Characterizing multi-pollutant emission impacts from US coal power plants: A Cost-Benefit approach

Xinran Wu[1], Tracey Holloway[1], Paul Meier[1,2], Morgan Edwards[1,3]

[1] Nelson Institute Center for Sustainability and the Global Environment (SAGE), UW-Madison
[2] Wisconsin Energy Institute, UW-Madison
[3] La Follette School of Public Affairs, UW-Madison

Center for Sustainability and the Global Environment
NELSON INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN–MADISON

THE HOLLOWAY GROUP @ SAGE

❖ Introduction and Motivation

Coal-fired electricity generation units (EGUs) emit a mix of health- and climate-relevant air emissions. While most climate mitigation efforts bring co-benefits of air quality improvements, we investigate how end-of-pipe pollution controls, as compared to fuel-switching options, could affect emissions of multiple pollutants and CO_2, from a cost-benefit perspective.

❖ Data and Study Framework

Multi-pollutant Analysis, Pathway, and Location Evaluator (MAPLE)

Identify EGUs from CAMPD

135 uncontrolled coal-fired EGUs in the US as of 2017 have been selected.

Quantify emission change and total annual costs (TAC) using costs metrics from EPA and EIA

$$E = \frac{A \times ER \times (1-\eta)}{2000}$$

$$TAC_{BAU} = O\&M \times Capacity + Fuel$$

$$TAC = CAP \times Capacity \times \frac{i}{1-(1+i)^{-20}} + O\&M \times Capacity + Fuel$$

Develop sulfur reduction pathways

1. Install SO_2 controls
2. Fuel-switching to natural gas
3. Fuel-switching to renewables (wind and solar)

Apply EPA state-level Benefit-Per-Ton health benefits

SO_2	NO_X	VOCs	$PM_{2.5}$	CO_2
Control costs, $ / Health benefits, $/ton	Health benefits, $/ton	Health benefits, $/ton	Health benefits, $/ton	Social Cost of Carbon, $/ton

Calculate net benefits

$$Net\ Benefits = (\sum_{pollutant} BPT_{Pollutant} \times \Delta e_{pollutant}) - TAC$$

❖ Characterization of uncontrolled coal-fired EGUs

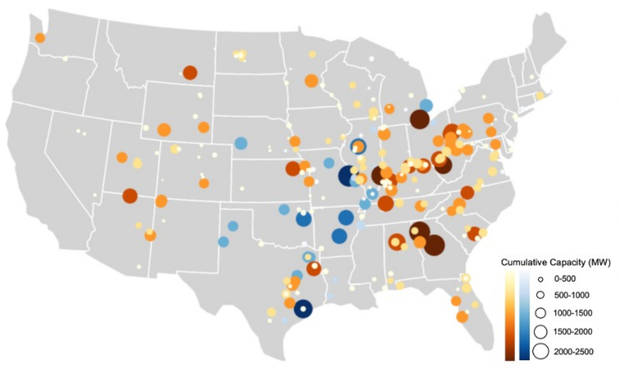

Fig 1. Map of 228 controlled coal power facilities (orange) and 68 uncontrolled coal facilities (blue) in the EPA CAMPD dataset as of 2017. Individual EGUs are aggregated at facility level.

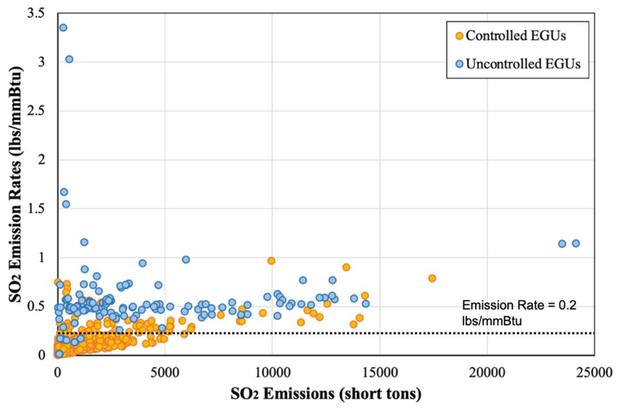

Fig 2. SO_2 emissions and emission rates of controlled coal EGUs and uncontrolled EGUs. Most uncontrolled EGUs exceed the EPA coal-fired EGU SO_2 emission rate (0.20 lb/MMBtu).

