EIPC
Eastern Interconnection Planning Collaborative

Gas-Electric System Interface Study Summary

May 28, 2015

LEVITAN & ASSOCIATES, INC.
MARKET DESIGN, ECONOMICS AND POWER SYSTEMS

Acknowledgement and Disclaimer

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Acknowledgement:

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Overview

- Highlights
- Study Region
- Adequacy Analysis
- Hydraulic Analysis
- Dual-Fuel Analysis
- Appendix

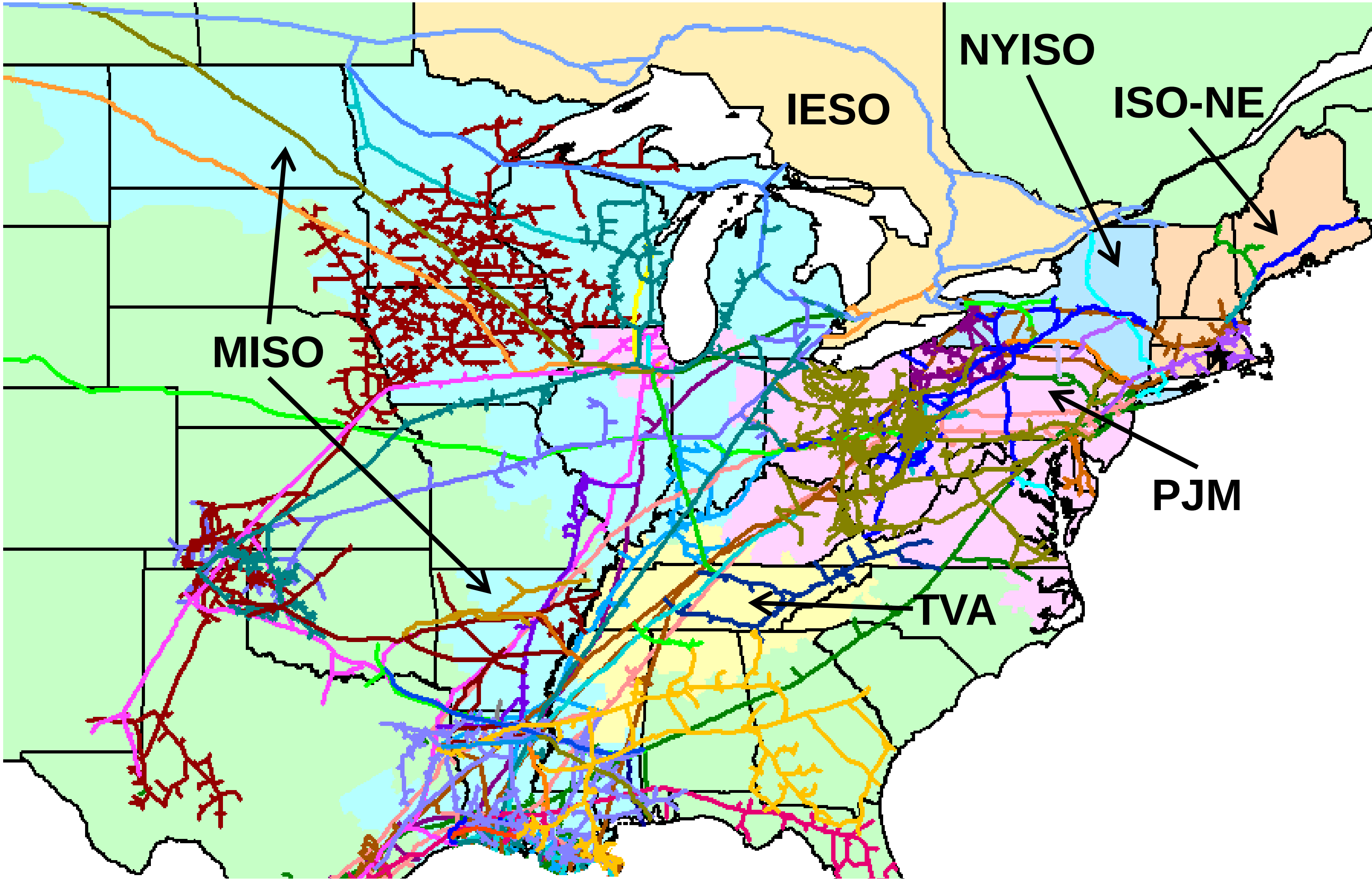
Study Highlights

- Character of service: Most generators do not hold firm transportation entitlements, except in TVA and Ontario
- Gas infrastructure adequacy analysis: Constraints affect generation in ISO-NE, NYISO, EMAAC and SWMAAC
- Contingency analysis: Most gas contingencies allow time for PPAs to schedule alternative resources
- Fuel assurance: Dual-fuel capability less expensive than incremental FT in almost all cases

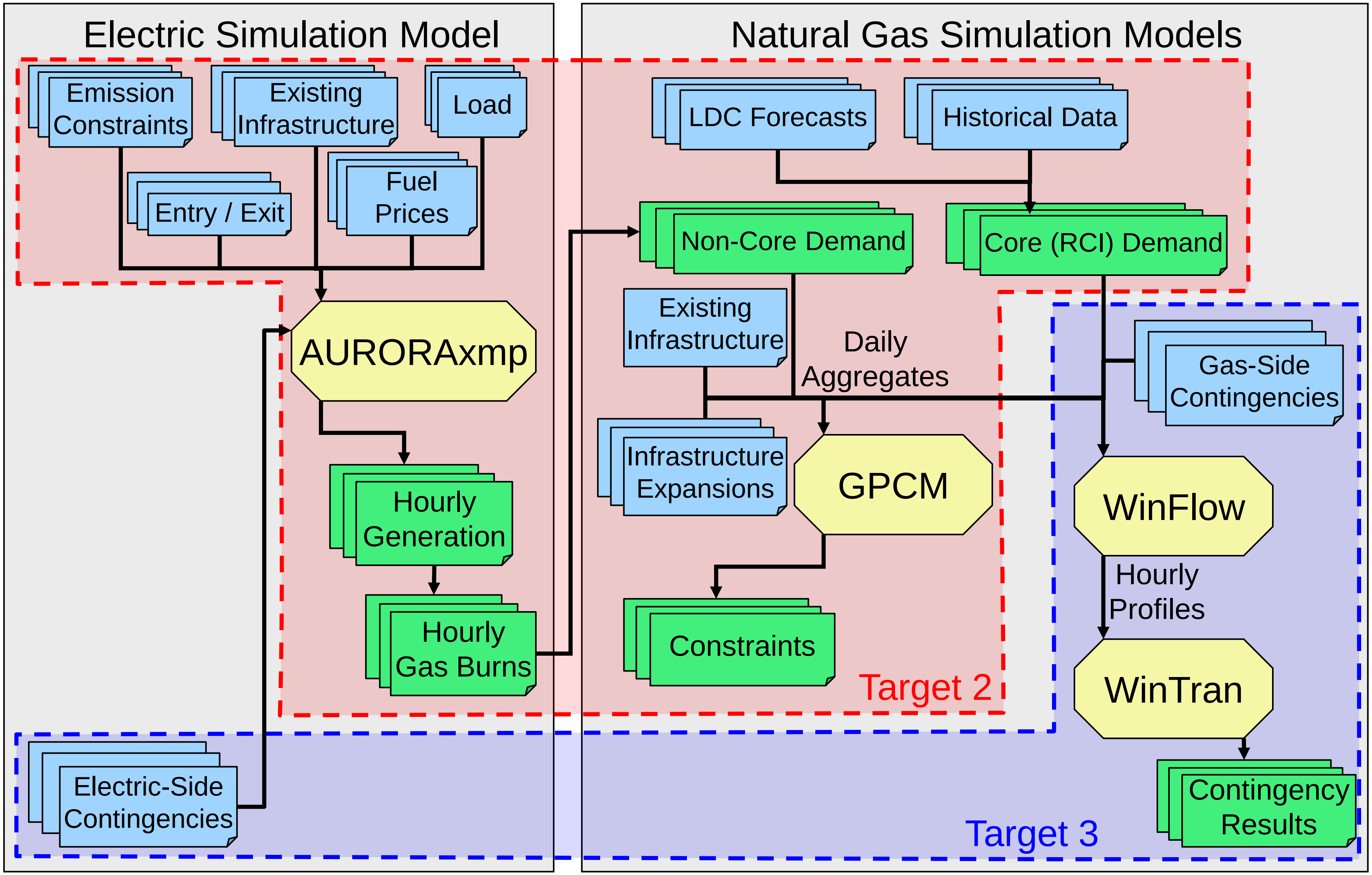
Study Overview – Four Targets

- Target 1: Develop baseline assessment of natural gas-electric system interfaces, interaction effects, and the current level of coordination between the electric and gas systems
- Target 2: Evaluate capability of the natural gas systems to supply the electric power sector fuel requirements over a five and ten year study horizon while serving higher priority firm shippers
- Target 3: Identify contingencies on the natural gas & electric systems that could adversely affect electric system reliability
- Target 4: Review operational / planning issues related to dual fuel capability, including the net benefits of fuel assurance alternatives

