Integrated Modeling of Gas-Electricity System Expansion under Decarbonization Scenarios

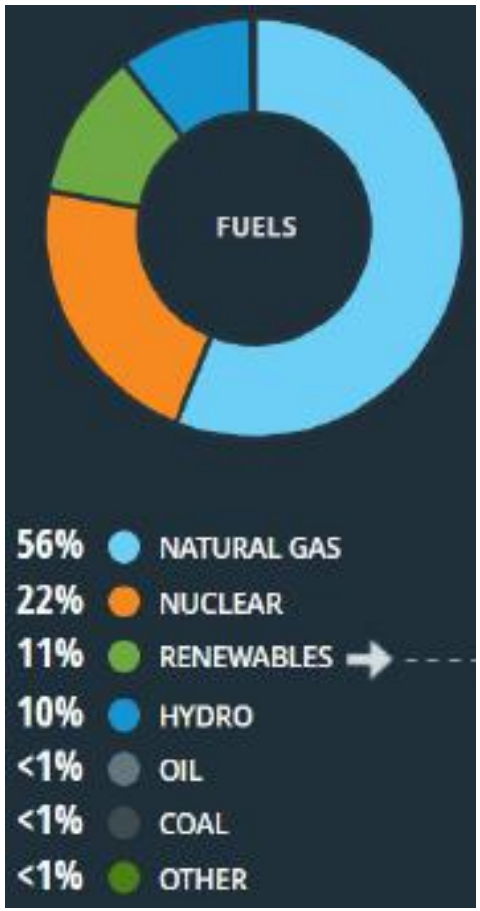
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May 2022

Electricity and Natural gas are the main energy vectors whose operations are heavily intertwined



ISO New England: Generation Mix, May 9, 5pm

- Joint planning improve efficiency and flexibility
- It can reduce the decarbonization cost, and increase system reliability/resiliency

- Shao et al., Integrated planning of electricity and natural gas transportation systems for enhancing the power grid resilience. IEEE TPS
- Odetayo et al.,A chance constrained programming approach to the integrated planning of electric power generation, natural gas network and storage, IEEE TPS
- Posada and Sanchez-Martin, Integrated power and natural gas model for energy adequacy in short-term operation. IEEE TPS

- Planning each network in exclusion of the other may be misleading and can lead to adverse impacts

WINTER STORM 2021

Texas largely relies on natural gas for power. It wasn't ready for the extreme cold.

> Texas largely relies on natural gas — especially during times of high demand — to power the state. Experts say natural gas infrastructure, from pumping it out of the ground to the plants in city centers, was unprepared for the plunging temperatures brought by the winter storm.

BY ERIN DOUGLAS FEB. 16, 2021 5 PM CENTRAL



2021 Texas Power Crisis

Overarching Research Objectives

- How does coordinated investment planning for power and gas sector impact energy infrastructure outcomes under deep decarbonization scenarios?
- What are the resiliency implications of alternative decarbonization pathways?

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- How does coordinated investment planning for power and gas sector impact energy infrastructure outcomes under deep decarbonization scenarios?
- What are the resiliency implications of alternative decarbonization pathways?
- How does substitution of natural gas with electricity for space heating impact infrastructure investments under carbon constraints?
- What is the role of energy storage, low carbon fuels, and negative emission technologies for energy system decarbonization?

Our Approach

- Construct a multi-vector network model that captures major constraints
- Parametrize model using multi-source data for New England system for existing capacity and network as well as 2050 technology, cost, and performance assumptions
- Develop tractable optimization model and accompanying solution algorithms to evaluate the model for a range of policy and technology scenarios

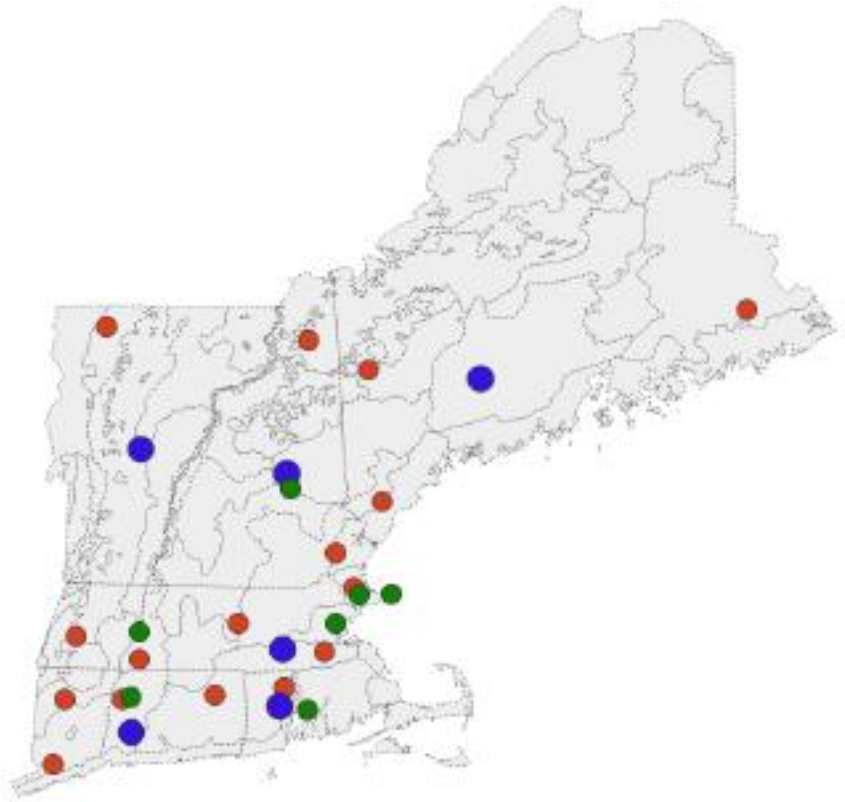
Challenges

- Heterogeneous and incomplete/noisy data sources
- Model validation and calibration by the base grid (2016)
- Input-intensive large scale optimization problem
- Both physical and policy related interdependency between systems

