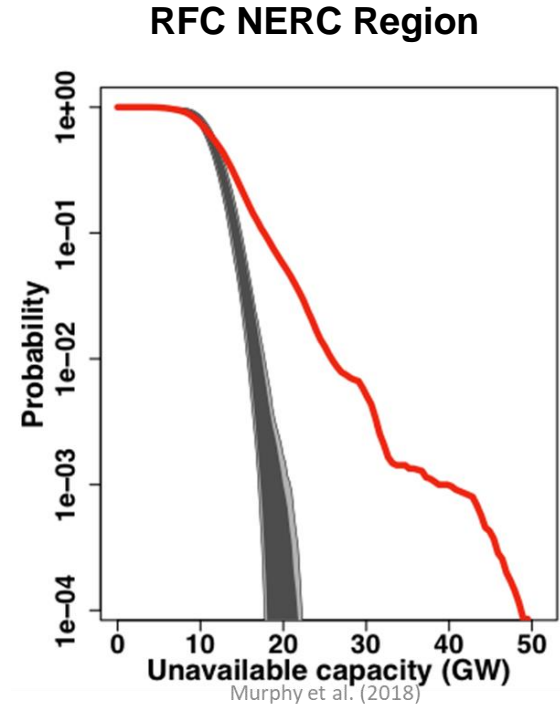


# **Natural gas fuel starvation at large power plants in the U.S. and the effect of gas delivery arrangements on reliability**

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# Power plant failures are correlated with each other.

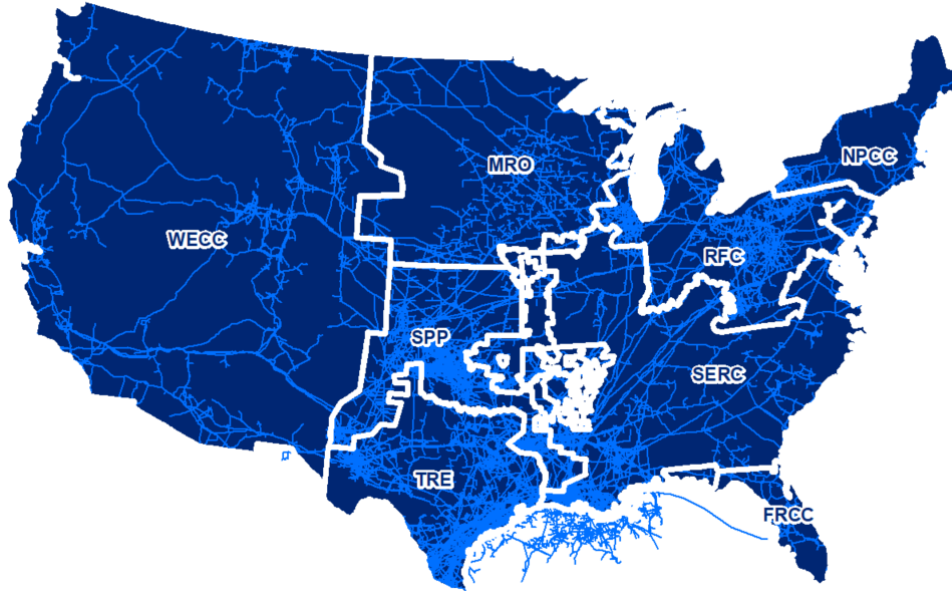
- Planners use historical data to anticipate the amount of power plant capacity needed.
- They previously assumed that power plants fail independently.
- In 2018, Murphy et al. showed that this assumption was violated in most regions
  - This could lead to increased risks of blackouts.
- They did not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



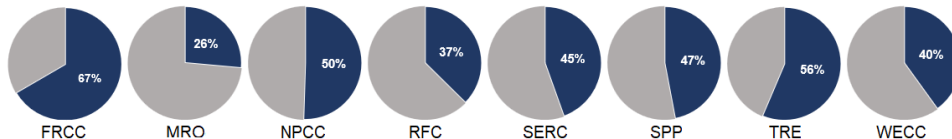
**Gray bands:** 95% and 99% confidence bands from 1,000 binomial simulations  
**Red:** empirical distribution from the data in their full study

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

## NERC regions and natural gas infrastructure



Fraction of nameplate capacity fueled primarily by natural gas (2017)