PPAs and Study Region Pipelines



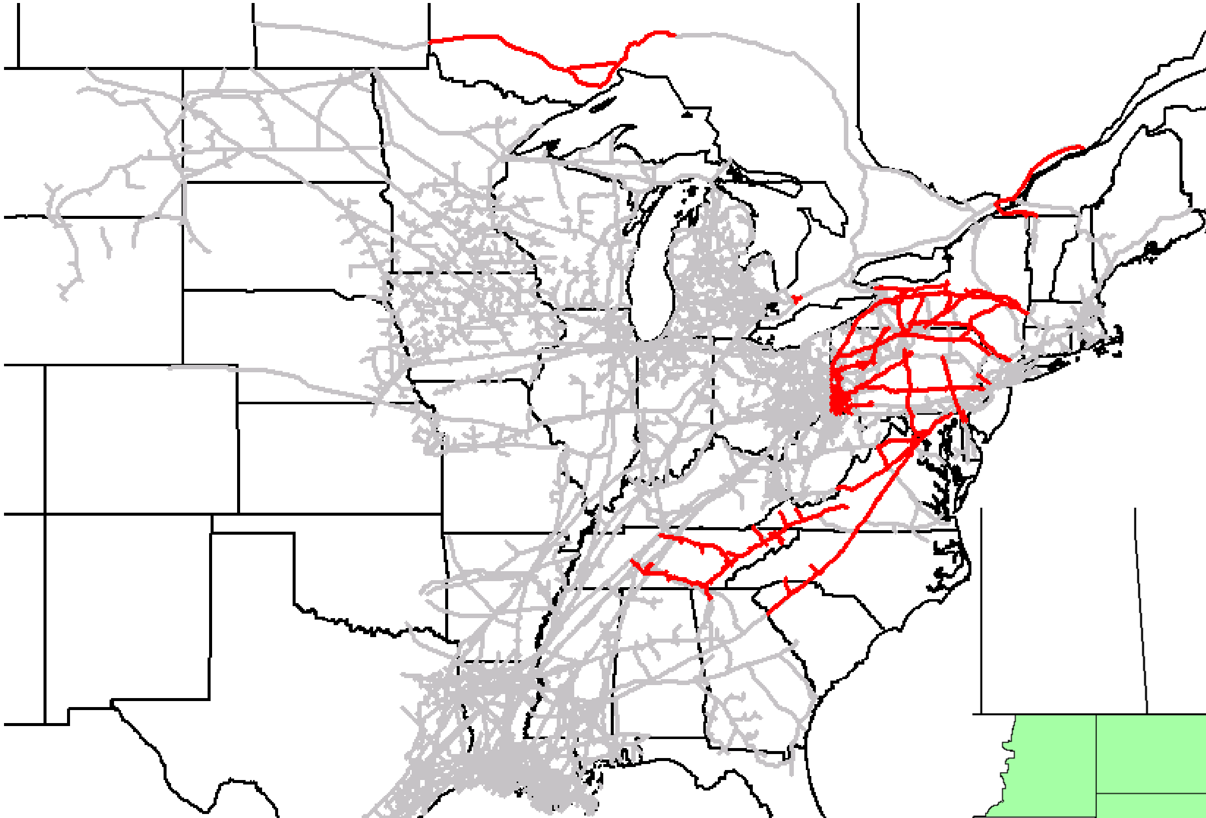
Model Framework



Constraint Identification Approach

- Develop electric system chronological dispatch model for 2018 and 2023 to estimate hourly gas demands for each generator
- Combine forecasts of RCI and generator gas demand to represent seasonal coincident peak days
- Quantify unserved gas demand using optimization modeling of the gas infrastructure network for seasonal peak hours, and allocate the unserved demand to affected generators
- Quantify frequency and duration of pipeline constraints during seasonal daily peak hours
- Identify gas transportation constraints causing unserved peak hour demand
- Identify potential mitigation measures to reduce or eliminate transportation constraints affecting generation

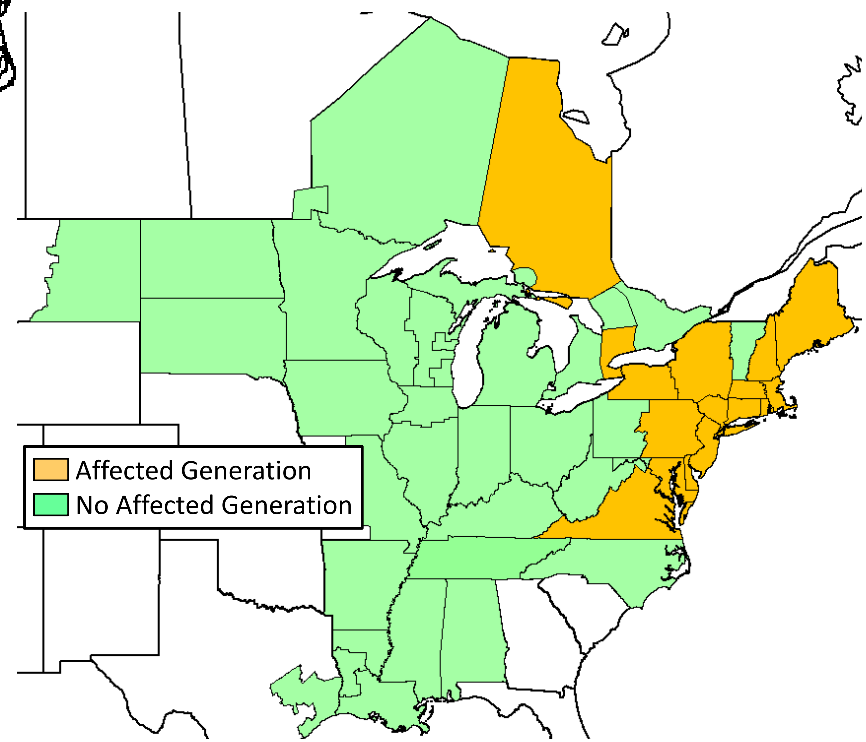
Constraints: Reference Demand Scenario Winter 2018



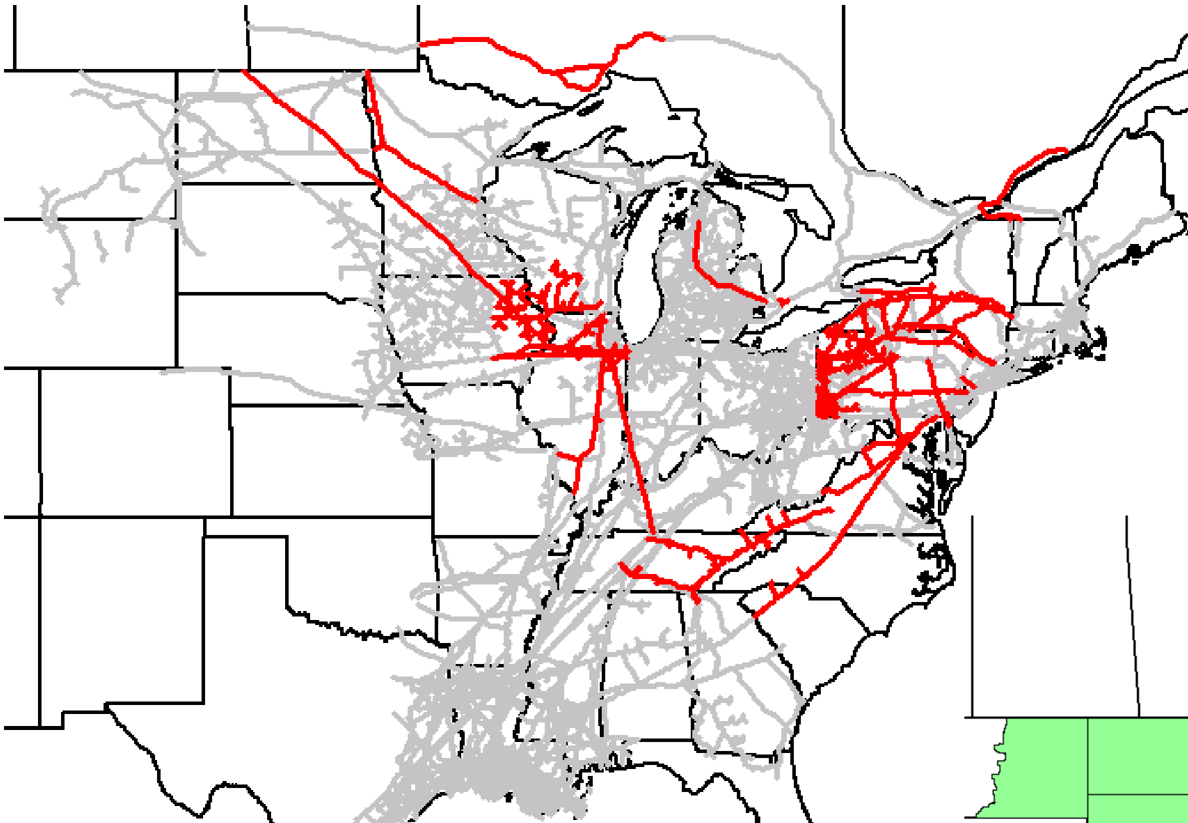
"Affected Generation" does not imply a risk to electric reliability

Peak Hour Unserved Generation Gas Demand: 165 MDth (27.6%)

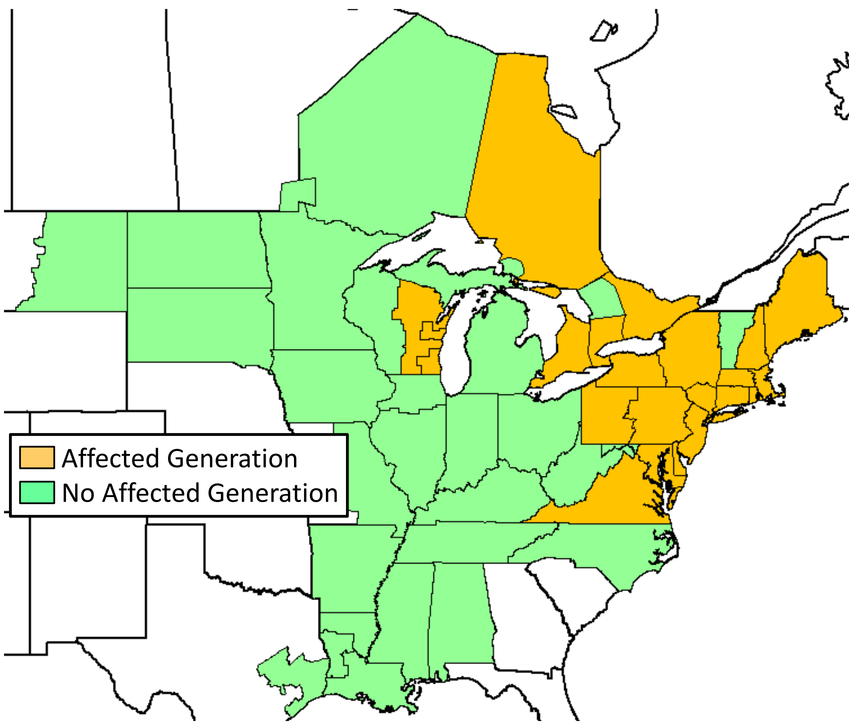
Peak Hour Affected Generation: 21,707 MWh (26.8%)



