Natural gas fuel starvation at large power plants in the U.S. and the effect of gas delivery arrangements on reliability

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Power plant failures are correlated with each other.

- Planners use historical data to anticipate the amount of power plant capacity needed.
- They previously assumed that power plants fail independently.
- In 2018, Murphy et al. showed that this assumption was violated in most regions
  - This could lead to increased risks of blackouts.
- They did not identify why there were correlated power plant failures.

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**Gray bands**: 95% and 99% confidence bands from 1,000 binomial simulations
**Red**: empirical distribution from the data in their full study

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Did the growing dependence on natural gas for power generation lead to correlated power plant outages? If so, why?

Data:
1. North American Electric Reliability Corporation (NERC) Generator Availability Data System (GADS)
   - ~8,000 units with events
   - ~85% of installed capacity
   - ~500,000 events logged each year
   Sample: 1/2012 – 12/2017
   - 6,187 events
     - At 924 natural gas units
   - Only unanticipated, lack-of-fuel causes

2. Generator characteristics including the pipelines connected to them from EIA.

3. Fuel receipts and pipeline contract statuses (EIA and FERC)
There is strong evidence of correlated failures due to fuel starvation on the same pipeline

- Correlated, fuel-starvation failures on one pipeline exceeded 10x the median unit's capacity in 6 of the 8 NERC regions.

- These types of correlated failures took ~2.6% of the total power plant capacity offline in both TRE and SPP.
Which pipelines are of heightened concern for power plant reliability?
Where are those pipelines?

Data sources: NERC-GADS; EIA-860 2017; EIA Interactive state maps shapefiles
Did the pipelines fueling these plants physically fail?

• Using available pipeline failure data from the Department of Transportation (PHMSA)
  • Only 0.6% of the fuel-starvation reports at power plants can be explained by a pipeline failure severe enough to affect gas delivery.
  • Even if less severe pipeline failures were included, they would only explain 3% of power plant reports.

Service interruptions on gas infrastructure (2012-2017)

Data sources: Pipeline and Hazardous Materials Safety Administration (PHMSA) Gas Transmission and Distribution Incident Reports; EIA Interactive state maps shapefiles
If pipeline failures can’t explain the fuel-starvation outages, were the power plants out-prioritized on pipelines?

Pipelines have set curtailment processes, for example:

- Residential
- Critical Industrial
- Commercial
- Non-critical Industrial
- Interruptible

Data sources: EIA-860 2017; EIA-923 2012-2017; NERC-GADS
Units with interruptible contracts had shorter mean times between fuel-starvation failures than units on firm contracts.

- We calculate each unit’s mean time between fuel-starvation failures (MTBFF):

\[
MTBFF = \frac{52,608h}{N_{Fuel-starvation\ failures}}
\]

- Then group units by pipeline contract status
- Non-parametric Mann-Whitney:
  Median Firm MTBFF > Int MTBFF
  at \( p = 0.01531 \) (\( n_{FT} = 255, n_{IT} = 299 \))
- Robustness checks show the same result:
  1. FERC 549B pipeline contract data (\( p < 0.01 \))
  2. Only units with no back-up fuel source (\( p < 0.05 \))
- But, firm units still reported these failures in all regions.

Red: units with firm pipeline contracts
Blue: units with interruptible pipeline contracts
Some evidence exists to support the hypothesis that residential customers out-prioritized power plants

- More than 60% of the capacity that reported fuel-starvation failures was at plants located in counties where more homes heat with gas than any other fuel.
- 46% of the natural gas power plant capacity is in those counties.
- The mean fraction of households that heat with gas in those counties was 63% (the national average was 56%).
Policy Conclusions

• Firm pipeline contracts increased reliability, as measured by MTBFF, in general **but did not prevent fuel-starvation failures.**
  • Does it make sense to promote firm contracts in all regions?
  • *PJM and ISO-NE are working on products that pay power plants for “capacity performance,” should gas units use these products and their payments to buy firm contracts?*
  • The “answer” is highly regional and depends on the mix of customers on the key pipelines in the region.
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