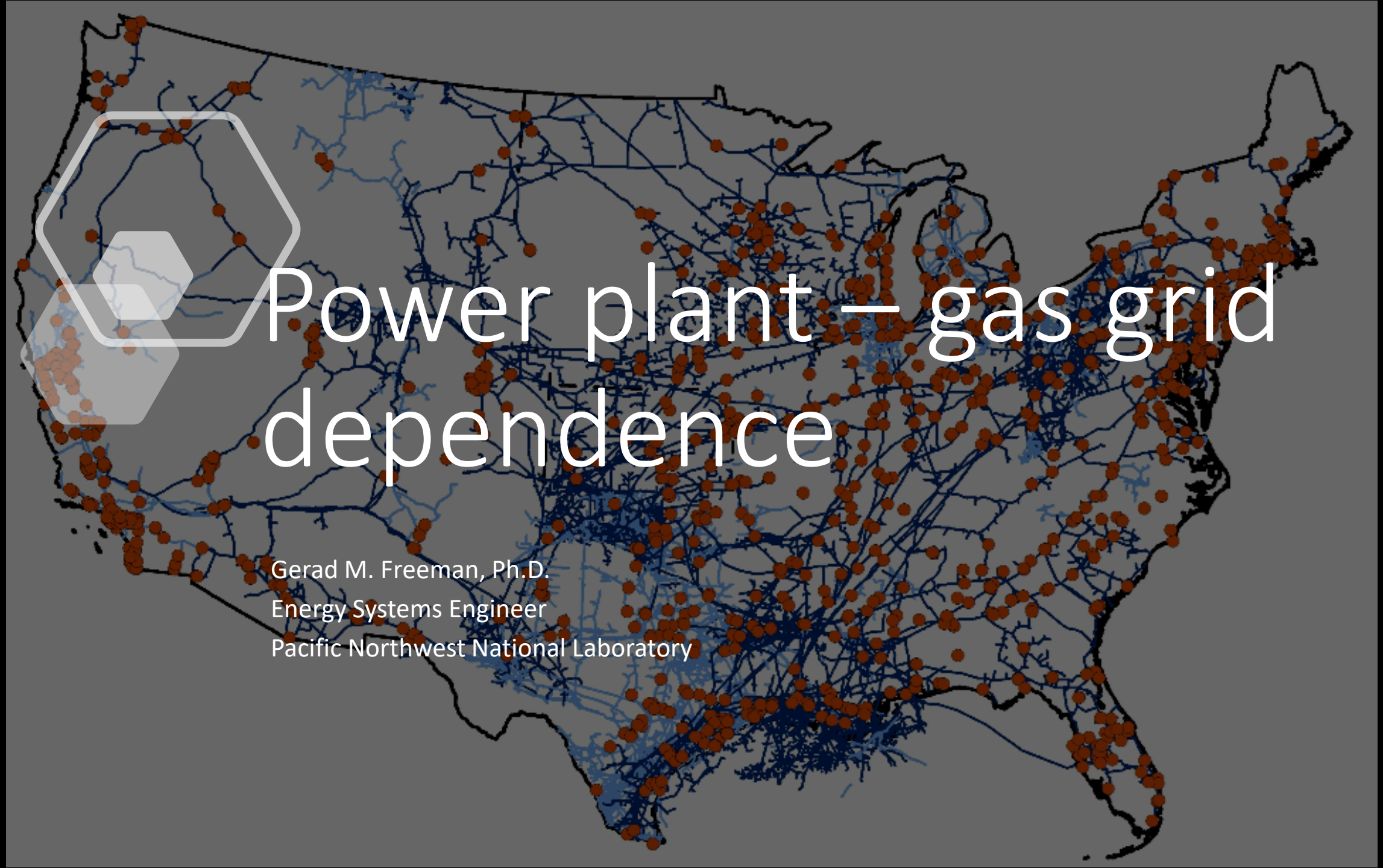

Power plant – gas grid dependence

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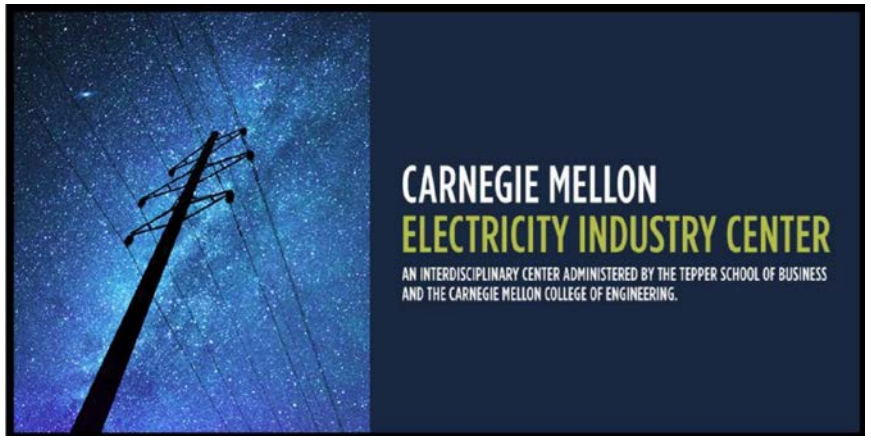