Data sources: EIA-860 2017; EIA Interactive state maps shapefiles

## Data:

1. North American Electric Reliability Corporation (NERC) Generator Availability Data System (GADS)

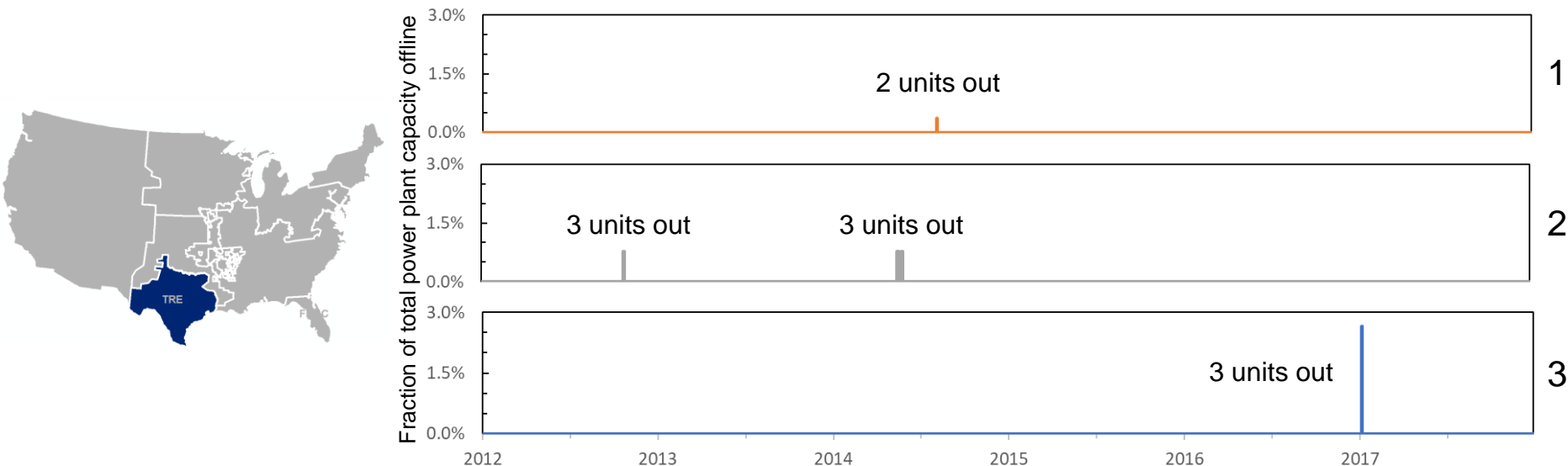
- ~8,000 units with events
- ~85% of installed capacity
- ~500,000 events logged each year

Sample: 1/2012 – 12/2017

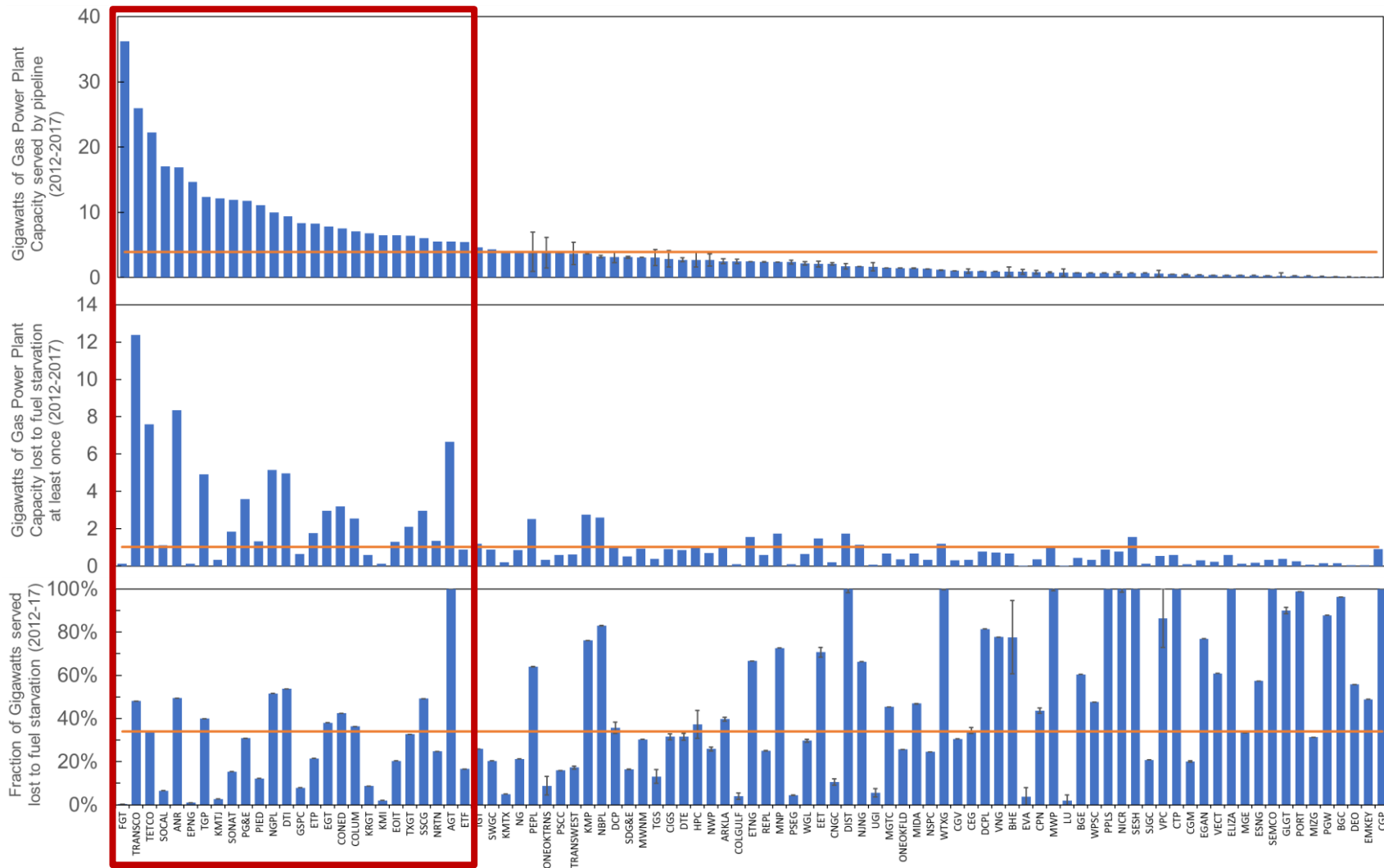
- 6,187 events
    - *At 924 natural gas units*
  - Only unanticipated, lack-of-fuel causes
2. Generator characteristics including the pipelines connected to them from EIA.
  3. Fuel receipts and pipeline contract statuses (EIA and FERC)