Constraints: High Demand Scenario Winter 2018



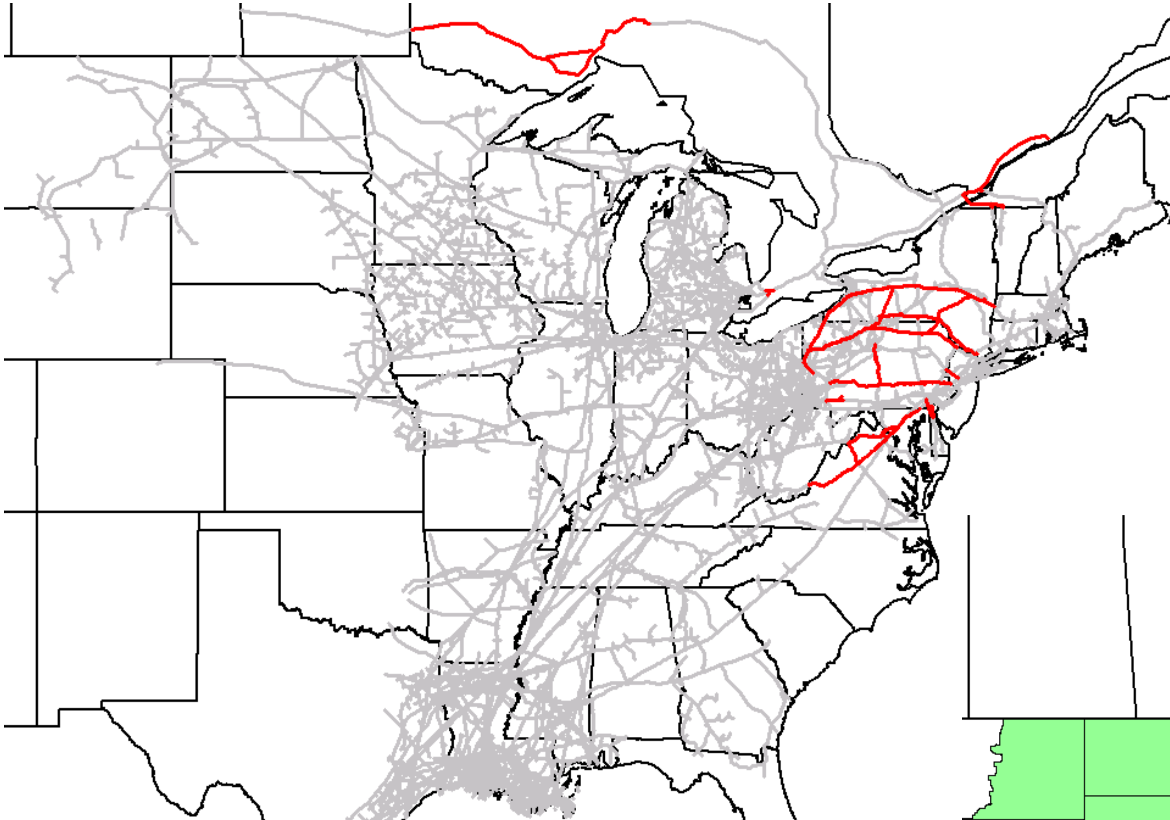
"Affected Generation" does not imply a risk to electric reliability



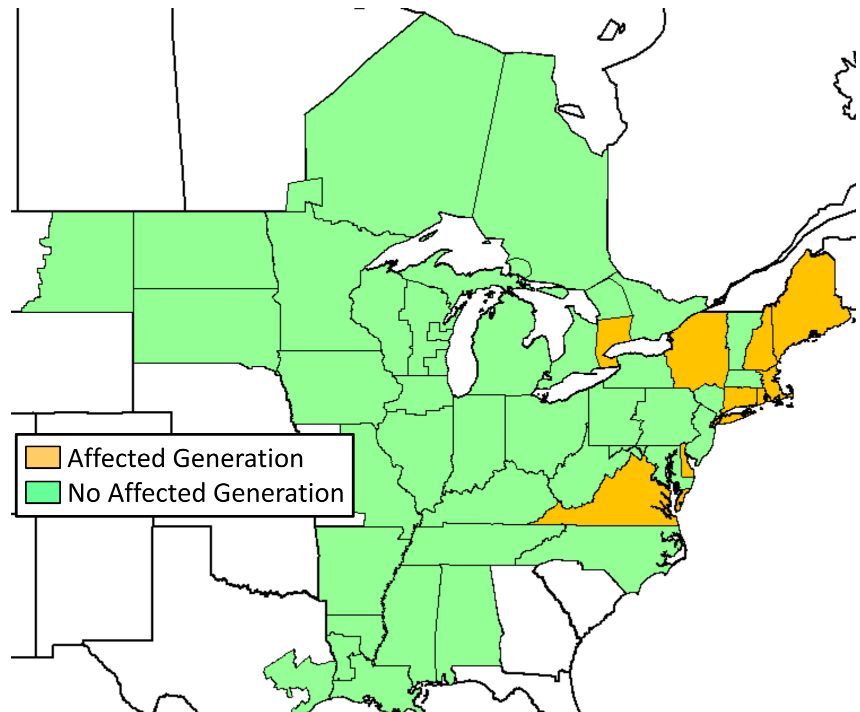
Peak Hour Unserved Generation Gas Demand: 351 MDth (29.4%)

Peak Hour Affected Generation: 45,269 MWh (29.3%)

Constraints: Low Demand Scenario Winter 2018



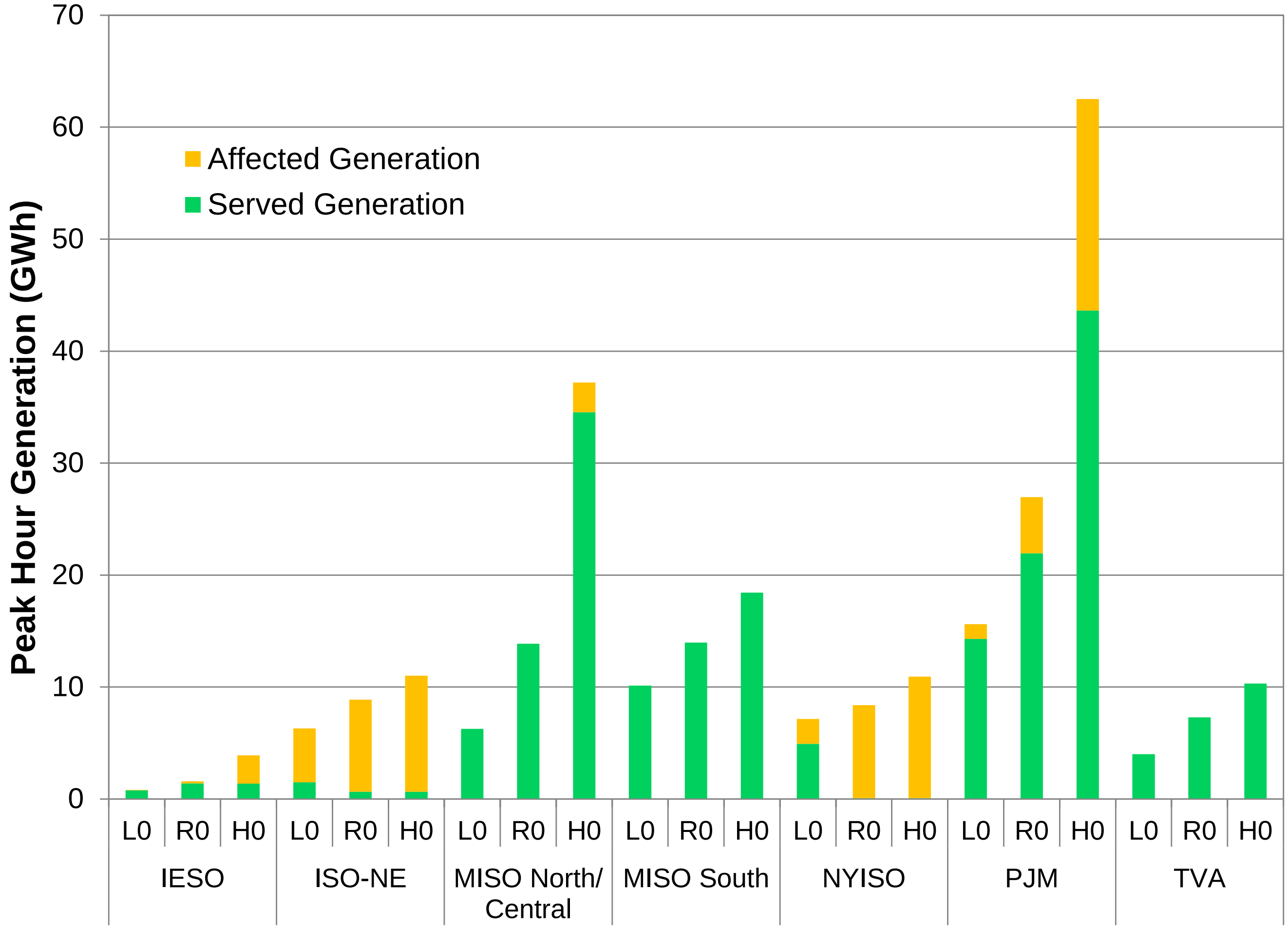
"Affected Generation" does not imply a risk to electric reliability



Peak Hour Unserved Generation Gas Demand: 64 MDth (17.6%)

