BILD AQ

A Modeling Framework for Evaluating the Environmental, Health, and Equity Impacts of Large-Scale U.S. Transportation Energy Transition

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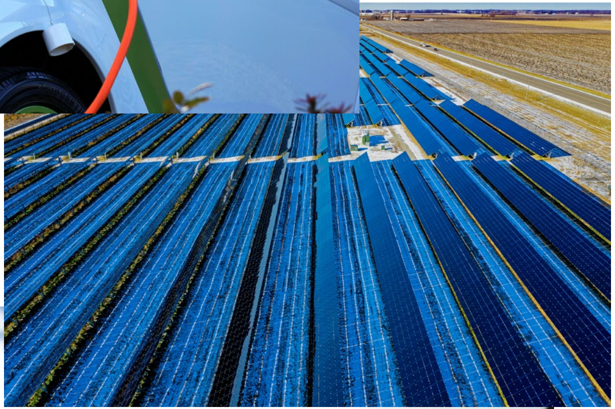


Goals and Overview

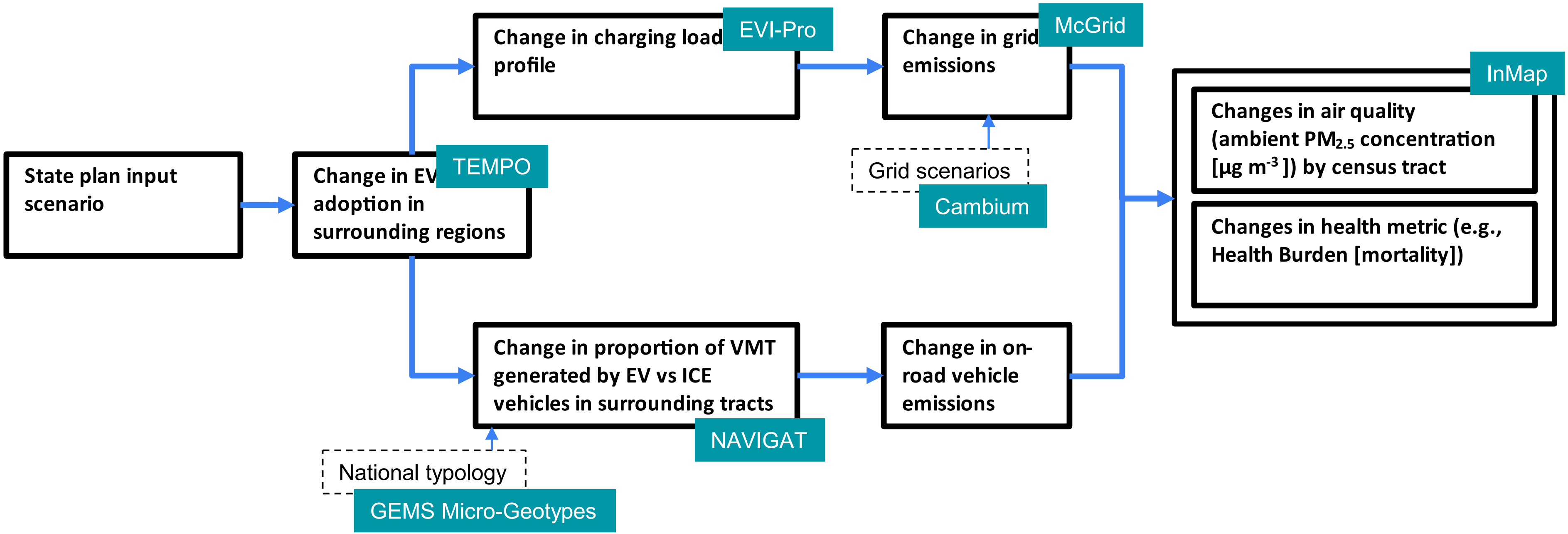
Goals

- Estimate the **air quality emissions concentration and mortality benefits**, **and to whom they accrue,** of:
    - alternative fuel refueling infrastructure deployment
    - power generation decarbonization
    - alternative fuel vehicle adoption incentives (rebates, tax credits, technology costs, etc.)
- **Primary application so far:** the Bipartisan Infrastructure Law-funded EV infrastructure deployment and Inflation Reduction Act incentives.