# There is strong evidence of correlated failures due to fuel starvation on the same pipeline

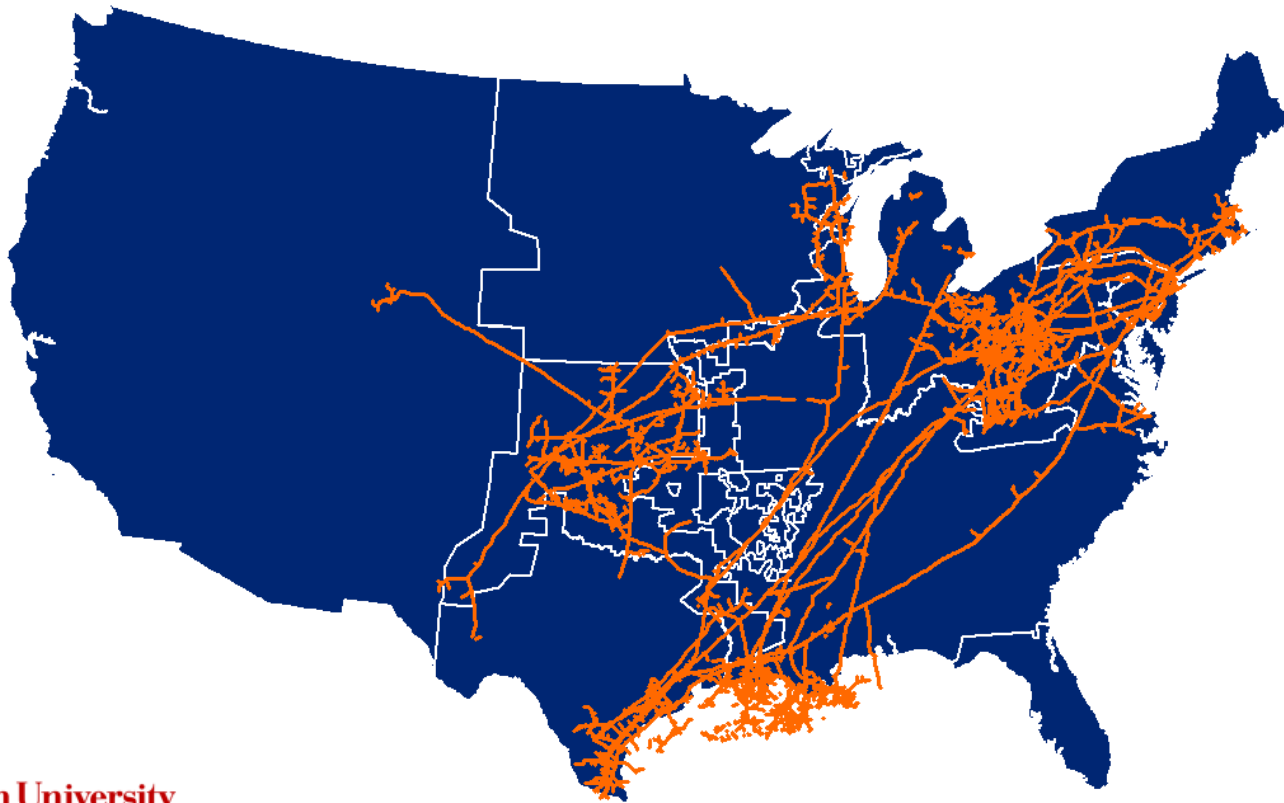
- Correlated, fuel-starvation failures on one pipeline exceeded 10x the median unit's capacity in 6 of the 8 NERC regions.



