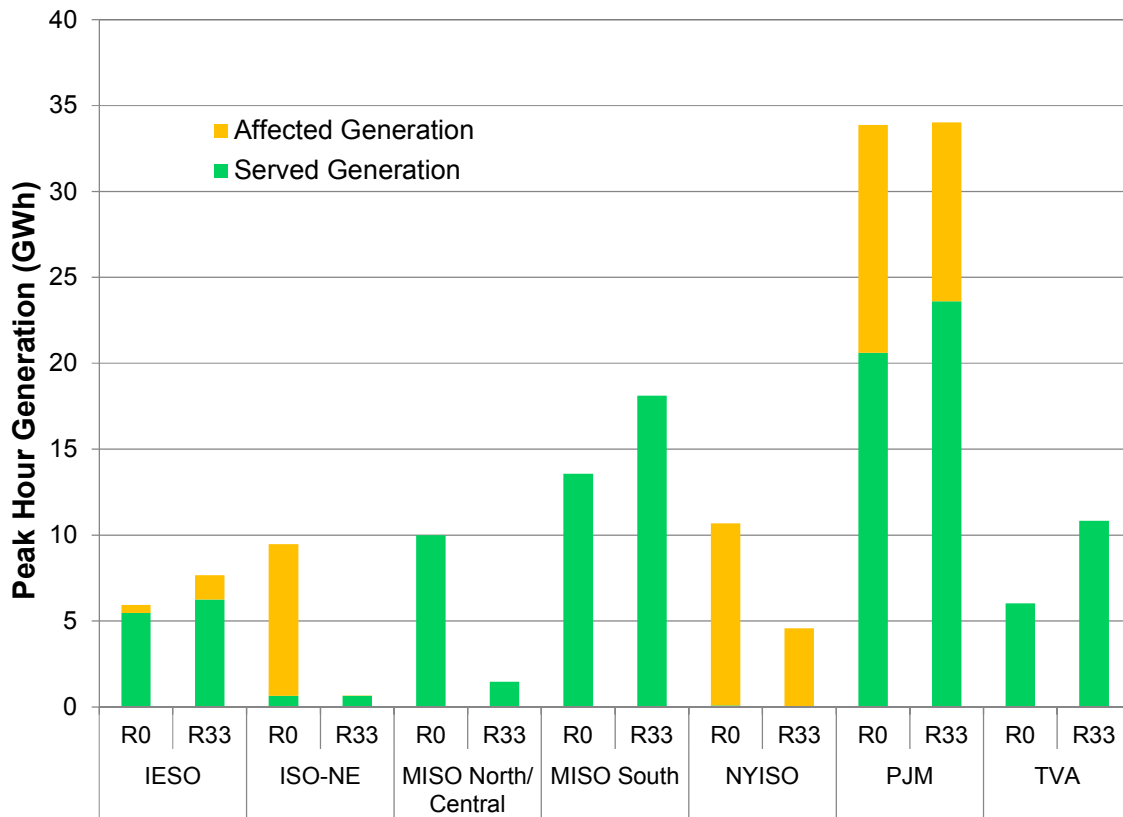


Figure S11 summarizes the unserved demand by GPCM location. The unserved demand and affected generation by location are quantified in Table S7.

Figure S11. RGDS S33 Winter 2023: GPCM Locations with Peak Hour Affected Generation

