HEI Annual Conference 2026

Abstracts

Listed alphabetically by presenter (underscored)

Key:

HEI	***HEI-funded Investigator***
HEI energy	***HEI Energy-funded Investigator***
RB	***Walter A. Rosenblith New Investigator Award Recipient***
JW	***Jane Warren Award Recipient***

What Can VOC Monitoring Data Tell Us About Air Quality and Health in the Great Lakes Region?

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Volatile organic compounds (VOCs) are air toxics that can cause a variety of health effects, ranging from irritation of the eyes, nose, and throat to cancer. VOCs are also important precursors to ozone and particulate matter pollution, which have their own health impacts. We will present a review of the available contemporary VOC data for the Great Lakes Region, characterize the data, and present a survey of their utility for air quality and health analyses.

We review data available from routine VOC monitoring conducted by states, as well as higher resolution but shorter-term data from four field studies in the Great Lakes Region. We will show VOC fingerprints and speciation data at sites and examine how these fingerprints vary across the region. This study will explore what this speciation data tells us about VOC emissions sources.

Since 2017, significant resources have been committed to the collection of ambient VOCs in urban areas through routine surface networks and special studies. While the VOC data lend significant insights into characterizing VOC concentrations for a wide range of chemical species and conditions, the data suffer from limitations in chemical speciation, consistency across the networks, and spatial representation of the larger airsheds in which they're located. Despite the constraints in the data, we show that there are trends over space and time, and chemical signatures for the areas in which the data are collected that can help us understand the sources of pollution in the region.

The available ambient VOC data can help us identify effective VOC emissions control programs to reduce both ozone and PM pollution and lower the direct health impacts of VOCs. We will discuss opportunities and gaps in the available VOC data for air quality and health applications and provide ideas for improvements.

Spatial and temporal variabelility in atmospheric emissions from oil and gas production in the Permian Basin

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Emissions from oil and gas production regions exhibit strong spatial and temporal variability that is not captured by conventional emission estimation methods based on annual, county level activity data and emission factors. Methods for developing detailed spatially and temporally resolved inventories were created in previous work but were computationally intensive. This work updates those methods to reduce computational requirements while preserving detailed spatial and temporal resolution and expands their application to the Permian Basin in west Texas.

Emission inventories of light alkanes, volatile organic compounds (VOCs), and nitrogen oxides (NO_x) in the Permian Basin for 2022-2024 were developed, including sources from well sites and midstream sites. Inventories were spatially aggregated at basin, county, and 12km-by-12km grid cell levels, and temporally resolved at hourly resolution, with underlying methods capable of generating inventories at other spatial and temporal scales.

At basin and county levels, methane emissions are dominated by tank flash, associated gas venting, and midstream operations, while heavier hydrocarbon emissions are dominated by tank flash. Temporal variability in methane emissions is primarily driven by episodic events, such as flaring and liquid unloadings, whereas propane variability is dominated by variations in tank flash emissions associated with production variations. Temporal variability in NO_x emissions is driven by preproduction activities and is sensitive to midstream engine types. At finer spatial scales, temporal variability in both hydrocarbons and NO_x emissions increases.

Compared with gas production dominated regions such as the Marcellus Shale, the Permian Basin exhibits lower hydrocarbon temporal variability due to fewer episodic sources specific to gas wells, such as liquid unloadings, and a greater contribution from near-continuous oil production related sources, such as associated gas venting. In contrast, NO_x emissions show higher temporal variability, due to more frequent preproduction activities associated with new well development.

JW

Twenty Years of High-Resolution $PM_{2.5}$ Exposure and Health Impacts in Ghana Using Satellite Data, Surface Observations, and Machine Learning

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Exposure to air pollution is the second leading cause of death worldwide, driven largely by fine particulate matter ($PM_{2.5}$). The risk is particularly severe in low- and middle-income countries, including those in sub-Saharan Africa, where limited air quality monitoring remains a major barrier to building effective mitigation policies. Such data scarcity is primarily due to the high cost of research-grade monitoring infrastructure.

Our study addresses this critical gap by estimating long-term $PM_{2.5}$ concentrations and associated health impacts in Ghana. We trained multiple machine learning (ML) models using freely available retrievals of satellite-derived aerosol optical depth, gas-phase pollutants, and atmospheric optical properties from NASA, combined with reanalysis meteorological variables, to generate daily surface $PM_{2.5}$ concentrations at 1km × 1km resolution across Ghana for a 20-year period (2005–2024). Model estimates were validated against surface observations from 2018–2024 collected by a network of 106 reference-grade and well-calibrated low-cost monitors, deployed nationwide through years of local collaborations.

Among the tested models, a fully connected neural network performed best (RMSE:6.4 μg/m^3, R^2:0.84), outperforming other ML models in estimating $PM_{2.5}$. SHapley Additive exPlanations analysis identified wind speed, precipitation, absorbing aerosol index and ozone as the key contributors to model performance. Leveraging the resulting high-resolution $PM_{2.5}$ dataset, preliminary health burden assessment with World Health Organization's AirQ+ tool estimates that approximately 20% of 77,800 annual premature deaths during 2023–2024 among adults aged 30 years and older in Ghana can be attributed to $PM_{2.5}$ exposure.

To our knowledge, this is the first study in Africa to use advanced ML techniques to generate actionably reliable long-term high-resolution $PM_{2.5}$ concentrations and the methodology can be readily applied to other countries across sub-Saharan Africa. The dataset is publicly available through an open-access website and thus strongly supports evidence-driven policymaking to address air pollution–related global health and socioeconomic inequities.

The Potential of the Salt Mine Microclimate in the Treatment and Rehabilitation of Respiratory Diseases

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Fine particles with an aerodynamic diameter below 4 µm can reach the distal regions of the respiratory tract and pulmonary alveoli, triggering inflammatory and fibrotic processes. Persistent exposure to respirable particles contributes to chronic respiratory diseases, including chronic obstructive pulmonary disease (COPD) and asthma, while also increasing susceptibility to infections and impairing lung function. The salt microclimate used in subterraneotherapy may have a protective or regenerative effect on the respiratory system. "Wieliczka" Salt Mine in southern Poland is a well-documented example of such an environment. Presence of saline aerosol containing microdroplets of NaCl and other mineral salts allows the inhalation supporting airway cleansing, mucus liquefaction, and the mitigation of mucosal inflammation. Consequently, therapeutic stays in underground salt chambers are used as supportive treatment for COPD, bronchial asthma, and recurrent bronchitis.

Quantitative and qualitative assessment of suspended particles respirable fractions, nitrogen dioxide (NO_2), and volatile organic compounds (VOCs) in the underground air of the "Wieliczka" Salt Mine was made to compare these parameters with outdoor atmospheric air. Potential dose of dry saline aerosol inhaled by patients was also estimated. Measurements were conducted using high-resolution particle analyzers.

Mean PM_1 and $PM_{2.5}$ concentrations in underground chambers were significantly lower than in ambient air. Fine fractions (PM_1–PM_4) comprised approximately 80% of the total aerosol mass, and chemical analysis confirmed the predominance of NaCl particles, indicating their mineral and saline origin. The indoor-to-outdoor (I/O) ratio revealed internal sources of coarser particles (mean I/O for PM_4 2.12 while for PM_1 is 0.64), while no significant internal sources of fine particles were detected. In contrast, NO_2 and total VOCs concentrations were influenced exclusively by external sources, with no evidence of accumulation underground.

Salt Mine microclimate exhibits highly favorable aerosol characteristics, combining low particulate pollution with the presence of natural saline aerosol with potential therapeutic effects. The study confirms that the salt mine can be a model of a health-promoting underground microclimate and also highlights its scientific importance in respiratory rehabilitation and subterraneotherapy.

The National Atmospheric Deposition Program: 48 Years of Monitoring Success Informing Acid Rain Policy and Beyond

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Acid rain emerged as a critical environmental threat in the 1970s, damaging ecosystems, infrastructure, and human health through acidification of aquatic ecosystems and elevated atmospheric pollutants. The National Atmospheric Deposition Program (NADP) was established in 1978 to provide long-term, consistent monitoring of many different chemical compounds within precipitation across North America. The program is comprised of five networks that examine trends in concentrations of sulfur, nitrogen, mercury, and ammonia and atmospheric deposition of these parameters to meet the needs of scientific, ecological, and regulatory communities.

NADP operates over 250 monitoring sites across North America, using standardized protocols to measure precipitation chemistry weekly. This consistent methodology across diverse geographic regions and decades enables detection of temporal trends and spatial patterns in atmospheric deposition. NADP data products are used by policymakers to reduce impacts from pollution that cause negative human and ecological health conditions (e.g., reductions in fish populations). The publicly accessible database has supported hundreds of research studies every year.

NADP data documented the severity and geographic extent of acid rain and provided critical monitoring that illustrated the success of air pollution policies, such as the 1990 Clean Air Act Amendments. Specifically, NADP measurements showed sulfate concentrations in precipitation declined across the United States between 1985 and 2017 (McHale et al., 2021). The NADP monitoring network demonstrated clear accountability between emission controls and environmental improvements.

NADP exemplifies how sustained, high-quality environmental monitoring enables evidence-based policy development and demonstrates policy effectiveness. The program's success illustrates the value of long-term data collection for environmental accountability and research, showing direct connections between regulatory actions and measurable environmental and health benefits. NADP data continues to inform emerging environmental challenges including monitoring of aeroallergens and deposition of per- and polyfluoroalkyl substances (PFAS).

Personal Air Pollution Exposure and Lung Function from Cooking Among Food Vendors in Barbados

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Indoor and outdoor air pollution may be experienced in occupational settings, resulting in potentially unhealthy work conditions. We sought to quantify occupational exposures to a variety of air pollutants and respiratory outcomes from cooking among food vendors in Ostin's Fish Market in Barbados.

We measured personal air pollution exposure among workers in the market that identified as either "grillers" (outdoor grilling) or "cooks" (indoor baking and cooking). Participants wore a lightweight running vest fitted with air pollution monitors for the duration of their work shift. We measured gravimetric $PM_{2.5}$ (UPAS) and passive NO_2 (Ogawa badges). Lung function was measured using the portal MIR Spirobank II. Demographic and exposure surveys were conducted with participants.

We monitored 24 unique individuals in 34 different monitoring sessions. Participants used either natural gas or liquid petroleum gas for their cooking and grilling and worked an average of 10 hours per day and 5 days per week. The median $PM_{2.5}$ gravimetric concentration during work shifts was 336 ug/m^3 (IQR: 103-597 ug/m^3). Significant differences existed between monitoring sessions of cooks and grillers; cooks (n=17 samples) median 93 µg/m^3 (IQR: 33-265) and grillers (n=17) median 608 µg/m^3 (IQR: 432-1145 µg/m3). Median NO_2 values varied by occupational roles: 8.54 ppb during shifts of cooks (n=14) and 14.86 ppb for grillers (n=17); p=0.77. After controlling for diagnosed asthma, a 10% increase in NO_2 exposure was associated with a 0.002% decrease in both forced vital capacity and forced expiratory volume in one second (p=0.21). Similar effect sizes were observed with $PM_{2.5}$.

Food vendors in Barbados experienced high levels of personal air pollution exposure; those who grill had the highest levels even though they worked outdoors. Patterns emerged with exposure to air pollutants and decreased lung function; although a larger sample size is warranted.

Air Pollution Mixtures and Alzheimer's Disease and Related Dementia Neuropathology

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Evidence links air pollution to Alzheimer's disease (AD) and related dementias (ADRD), but mechanisms remain unclear.

We evaluated whether higher exposure to air pollution mixtures, including ultrafine particles (UFP), $PM_{2.5}$, black carbon, NO_x, and CO_2, was associated with greater neuropathologic burden at autopsy in the population-based Adult Changes in Thought study (N=797). We evaluated AD neuropathologic change, cerebrovascular pathology, as well as other neuropathologies, applying g-computation with adjustment for potential confounders and inverse probability weighting to improve population representativeness.

We observed associations between higher air pollution exposure and greater neuropathologic burden. Each standar ddeviation (SD) increment in the weighted pollution mixture was associated with a 7% higher prevalence of moderate or severe atherosclerosis (PR: 1.07, 95% CI: 1.00-1.14), an 8% higher prevalence of moderate or severe arteriosclerosis (1.08 [0.98–1.18]), and a 9% higher prevalence of microinfarct presence (1.09 [1.00–1.20]). Associations with atherosclerosis and arteriosclerosis were primarily driven by $PM_{2.5}$ and UFP, and they were stronger among participants who had resided in disadvantaged neighborhoods and among males. Additionally, conditional associations were observed for individual pollutants, including $PM_{2.5}$ with CERAD score (1.09 [0.99-1.20]) and NO_x with hippocampal sclerosis (1.62 [1.00-2.63]). Contrary to hypothesis, an inverse association was observed for moderate or severe cerebral amyloid angiopathy (0.80 [0.66-0.96]).

Higher exposure to air pollution mixtures and individual pollutants may be associated with greater ADRD neuropathologic burden, with the most consistent associations observed for vascular pathology and for $PM_{2.5}$ and UFP. Future studies should evaluate these associations in other population-based samples as exposure models improve and methods to address selection bias advance.

Challenges of Interpreting Machine-Learning-Based Ensemble Exposure Models in Air Pollution Epidemiology Studies Evaluated in NAAQS Reviews

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In recent years, the use of machine-learning-based ensemble models (MLEMs) to estimate air pollution exposures in epidemiologic studies has increased substantially. MLEMs use multiple machine learning techniques (e.g., random forest, neural network, and gradient boosting) in tandem, and may also incorporate ensemble stacking methods, such as generalized additive models, to improve predictions of air pollution exposures. Understanding the potential for exposure measurement error from the use of MLEMs, and the impact of this error on bias and precision of exposure and health effect estimates, is critical when assessing the epidemiologic literature to support reviews of national ambient air quality standards (NAAQS).

