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Are Electric Vehicles a Panacea for Reducing Ozone Precursor Emissions?

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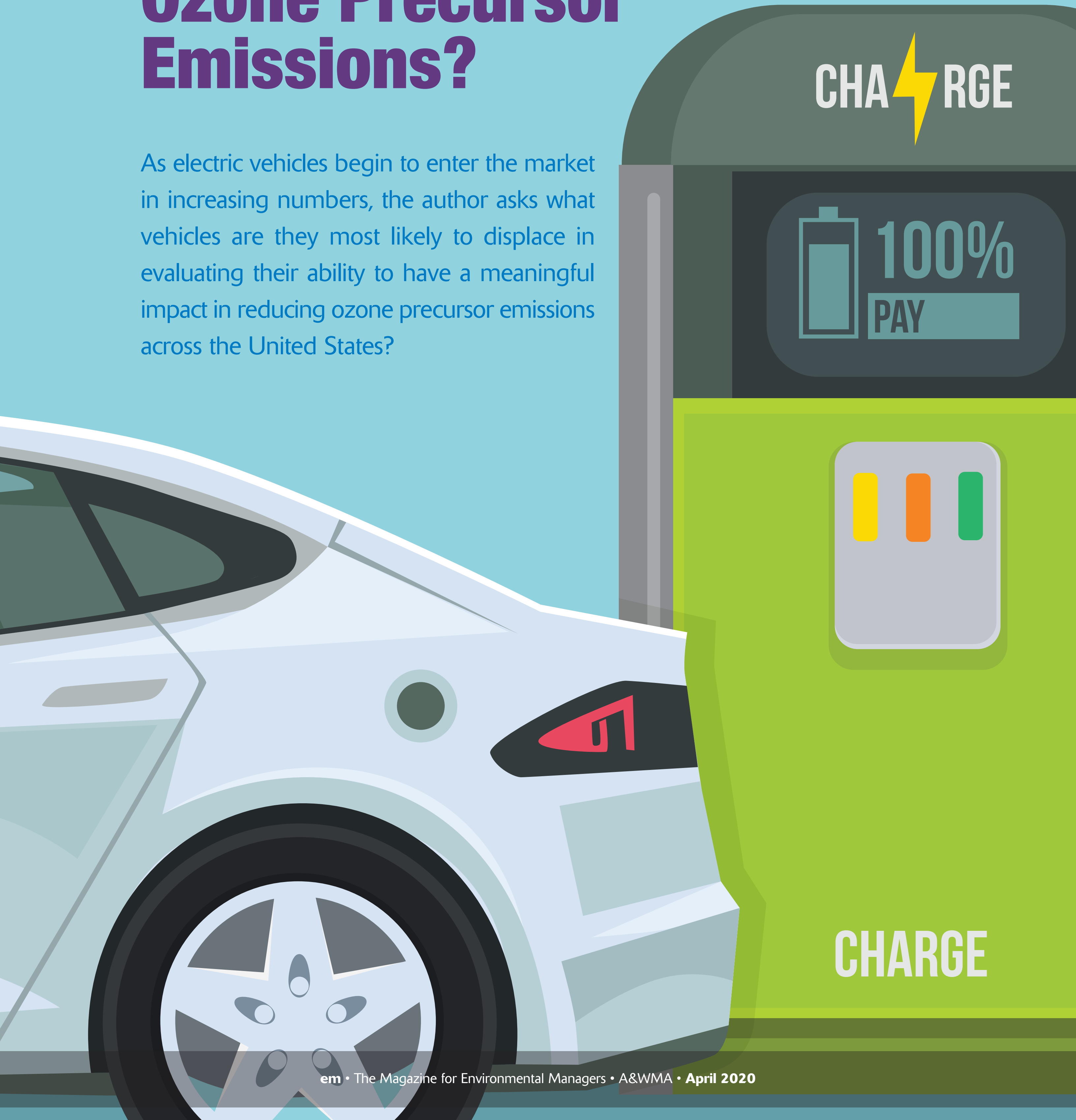
As electric vehicles begin to enter the market in increasing numbers, the author asks what vehicles are they most likely to displace in evaluating their ability to have a meaningful impact in reducing ozone precursor emissions across the United States?