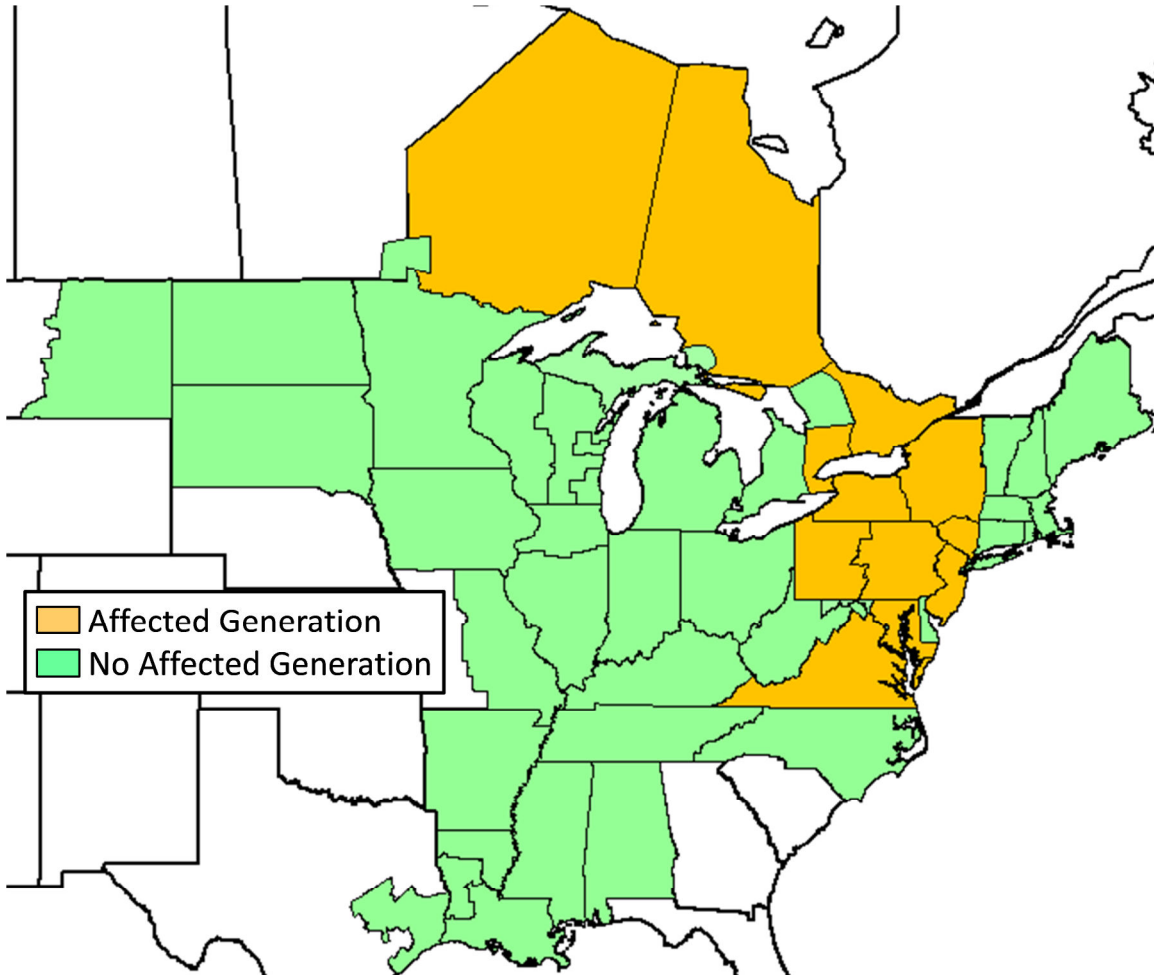


Table S7. RGDS S33 Winter 2023: Peak Hour Unserved Generator Gas Demand and Affected Generation

GPCM Location	Unserved Generation Gas Demand (MDth)	Affected Generation (MWh)
Maryland Eastern	3.3	315
New Jersey	0.6	77
New York Central Northern	27.2	2,824
New York Southern	14.3	1,537
New York Western	1.9	216
Ontario (CDA)	0.5	55
Ontario (EDA)	8.5	1,133
Ontario (NDA)	1.5	186
Ontario (WDA)	0.4	38
Pennsylvania Eastern	44.3	5,629
Pennsylvania Western	1.1	101
Virginia	36.2	4,285

Figure S12 shows the constrained pipeline segments, in red, that result in the affected generation shown in Figure S10 during the Winter 2023 peak hour.

