Air quality and health impacts of transition to zero tailpipe emission medium and heavy-duty vehicles (MHDVs) in the Chicago region

Research Highlights

Medium and heavy-duty vehicles (MHDVs) are major sources of harmful air pollution and greenhouse gases, and disproportionately burden communities of color. To study the impact of potential policy interventions aimed at reducing MHDV emissions, we estimated pollution changes and health impacts for the 7-county Chicago Metropolitan Agency for Planning (CMAP) region (Cook, DuPage, Kane, Kendall, Lake, McHenry, Will Counties) for two policy scenarios:

1. Implementation of the Advanced Clean Trucks (ACT) regulation, which would require manufacturers to sell an increasing percentage of zero tailpipe emission trucks and school buses.
2. A full transition to 100% zero tailpipe emission medium and heavy-duty vehicles (eMHDVs).

ACT Scenario Results

- If Illinois were to adopt the ACT regulation, the state's medium and heavy-duty vehicle (MHDV) fleet would begin to undergo a steady transition to zero tailpipe emission MHDVs through increased sales percentages. Assuming implementation starting with model year 2027, this regulation would mean that **by 2050, approximately 50% of on-road MHDVs in Illinois would have zero tailpipe emissions**.
- Based on today's truck technology and population demographics, the corresponding reduction in nitrogen dioxide pollution (NO_2) would equate to around **500 fewer deaths** and **600 fewer new cases of childhood asthma** annually in the CMAP region (Figure 1).
- **Total NO_2 concentrations would be reduced up to 18% in the most impacted census tracts**, with the average census tract seeing an **8% reduction** in NO_2 (Figure 1).
- The **health benefits of ACT adoption would be largest in neighborhoods with higher percentages of residents of color** (Figure 2). For example, the residents of census tracts with the largest (top 10%) NO_2-associated reductions in mortality are 48% Black, 12% Hispanic or Latino, 7% Asian and 31% white, while the region as a whole is 17% Black, 23% Hispanic or Latino, 7% Asian and 51% white.

- Adoption of the ACT regulation would also lead to reductions in fine particulate matter ($PM_{2.5}$) concentrations (1% reduction on average) associated with a reduction in mortality of 60 deaths per year. Due to complex patterns of atmospheric chemistry, the reductions in NO_2 would lead to small increases in ozone in some areas (1% increase on average), associated with an additional 40 deaths per year. Even in areas where ozone would be increased, the health benefits of the reduction in NO_2 are larger than the harm associated with additional ozone.

100% Transition Scenario Results

- If all on-road MHDVs in the CMAP region were transitioned to zero tailpipe emission vehicles, **there would be around 1,300 fewer deaths** and **1,500 fewer new cases of childhood asthma each year** due to reduced NO_2 pollution.
- **Total NO_2 concentrations would be reduced up to 54% in the most impacted census tracts**, with the average census tract seeing a **22% reduction** in NO_2 (Figure 3).
- The **health benefits of a full eMHDV transition would be largest in neighborhoods with higher percentages of residents of color** (Figure 4). For example, the residents of census tracts with the largest (top 10%) NO_2-associated reductions in mortality are 45% Black, 13% Hispanic or Latino, 7% Asian and 33% white, while the region as a whole is 17% Black, 23% Hispanic or Latino, 7% Asian and 51% white.
- A full eMHDV transition would also lead to reductions in fine particulate matter ($PM_{2.5}$) concentrations (3% reduction on average) associated with a reduction in mortality of 130 deaths per year. Due to complex patterns of atmospheric chemistry, the reductions in NO_x would lead to small increases in ozone in some areas (2% increase on average), associated with an additional 110 deaths per year. Even in areas where ozone would be increased, the health benefits of the reduction in NO_2 are larger than the harm associated with additional ozone.