Approach

- Integrated modeling framework, known as Benefits of Infrastructure in Large-Scale Deployment: Air Quality (BILD AQ)
- Major features of BILD AQ:
    - Geographic scope: full United States; spatial resolution at census tract level (with 11-state WECC region example).
    - Evaluates passenger vehicles for now, with heavy-duty vehicles able to be incorporated.
    - Incorporates spillover effects of EV adoption, operation, and grid dispatching across states.

BILD AQ Workflow

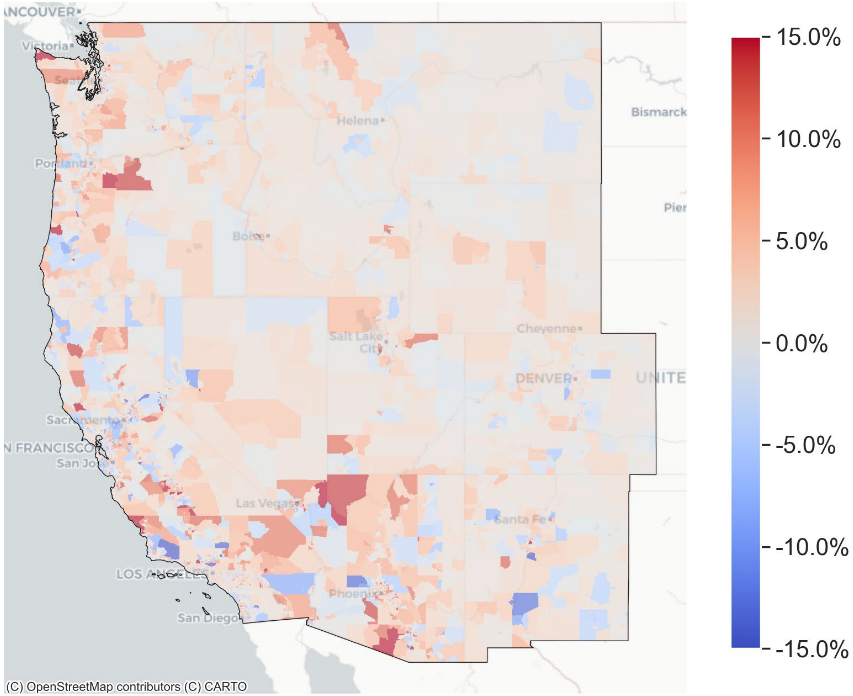


Electric Vehicle (EV) Adoption

EV adoption scenarios:

- Baseline: Infrastructure deployed at current (2022) levels.
- National Electric Vehicle Infrastructure (NEVI) program: Charging infrastructure deployed under proposed NEVI plans
- Inflation Reduction Act (IRA): purchase incentives
- Considers build-out of infrastructure in neighbor states

EV Adoption Change Compared to Baseline (%)

