

Carbon emissions and exposure to PM2.5 due to electricity imports in the US



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Introduction

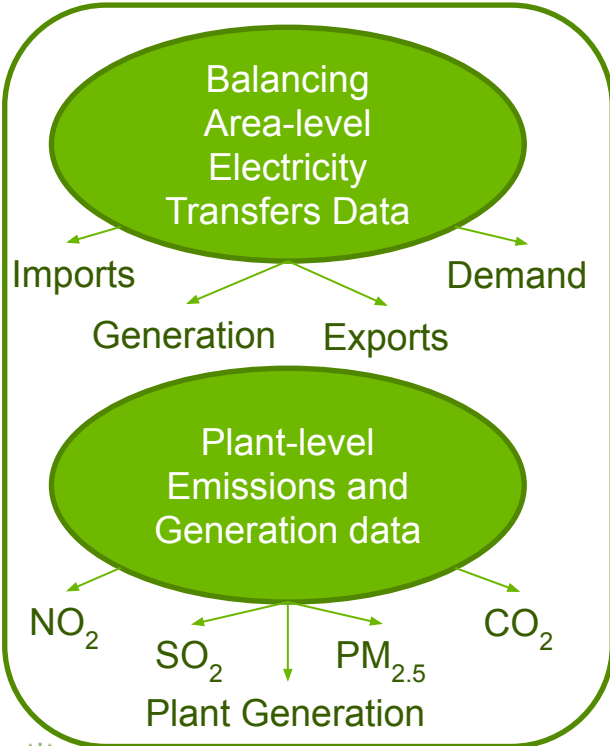
- Exposure to air pollution can have significant health impacts [1], [2], and previous studies have shown that exposure to fine particulate matter (PM2.5) is responsible for thousands of deaths in the US each year [3].
- Electricity production is a major contributor to PM2.5 production [3], [4].
- Many regions in the US import significant amounts of electricity. As renewable energy penetration has increased, many Western Balancing Areas in particular now import large amounts of power [5].
- As the grid becomes more interconnected, it will be more important than ever to understand the effects of electricity imports on public health and carbon emissions.
- Understanding these effects is essential to developing informed policies and regulations for the changing electric grid.

Objective

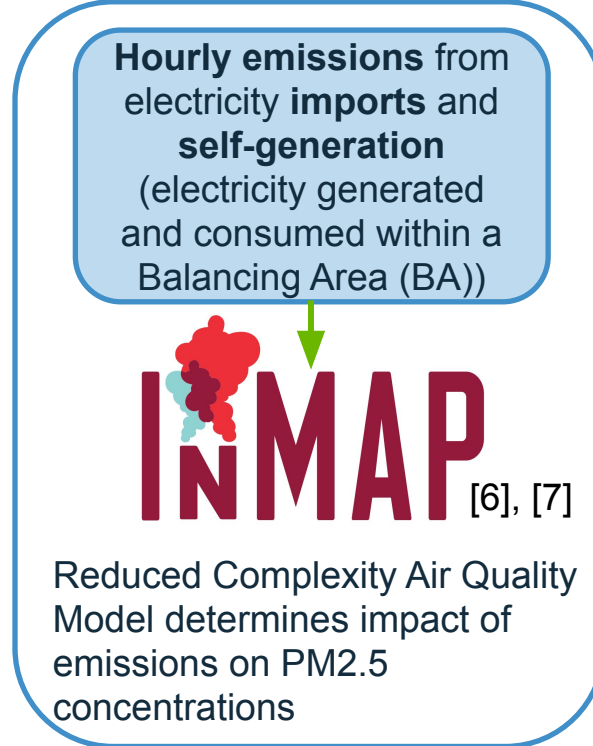
- The primary goal of this work is **to determine the effects of electricity imports in the US on health damages due to exposure to fine particulate matter (PM_{2.5})**.
- A secondary goal of this work is to **understand the role of imports in CO₂ emissions in the US**.
- The final goal of this work is to **trace the which balancing areas are responsible for both carbon emissions and PM_{2.5}-related health effects**.

