The Interface of Infrastructures, Markets, and Natural Cycles:

Innovative Modeling and Control Mechanisms for Managing Electricity, Water and Air Quality in Texas

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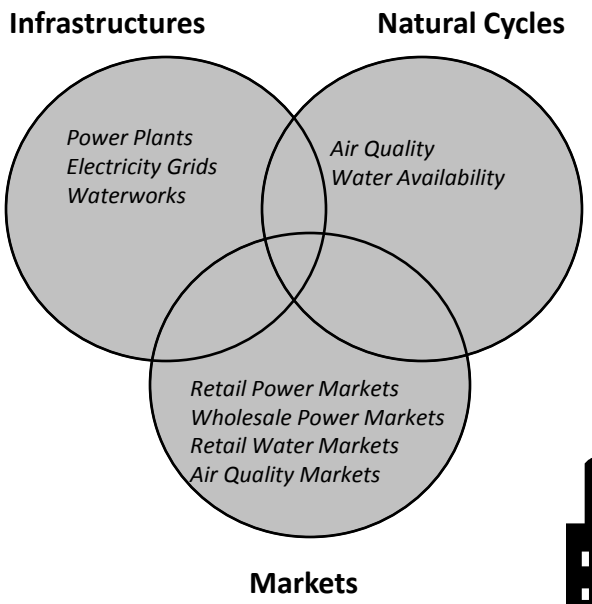
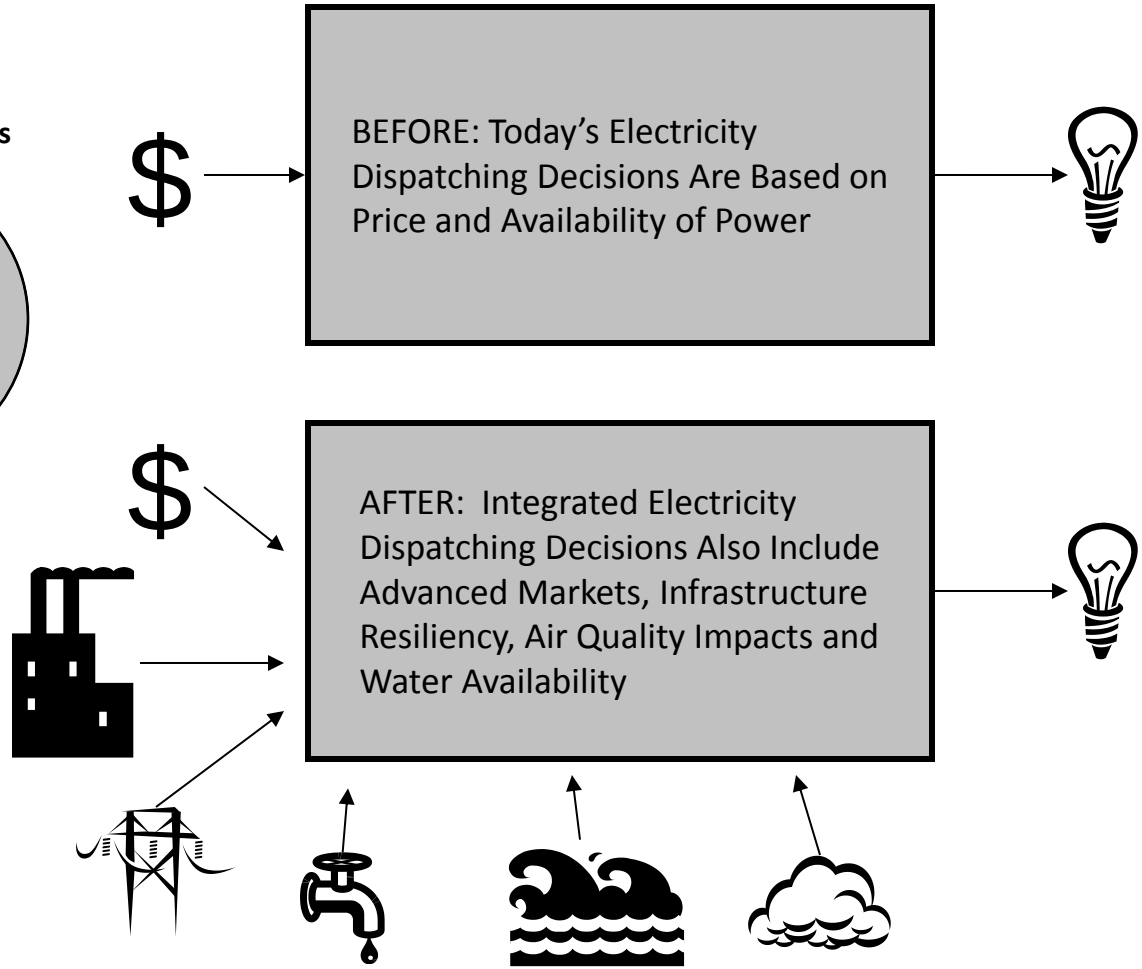
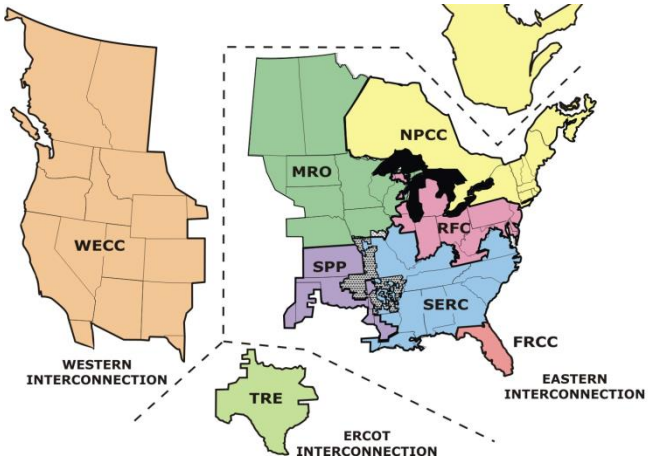
How can a smart electrical grid balance water use, regional air quality, carbon emissions, and electricity demand and cost?

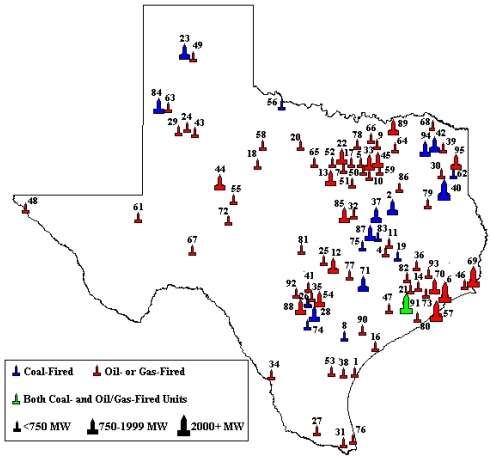




Why Texas?

- Grid entirely contained within the state
- Water-rich east, water-poor west
- Air quality limits in the east but not in the west
- A diverse base of Electricity Generating Units (EGUs), including more installed wind power than any other state





Agenda

- General Background on the UT-MIT Integrated Model
- Case Studies of the Response of the Electricity-Water System

  Air Quality and Water Use Impacts of Increased Natural Gas Production and Use in Texas

  Response to drought

Flexibility in Grid Operation

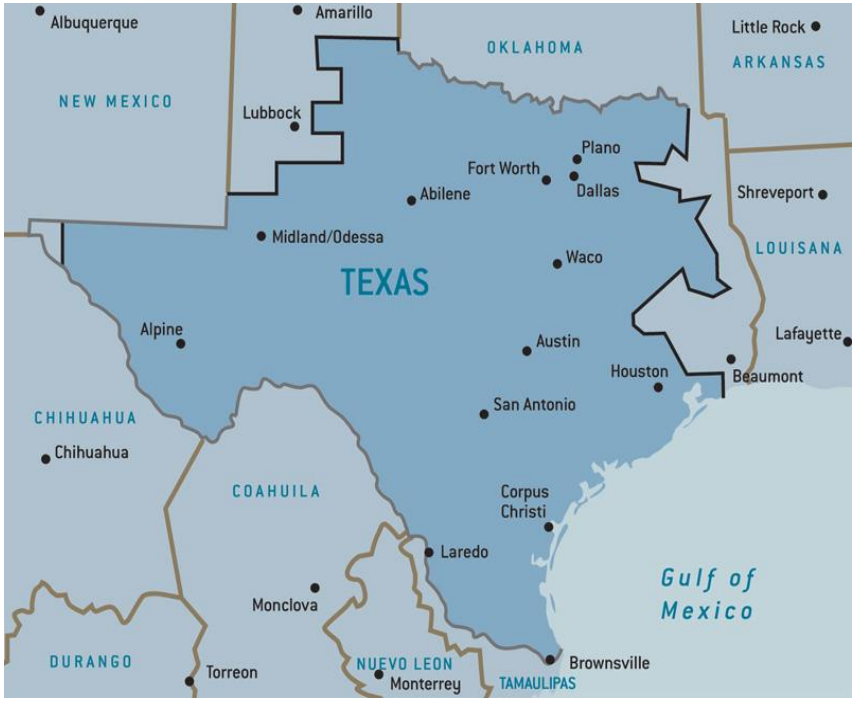


Image courtesy of ERCOT

- Electricity Reliability Council of Texas (ERCOT)
- Installed Capacity: 74,000 MW
- Average Generation: 38,200 MW
- Minimize the cost of meeting demand