- These types of correlated failures took ~2.6% of the **total** power plant capacity offline in both TRE and SPP.



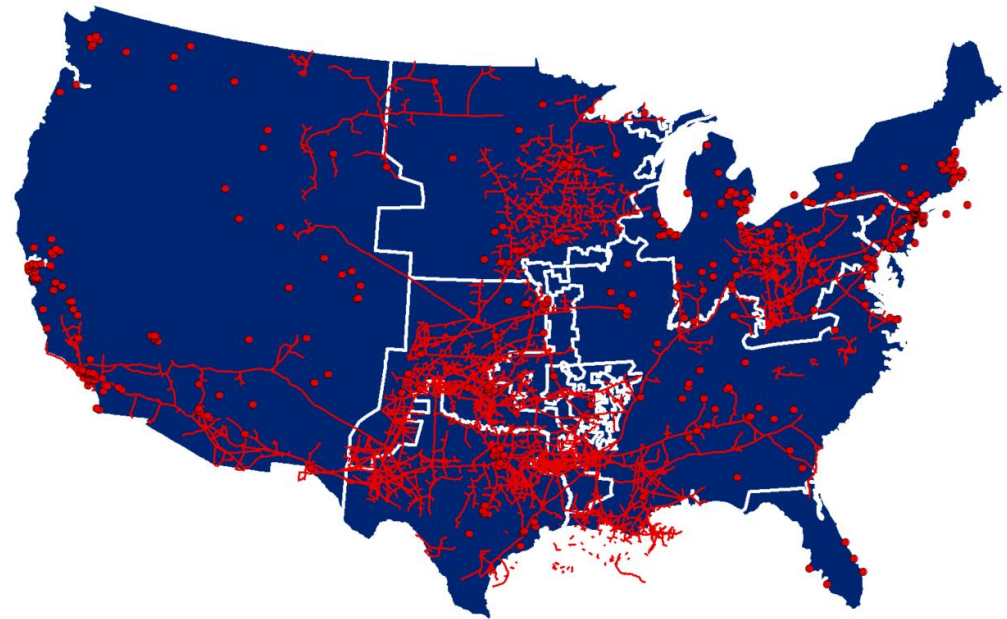
# Where are those pipelines?



# 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)



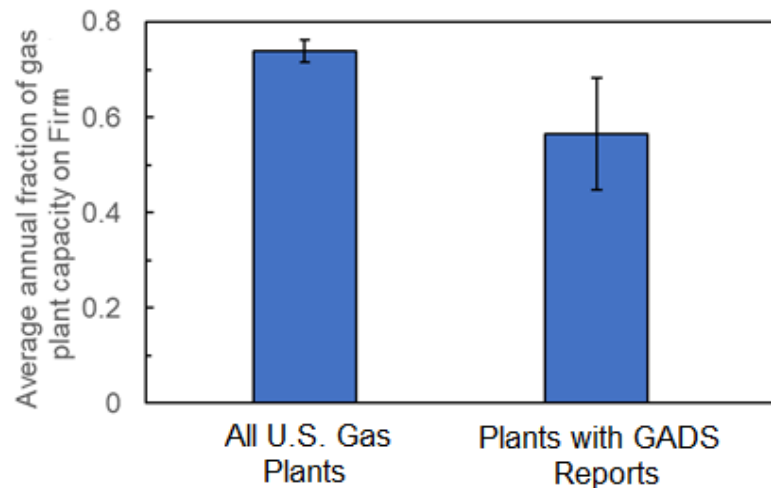
- Service interruption on gas distribution network
- Transmission pipeline reporting service interruption

# 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
- } Firm

Priority





# Units with interruptible contracts had shorter mean times between fuel-starvation failures than units on firm contracts.