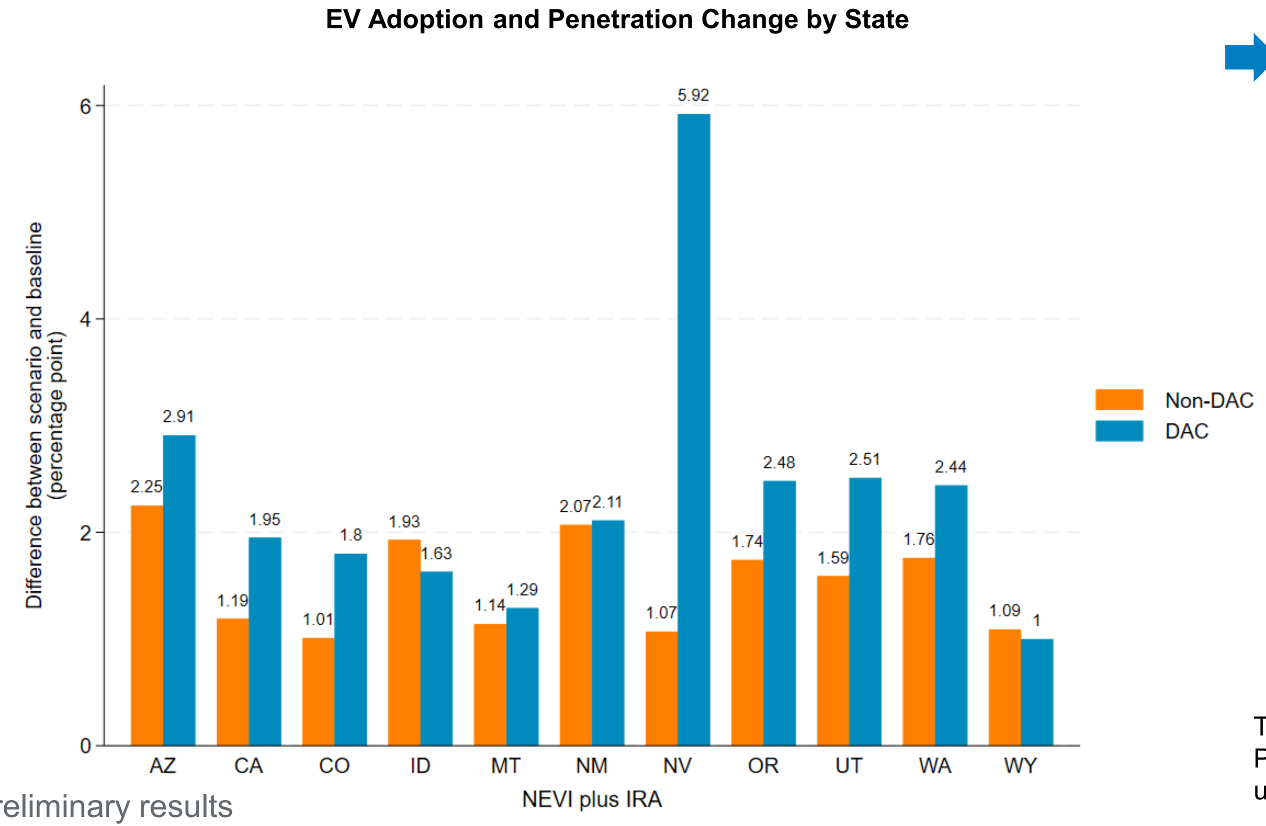


The Transportation Energy & Mobility Pathway Options™ (TEMPO) model is used to estimate EV adoption.

TEMPO

*Preliminary results

Electric Vehicle (EV) Adoption



*Preliminary results

- Overall 3.3% increase in EV adoption across the WECC region.
- Increase in the share of the fleet made up of EVs is larger in DACs compared to non-DACs in a majority of the states, the exceptions being ID and WY.

The Transportation Energy & Mobility Pathway Options™ (TEMPO) model is used to estimate EV adoption.

TEMPO

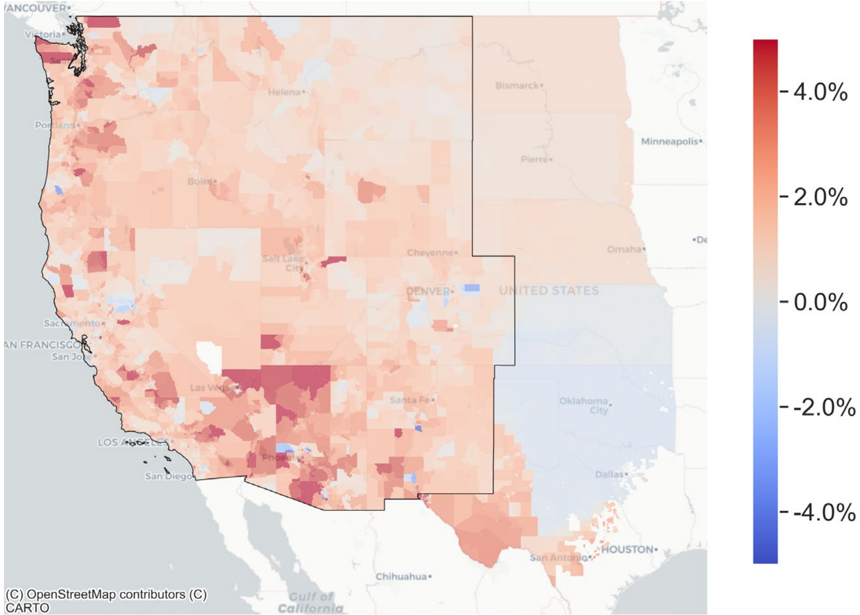
EV Vehicle Miles Traveled (VMT)

EV VMT penetration:

- Simulate passenger VMT using a four-step approach:
  - Generate trips based on land use typology and income group.
  - Apply destination choice model
  - Apply shortest path for through traffic.
  - Allocate observed VMT to home tract.