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Overview

1. A comparison of gas grid and power generation reliability reporting standards

2. What causes natural gas fuel shortages at U.S. power plants?

3. Is on-site fuel storage an inexpensive mitigation measure for power plant – gas grid dependence in New England?

GERAD FREEMAN, JAY APT, AND MICHAEL DWORKIN

The Natural Gas Grid Needs Better Monitoring

Hundreds of times each year the natural gas pipeline system fails, shutting down electric power plants, but there is no national system to record these events and help us improve reliability.

We are familiar with cascading electric grid outages such as the September 8, 2011, blackout that hit San Diego at rush hour, and the August 14, 2003, blackout that essentially shut down the Northeast. Less familiar are failures in the US natural gas pipeline system. But they occur.

Fuel-starvation outages at US gas power plants happened at an average rate of a thousand events per year and affected one in five plants between January 2012 and April 2016, according to the North American Electric Reliability Corporation (NERC). Sometimes, in very cold weather, many gas plants are starved of fuel at the same time.

Because data on the reliability of the natural gas pipeline system is almost impossible for anyone to find, our team spent a year combing through the reports filed by power plants—not pipelines—to count these outages. To our knowledge this is the first time anyone has done so.

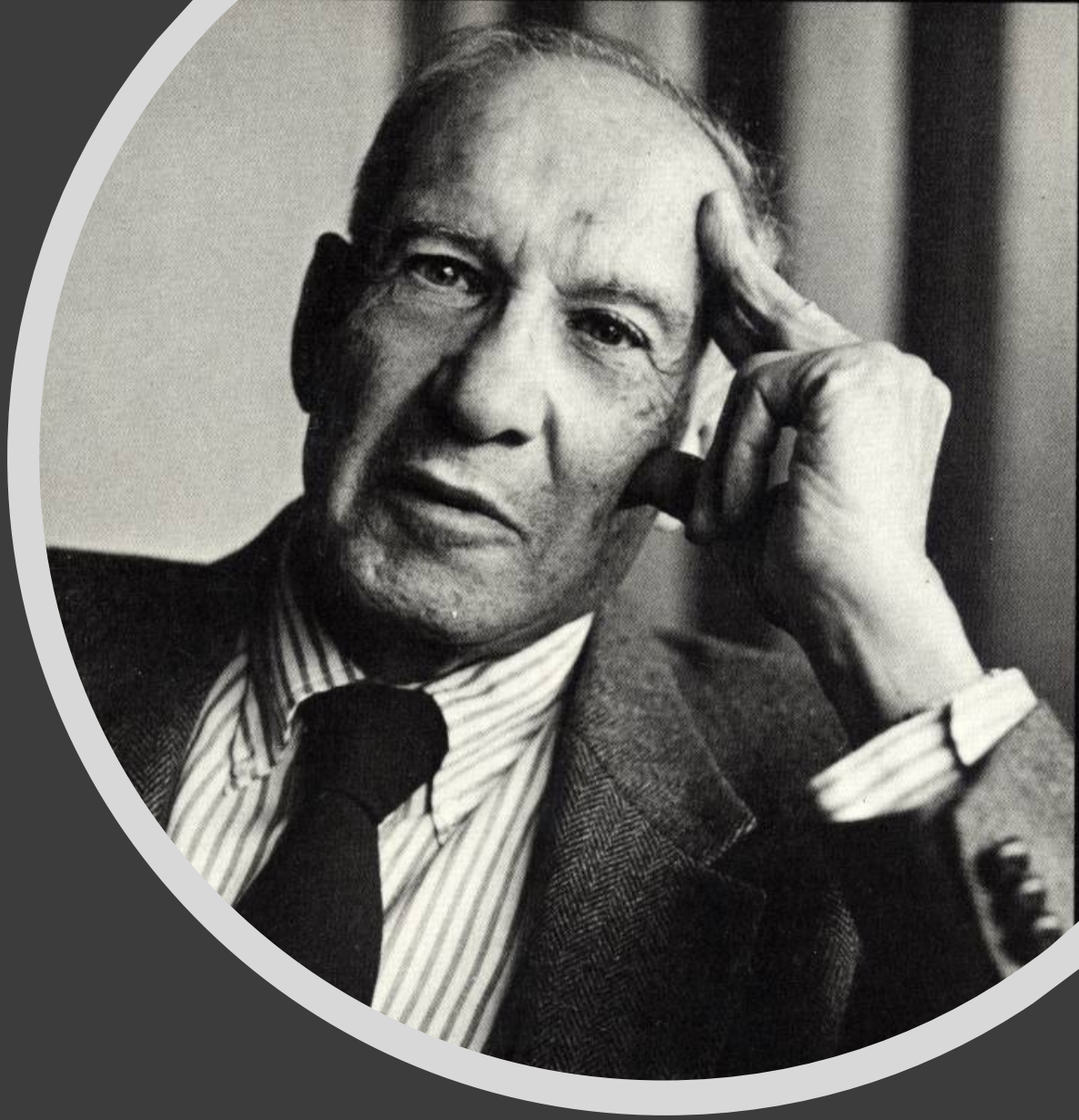
Unlike electric power generator failures, gas pipeline outages are either not recorded or not available without a Freedom of Information Act request in most states. But disruptions in the natural gas system can have serious consequences, particularly for electric power generation.