To examine the difficulties in interpreting MLEMs[1], we used U.S. EPA's Integrated Science Assessments (ISAs) as a case study. Epidemiological and exposure studies containing MLEMs used to estimate human exposure were identified during systematic literature searches for the ozone and oxides of nitrogen ISAs. These studies were further evaluated for their model structure, cross-validation results, and the potential for exposure measurement error to affect bias and precision of exposure and health effect estimates as part of the study evaluation process.

The abundance and differences in structures of MLEMs in literature will be highlighted, along with the challenges associated with interpreting MLEMs during study evaluation. Discussion topics will include why R^2 and root mean square error used in cross validation may not be sufficient to evaluate error in fine-scale population exposure estimates for pollutants with higher spatiotemporal variability. Suggestions will be made to improve interpretability for study evaluators.

MLEMs provide useful exposure estimates but may lack transparency. Understanding how to bridge the gap between environmental health study evaluators and both MLEM users and developers will be important for accurately incorporating their results into scientific health assessments used to inform NAAQS reviews.

Views expressed represent the authors and not EPA policy.

[1]Zhou et al. (2021) Ozone Concentration Forecasting Based on Artificial Intelligence Techniques: A Systematic Review. 232, 79. *Water, Air, & Soil Pollution.*

Rural outdoor air pollution exceeds urban levels in the Delhi megacity region

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India routinely experiences some of the highest concentrations of fine particulate matter ($PM_{2.5}$) air pollution in the world. Although most of India's population lives in rural areas and smaller cities, scientific and policy efforts to date have emphasized characterizing and controlling $PM_{2.5}$ in India's large cities. In contrast, there is limited understanding of air pollutant dynamics in India's rural and less urbanized areas.

In this study, we established a well-calibrated lower-cost $PM_{2.5}$ sensor network spanning a wide range of urbanicity (population densities: 300 – 30,000 people/km^2) outside and inside of Delhi. The network of 47 sites incorporated a carefully designed 150 km measurement transect to capture inflow and outflow conditions of the Delhi megacity, as well as stratified measurements in villages, small cities, and Delhi itself. We compare our results to satellite $PM_{2.5}$ products with spatial completeness, but less temporal coverage.

We report here on data from 5 months of operation (Jul - Nov 2024) spanning the cleanest and most polluted times of the year. $PM_{2.5}$ concentrations at non-urban sites consistently exceeded those at urban sites by about 20% during every month of our study. Analysis of diurnal $PM_{2.5}$ cycles showed sharp morning (approximately 06:00-10:00 LT) and evening (approximately 16:00-20:00 LT) concentration peak components (+25-75 µg/m^3 above the high baseline component concentrations of 60-100 µg/m^3) at non-urban sites that were absent at urban sites. Satellite spatial trends report the opposite trend, but only overpass around solar noon.

We attribute these events to widespread use of solid fuels for cooking, heating, and small-scale industry in suburban and rural settings. These striking enhancements in rural air pollution are missed by satellite remote sensing data and run contrary to the general societal perception that Indian cities are pollution hotspots relative to non-urban areas.

Neurocognitive Effects of Episodic Exposure to Wildfire Smoke: Mechanisms and Patterns of Exposure

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Population exposure to wildfire smoke (WFS) is increasing across North America. Despite growing evidence of the adverse health effects of WFS, there remain unanswered questions about the longer-term health risks and mechanistic pathways. We will use complementary experimental and epidemiologic studies to investigate how different durations, frequencies, and intensities of WFS exposure contribute to cognitive decline and chronic neurological conditions at the biological and population levels.

The experimental aim will use an order-randomized, crossover-controlled human exposure study to examine neurocognitive changes across different intensities of episodic WFS exposure. We will use filtered air and differing concentrations of freshly generated wood smoke to assess potential changes in brain function, memory, executive function, and psychomotor speed. The epidemiologic aim will use two observational studies, one population-based and one cohort-based, to examine the neurocognitive effects of multiyear WFS exposure. The first will focus on incident dementia and Parkinson's and the second will focus on the same neurocognitive endpoints as the experimental aim. Both aims will explore effect modification by individual characteristics including age, sex, genetics, and exposure patterns.

This study will elucidate how episodic WFS exposure contributes to the development of chronic neurological diseases in adults, identifying susceptible populations and high-risk exposures. We hypothesize that the experimental aim will demonstrate neurocognitive changes relevant to the development of chronic neurological diseases, with intensity-, age-, and genotype-dependent effects. We expect that the epidemiologic aim will demonstrate that multiyear WFS exposure contributes to cognitive decline and the onset of neurological disease, with differences in effect by patterns of exposure and sociodemographic characteristics.

The alignment of findings from the experimental and epidemiologic studies will bolster evidence of casual relationships. These findings may have implications for how public health and air quality professionals communicate and manage the risks of increasingly frequent and severe WFS events.

JW

Modeling Truck-Attributable $PM_{2.5}$ and Health Risks in Little Village, Chicago, Pre- and Post-COVID-19

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Little Village is a predominantly Hispanic/Latino neighborhood in Chicago bordered by Interstate 55, a major freight corridor. Residents face disproportionate exposure to truck-related air pollution, yet localized health impact assessments remain limited. This study aimed to (1) quantify changes in truck-related $PM_{2.5}$ emissions between 2019 and 2023, and (2) estimate associated health impacts and economic burden in this environmental justice community.

We adopted an integrated modeling framework linking U.S. EPA's Motor Vehicle Emission Simulator (MOVES5) (emission estimation), AERMOD (dispersion modeling), and U.S. EPA's Environmental Benefits Mapping and Analysis Program-community edition (BenMAP-CE) (health impact assessment). Truck emissions were modeled for January and July of 2019 and 2023 using local traffic data. $PM_{2.5}$ concentrations were estimated at 503 receptors across the neighborhood. Health impacts were quantified using established concentration-response functions for short-term (Zanobetti et al., 2014) and long-term (Krewski et al., 2009; Pope et al., 2015) mortality among adults.

Truck $PM_{2.5}$ emissions decreased by 48% in January and 31% in July between 2019 and 2023. Median gridded annual $PM_{2.5}$ concentrations declined from 12.81 ug/m^3 to 11.37 ug/m^3. The emission reductions were associated with 0.117 (95% confidence interval (CI): 0.109-0.125) and 0.599 (95% CI: 0.280-0.919) preventable premature deaths annually among adults aged 65+ and 35+, respectively, valued at approximately $0.97 million and $5.2 million USD. However, spatial analysis revealed that $PM_{2.5}$ hotspots persisted along the I-55 corridor, and annual concentrations (with background) exceeded the revised 9 ug/m^3 National Ambient Air Quality Standards (NAAQS) throughout the neighborhood.

While truck emission reductions yielded measurable health benefits at the neighborhood scale, freight corridor hotspots persist, highlighting the need for targeted interventions in environmental justice communities.

JW

A Decade of Progress: Quantifying Air Pollution Reductions in West Oakland, CA with Hyperlocal Monitoring (2015-2025)

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West Oakland, California has experienced disproportionate exposure to diesel-related air pollution due to its proximity to the Port of Oakland, major freeways, and freight corridors. In the last decade, California has increased statewide diesel truck emission regulations while Assembly Bill 617 (AB617) has directed targeted local mitigation investments through community-engaged planning. This study quantifies changes in air pollution across West Oakland spanning the decade of 2015-2025 to evaluate these multilevel interventions.

We augmented Google Street View vehicle measurements from 2015-2017 by deploying the UC Berkeley Mobile Air Pollution Laboratory to systematically map air pollution at a 30 m resolution on all accessible roads in West Oakland throughout 2025. We focus on black carbon (BC) and nitrogen oxides (NO, NO_2), but draw on additional extensive gas and particle phase air toxic measurements. Spatial patterns were analyzed across seven community-identified impact zones and supplemented with long-term regulatory monitoring trends contextualized against California and national networks.

We find substantial reductions of all pollutants between 2015 and 2025. On average, BC, NO and NO_2 decreased by 55%, 39% and 38% respectively, with most impact zones meeting community-designated air quality targets. The largest improvements were seen on diesel-heavy port and freeway corridors from which concentration gradients diminished, indicating reduced near-source exposures. West Oakland's improvements exceeded regional trends at other monitoring sites, suggesting local interventions provided benefits beyond statewide policies.

California's combination of statewide regulations and community-directed AB617 investments produced quantifiable air quality improvements in West Oakland over the last decade. Our hyperlocal monitoring strategy revealed spatial heterogeneity across zones that still exists, informing ongoing mitigation prioritization in the freight movement sector. These findings demonstrate the effectiveness of multilevel approaches combining regulatory standards with targeted, community-guided local investments in overburdened communities.

Health and Non-CO_2 Emissions from Point-Source Carbon Capture Technology

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Point-source carbon capture removes carbon dioxide (CO_2) directly from large, concentrated emission sources, such as heavy industry and electricity generation, before it enters the atmosphere. Related approaches, such as direct air capture and biological sequestration, remove CO_2 directly from the atmosphere. Captured CO_2 is then either stored or used for industrial purposes, including enhanced oil recovery and manufacturing.

There are a variety of approaches to point source carbon capture, typically using chemical or physical methods. These methods can be broadly categorized into those that separate CO_2 from mixed gas streams before or after combustion, and those that modify the combustion process to produce an exhaust stream that is primarily CO_2, thereby minimizing the need for separation.

At several recent convenings, experts discussed potential effects of large-scale carbon capture systems on human health and the environment. For example, one of the most common and well-established point-source carbon capture technologies is amine-based solvent extraction. However, amines can react with co-emitted or ambient compounds, forming byproducts, including nitrosamines and nitramines, a class of compounds with known or suspected human health hazards. In addition, some amines may volatilize and be released with flue gas, a phenomenon known as amine slip, and transform in the environment into chemicals of potential concern.

Carbon capture operations can also have co-benefits, including reductions in fine particulate matter ($PM_{2.5}$) and co-pollutants such as sulfur oxides and nitrogen oxides.

With guidance from a Special Panel of external experts, we synthesize the findings from expert convenings to date alongside the broader scientific literature. Here, we examine the current state of the science on the potential benefits and disbenefits of non-CO_2 emissions associated with carbon capture technologies.

Effect of ambient $PM_{2.5}$ exposure on hospital admissions due to heart failure and post-discharge survival rate in India

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Heart failure (HF) is a major cause of illness and death in India. However, there is limited evidence on the effects of ambient fine particulate matter ($PM_{2.5}$) exposure on HF outcomes in low- and middle-income countries. In particular, the effect of $PM_{2.5}$ on survival rates after heart failure is largely unknown. This study aimed to estimate the relationship between ambient $PM_{2.5}$ exposure derived from satellite data and hospital admissions for HF and to assess the connection between $PM_{2.5}$ exposure and post-discharge survival among HF patients.

We conducted a multicenter, time-stratified case-crossover study using data from the National Heart Failure Registry, which enrolled 10,850 patients admitted with acute decompensated HF across 53 hospitals in India between October 2018 and December 2020. Daily $PM_{2.5}$ exposure was estimated using a validated satellite-based model (1 × 1 km resolution) linked to patient geocodes. Conditional logistic regression was used to estimate odds ratios (ORs) for HF admissions per 10 µg/m³ increase in 3-day mean $PM_{2.5}$, adjusting for temperature and humidity. To examine the survival rate after HF hospitalization for 90 days, we used Cox proportional hazards models to estimate hazard ratios (HRs) associated with short-term $PM_{2.5}$ exposure.

Among 8,081 patients (mean age: 60 years; 69% men), $PM_{2.5}$ levels varied significantly across regions (range: 9.9–366.3 µg/m³). Each 10 µg/m³ increase in 3-day mean $PM_{2.5}$ was linked to 3.6% higher odds of HF admission (95% CI: 1.6-5.7%). These associations were consistent across sex, age groups, and HF subtypes. Each 10 µg/m³ increase in post-discharge $PM_{2.5}$ exposure was also associated with a 6.6% (4.4-9.0%) higher risk of mortality after discharge.

Higher ambient $PM_{2.5}$ exposure increases the risk of hospital admission for heart failure and reduces survival rates after discharge. These findings provide important evidence from India, demonstrating that even short-term rises in air pollution significantly impact vulnerable cardiac patients.

Analysis of 69-node Clarity $PM_{2.5}$ and NO_2 Air Quality Data in Chicago's Environmental Justice Communities

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We established a 277-node sensor-based air monitoring network in Chicago in 2025, in collaboration with the Chicago Department of Public Health (CDPH), using Clarity $PM_{2.5}$ and NO_2 sensors. The technical design of the network, based on the EPA Monitoring Network Design Criteria, was enhanced by qualitative lived-in experience data collected through community engagement sessions.

We performed a preliminary analysis of air quality data collected for PM2.5/NO_2 during August 31-October 31, 2025, to assess spatial and temporal trends in environmental justice communities on the west (zip codes: 60623, 60608, 60609, and 60616) and south sides of Chicago ((zip codes: 60617, 60633, and 60827), which has 69 sensor locations.

The $PM_{2.5}$ concentrations across seven zip codes varied from 1.3 µg/m^3 to 386.1 µg/m^3 (mean = 9.1 µg/m^3). The diurnal pattern of $PM_{2.5}$ showed a typical urban pattern, characterized by two daily peaks: one in the early morning (6 am to 8 am) and another at night (9 pm to 11 pm), with the lowest concentrations in the afternoons (3 pm to 5 pm). The NO_2 concentrations ranged from 2.1 ppb to 55.7 ppb (mean =14.5 ppb). The diurnal pattern also showed a typical urban pattern, characterized by two daily peaks: one in the early morning (6 am to 7 am) and another at night (8 pm to 9 pm), with the lowest concentrations in the early afternoon (1 pm to 2 pm).