Current Focus

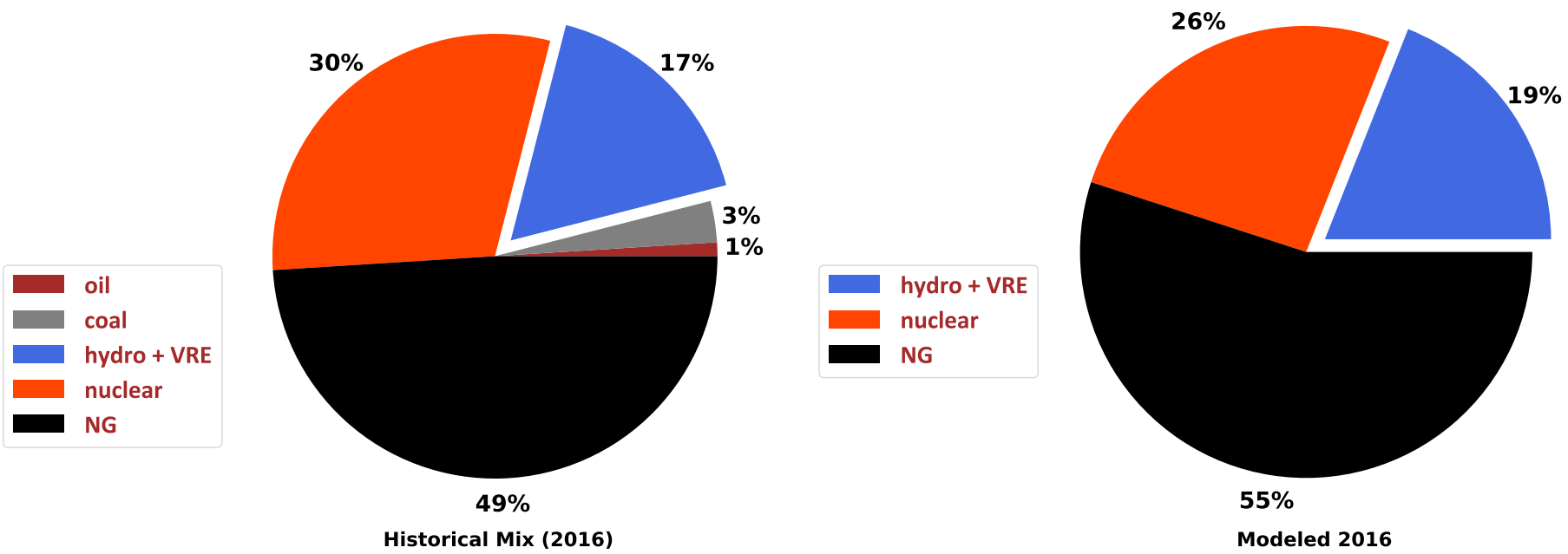
- Consider New England power-gas system in 2050
- Construct the realistic power and NG networks
- Power system operates on hourly basis and gas system on daily basis

Blue: Electricity Nodes
Red: NG Nodes
Green: NG Storage, Vaporization and Liquefaction facilities



Model Validation

- Cross validation with existing system
- Run the model for 2016 and compare it with historical mix

