2020 JISEA Virtual Meeting Presenter Profile

- Dr. Bri-Mathias is Chief Scientist in the Power Systems Engineering Center at the National Renewable Energy Laboratory (NREL). He is also an Associate Professor in the Department of Electrical, Computer and Energy Engineering and a Fellow of the Renewable and Sustainable Energy Institute (RASEI) at the University of Colorado Boulder His research focuses on the modeling and simulation of power and energy systems, with an emphasis on the operational and planning challenges posed by the integration of renewable energy sources, such as wind and solar power.

JISEA Joint Institute for Strategic Energy Analysis

Power and Natural Gas Systems Interface Study

Bri-Mathias Hodge

2020 Virtual JISEA Meeting on Power Systems and Industry & Agriculture

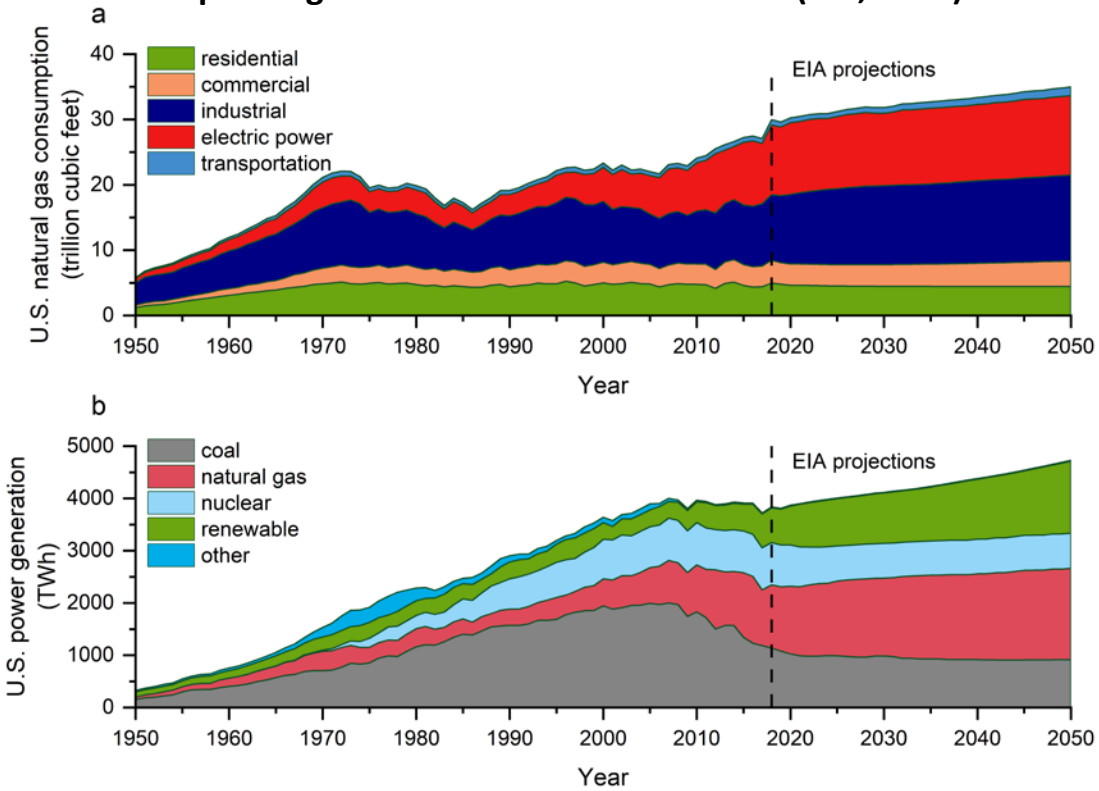
Thursday 9 April 2020

Outline

- Motivation
- Overview of existing and proposed approaches
- Description of the proposed coordination framework
- Case study: Colorado's electricity and natural gas system
- Results & Conclusions

The Importance of Coordinated Electricity and Natural Gas Systems

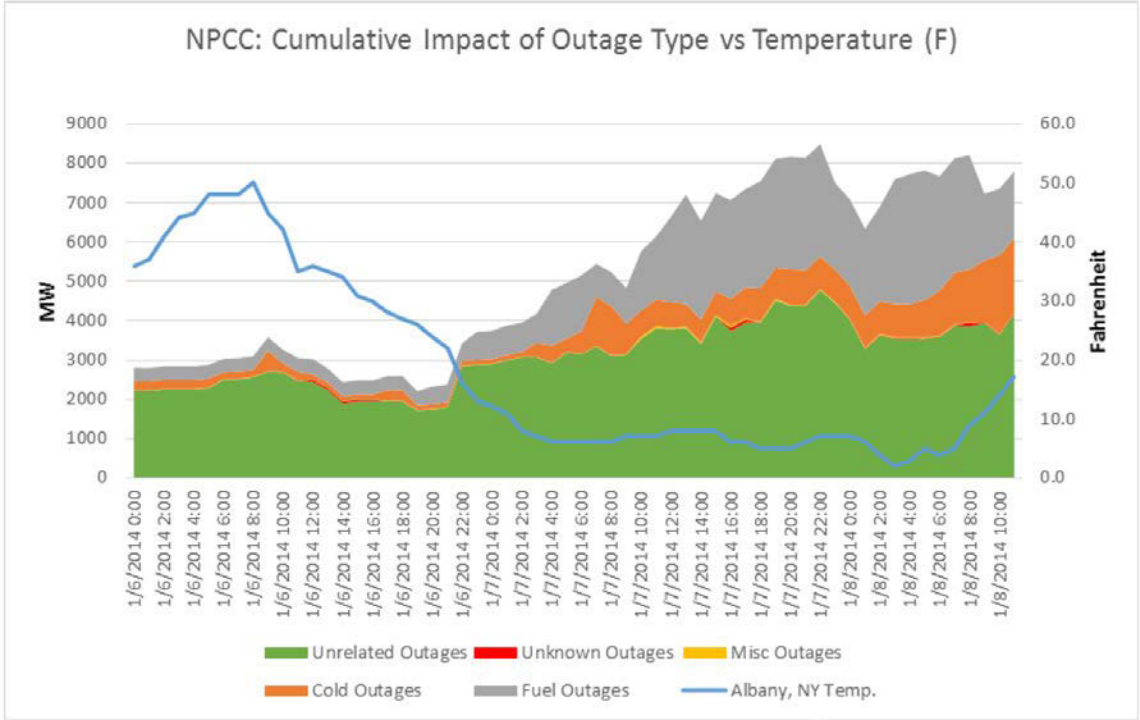
Historical and projected data for natural gas consumption and power generation in the United States (EIA, 2019)