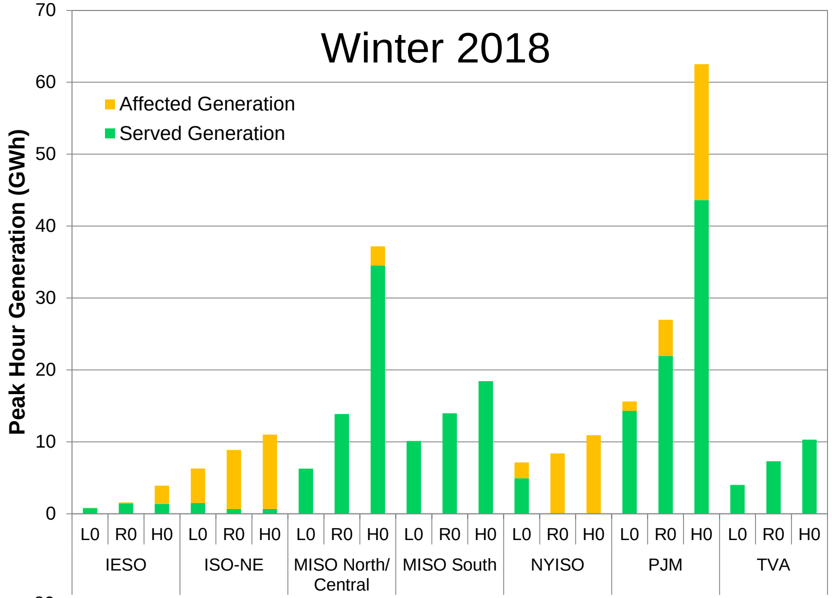
Peak Hour Affected Generation: 8,350 MWh (16.6%)

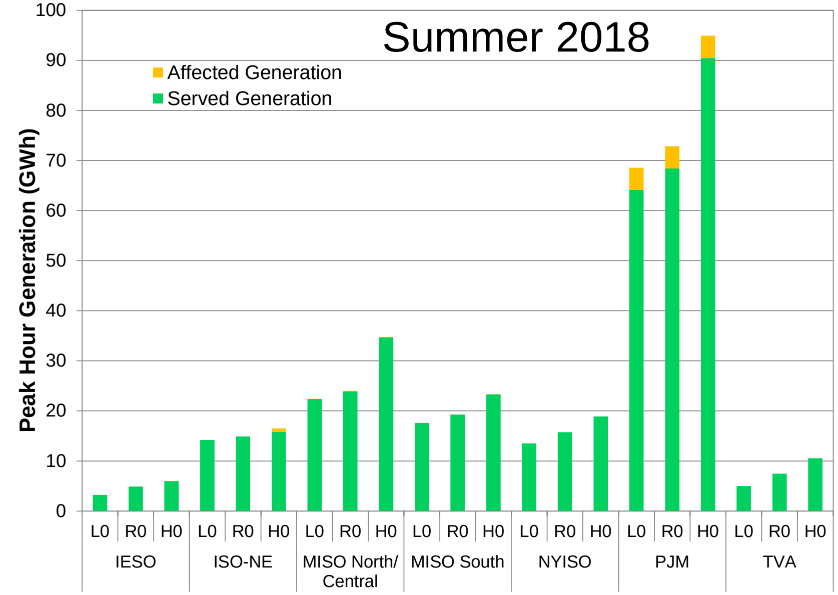
Winter 2018: Affected Generation by Scenario

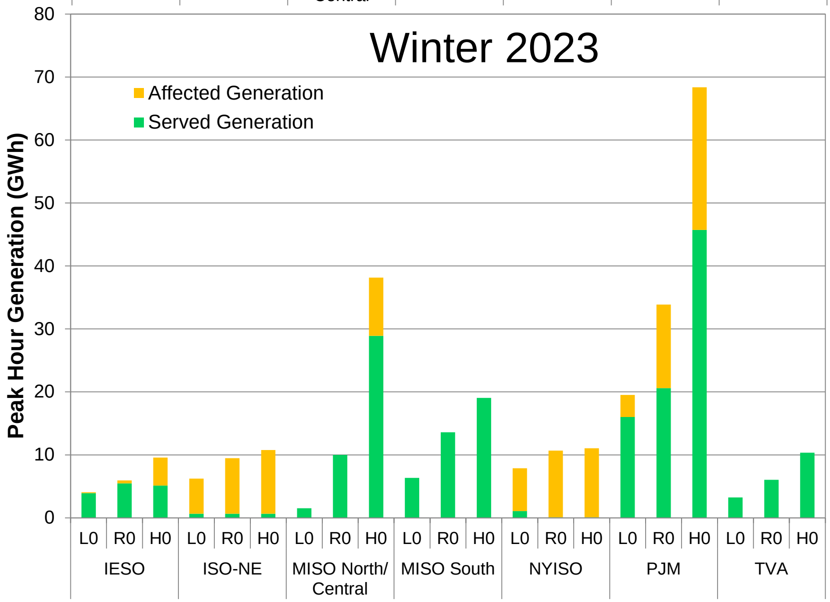


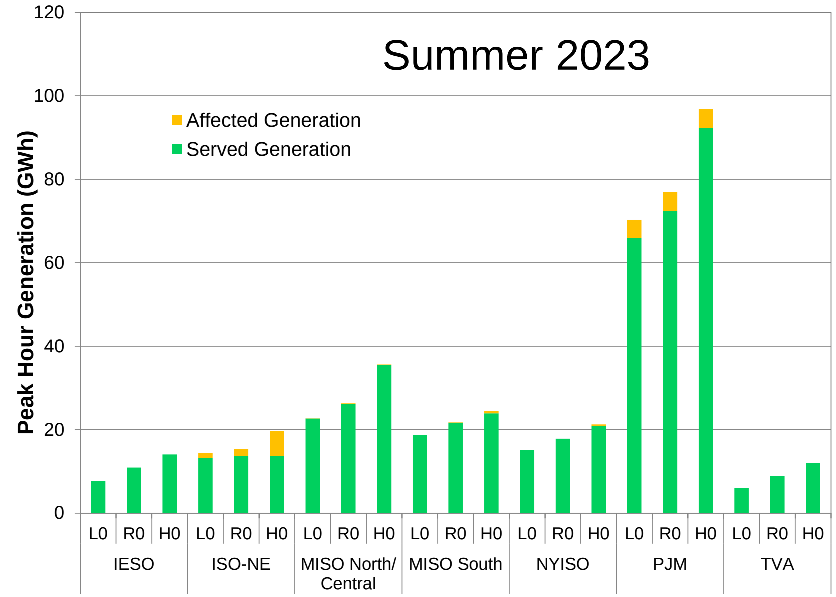
"Affected Generation" indicates the amount of energy for gas-fired generation that cannot be supplied due to the limitations of the pipeline system – which represents either full or partial scheduled requirements. Mitigation measures include switching to liquid fuel and/or redispatch.