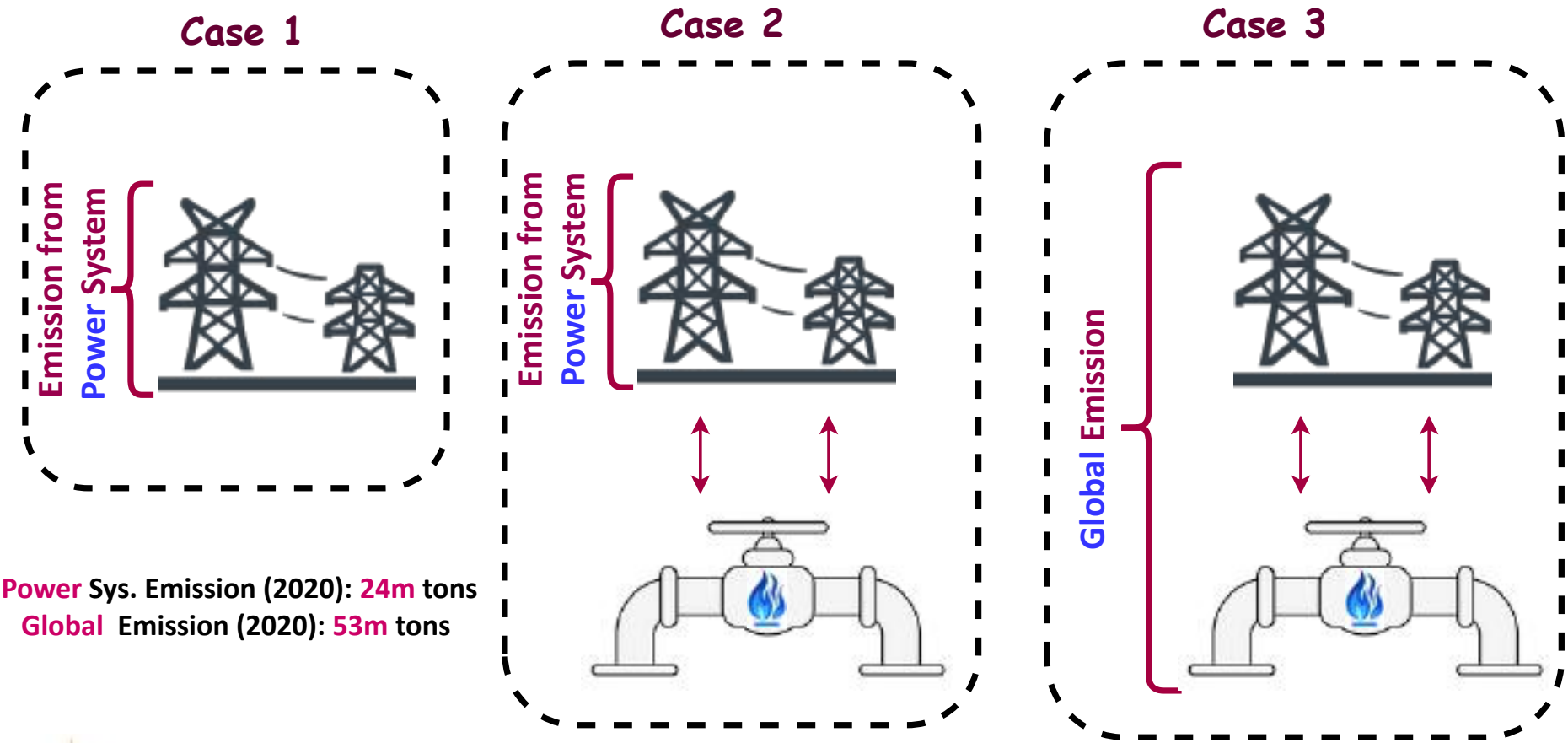


Current Focus

- Existing and new plant types
- Availability of renewable natural gas (RNG) for gas system at \$20/MMBtu
- Note: RNG as a proxy for expensive low-carbon fuel. Have yet to evaluate its availability, cost and emissions impact
- Model does not include demand-side variables (i.e. substitution of gas with electricity) but will be included in the future

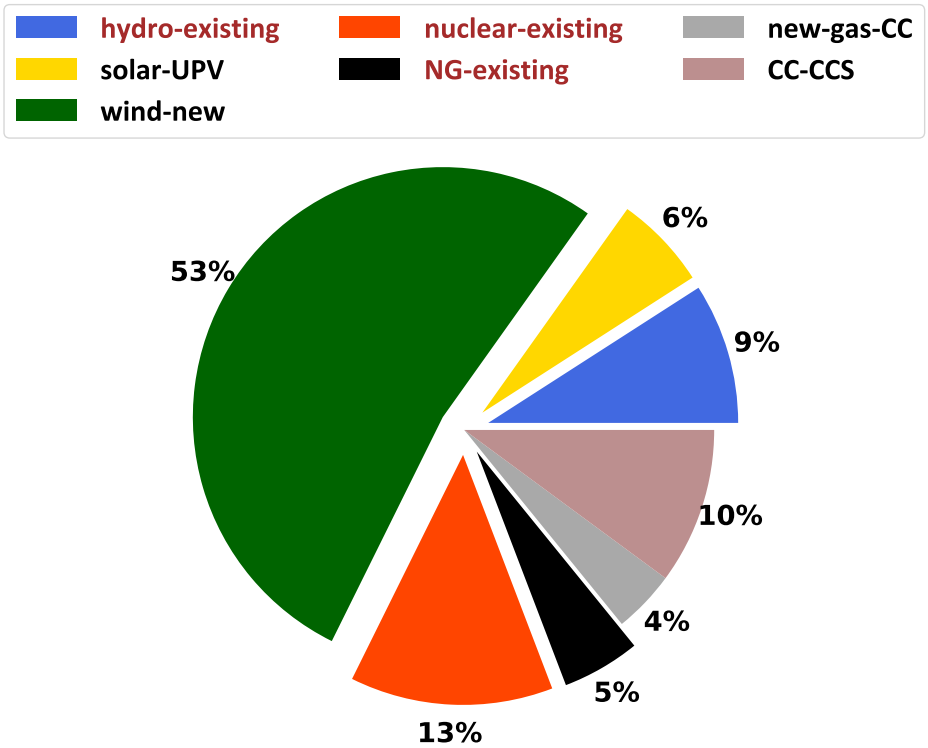
Results and Analysis

Counterfactual analysis to assess impact of different modeling boundary and emissions policy scope for 2050 system