- Across the whole WECC region EV VMT increased 8.1% compared to the 2030 Baseline.
- Electrified VMT increases 8.5% in DAC tracts and 7.8% in non-DAC tracts.

EV VMT Penetration Change Compared to Baseline (%)

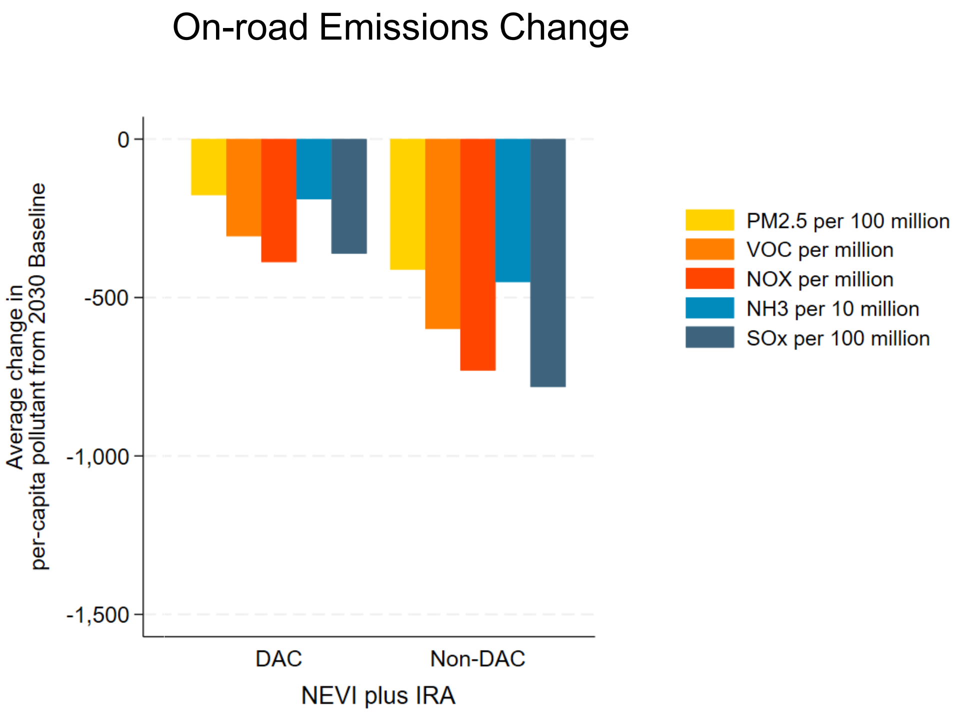


*Preliminary results

On-Road Emissions

On-road emission model with InMAP Source-Receptor Matrix (ISRM):

- Key inputs: 2017 on-road emission inventory from the U.S. Environmental Protection Agency allocated to ISRM grids; change in VMT by tract, powertrain type, and scenario.
- Generate changes in on-road vehicle emissions in each ISRM grid using a difference in VMT approach.



- All pollutants reduced from on-road emissions.
- Per-capita reductions are larger in Non-DAC tracts compared to DAC tracts.

*Preliminary results

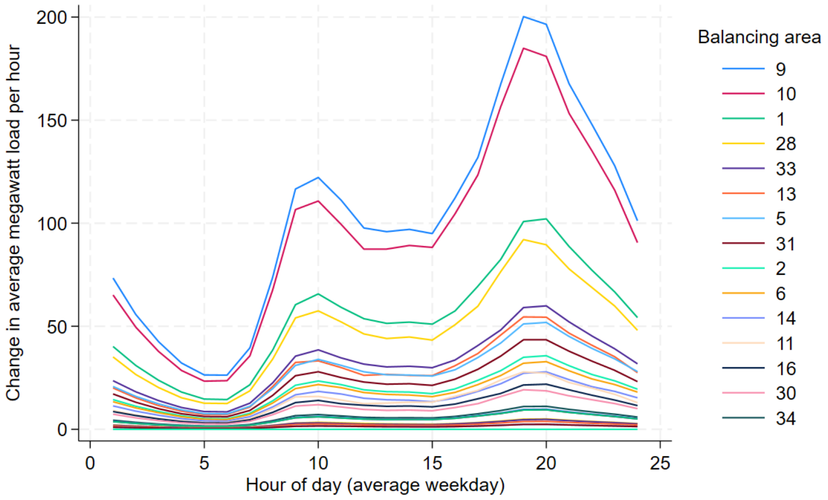
Electricity Generation and Grid Emissions