Flexibility in Grid Operation

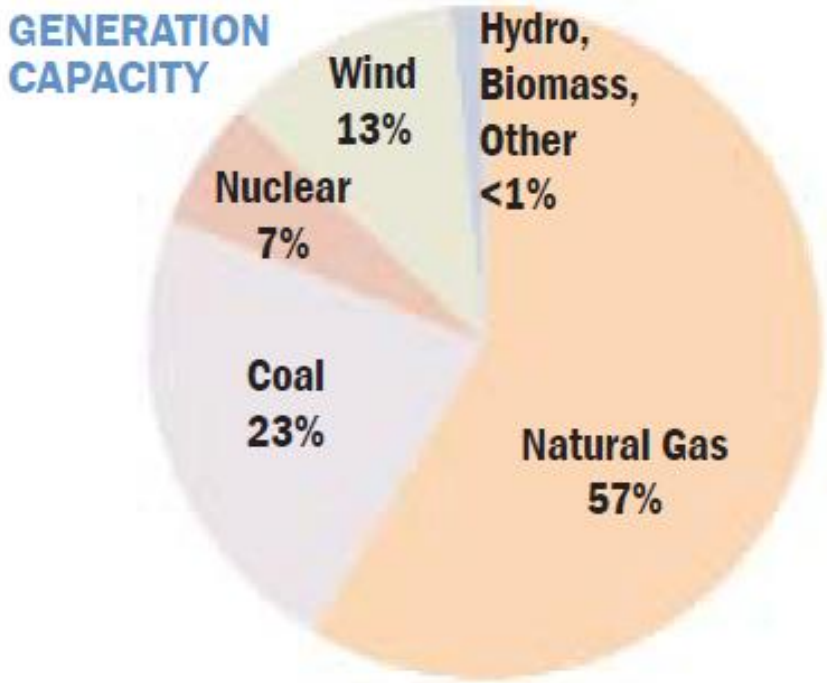


Image courtesy of ERCOT

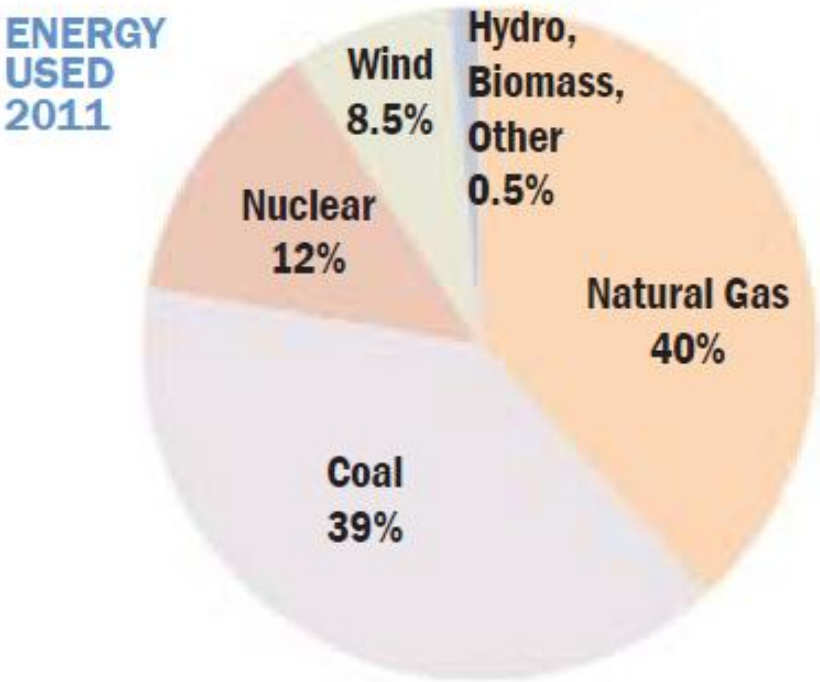
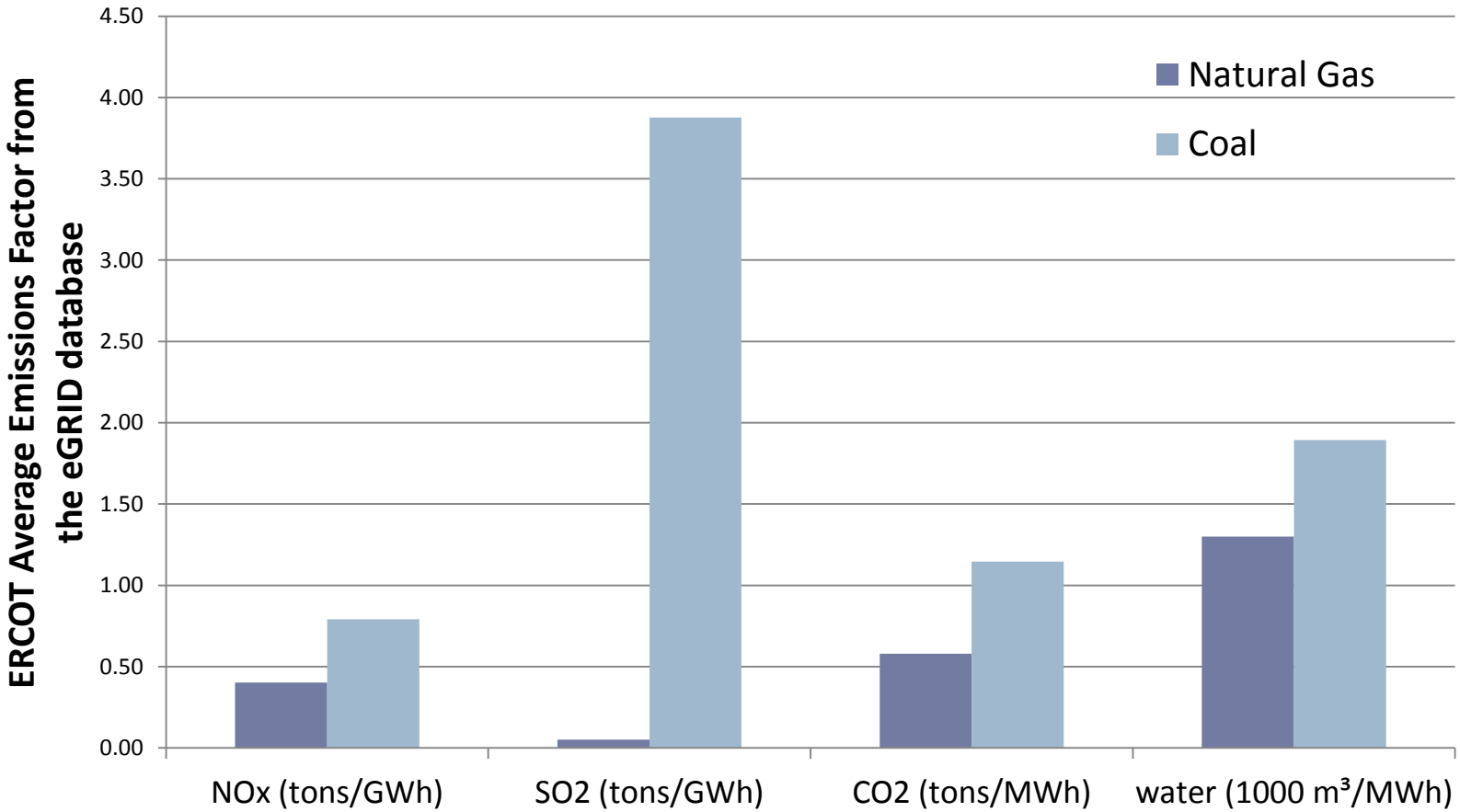
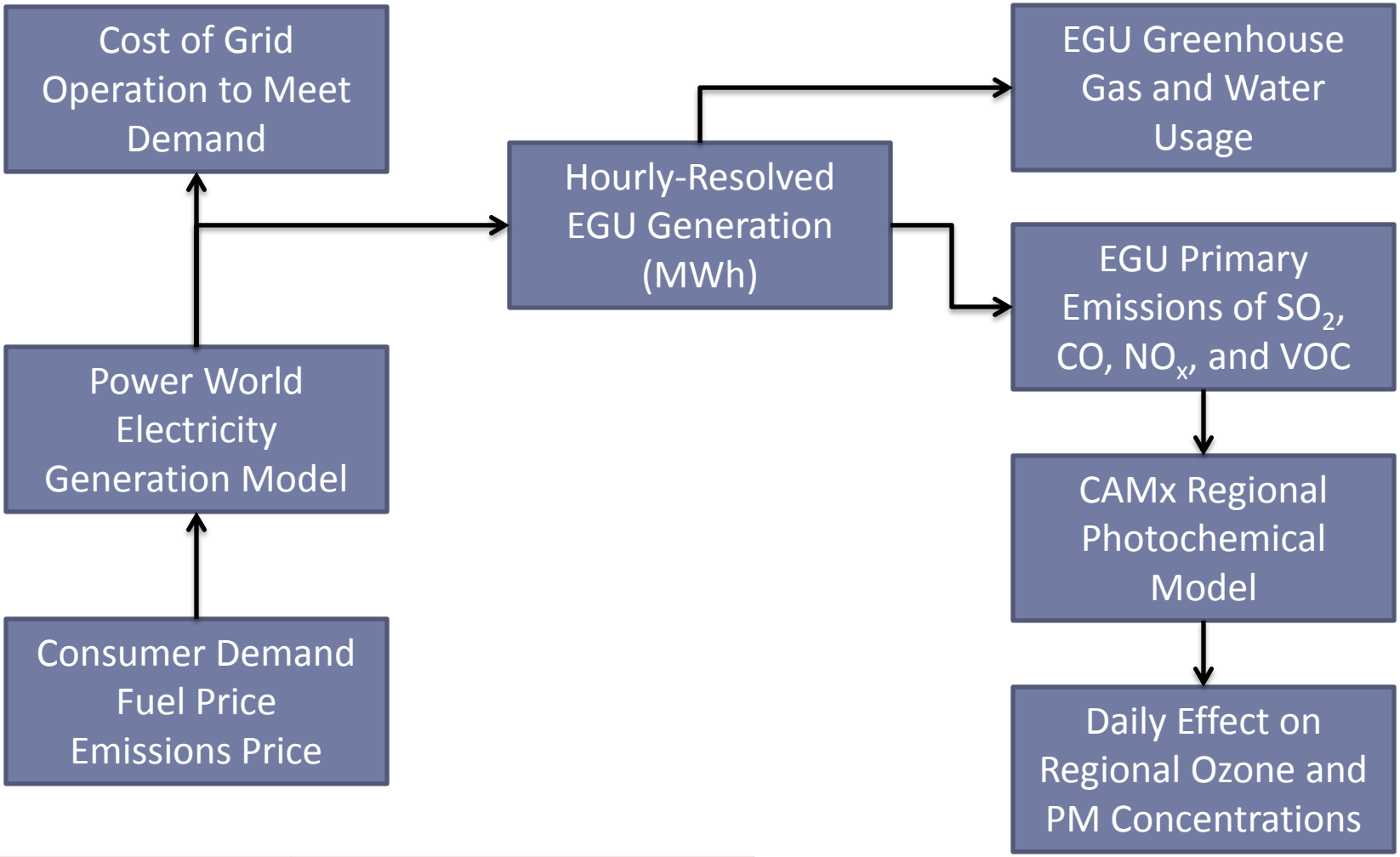