Affected Generation by Season

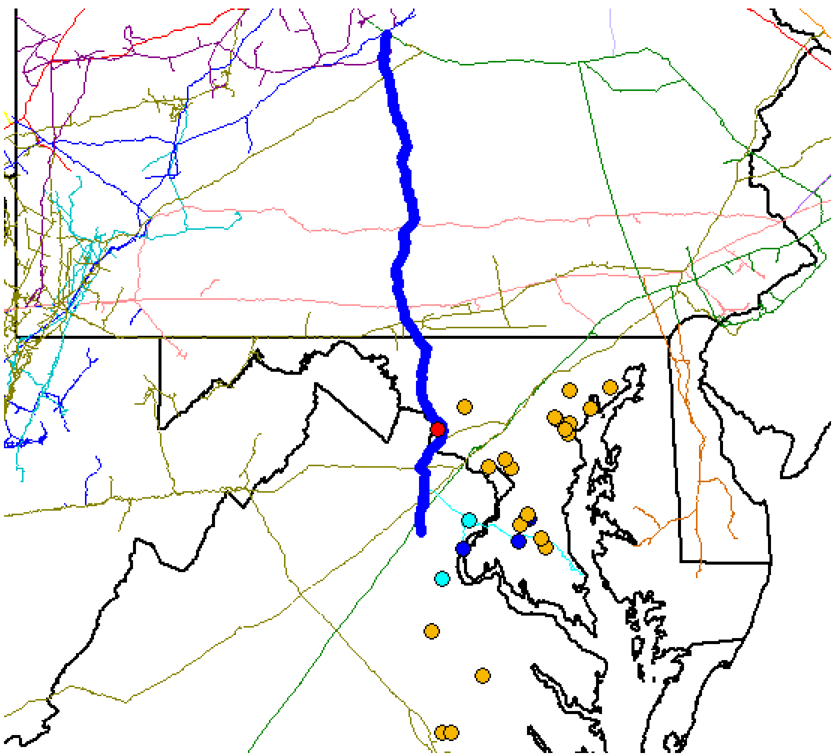




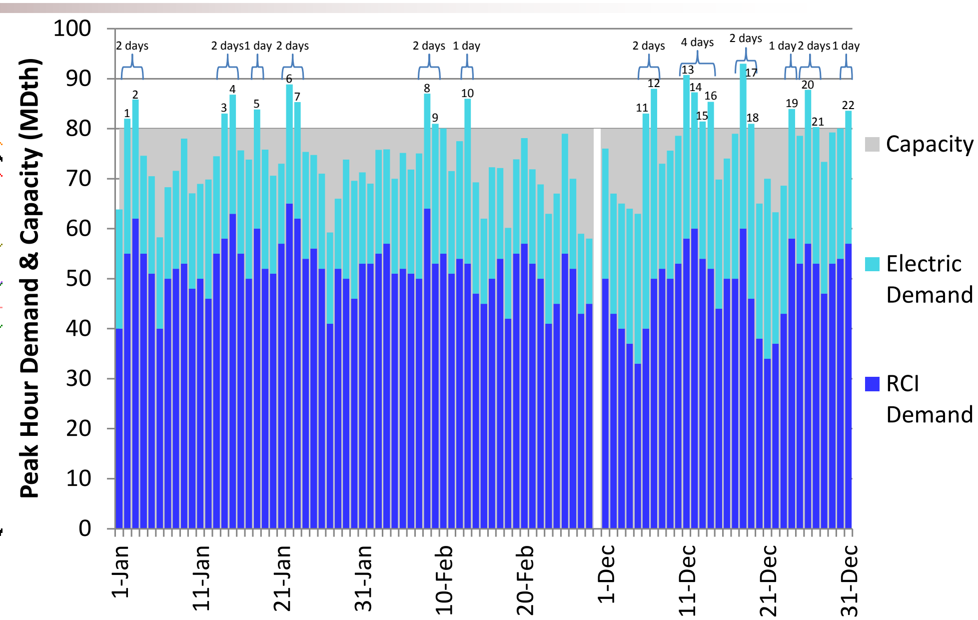


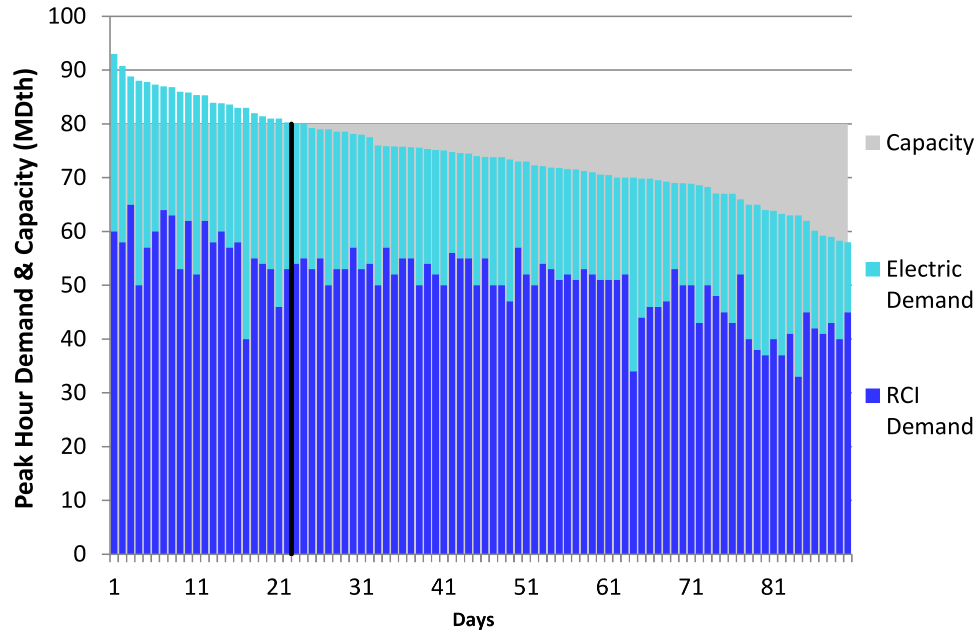


Frequency-Duration Results Format



- Dominion Southeast
- Direct-Connect Generator
- LDC-Served Generator
- Downstream Pipeline-Served Generator
- Downstream Pipeline → LDC-Served Generator





Note: Frequency-Duration charts are examples, not for this specific segment

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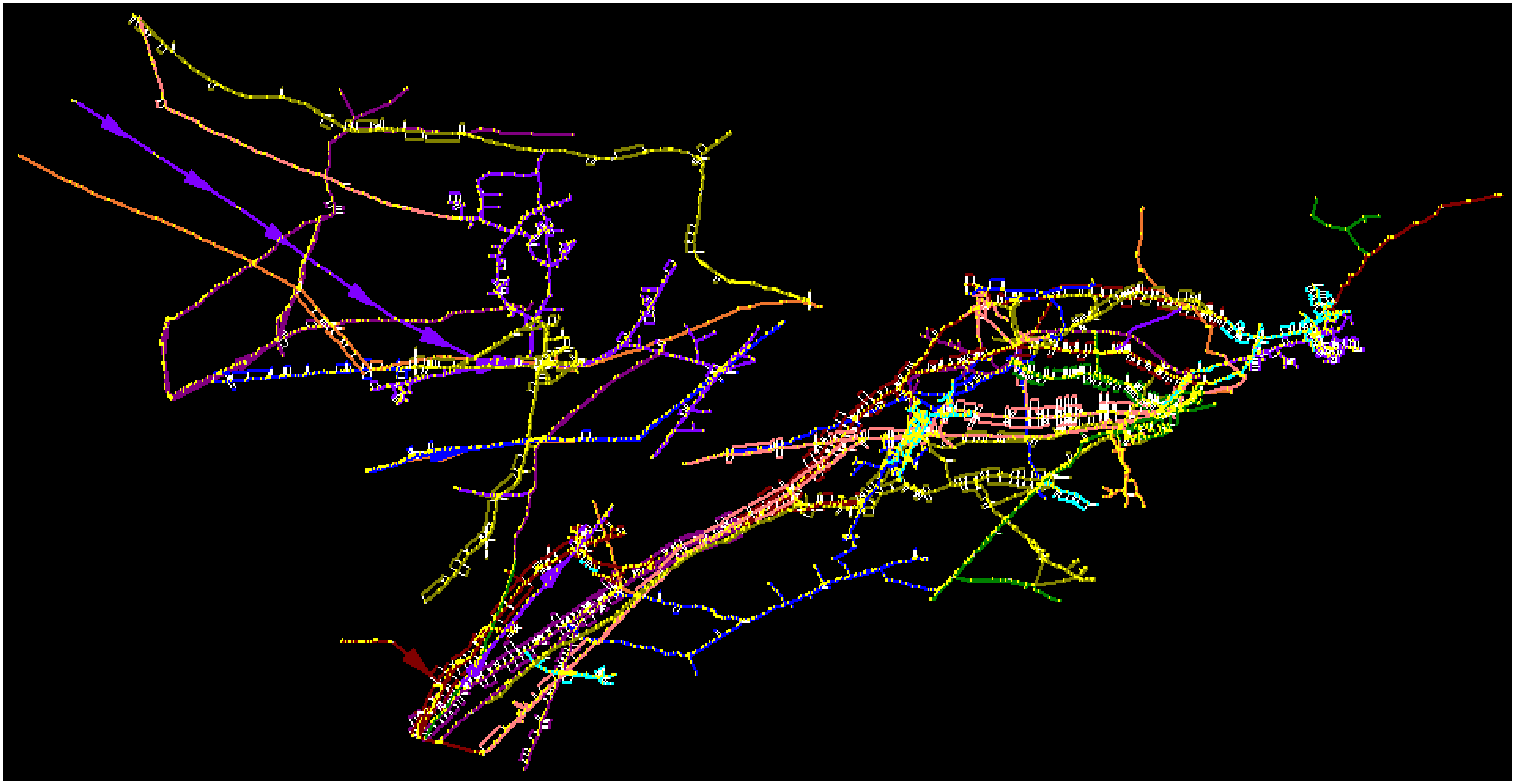
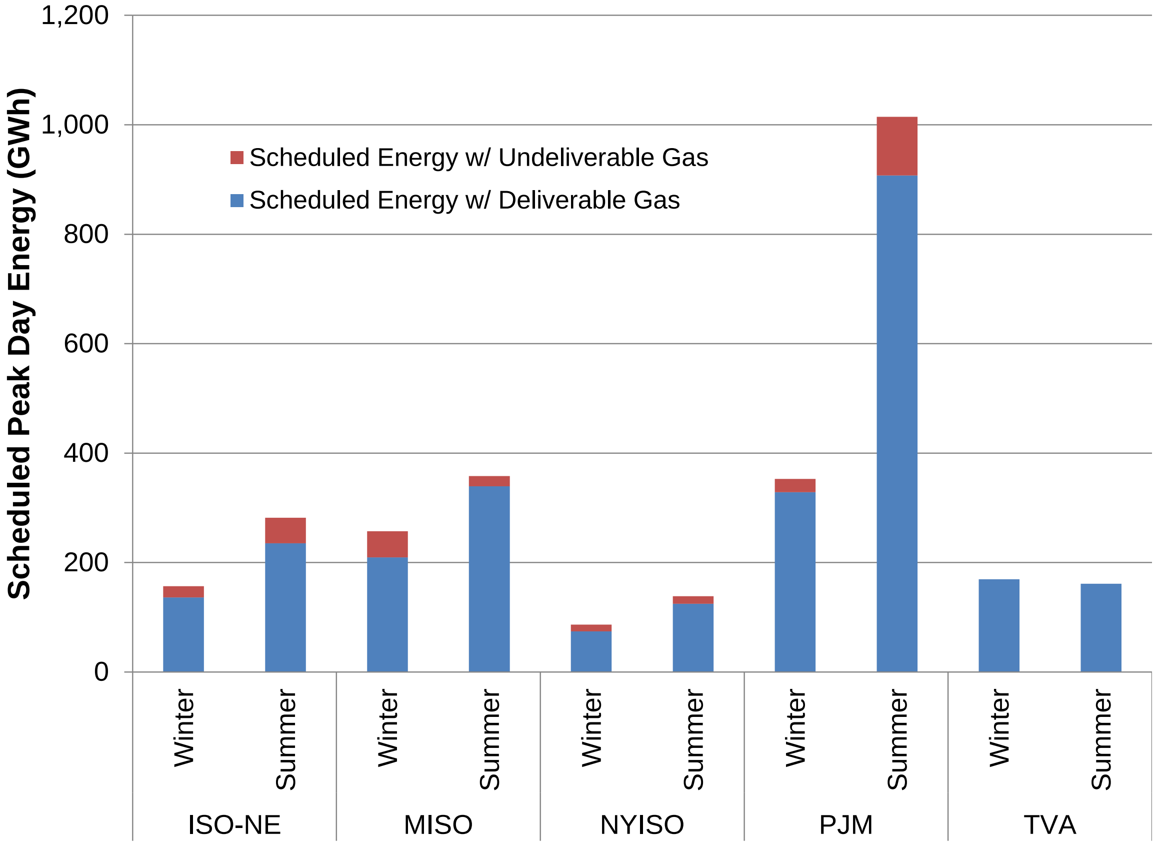
Hydraulic Model Study Region Footprint