Figure S12. RGDS S33 Winter 2023: Peak Hour Constraints

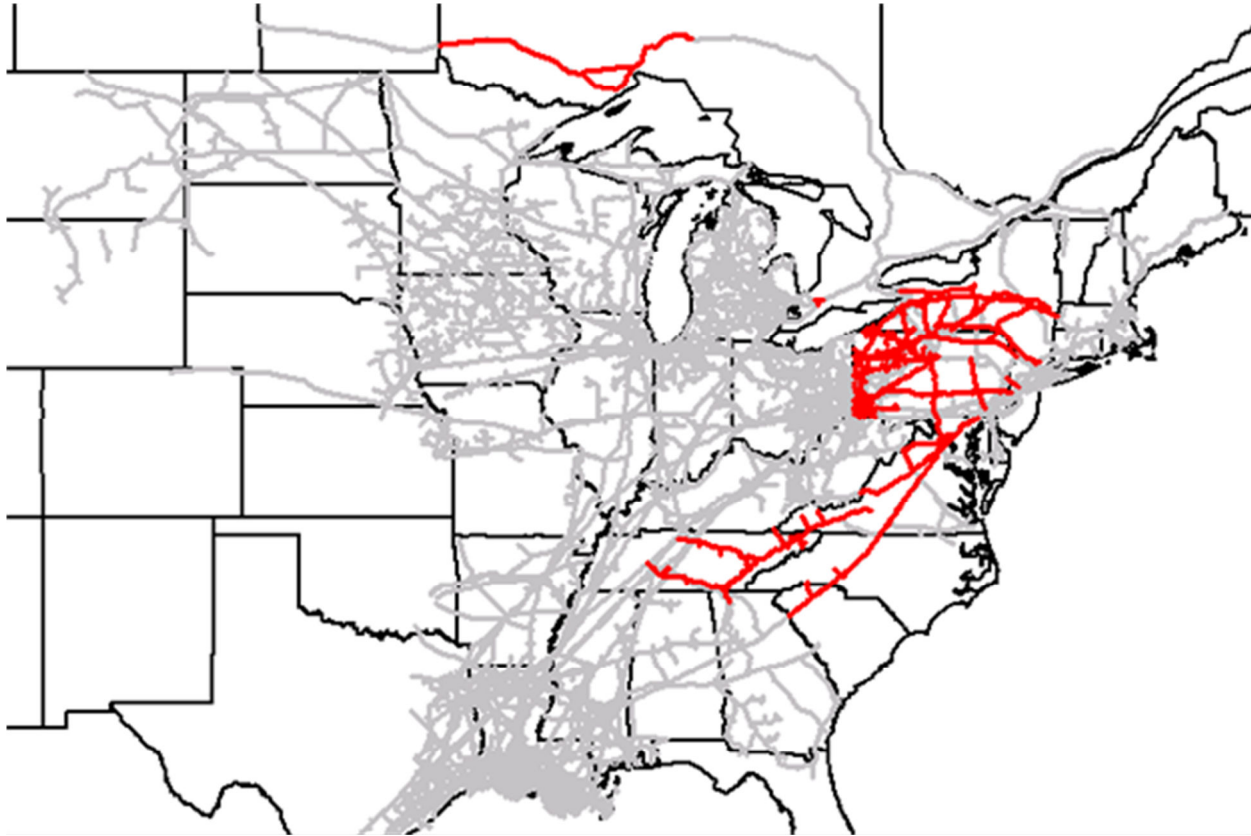


Table S8 lists the segments that are constrained during the peak hour.

Table S8. RGDS S33 Winter 2023: Peak Hour Constraints

Columbia Gas VA/MD	Empire Mainline	Texas Eastern M3 North
Columbia Gas W PA/NY	Millennium	TransCanada Ontario West
Constitution	NFG Mainline	Transco Leidy Atlantic
Dominion Eastern NY	Tennessee Z4 PA	Transco Z5
Dominion Western NY	Tennessee Z5 NY	Transco Z6 Leidy to 210
Dominion Southeast	Texas Eastern M2 PA South	Union Gas Dawn
East Tennessee Mainline		

3 S36: S33 + SELECTED NUCLEAR UNITS UNAVAILABLE

Sensitivity 36 tests the gas system capability to compensate for selected nuclear plant outages in addition to the coal- and oil-fired unit outages modeled in Sensitivity 33, during the cold weather event modeled in Sensitivity 31.

3.1 RGDS S36 WINTER 2018

Figure S13 summarizes the affected generation during the Winter 2018 peak hour by PPA. In IESO the amount of affected generation is unchanged relative to RGDS S33 because of firm transportation contracts held by generators. In New England and MISO North/Central, neither then total generation nor the unserved generation changes relative to RGDS S33. In MISO South and TVA, total generation increases, but all generation is still served. In NYISO, affected generation increases commensurately with total generation. In PJM, both total generation and affected generation increase relative to RGDS S33, but the increases are not proportional due to the locations and connectivity of the incremental generation, therefore a slightly smaller percentage of PJM’s generation is affected in RGDS S36.