While $PM_{2.5}$ concentrations on the West/Southeast Sides are in alignment, slightly higher NO_2 concentrations were observed on the West Side than on the Southeast Side. Further analysis of hyperlocal Clarity air quality data will support policies for air quality control and management, public health protection, urban and transportation planning, community advocacy, and empowerment efforts in Chicago, IL.

A critical review of concentration–response functions in assessing the health impacts of the electric vehicle transition

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As the electric vehicle (EV) transition accelerates, policymakers need scientific tools that clearly quantify who benefits from cleaner air, and where those benefits occur. Health impacts are commonly estimated using concentration–response functions (CRFs), which link changes in pollution levels to changes in health outcomes. While indispensable, small differences in how CRFs are implemented can yield counterintuitive results that, if unexamined, may misdirect policy and exacerbate environmental health inequities.

We reviewed published studies that apply CRFs to evaluate the EV transition, spanning endpoints from premature mortality, respiratory and cardiovascular hospitalizations, and respiratory morbidity to leukemia, as well as economic and productivity outcomes.

Across studies, estimates vary with methodological choices, including assumptions about concentration thresholds, treatment of non-tailpipe emissions, choice of CRF shape (linear vs non-linear), and approaches to uncertainty quantification. These choices materially affect both the size of estimated health effects and the confidence that can be placed in them.

Our synthesis highlights the need for greater methodological transparency and reflexivity: clear reporting of assumptions and system boundaries, equity-relevant spatial resolution, and routine sensitivity analysis, so that decisions align with legislative and policy guidance to use the best available evidence.

HEI energy

Assessing methane source contributions in the Permian Basin using satellite and ground observations

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Source attribution of methane emissions in unconventional oil and gas development (UOGD) regions can be improved by integrating ground observations with remote sensing. We developed a framework that couples continuous ground measurements, satellite-based flaring observations from the Visible Infrared Imaging Radiometer Suite (VIIRS), and MethaneSAT methane mapping over the western Permian Basin. We characterized spatial and temporal methane patterns and evaluate the relative roles of flaring, combustion, and venting in driving observed enhancements.

Ground measurements included time-resolved methane and meteorology, along with VOCs, nitrogen oxides, ozone, sulfur compounds, and radioactivity at a stationary site in Loving, New Mexico. Nonnegative matrix factorization (NMF) was applied to infer source-related factors from the multipollutant record. VIIRS Nightfire provided nightly flare detections and methane-equivalent estimates while MethaneSAT provided scene-based snapshots of column-averaged methane. Using Loving, New Mexico, as the center, we fused satellite variables within 50 km. Both ground and VIIRS were available from May 2023 to November 2024, and MethaneSAT provided a subset of available scenes in 2024. We used regression to relate methane and NMF factors to distance-weighted VIIRS flare counts, VIIRS methane equivalents, and MethaneSAT total-column methane.

Methane enhancements exhibited strong plumes and were correlated with hydrocarbons, particularly ethane and n-hexane (R^2 = 0.74–0.90). NMF indicated methane variability was dominated by fugitive/venting emissions, with smaller contributions from combustion and area sources. The association between methane and satellite-observed flaring was modest (r = 0.18), and per 10-flare increase within 50 km corresponded to a 1.1% increase in methane. In contrast, the fugitive/venting NMF factor increased by 5.0% per 10 flares, suggesting that flaring activity covaries more strongly with non-combustion methane than with methane concentration alone. Preliminary MethaneSAT scenes available during the study period showed column methane enhancements of the western Permian that were qualitatively consistent with the timing of regional methane episodes observed at the ground site.

Our ground data resolved short-lived plumes and chemical signatures, VIIRS characterized combustion activity and persistence, and MethaneSAT offers spatial context for basin-scale methane concentrations. Integrating these data provides complementary information to assess methane sources from UOGD in one of the most actively producing regions globally.

Development and Validation of a Long-Term Personal $PM_{2.5}$ Exposure Model and Its Association with Cardiovascular Markers in Indian Cohorts

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Long-term exposure to household air pollution (HAP), largely driven by biomass fuel use, contributes substantially to chronic cardiometabolic risk in low- and middle-income countries. However, estimating sustained personal exposure to fine particulate matter ($PM_{2.5}$) remains challenging due to reliance on short-term measurements and limited integration of ambient and household-level data.

To develop and validate a long-term personal $PM_{2.5}$ exposure model by integrating satellite-derived ambient $PM_{2.5}$, repeated 24-hour personal exposure measurements, and HAP indicators, and to examine its association with cardiovascular markers across multiple population-based cohorts in India.

We pooled data from three cohorts: HAPIN (n=799), APCAPS/CHAI (n=3,704), and PURSE-HIS (n=7,135). Personal $PM_{2.5}$ measurements were available from CHAI, while APCAPS and PURSE-HIS contributed carotid intima-media thickness (CIMT) and cardiometabolic outcomes. Log-linear mixed-effects models (LLMM) were developed using household- and individual-level HAP indicators-including cooking fuel, kitchen characteristics, ventilation, socioeconomic status, and household smoking-combined with satellite-based $PM_{2.5}$. Multiple machine-learning algorithms (Random Forest, XGBoost, Gradient Boosting Machine, Support Vector Machine, and Artificial Neural Network) were evaluated using 5-fold nested cross-validation. Exposure–response associations between predicted long-term $PM_{2.5}$ and CIMT were estimated after adjusting for key confounders.

XGBoost demonstrated the best predictive performance; however, LLMM showed comparable accuracy and was selected for interpretability and simplicity. Overall prediction performance was modest, with no model exceeding 35% explained variance for 24-hour personal exposure. To reduce exposure misclassification, predicted personal $PM_{2.5}$ was averaged over a five-year period. Each 10 $\mu g/m^3$ increase in long-term personal $PM_{2.5}$ was associated with a 0.0041 mm increase in CIMT across combined cohorts, with substantially stronger associations observed in APCAPS (0.036 mm; 95% CI: 0.033–0.039). Effects were more pronounced among individuals with low physical activity levels.

A parsimonious parametric exposure model performed comparably to advanced AI/ML approaches for predicting personal $PM_{2.5}$ exposure. Although short-term prediction accuracy was limited, averaging exposure over time may substantially reduce misclassification. The observed associations with subclinical atherosclerosis underscore the cardiovascular relevance of long-term household air pollution exposure in India.

Traffic-Related Air Pollution, Lipoproteins, and Cardiovascular Disease Risk in the VITamin D and OmegA-3 TriaL (VITAL)

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This study examines cross-sectional and longitudinal associations of traffic related air pollution (TRAP) with incident cardiovascular disease (CVD, including coronary heart disease [CHD] and stroke) and with lipid-related biomarkers in the VITamin D and OmegA-3 TriaL (VITAL) population.

We used satellite-based exposure models to estimate residence-specific ambient concentrations of NO_2, $PM_{2.5}$, and 11 $PM_{2.5}$ components and applied source apportionment methods to identify and quantify contributions from tailpipe, non-tailpipe, and road dust $PM_{2.5}$. Lipid and lipoprotein biomarkers were assessed by standard lipid tests and nuclear magnetic resonance spectroscopy. Stratified Cox proportional hazards models estimated associations (per interquartile range of exposure) of long-term TRAP exposure with CVD, and multivariable linear regression models examined associations with biomarkers.

During 11 years of follow-up, 2,314 CVD events (1,167 CHD, 523 strokes) occurred in 25,747 participants (50.6 % women, 19.8 % Black, mean baseline age 67.1 yrs) from 50 U.S. states. While baseline annual means of NO_2 and total $PM_{2.5}$ mass were not associated with the combined total CVD endpoint, exposure to road dust was associated with CHD (HR= 1.14 [1.02-1.27]), and exposure to non-tailpipe sources was borderline associated with stroke (HR= 1.15 [1.00-1.31]). Among 16,710 participants with biomarkers, road dust exposure was associated with increased concentrations of larger triglyceride-rich lipoprotein (TRL) particles, larger TRL average size, greater TRL-triglyceride and TRL-cholesterol content, increased total triglycerides, and decreased concentrations of large LDL and large HDL particles. By contrast, both NO_2 and tailpipe $PM_{2.5}$ had the opposite lipid profile, and non-tailpipe $PM_{2.5}$ was not associated with lipids.

Exposure to road dust was associated with increased risk of incident CHD and correlated with a shift in the TRL distribution towards larger, more cholesterol and triglyceride enriched TRL particles. By contrast, non-tailpipe $PM_{2.5}$ exposure was moderately associated with higher risk of incident stroke but was not associated with lipids.

Health equity and e-commerce: Evaluating warehouse-based electrification and land use policies

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The rapid rise of e-commerce and home delivery has intensified concerns about the uneven impacts of commercial vehicle traffic in cities. Populations of color face disproportionate exposure to delivery-related traffic despite ordering fewer packages, driven in part by proximity to warehouses and distribution centers (W&D). This proximity is associated with increased exposure to harmful pollutants like NOx, and while overall vehicle emissions have declined, disparities in exposure have persisted. These inequities have prompted regulatory responses, including Indirect Source Rules, zero-emission vehicle mandates, and land use controls such as moratoriums and conditional use permits. However, given the place-based nature of pollution, addressing disparities likely requires strategies beyond fleet electrification.

This study evaluates the health effects of freight-related air pollution from e-commerce W&D in historically marginalized neighborhoods in Seattle and New York City. It compares baseline conditions (2017) with future scenarios (2034) focused on electrification and land use shifts, particularly "proximity logistics," which aims to shorten delivery distances through neighborhood-integrated facilities.

We develop a mixed-method integration of qualitative and model-based approaches across four phases: (1) estimating household-level delivery demand using NHTS and synthesized populations; (2) simulating link-level emissions under varying operating conditions; (3) estimating $PM_{2.5}$ concentrations and associated health effects using InMAP and epidemiological functions; and (4) assessing disparities and conducting sensitivity analyses across electrification and land use scenarios.

While results are preliminary, the study highlights the importance of combining technological and land use strategies to advance more equitable freight systems.

Hybrid dispersion and chemical transport modeling frameworks for characterizing sources of ambient hydrocarbons in the Permian Basin

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Emissions from oil and gas operations contribute to elevated air pollutant concentrations in oil and gas production regions. Attribution of elevated concentrations to specific oil and gas sources is challenging because the sources are extensive and their emissions have highly complex spatial, temporal, and chemical emissions profiles.

In this work, detailed emissions modeling is coupled with dispersion- and chemical transport modeling to evaluate the sources of light alkanes (ethane and propane) measured at an air quality monitor in the Permian Basin in west Texas.

Local sources (< 50km away) are shown to produce the largest observed concentrations, but concentrations from distant sources (≥ 50 km away) are, at times, dozens of ppbv and contribute, on average, 20% of observed concentrations. At some times, distant sources are predicted to contribute more than 90% of the observed concentrations. Atmospheric chemistry is not predicted to significantly impact ethane and propane concentrations from local sources, but concentrations from distant sources and of higher molecular weight reactive hydrocarbons (e.g., benzene) can be decreased by up to 40% due to reactive losses, depending on the species and the season.

These findings suggest modeling approaches for predicting ambient air quality in complex and extensive oil and gas regions like the Permian Basin require detailed treatment of both local and regional sources as well as atmospheric chemistry.

Assessing On-Road NO_2 Emissions and Concentration Responses to Congestion Pricing Using High-Resolution CMAQ Modeling

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Transportation-related air pollution (TRAP) is a major contributor to urban nitrogen dioxide (NO_2) exposure in densely populated regions. Congestion pricing is a policy tool to reduce traffic volumes and emissions, with outcomes dependent on toll levels and spatial design. This study evaluates how alternative congestion pricing scenarios influence on-road NO_2 across the Washington, D.C. region using a high-resolution air quality modeling framework.

Congestion pricing impacts on on-road emissions were represented through scenario-based adjustments to the Neighborhood Emission Mapping Operation (NEMO) inventory. Total on-road NEMO emissions were separated into gasoline and diesel components using county-level fractions from the 2017 National Emissions Inventory, enabling differential responses by vehicle class. Gasoline and diesel emissions were independently scaled using traffic volume ratios between congestion pricing and base scenarios to capture demand reduction and rerouting. The adjusted components were recombined to generate scenario-specific on-road emissions inventories used as inputs to high-resolution CMAQ simulations.

Six congestion pricing scenarios were evaluated, varying toll level, cordon size, and inclusion of a pass-through highway, with impacts quantified as percentage changes in daily on-road NO_2 emissions. Across the domain, low-toll scenarios produce reductions of approximately 10–20%, while high-toll scenarios yield roughly twofold larger decreases. Higher tolls generate more spatially coherent reductions, with benefits intensifying from low- to high-toll cases across all cordon designs. Scenarios including the pass-through highway exhibit stronger and more concentrated reductions along major traffic corridors and within the urban core. Under low tolls, highway inclusion creates distinct reduction corridors largely absent without the highway; under high tolls, these corridor-aligned benefits intensify and expand. Cell-by-cell comparisons indicate that high-toll scenarios scale low-toll responses, producing larger reductions at consistent locations.

These results highlight the importance of toll magnitude and corridor coverage in congestion pricing design. High-resolution modeling suggests that targeting high-emission corridors delivers greater NO_2 reductions than diffuse interventions.