- The power sector accounted for 35.5% of total natural gas demand in 2018, up from just 22.3% in 2000.
- The share of generation from natural gas increased from 14.2% to 31.5% over the same period.
- The share from renewable energy—driven by increases in wind and solar—has increased from 8.8% to 17.4%, with these trends expected to persist into the future.

Rising interdependence may result in reliability issues

Northeast Power Coordinating Council



2014 "Polar Vortex" resulted in large gas outages due to fuel starvation

Source: North American Electric Reliability Corporation, "Polar Vortex Review," NERC, Atlanta, 2014.

Overview of approaches for coordination between electricity and natural gas systems

Decision making level

- **Planning**: Optimize the location, capacity, and timing of investment decisions associated with generation or production, transmission, and storage assets in an integrated system.
- **Operation**: Improve reliability and minimize the operational costs associated with natural gas and electricity supply, natural gas supply contracts, and load shedding or unserved natural gas.

Coordination strategy

- **Central-planning**: The operation of the two systems is optimized simultaneously.
- **Market-based**: The two systems are optimized or simulated separately, with coordination occurring via the exchange of information such as prices, gas demand from generators, gas availability from the gas network, etc.

Policy and regulation

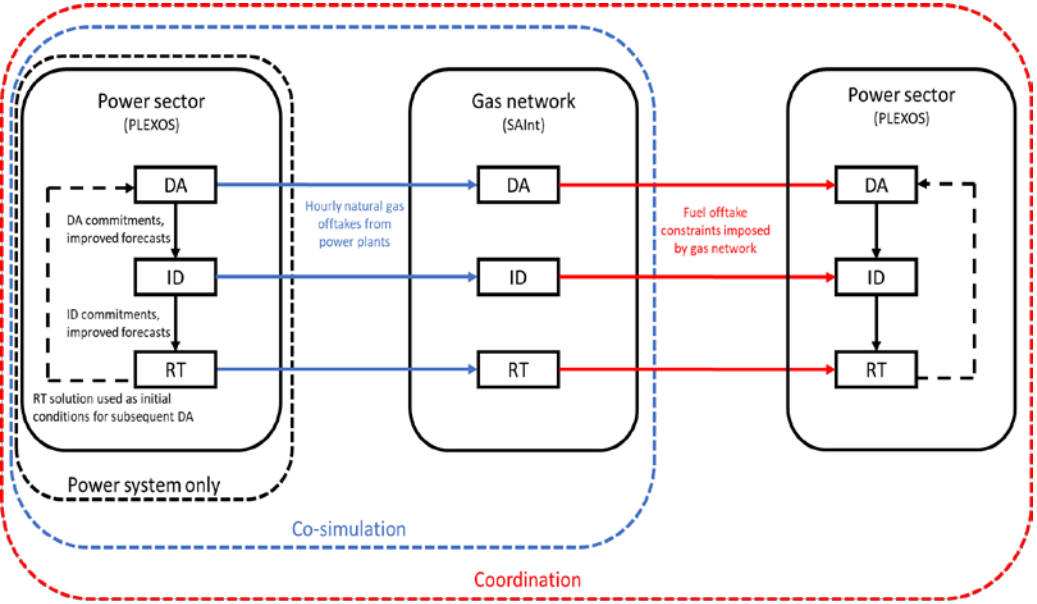
- **FERC Order 809**: Among other changes, includes a third intra-day market for scheduling natural gas deliveries.
- **Shaped flow**: Time-variant gas nominations at the day-ahead and intra-day market.

Our approach:

- **Operation focus**
- **Market-based coordination**
- **Includes FERC Order 809**
- **Includes the analysis of shaped flows**

Proposed approach for Coordinated Electricity and Natural Gas Systems

Electricity and natural gas systems coordination framework (implemented in Python)

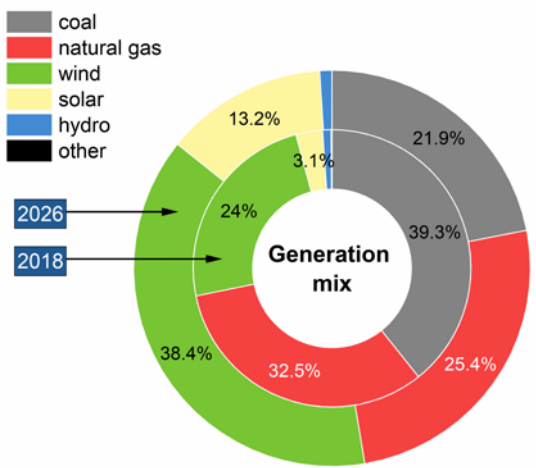


DA: day-ahead market, ID: intra-day market, and RT: real-time market

- **Power system only**: results from the first iteration of the power system model, before any communication with the gas network.
- **Co-simulation**: results after simulating gas offtakes from the power system model in the gas network; reflects curtailed gas but has not yet reoptimized the power system in response to gas constraints.
- **Coordination**: results after re-optimizing the power system with constraints from the gas simulation.