Figure S13. RGDS S36 Winter 2018: Peak Hour Affected Generation

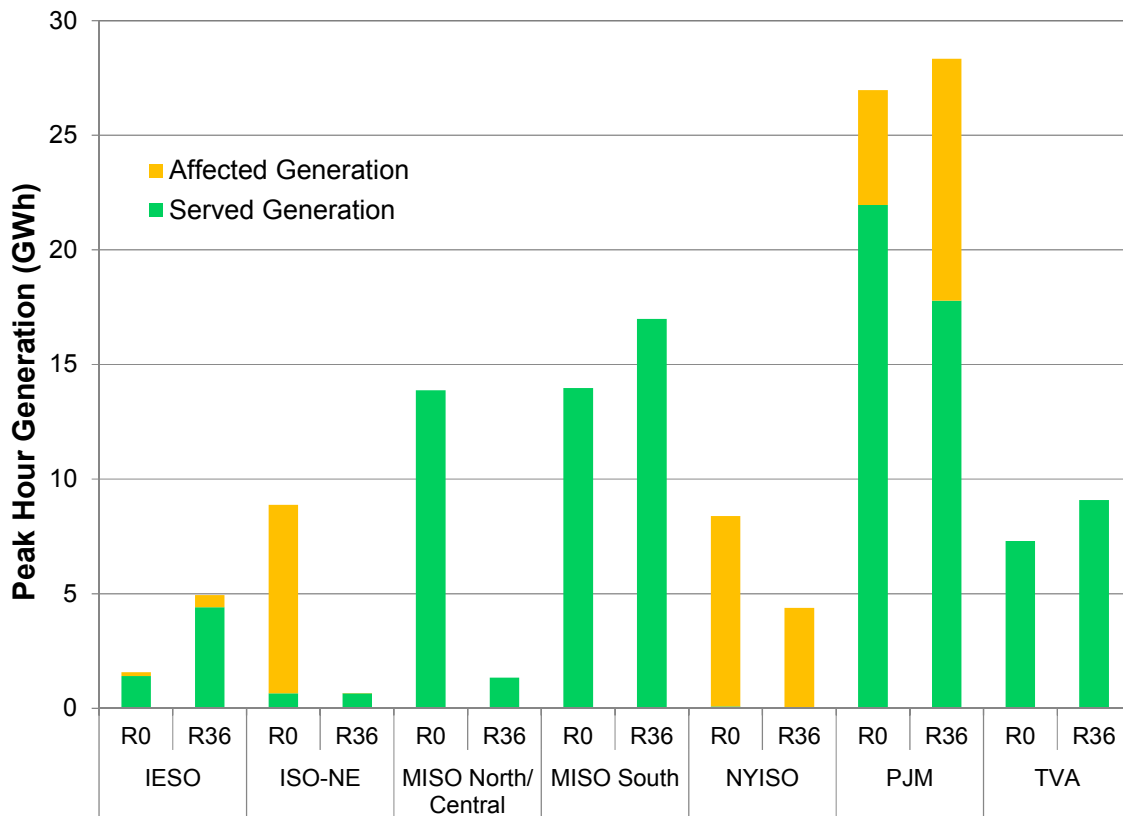


Figure S14 summarizes the unserved demand by GPCM location. The unserved demand and affected generation by location are quantified in Table S9. Generation is affected in the same GPCM locations as in RGDS S33.

Figure S14. RGDS S36 Winter 2018: GPCM Locations with Peak Hour Affected Generation