Geostationary Satellite Observations Resolve Transboundary Urban Ozone Dynamics and Their Association with Sleep Health

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Ground level ozone remains one of the most widespread secondary air pollutants affecting urban populations, yet its short term spatial and temporal variability is difficult to characterize. Conventional monitoring networks provide accurate measurements but are spatially sparse, and most satellite instruments observe each location only once per day. These limitations restrict the ability to capture intra urban exposure gradients and rapidly changing ozone conditions. The U.S. Mexico border region is a rapidly urbanizing transboundary corridor where complex emissions, strong photochemistry, and limited monitoring infrastructure create substantial uncertainty in exposure assessment. The objective of this study was to combine geostationary satellite observations from the TEMPO mission with machine learning methods to produce high resolution ozone exposure estimates and examine their relationship with sleep health in a population based border cohort.

Hourly observations from the TEMPO satellite were integrated with meteorological variables, land use data, emissions inventories, night light intensity, and outputs from chemical transport models to estimate ground level ozone at 1 km spatial resolution across Texas and the U.S. Mexico border region. Machine learning models were trained using ground based measurements from EPA Air Quality System stations and evaluated through cross validation and independent ozonesonde observations from the Synergistic TEMPO Air Quality Science campaign. Annual maximum daily 8 hour average ozone exposure was assigned to participants in the Border Health Research Cohort. Associations between ozone exposure and sleep outcomes were examined using multivariable linear regression models adjusted for age, body mass index, and socioeconomic status.

The model reproduced observed ozone concentrations with strong predictive performance, achieving a cross validation R^2 of 0.90 and a root mean square error of 5.29 ppb. Predicted fields captured seasonal patterns and spatial contrasts across Texas, including elevated ozone levels in inland metropolitan regions and along the El Paso Ciudad Juárez urban corridor. When linked with cohort data, higher ozone exposure was associated with poorer sleep health. Each 1 ppb increase in annual maximum daily 8 hour average ozone corresponded to a 0.75 point increase in the Pittsburgh Sleep Quality Index global score. Additional associations were observed for subjective sleep quality and sleep duration.

Geostationary satellite observations combined with machine learning provide a practical framework for resolving fine scale urban ozone variability in regions where monitoring networks are limited. The results also suggest that ambient ozone exposure may influence sleep health in vulnerable border populations even at concentrations below regulatory standards. Integrating high resolution atmospheric observations with epidemiological cohorts can improve exposure assessment and support research on the broader health implications of urban air pollution.

JW

Mapping the spatial distribution of sub-10 nm particles in Raleigh, NC

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Ultrafine particles below 10 nm constitute an important but poorly characterized component of urban air pollution from freight and goods movement operations, with substantial implications for air quality and public health. This study aimed to quantify particle number concentrations in the 2.5-10 nm size range from mobile sources, particularly from diesel trucks and aircraft operations, utilizing an innovative mobile measurement platform.

We deployed a mobile platform equipped with multiple condensation particle counters paired with real-time video recording for simultaneous concentration measurement and visual source identification. Systematic sampling campaigns were conducted in Raleigh, North Carolina, USA, targeting major highway segments and Raleigh-Durham International Airport (RDU). Aircraft impacts were evaluated through combined field observations and atmospheric dispersion modeling. Laboratory investigations using a diesel generator are underway to examine how various fuel additives affect ultrafine particle emissions.

Highway measurements revealed 2.5-10 nm particle concentrations averaging 10,000-15,000 particles/cm^3 (10 times background levels), with peak values of 70,000 particles/cm^3 where these ultrafine particles comprised over 70% of total particle numbers. Video analysis revealed "super-emitter" diesel freight trucks as primary contributors. Spatial analysis demonstrated concentration decay to background within 120 meters from roadways. At the airport, aircraft taxiing and takeoff operations were identified as significant 2.5-10 nm particle sources, with meteorological conditions influencing dispersion beyond the airport perimeter.

This research identifies freight-related ultrafine particle sources and their spatial distributions, providing critical data for exposure assessment. The integrated measurement-visualization methodology facilitates targeted mitigation strategies, from detecting high-emission vehicles to assessing fuel additive effectiveness for emission control.

The Bronx Environmental Health Summer Training Program: High School Students Explore Multi-Pollutant Exposures in Their Community

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The South Bronx community in New York City (NYC) not only experiences some of the highest air pollution and noise levels in NYC but is also less likely to have members of their community pursue higher education including careers in the biomedical field. To address these issues, we have developed a partnership with a public high school in the South Bronx. In 2022, we introduced a year-long STEM course, in which students received hands-on training to build air pollution and noise monitors. Students then deployed the monitors in the South Bronx and analyzed the measured data. The objective has been to sustain these efforts for years to come, to engage youth from the South Bronx in environmental health research and prepare them for a career in environmental health science (EHS).

We established a structured, on-site summer EHS research program for high school students from the Bronx, the Bronx Environmental Health Summer Training program. Each year, a group of students (n=12) is recruited to participate in a 3-week long STEM summer program in Columbia's engineering school, conduct EHS research in their community, receive training in scientific writing and tutoring to submit successful college applications.

We recruited 12 student trainees who participated in the program during the summer of 2025. All students participated in the SHAPE program, and 11 of the 12 students also completed the research module. Students developed research hypotheses related to air, noise, or light pollution, and conducted measurements with suitable low-cost environmental monitors.

We successfully implemented a structured EHS research program for high school students from the Bronx that not only allows them to conduct research on multipollutant exposures in their community but also prepares them for a career in EHS.

HEI

Efficacy of Vehicle Emission Control Interventions in Ameliorating Air Pollution Exposure and Health Burdens in Marginalized Communities

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Air pollutants from the transport sector are substantial drivers of negative and often inequitably distributed health outcomes. Clean air regulations have successfully reduced transport-related pollution, but disparities in exposure and health impacts persist, suggesting that targeted policies may be needed. However, assessing the efficacy of policies designed to reduce inequitable air quality and health burdens requires highly spatially resolved and accurate characterizations of air quality and population exposure.

To advance air quality characterization and regulation assessment, this project leverages multiple state-of-the-science tools, including satellite observations from the geostationary TEMPO instrument, a high-resolution statistics-based land-use regression model (LURM), vehicle telemetry data, and a high-resolution regulatory-grade chemical transport model (CTM). These tools are applied over the Chicago, Il region to improve an inventory-based emissions dataset, better constrain air pollutant exposure, identify overburdened communities, and assess the recent TropOMI-based finding that inventory-based emissions datasets underestimate heavy-duty vehicle pollutant emissions in warehouse-adjacent environments.

TEMPO observations of warehouse-adjacent environments confirm elevated NO_2 downwind of warehouses, as well as notable diurnal fluctuations driven by meteorology, chemistry, and truck activity. LURM results indicate marginal but robust improvement of NO_2 characterization when warehouse location and size are considered. Truck telemetry data indicates substantial differences in heavy-duty truck emissions compared to EPA estimates due to changes in idling location and magnitude. Simulated policy scenarios, including the EPA Clean Trucks Rule and the Advanced Clean Truck Rule, reveal substantial NO_x and $PM_{2.5}$ emission reductions, with CTM simulations to constrain pollutant concentration changes and health impacts underway.

This work advances air pollution exposure characterization capabilities and provides a rigorous assessment of the efficacy of transport-related emission reduction policies to ameliorate harmful and disparate exposure and health outcomes.

Advancing Children's Environmental Health Knowledge and Partnerships

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The Children's Health Protection Division aims to ensure that the U.S. Environmental Protection Agency's policies and actions protect children from environmental exposures by consistently and explicitly considering the health impact of early life exposures on lifelong health in all human health decisions. Children may be at greater risk to environmental contaminants than adults due to differences in behavior, biology, and their unique temporal windows of developmental susceptibility during which irreversible health effects may manifest. The effects of early life exposures to criteria pollutants and air toxics may also arise in adulthood or in later generations. In 2025, the Make America Healthy Again (MAHA) Commission released the Make Our Children Healthy Again Assessment and Strategy Reports. The MAHA Assessment identified chemical exposure as one of four potential drivers behind the rise in childhood chronic disease that present opportunities for progress. The MAHA Strategy outlines a set of federal actions to address the root causes of childhood chronic disease across principles of advancing critical research to drive innovation and increasing public awareness and knowledge. EPA is working across the agency, and in collaboration with other federal agencies, on several concrete activities to address these recommendations and further provide information, tools, and partnerships to improve children's health outcomes and the health of future generations.

This poster will provide an overview of ongoing efforts within EPA to reduce exposure to environmental contaminants and promote children's environmental health.

Views expressed represent those of the author and not EPA policy.

Silent Threats in the Air: Linking $PM_{2.5}$ and Black Carbon to Pulmonary Disease Across Karachi

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Air pollution - particularly fine particulate matter ($PM_{2.5}$) - is a major public health concern associated with cardiopulmonary disease. This study aimed to analyze the relationships between black carbon (BC), $PM_{2.5}$ levels, and the occurrence of pulmonary diseases in Karachi, Pakistan.

Daily $PM_{2.5}$ samples were collected over six consecutive weeks in each quarter from four monitoring sites across Karachi. A time-series analysis using a Generalized Linear Model (GLM) was applied to estimate the relative risks associated with BC and $PM_{2.5}$ exposure and various pulmonary diseases. Analyses were stratified by site, sex, age group, and lag days to capture temporal and demographic variations in risk.

Associations between $PM_{2.5}$ exposure and pulmonary diseases varied across monitoring sites. Significant associations were found, where $PM_{2.5}$ levels were linked to increased risk of shortness of breath (SOB) among both sexes, with females showing a stronger risk. At the industrial/residential site, males exhibited a higher risk of total pulmonary disease. Age-stratified analyses indicated elevated pulmonary disease risks among individuals aged 0–50 at the Macro, KU, and Malir sites. In this age group, $PM_{2.5}$ exposure was associated with SOB and asthma, with significant effects observed at delayed lag days. Elevated BC levels were significantly associated with asthma in patients aged 0–50 and with chronic obstructive pulmonary disease (COPD) among elderly individuals at the KU site.

The study underscores the substantial pulmonary health risks posed by exposure to $PM_{2.5}$ and BC in Karachi. Vulnerable populations - particularly younger individuals and the elderly - face heightened risks of asthma, SOB, and COPD associated with pollutant exposure. These findings highlight the urgent need for targeted air quality interventions and public health strategies to reduce pollution levels and mitigate associated health impacts in major cities of Pakistan.

Daily NO_2 Estimates with Rigorous Spatiotemporal Uncertainty Quantification for Use in Health Studies

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Satellite data have greatly improved our ability to estimate air pollution levels for health research, but challenges remain in understanding how accurate these estimates are and how much uncertainty they carry across space and time. We propose to develop a comprehensive framework to predict nitrogen dioxide (NO_2)—a traffic-related pollutant linked to harmful health effects—while addressing limitations in current approaches.

We will develop a novel Bayesian machine learning ensemble model to predict daily NO_2 levels for 2024 across the contiguous US at high spatial resolution by integrating retrievals from two satellite instruments (TROPOMI and TEMPO) and three chemical transport models, alongside meteorological data, emissions, and land-use information. We will rigorously quantify prediction uncertainty. We will also develop a robust validation framework to test model accuracy and compare it to standard approaches, which we hypothesize overestimate performance by failing to fully consider spatiotemporal dependencies. Our transdisciplinary team combines expertise in atmospheric science, exposure assessment, environmental epidemiology, and machine learning.

All code, NO_2 predictions, and uncertainty estimates will be shared through an open-access platform to support transparency, reproducibility, and use in health studies.

HEI's Undergraduate Summer Fellowship Program

Hlina Kiros, Allison P. Patton, Samantha Miller, Lenny Howard, Ellen Mantus

Health Effects Institute, Boston, MA

Hands-on research provides foundational platforms for undergraduate students to learn about and discover potential educational and career pathways. The HEI Summer Fellowship Program, run in partnership with ISES and ISEE, supports paid, mentored environmental health research experiences and professional development seminars for highly qualified and motivated students who might not otherwise have a similar opportunity.

Since 2023, the program has supported 24 undergraduate students, and the number of fellow applications has grown from 52 applications in 2023 to 201 applications from 31 states in 2026. Similar to last year, we anticipate supporting nine fellows in the 2026 cohort. Fellowship alumni have shared that this experience provided them with crucial research skills and professional development training. Mentors have shared their appreciation for the ability to integrate talented students into their research without funding concerns.

This program is generously funded by the American Chemistry Council, Burroughs Wellcome Fund, and individual donors.

Predicting cardiometabolic health and air pollution in future transportation landscapes using agent-based models (TRANSCAPE)

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Ambient air pollution is among the top five risk factors for the global disease burden, with compelling evidence linking fine particulate matter ($PM_{2.5}$) to various health issues. Particles from mobile sources (traffic-related air pollution, TRAP) are strongly linked to cardiometabolic disease exacerbation, likely due to their small size (mostly in the fine and ultrafine range below 2.5 µm and 100 nm, respectively) and chemical composition (e.g., trace metal, black carbon). However, our understanding of the effects of non-tailpipe emissions (brake and tire wear) is still inconclusive. Additionally, the impacts of future changes in the transportation landscape on cardiometabolic health are understudied.

We develop an advanced exposure model from a combination of comprehensive urban-scale air quality modeling using the Parallelized Large-Eddy Simulation Model (PALM) with a representation of human activity using the Multi-Agent Transport Simulation (MATsim) agent-based model. This exposure model is linked to strong epidemiological evidence, allowing us to use an existing population cohort (Cooperative Health Research in the Region of Augsburg, KORA) to estimate individual health effects, focusing on clinical and subclinical markers of cardiometabolic disease. Personal Exposure Monitors (PEMs) are used, amongst other methods, for exposure model evaluation.