Contingency Analysis Approach

- Emphasis is placed on the physical capability of the consolidated network of pipeline and storage infrastructure to maintain service to RCI and generation customers post-contingency
  - Pipeline contractual obligations are not modeled
  - Generator and RCI demands not differentiated, revealing the outer bound in terms of continued service to scheduled gas-fired generators
- Identify plants that trip off line due to delivery pressures below 485 psig, and the time interval between the contingency event and the pressure trigger
- Affected generation following a contingency is not tantamount to unserved electric energy since mitigation measures are available
- MISO South not hydraulically modeled due to its robust available capacity
- LDC assessments either included in hydraulic models or evaluated by LDC separately

Baseline Hydraulic Results: 2018 RGDS



"Affected Generation" does not imply a risk to electric reliability

IESO is not included because it was not hydraulically modeled by LAI

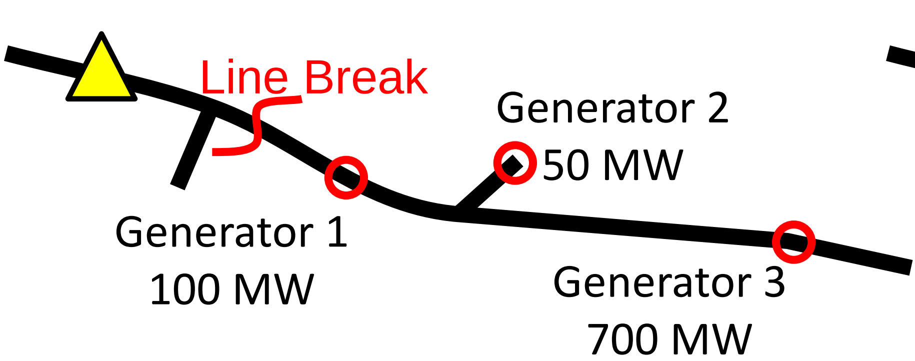
- Baseline examines gas infrastructure adequacy to meet peak day demands under normal operating conditions
- Undeliverable generator volumes due to prioritization of RCI customer deliveries, delivery pressures below 485 psig

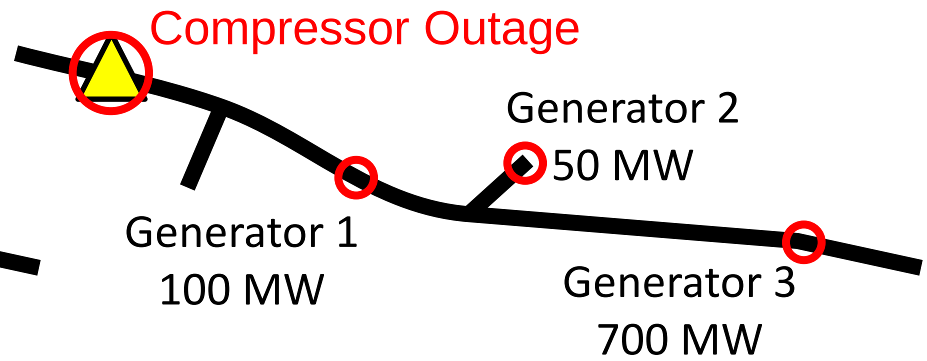
Contingency Analysis Results

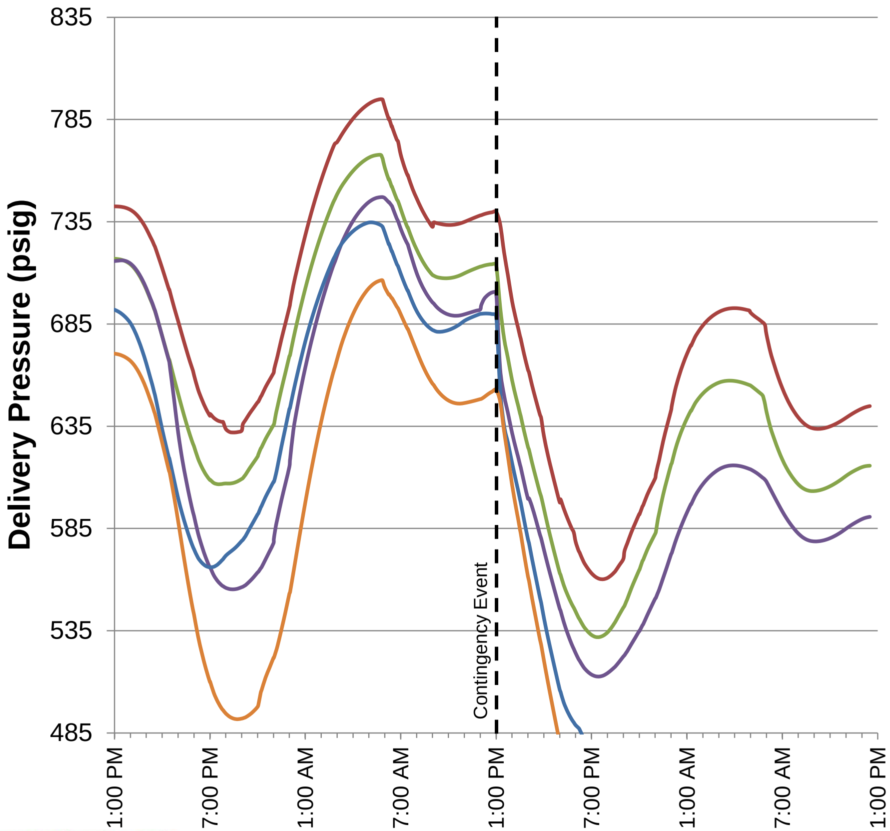
- Gas contingencies
  - Types: line breaks, compressor outages, loss of supply, loss of storage
  - Line breaks are the most impactful in each PPA

- Electric contingencies
  - Types: outages of large non-gas generators, loss of large transmission lines
  - Most severe contingencies are generator outages in PJM
    - Time before plants trip offline likely sufficient for PPA to take remedial action, *i.e.*, system redispatch

Example Contingency Result Outputs







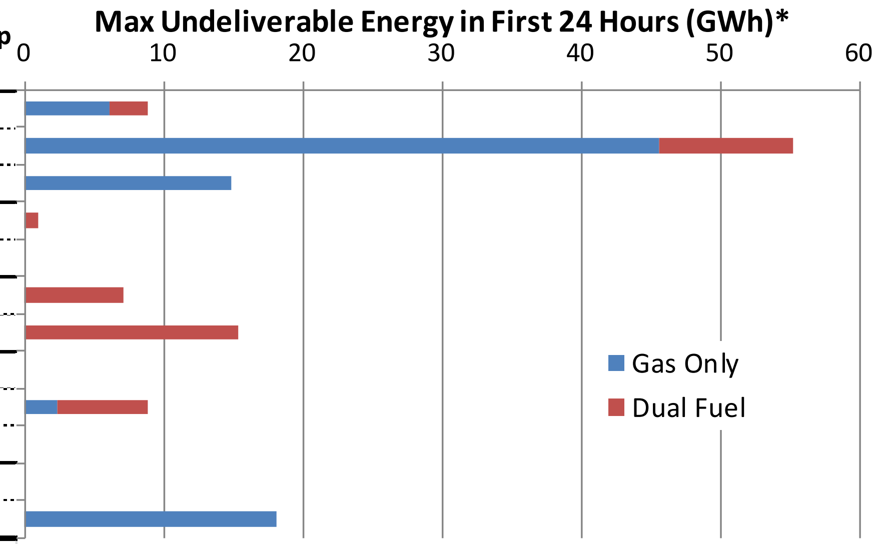
Plant	Time to Trip Following Contingency (h:m:s)	Scheduled Energy (MWh)	Undeliverable Energy (MWh)	Undeliverable Energy (%)
Plant 1	N/A	5,000	0	0
Plant 2*	3:30:00	2,500	2,200	88%
Plant 3	N/A	10,000	0	0
Plant 4*	N/A	15,000	0	0
Plant 5*	N/A	315	0	0
Plant 6	N/A	600	0	0
Plant 7	N/A	750	0	0
Plant 8	4:48:41	5,000	4,000	80%
Total			4,000 (gas only) 2,200 (dual fuel)	

Contingency Results Summary by Type

Reference Scenario, Winter 2018

Gas-Side Contingencies

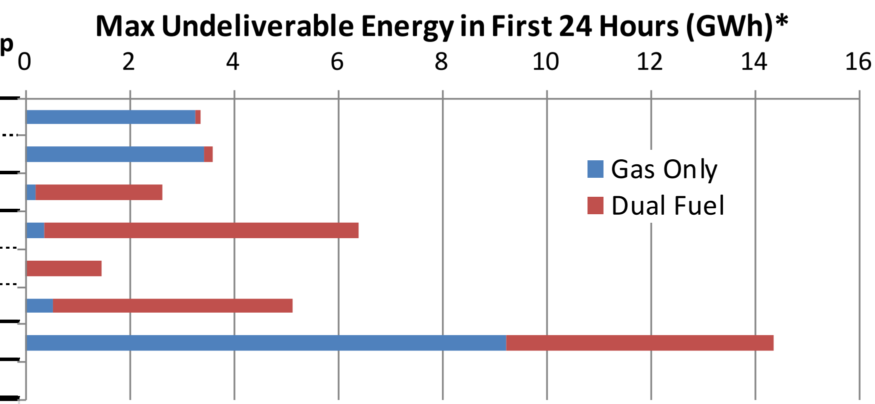
PPA	Type	# Tested	Shortest Time to Trip (h:m:s)
ISO-NE	Compression	3	3:52:47
	Line Break	3	0:11:03
	Supply	2	0:00:00
MISO	Compression	3	9:17:42
	Line Break	3	18:53:42
NYISO	Compression	3	12:22:51
	Line Break	3	0:54:20
PJM	Compression	1	None
	Line Break	6	0:03:00
	Storage	1	None
TVA	Compression	3	None
	Line Break	3	4:21:49