Image courtesy of ERCOT

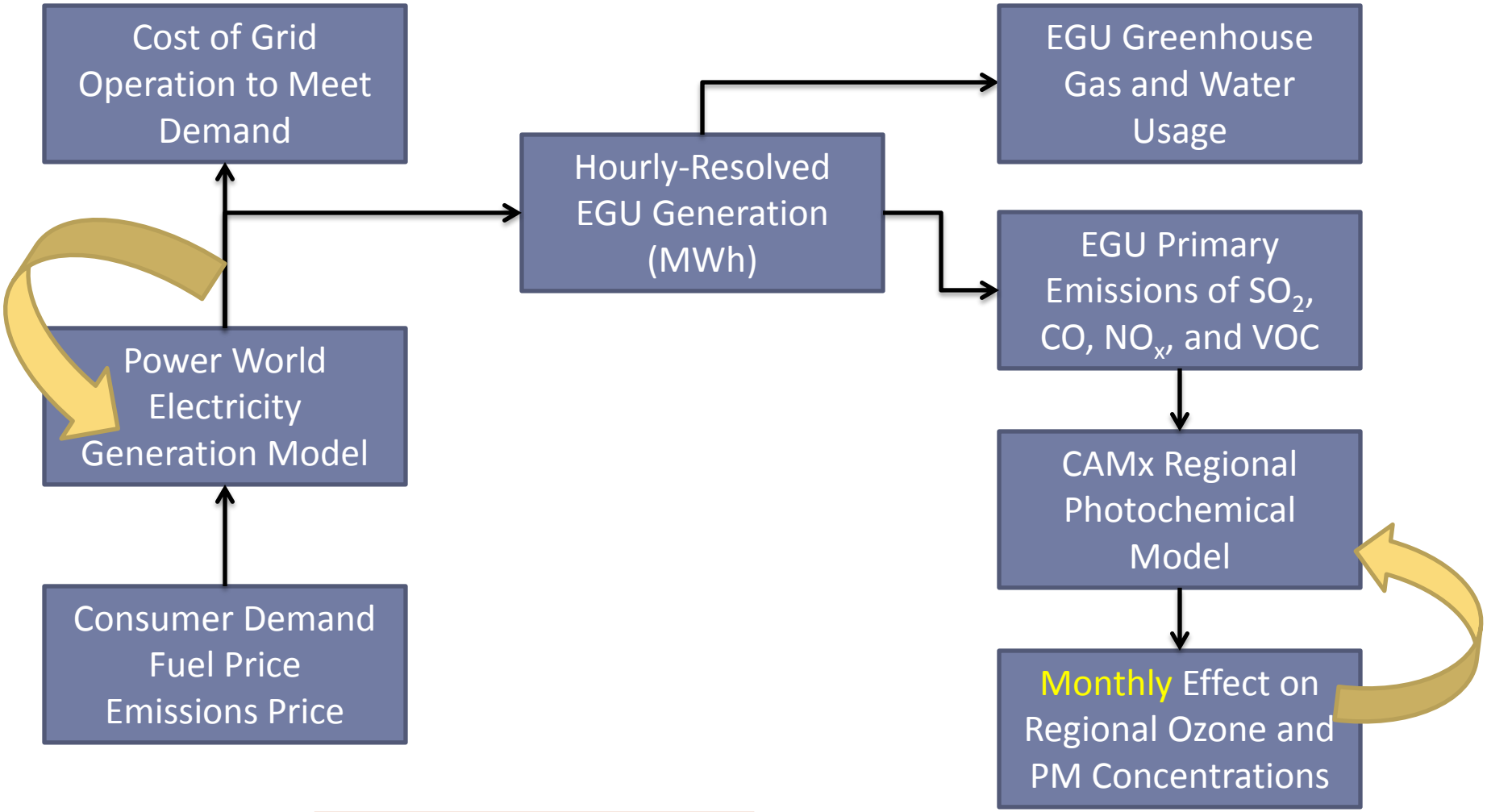
Generation Choices Matter



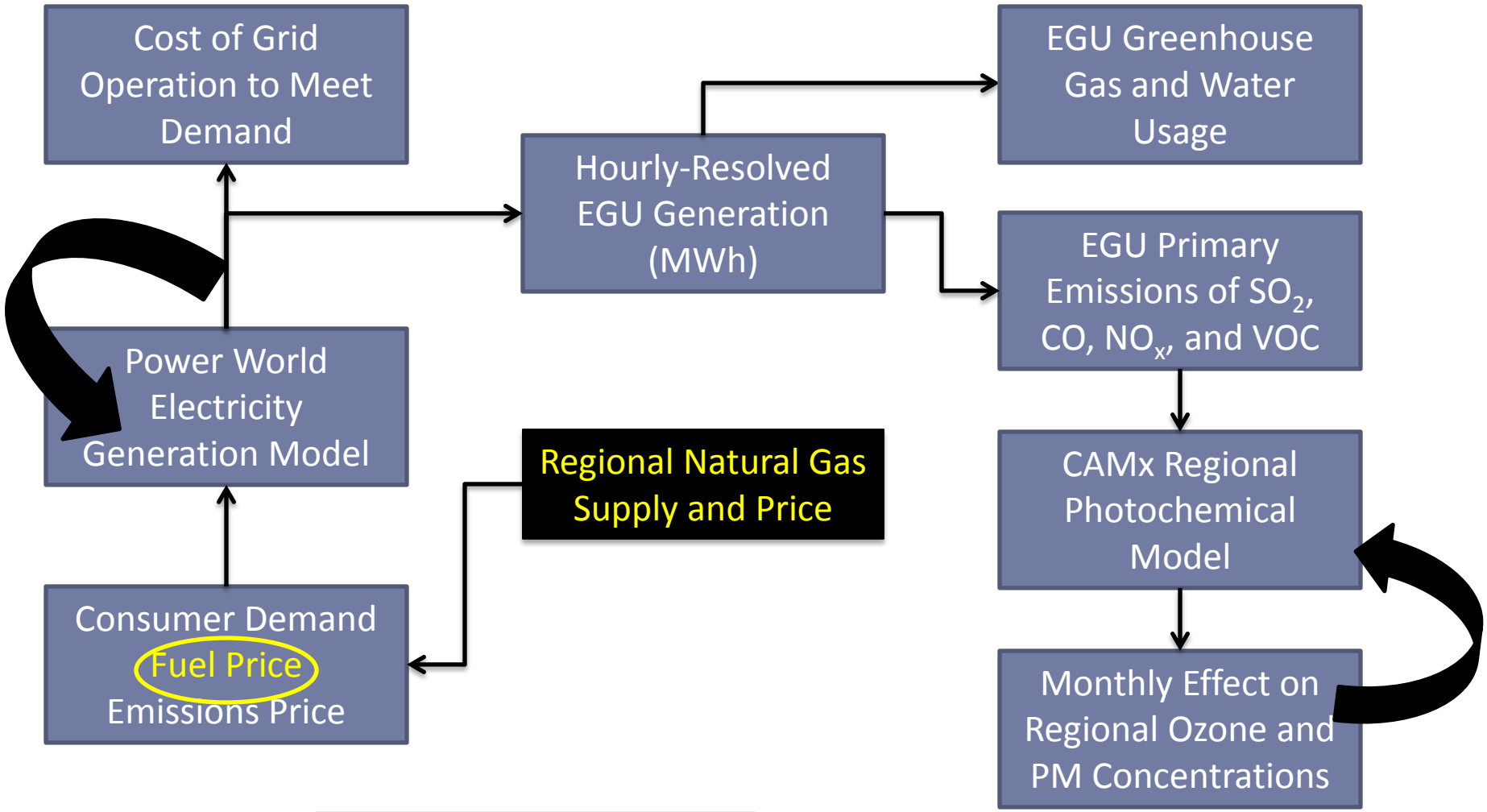
UT-MIT Integrated Model



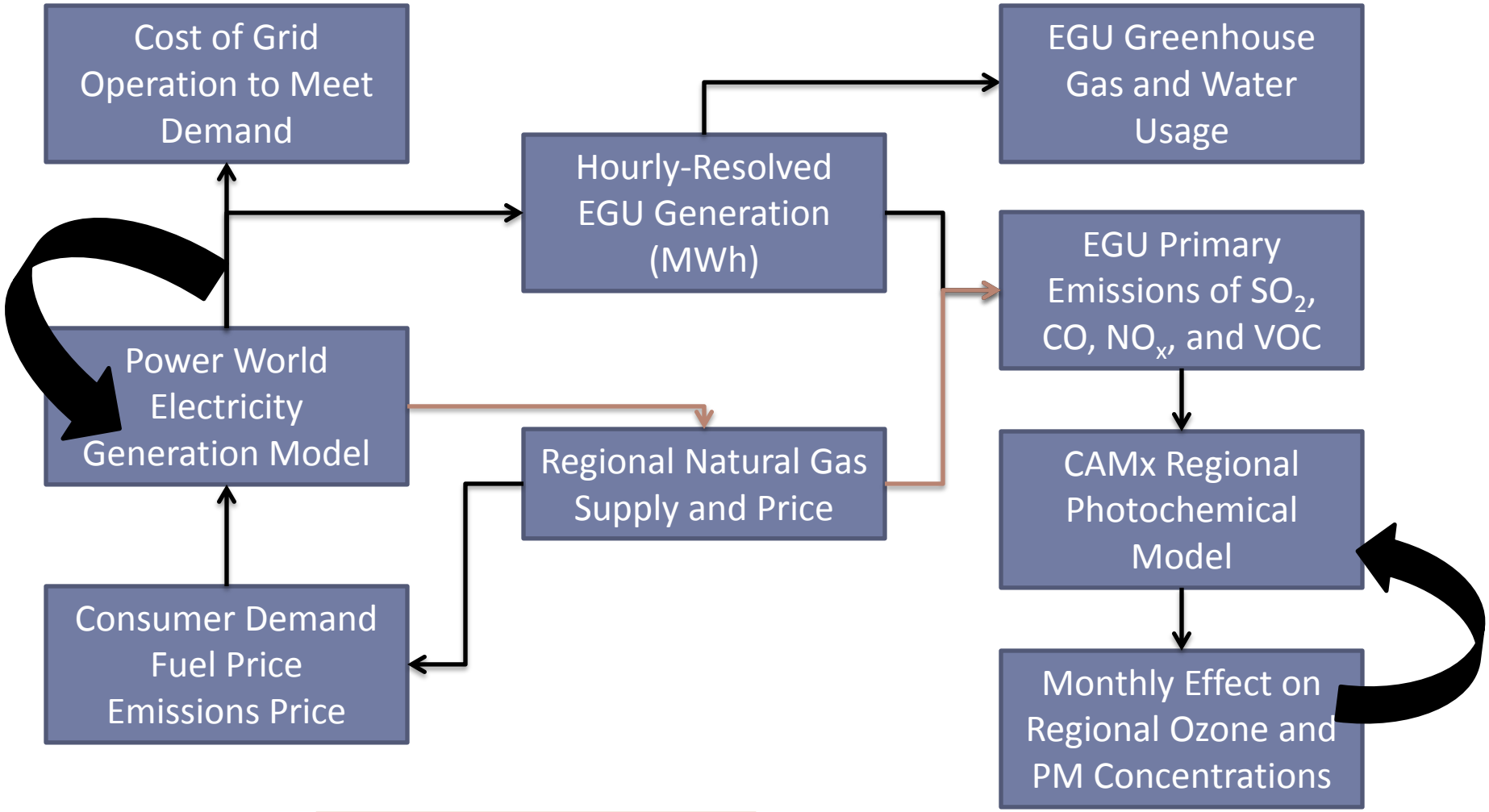
Extension to Multiple Days



Natural Gas Supply and Price Effect

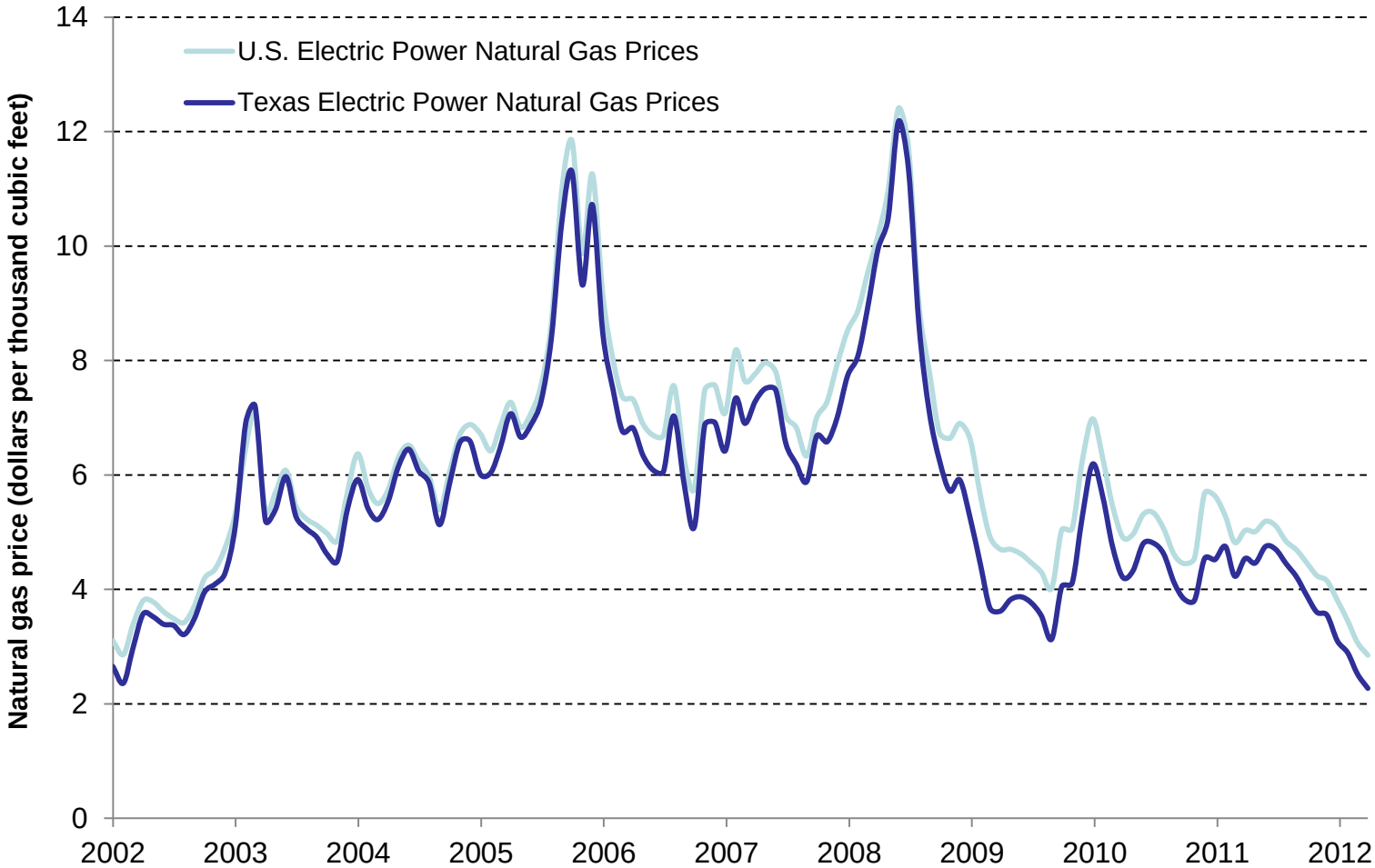


Full Supply Chain Integration



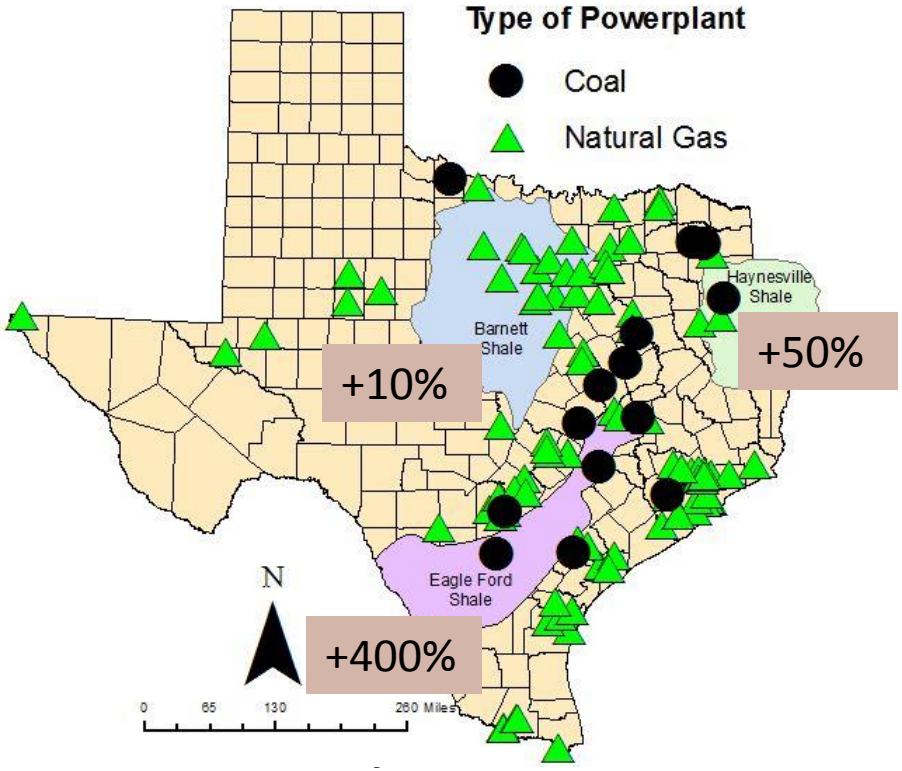
CASE STUDY 1:
AIR QUALITY AND WATER USE IMPACTS OF INCREASED NATURAL GAS PRODUCTION AND USE IN TEXAS

How resilient is system to these changes in fuel prices?