We present preliminary findings from the KORA cohort personal exposure measurements and evaluate performance of the PEMs against reference monitors. A tagging mechanism for traffic emissions within the PALM model is detailed. We detail the matching of MATsim agents to KORA cohort participants. Finally, we outline the plan for statistical analysis and discuss the suite of planned future climate scenario simulations.

Gathering ground truth from the KORA cohort has ended and quality assurance is underway. Model developments are progressing to prepare the integrated modeling system for baseline simulations.

Improving characterization of freight-related emissions within SMOKE-MOVES at equity-relevant spatial scales

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Medium- and heavy-duty vehicles (MHDVs) account for only ~10% of on-road vehicles yet disproportionately emit health-harming pollutants and greenhouse gases. Current regulatory-grade emission modeling approaches rely on national vehicle activity assumptions and spatial surrogates. Both inputs inadequately capture localized freight-specific on-road and idling behavior. This can systematically misrepresent MHDV emission totals and localized hotspots in dense urban freight hubs, such as Chicago, IL.

We use the EPA's SMOKE–MOVES emission modeling framework to simulate annualized on-road MHDV emissions of NO_x and $PM_{2.5}$ across a Chicago metro domain at ~1 km. Freight activity is refined by incorporating telemetric idling data from LOCUS and augmenting the spatial allocation of combination trucks with vehicle-class–specific traffic counts from the Federal Highway Administration. Distributional impacts are evaluated at the census-tract level to quantify population-weighted mean emissions (PWE), and relative and absolute disparities across demographic population groups.

Incorporating telemetric idling data increases localized MHDV emissions near freight facilities and airport-adjacent areas. Refining combination truck on-road activity redistributes emissions away from passenger vehicle dominated corridors within Chicago's urban core. When combined, these refinements reduce domain-average PWE by 0.34 tons/year (-6.5%) for NO_x and 0.02 tons/year (-6.7%) for $PM_{2.5}$, relative to the EPA default configuration. Despite aggregate decreases, changes in PWE vary in both magnitude and direction across demographic groups. While PWE of NO_x decrease across all other race/ethnic groups, Hispanic/Latino populations see a slight increase (~0.05 tons/year), shifting absolute disparities from below the domain average to marginally above it, while simultaneously increasing relative disparities by ~7%.

As emission models are applied at equity-relevant spatial resolutions for downstream health assessments, accurate representation of emission sources becomes increasingly critical. This work demonstrates that assumptions suitable for coarse-resolution regulatory modeling can break down at finer scales, leading to systematic misrepresentation of freight-related emissions and downstream impact assessments.

Ambient Fine Particulate Matter Components and Liver Fat and Stiffness in Adolescents: Stronger Associations in PNPLA3 I148M Carriers With Evidence of Metabolic Mechanisms

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Exposure to fine particulate matter ($PM_{2.5}$) has been linked to metabolic dysfunction–associated steatotic liver disease (MASLD), but the responsible chemical components and mechanisms remain unclear. PNPLA3 I148M variant (GG vs. GC/CC), the strongest known genetic contributor to MASLD, may interact with exposure to amplify risk. We aimed to examine associations of $PM_{2.5}$ components with hepatic fat fraction (HFF) and liver stiffness (LS) in Latino adolescents with obesity and assessed whether metabolomic pathways mediate PNPLA3 genotype-specific effects.

Baseline data from two Los Angeles studies (N=113) were analyzed, including Magnetic Resonance Imaging (MRI)-measured HFF and LS, PNPLA3 genotype, and serum metabolomics and lipidomics. Residential addresses were used to estimate visit-year average exposures of 15 components. Associations were assessed using linear regression and G-computation models, with PNPLA3 genotype as an effect modifier. Moderated mediation analyses evaluated whether metabolomics and lipidomics features mediated PNPLA3 genotype-specific effects, followed by pathway enrichment to interpret biological functions.

Individual $PM_{2.5}$ components and mixture were predominantly positively associated with HFF and LS, with stronger effects in PNPLA3 GG carriers. Potassium (K), bromine (Br), elemental carbon (EC), lead (Pb), and copper (Cu) were identified as key components. GG carriers exhibited more metabolomic and lipidomic mediating features (n=550) than GC/CC carriers (n=196). In GC/CC carriers, few pathways were enriched. In contrast, GG carriers showed broad pathway involvement, including carbohydrate, lipid, and amino acid metabolism, as well as signal transduction and endocrine-related pathways, many of which are central to MASLD pathophysiology. Significant total mediation effects were observed exclusively in GG carriers.

$PM_{2.5}$ components, especially combustion-related, are associated with adverse liver outcomes in adolescents, with stronger effects in PNPLA3 GG carriers. Differential metabolomic and lipidomic pathways may underlie genotype-specific susceptibility linking air pollution to MASLD risk.

Bayesian Ensemble Estimation of Uncertainty in High- Resolution Satellite-Based Air Pollution Predictions: Patterns and Driving Factors

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Satellite data have expanded national air-pollution exposure assessment, but estimates for NO_2, O_3, and $PM_{2.5}$ remain difficult to use confidently because their uncertainty is uneven and often undocumented. Errors are greatest in rural areas, underserved communities, and aggregated units such as ZIP codes, where misclassification can weaken epidemiologic inference. This proposal seeks to address that gap by generating daily 1×1 km exposure surfaces for the contiguous United States from 2018–2023. The main goals are to build a harmonized database, identify where predictions are least reliable, and support uncertainty-aware health research.

To achieve this, the project will assemble a unified daily 1×1 km database linking satellite retrievals, EPA and independent monitors, meteorology, CMAQ outputs, emissions inventories, wildfire data, and land-surface predictors. It will train several base learners for each pollutant and combine them in a Bayesian ensemble that yields full posterior exposure distributions rather than single estimates. Performance will be tested with spatial, temporal, clustered, and external validation, and random forest analyses will identify the main drivers of uncertainty. The team will also extend software tools and apply them in the ENVISION cohort.

These efforts will produce a validated, public national exposure product for NO_2, O_3, and $PM_{2.5}$ with daily concentrations and uncertainty metrics for every grid cell. The results will show how uncertainty varies by pollutant, season, region, emissions context, and extreme events, helping researchers judge when satellite-based estimates are most dependable. The project will also release open-source R packages, a dashboard, gridded and ZIP Code products, and user documentation. By showing how uncertainty-aware exposures affect bias, calibration, power, and interpretation, it will make satellite-derived pollution data more transparent, reproducible, and useful for health studies.

BREATHE: Bridging REalms for Assessment of Traffic-related Health Effects

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Traditional approaches to studying exposure to traffic related air pollution (TRAP) rely on aggregate, rule based transportation models. We instead apply BEAM CORE, a MATSim-based open-source multi-agent framework that integrates land use, vehicle ownership, activity-based travel, energy modeling, and freight supply chains, to the nine county San Francisco Bay Area. Its spatial and temporal resolution and explicit representation of demographics and individual behavior enable counterfactual analysis, letting us quantify how changes in vehicle technology, policy, and infrastructure affect TRAP exposure and health outcomes while holding other factors constant.

We couple emissions and air quality models with BEAM CORE by mapping vehicle types and emission processes from EMission FACTor (EMFAC) to BEAM CORE fleets and by incorporating source receptor matrices from InMAP and AERMOD to estimate pollutant concentrations. EMFAC and InMAP integrations are complete, and we have identified key inputs needed to run AERMOD and produce link level concentration patterns. We also incorporate power sector emissions to represent marginal electricity generation under electric vehicle adoption scenarios. Scenario levers include passenger and freight powertrain composition and telecommuting, and an expert advisory board is defining a third, Bay Area specific scenario. Health models will combine scenario exposure estimates with exposure response functions from HEI Special Report 23 to estimate changes from baseline. Baseline health data include mortality (all cause, ischemic heart disease, lung cancer) and childhood asthma and acute lower respiratory infections.

Adult current asthma ranges from 5.9% to 14.1% across 1,759 census tracts. While AERMOD sensitivity analyses at 12 sites, emission release height (1 m, 3.5 m, 5.5 m, 9 m) explains 75.7% of variance in ambient concentration on average (SD 9.25%). Emission rate (0, freeway, city) explains 12.8% (SD 4.22%), and urban rural classification explains 1.59% (SD 2.18%). AERMOD results will guide refinement of spatial resolution within the InMAP grid.

Assessing Mortality and Morbidity Associated with $PM_{2.5}$ Exposure Using Hospital Records and Beta Attenuation Monitor Data in Kampala, Uganda

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$PM_{2.5}$ concentrations in Kampala frequently exceed World Health Organization guidelines, posing a significant public health risk. Major sources of pollution in the city include waste burning, solid-fuel use, unpaved roads, and aging vehicle fleets. Exposure to air pollution is associated with a wide range of adverse health outcomes, including increased hospitalizations and mortality. Despite growing evidence linking air pollution exposure to nearly all major health conditions, few studies in Kampala have directly examined the relationship between $PM_{2.5}$ exposure and hospitalization. This study aims to assess the previously unexplored association between $PM_{2.5}$ exposure and hospitalization rates across Kampala.

Using daily mortality and morbidity hospital records and $PM_{2.5}$ data logged at one-hour intervals—yielding 24 daily observations—from a Beta Attenuation Monitor (BAM) at the U.S. Embassy in Kampala between 2017 and 202. We apply a Granger causality test to understand the predictive association between air pollution and mortality and morbidity. Analyses include individuals across age groups with conditions such as tuberculosis, COVID-19, asthma, wheezing, diabetes, respiratory conditions, hypertension, pulmonary disease, heart disease, bronchitis, pneumonia, and cough, for both morbidity and mortality outcomes.

Results indicate a predictive relationship between $PM_{2.5}$ and daily hospitalization rates.Results indicate a predictive relationship between $PM_{2.5}$ and daily hospitalization rates.

Understanding this relationship is critical for informing public health interventions and policies to mitigate the adverse effects of air pollution on Kampala’s rapidly growing and predominantly young population.

Quantifying Wildfire Contributions to Ambient Polycyclic Aromatic Hydrocarbon (PAH) Levels over North America Using a Chemical Transport Model

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Polycyclic aromatic hydrocarbons (PAHs) are hazardous air pollutants with well-established health risks, and wildfires are a major natural source. However, the spatial and temporal contributions of wildfire emissions to regional PAH levels remain poorly quantified. This study examines the distribution and decadal trends of EPA 16 PAHs over North America using the GEOS-Chem chemical transport model.

We developed a new wildfire PAH emission inventory based on land-cover-specific emission factors and updated dry matter and burned area data from GFED5 and conducted simulations for the 2000s and 2010s.

Model results capture the overall magnitude of observed PAH concentrations, though point-to-point agreement is limited by model resolution and sparse observations. Wildfire-related PAHs peak in summer, contributing ~23.5% of total concentrations, with highest levels over wildfire-prone regions in Canada, Mexico, and the western United States.

Results indicate an increasing contribution of wildfires to ambient PAH levels over recent decades, highlighting the importance of improved emissions data, higher-resolution modeling, and expanded observations for more accurate health effects assessment.

Unmasking the Invisible: Natural Gas Power Plants as Hidden Sources of Urban Ultrafine Particles

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Natural gas is widely perceived as a "clean" energy source, yet ultrafine particle emissions from gas-powered facilities remain poorly characterized. This study aims to identify and quantify sub-10 nm particle emissions from natural gas co-generation plants in an urban setting and assess their potential public health implications, particularly as AI and data centers drive rapid expansion of distributed natural gas infrastructure near populated areas.

We conducted a year-long atmospheric monitoring campaign in Raleigh, NC, using continuous ambient measurements of particle number concentrations and size distributions. Integrated AERMOD dispersion modeling was employed to identify source contributions from three NC State utility plants. Statistical analyses examined meteorological drivers of particle concentrations, with particular focus on wind direction patterns and their correlation with episodic particle burst events.

Gas-powered co-generation plants produced sub-10 nm particle concentrations exceeding 3.7×10^{5} cm^{-3} at 270 m from the source. Particle burst events persisted for days with stable modal diameters, confirming primary emissions rather than regional nucleation. Remarkably, particle growth rates of 95-136 nm hr^{-1} exceeded those from automobile exhaust or coal-fired plants by over an order of magnitude. Wind direction emerged as the dominant predictor, with 73% of high concentration events occurring when winds originated from the nearest cogeneration plant.

Our findings challenge the perception of natural gas as a "clean" energy source by revealing significant ultrafine particle emissions from co-generation plants. These sub-10 nm particles, which readily penetrate the respiratory system and cross the blood-brain barrier, represent an unmonitored health threat as particle number concentrations lack specific regulatory limits in the US. With increasing reliance on "efficient" combined heat and power systems near urban areas, comprehensive emission monitoring of natural gas infrastructure is urgently needed to protect public health.

VOC emissions from oil and gas wells in Ontario, Canada

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Oil and gas development started in the nineteenth century in southeastern Ontario, leaving a legacy of approximately 60,000 wells (both producing and non-producing), of which around half remain undocumented. These wells are associated with environmental and safety issues, including methane emissions, explosion hazards, groundwater contamination, and air quality degradation through the release of volatile organic compounds (VOCs). VOC emissions contribute to tropospheric ozone formation and can cause adverse human health effects. In particular, benzene, toluene, ethylbenzene, and xylenes (BTEX) are VOCs that can impact human health due to their neurological and respiratory impacts, as well as the carcinogenicity of benzene. Although VOC emissions from producing wells are accounted for in the Air Pollutant Emissions Inventory by Environment and Climate Change Canada, VOC emissions from non-producing oil and gas wells are currently not included and remain poorly characterized.