* Scheduled energy with undeliverable gas

Electric-Side Contingencies

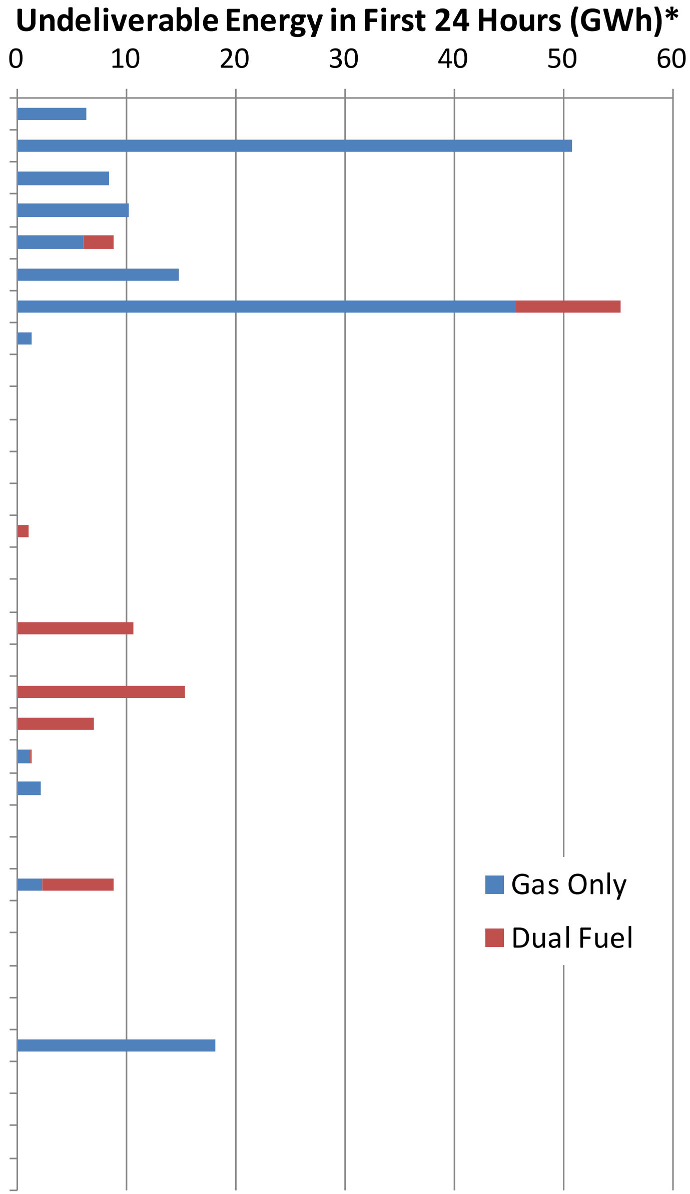
PPA	Type	# Tested	Shortest Time to Trip (h:m:s)
ISO-NE	Generation	3	None
	Transmission	2	None
MISO	Generation	8	None
NYISO	Generation	3	10:48:17
	Transmission	2	None
	Gen + Trans	1	10:50:37
PJM	Generation	3	2:45:10
TVA	Generation	5	None



* Scheduled energy with undeliverable gas

Individual Gas-Side Contingency Results

Region	PPA Type	First Trip (h:m:s)
ISO-NE	Compression	3:52:47
ISO-NE	Line Break	0:11:03
ISO-NE	Compression	6:25:06
ISO-NE	Line Break	4:20:42
ISO-NE	Compression	7:36:01
ISO-NE	Supply	0:00:00
ISO-NE	Line Break	0:33:00
ISO-NE	Comp./Supply	21:14:21
MISO	Compression	None
MISO	Line Break	18:53:42
MISO	Line Break	None
MISO	Compression	None
MISO	Line Break	None
MISO	Compression	9:17:42
NYISO	Compression	None
NYISO	Line Break	None
NYISO	Line Break	0:54:20
NYISO	Compression	None
NYISO	Line Break	4:17:48
NYISO	Compression	12:22:51
PJM	Line Break	0:03:00
PJM	Line Break	1:42:40
PJM	Line Break	None
PJM	Storage	None
PJM	Line Break	0:07:43
PJM	Line Break	None
PJM	Comp./Line Br.	None
PJM	Compression	None
TVA	Compression	None
TVA	Line Break	4:21:49
TVA	Compression	None
TVA	Line Break	None
TVA	Compression	None
TVA	Line Break	N/A



* Scheduled energy with undeliverable gas

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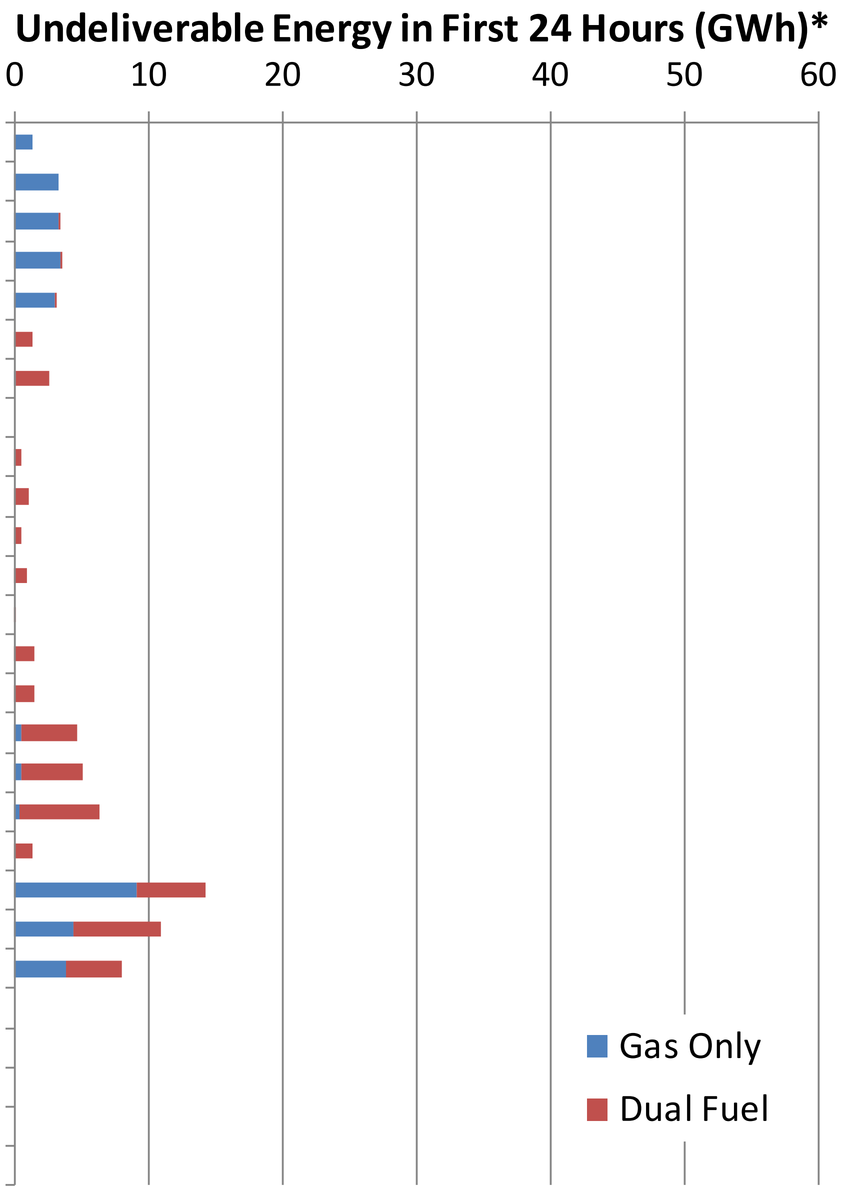
Individual Electric-Side Contingency Results

Region	PPA Type	First Trip (h:m:s)
ISO-NE	Generation	None
ISO-NE	Generation	None
ISO-NE	Generation	None
ISO-NE	Transmission	None
ISO-NE	Transmission	None
MISO	Generation	None
MISO	Generation	None
MISO	Generation	None
MISO	Generation	None
MISO	Generation	None
MISO	Generation	None
MISO	Generation	None
MISO	Generation	None
NYISO	Transmission	None
NYISO	Transmission	None
NYISO	Generation	10:48:17
NYISO	Gen + Trans	10:50:37
NYISO	Generation	None
NYISO	Generation	None
PJM	Generation	10:41:00
PJM	Generation	2:45:10
PJM	Generation	10:34:08
TVA	Generation	None
TVA	Generation	None
TVA	Generation	None
TVA	Generation	None
TVA	Generation	N/A



* Scheduled energy with undeliverable gas

LDC Contingency Analysis Approach

- Evaluation at specific temperatures rather than peak day
  - On a peak day, interruptible service typically not available to generators
- Evaluation by LAI (Central Hudson Gas & Electric, New Jersey Natural Gas, Public Service Electric & Gas, Washington Gas Light)
  - LDCs provided hydraulic details of segments that serve generation
  - Segments added to regional hydraulic models
  - Results and assessment reviewed with LDCs
- Evaluation by LDC (Con Edison, National Grid, Baltimore Gas & Electric, Nicor Gas, Peoples Gas, Enbridge Gas, Union Gas)
  - LAI provided generator gas demands to LDCs
  - LDCs provided results to LAI
  - Assessment reviewed with LDCs