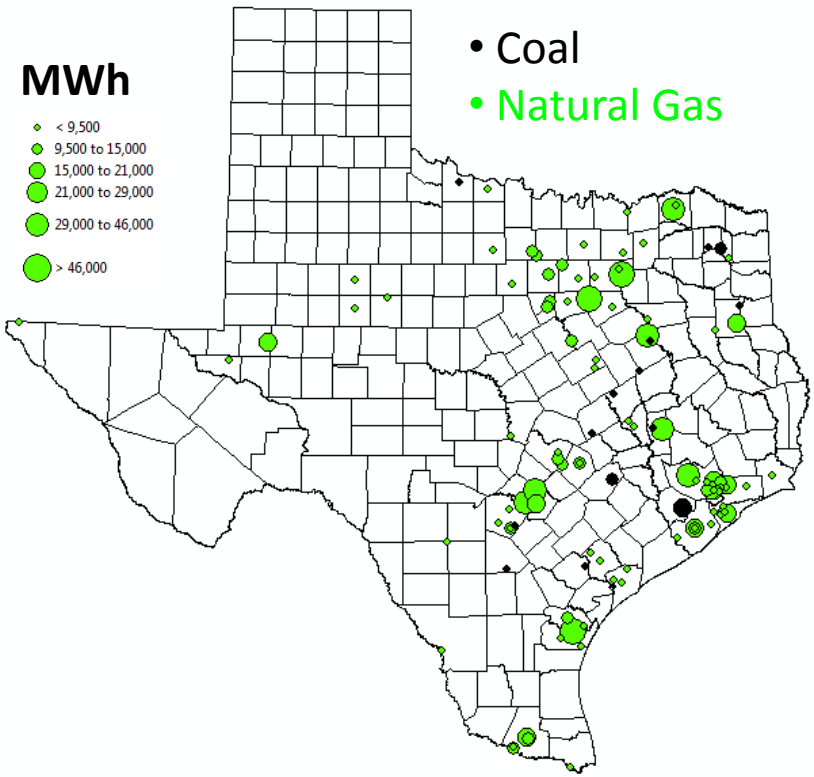
General Background Conceptual Model Change **Case Studies**

Natural Gas in Texas

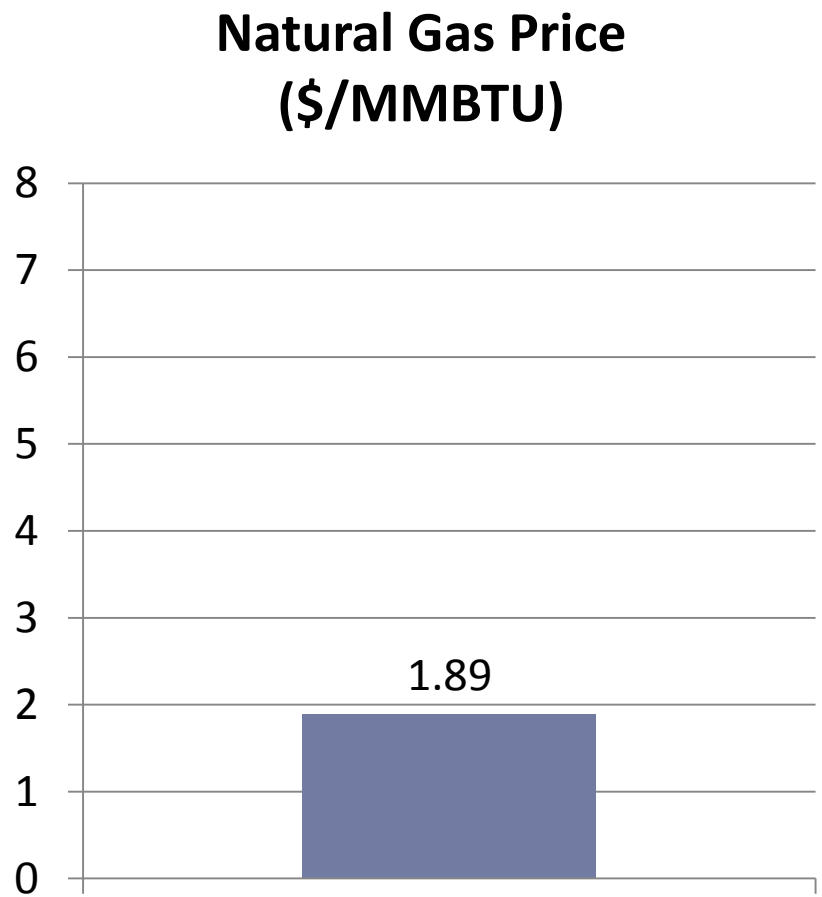


% Growth Since 2010
(Texas Railroad Commission)