For power system reliability, it is important to know how often, where, and why pipeline failures occur so that power plant operators can be better prepared for gas interruptions. Storing backup gas supplies at the generator site is impractical because the required tank farm to hold compressed gas for just one day's power plant operation would increase the plant's footprint by at least 10%, and that doesn't even consider the ancillary equipment required to support the gas storage. Liquefied natural gas storage, even for a few hours' worth of plant operation, is very expensive. And underground storage at the plant is equally impractical for most plants. Another option to protect against gas supply interruptions is to design in fuel-switching capability that can easily substitute oil for gas. But only one-quarter of gas power plants have the ability to switch to oil without halting operation, and about half of those plants can operate for only a short time with oil because of on-site oil storage limitations.

The remaining three-quarters of plants that do not have fuel-switching abilities are tied to the real-time reliability of the natural gas pipeline transportation network. When emergency situations arise on the natural gas grid, pipeline operators turn to a load-shedding protocol that outlines the order in which customers will have their gas supply turned

Research question

- How do gas grid outage reporting standards compare to electric power generator outage reporting standards?

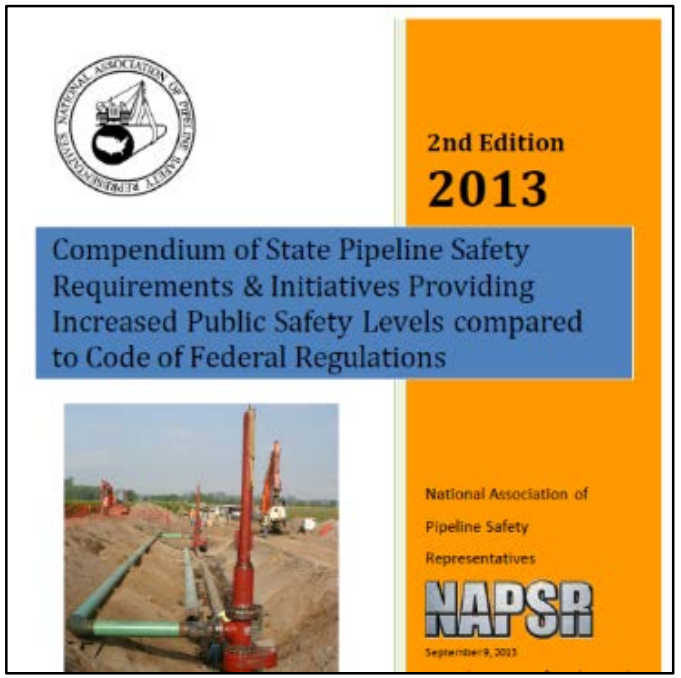


Data:

1. NERC Generating Availability Data System
2. PHMSA gas transmission, gathering and distribution incident reports (also U.S. Code of Federal Regulations)
3. ABB Velocity Suite gas pipeline notices from electronic bulletin boards (EBBs)
4. National Association of Pipeline Safety Representatives (NAPSR) Compendium
   - PUC/PSC enhanced reporting standards

Methods:

1. Side-by-side quantitative threshold comparison
2. Failure event coincidence analysis
3. Spatial proximity analysis



NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Results

1. Numerical thresholds for reliability event reporting are misaligned between the natural gas grid and electric power generators due to varying jurisdictional motivations.
   - Outage reporting thresholds on the gas side vary substantially by jurisdiction.
2. Data for gas grid events are largely unavailable without request.

Recommendations

- Lower thresholds for gas grid reliability events to the equivalent of the smallest power plant event threshold.
- Consider establishing a gas equivalent to NERC to collect reliability data and recommend overall system reliability guidance

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What causes natural gas fuel shortages at U.S. power plants?