In this study, we quantified VOC emissions from 30 wells in southeastern Ontario (producing and non-producing) using a static chamber approach and thermal desorption tubes, which were subsequently analyzed by gas chromatography coupled with mass spectrometry in laboratory.

In total, we detected the presence of 16 different VOCs and found BTEX compounds in 25% of the surveyed wells, with emitted gas concentrations ranging from 6.9 to 58.3 ppmv. While VOCs were mainly detected at producing wells, we found evidence of their presence (including BTEX compounds) in 47% of the surveyed leaking non-producing wells. Furthermore, we characterized the origin of the leaking methane, which was predominantly thermogenic and therefore more likely to be associated with aromatic VOCs such as BTEX, in contrast to microbial methane, which typically produces dry gas dominated by methane.

Together, these results highlight the need to further investigate VOC emissions from producing and non-producing wells, to assess their potential impacts on population health, and to better inform national emission inventories.

Estimating the impact of vegetative cover and traffic on $PM_{2.5}$ exposure in South Phoenix school zones

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High-resolution exposure data is critically lacking at schools, especially in arid climates. These unique environments warrant specific investigation of factors that influence air quality.

Using data from 2021, we investigated the localized drivers of daily $PM_{2.5}$, specifically vegetation density (NDVI) and traffic (road length density), and the limitations of centralized regulatory monitoring in capturing school-level exposures in Phoenix, Arizona.

We identified that annual average $PM_{2.5}$ concentrations exhibited a disparity across the eight monitored schools (6.23 to 11.90 $\mu g/m^3$). Further, the school with the highest road length and lowest NDVI (within a 500m radius) recorded the highest annual $PM_{2.5}$ levels, while the school with the lowest road density and the highest NDVI recorded the lowest levels. Individual mixed-effects models revealed that monthly NDVI had a significant negative association with $PM_{2.5}$ ($p < 0.001$), while road length density showed a non-significant positive association. Correlations between individual school sensors and the nearest regulatory monitoring station exhibited clear spatial decay. While the school closest to the regulatory monitoring station (within 1 km) showed high correlations ($r = 0.88$), representativeness dropped to $r = 0.57$ at a school 4 km away. This underscores the necessity of hyper-local sensing, as centralized monitors become less representative of actual exposure at farther schools. We developed an explanatory model for daily $PM_{2.5}$ at the schools using regional $PM_{2.5}$ as the primary temporal driver, with monthly NDVI and road length as spatial modifiers. The model demonstrated high predictive utility, with fixed effects explaining 49% of the variance and a total explained variance of 61%.

In conclusion, NDVI and road density provided critical contributions to capture localized exposures. Work is underway to expand and validate the model's transferability to other years and schools, offering a pathway for a robust and scalable framework for estimating school-level $PM_{2.5}$ using only publicly available data.

RB

Estimating subgroup- and region-specific causal exposure-response curves and designing optimal policies for air pollution and mortality

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In the US, certain marginalized groups experience heightened exposure to fine particulate matter ($PM_{2.5}$) and may also be more susceptible to its adverse health impacts as a result of social structural forces. Health effects of $PM_{2.5}$ may also vary over space due to differing sources and climate patterns. Characterizing the heterogeneity in health impacts of pollutant exposures across space and groups is a critical first step to designing more effective policies to reduce air pollution health burdens and inequities. In this work, we develop causal inference methods to estimate spatially-varying subgroup-specific causal exposure-response curves (ERC) and leverage them in the design of optimal $PM_{2.5}$ reduction policies.

Our proposed method is a variant of the Bayesian Additive Regression Trees (BART) model, a tree ensemble method well-regarded for its performance in causal inference. To accommodate data sparsity when estimating spatially-varying subgroup-specific causal ERCs, we propose a modularized variant of BART that allows for sharing information across subgroups while maintaining computational scalability. We evaluate the performance of our method via simulation studies and apply it to nationwide Medicare data to estimate spatially-varying $PM_{2.5}$ and mortality ERCs for each of the three largest racial/ethnic groups in the US. We also integrate the ERCs into a Monte Carlo-based policy design procedure to generate optimal $PM_{2.5}$ reduction policies for each racial/ethnic group.

Our simulations demonstrate that, in the context of data sparsity for some groups/locations, the proposed method provides ERC estimates with reduced bias and mean square error compared to all existing methods considered. We report climate region-specific $PM_{2.5}$-mortality ERC estimates for each of the non-Hispanic white, Black, and Hispanic racial/ethnic groups and visualize the optimal $PM_{2.5}$ reduction policies that minimize mortality burdens for each group.

Our proposed approach allows for accurate estimation of spatially-varying subgroup-specific causal air pollution ERCs and for downstream optimal policy design.

Same Pollution, Different Numbers. AQI Hub: Comprehensive Documentation for Global Air Quality Indices

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Air Quality Index (AQI) is the primary way the general public interacts with air quality data through alerts and apps. It provides a comprehensive way to express potential exposure to multiple pollutants (e.g., $PM_{2.5}$, PM_{10}, NO_x, etc.). AQIs are shaped by public health considerations, atmospheric chemistry, and political factors. Consequently, countries and other regulatory bodies develop their own AQIs to reflect their particular air quality standards and health guidelines. However, because of this no single methodology exists for converting measurements to AQIs. Despite well-established studies on the effects of pollution on human health, these different AQIs use different breakpoints, algorithms and rules to communicate the effects of pollution. As a metric that is built from aggregated and often averaged values over varying periods of time, an AQI can obscure details about the pollutants and how they may affect human health.

This poster presents AQI Hub (https://aqihub.info), a comprehensive web-based resource documenting the methodology and background on over 35 different AQIs worldwide. The platform covers national indices from the United States, China, India, and South Korea, as well as sub-national systems from Colombia and Australia, spanning six continents. Detailed pages document major systems including China's AQI, South Korea's CAI (Comprehensive Air-quality Index), the European CAQI, and India's AQI. Through interactive graphics and tools, the platform illustrates similarities and differences between different AQIs. For example, it features an interactive calculator that allows one to simulate conversions of air quality measurements to AQIs.

As an open-source and open-access platform, AQI Hub is a resource to help translate air quality data measurements to and from AQIs from all around the world, and help people to better assess their exposure to air pollution and take appropriate actions to safeguard their health and well-being.

JW

Development of an Emissions Inventory for Illinois Warehouses for Modeling the Implementation of an Indirect Source Rule

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Over 2 million Illinois residents – disproportionately from Hispanic/Latinx, Black, and low-income communities – live within a half mile of a warehouse. Because warehouses aggregate multiple emission sources and are located near populations of higher susceptibility, multifaceted emissions characterization and regulation is critical for developing impactful air-quality policies. One such policy under consideration in Illinois is the Indirect Source Rule (ISR), modeled after California's 2021 regulation. The ISR aims to reduce freight emissions by regulating facilities rather than vehicles. This study develops a baseline emissions inventory for Illinois warehouses with the intention of comparing warehouse-related emissions to an ISR scenario.

We integrate multiple datasets from academic freight studies, federal agencies, and industry-reported warehouse activity to construct a harmonized database of warehouse operations and emissions. Warehouse-related emissions include trips from medium- and heavy-duty trucks and passenger vehicles navigating to-and-from the warehouse site, on-site idling and exhaust, on-site yard-truck and forklift activity, and on-site building-level fuel use (e.g., HVAC systems and generators). To analyze impacts on nearby residents, warehouse locations are overlaid with census-tract level demographic data to assess co-location between emissions and at-risk populations.

This work provides the first comprehensive warehouse emissions inventory for Illinois, estimating health-harming primary emissions at warehouse, county, and census tract levels. Preliminary estimates indicate that medium- and heavy-duty trucks make up ~80% of fine particulates and ~85% of volatile organics from warehousing. Emission estimates differ from the EPA's National Emissions Inventory, and results confirm prior findings of co-location between warehouse-related emissions and communities with higher susceptibilities to poor air-quality.

This work establishes a foundation for evaluating the air-quality and health implications of the potential adoption of an Illinois ISR. By quantifying warehouse emissions, this work supports the development of targeted policies that could more effectively reduce the disproportionate impact of warehousing on disadvantaged and marginalized communities.

RB

What's in the air? Engaging Native American youth in the Northern Plains to reduce air pollution

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Over recent decades, air pollution levels in the United States have declined due to regulatory investment, however, these benefits have largely excluded Native American communities. Our project seeks to characterize sources of air pollution and engage youth in the formation of a community-based air monitoring network.

We partnered with two high schools in two Indigenous communities in South Dakota. At each school we engaged 2-3 students and a teacher to install QuantAQ Modulair units and PurpleAir units to measure $PM_{2.5}$ and PM_{10}. The students documented any air quality anomalies they observed through photovoice to embrace the concept of 'ground truthing.'

From May 2024 to July 2025, sensors measured PM across four sites. Across all sites, PurpleAir sensors measured mean $PM_{2.5}$ and PM_{10} concentrations of 6.7 and 8.9 µg/m^3 and 10.2 and 16.0 µg/m^3, respectively, in the summer. QuantAQ sensors measured mean $PM_{2.5}$, and PM_{10} concentrations of 4.7, and 21.2 µg/m^3 overall and 9.2, and 23.4 µg/m^3, respectively, during the summer. On average daily $PM_{2.5}$ measurements exceeded the EPA annual standard (9 µg/m^3), for 9.3% (4.2 - 13.5%) for all observation days. Youth identified wildfires and heavy-duty vehicles as major pollution sources.

Photovoice methods grounded research activities into youth's lived realities and enabled their situated knowledge of the region to inform analysis and interpretations. These findings demonstrate the importance of youth-engaged, sovereignty-centered approaches to air quality management and the need for expanded air quality monitoring on tribal lands.

Evaluating Turnover of On-Road Medium- and Heavy-Duty Diesel Fleets in the United States

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Many older freight vehicles continue to be operated without modern air pollution control technologies, with some areas of operation concentrated near human populations. Thus, air pollutant emissions from older medium- and heavy-duty diesel vehicles continue to affect health, and their transition to newer technologies likely carries substantial exposure and health benefits for communities residing near operation hotspots. Potential economic and societal opportunities and barriers also likely exist.

Therefore, HEI formed an expert Heavy-Duty Diesel Vehicle Fleet Turnover Panel to provide information on the current state of knowledge on the potential exposure and health benefits, opportunities, and barriers associated with accelerated fleet turnover in the United States. The Panel was charged with comparing potential impacts from new medium- and heavy-duty vehicles (regardless of the specific technologies) to those from model years prior to the 2010 requirements for diesel particulate filters and selective catalytic conversion.

The Panel identified several factors that affect fleet turnover and associated impact assessments, including fleet sizes and characteristics of their ownership and operation, assumptions about vehicle fuels and powertrains, and assumptions used in underlying data sources for vehicle activity and emissions. In parallel, the Panel is overseeing an HEI-funded urban-scale case study of the potential opportunities and barriers associated with diesel fleet turnover in Chicago. The landscape of medium- and heavy-duty vehicles and the case study will be published in an HEI Special Report, together with a chapter synthesizing the findings and their implications for policy and science.

The Special Report is expected to inform government and industry, identify literature gaps, and guide HEI's continuing work on the health effects of the legacy diesel fleet.

HEI

Novel Exposures, Birth Outcomes and Environmental Justice in a Changing Transportation Landscape

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Transportation–including roadway vehicles, aircraft, and trains–is a dominant source of particulate matter (PM) in many urban areas. After years of successful controls on tailpipe emissions, and future mandates to restrict the sale of internal combustion vehicles (ICVs), the relative contribution of non-tailpipe emissions from brake and tire wear, aircraft and trains continues to increase. Additionally, electric vehicle (EV) charging may contribute an additional source of PM in urban areas.

To address these non-tailpipe sources, we have performed mobile monitoring downwind of Los Angeles International Airport (LAX), and several two-week stationary monitoring campaigns around trains, LAX, EV charging stations and at sites intended to elucidate the impact of brake and tire wear PM emissions. The stationary sampling is complete, as are filter-based measurements of oxidative potential, mass and black carbon.

While a recent study indicated higher concentrations of particulate matter near EV charging stations, our measurements of 12 paired EV and gas station sites shows no significant difference in any of our measurements between the two types of fueling stations. For rail, we observe a moderate distance-decay gradient in oxidative potential and black carbon, but not mass in the community adjacent to high rail traffic. In a different community adjacent to a rail line, however a distance-decay gradient was less clear; a gradient is evident in the samples closest to the rail line, but pollutant levels at these sites are not higher than the household furthest from the rail line. Other factors contributing to the difference in the observed gradients between the two sites may include: the second site carries fewer trains, and the background concentrations of $PM_{2.5}$ mass and black carbon were both considerably higher during the two-week sampling period for the second rail site compared to the first.

We have collected a dataset of about 150 hours of mobile data both downwind and around LAX, covering a variety of wind directions and hours of the day when aircraft are active. Results from mobile monitoring under the flight path of the approach to LAX indicate that ultrafine particles are substantially elevated over a large swath of Los Angeles, extending at least 13 km from the airport. The plume is usually a few km wide, and its precise location moves as the wind direction shifts. We will present comparisons with earlier data collected around LAX, and explore the relative contribution of incoming aircraft vs. on-airport emissions from creating the large plume.

Beyond Single Pollutants: Analysis of Air Pollution Mixtures and Chronic Pain in U.S. Children

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Chronic pain affects 15–25% of children and is linked to adverse physical and mental health outcomes. As climate change progresses, children may face a greater risk of chronic illness from air pollution exposure, yet pediatric data on chronic pain and pollution remain limited, particularly in the United States. This study examined associations between ambient air pollutants and chronic pain in U.S. children and whether these associations differ by metropolitan status.