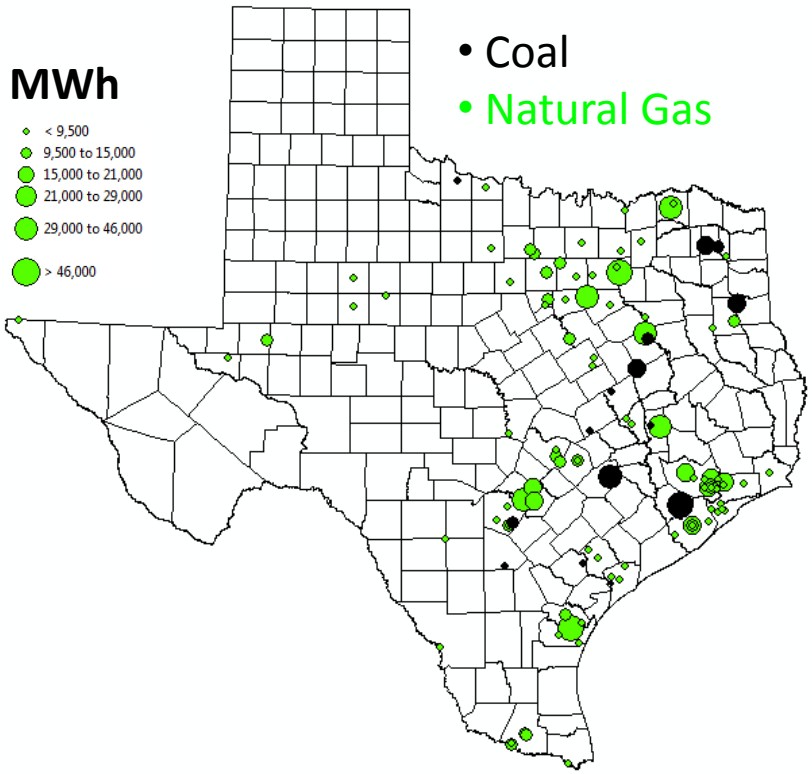
Effect on Electricity Generation



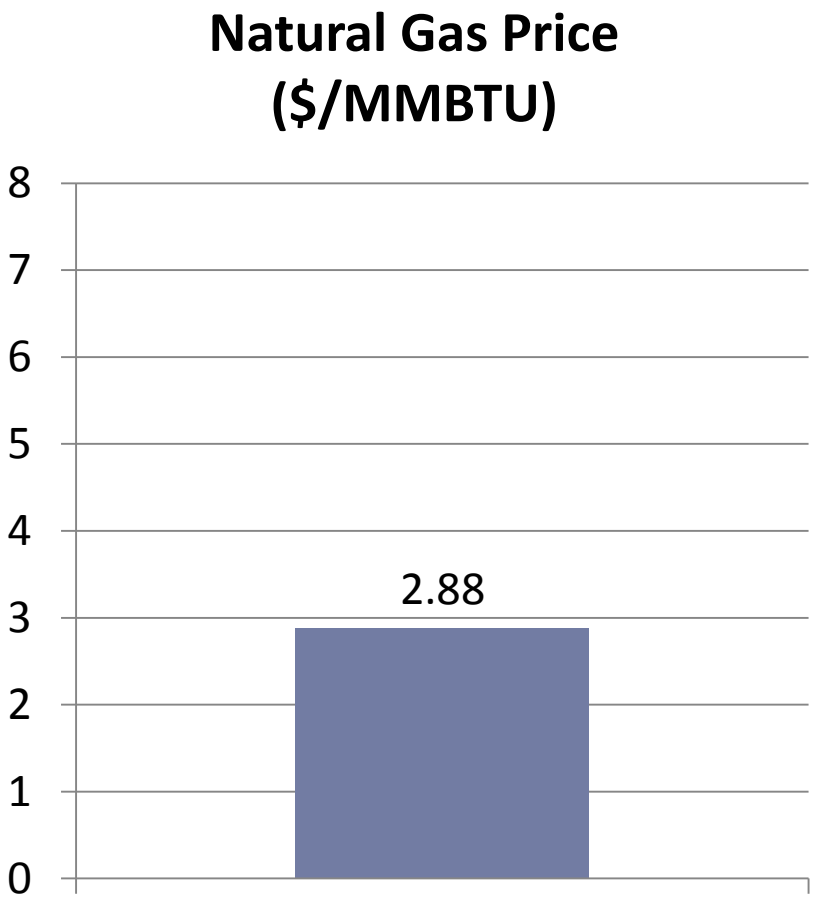
Average Daily Generation over Episode



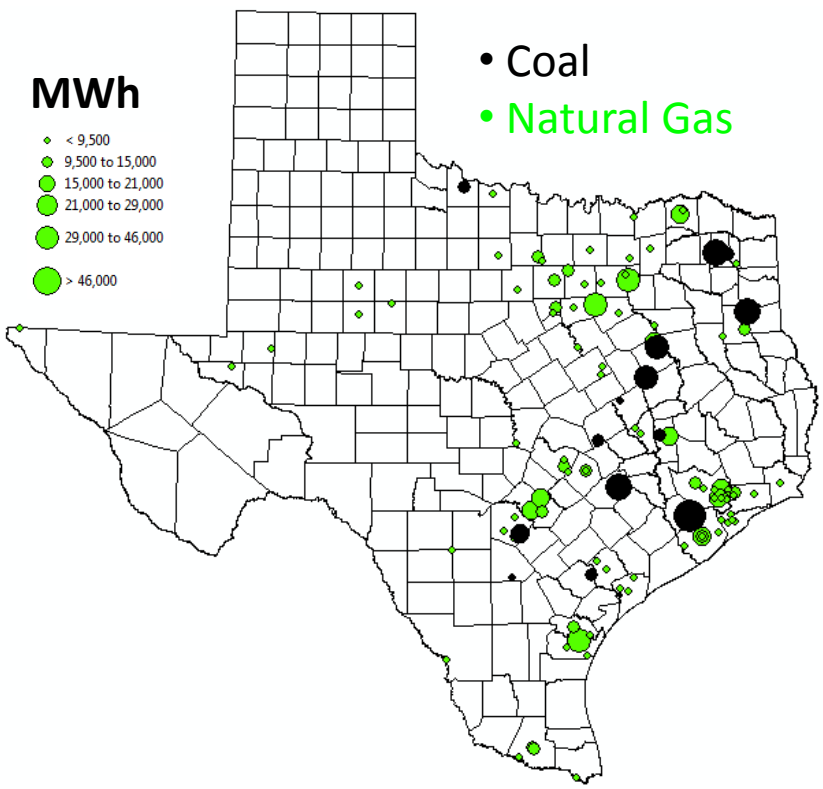
Effect on Electricity Generation



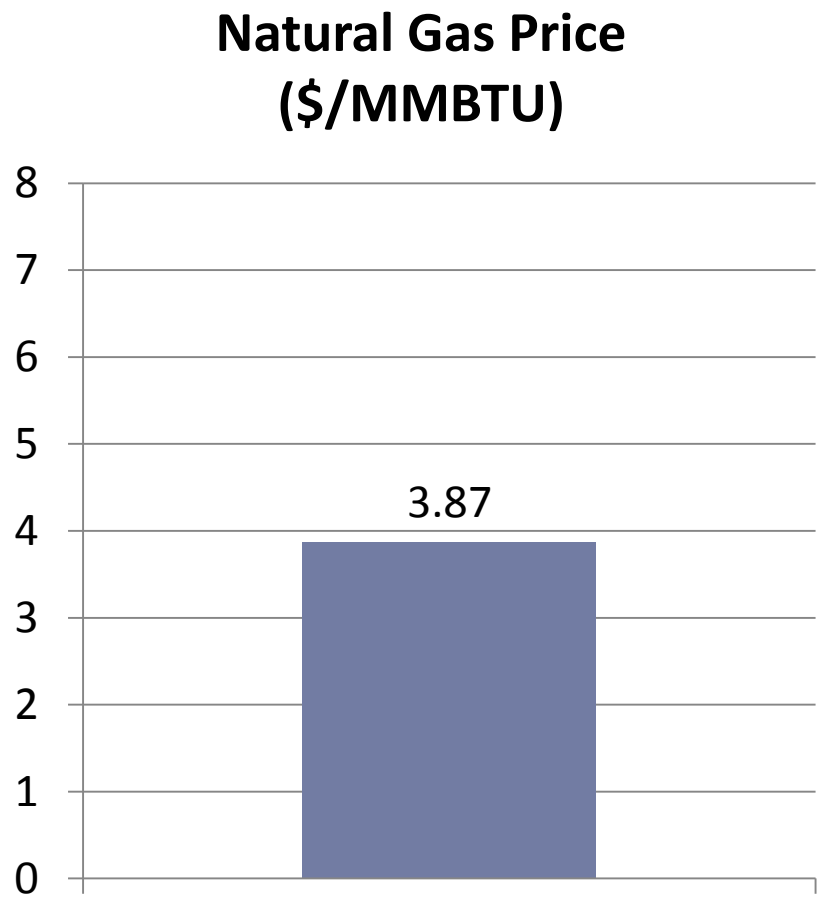
Average Daily Generation over Episode



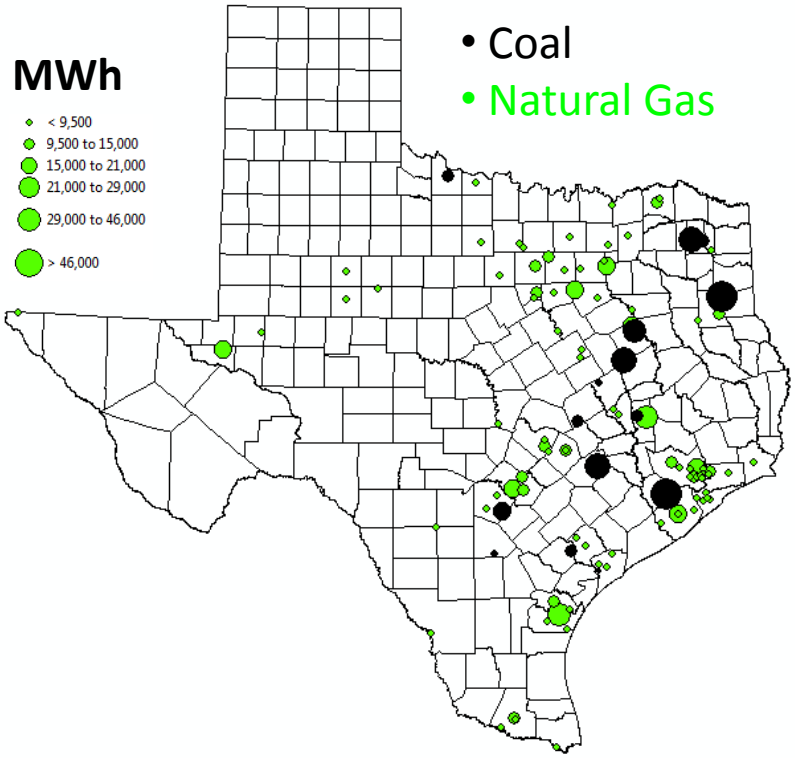
Effect on Electricity Generation



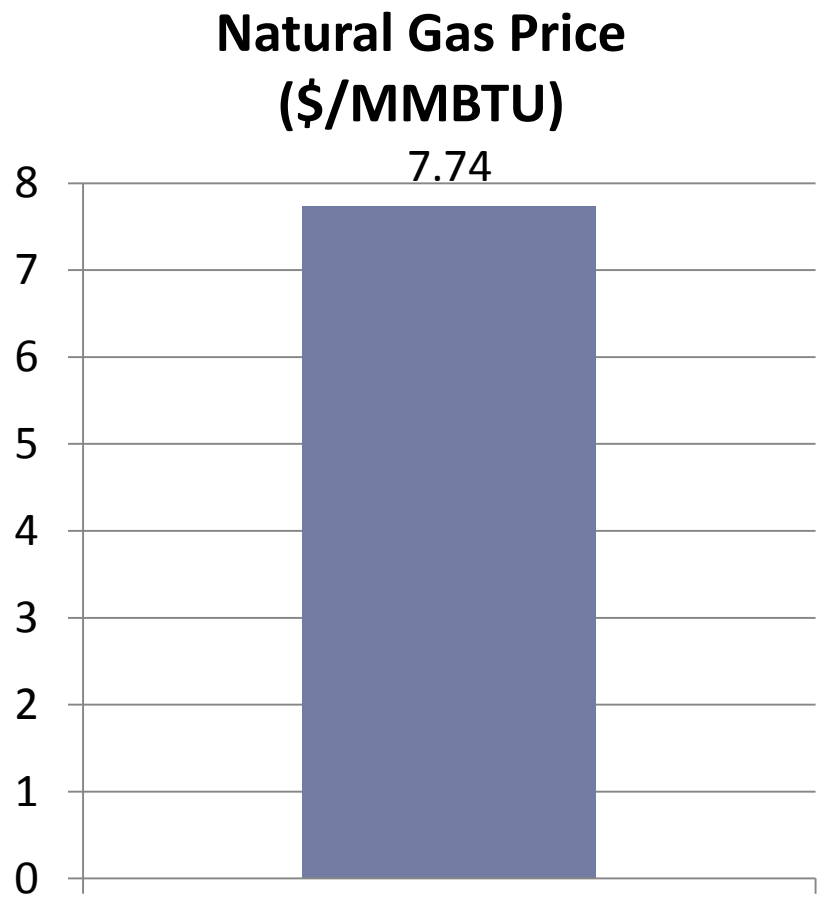
Average Daily Generation over Episode



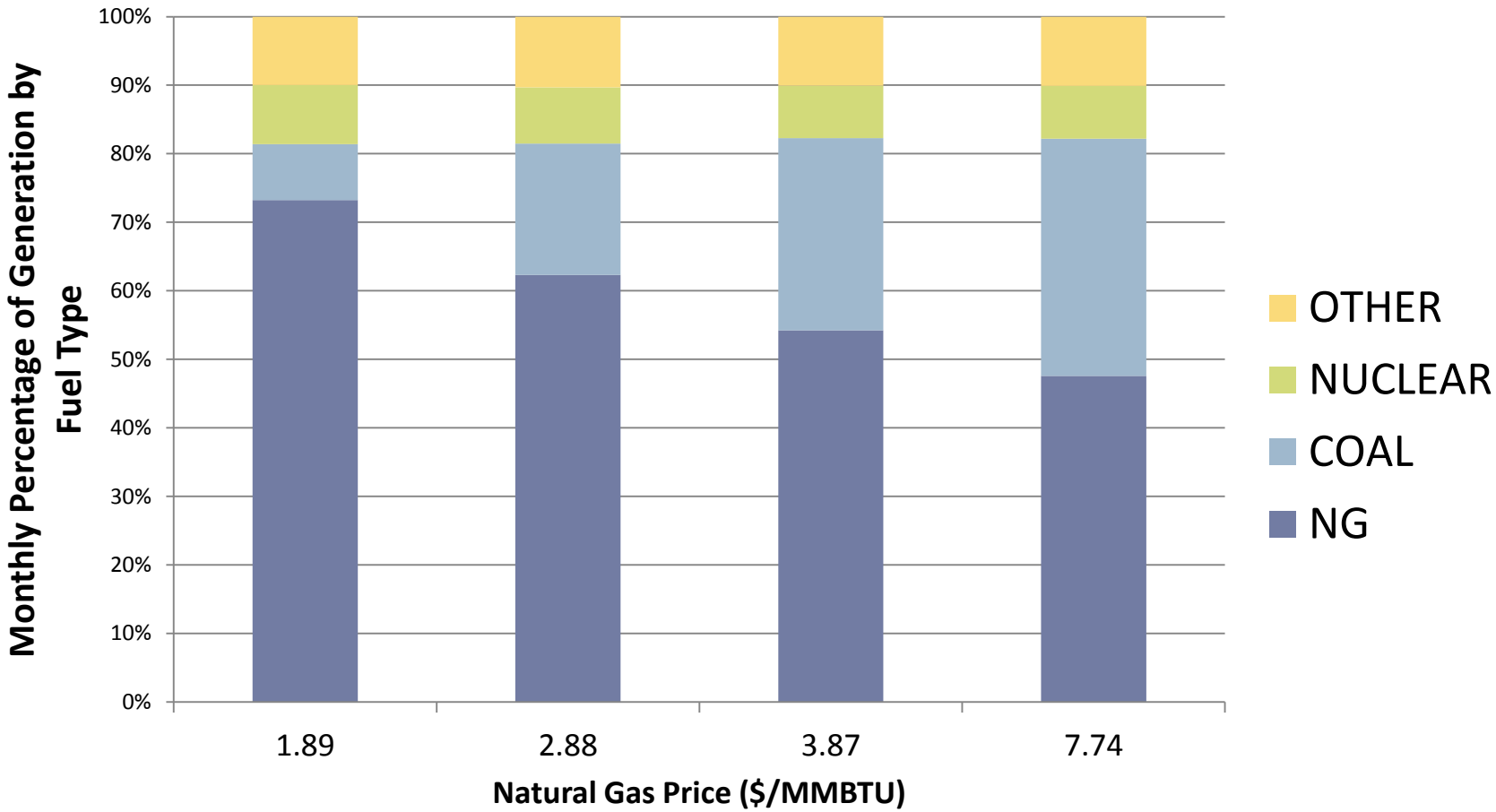
Effect on Electricity Generation



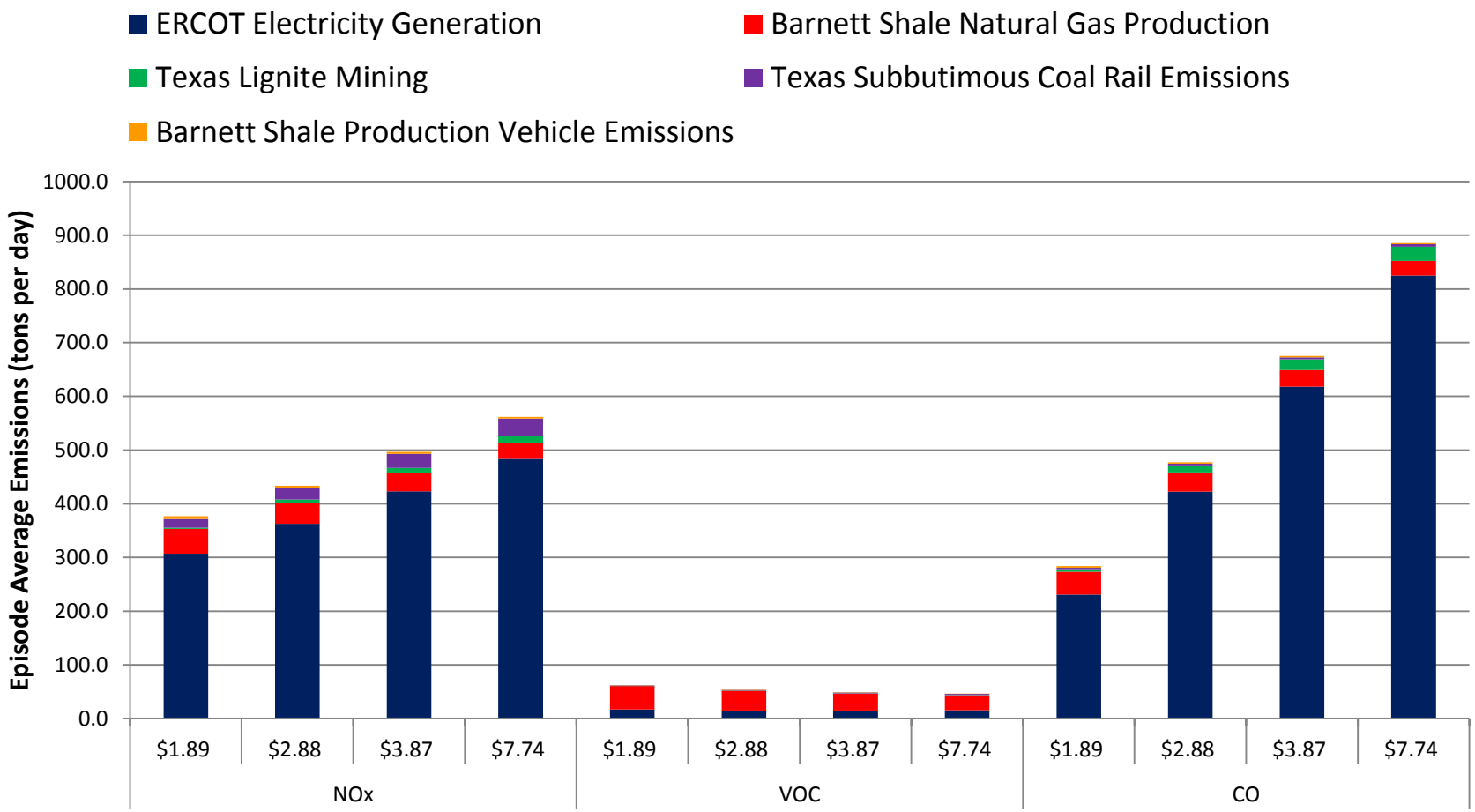
Average Daily Generation over Episode



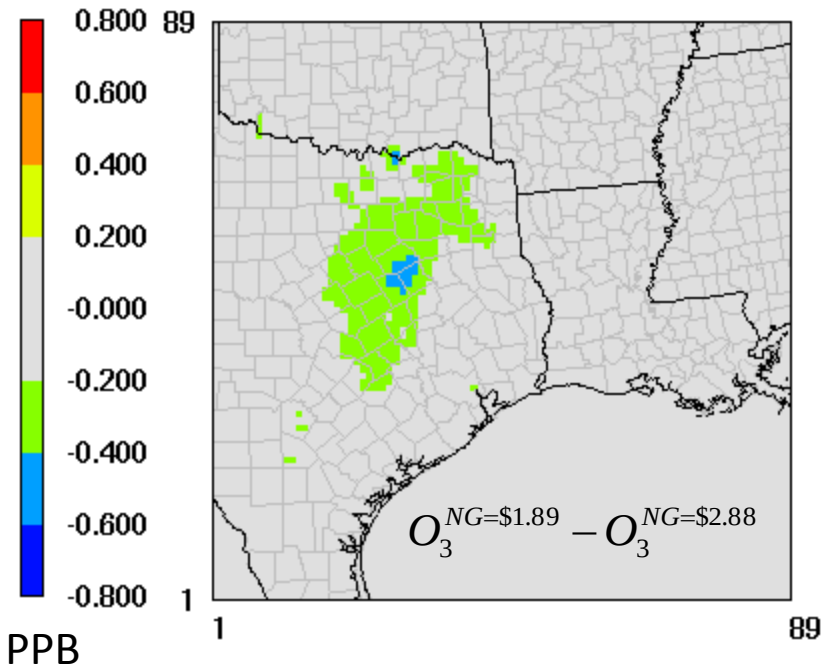
Effect on Electricity Generation

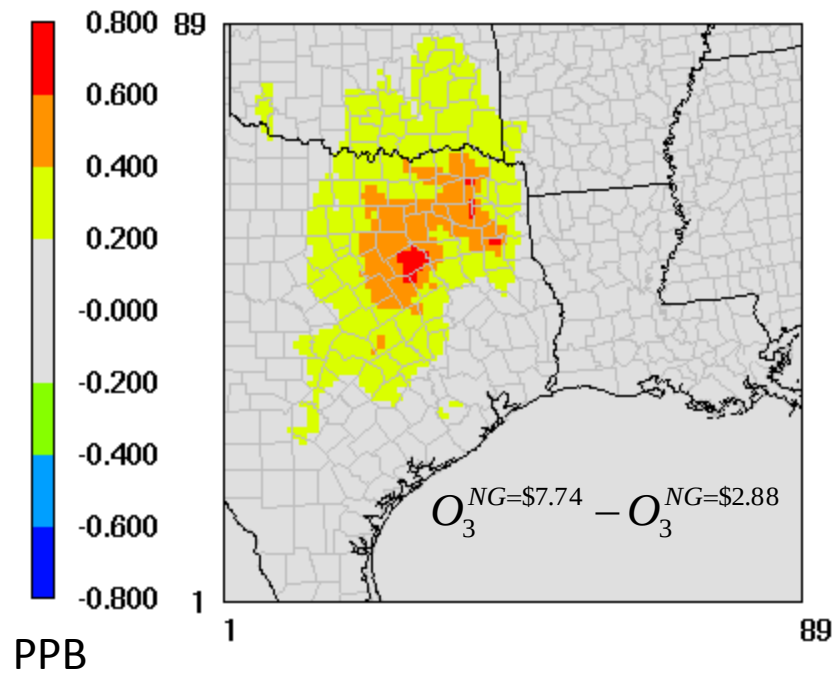


Regional Life Cycle Assessment



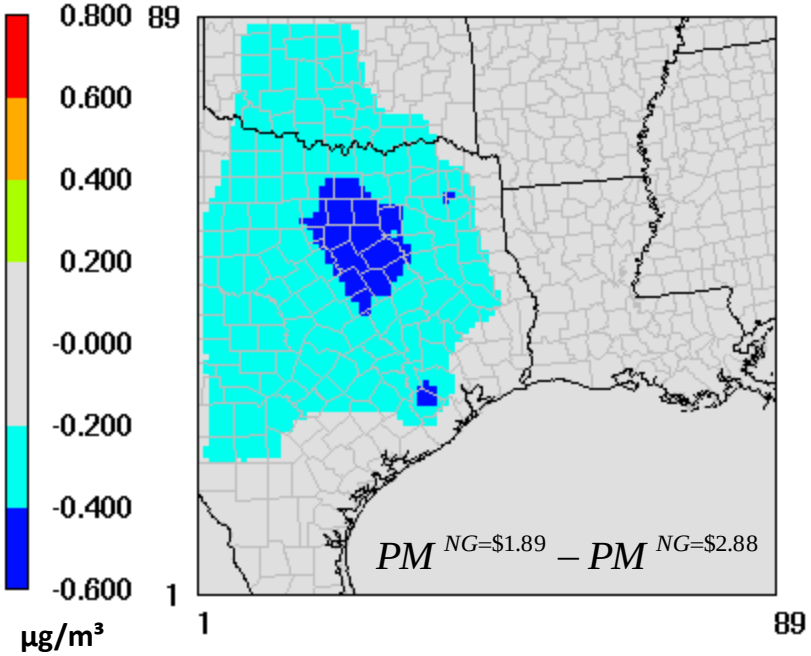
Average Ozone Impacts