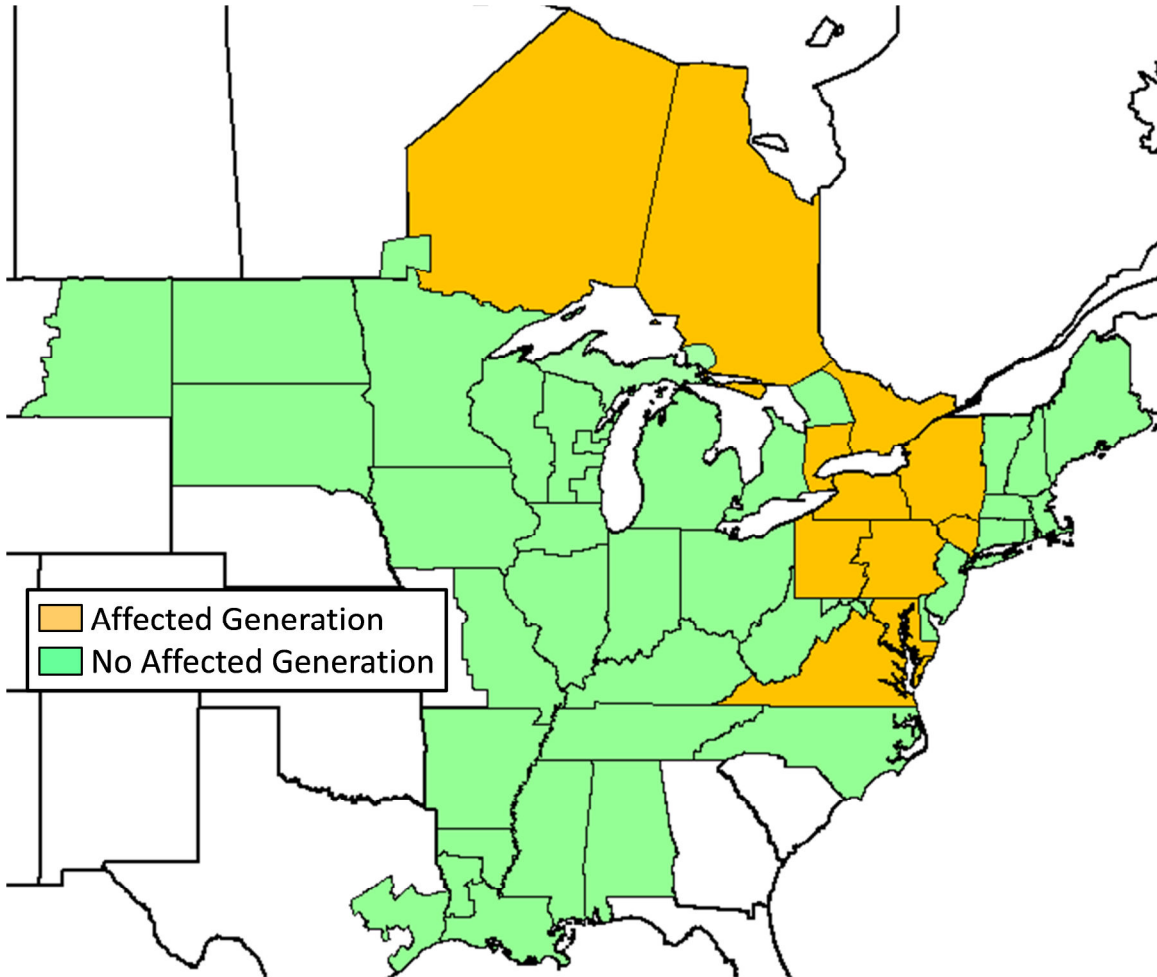


Table S9. RGDS S36 Winter 2018: Peak Hour Unserved Generator Gas Demand and Affected Generation

GPCM Location	Peak Hour Unserved Generator Gas Demand and Affected Generation	
	Unserved Generation Gas Demand (MDth)	Affected Generation (MWh)
Maryland Eastern	3.3	315
New York Central Northern	25.8	2,633
New York Southern	14.3	1,537
New York Western	1.8	209
Ontario (CDA)	0.5	55
Ontario (EDA)	2.1	249
Ontario (NDA)	1.5	186
Ontario (WDA)	0.4	38
Pennsylvania Eastern	43.8	5,557
Pennsylvania Western	4.1	393
Virginia	36.2	4,285

Figure S15 shows the constrained pipeline segments, in red, that result in the affected generation shown in Figure S13 during the Winter 2018 peak hour. The same segments are constrained in RGDS S36 as in RGDS S33.