Methods: Model Overview

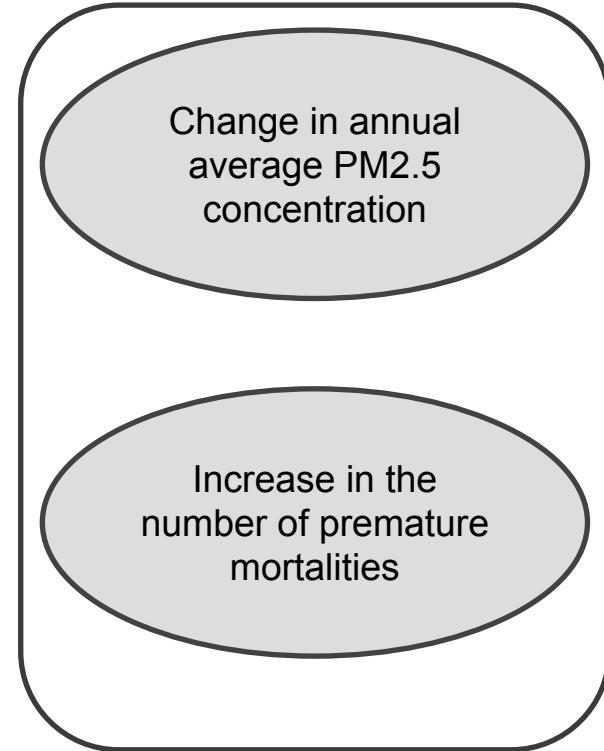
Model Inputs



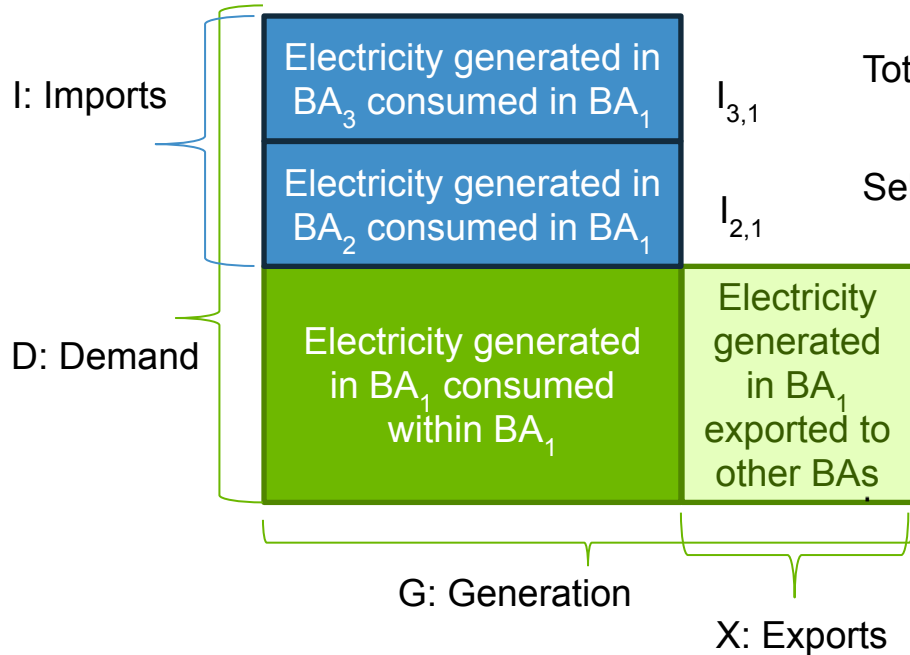
Model Calculations



Model Outputs



Methods: Responsibility for generation from imports and self-generation



Fraction of electricity consumed within BA: $f_{BA} = \frac{D}{D + X}$

Total demand: $D = \left(\sum I + G \right) \cdot f_{BA}$

Self-generation: $G \cdot f_{BA}$

Fraction of generation in BA_i being imported by BA_j:

$$f_{i,j} = \frac{I_{i,j}}{G_i}$$

We assume the fraction of generation from each plant in BA_i going towards self-generation is f_{BA} .

Likewise, we assume the fraction of generation from each plant in BA_i going towards imports in BA_j is $f_{i,j}$.