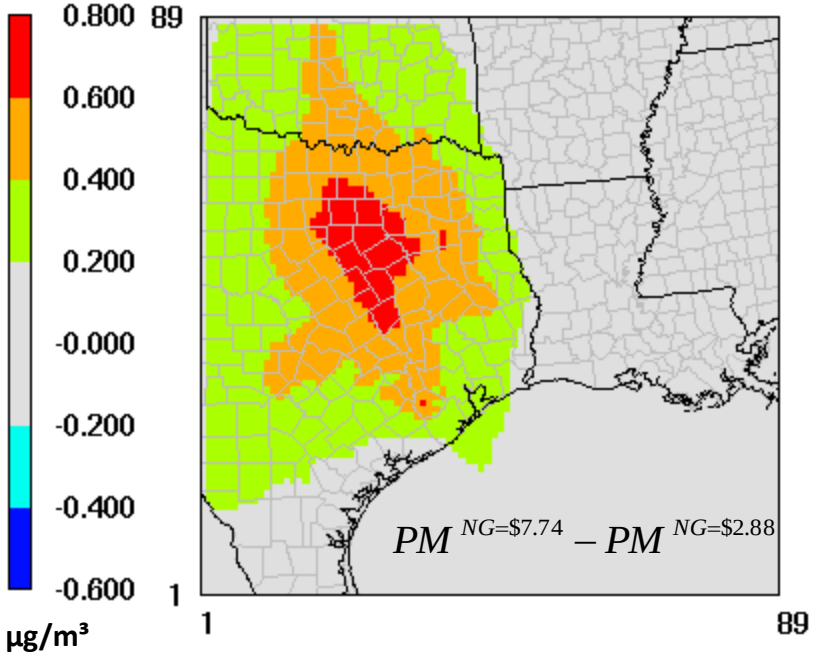




- Base Case = $2.88 per MMBTU natural gas
- Austin Vehicle Emissions and Inspection Program: 0.35 ppb reduction (Durrenberger et al (2005) A&WMA Conference Proceedings)

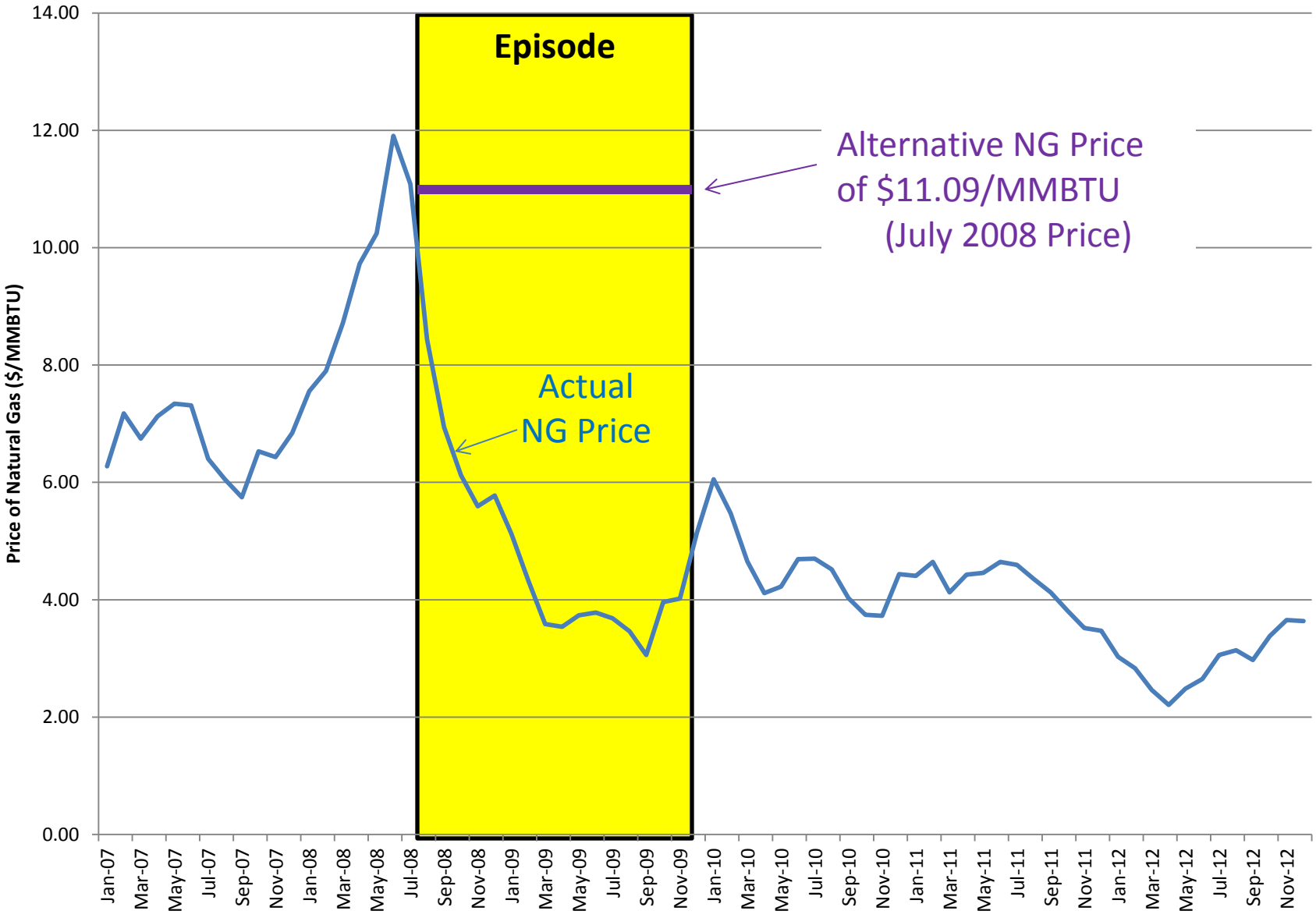
Average PM Impacts





- Base Case = $2.88 per MMBTU natural gas
- Average Cross State Air Pollution Rule Reduction for Texas monitors in 2014: 0.8 µg/m³ (EPA Technical Documentation)

Overall water use decreases but increases in some watersheds


Episode
Alternative NG Price
of $11.09/MMBTU
(July 2008 Price)
Actual
NG Price
Price of Natural Gas ($/MMBTU)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Jan-07
Mar-07
May-07
Jul-07
Sep-07
Nov-07
Jan-08
Mar-08
May-08
Jul-08
Sep-08
Nov-08
Jan-09
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Nov-11
Jan-12
Mar-12
May-12
Jul-12
Sep-12
Nov-12