Case study: Colorado's electricity and natural gas systems

Colorado's annual generation (left) and capacity mix (right) (PLEXOS was used to optimize power system operations in the DA, ID, and RT markets)

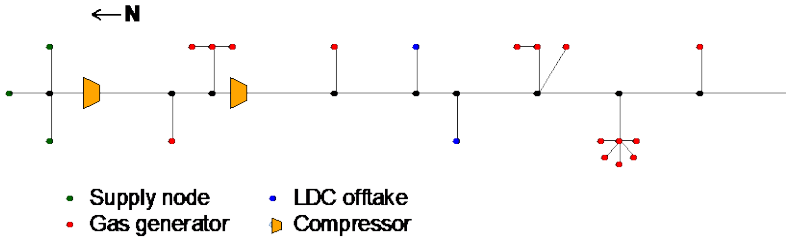


Technology	2018 (GW)	2026 (GW)
Coal	3.88	2.42
Gas	7.58	
Wind	6.02	9.81
Solar	2.25	9.88
Hydropower	0.73	
Other	1.5	

The 2018 fleet is based on current Colorado fleet, benchmarked to actual generation levels; the 2026 fleet is based on plans developed by Western Resource Advocates to meet Xcel targets: https://westernresourceadvocates.org/blog/colorado-energy-plan-explained/

Representation of the gas network. Based on data of the Front Range gas network in Colorado.

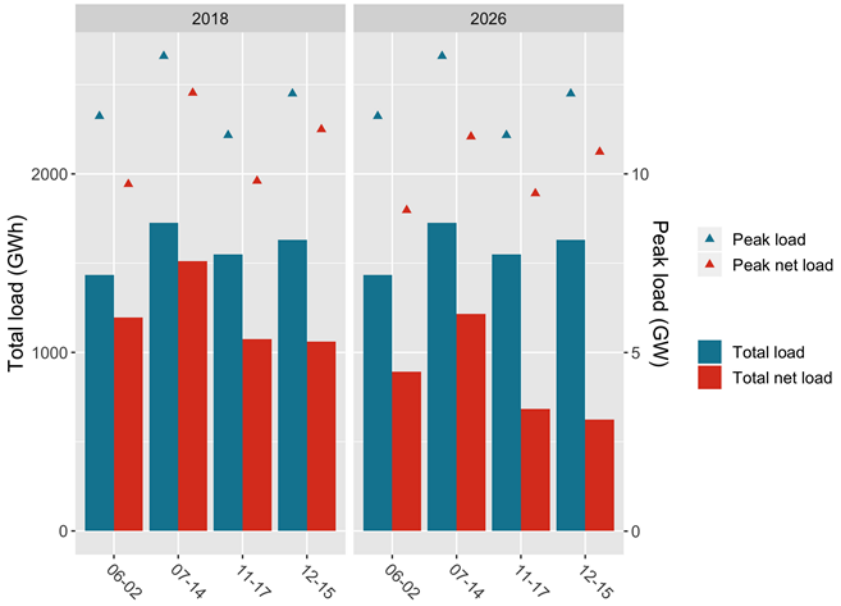
(SAInt was used to perform a transient hydraulic simulation of the operation of the natural gas system)



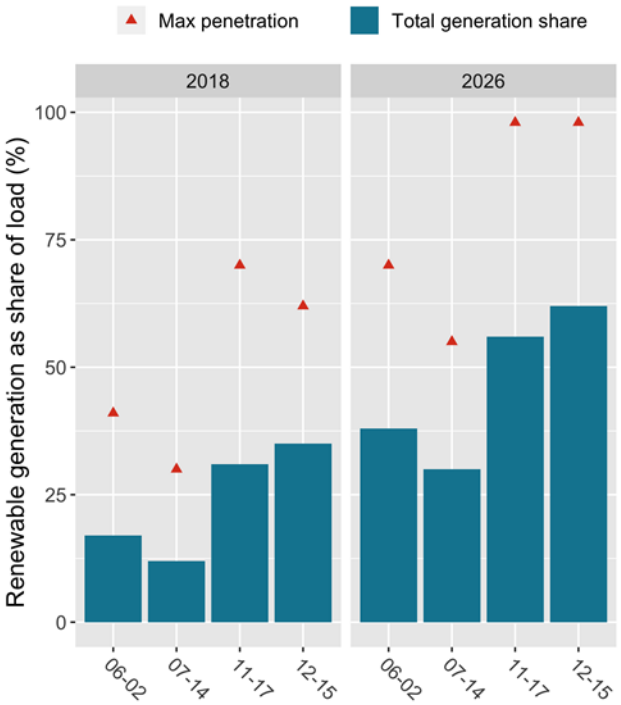
The offtake nodes include gas generators representing about 70% of the natural gas generator offtakes in the power system model, as well as information on demand profile for local distribution companies (LDCs).

Power system characteristics

Total load, peak load, and peak net load for selected weeks



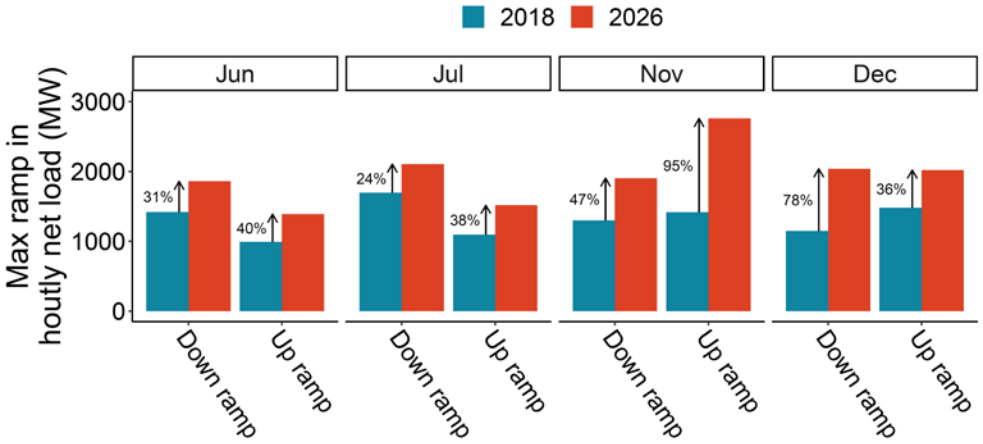
Share of renewable energy



Selected weeks for each season: Highest natural gas demand from the power sector, these weeks are likely to be the times when coordination between the two systems is critical (June 2-8 (spring), July 14-20 (summer), November 17-23 (fall), and December 12-18 (winter)).