Figure S15. RGDS S36 Winter 2018: Peak Hour Constraints

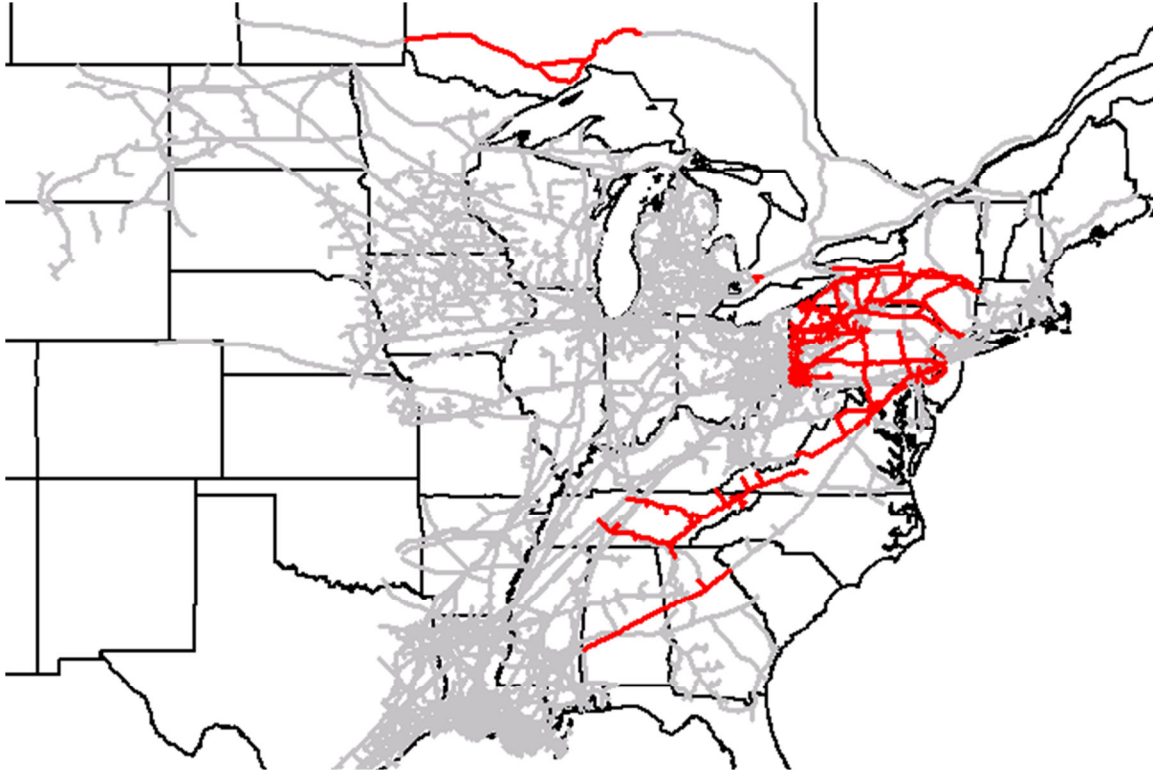


Table S10 lists the segments that are constrained during the peak hour.

Table S10. RGDS S36 Winter 2018: Peak Hour Constraints

Columbia Gas VA/MD	Empire Mainline	TransCanada Ontario West
Columbia Gas W PA/NY	Millennium	Transco Leidy Atlantic
Constitution	NFG Mainline	Transco Z4
Dominion Eastern NY	Tennessee Z4 PA	Transco Z6
Dominion Western NY	Tennessee Z5 NY	Transco Z6 Leidy to 210
Dominion Southeast	Texas Eastern M2 PA South	Union Gas Dawn
East Tennessee Mainline	Texas Eastern M3 North	

3.2 RGDS S36 WINTER 2023

The RGDS S36 Winter 2023 results are very similar to the RGDS S33 Winter 2023 results for the same reasons expressed regarding Winter 2018 in the previous section. Figure S16 summarizes the affected generation during the Winter 2023 peak hour by PPA.