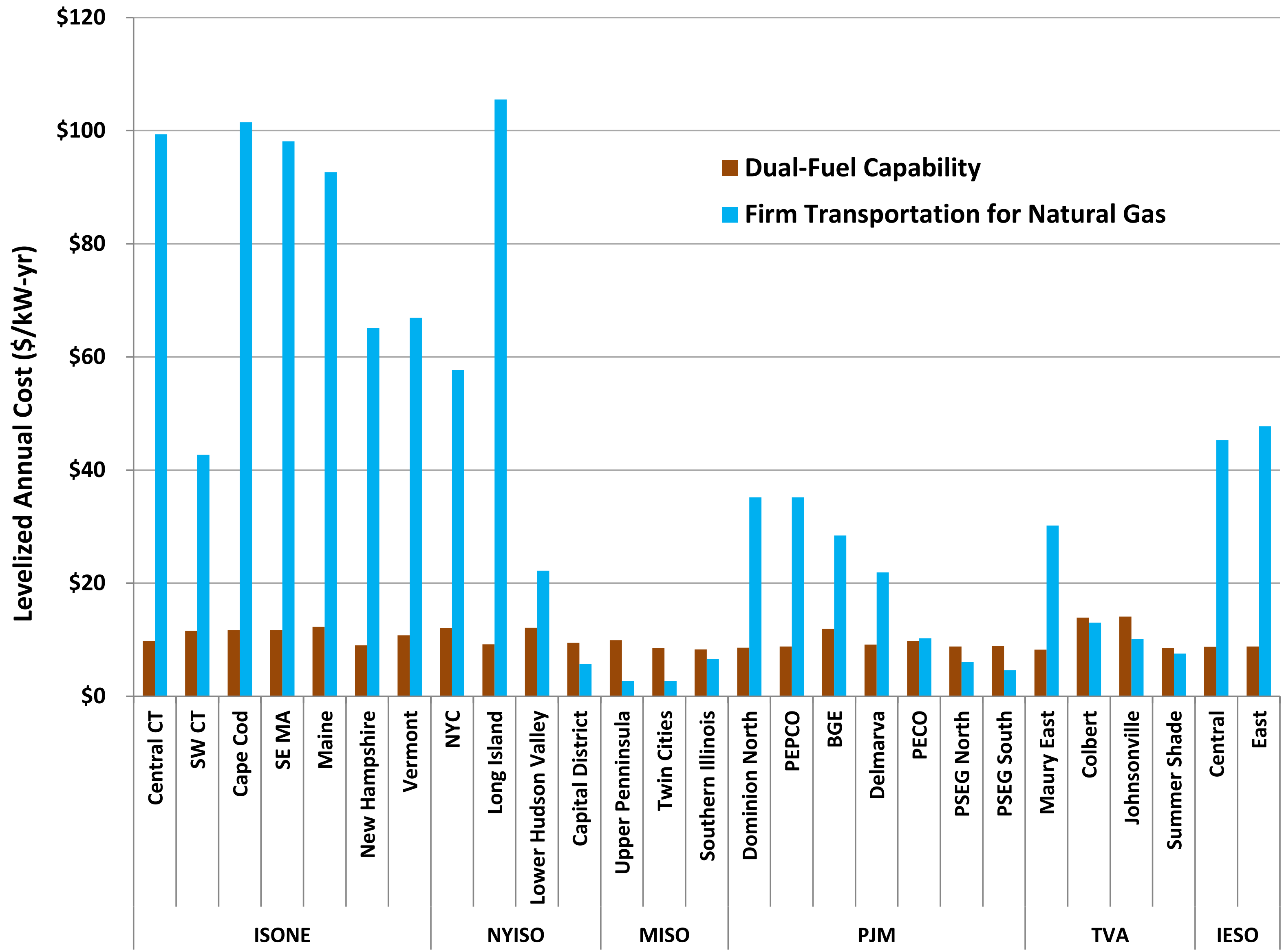
Fuel Assurance Analysis Approach

- SC and CC configurations based on recently constructed and planned dual-fueled plants across the Study Region
  - Performance and operating characteristics from manufacturers
  - Cost estimates from turbine manufacturers, recent CONE studies, FERC filings
  - Dual-fuel capable plants incur higher fixed O&M costs
- Dual-fuel capability compared to incremental FT service for 27 locations
  - Dual-fuel cost inputs: labor cost factor, tax rates, permit restrictions, fuel source, delivery logistics
  - FT cost inputs: reservation charges for incremental capacity, avoided cost of non-firm transportation, # of days w/ interrupted non-firm service, LDC transportation costs (where appropriate)
  - Inputs differentiated between locations
- Costs expressed as an annual levelized cost per kW over a 20-year term beginning in 2018
  - Allows for relative comparison between different capacities and heat rates

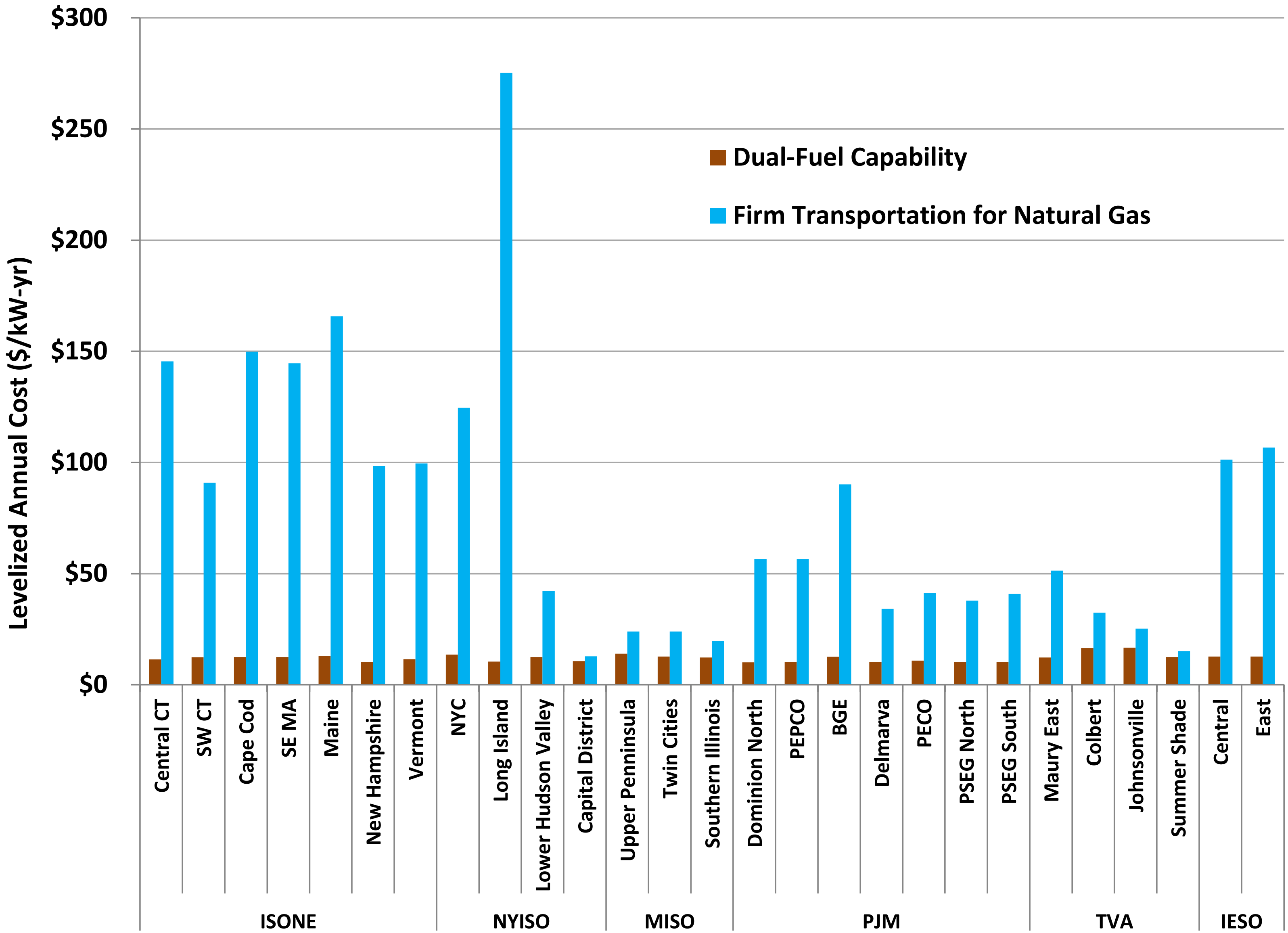
Fuel Assurance Analysis Results

- Cost of dual-fuel capability generally similar across locations
  - Variations between barge- and truck-supplied locations
- Cost of incremental FT varies across Study Region
  - Expensive in New England due to existing bottlenecks
  - Expensive at the local level (New York Facilities System, in particular)
- Dual-fuel capability typically much lower cost for a new combined-cycle (CC) plant than FT; far more pronounced for simple cycle (SC) plants
  - LDC-served generators additionally incur local facility improvement costs
  - Restrictive environmental permit requirements limit liquid fuel usage
  - Structural changes continue to improve ULSD replenishment logistics

Fuel Assurance Analysis: Combined Cycle



Fuel Assurance Analysis: Simple Cycle



Gas-Electric Interface Attributes

	Criterion	IESO	ISO-NE	MISO	NYISO	PJM	TVA
Natural Gas Supply	Gas Supply Portfolio Diversity	Favorable	Unfavorable	Favorable	Favorable	Favorable	Neutral
	Pipeline Connectivity	Neutral	Unfavorable	Favorable	Favorable	Favorable	Neutral
	Conventional Storage Deliverability	Favorable	Unfavorable	Favorable	Neutral	Favorable	Neutral
	LNG Storage Capability	Neutral	Favorable	Neutral	Neutral	Neutral	Neutral
Electric-Gas Interface	Firm Transportation Entitlements	Favorable	Unfavorable	Neutral	Neutral	Neutral	Favorable
	Direct Pipeline Connectivity	Favorable	Favorable	Favorable	Neutral	Favorable	Favorable
Electric-Gas Tariff	Pipeline or LDC Penalties	Favorable	Unfavorable	Unfavorable	Unfavorable	Unfavorable	Unfavorable
	LDC Provision of Flexible Service	Favorable	Neutral	Neutral	Favorable	Favorable	Neutral
	Active Secondary Market	Unfavorable	Favorable	Favorable	Favorable	Favorable	Neutral

Legend	Favorable Relative to Other PPAs	Neutral	Unfavorable Relative to Other PPAs

Risk Factors and Market Dynamics

Market Dynamic and/or Risk Factor	IESO	ISO-NE	MISO North/ Central	MISO South	NYISO	PJM	TVA
Transport Deficits							
New Pipeline Additions							
Proximity to Shale Gas							
Reversal-of-Flow							
Available Coal Output							
Nuclear Retirements							
LNG Import Constraints							
LNG Export Constraints							
Generator FT Entitlements							
Generator Reliance on Non-Firm Arrangements							
Dual Fuel Capability							
Renewables Penetration							

Legend	Negligible or no impact on affected generation	Low to moderate impact on affected generation	High impact on affected generation