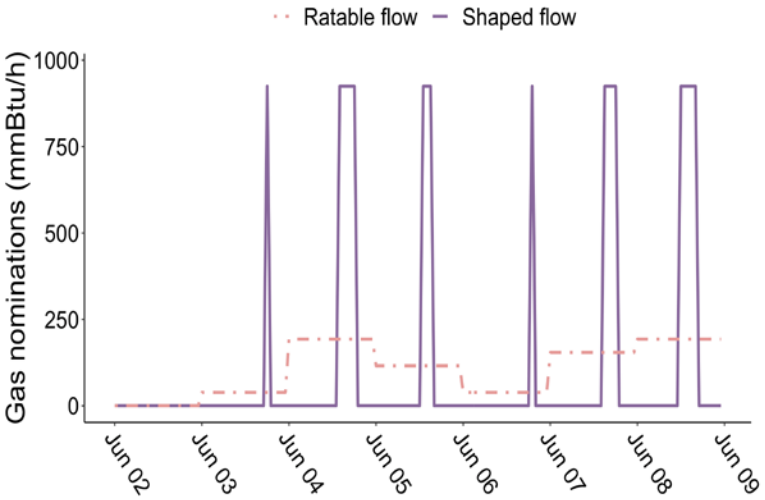
Ramping requirements and gas nominations

Largest up and down ramps in net load (MW) in 2018 and 2026;



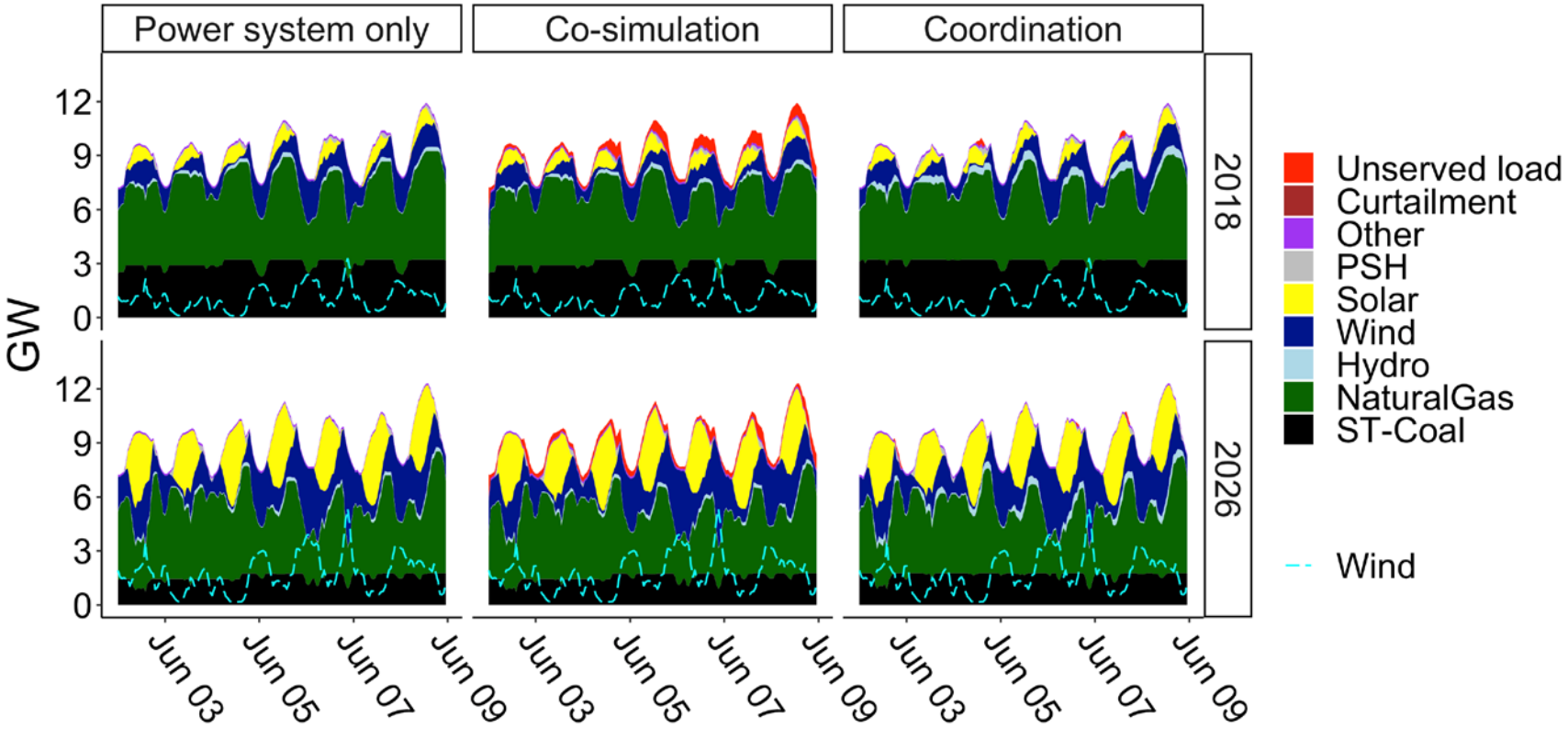
- Selected weeks for each season: Highest natural gas demand from the power sector, these weeks are likely to be the times when coordination between the two systems is critical (June 2-8 (spring), July 14-20 (summer), November 17-23 (fall), and December 12-18 (winter).
- Higher penetration of renewables in 2026 results in greater ramping requirements.
- Higher ramping requirements could be better accommodated when the operation of the two systems is coordinated.