Figure S16. RGDS S36 Winter 2023: Peak Hour Affected Generation

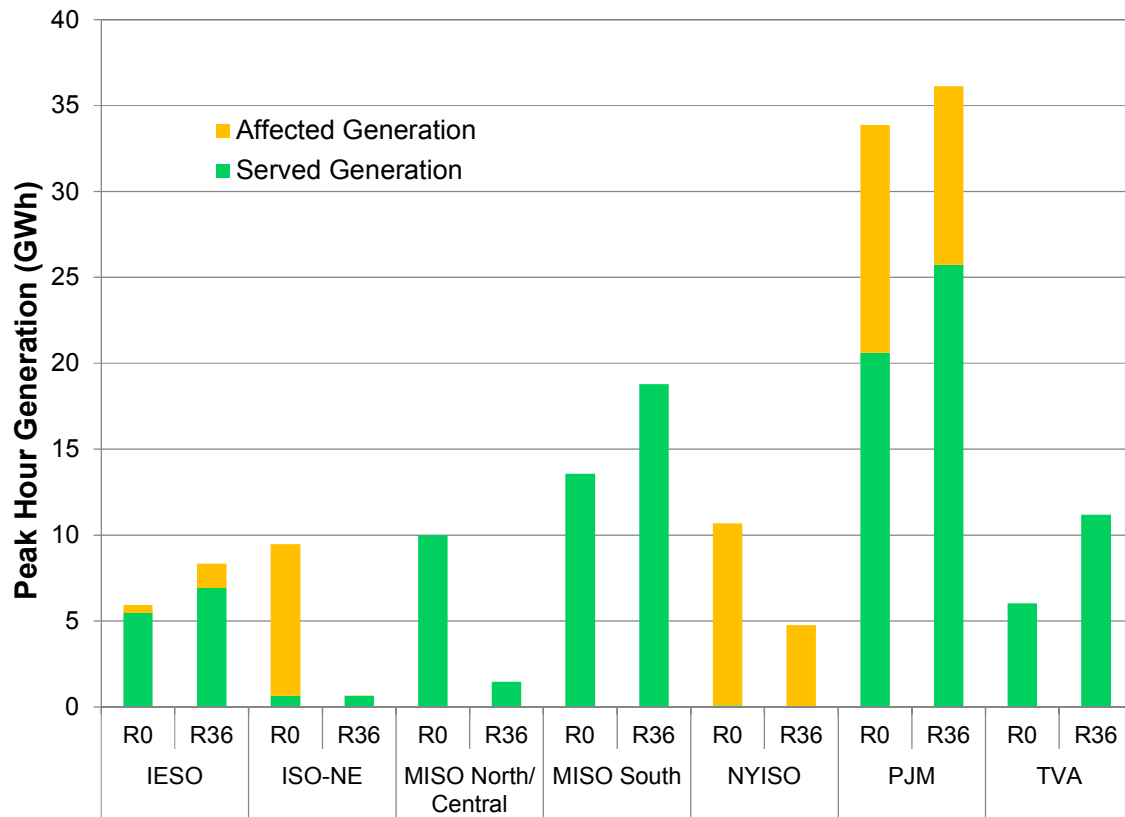


Figure S17 summarizes the unserved demand by GPCM location. The unserved demand and affected generation by location are quantified in Table S11.

Figure S17. RGDS S36 Winter 2023: Locations with Peak Hour Affected Generation

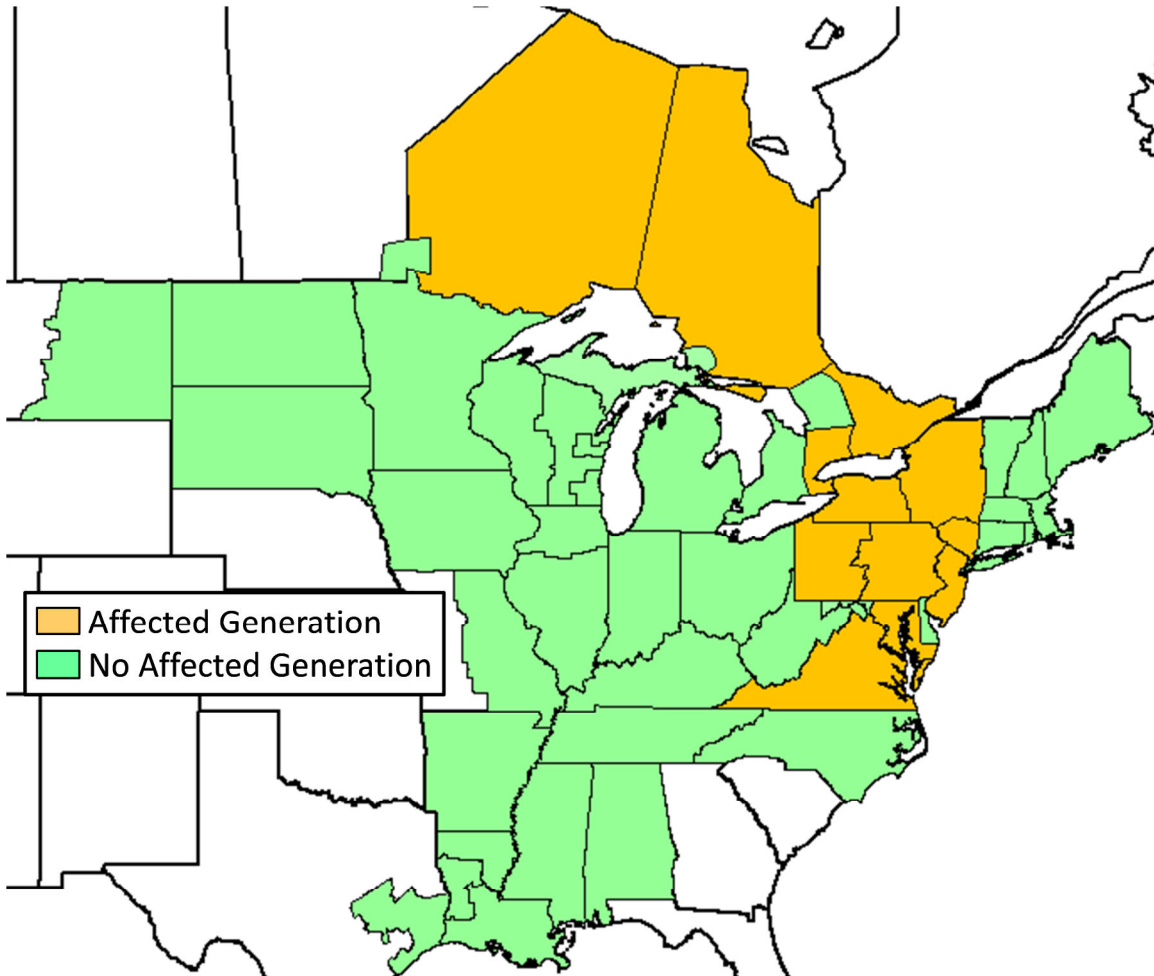


Table S11. RGDS S36 Winter 2023: Peak Hour Unserved Generator Gas Demand and Affected Generation