Charging load from Electric Vehicle Infrastructure – Projection (EVI-Pro):

- TEMPO's EV adoption rates are used as EVI-Pro Lite inputs.
- Estimate 15-minute charging load in a day, with temperatures and charging strategy as inputs.
- Hourly EV charging loads in and around urban areas are aggregated spatially to balancing areas on the grid.

- Charging load increases in majority of balancing areas in WECC region, some as high as 200 MW during a typical weekday peak hour.

Charging Load Change



EVI Pro Lite: Load profile tool

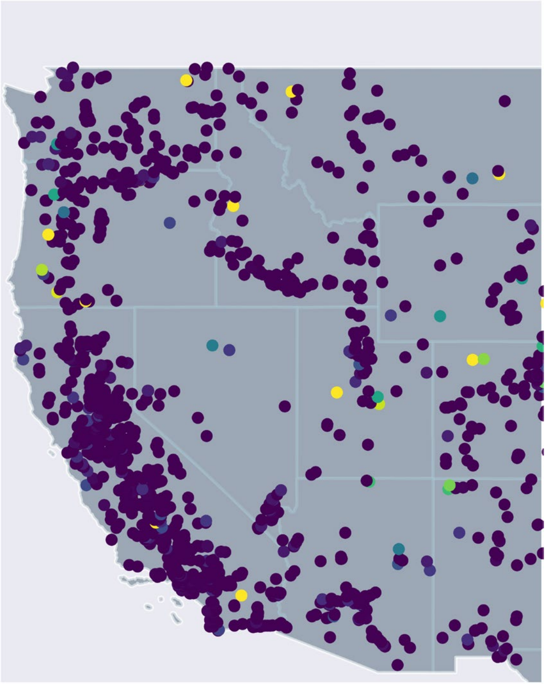
*Preliminary results

Electricity Generation and Grid Emissions

Grid emissions from McGrid model:

- Use load profile change from EVI-Pro Lite and Cambium grid scenarios.
- Electricity load proportionally allocated to power plant locations across the United States based on the shared marginal generator to estimate annual emissions.
- **IRA Scenario**: includes clean energy incentives for greening the grid included in the IRA as characterized by the new Cambium grid scenarios for the scenario results, compared to a baseline without those investment.