Data from children aged 0–17 years (n=55,162) in the 2023 National Survey of Children's Health were linked to 2023 U.S. Environmental Protection Agency state-level air pollution estimates. Parents reported whether their child had "chronic or frequent pain" in the past 12 months. Survey-weighted logistic regression estimated associations between particulate matter, gases (ozone, nitrogen oxides, carbon monoxide, sulfur dioxide), lead, and chronic pain, adjusting for age, sex, asthma, and household income. Models additionally tested pollutant-by-metropolitan status interaction terms and stratified by metropolitan residence type. Principal component analysis (PCA) characterized pollutant mixtures and assessed whether patterns differed by urbanicity.

Sulfur dioxide (SO_2) showed a statistically significant positive association with chronic pain (odds ratio ≈1.08 per interquartile-range increase; $p \approx 0.004$; $q \approx 0.03$), although this association was less consistent across metropolitan strata and mixture models. PCA identified interpretable pollutant mixtures, but these mixtures were not clearly related to chronic pain.

Combustion-derived pollutants and markers of fossil fuel burning, like SO_2, may reflect broader mixtures relevant to pediatric pain through pathways involving inflammation and oxidative stress. The modest SO_2 association may suggest that ambient combustion-related pollution could play a role in pediatric chronic pain alongside more proximal clinical and psychosocial factors. Future studies using finer-scale exposure metrics and longitudinal designs are needed to clarify whether higher local SO_2 levels or specific sources meaningfully contribute to chronic pain risk in children.

Beyond $PM_{2.5}$: Growing impacts of wildfire on ozone pollution and associated mortality burden in the United States

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Increasing wildfire smoke represents a substantial threat to air quality and human health in the United States and globally. However, prior studies mostly focus on health impacts of smoke fine particulate matter ($PM_{2.5}$) and have overlooked impacts from other pollutants, most notably ozone.

Here, we quantify changes in ground-level ozone concentrations during fire smoke episodes across the contiguous U.S. using surface air quality measurements, satellite data, and machine learning models.

We find that ground-level ozone increases by as much as 6.9 ppb (16%) at certain U.S. monitoring locations when averaged over smoke days. Importantly, the spatial and temporal patterns of smoke-related ozone are weakly correlated with those of smoke $PM_{2.5}$. Applying established exposure–response relationships for all-source ozone, we estimate that smoke-related ozone exposure leads to an average of 2,045 excess deaths per year (95% confidence interval: 1,325–2,755) over 2006–2023. This mortality burden corresponds to 15.8% of deaths attributable to smoke $PM_{2.5}$. The increasing mortality associated with smoke-related ozone has offset declines in non-smoke ozone mortality over time and, by 2023, is equivalent to more than 60% of smoke $PM_{2.5}$–attributable mortality.

Together, these results demonstrate that assessments focused on a single pollutant substantially underestimate the health burden of wildfire smoke and underscore the importance of multipollutant exposure and joint health estimation in evaluating the public health impacts of smoke pollution.

A Framework for Assessing Cumulative Environmental and Public Health Effects of Data Centers

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Data centers underpin the digital infrastructure relied on by everyone in society. As their number and size expand to meet growing computational needs, there is a critical opportunity to maximize the advantages they offer to communities and society at large. However, as with any rapidly advancing form of development, there is also potential for unintended outcomes. The combined economic and societal benefits alongside potential consequences related to air quality, noise, water consumption, and energy demand can affect public health in complex ways.

Cumulative impact assessment (CIA) offers a way to broaden both scientific inquiry and policy discussions by accounting for the full range of environmental, social, and economic factors that shape health outcomes. By taking this more comprehensive perspective, decision-makers are better equipped to maximize potential benefits while minimizing potential adverse outcomes. In the context of the fast-paced expansion of data centers, CIA can be a valuable tool to inform siting and permitting processes, and to fill in critical information gaps. A key challenge, however, is the absence of flexible approaches for conducting these assessments that can be applied to a wide array of contexts.

To build on existing efforts to develop CIA frameworks and to help address this gap, the Health Effects Institute (HEI) developed a framework for cumulative impact assessment titled *Roadmap to Health: Assessing Adverse and Beneficial Environmental, Social, and Economic Cumulative Exposures*. This framework is designed to provide clear, practical, and transparent guidance that can be applied across diverse settings and use cases. Accompanied by a checklist, it supports consistent evaluation of cumulative environmental effects at national, state, and local levels, as well as in research and educational contexts. Here we describe the HEI cumulative impacts framework and demonstrate its use in evaluating a proposed data center, highlighting how cumulative impact assessment can support more informed, forward-looking environmental decision-making.

Health Impacts of Non-Exhaust Emissions (NEXUS): An International Partnership to Improve Research Infrastructure and Capacity for Evaluation and Policy

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Non-exhaust emissions (NEE) from brake, tyre and road wear are increasingly dominant contributors to urban particulate matter as exhaust emissions decline. Yet NEE remain poorly characterised in terms of measurement, exposure modelling, toxicology and population health impact. NEXUS aims to deliver a step change in infrastructure, methodological capability and research capacity to enable robust evaluation of NEE health effects and inform European and North American policy.

NEXUS is structured around five Work Packages (WPs) and a Cross-Cutting Theme. WP1 (Priority Setting) integrates literature review, stakeholder engagement and policy analysis to define knowledge gaps and produce a strategic framework. WP2 (Early Career Researcher Capacity) establishes an international accelerator programme with placements, bursaries and interdisciplinary supervision. WP3 (Infrastructure Enhancement) develops a global infrastructure audit, shared instrument pool (including oxidative potential and wheel-arch sampling systems), standardised facility agreements, characterised NEE materials for inter-laboratory comparison, and open-access downscaled NEE emissions datasets. WP4 (Improving Study Design and Linkage) advances spatiotemporal exposure modelling, time-series methods, semi-experimental designs and cohort linkage protocols. WP5 delivers five pump-priming projects spanning toxic potency ranking, short-term health effects modelling, long-term cohort feasibility, mobile hotspot mapping and COPD exposure study development. The Cross-Cutting Theme embeds stakeholder engagement, knowledge mobilisation and sustainability.

NEXUS will generate prioritised research agendas, harmonised measurement protocols, open NEE exposure datasets, characterised reference materials, improved causal inference methods, and pilot data to support major international grant applications. It will also produce policy-facing reports, adverse outcome pathway frameworks and trained early-career researchers.

We are recruiting organizations, researchers and practioners to join our work across all work packages which will result in the development of large multinational research projects.

Improving Classroom Air Quality in Schools Near the Port of Los Angeles: Results from a HEPA Air Cleaner Study

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CARB promotes using air cleaning devices for reducing exposures to particulate matter indoors through several incentive programs such as CARB's Supplementary Environmental Projects and Community Air Protection Incentive programs that benefit communities impacted by disproportional levels of air pollution. This study, coordinated with the Los Angeles Unified School District, was conducted at schools near the Port of Los Angeles, major highways, industries, and oil refineries, where air quality has historically been poor and investigated additional indoor air quality benefits that air cleaning devices can provide in schools with existing HVAC systems with MERV-13 filtration.

A block-randomized crossover trial was conducted to assess the benefits of portable HEPA air cleaners in 350 instructional classrooms across 17 elementary schools in Carson, Torrance, Harbor City, and Lomita which had existing HVAC filtration. Each classroom received the intervention for a full school year during 2022–2023 and 2023–2024 using air cleaning devices with HEPA level or non-HEPA (control) filtration. PM levels were assessed via IQAir AirVisual Pro monitors in selected classrooms. Monthly and school-year average PM concentrations and standard deviations were calculated for both groups and compared using Welch's two-sample t-test. A linear mixed effects model tested the impact of having devices with HEPA filters on $PM_{2.5}$.

For classrooms with HEPA level filtration devices, average schoolyear PM2.5 was 39.9% lower (0.581 $\mu g/m^3$; $p < 0.001$) and infiltration of outdoor $PM_{2.5}$ into classrooms was 13.8–82.4% lower than classrooms with non-HEPA level devices depending on the school.

Few studies have evaluated the benefits of devices with HEPA level filtration in schools which have existing MERV 13 filtration HVAC systems especially in a post-COVID world. This study shows that additional filtration can further improve classroom PM levels, particularly in environmentally burdened communities.

Health Effects of Particulate Matter Air Pollution in India: A Systematic Review and Meta-Analysis Protocol

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Air pollution is a leading risk factor for premature death and poor health in India. The health burden associated with both ambient and household particulate matter (PM) exposure continues to rise. Numerous epidemiological studies have examined associations between PM exposure and adverse health outcomes. However, findings remain fragmented across locations and health outcomes. A comprehensive synthesis of evidence specific to India is needed to quantify pooled effect estimates. Through this systematic review and meta-analysis, we aim to quantify the associations between short-term and long-term exposure to ambient particulate matter ($PM_{2.5}$ and PM_{10}) and household air pollution (measured by fuel use) and multiple health outcomes in India.

We included observational studies that report quantitative associations between exposure to $PM_{2.5}$ and/or PM_{10}, as well as household fuel use, and predefined health outcomes (e.g., all-cause mortality, cardiovascular disease, respiratory disease, asthma, stroke, adverse birth outcomes, and diabetes). In addition, we included studies using proxy measures such as primary cooking fuel type (e.g., biomass, coal, kerosene versus LPG or electricity) or solid fuel use. We excluded non-observational studies, animal studies, burden-of-disease analyses using secondary exposure-response functions, and occupational studies.

A comprehensive search has been conducted in Embase, Ovid Medline, Scopus, and Web of Science through September 18, 2025. In total we found 18,513 articles across the databases and around 4,838 were resolved for duplicates. Two independent reviewers have screened titles/abstracts and full texts. A total of 497 studies met the inclusion criteria. An additional 50 studies were identified through manual searches, resulting in 547 studies included for full-text screening. Abstract and full-text screening was carried out using Rayyan (Systematic Review Management Software).

Data extraction will include study characteristics, location, population demographics, exposure metrics, health outcomes, confounders, and effect estimates. Risk of bias assessment will be carried out using the ROBINS-E tool. Effect estimates will be standardized per 10 μg/m³ increase in PM levels. Meta-analysis will be conducted to calculate pooled estimates. The protocol will be registered with PROSPERO prior to data extraction.

This review will identify and synthesize the available epidemiological evidence and summarize the health effects associated with exposure to particulate matter in India. The findings from this review will help to inform the design of targeted interventions and support the advancement of air quality management strategies in India.

Compounding socio-environmental health inequities: Simultaneous impacts of multiple air pollutants, temperature, and social stressors on pediatric seizures and epilepsy in New York City

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Prior research has independently linked air pollution, temperature variation, and social stressors to adverse neurological outcomes. However, their combined contribution as co-occurring environmental and social exposures, particularly for vulnerable populations such as young children, remains poorly understood.This study applies covariance-based structural equation modeling (CBSEM) to quantify how multiple air pollutants, temperature, and social stressors simultaneously influence pediatric seizure- and epilepsy-related hospital visits in New York City (NYC).

Age-standardized, census tract–level annual visit rates for seizures and epilepsy among children aged 0–4 years were derived from state-wide electronic health records (2005–2019). Annual averages of fine particulate matter ($PM_{2.5}$), black carbon, nitrogen dioxide, nitric oxide, ozone, sulfur dioxide, and temperature metrics were assigned at matching spatial and temporal scales. Violent crime rates were calculated from geocoded police reports, and 54 sociodemographic indicators of poverty, education, unemployment, race/ethnicity, and other social stressors were incorporated from the American Community Survey. CBSEM simultaneously estimated the direct, indirect, and covariance pathways between environmental exposures, social stressors, and pediatric seizures and epilepsy hospital visit rates.

$PM_{2.5}$ was positively associated with hospital visits, while nitric oxide showed an inverse association. Violent crime rates and racial minority population proportion were positively associated with visits, whereas areas with higher proportions of children under five showed inverse associations. Covariance structures indicated significant clustering of air pollution with social disadvantage. Patterns remained consistent in sensitivity analyses restricted to first-time visits and pollutant levels below current National Ambient Air Quality Standards.

Findings suggest that the burden of pediatric seizures and epilepsy in NYC is shaped by the structural co-occurrence of environmental pollution and social inequity. Air quality improvements alone may be insufficient; parallel investments in violence prevention, social infrastructure, and community protection may be essential to narrow pediatric health disparities in urban settings.

A Novel, Timely Tool to Track Hazardous Air Pollutants (HAPs), Cumulative Health Effects, and Emission Sources in Houston, Texas

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Communities near industrial sources experience higher concentrations of hazardous air pollutants (HAPs) and the associated human health risk than those farther away. While there are many air monitoring tools publicly available, few exist that track HAPs and related health risks, and the information available is not easily digestible to non-scientists or may face significant data lags. Recognizing the need to provide timely, hyperlocal HAP tracking with associated cumulative health impacts in a manner understood by the community, a local health department, environmental advocacy group, and academic partner came together to develop a new tool in Houston.

We assessed historical air monitoring data to identify the HAPs that pose the greatest risk based on screening level exceedances and developed real-time heatmaps indicating HAP concentration levels and their respective cumulative health impacts. We provided interpretations of the concentration values compared to screening levels for residents to understand magnitude of risk. We also developed geospatial maps for community residents to identify their closest air monitor(s) and locations of emissions sources in their area, with type and tonnage of pollutants emitted at each source.

We identified 13 unique HAPs to be included in the tool, with 7 unique pollutants identified as high priority. An example fenceline community had 5 air monitors nearby and 25 HAP emitting facilities that released a total estimated 183 tons of pollutants in 2020, including benzene, 1,3-butadiene, xylenes, and more.