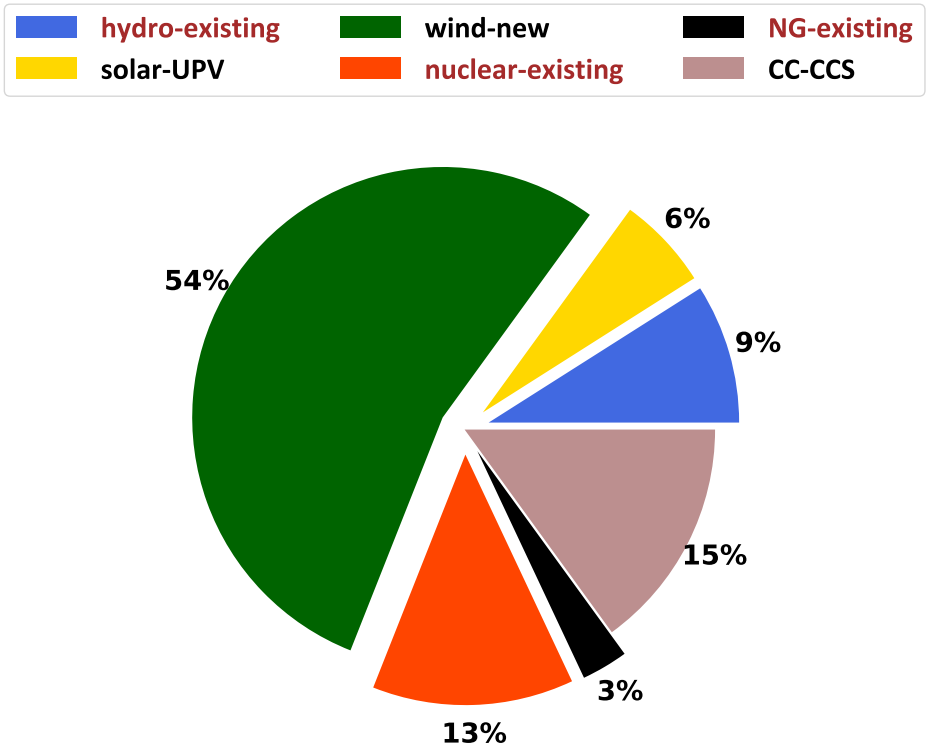


Power Sys. Emission (2020): 24m tons
Global Emission (2020): 53m tons

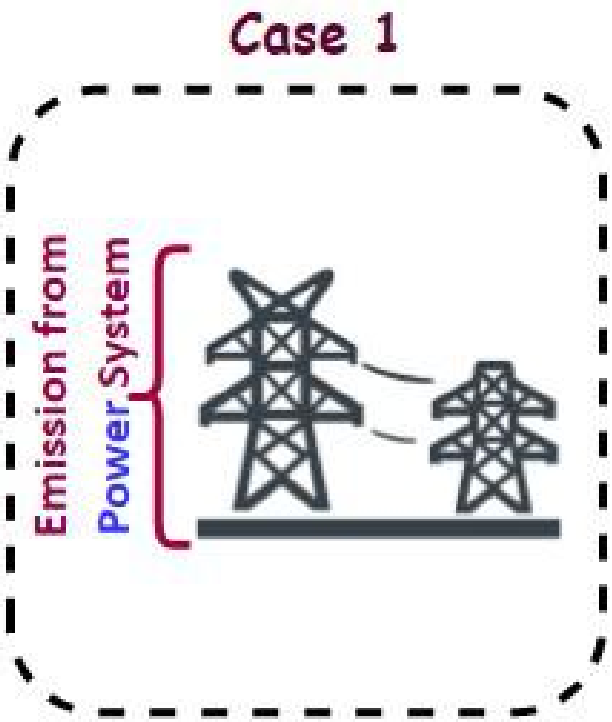
Case 1: impact of emissions limits on power system outcomes

