Electrifying heavy-duty vehicles could reduce environmental inequalities

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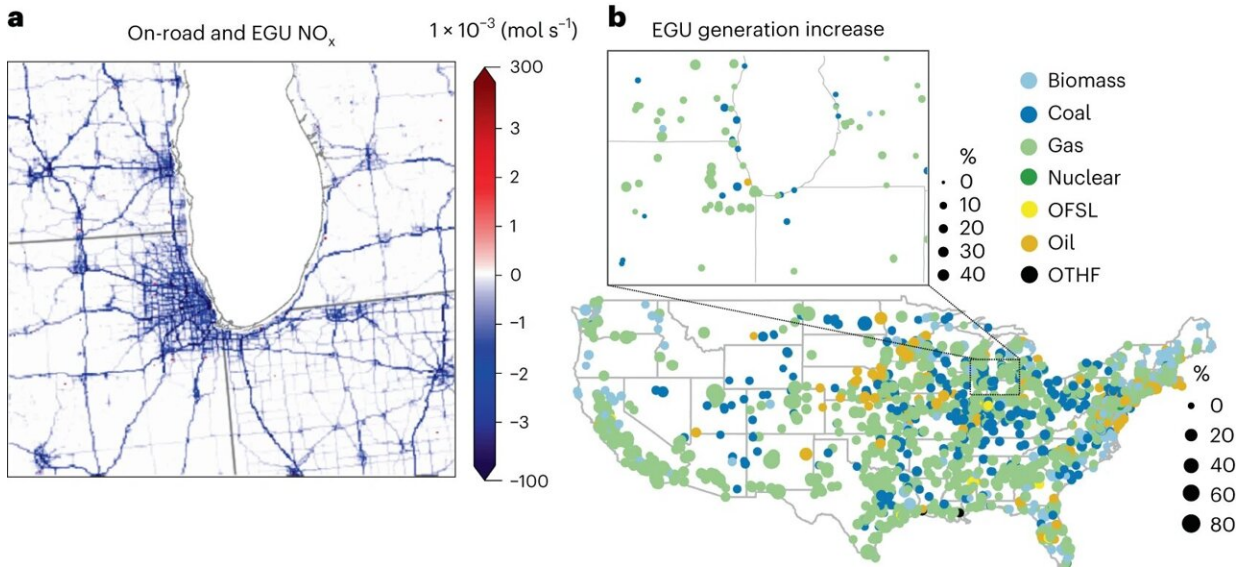

Emission changes. **a**,**b**, On-road and EGU NO_x emission changes compared with the baseline scenario in mol s^{-1} (**a**) and EGU percentage generation increase by fuel type following 30% electrification of HDVs (**b**). Numbers at the tails of color bar in **a** indicate minimum and maximum differences in emissions within the domain. Note that increases in emissions are depicted in **a**; however, they are restricted to grid cells that contain EGUs. While accounting for clean electricity generation from emission-free renewable EGUs (other than nuclear), the increase in electricity demand depicted in **b** represents only the portion of electricity sourced from non-renewable powered EGUs and nuclear EGUs. OFSL and OTHF fuel types refer to other fossil fuel types and fuel derived from waste heat, unknown or purchased sources, respectively. Credit: *Nature Sustainability* (2023). DOI: 10.1038/s41893-023-01219-0

If the region surrounding Chicago—North America's largest freight hub—shifted just 30% of its current on-road heavy-duty vehicles to electric versions, it would substantially reduce pollution and save hundreds of lives per year, with the benefits largely concentrated in disadvantaged communities, according to a new Northwestern University-led study.

The study authors highlight that neighborhoods with predominantly Black, Hispanic and Latinx residents would benefit the most—potentially reducing disproportionate pollution and health burdens in historically marginalized areas.

Although the study specifically focuses on the lower Great Lakes region (including Chicago, Milwaukee and Grand Rapids, Michigan), these findings hint that electrifying heavy-duty vehicles across the nation could help reduce long-standing environmental injustices related to pollutant impact disparities in major metropolitan areas.

The study was published in *Nature Sustainability*.

"Heavy-duty vehicles only constitute a small portion of the total on-road vehicle fleet—about 6%—but they disproportionately contribute to the emission and/or creation of health-harming air pollutants and greenhouse gases," said Northwestern's Sara Camilleri, who led the study. "In fact, the heavy-duty vehicle sector is the largest contributor to on-road nitrogen oxides and second largest source of on-road carbon dioxide emissions. Targeting this small portion of vehicles could have outsized implications for emission reductions."

"When designing policies, optimizing beneficial impacts is ideal," added Northwestern's Daniel Horton, the study's senior author. "Of course, incentivizing the electrification of passenger vehicles is important given their sheer numbers. But, from an impact perspective, our study suggests

that it also makes sense to incentivize transitioning fossil fuel-powered heavy-duty vehicles to electric vehicles because they have such negative consequences for the climate and for human health, particularly in disadvantaged communities."