This tool fills a gap in air pollutant tracking as the first to provide real-time data regarding HAP concentrations, health risks, and emissions sources, with interpretations that effectively convey this information to the community. With this tool, community members can be aware of their local risks and hazards, and use this information to advocate for action when pollutant concentrations in their area are in unacceptable exceedance of screening limits.

JW

Ambient Air Quality and Health Impacts of PM2.5 from U.S. Residential Wood Combustion

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Residential wood combustion (RWC) is the primary heating fuel source in just 2% of U.S. homes and a secondary source in just 8%. However, the U.S. Environmental Protection Agency's National Emissions Inventory (NEI) estimates that RWC emissions contribute 8% of total annual U.S. fine particulate matter ($PM_{2.5}$) emissions and 99% of annual $PM_{2.5}$ emissions from residential sources, suggesting that nationwide ambient $PM_{2.5}$ concentrations could be substantially reduced if RWC were curtailed. Despite its substantial contribution to $PM_{2.5}$ emissions and the newly updated RWC emissions estimates in the 2020 NEI, recent estimates of U.S. air quality, health, and distributional impacts of RWC are lacking.

We use the two-way coupled Weather Research and Forecasting (WRF) and Community Multiscale Air Quality (CMAQ) model to estimate the contribution of winter-time RWC to $PM_{2.5}$ concentrations across the contiguous United States (CONUS) at the 4 km resolution. These concentrations were then used to estimate census tract-level population exposures, premature all-cause mortality, and distributional disparities using an established concentration–response functions and demographic data from the American Community Survey.

We find that RWC contributes 2.43 $\mu g/m^3$ (21.9%) of winter population-weighted mean $PM_{2.5}$ concentrations, with the highest weighted concentrations located in major cities including Philadelphia (4.52 $\mu g/m^3$), Denver (6.22 $\mu g/m^3$), Seattle (4.84 $\mu g/m^3$), and Minneapolis (5.47 $\mu g/m^3$). We estimate that $PM_{2.5}$ exposure from winter-time residential wood combustion is associated with ~8,600 (95% CI 6,500 – 9,600) premature deaths per year. Moreover, non-white communities are disproportionately affected by both RWC-related $PM_{2.5}$ concentrations and associated mortality, especially in urban areas.

We suggest that policies targeting RWC emissions could be an attractive strategy to mitigate air pollution, reduce public health impacts, and address health disparities.

Assessing Air Quality and Health Benefits of MHDV Fleet Conversion in Chicago Using Enhanced Emissions Modeling and Stakeholder Insights

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Substantial reductions in diesel fueled Medium and Heavy Duty Vehicle (MHDV) emissions cannot be achieved with normal fleet turnover rates, suggesting that an accelerated transition to lower emission MHDVs may be needed to rapidly reduce air pollution and associated health burdens. Here, we: (1) identify Chicago communities experiencing the highest exposure to MHDV related pollutants; (2) simulate air pollution changes when older MHDVs are replaced; and (3) examine challenges and opportunities for MHDV fleet turnover through engagement with logistics and trucking industries and residents of disproportionately affected neighborhoods.

We integrate complementary air quality modeling and fleet behavior research. First, we advance neighborhood scale exposure modeling by improving inventory based MHDV emissions estimates. This includes updating MHDV idling patterns with LOCUS telemetric data and on-road activity patterns with truck count data. Next, we run air quality simulation scenarios with (a) no pre-2010 MHDVs and (b) with pre-2010 MHDVs replaced with newer, lesser emitting vehicles. We then quantify changes in pollutant exposure for each scenario. Second, we pair this with participatory fleet behavior research through a Fleet Manager Survey developed with detailed feedback from industry experts. The survey captures fleet assets, operational context, renewal and innovation adoption considerations, and perceived outlook, barriers, and opportunities. Because high level barriers alone cannot explain whether, where, and when MHDV turnover occurs, this component provides essential insight into firm level decision rules and how cost, infrastructure, and technology constraints shape fleet behavior.

Refined emissions modeling produced improved neighborhood-scale estimates of MHDV-related PM and NO_x emissions relative to the EPA Baseline. Integrating LOCUS and truck count data revealed localized idling and activity hotspots and identified communities with the greatest potential reductions under accelerated fleet turnover. Fleet-transition modeling generated renewal-timing profiles and modernization portfolios, while qualitative responses highlighted poorly understood decision drivers and evolving technology expectations.

This interdisciplinary, co created approach identifies where emissions reductions and health benefits would be greatest and supports the design of incentives and strategies to accelerate equitable MHDV fleet modernization.

Insights from the use of sub-daily $PM_{2.5}$ in respiratory health analyses

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Public health assessments of $PM_{2.5}$ typically rely on daily 24-hour averages; however, $PM_{2.5}$ varies on hourly timescales due to emissions, chemistry, and meteorology. This study has two goals: 1) to explore sub-daily peaks and associated respiratory outcomes and 2) to look at misclassification of hourly exposure with the Air Quality Index (AQI) and potential respiratory risk differences.

This study used an hourly 3-km gridded $PM_{2.5}$ dataset for California (2018–2023), aggregated to ZIP-code levels via population-weighted centroid assignment. For the first goal, daily means and sub-daily metrics (e.g., 1-hour maximum) were calculated and compared using Spearman coefficients. For the second goal, hourly and daily values were assigned AQI categories using 2024 EPA-defined $PM_{2.5}$ breakpoints to compare hourly category frequencies. To evaluate differences in health risks across daily and subdaily metrics, we queried UCSF Health system asthma- and COPD-related hospitalizations and emergency department visits (EDVs) identified by ICD codes for 2018 to 2023, and daily ZIP-code counts as a function of daily or sub-daily $PM_{2.5}$ metrics and daily AQI categories or hourly AQI counts using conditional quasi-Poisson models adjusted for temperature and temporal trends.

Across California, the average 1-hour maximum $PM_{2.5}$ was approximately twice the 24-hour mean over the 6-year study period. When scaled to metric-specific IQR, the average daily $PM_{2.5}$ had the lowest risk (IRR: 1.014, 95% CI: 1.007, 1.022) whereas the 1-hour max had the highest risk (IRR: 1.018, 95% CI: 1.009, 1.027), though all metrics had overlapping intervals. Secondly, hours that occur on days with the same day-level AQI category span a wide range of $PM_{2.5}$ concentrations. For example, 18% of hours on days labeled “Unhealthy for Sensitive Groups” exceeded the category’s threshold, 55.4 μg/m^3. However, for “Unhealthy for Sensitive Groups” and higher risk AQI categories, the positive risk associated with hourly AQI exceeded daily AQI after ~10-18 hours.

Sub-daily $PM_{2.5}$ metrics identify acute exposures missed by daily averages and that materially change AQI characterizations. Incorporating hourly exposure metrics could improve acute-risk communication and interventions during pollution events.

RB

A Prospective Cohort Study of Air Pollution and Postpartum Depression

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Postpartum depression (PPD) affects 10-20% of birthing people and has adverse consequences for the birthing person and their infant. Air pollution has been associated with neuropathology in the general population, yet its association with PPD is less well studied. Our objective is to examine the independent and joint effects of prenatal air pollution and outdoor temperatures on PPD risk in a web-based preconception cohort study.

Pregnancy Study Online (PRESTO) is an ongoing prospective preconception cohort study of pregnancy planners residing in the U.S. and Canada. Participants complete questionnaires during preconception, early and late pregnancy, and 6 months postpartum. We leveraged data from 3,510 U.S. participants who gave birth from 2013-2024 and completed the postpartum questionnaire. We ascertained PPD symptoms using the 10-item Edinburgh Postpartum Depression Scale (EPDS) and physician diagnoses. We will link participant addresses to 1) national spatiotemporal models for particulate matter <2.5 µm ($PM_{2.5}$), nitrogen dioxide (NO_2), ozone (O_3), and $PM_{2.5}$ components and 2) meteorological data from a gridded climate dataset to assess trimester- and gestational week-specific exposures to air pollution and heat. We will fit modified Poisson regression models and distributed lag non-linear models to estimate the effect of prenatal air pollution and heat on risk of PPD. We will also implement mixtures modeling to estimate the joint and independent effects of air pollution and heat on PPD risk.

During the project period, we will present results on the effects of air pollution (Aim 1), temperature (Aim 2), and the interactive effects of air pollution and temperature (Aim 3) on PPD risk.

This work may inform clinical practice and the development of policies and interventions aimed at reducing pregnant people’s exposure to air pollution, particularly in the context of ongoing climate change.

Oxidative Potential and Toxicological Implications of Brake-Wear Particulate Emissions from Light- and Heavy-Duty Vehicles

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Non-exhaust emissions such as brake-wear particles have become an important component of ambient air pollution. However, the toxicity and potential health effects of brake-wear particles remain less well understood. We aim to collect fine particulate matter ($PM_{2.5}$) directly emitted from brake-wear from both light-duty and heavy-duty vehicles and to assess its oxidative potential, a metric of particle toxicity.

We collected brake-wear $PM_{2.5}$ at the California Air Resources Board mobile testing facility from November 2024 to July 2025 using 37-mm polytetrafluoroethylene filters paired with Ultrasonic Personal Aerosol Samplers operating at a flow rate of 2 L/min. Brake-wear $PM_{2.5}$ from three light-duty vehicles was sampled in the Running Loss–Sealed Housing for Evaporative Determination (RL-SHED) system. Samples from three heavy-duty vehicles (Class 6–8) were collected on a chassis dynamometer at the Heavy-Duty Vehicle Emissions Testing Laboratory. We then evaluated the oxidative potential of the collected $PM_{2.5}$ based on hydroxyl-radical formation (OPOH) from all six vehicles.

The mass-normalized OPOH of brake-wear $PM_{2.5}$ from six vehicles ranged from 0.47 to 1.24 pmol/min/µg, with the highest values observed from the Class 8 heavy-duty vehicle. The average mass-normalized OPOH for brake-wear $PM_{2.5}$ from light-duty and heavy-duty vehicles were 0.65 ± 0.07 and 0.78 ± 0.41 pmol/min/µg, respectively. Both light-duty and heavy-duty vehicle brake-wear $PM_{2.5}$ exhibited higher average OPOH values than ambient $PM_{2.5}$ in the Greater Los Angeles area (0.48 ± 0.10 pmol/min/µg in summer and 0.63 ± 0.13 pmol/min/µg in winter).

Brake-wear emissions from both light-duty and heavy-duty vehicles emitted $PM_{2.5}$ with higher oxidative potential than ambient $PM_{2.5}$, indicating greater toxicity. These results underscore the importance of accounting for non-exhaust emissions in air-quality assessments and health impact evaluations.

HEI

Investigating Impacts of Zero-Emission Truck Regulations on Tailpipe and Non-Tailpipe Air Pollutant Exposures and Health Risks in Southern California Communities

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Heavy-duty truck emissions are one of the main contributors to air pollution in Southern California, disproportionately impacting communities along freeways and near seaports. We assess the impact of California's zero-emission truck (ZET) regulations on health risks in historically marginalized Southern California communities along freight movement corridors.

We develop an integrated modeling and community engagement framework for evaluating the air quality, health, and equity impacts of California's Advanced Clean Trucks (ACT) and Advanced Clean Fleets (ACF) regulations. Specifically, we utilize newly available transportation big data for heavy-duty trucks to create a high-resolution air pollutant emissions inventory, covering tailpipe diesel fine particulate matter ($PM_{2.5}$) and NO_x, and non-tailpipe brake and tire wear $PM_{2.5}$ and PM_{10} emitted from trucks. Using a sophisticated air quality model and established concentration-response functions, we quantify the impact of regulations on PM, NO_x, and ozone concentrations and estimate associated changes in mortality and morbidity.

Implementation of ACT and ACF regulations leads to air quality improvements across the South Coast Air Basin (SCAB). In 2045, adopting of ZET regulations reduce annual $PM_{2.5}$ by up to 0.4 μg/m^3 in densely populated areas and on average of 0.05 μg/m^3 in SCAB, with greater benefits in disadvantaged (SB535) communities (0.08 μg/m^3). The population-weighted average $PM_{2.5}$ concentration in SCAB decreases by 0.07 μg m^{-3} following implementation of ACT and ACF. Non-tailpipe emissions (e.g., brake and tire wear) constitute an increasing share of $PM_{2.5}$ as tailpipe emissions decline. ZET regulations also reduce NO_2 concentrations, particularly near roadways, with average reductions of 0.09 ppb across SCAB and 0.2 ppb in disadvantaged communities. Ozone generally decreases, although localized increases are projected in parts of urban Los Angeles. While ACT alone improves air quality, the combined ACT+ACF scenario yields greater benefits. Seasonal patterns are evident: NO_x reductions are larger in fall and winter, whereas $PM_{2.5}$ and ozone reductions are more pronounced in summer, reflecting seasonal differences in meteorology and emissions. Our ongoing work is quantifying the associated health impacts of these air quality changes.

Our simulations indicate decreases in annual average $PM_{2.5}$ and NO_x concentrations in 2045 relative to 2019 levels, attributable to existing air quality regulations, excluding ACT and ACF. The implementation of ACT and ACF regulations leads to further reductions in $PM_{2.5}$ and NO_x concentrations in SCAB in 2045, although these reductions are smaller in magnitude compared to the projected reductions between 2019 and 2045. Following the implementation of ACT and ACF, non-tailpipe emissions account for an increasing share of PM, contributing 81% of $PM_{2.5}$ and 91% of PM_{10}. The study also finds that the impact of ZET regulations differs between population-weighted and unweighted average pollutant concentrations. Finally, the high-resolution air quality modeling conducted in this study provides data for ongoing assessments of health and equity impacts of ZET regulations in SCAB.