Methods: Calculating emissions and premature mortality

Emissions associated with **self-generation**:

$$E_{SG} = f_{BA} \cdot E_p$$

Emissions associated **with imports from BA_i to BA_j**:

$$E_{i,j} = f_{i,j} \cdot E_p$$

Additional premature mortalities (ΔM_x) in grid cell x resulting from an increase in annual average PM_{2.5} concentration of $\Delta PM_{2.5}$ due to self-generation or imports in BA_i

$$\Delta M_x = M_x^0 (e^{\beta \Delta PM_{2.5}} - 1) \cdot P_x$$

M_x^0 : All-cause mortality rate in cell x

β : PM_{2.5} coefficient

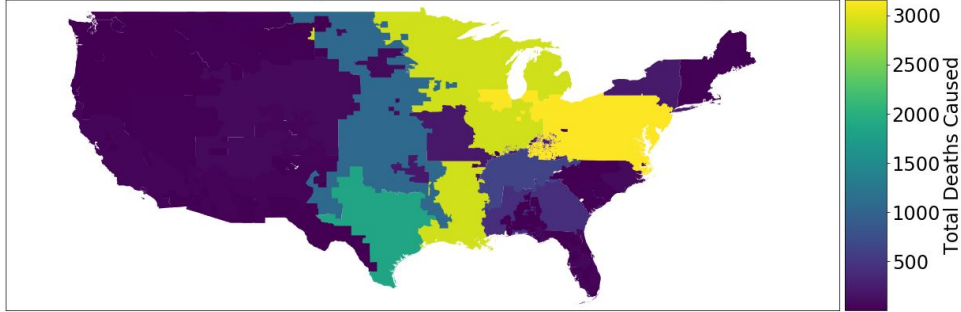
P_x : Population in grid cell x

E_p : Hourly emissions from power plant p

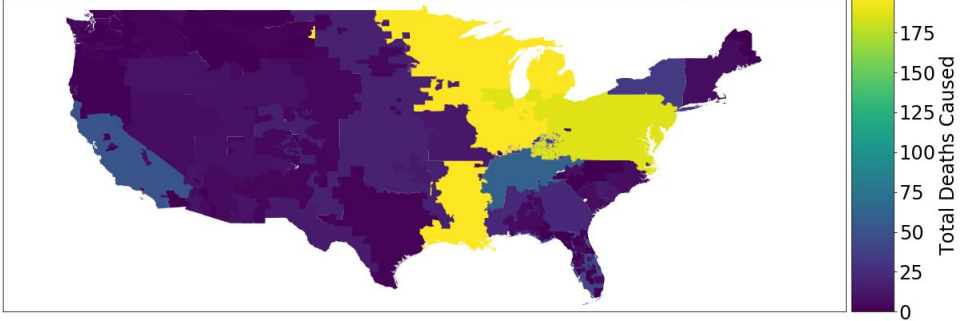


Results: Total Premature Mortalities Due to PM2.5 Exposure

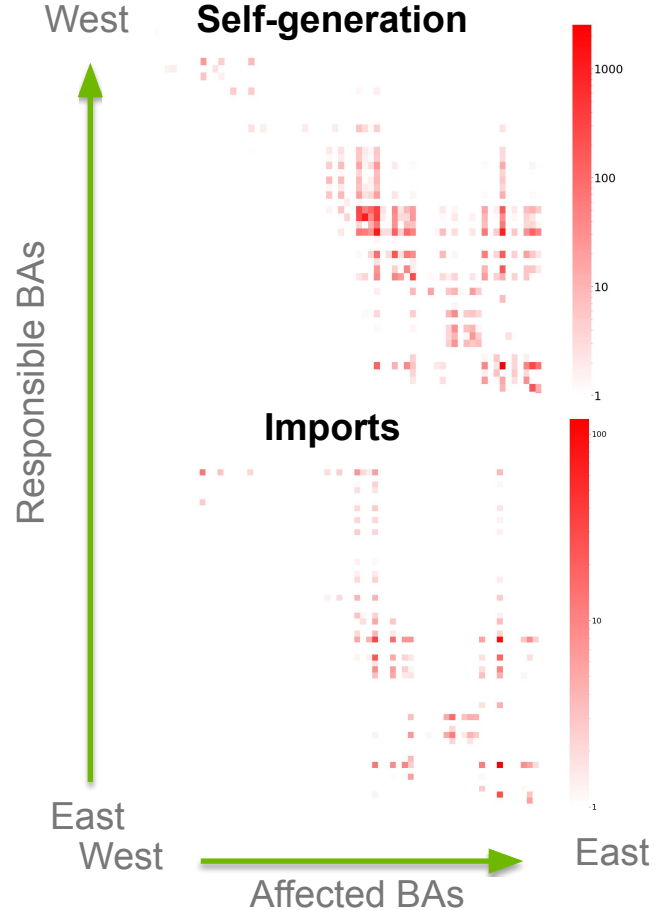
Total Deaths Caused by Self-Generation in Each Balancing Area