Retable flow (current practice) and Shaped flow (proposed practice)

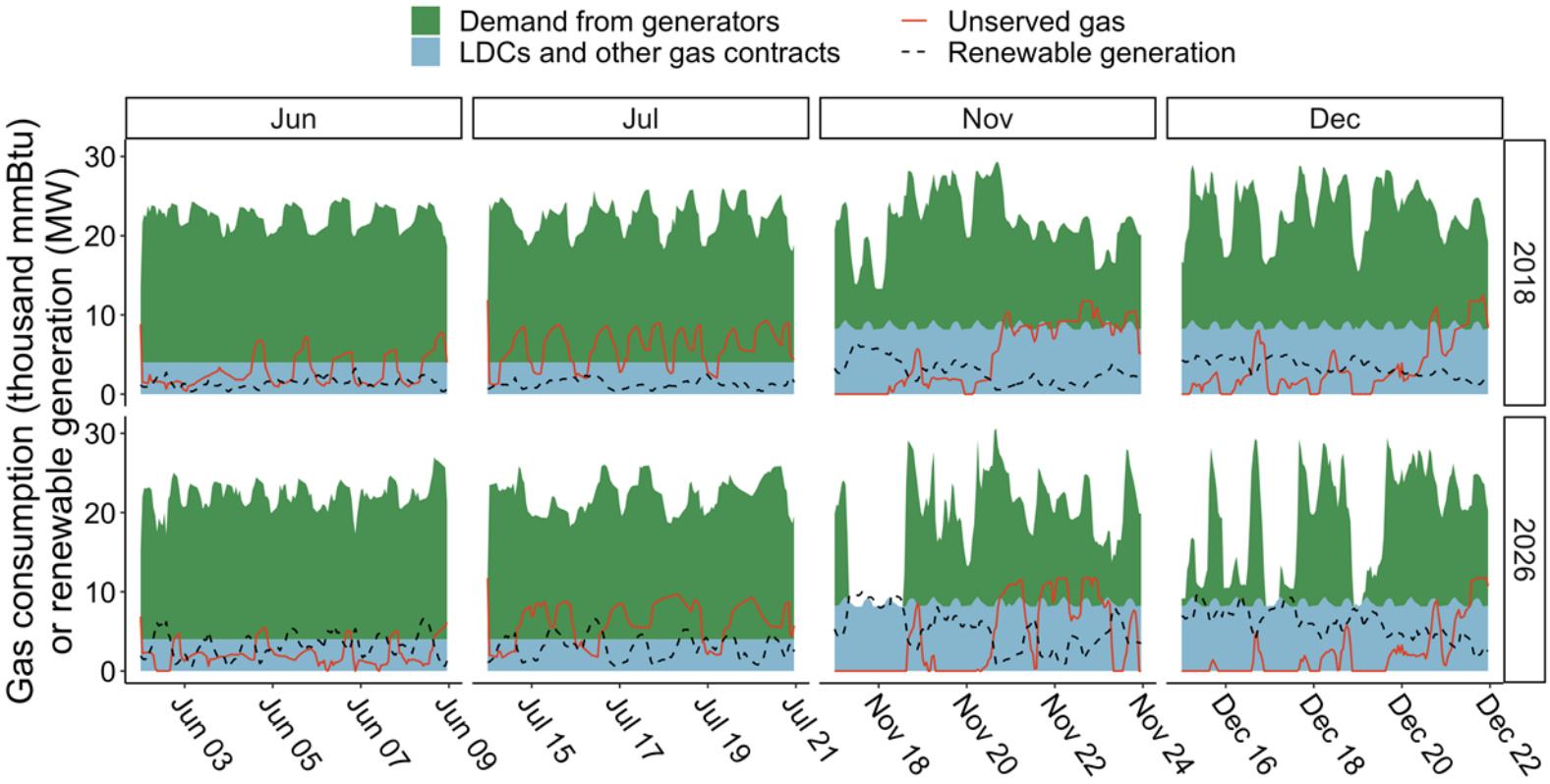


Hourly natural gas nominations from a single combustion turbine during the June week when using ratable gas nominations—in which nominations are the average of hourly gas offtakes over 24 hours—and shaped flow nominations—in which nominations are allowed to vary by hour.

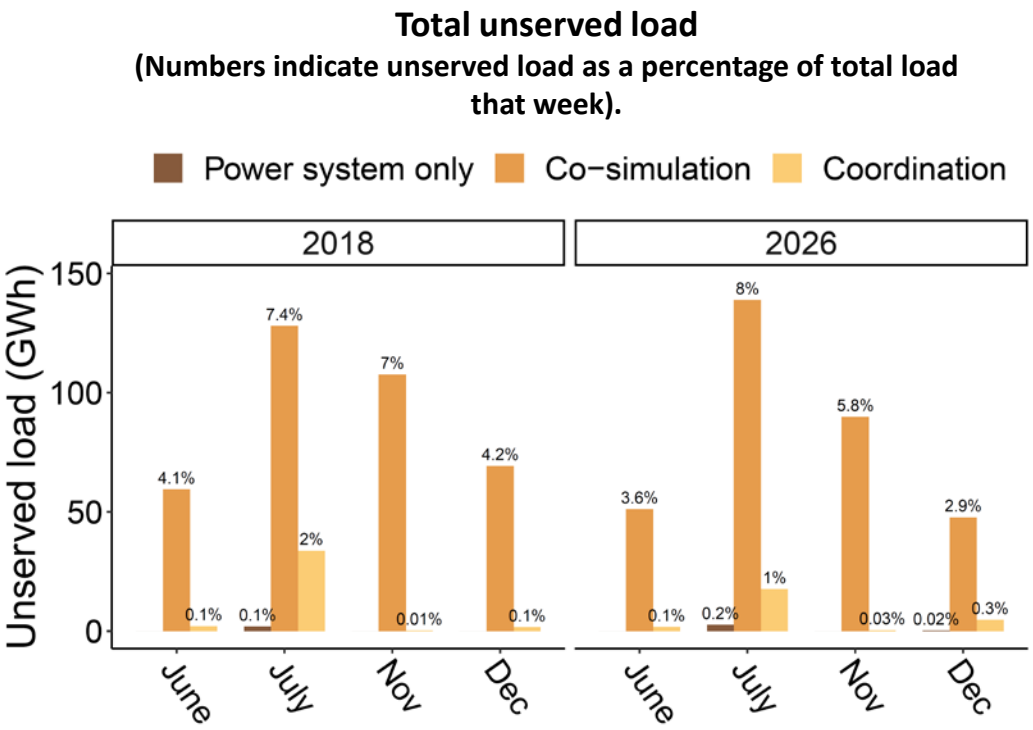
Real-time dispatch (June scenario)