Horton is an assistant professor of Earth and planetary sciences at Northwestern's Weinberg College of Arts and Sciences, where he directs the Climate Change Research Group. Camilleri is a postdoctoral scholar in Horton's laboratory.

Modeling pollution by neighborhood

To conduct the study, the researchers looked to a high-resolution air quality model previously developed in Horton's lab. The model simulates and quantifies pollution levels by neighborhood, tracking hour-by-hour levels of nitrogen dioxide, ozone and particulate matter across areas as small as one kilometer.

The simulations provide neighborhood-scale estimates of air quality over the region by combining high-resolution emissions data with simulated meteorology to show how air pollutants chemically interact and accumulate—across time and space—throughout Chicago and surrounding areas. Not only does this approach show where different pollutants form, it also shows how pollutants spread, interact with other gases and sunlight in the air and change according to seasons.

In the new research, Horton's group first ran the air quality model—without making any adjustments—to establish a baseline of pollution levels throughout the region. To characterize the residents within each census tract, Camilleri, Horton and their team used American Community Survey information for population and demographic data and incorporated mortality rates derived from health data by Industrial Economics, Inc.

Then, Camilleri ran the simulation again. But, this time, she removed 30% of tailpipe, refueling and extended idling emissions from heavy-duty vehicles—a class that includes municipal buses, school buses, refuse trucks, short- and long-haul trucks and motor homes. She also estimated increases in emissions at power plants due to the increase in electricity demand needed for charging the vehicles' batteries.

Lives saved

The results were striking.

If 30% of heavy-duty vehicles were converted to electric-powered versions—and the power required to charge their batteries came from the 2016 energy-generation infrastructure—reductions in on-road emissions would far outweigh increases at power plants. Pollution concentrations would decrease throughout the region, with the exception of increases in ground-level ozone in urban areas.

Even though the experiments presented in this study assume reliance on the 2016 electric grid, which includes a substantial fraction of fossil fuel-based electricity generation, net carbon dioxide emissions would still decrease by about 2.5 million tons (or 2.76 million tons) per year.

Across the region, reduction of traffic-related pollution would result in a decrease of about 590 premature deaths per year due to reduced nitrogen dioxide concentrations and a decrease of about 70 premature deaths per year from particulate matter reductions. Premature deaths from ozone, however, would increase by about 50 deaths per year.

"The health benefits from reductions in nitrogen dioxide are still so high—irrespective of the increase in ozone—that the overall benefits are substantial," Camilleri said. "The chemistry that controls ozone pollution is complicated, and additional measures to regulate volatile organic

compounds may be needed."

According to the results presented in this study, predominantly Black, Hispanic and Latinx populations would experience the largest health benefits. Traffic-related pollution can trigger a variety of health problems, including asthma, emphysema, chronic bronchitis, heart disease and ultimately premature death. Air pollution from heavy-duty vehicles is higher in urban settings, in areas close to interstate highways and along truck routes. Most people living within 300 feet of major road networks in the United States are people of color.

"When we estimate health benefits, we do not solely look at where the concentrations of pollutants decrease," Camilleri said. "We also look at the susceptibility of the population. These populations might have higher occurrences of underlying health conditions, like asthma and respiratory disease. They might not have access to regular health care or the financial stability to seek treatments for these underlying conditions."

"Many of the largest benefits we see occur in disinvested communities," Horton added. "Systemic disadvantages and barriers within these communities can increase residents' susceptibility to poor air quality. Improvements in air quality in these areas can therefore have outsized positive effects."

Money saved

The researchers assigned dollar values to the avoided health and climate damages by applying the social cost of carbon and value of statistical life metrics to their results. These commonly used policy tools attach a price tag to long-term health and environmental damages.

With the current power grid, the researchers estimate $5.7 billion and $0.6 billion in avoided annual health costs related to nitrogen dioxide

and particulate matter reductions, respectively. But the slight increase in ozone levels would cause an additional cost of $0.5 billion annually.

The avoided carbon dioxide-related damages would save $456 million per year. This result highlights the higher financial savings from health co-benefits, which are often overlooked in climate mitigation policies.

The number of lives and dollars saved would increase drastically if the power grid shifted to incorporate more emissions-free electricity sources (like wind and solar). For example, if the additional electricity required to power 30% adoption of electric heavy-duty vehicles came from renewable sources, the region would save $1.4 billion per year due to lesser carbon dioxide emissions, compared to the $456 million saved with the current grid composition.

"Electric heavy-duty vehicle adoption not only reduces the greenhouse gas emissions that drive human-caused climate change, it also saves lives and helps tackle historical inequities in pollutant exposure," Horton said. "While electric-vehicle adoption won't solve all of our collective climate, air quality and environmental justice problems, it does offer a number of benefits relative to our current fossil-fuel intensive transportation system."

More information: Camilleri, S.F., et al, Air quality, health and equity implications of electrifying heavy-duty vehicles, *Nature Sustainability* (2023). DOI: 10.1038/s41893-023-01219-0.
www.nature.com/articles/s41893-023-01219-0

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