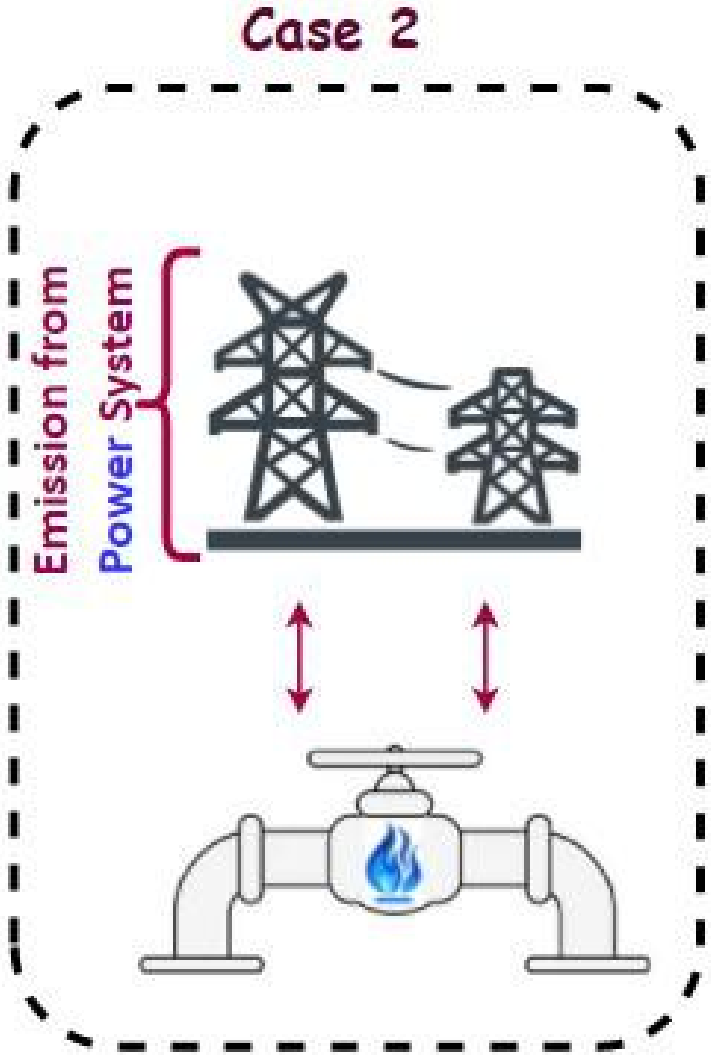


Generation Mix for Case 1, Emis. Reduc.= 60%

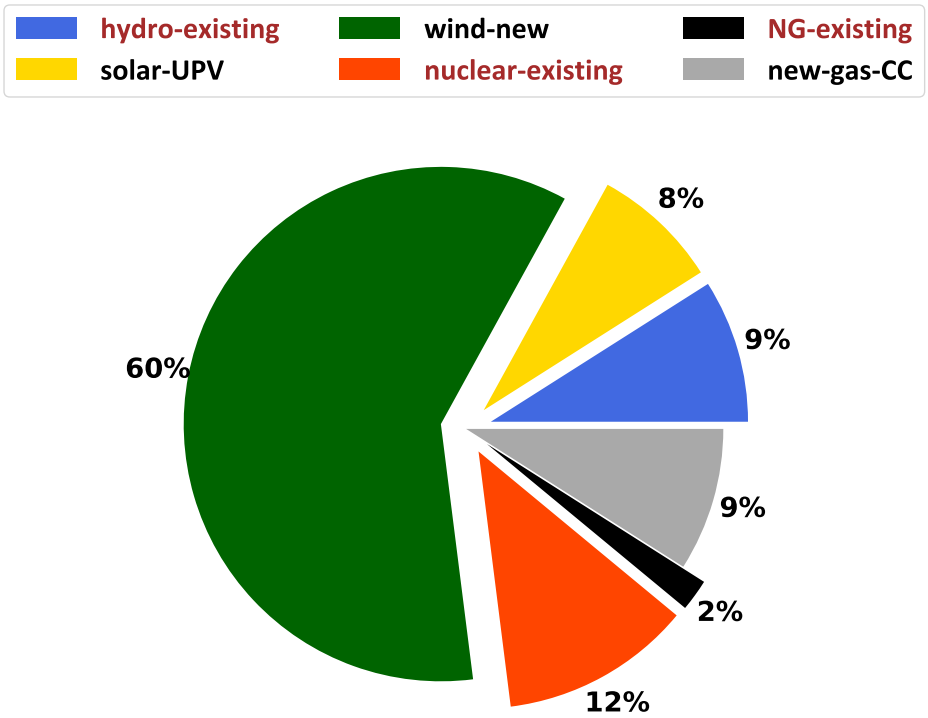


Generation Mix for Case 1, Emis. Reduc.= 80%

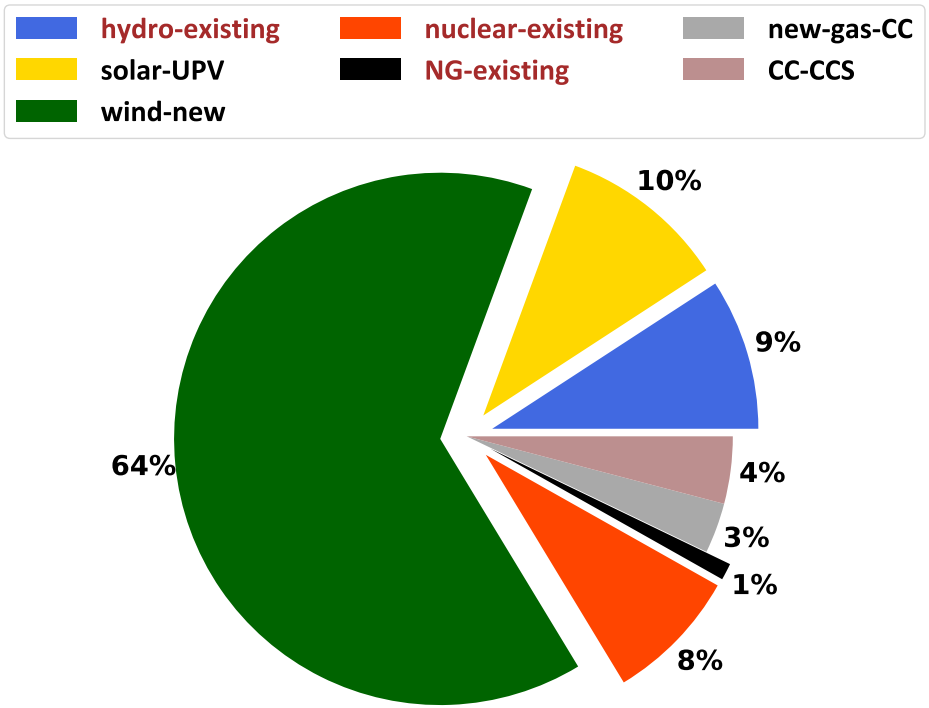

Case 1
Emission from
Power System


Case 2
Emission from
Power System

Case 2: power-gas system with emission limit on power sys.