Gas offtakes from the gas network (RT, co-simulation level)

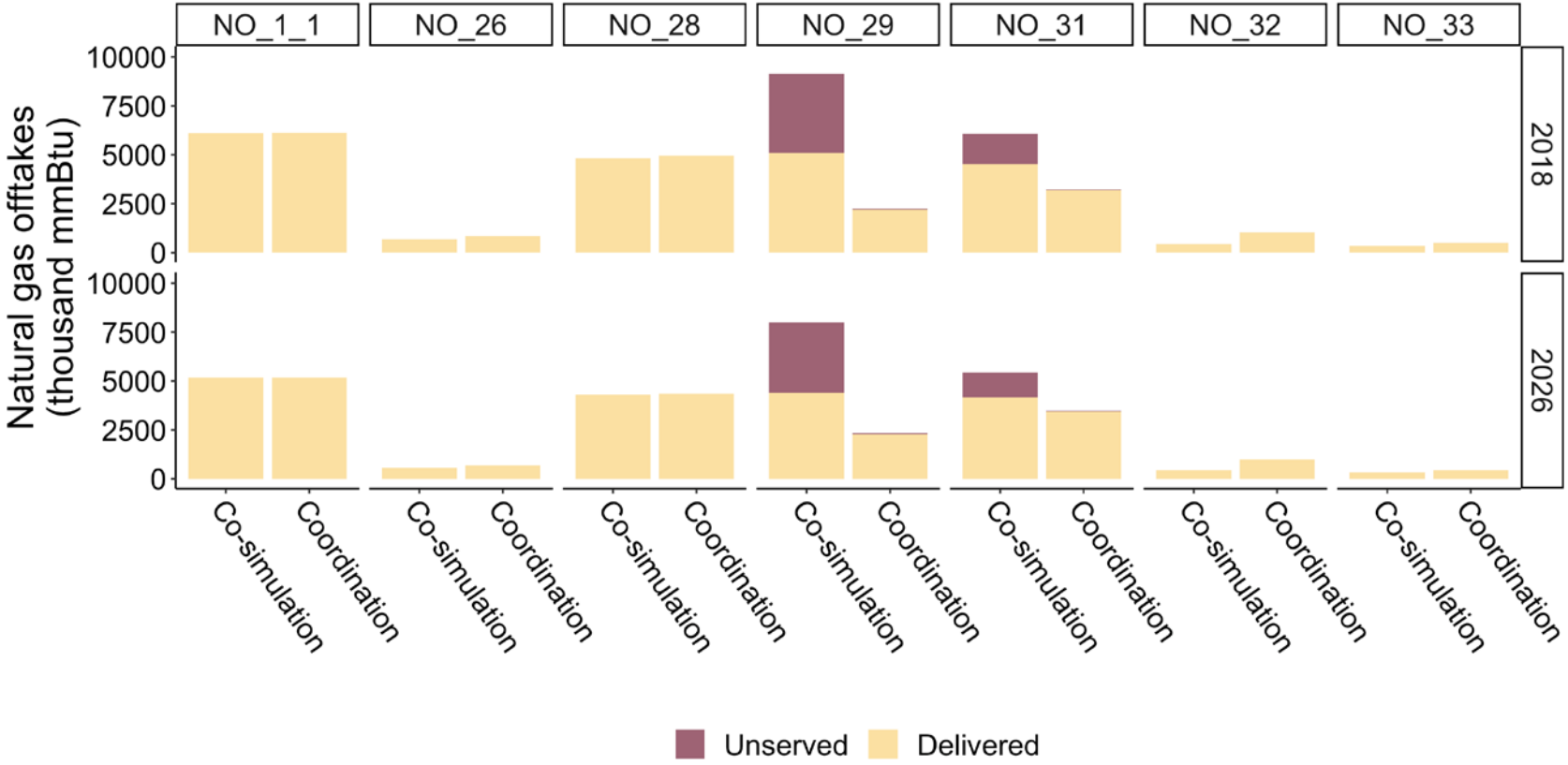


Impacts of coordination on unserved load



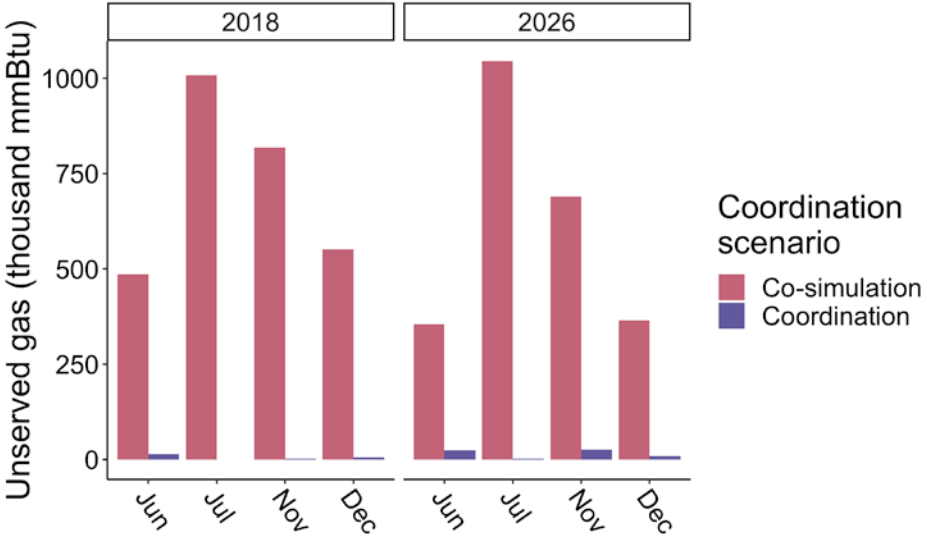
- No unserved load in the initial power system optimization (power system only); however, when gas curtailments are imposed from constraints in the gas network (co-simulation), large amounts of unserved load occur.
- If the power system is re-optimized based on input from the gas network (coordination), the amount of gas curtailment and unserved load is substantially reduced.

Total real-time gas offtakes by node

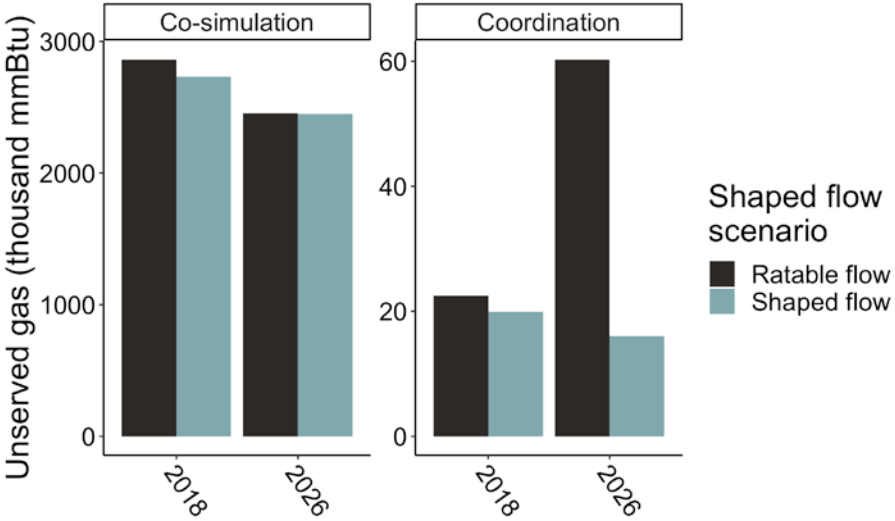


Impacts of coordination and gas nominations on unserved gas

Total unserved natural gas by week for the co-simulation and coordination scenarios (based on retable flows)



Total unserved natural gas using constant flows at the DA and ID market levels (ratable) and using hourly gas offtakes from generators (shaped flow)



- Redispatch of the power sector based on constraints from the gas model (i.e. coordination) serves to reduce unserved gas by upwards of 97% relative to co-simulation.

- Shape flow gas nominations reduce curtailed gas offtakes when compared with ratable gas nominations

Conclusions

- For the Colorado system, coordination greatly reduces the amount of curtailed gas generation without substantial cost increases, particularly in high electricity demand time periods (e.g. summer).
- The introduction of coordinated intra-day markets (as proposed by FERC Order 809) reduces unserved natural gas by almost 97% relative to uncoordinated operations for the Colorado system.
- The unavailability of gas for power generation can be caused by different factors; in periods of high electricity demand it may be driven by total delivery constraints, whereas in periods with high ramping requirements, it may be a function of constraints at the natural gas compressors.
- Moving from constant (i.e. ratable) flow to nominations that can vary by hour (i.e. shaped flow) in the day-ahead market can reduce curtailed gas offtakes, particularly for systems with larger penetrations of renewable generation.