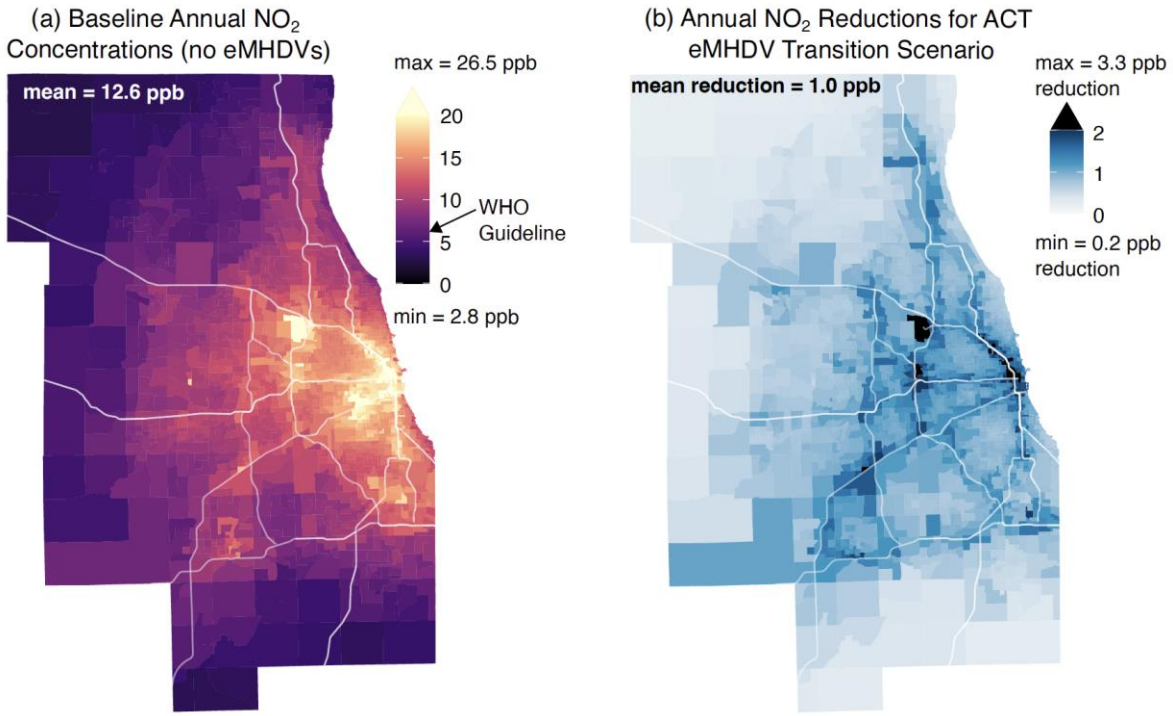

Figure 1. This figure shows the current (baseline) NO_2 concentrations across the CMAP region (left), and reductions in NO_2 resulting from the modeled ACT scenario (right). Reductions in NO_2 pollution would be particularly pronounced along highway corridors, at transportation hubs, and within urban centers, where NO_2 is currently highest. The 2021 World Health Organization (WHO) air quality guideline (recommended limit to protect public health) for NO_2 is 5.3 ppb (10 mg m^{-3}).