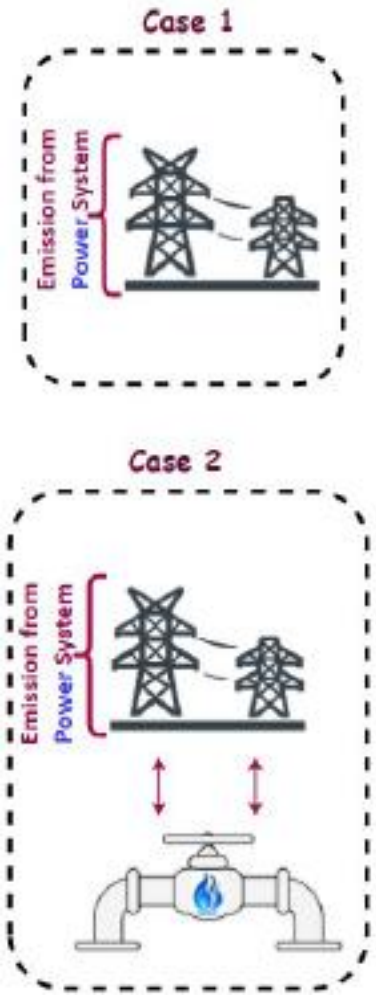


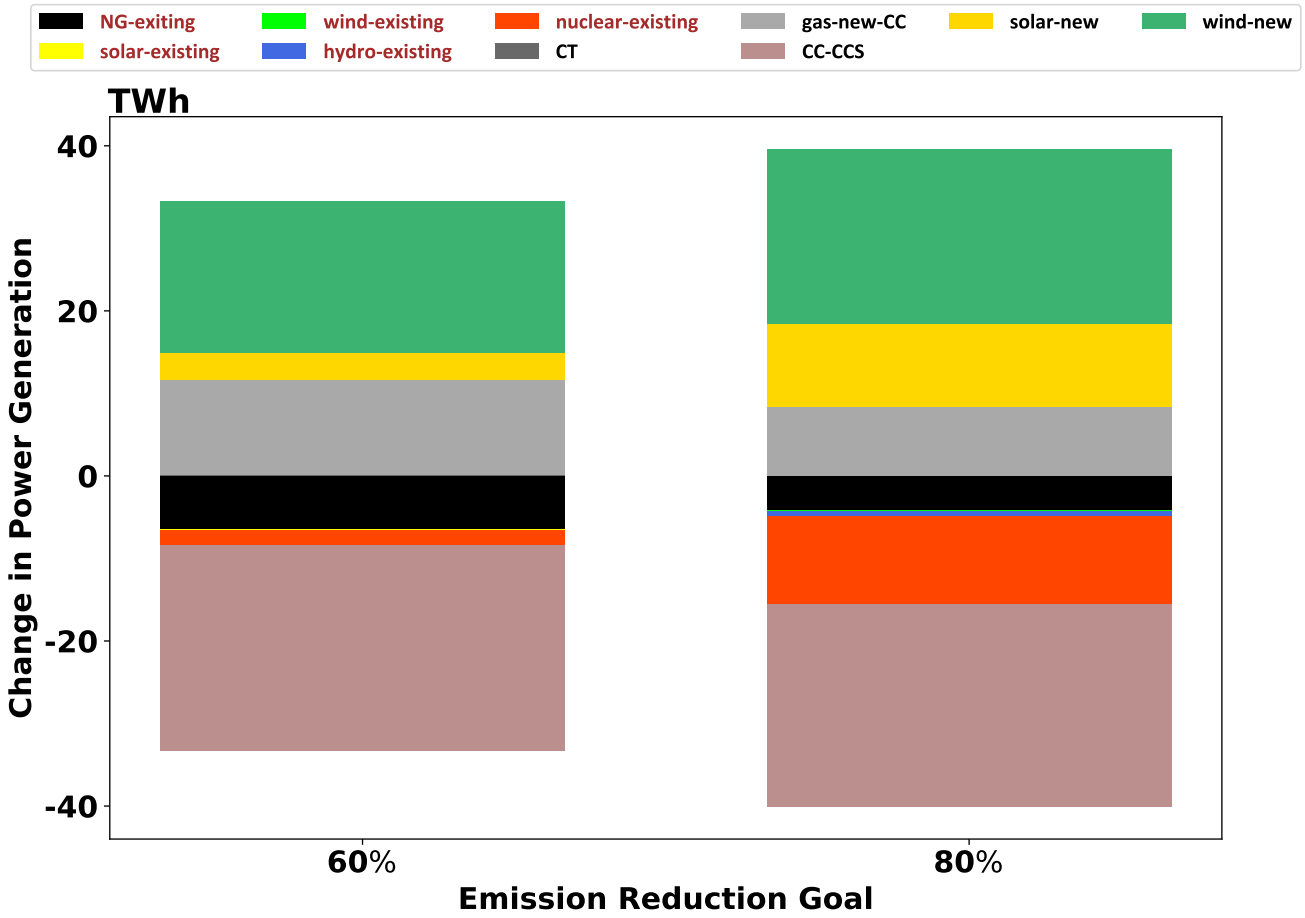
Generation Mix for Case 2, Emis. Reduc.= 60%