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ABSTRACT

Using 2012–2018 power plant failure data from the North American Electric Reliability Corporation, we examine how many fuel shortage failures at gas power plants were caused by physical interruptions of gas flow as opposed to operational procedures on the pipeline network, such as gas curtailment priority. We find that physical disruptions of the pipeline network account for no more than 5% of the MWh lost to fuel shortages over the six years we examined. Gas shortages at generators have caused correlated failures of power plants with both firm and non-firm fuel arrangements. Unsurprisingly, plants using the spot market or interruptible pipeline contracts for their fuel were somewhat more likely to experience fuel shortages than those with firm contracts. We identify regions of the Midwest and Mid-Atlantic where power plants with non-firm fuel arrangements may have avoided fuel shortage outages if they had obtained firm pipeline contracts. The volume of gas needed by power plants to fuel the lost MWh in those regions was only a small fraction of the total volume delivered to potentially non-essential commercial and industrial pipeline customers in those regions and modest prices there at the times when power plants failed indicate gas was available.

Research questions

- Did pipeline failures or gas service priority cause natural gas fuel shortages at U.S. power plants?
- Are there regions in which generators could have avoided fuel shortages if they had held firm pipeline contracts?

Image: CPV Energy

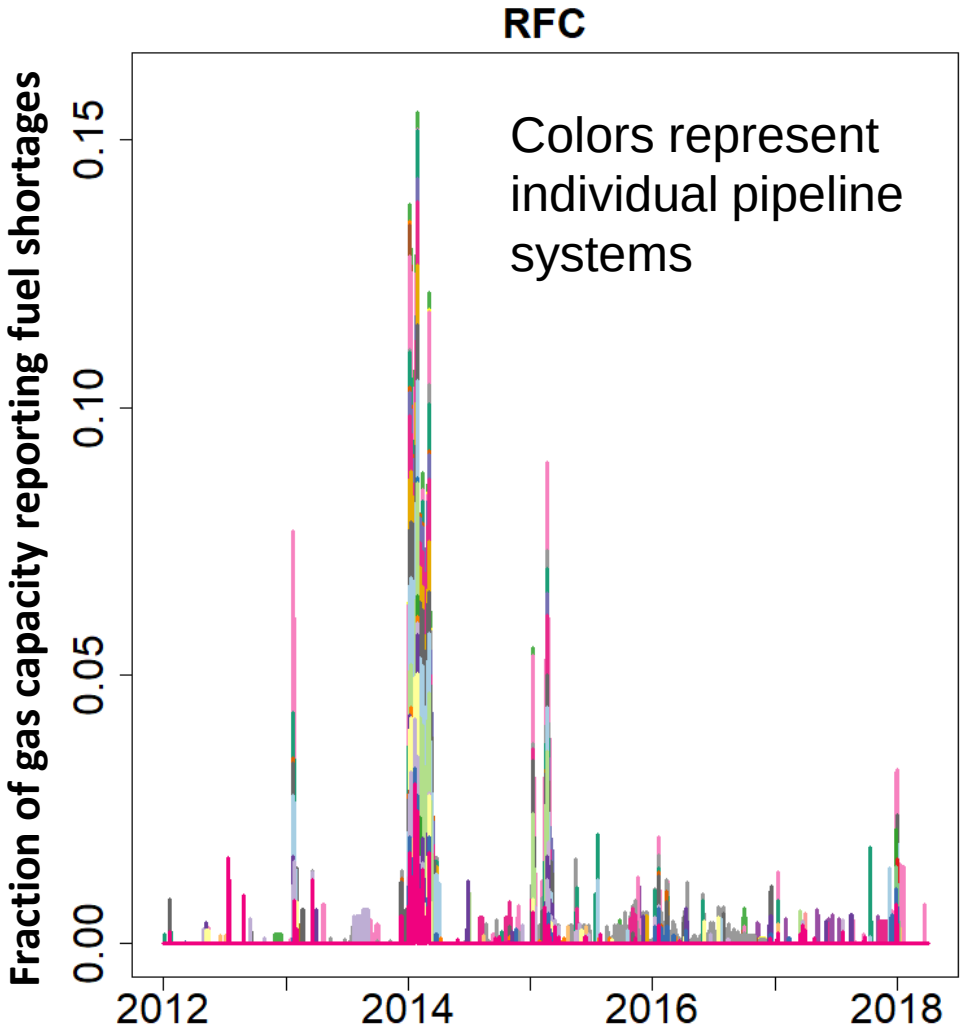
Data mapping power plants to pipelines

1. **NERC Generating Availability Data System** (GADS)
   Sample: 1/2012 – 3/2018 (6 years)
   - 6,505 events at 328 natural gas plants
   - Only unscheduled fuel shortage or fuel conservation causes (9130, 9131, 9134)

2. **Generator characteristic data** (EIA-860)
   - To group events by pipeline

3. **Fuel receipt and contract status data** (EIA-923)
   - To group events by contract type

4. **Pipeline scheduling and pricing data** (EIA-857, EBBs, ABB Velocity Suite)
   - To examine capacity and spot market gas availability on pipelines



Illustrative example images re-used with permission from S. Murphy

Pipeline failures did not explain the majority of fuel shortage failures

- Pipeline and Hazardous Materials Safety Administration pipeline incidents explained only ~200 of the 6,200 fuel shortage failures between 2012-2017.