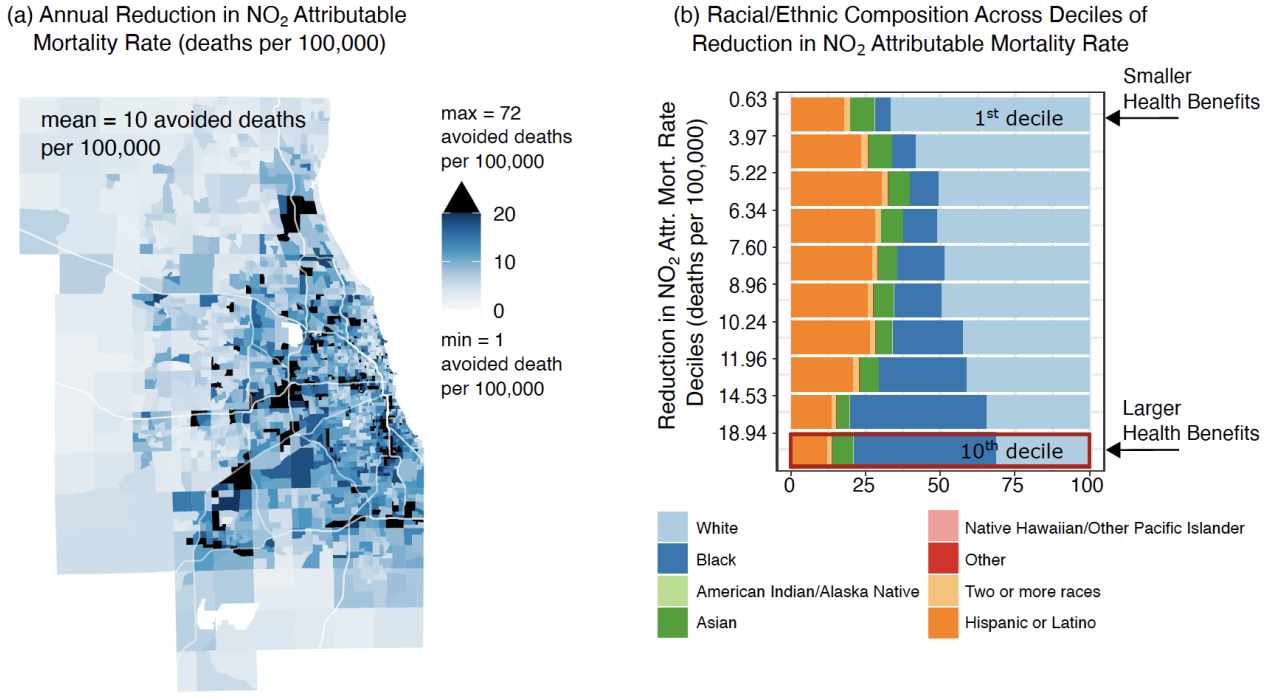

Figure 2. The left-hand map (a) shows the reduction in mortality rates (deaths/100,000 people) associated with the reductions in NO_2 from the ACT implementation scenario across census tracts in the CMAP region. The right-hand figure (b) shows population percentages by race and ethnicity by deciles of NO_2-attributable reductions in mortality. The 10th decile represents the tracts with largest (top 10%) NO_2-associated reductions in mortality.

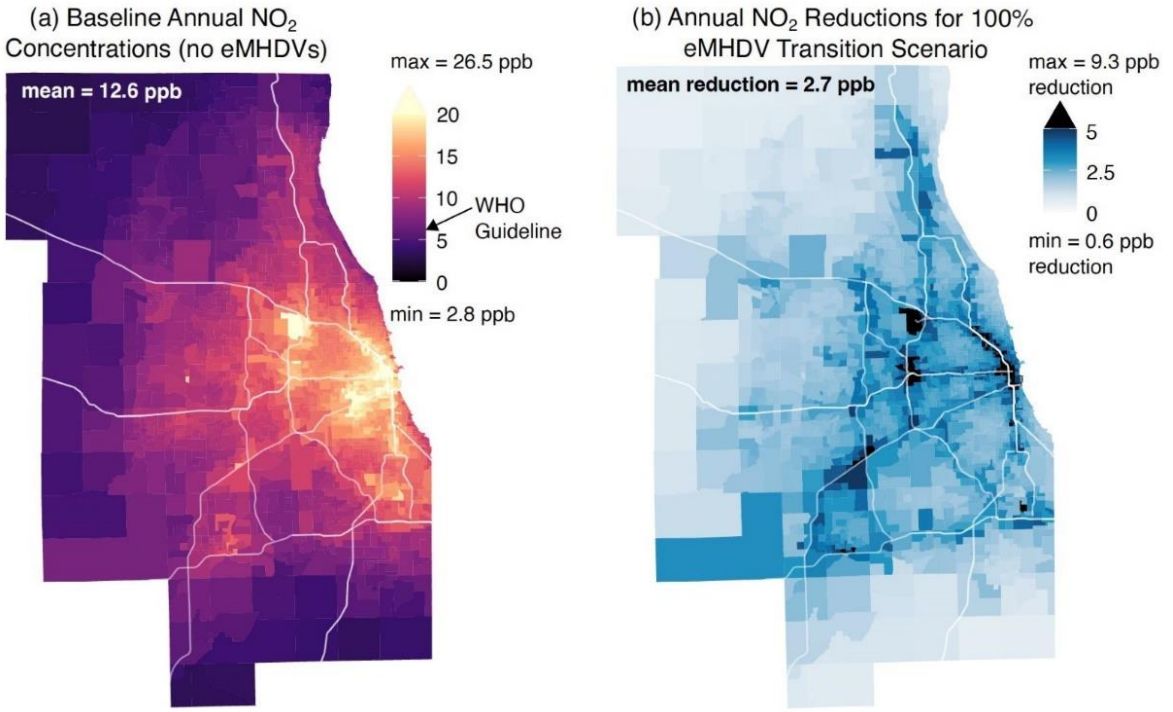

Figure 3. This figure shows the current (baseline) NO_2 concentrations across the CMAP region (left), and reductions in NO_2 resulting from the modeled 100% transition to zero tailpipe emission medium and heavy-duty vehicles (right). The 2021 World Health Organization (WHO) air quality guideline (recommended limit to protect public health) for NO_2 is 5.3 ppb (10 mg m^{-3}).