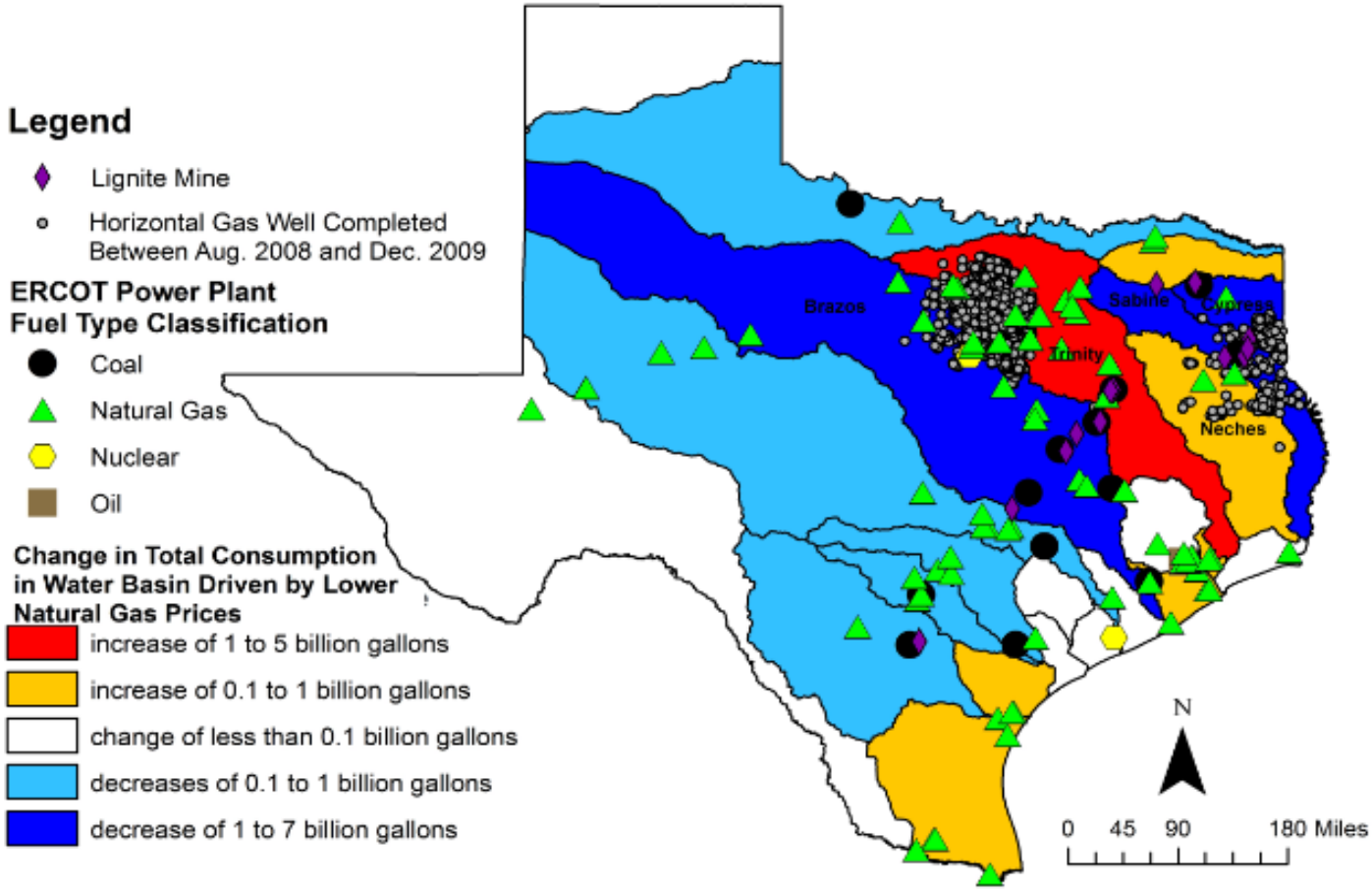
Scenarios in Work

Actual NG Price and Production

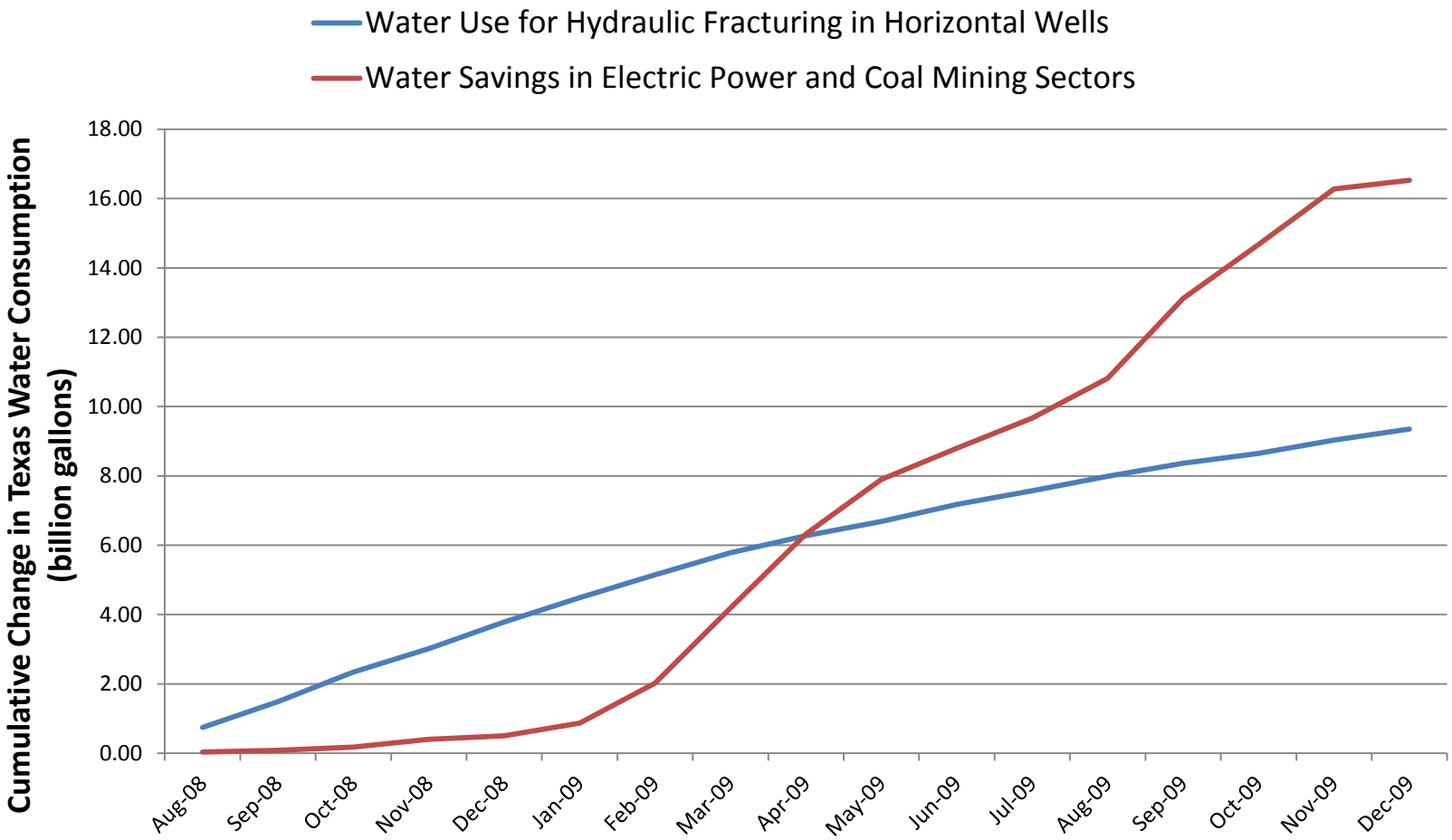
- Actual NG Price used in ERCOT model
- 2996 horizontal wells with hydraulic fracturing in Haynesville (5.7 million gal/well) and Barnett (2.8 million gal/well) Shales
- Included upstream water use for lignite used at ERCOT power plants

High NG Price and no Hydraulic Fracturing of Horizontal Wells

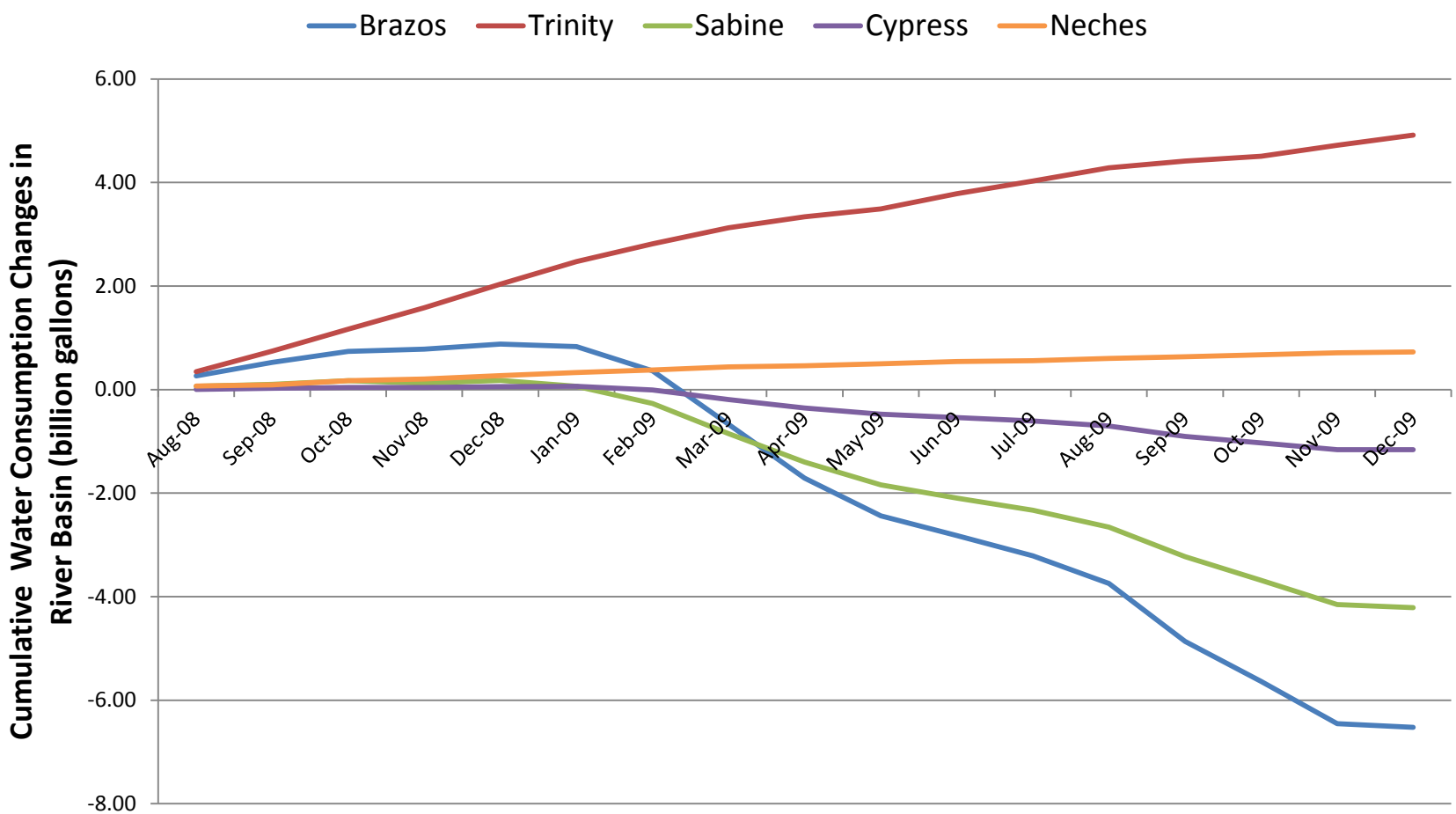
- Constant $11.09/MMBTU price used in ERCOT Model
- No hydraulic fracturing of horizontal wells in the Haynesville or Barnett Shales
- Included upstream water use for lignite used at ERCOT power plants



Change in total water consumption in Texas water basins during the August 2008 through December 2009 episode related to the drilling of horizontal wells in the Haynesville and Barnett shales as well as modeled changes in the ERCOT and lignite production sectors. Red and orange areas indicate regions with increased water consumption in the scenario with actual natural gas prices compared to the scenario in which natural gas prices in the state remained elevated.

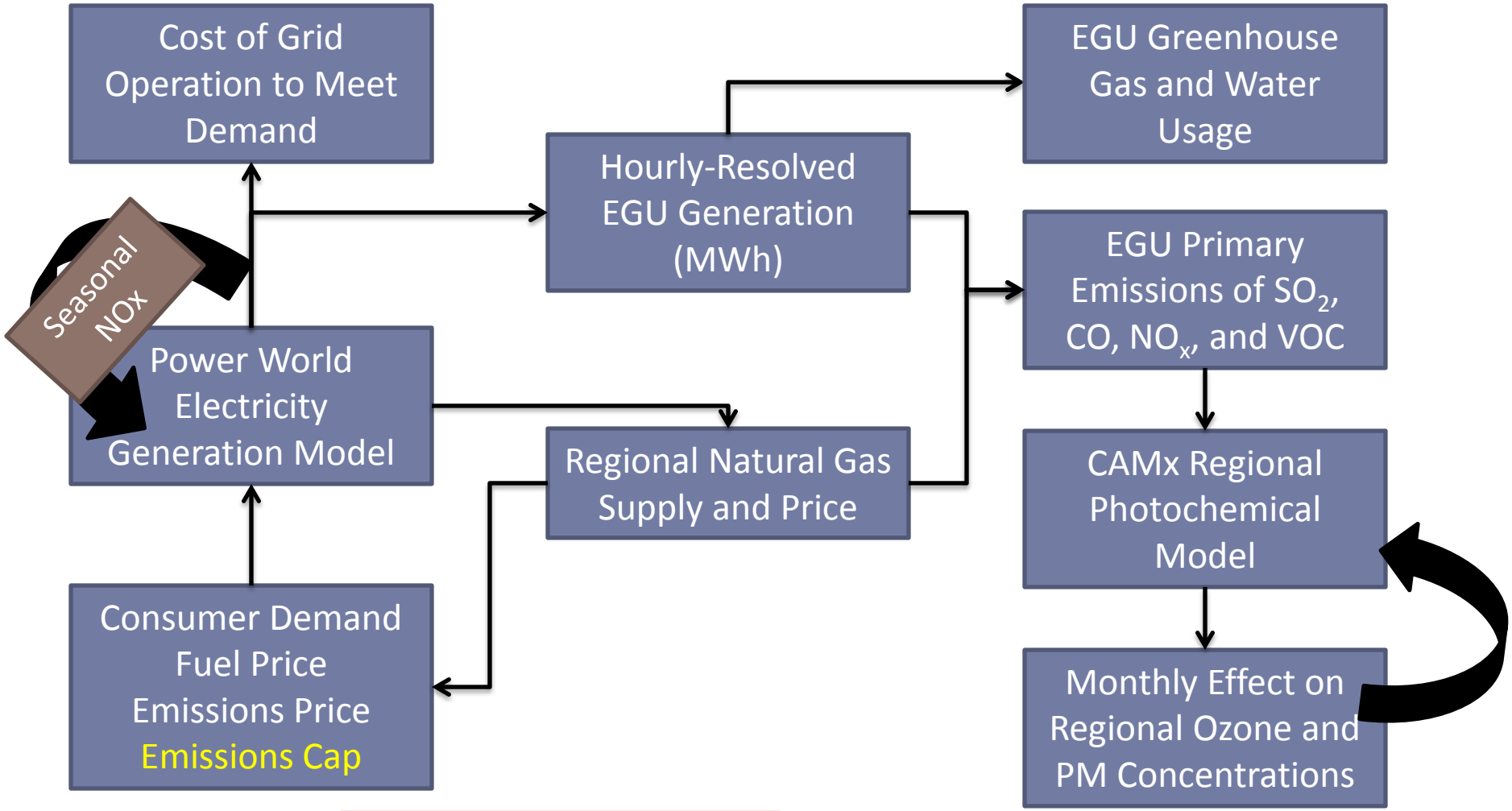


Comparison of the cumulative water consumed in hydraulic fracturing activities in horizontal wells in the Haynesville and Barnett shales to cumulative consumptive water savings in the electricity generation and coal mining sectors since the start of the episode (August 2008).



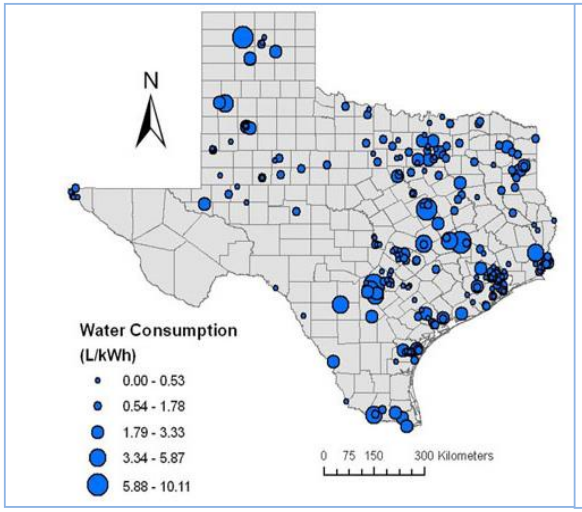
Selected change in cumulative water consumption (billion gallons) in selected river basins since the start of the episode (August 2008), reported monthly. Note that negative values indicate a net reduction in consumption in the water basin in the scenario with actual natural gas prices compared to the scenario with a constant $11.09 price for natural gas.