Annual Primary Power Plant $PM_{2.5}$ Change

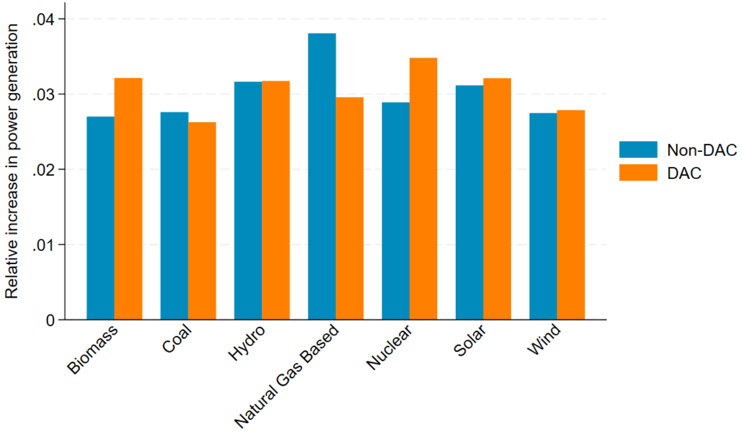


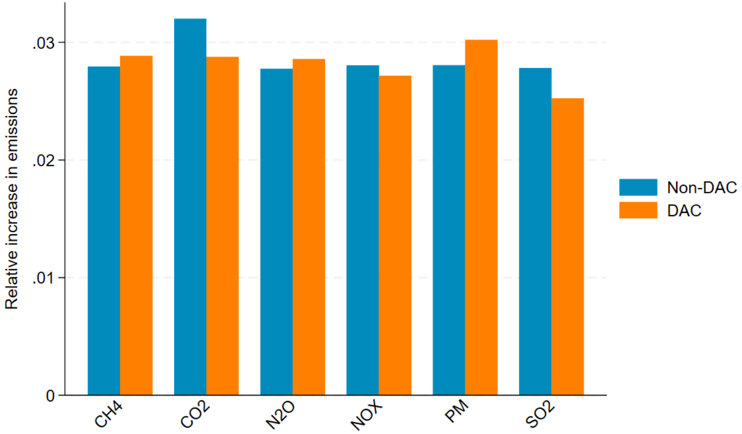
Cambium and McGrid Model

*Preliminary results

Electricity Generation and Grid Emissions

- Power generation from biomass, nuclear and renewable plants increase slightly more in relative terms in power generating units located in DAC regions compared to non-DAC regions.





- This results in relatively comparable increases in emissions across various pollutants from power generating units located in DAC regions compared to non-DAC regions.

*Preliminary results

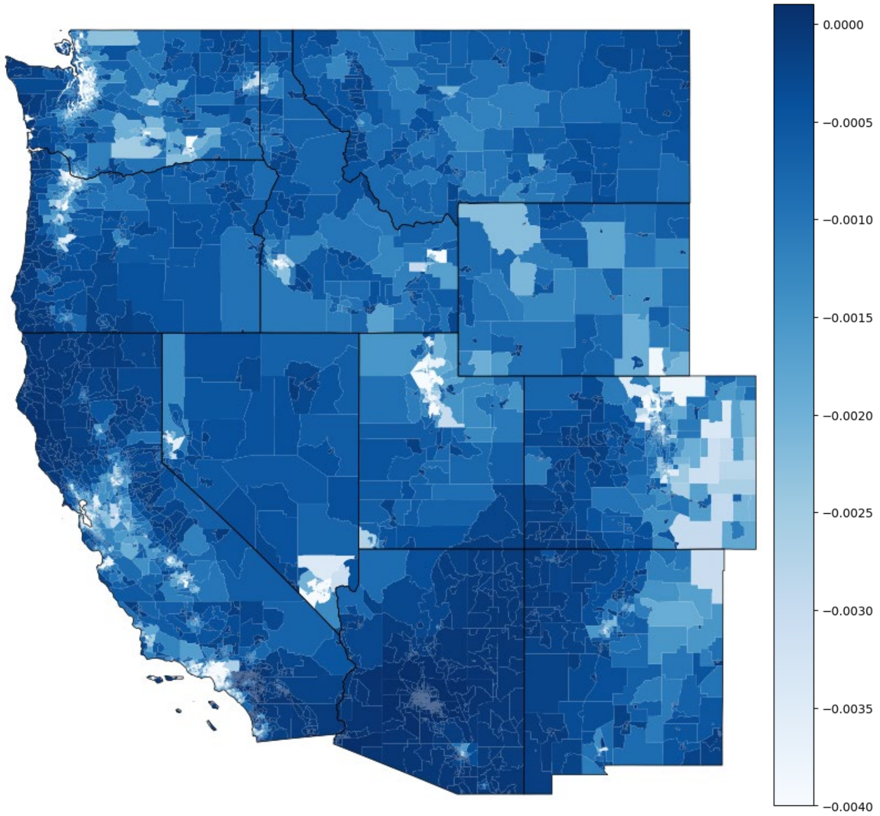
Cambium and McGrid Model

Air Quality and Health Outcomes

Air quality and health outcomes using InMAP:

- Transport and transformation of pollutants and resulting mortality are modeled using InMAP.