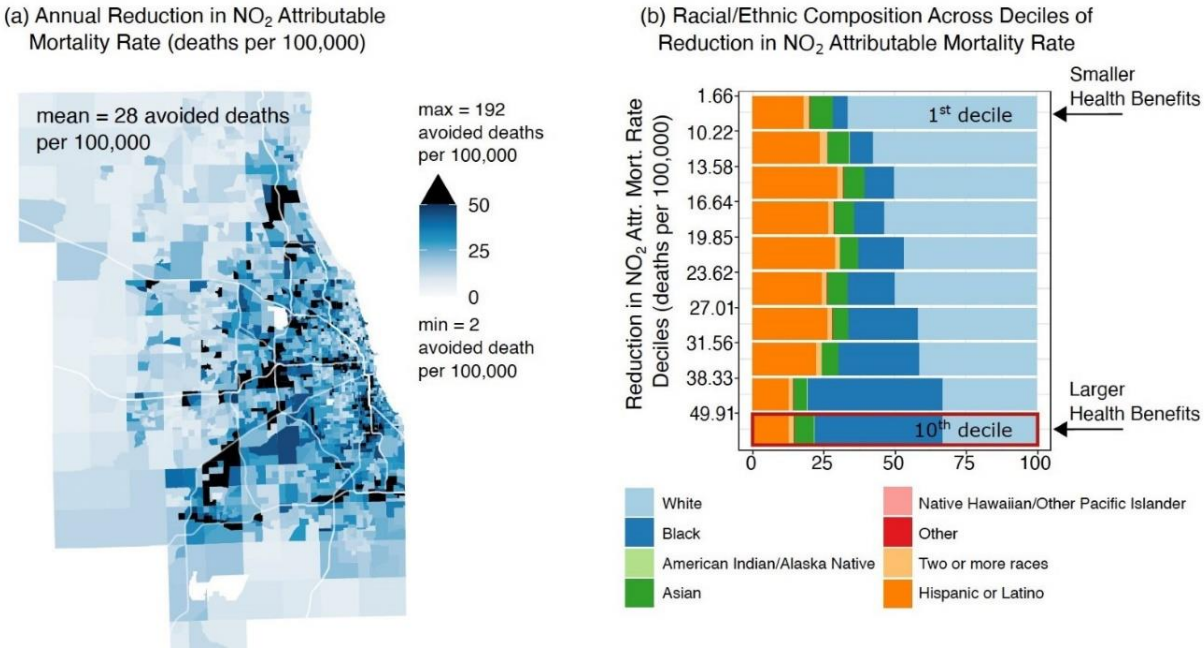

Figure 4. The left-hand map (a) shows the annual reduction in NO_2-attributable mortality rates (deaths/100,000 people) associated with the modeled 100% transition to zero tailpipe emission medium and heavy duty vehicles across census tracts in the CMAP region. The right-hand figure (b) shows population percentages by race and ethnicity by deciles of NO_2-attributable reductions in mortality. The 10th decile represents the tracts with largest (top 10%) NO_2-associated reductions in mortality.

Research Methods

To estimate the potential pollution reduction and health benefits of ACT adoption in the Chicago region, we conducted an atmospheric modeling simulation and health impact assessment of an instantaneous transition to zero tailpipe emission MHDVs consistent with on-road percentages that would be achieved by 2050 if ACT was implemented in Illinois. These percentages [46% of Class 2b vehicles, 47% of Class 3 vehicles, 65% of buses, 62% of vocational vehicles (such as refuse trucks, motor homes, and single-unit trucks), and 35% of tractor-trailers] were estimated assuming implementation of the ACT starting with model year 2027, using a fleet turnover modeling approach similar to the methodology described in Robo et al. 2022.

For the 100% on-road eMHDV scenario, we modeled the impacts of an instantaneous transition to 100% zero tailpipe emission MHDVs, equivalent to eliminating all tailpipe emissions from the current fleet of on-road MHDVs.

Atmospheric modeling and health impact assessment was conducted by the Climate Change Research Group at Northwestern University using a high spatial resolution (~1 km) two-way coupled Weather Research Forecast and Community Multiscale Air Quality chemistry transport model. The modeling approach was similar to the methodology described in Camilleri et al. 2023, with several refinements. Vehicle emissions were modeled using the MOVES3 EPA emission model with adjustments in the spatial allocation of off-road MHDV idling emissions conducted by the Northwestern team to improve the simulation of these emissions occurring in proximity to freight warehouse locations. Estimates of pediatric asthma impacts associated with NO_2 were conducted using a risk ratio derived from the 2022 Health Effects Institute systemic review and meta-analysis and baseline disease rates from the 2019 Global Burden of Disease study.

References

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