- But, PHMSA reporting isn't adequate for these types of reliability studies. (See section 1)

- Transmission pipeline force majeure (FM) events explain only a maximum* of 9% of unscheduled fuel shortage events (5% of MWh lost).

*This upper bound is constructed by considering FM events that occurred anywhere along the pipeline

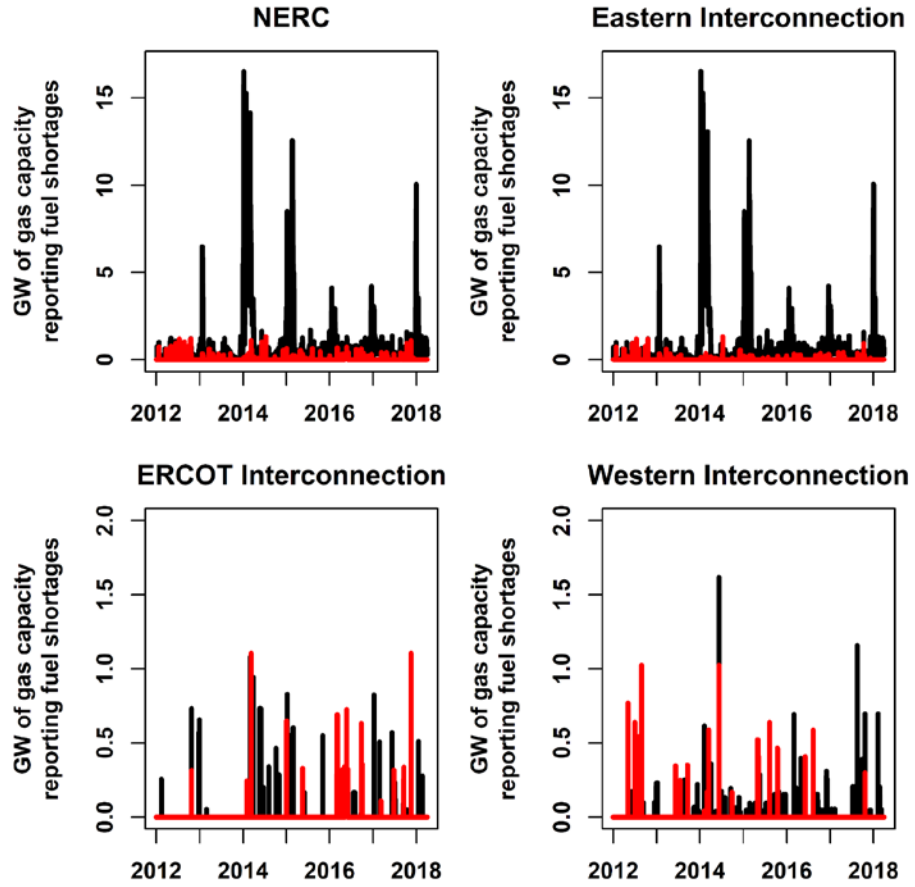
Grouping plants by the pipeline contract through which the majority of gas was delivered over the study period, we find plants with non-firm fuel procurement strategies are, as expected, over-represented in fuel shortage data

Region (N)	EIA-923 database non-firm plant proportion (p_o)	GADS fuel shortage plants non-firm proportion ($\hat{p}$)	Number of plants reporting fuel shortages (n)	Smallest sample size required to produce α = 0.1 level significant result
NERC (981)	0.738	▲ 0.802***	232	75
FRCC (47)	0.404	0.000	1	-
MRO (81)	0.790	△ 0.857	7	-
NPCC (74)	0.838	0.833	36	-
RFC (192)	0.797	▲ 0.866*	82	55
SERC (227)	0.749	▲ 0.886**	44	30
SPP (77)	0.792	0.563**	16	5
TRE (101)	0.644	△ 0.684	19	-
WECC (182)	0.714	0.667	27	-

Notes: Upward triangles represent regions where non-firm plants were over-represented in our sample.
One-sample proportion test result significance is indicated as: * : α = 0.1 ** : α = 0.05 *** : α = 0.01

- We construct the test with plant proportion because the EIA data do not allocate capacity share to contract type for plants using mixed firm and non-firm strategies of monthly fuel procurement. (We also observed the same qualitative results conducting these tests by capacity)
- **Robustness checks:**
  1. non-firm over-represented in overall NERC every individual year
  2. non-firm over-represented in four individual NERC regions
  3. non-parametrically reduce the sample size (column 5)
  4. non-firm over-representation retained with stricter non-firm definition (we exclude mixed-strategy plants)

But gas plants were affected by fuel shortages regardless of their pipeline contract statuses