During the past three decades emissions from on-road vehicles have been reduced dramatically.[1,2] With the introduction of new vehicles that have met increasingly stringent emissions standards, reductions of 80%–90% in carbon monoxide (CO) and hydrocarbon (HC) emissions have been achieved, while oxides of nitrogen (NO_x) emissions have been cut by more than half. These reductions have enabled all areas of the country to meet the U.S. National Ambient Air Quality Standards (NAAQS) for CO and nitrogen dioxide. However, ozone, which is a secondary product formed in the atmosphere from the reaction of HC and NO_x emissions, still exceeds the standard in many areas of the country.[3]

The continuing difficulty in meeting the NAAQS for ozone, combined with the large reductions in vehicle emissions that has already occurred, has led some state authorities to look at electrification of the vehicle fleet as a way to further reduce vehicle tailpipe emissions. For example, the Denver metro area was recently reclassified from a moderate to a serious ozone non-attainment area and the Governor of Colorado has publicly touted electric cars as one way the state plans to meet the ozone NAAQS by 2021.[4] This is an easy sell to the public because the idea of replacing an internal combustion engine with a "zero-emitting" vehicle seems a simple slam dunk for quickly reducing all tailpipe emissions, not just carbon dioxide (CO_2) emissions. However, careful analysis of current fleet emission distributions leads to predictions of significantly lower reductions from this strategy in the near term.

Fuel Efficiency Automobile Tests

The University of Denver has been remotely collecting fuel-specific emission measurements from passing vehicles at locations across the United States since the late 1980s. Using absorption spectroscopy our Fuel Efficiency Automobile Test (http://www.feat.biochem.du.edu) units measure tailpipe emitted pollutants as molar ratios to CO_2, which can be easily converted into grams of pollutant/kilogram of fuel consumed knowing the carbon fraction of the fuel.[5] One of the most significant results of this work has been to highlight the importance of the vehicle fleet's emission distribution to total emissions.

Vehicle emissions are not normally distributed—where the median vehicle in the fleet is close to also representing the mean emission vehicle—but are highly skewed, where a small number of vehicles are responsible for a disproportionate share of the total. In today's on-road fleets, it is common to find that the highest emitting 1% of the fleet is responsible for more than a third of the CO and HC emissions, and a quarter of the NO_x emissions. In these distributions one finds that the most common vehicle (the median) has emissions that are factors of 2 to 10 lower than the mean. This results from the fact that the majority of vehicles in the current U.S. fleet (60% or more, depending on the pollutant) today have near-zero tailpipe emissions.

Emissions Percent Contributions

Figure 1 contains three graphs that detail the emissions percent contributions by fuel and vehicle type versus model-year for CO (top), HC (middle), and NO_x (bottom) emissions using data all collected in 2018 in Denver (January), Chicago (September), and Los Angeles (May). For these graphs, gasoline trucks, as classified for emission purposes

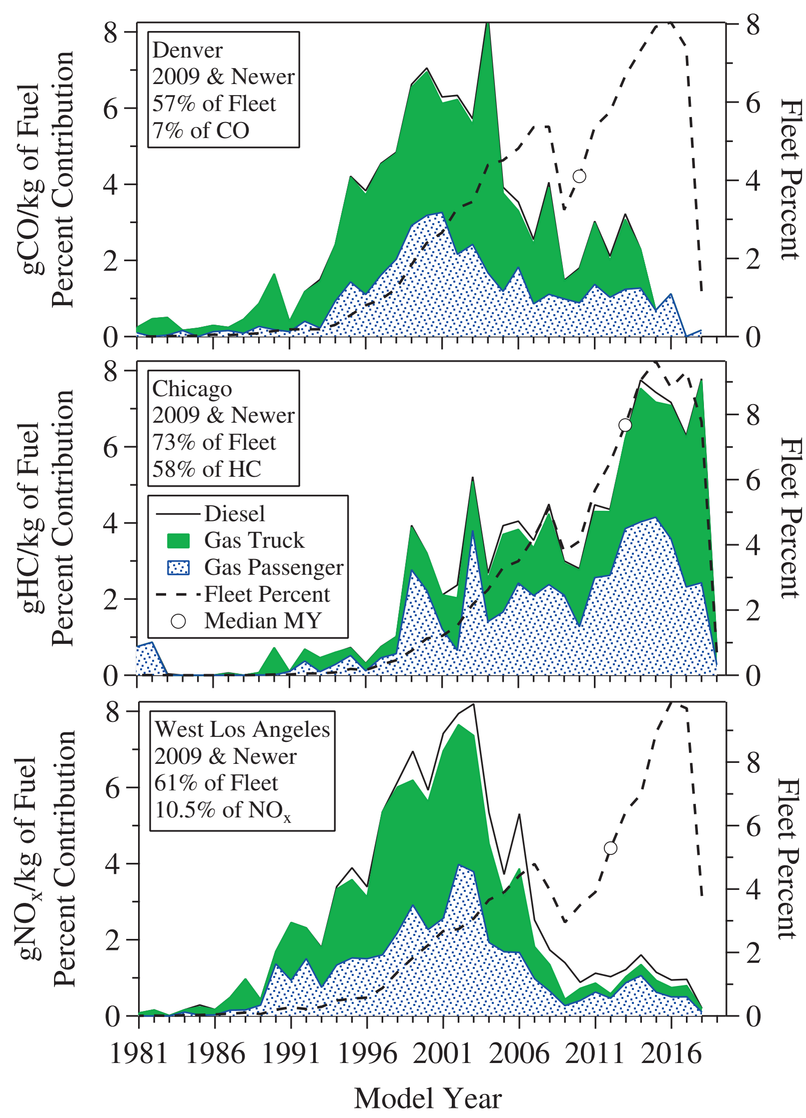


Figure 1. Percent emissions contribution by fuel and vehicle type (left y-axis) for CO in Denver (top), HC in Chicago (middle), and NO_x emissions in West Los Angeles (bottom) versus model-year data collected in 2018.