Total Deaths Caused by Imports in Each Balancing Area

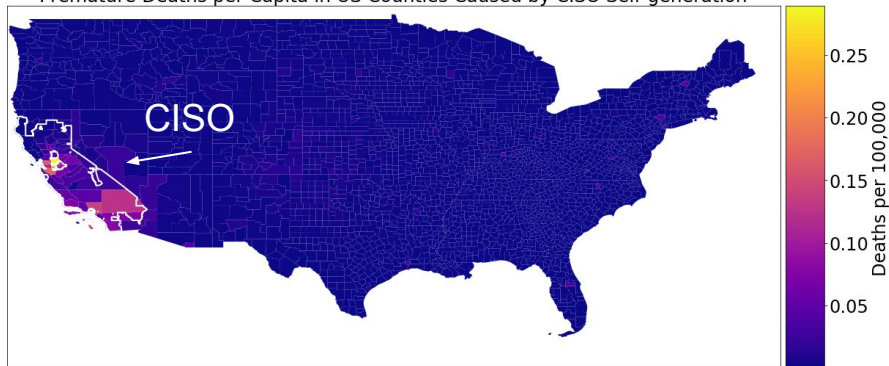


Overall, **11,699** premature mortalities caused by self-generation, and **889** caused by imports in 2016

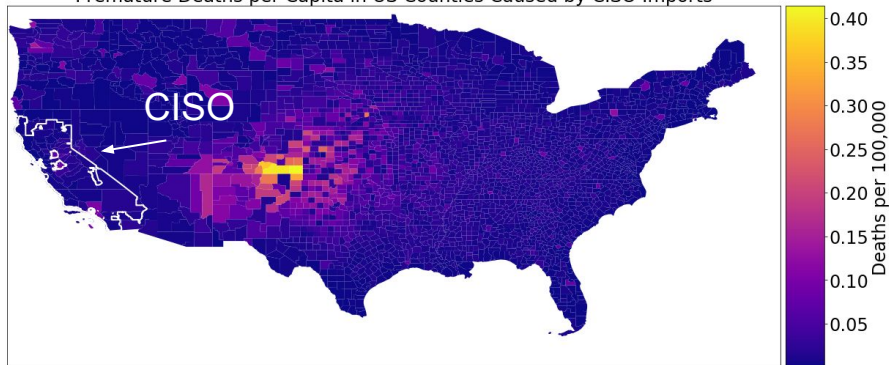


Results: Premature Mortalities Caused by CISO

Premature Deaths per Capita in US Counties Caused by CISO Self-generation



Premature Deaths per Capita in US Counties Caused by CISO Imports

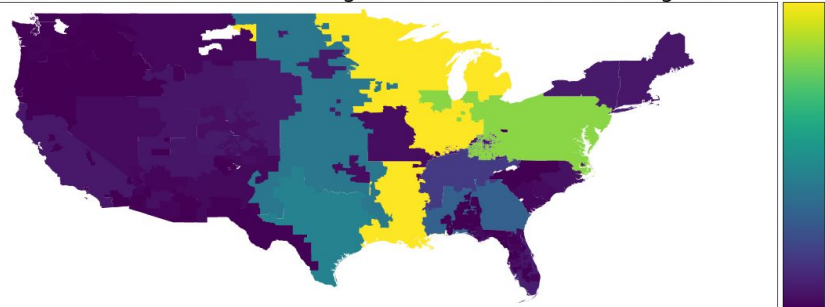


- **51** premature mortalities caused by electricity imports
- **39** premature mortalities caused by self-generation
- The majority of premature mortalities caused by CISO's imports occur well outside of its boundaries.
- CISO is representative of Western BAs that import large amounts of electricity
- Midwestern and Eastern BAs, in contrast, tend to cause more damage through generation within the BA to meet their own demand.