Decrease in $PM_{2.5}$ Concentrations From NEVI and IRA (μg/m^3)

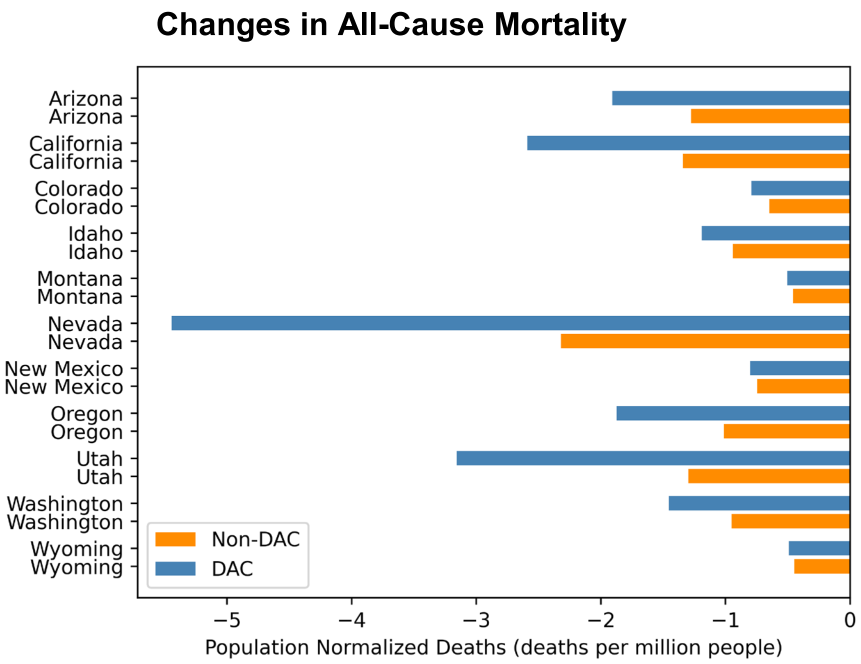


*Preliminary results

Air Quality and Health Outcomes

- Significant improved PM2.5 concentrations, especially in more populated regions.

- Mortality benefits across full WECC: 97 avoided deaths per year by 2030 (1.2% of premature deaths in the region due to transportation emissions)[7].
- In population normalized terms, DAC regions experience proportionally higher mortality benefits than non-DAC regions.



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Highlights and Future Work

Highlights:

- Demonstrated the full chain impacts of large-scale EV charging deployment, EV adoption and EV clean power generation incentives on EV adoption, operation, emissions, air quality, and health outcomes.
- Populations living in DACs avoid more deaths per million people than those in non-DACs under the NEVI plus IRA scenario.

Future work:

- Extending analysis out to 2040 and refining some of the analyses

References:

1. M. Muratori, P. Jadun, B. Bush, C. Hoehne, L. Vimmerstedt, A. Yip, J. Gonder, E. Winkler, C. Gearhart, and D. Arent. 2021. “Exploring the future energy-mobility nexus: The transportation energy & mobility pathway options (TEMPO) model.” *Transportation* Research Part D: Transport and Environment 98: 102967. https://doi.org/10.1016/j.trd.2021.102967.
2. N. Popovich, C. A. Spurlock, Z. Needell, L. Jin, T. Wenzel, C. Sheppard, and M. Asudegi. 2021. “A methodology to develop a geospatial transportation typology.” Journal of Transport Geography 93: 103061. https://doi.org/10.1016/j.jtrangeo.2021.103061.
3. U.S. Department of Energy. 2023. “Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite.” Accessed Dec. 15, 2023. https://afdc.energy.gov/evi-pro-lite.
4. P. Gagnon, B. Cowiestoll, and M. Schwarz. 2023. *Cambium 2022 Scenario Descriptions and Documentation*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A40-84916. https://www.nrel.gov/docs/fy23osti/84916.pdf.
5. W. H. McNeil, F. Tong, R. A. Harley, M. Auffhammer, and C. D. Scown. n.d. "Corridor-Level Impacts of Battery-Electric Heavy-Duty Trucks and the Effects of Policy in the United States.” *Environmental Science & Technology* (forthcoming).
6. C. W. Tessum, J. S. Apte, A. L. Goodkind, N. Z. Muller, K. A. Mullins, D. A. Paolella, S. Polasky, et al. 2019. “Inequity in consumption of goods and services adds to racial–ethnic disparities in air pollution exposure.” *Proceedings of the National Academy of Sciences* 116 (13): 6001–6006. https://doi.org/10.1073/pnas.1818859116.
7. Caiazzo, F., Ashok, A., Waitz, I. A., Yim, S. H., & Barrett, S. R. (2013). Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005. Atmospheric Environment, 79, 198-208. https://doi.org/10.1016/j.atmosenv.2013.05.081