❖ Multi-pollutant Emission Change at unit- and national level

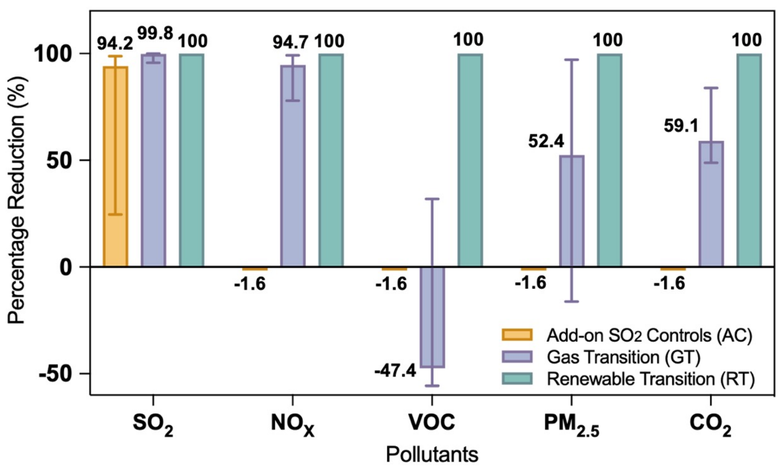

Fig 3. EGU-level multi-pollutant emission percentage reductions.

Traditional "add-on" controls for SO_2 can reduce unit-level uncontrolled emissions of SO_2 up to 94.2%, while increasing emissions of NO_X, $PM_{2.5}$, VOCs, and CO_2 by 1.6% due to heat efficiency loss.

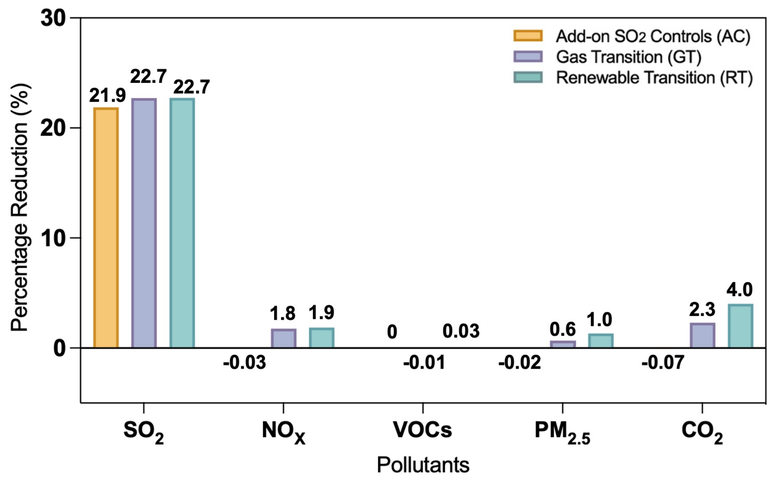

Fig 4. National multi-pollutant emission percentage reductions.

Add-on pollution controls only reduce national SO_2 emissions by 21.9%; transitions to natural gas and renewables reduce SO_2 emissions by 22.7%, while also reducing national NO_X, $PM_{2.5}$, and CO_2 emissions up to 4%.

❖ Unit-level and state aggregated Net Benefits

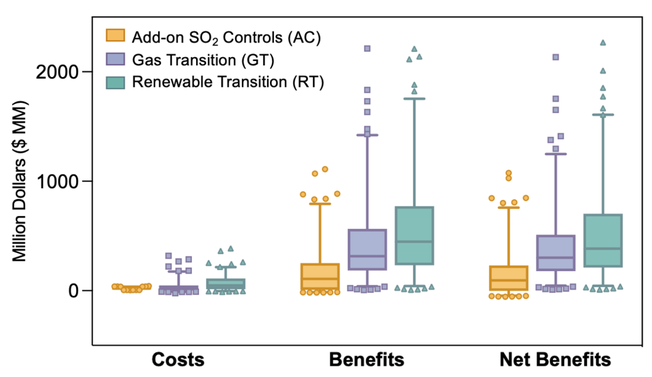

Fig 5. EGU-level costs, benefits, and net benefits of multi-pollutant emission reductions, in million dollars.

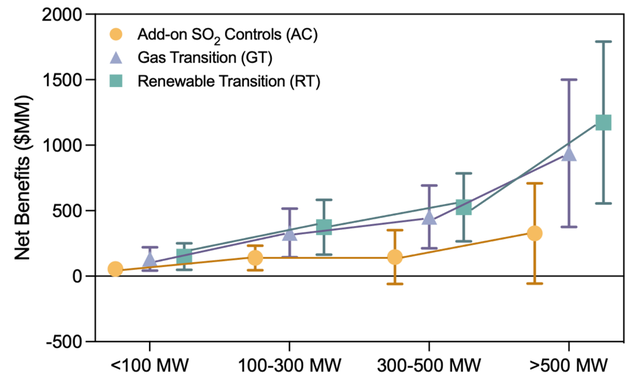

Fig 6. EGU-level net benefits across capacity size groups, in million dollars.

Add-on control scenario results in the lowest EGU-level net benefits, at an annual average of $179.3 million (95% CI: $137.5-$221.0 million) per EGU, renewable transition scenario results in the highest net benefits, at an annual average of $537.9 million (95% CI: $457.1-$618.9 million) per EGU.