Results: Carbon Emissions

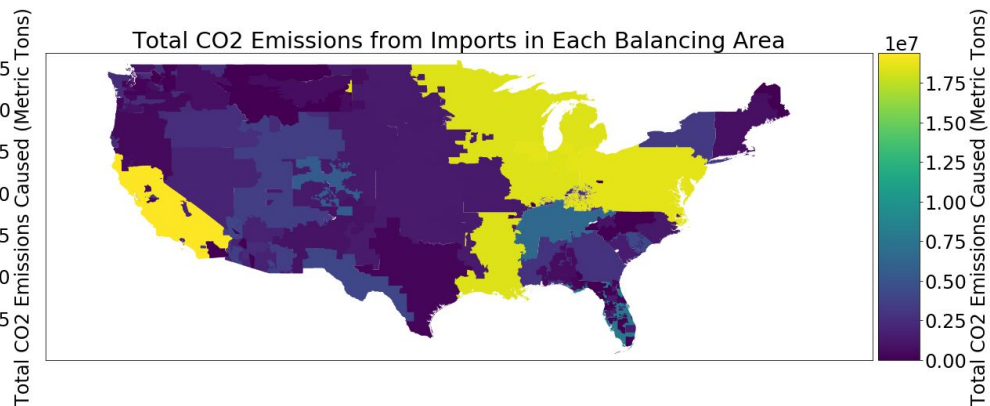
- Imports are responsible for **8.8 %** of carbon emissions in the US.
- Midwestern BAs cause the majority of emissions.

Total CO2 Emissions from Self-generation in Each Balancing Area



In total, **1,684.5** Million metric tons of CO2 are caused by **self-generation**

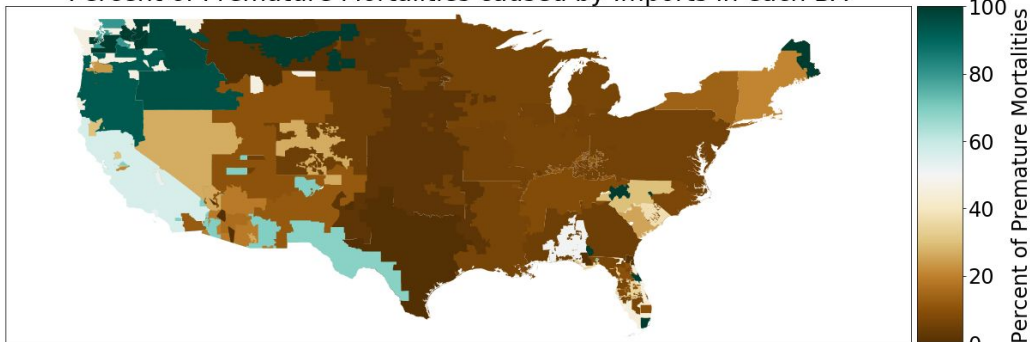
Total CO2 Emissions from Imports in Each Balancing Area



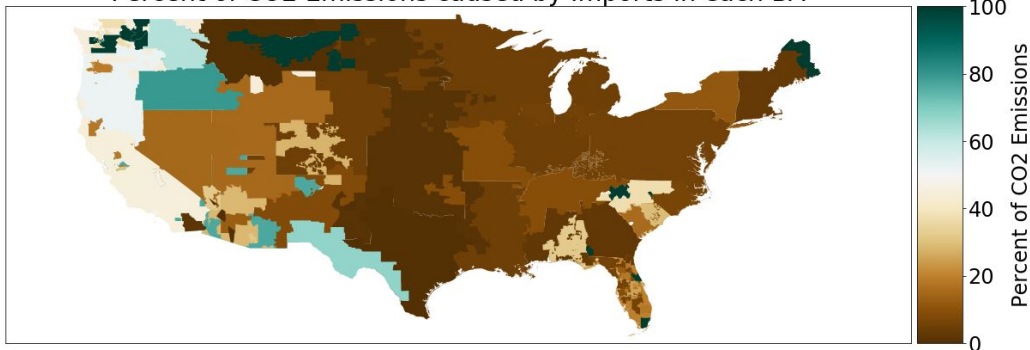
In total, **160.2** Million metric tons of CO2 are caused by **imports**

Conclusions

Percent of Premature Mortalities caused by Imports in each BA



Percent of CO2 Emissions caused by Imports in each BA



- In 2016, electricity imports were responsible for **7% of premature mortalities** due to PM_{2.5}, and **8.8% of CO₂ emissions** from electricity generation.
- Overall, Midwestern and Eastern BAs are responsible for more carbon emissions and premature deaths than Western BAs. However, in Western states imports cause more damage.
- These results suggest that increasing grid interconnection may not always result in reduced carbon emissions, and in some cases will have significant public health consequences.

Future work

- Further analysis is needed to understand the distributional consequences of these results.
- Future work will include a finer-scale analysis of premature mortalities at the sub-county level, and will incorporate sociodemographic indicators to assess impacts on vulnerable groups.
- Additional future work could assess the impact changes in the composition of generators in the electric grid on the distribution of carbon emissions and premature mortalities.

References

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