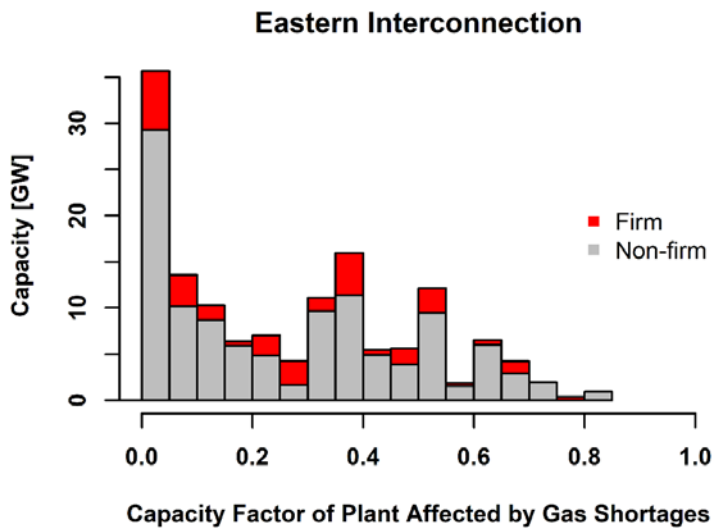


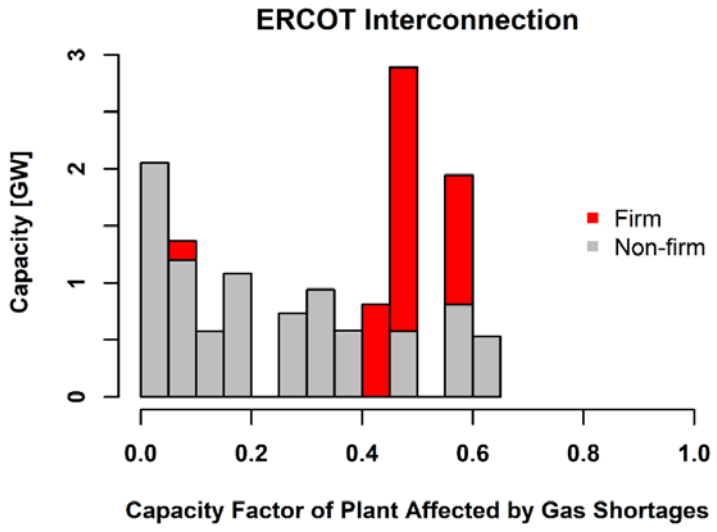
- During some hours, firm contract plants made up all fuel shortages (firm is not a cure-all)
- In some regions, the peaks in the gas fuel shortage time series were sometimes mostly made up of capacity on firm pipeline contracts

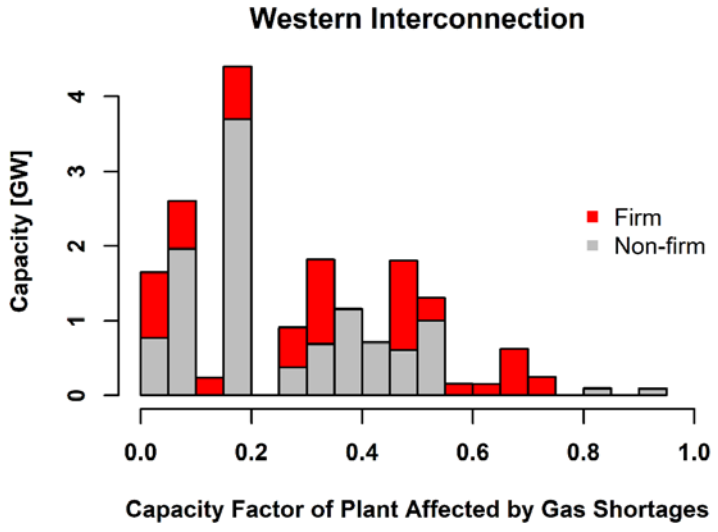
Fuel shortages at gas plants with firm pipeline contracts

Fuel shortages at all gas plants (plot is overlaid by firm plot)

Peaker, shoulder and sometimes baseload plants in each pipeline contract grouping were all affected by gas shortages in just the 6-year study period.