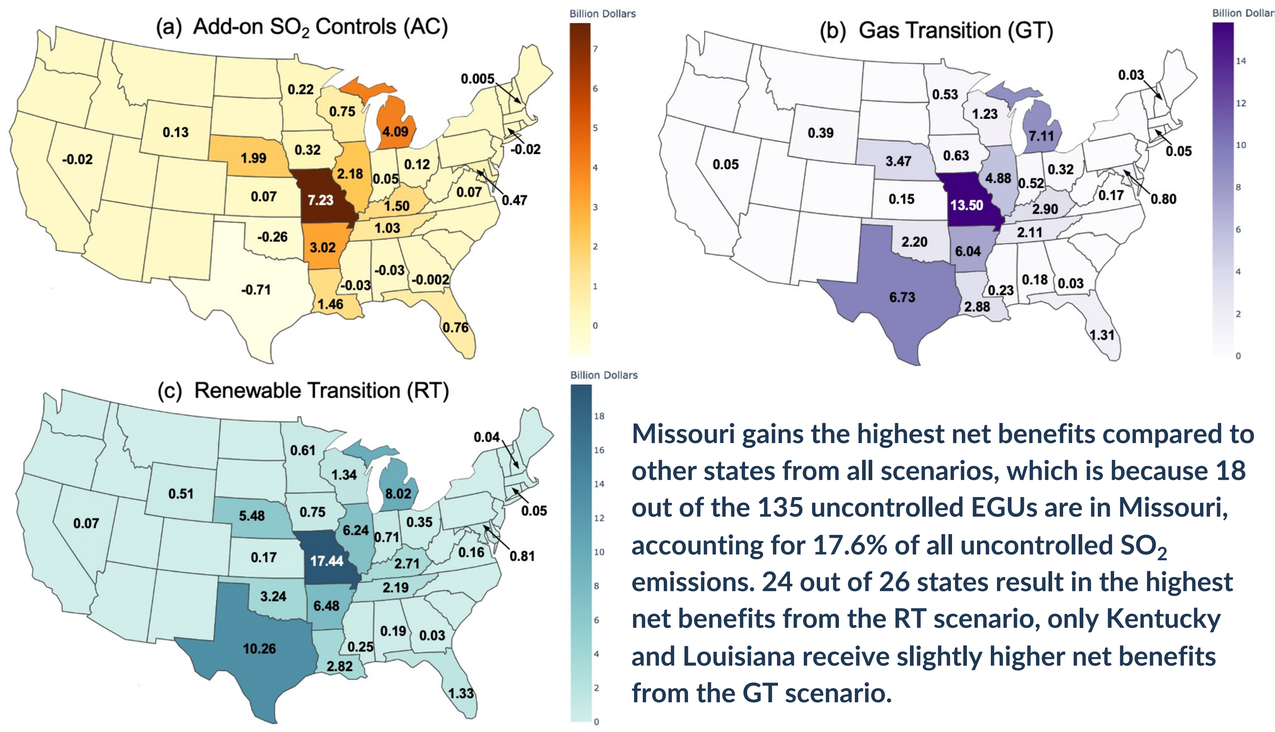

Fig 7. State-aggregated net benefits from (a) add-on control scenario, fuel-switching to natural gas scenario, and (c) renewable energy scenario. The unit is billion dollars. States with no uncontrolled EGUs are shown as blank values.

Missouri gains the highest net benefits compared to other states from all scenarios, which is because 18 out of the 135 uncontrolled EGUs are in Missouri, accounting for 17.6% of all uncontrolled SO_2 emissions. 24 out of 26 states result in the highest net benefits from the RT scenario, only Kentucky and Louisiana receive slightly higher net benefits from the GT scenario.

❖ Conclusions

- A Multi-pollutant Analysis, Pathways, and Location Evaluator (MAPLE) framework for simultaneous evaluation of multi-pollutant (SO_2, NO_X, VOCs, $PM_{2.5}$, and CO_2) is developed.
- Shifting from coal towards natural gas and renewables reduces multiple air pollutants and CO_2 simultaneously with substantial net benefits than new installations of pollution controls on coal-fired facilities.
- The co-reduction of both air pollution and carbon emissions through energy structure transitions highlights the potential of multi-pollutant reduction strategy as a win-win approach for future policymaking.

❖ Future Work

[1] Expand the MAPLE framework for other high-emitting sectors including transportation and industry.
[2] Apply the monetized health benefits ($/ton) of reducing each pollutant at finer spatial scales (county- and city-level) to validate location-specific multi-pollutant reduction pathways.

❖ Acknowledgments

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Contact: Xinran Wu, xwu464@wisc.edu