Generation Mix for Case 2, Emis. Reduc.= 80%

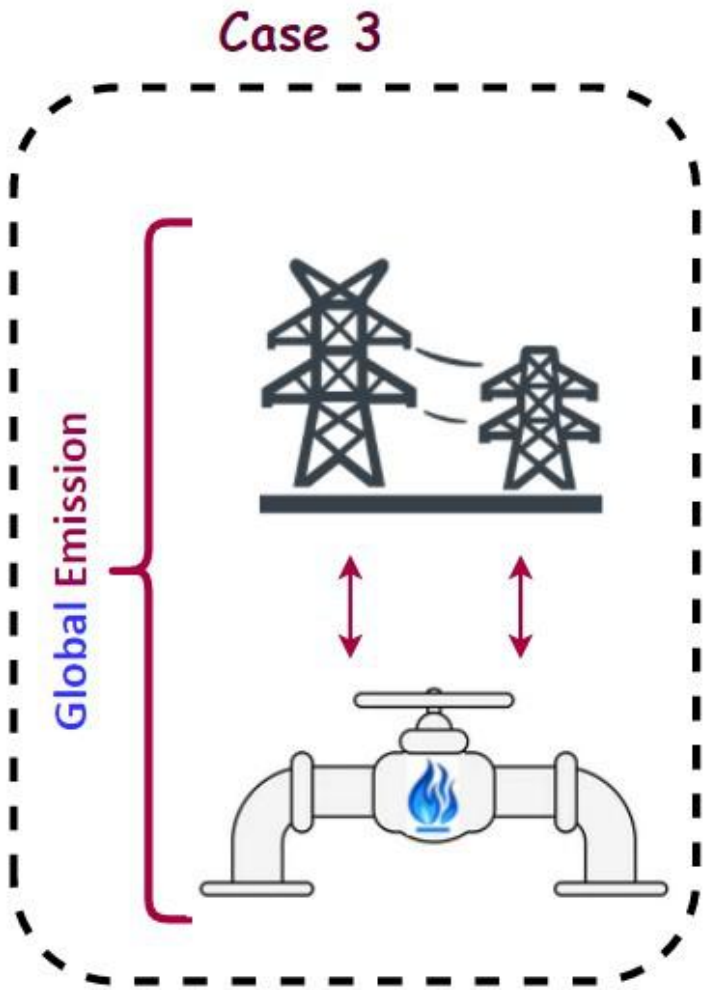
Case 1 vs. Case 2



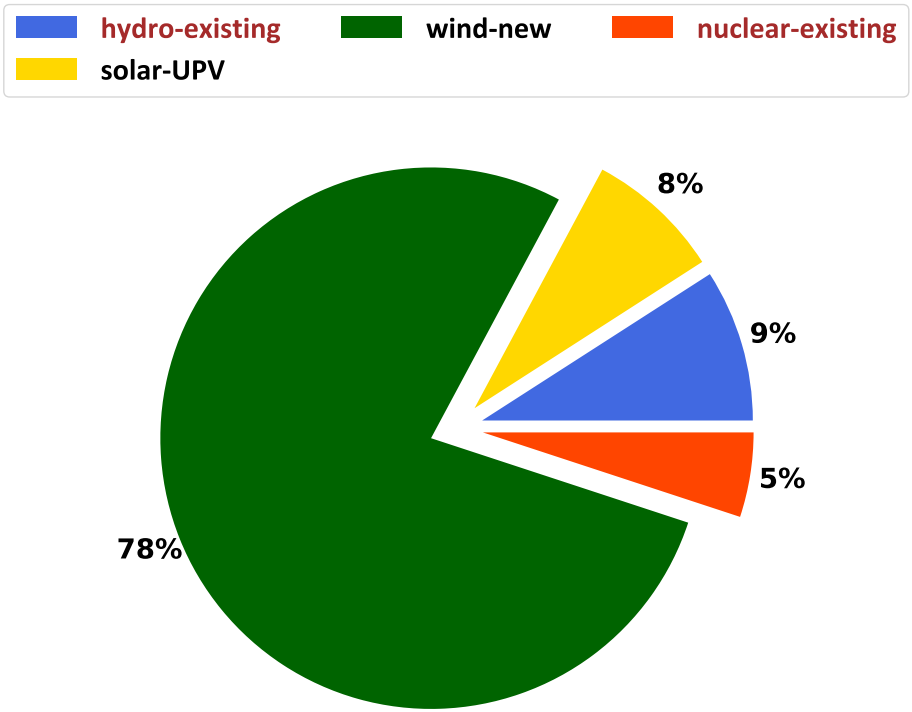


Change in power generation mix per different emission reduction goals from electricity system

Gloabal Emission= power + non-generational gas utilization (building and industry)