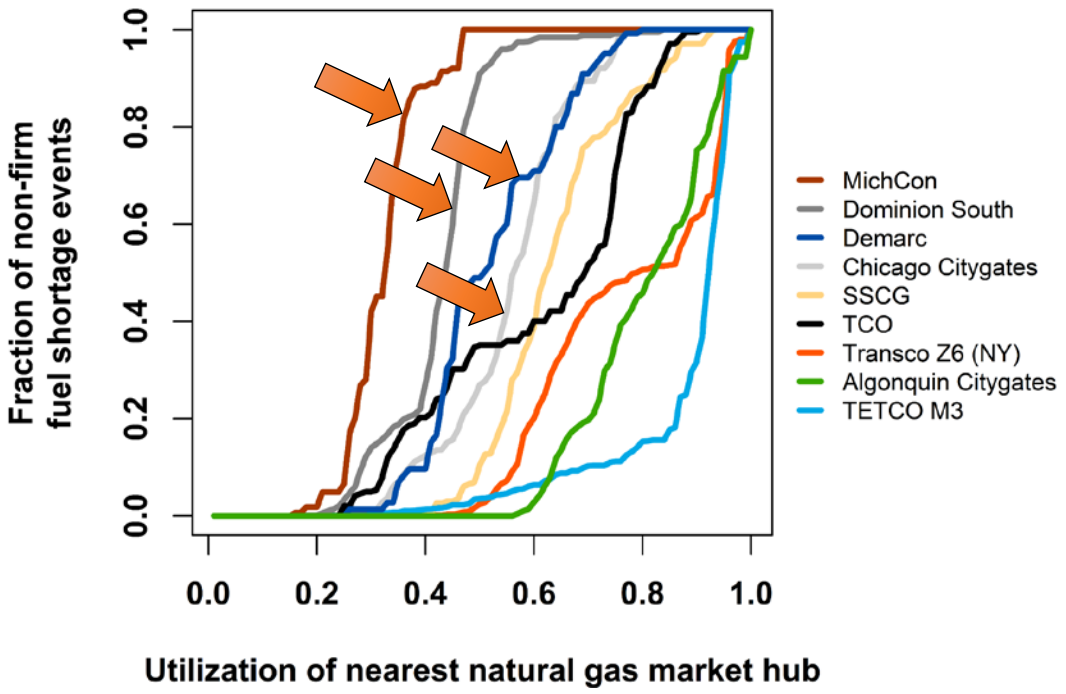




Notes: Bars are weighted by gas-fired power plants' maximum nameplate capacity over the study period. Capacity factors were constructed from EIA-923 data over the study period. Plots show initial grouping of plants by contract using majority of quantity of gas consumed over the study period. "Affected" means that the plant reported one or more fuel shortage failures of any magnitude over the study period.

Gas trading hub reports show gas system under-utilization during fuel shortages at non-firm plants in some regions

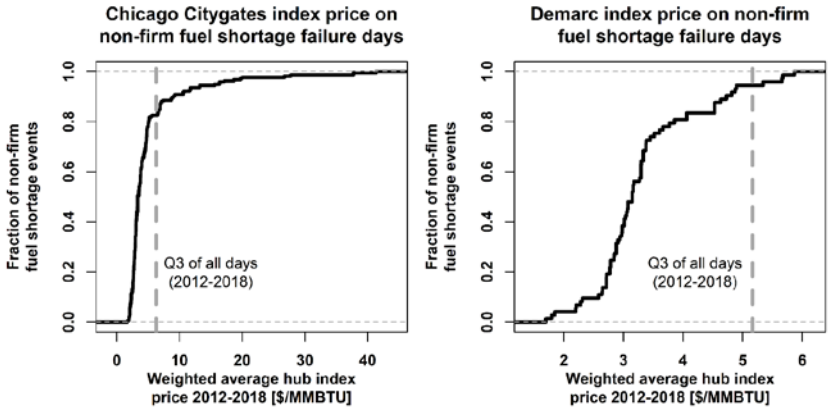
- 60% of all MWh lost to fuel shortages occurred at plants near four hubs: MichCon, Dominion South, Demarc, and Chicago Citygates
- These hubs were under-utilized (flowing gas at <60% demonstrated peak) during the majority of days with fuel shortages at nearby power plants using non-firm pipeline contracts.
- So, there was space to move gas through the hub but, was there gas supply to be had?

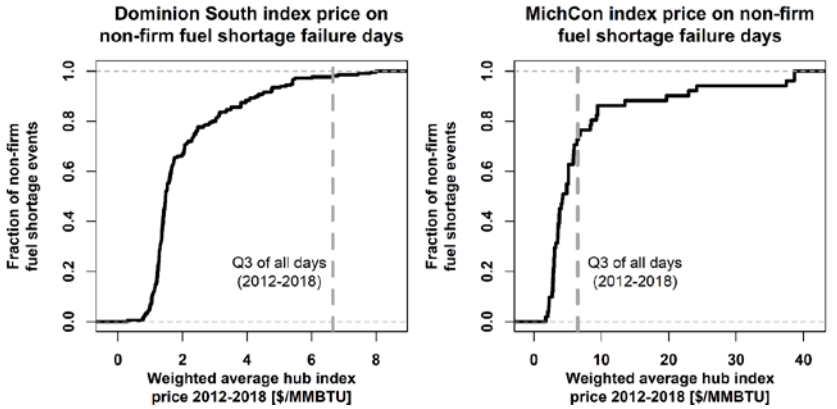


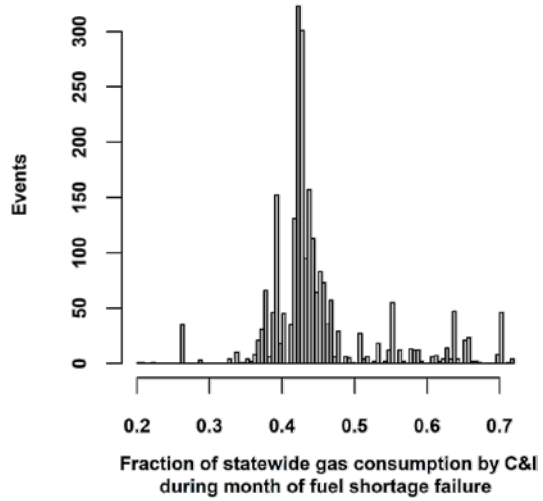
Was there gas to be had?