Thank you

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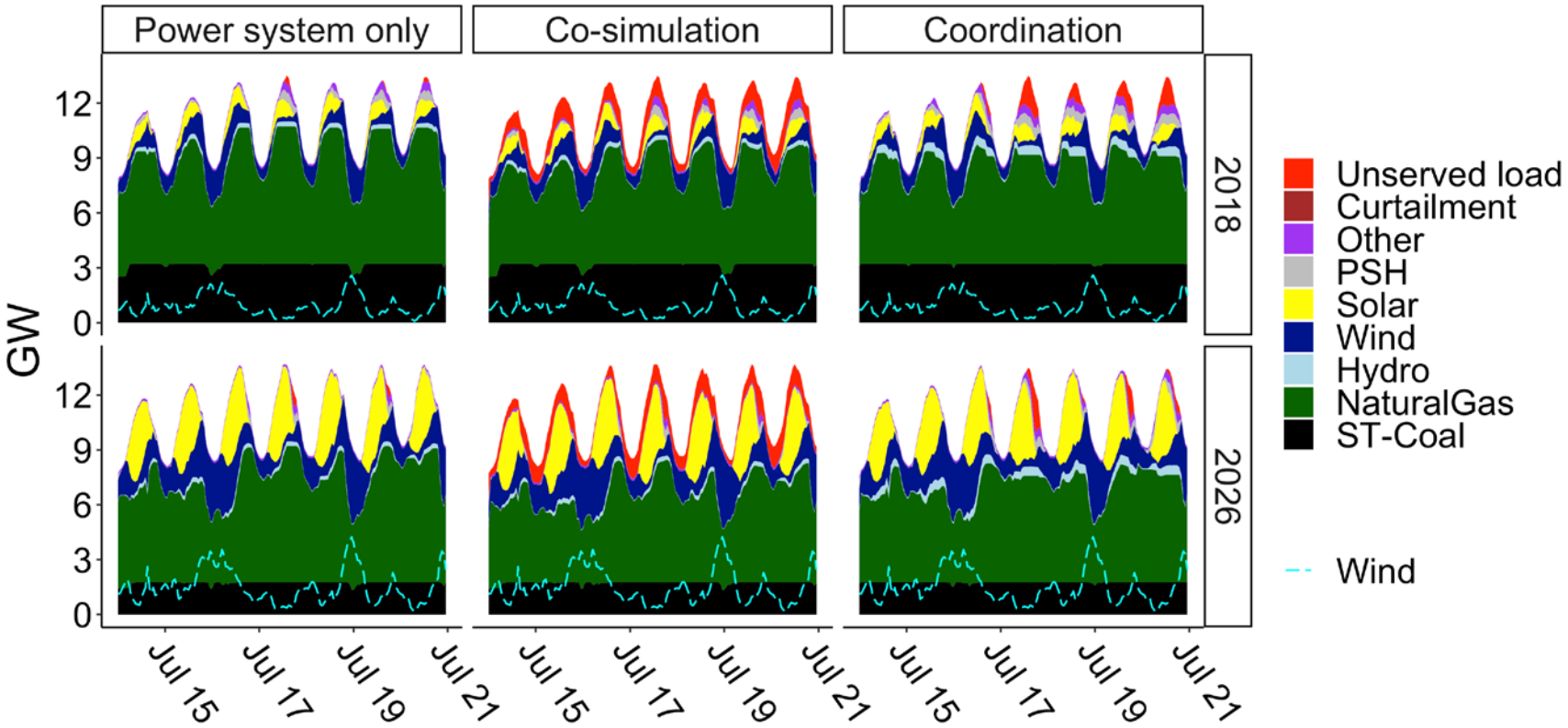
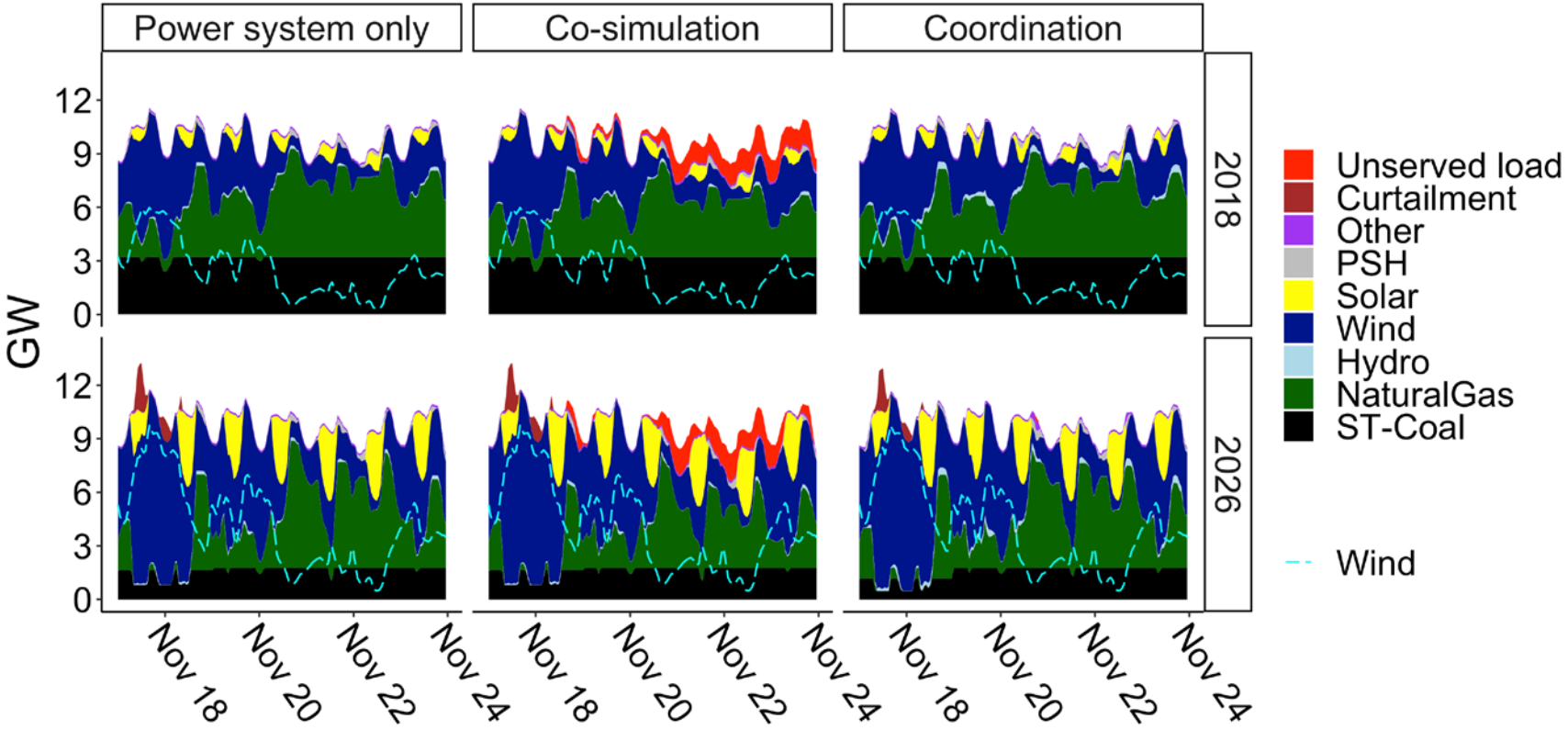
Real-time dispatch (July scenario)



Real-time dispatch (November scenario)



Real-time dispatch (December scenario)