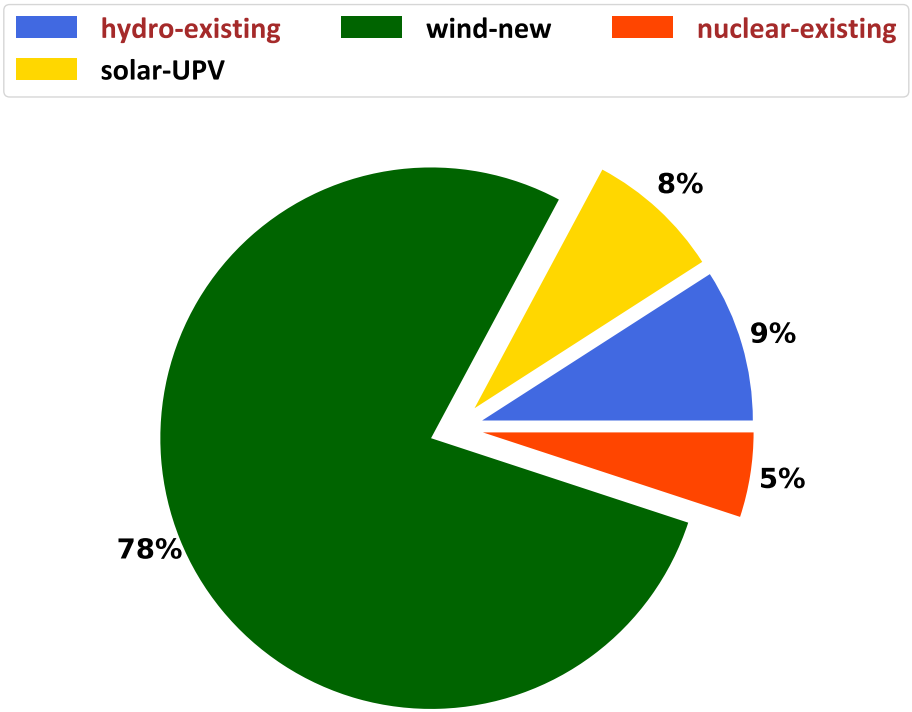


Case 3



Generation Mix for Case 3, Emis. Reduc.= 80% and RNG=30%

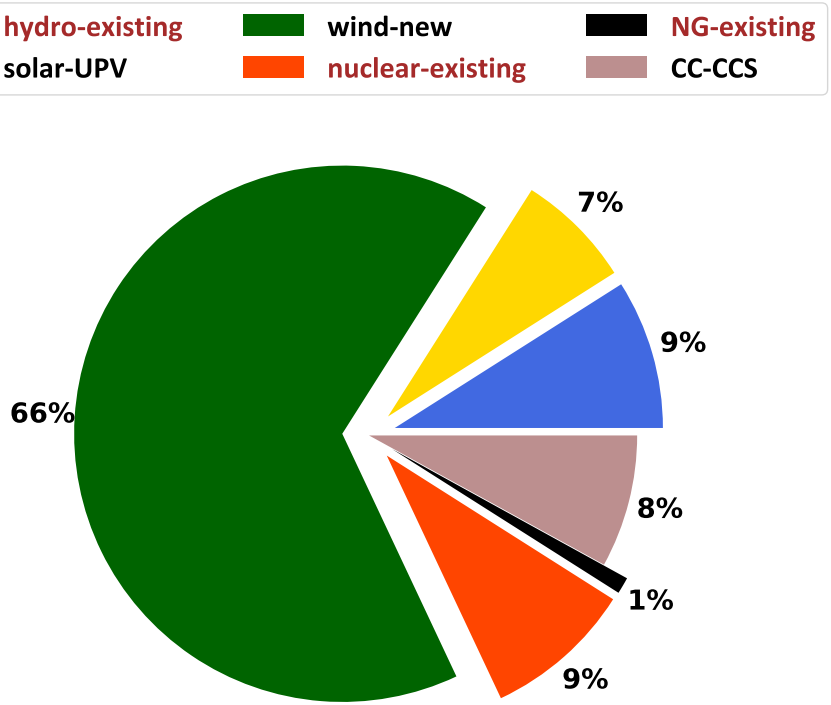
Case 3



Generation Mix for Case 3, Emis. Reduc.= 80% and RNG=30%

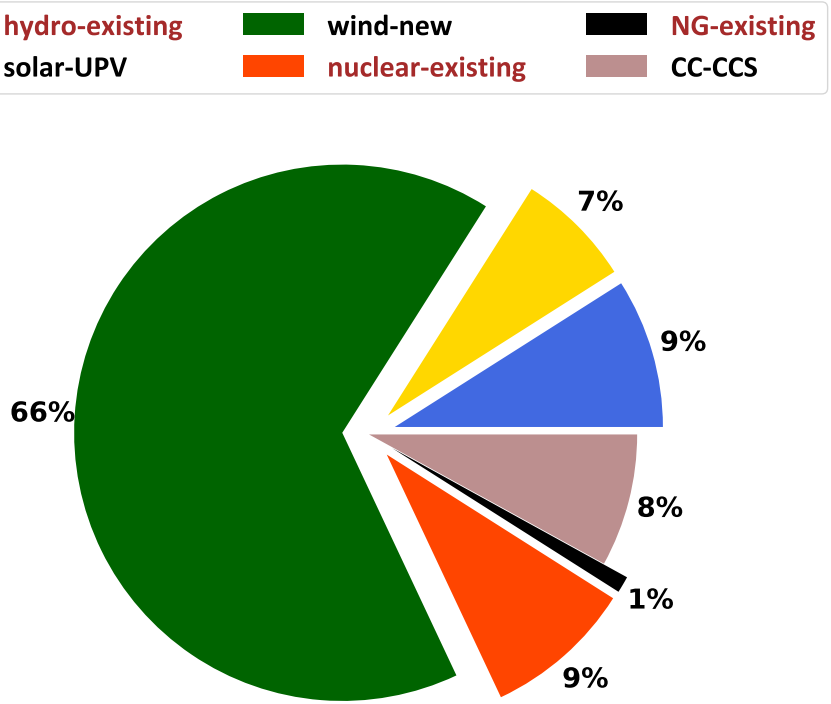
- RNG availability capped at 30% of NG load and is fully utilized
- NG load shedding in this scenario
- NG use in power sector when RNG availability is increased

Case 3



Generation Mix for Case 3, Emis. Reduc.= 80% and RNG=50%

Case 3



Generation Mix for Case 3, Emis. Reduc.= 80% and RNG=50%

- No NG load shedding in this scenario
- CCS plants and lower share of wind share

Next Steps

- Refine the current model (renewable plants characterization, imported hydro power, improve characteristics of thermal plants)
- Evaluate the impact of gas demand substitution for space heating via electrification and hydrogen use
- Incorporate uncertainty, define resiliency measures and develop a robust planning strategy
- Extend the region to US Northeast

Thank You!