1. Was there coupled gas commodity and transportation available on the hub spot market?
   - We see modest gas hub prices** at Chicago, Demarc, and Dominion South during days with fuel shortages at non-firm plants

2. Could we have diverted gas from other customers?
   - Between 0.1-9% of statewide gas delivered to C&I could have supplied all of the MWh lost to fuel shortages

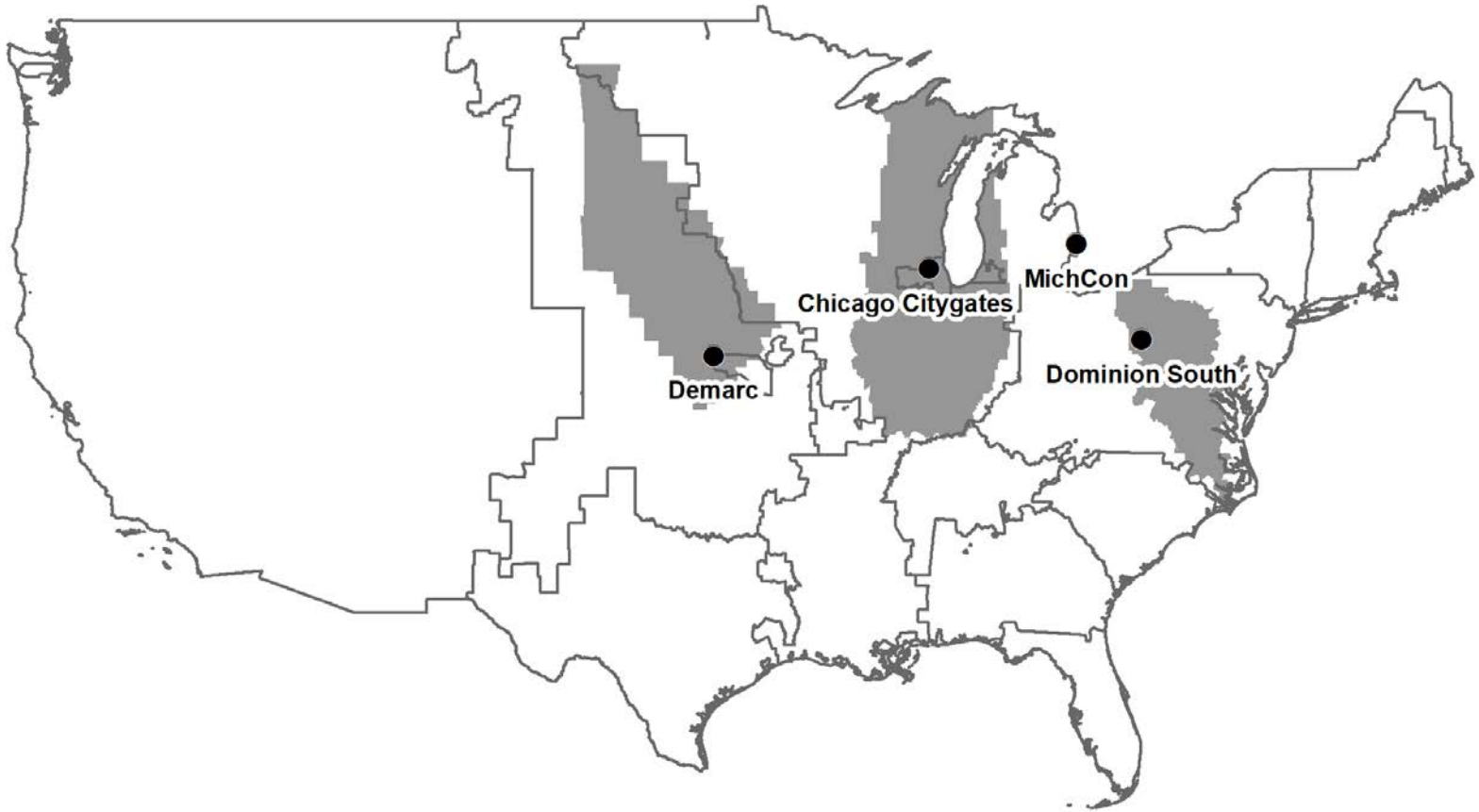






**Hub spot price < third quartile price of overall study period distribution for >80% of non-firm events

Where were the areas with underutilized hubs and modest spot prices?



Note: MichCon displayed here for informational purposes only.