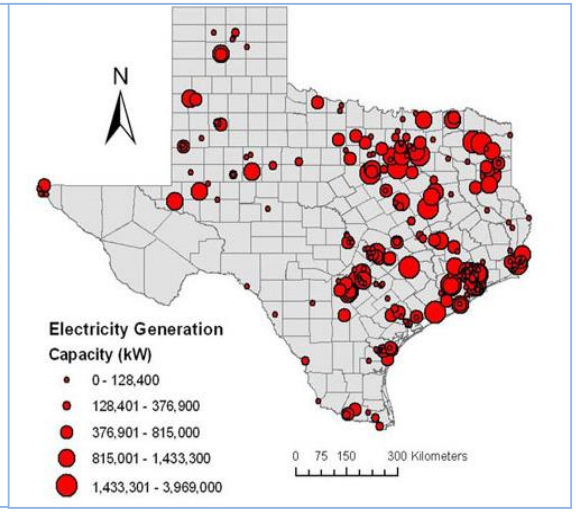
EGU Emission Caps

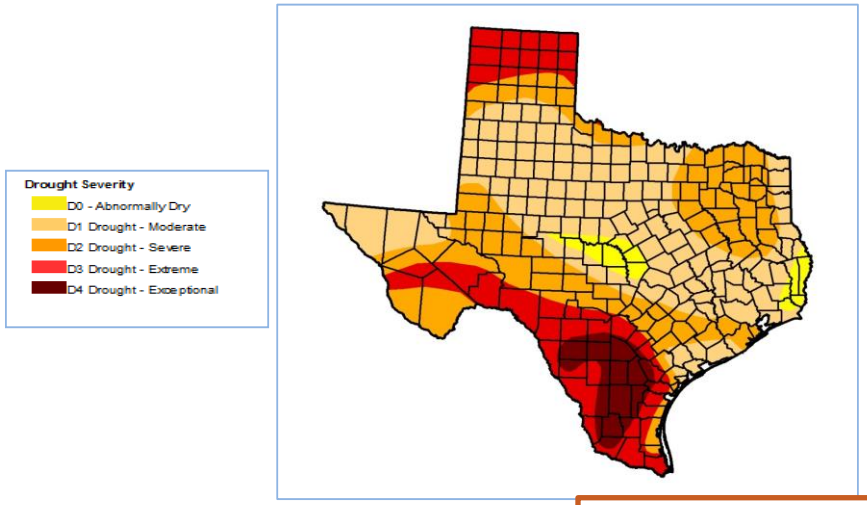


CASE STUDY 1:
THE ELECTRICAL GRID AS A WATER PIPELINE

Can an electrical grid be a virtual water pipeline during drought?





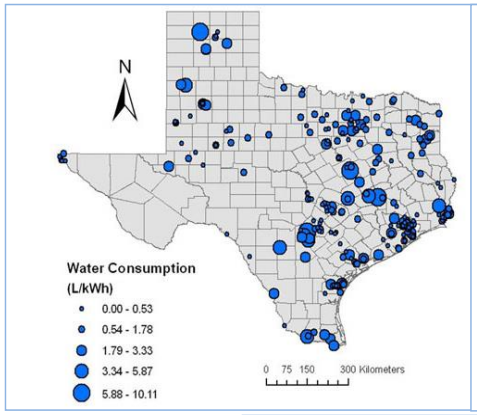


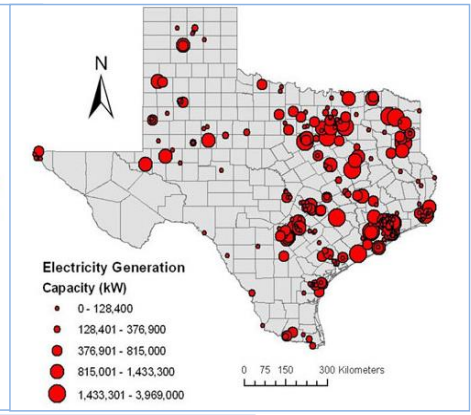
Shift generation from regions of extreme and exceptional drought

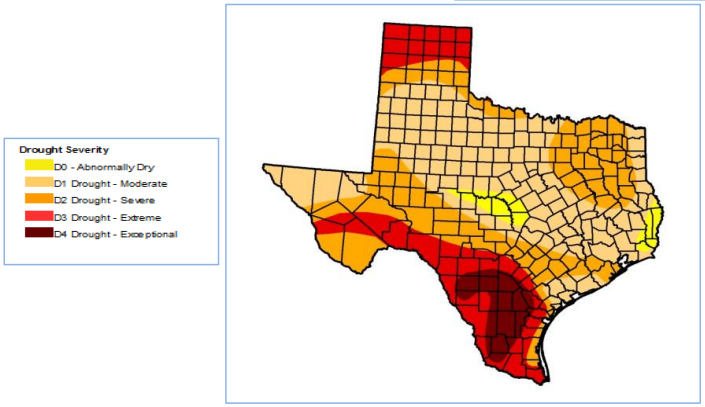
General Background Conceptual Model Change **Case Studies**

Virtual water pipelines

- Could it be done – yes, with little net change in overall water consumption, even at times of high electricity demand
- At what cost – costs similar to dry cooling technologies





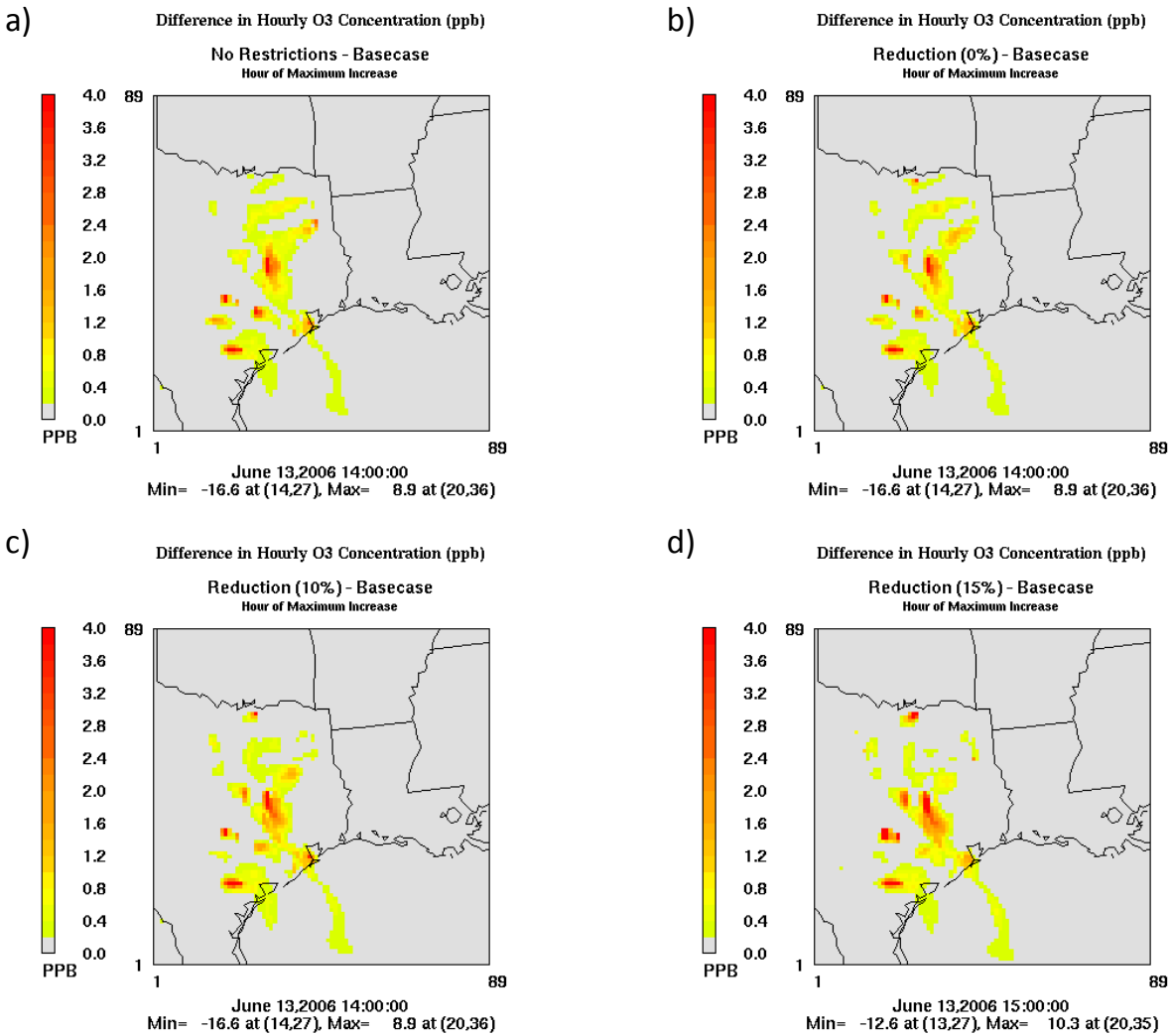


What are the non-monetized costs?

Consider air quality

Virtual water pipelines

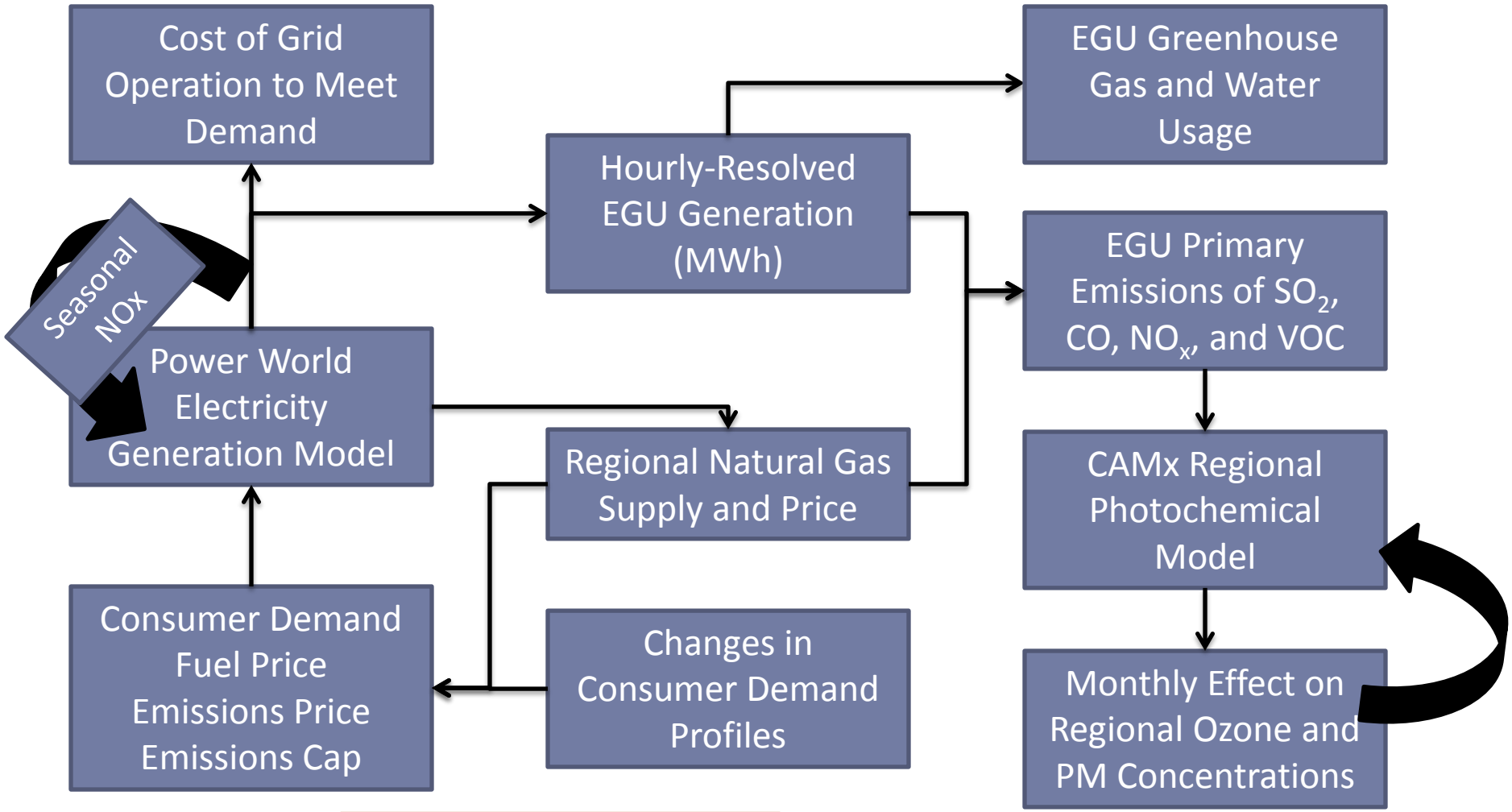
- At what cost – increases in SOx, CO_2 and NOx emissions – and in ozone concentrations



Case Study Outline

1. Air Quality Impacts of Increased Natural Gas Production and Use in Texas
2. Response to drought

Integrated Model: Many case studies



Generic observations

- Infrastructures, by their nature, influence and are influenced by most large scale societal decisions*; challenge is to identify the critical interactions; many of the interactions will be place dependent
- Resilience and adaptability in the grid is in (large?) part due to the diversity of power sources and a built capacity that is much greater than average daily needs (due to lack of storage)

*electricity generation choices impact water; fuel availability and transportability impacts electricity generation and materials manufacturing; transportation choices impact electricity generation

Acknowledgements

- Funding for the project was provided by the National Science Foundation under the EFRI Program (Grant Number 0835414).
- Texas Advanced Computing Center (TACC) for time on Ranger

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