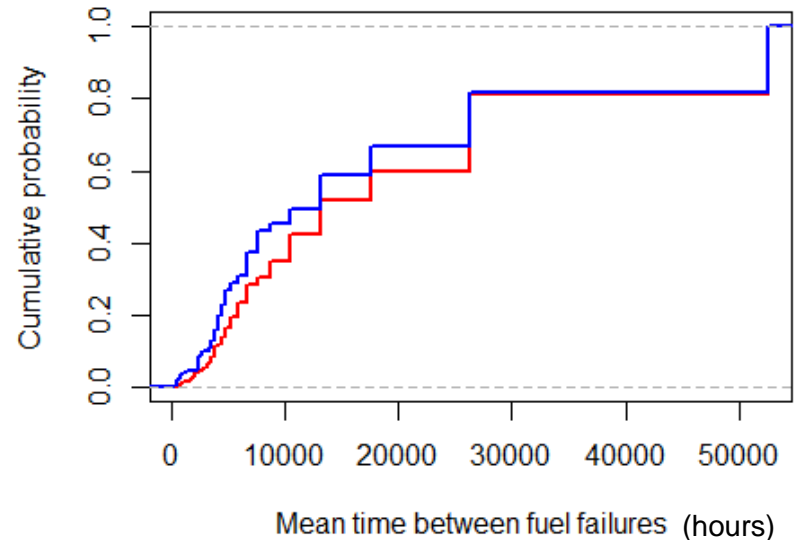
- We calculate each unit's mean time between fuel-starvation failures (MTBFF):

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

- Then group units by pipeline contract status
- Non-parametric Mann-Whitney:

Median Firm MTBFF > Int MTBFF  
at  $p = 0.01531$ . ( $n_{FT} = 255$ ,  $n_{IT} = 299$ )

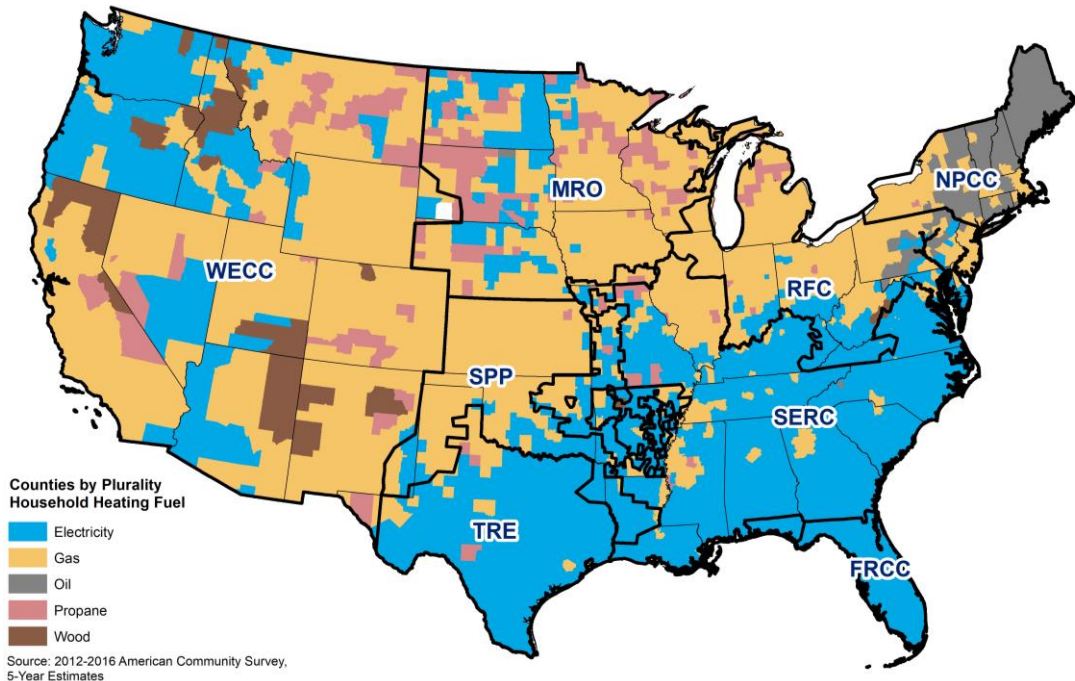
- Robustness checks show the same result:
  1. FERC 549B pipeline contract data ( $p < 0.01$ )
  2. Only units with no back-up fuel source ( $p < 0.05$ )
- **But, firm units still reported these failures in all regions.**



**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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