Location	Unserved Generation Gas Demand (MDth)	Affected Generation (MWh)
Maryland Eastern	3.3	315
New Jersey	0.6	77
New York Central Northern	28.6	3,011
New York Southern	14.3	1,537
New York Western	1.9	216
Ontario (CDA)	0.5	55
Ontario (EDA)	8.5	1,133
Ontario (NDA)	1.5	186
Ontario (WDA)	0.4	38
Pennsylvania Eastern	44.3	5,629
Pennsylvania Western	1.1	101
Virginia	36.2	4,285

Figure S18 shows the constrained pipeline segments, in red, that result in the affected generation shown in Figure S16 during the Winter 2023 peak hour.

Figure S18. RGDS S36 Winter 2023: Peak Hour Constraints

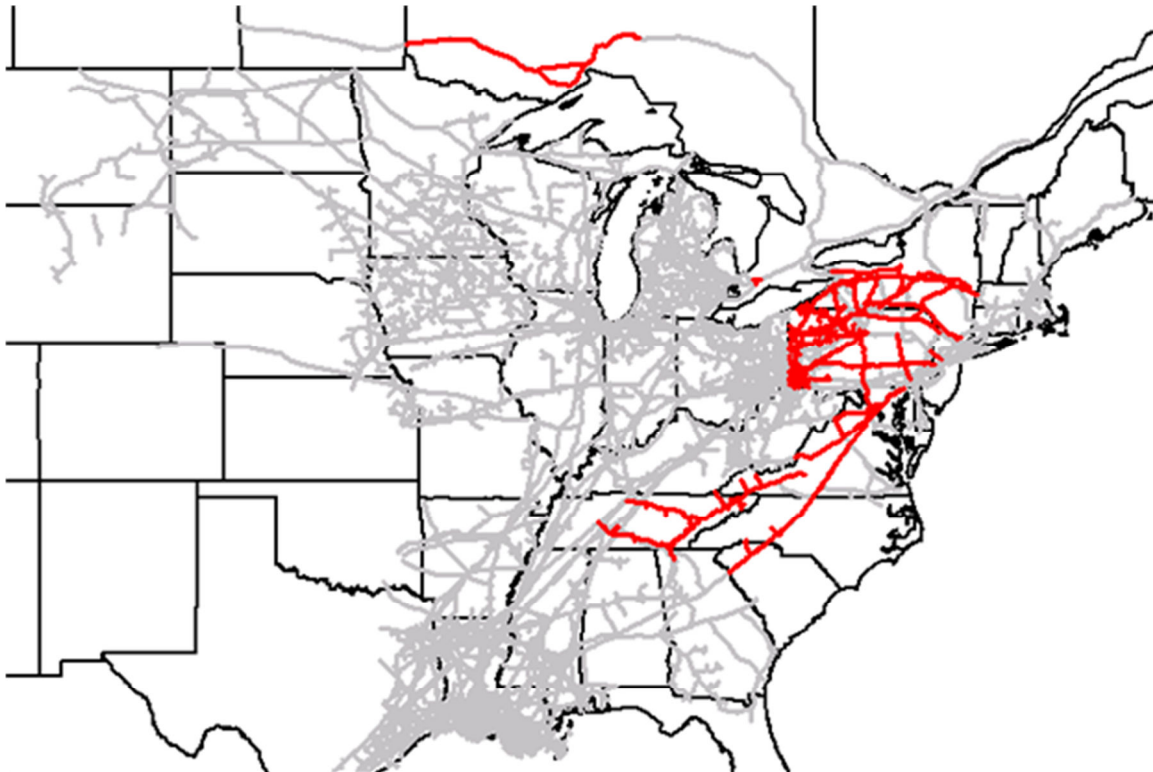


Table S12 lists the segments that are constrained during the peak hour.

Table S12. RGDS S36 Winter 2023: Peak Hour Constraints

Columbia Gas VA/MD	Empire Mainline	Texas Eastern M3 North
Columbia Gas W PA/NY	Millennium	TransCanada Ontario West
Constitution	NFG Mainline	Transco Leidy Atlantic
Dominion Eastern NY	Tennessee Z4 PA	Transco Z5
Dominion Western NY	Tennessee Z5 NY	Transco Z6 Leidy to 210
Dominion Southeast	Texas Eastern M2 PA South	Union Gas Dawn
East Tennessee Mainline		