Notes: The fleet percent (dashed line) is plotted on the right y-axis. Each city's median model-year vehicle is the open circle. The percent of the total of each fleet 2009 and newer model-year vehicles is given and its contribution to the total emissions.

by the U.S. Environmental Protection Agency (EPA), include vans, sport utility vehicles (SUVs), and light- and medium-duty trucks (weight classes 1-6). The fuel-specific percent contribution (left axis) of the fleet total is the product of each model-year's mean emissions and its fleet percent representation (right axis) divided by the total. The median model-year for each data set is plotted as an open circle and the minimum in fleet percentage seen in 2009 is the result of the 2008 recession. Each species graph looks substantially similar regardless of location used.[6] We have chosen to show a different species for each city to emphasize that this is a not just a characteristic of a single area of the country but reflects the entire U.S. fleet. Chicago has the youngest fleet (7.5 years old), likely due to wintertime road salt, and the lowest diesel fraction (1.6%). Denver has the oldest fleet (9.2 years old) and the largest truck (69%) and diesel fractions (3.4%), while the Los Angeles site has the highest percentage of vehicles classified as passenger (59%) and hybrids (7%). While these differences are influenced by factors specific to that region of the country, the emissions behavior of the vehicles result in an emissions distribution that are all similar.

Beginning with the 2009 model-year, all new vehicles sold in the U.S. met the Federal Tier II or California Low Emission Vehicle (LEV) II standards for tailpipe emissions. These vehicles have proven to have consistently low emissions for CO, HC, and NO_x and the ability to maintain those low emissions for many years.[6] This is reflected in the annotations for each city that details the fraction of the fleet represented by these 2009 and newer vehicles and their contribution to the total emissions. For CO and NO_x, the overwhelming majority of the emissions are contributed by a minority of the fleet that is older than these 2009 and newer model-year vehicles. HC is the one exception; however, keep in mind that these graphs are the percent of the total emissions generated by the observed fleet. Successful reductions in HC emissions have extended to vehicles significantly older than the 2009 model-year vehicles and we now generally find that HC emissions do not increase with age until after the first 20 model years that have the same near-zero emissions.[2] This results in the emissions contribution trend closely following the fleet percentage trend as seen in the middle graph.

As emissions have decreased, dramatic changes in the fleet makeup have occurred as well. U.S. vehicle fleets have historically been dominated by passenger vehicles with trucks being largely composed of pickups. With the popularity of vans and all sizes of sport utility vehicles the in-use truck fleet, as classified by EPA emissions certification standards, has steadily grown to where today trucks are typically the dominant type found. This is often also reflected in the emission contributions breakdown, as shown in Figure 1, where trucks (gas and diesel) account for 59% of the total CO in Denver, 47% of the HC in Chicago, and 58% of the total NO_x in West Los Angeles.

The Future for Electric Vehicles?

As electric vehicles begin to enter the fleets in increasing number, one needs to ask what vehicles are they most likely to displace in evaluating their ability to have a meaningful impact in reducing ozone precursor emissions across the United States? Vehicle replacement left on its own will generally follow the fleet's age distribution, meaning the most likely vehicle replaced is the most common one in the fleet or a near-zero emissions median-aged vehicle. However, the median vehicle in many markets is a truck or SUV and there are currently few all-electric choices for these types of vehicles, though many more are promised in the future.

Economic considerations involved in the purchase of electric vehicles likely works against even a median-aged vehicle being replaced as older higher emitting vehicles will be disproportionally owned by individuals where the purchase price of an electric vehicle will be a significant hurdle. This presents a major problem for reducing ozone precursor emissions from the current fleet as the vehicles most likely to be replaced are already a near-zero emissions vehicle.

Of course, Tier II/LEV II vehicles will continue to move down the replacement chain and provided they can continue to maintain their low emissions breakage rate, emissions will continue to slowly decrease. Without a concerted effort to target the replacement of older vehicles with an all-electric vehicle, it will likely require replacement of a majority of the current fleet before realizing any significant emissions reduction. It is unfortunate, but unlikely, that municipalities can expect significant reduction in ozone precursor emissions from electric vehicle adoption to help with their ozone problems in the near future. **em**

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