CRITICAL PERSPECTIVE

"ELECTRIC VEHICLES IN CHINA: EMISSIONS AND HEALTH IMPACTS" STUDY CRITIQUE

Can electric vehicles have a worse environmental and health impact than gasoline vehicles? According to a study by lead author Christopher Cherry from the University of Tennessee and co-authors from the University of Minnesota and Tsinghua University, the answer is affirmative in China. The "Electric Vehicles in China: Emissions and Health Impacts" study, published in Environmental Science and Technology journal, compared four emissions – carbon dioxide (CO_2), fine particles (PM2.5), nitrogen oxide (NO_x), and hydrocarbons (HC) – from five vehicle technologies in 34 major Chinese cities[1]. The vehicles included electric bikes, which form the primary mode of transportation in China; electric vehicles; gasoline vehicles; diesel cars; and diesel buses. The environmental health impact of each vehicle type was primarily determined from PM2.5 emissions. Because their diameter is smaller than 2.5 micrometers, fine particles such as nitrates formed from NO_x emissions can penetrate deeply into the lungs; studies have conclusively associated PM2.5 with respiratory and cardiovascular illness and premature death[2]. The study found that the range of CO_2 emissions was highest for electric cars and lowest for e-bikes. Next, after accounting for the lower intake fraction[3] of EVs compared to ICEs, the authors found that in most cities the environmental health impact of PM2.5 emissions per passenger-km was highest for diesel cars, followed by equally polluting electric cars and diesel buses. On average EVs had a 3.6 times greater impact than gasoline cars. E-bikes had the lowest impact (half that of ICEs).

While EV skeptics were quick to add the study to their arsenal of critiques of efforts to promote alternative fuel vehicles, limitations in the study's methodology skewed its results in favor of gasoline vehicles while its true implications were misrepresented. In an interview, Mark Z. Jacobson, professor of civil and environmental engineering and director of the Atmosphere/Energy Program at Stanford University explained how factoring in some additional metrics might change the results. For example, since an EV's plug-to-wheel efficiency is around 85% (versus less than 20% for ICEs) it takes 4-5 times less energy to move an EV than an ICE. In the U.S. this translates into 30% lower CO_2 emissions from an EV, even assuming a 60% coal grid. Given China's higher use of coal, and the more polluting type of coal used in China, the result would be closer to 15% lower CO_2 emissions from EVs than ICEs. With regard to PM2.5 emissions, the intake fraction from the exhaust of a coal-powered plant is one tenth to one thirtieth that of vehicle exhaust. One would therefore expect the environmental health impact per passenger-km to be highest for diesel and gasoline cars.

A similar study by the Union of Concerned Scientists (UCS) on CO_2 emissions from EVs in the United States provides a useful starting point to contextualizing the Chinese study. In "State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-cost Savings Across the United States," the UCS showed that in the U.S. any EV runs cleaner than the average compact gasoline car[4], even if the EV is charging from an electric grid that is solely powered by coal. The study found that greenhouse gas (GHG) emissions from a coal-powered EV are equivalent to those of a 30-mpg gasoline vehicle[5]. The report furthermore found that almost half the U.S. population lives in areas where EVs produce less global warming emissions than a 50 mpg gasoline vehicle; more than a third reside in regions where EVs compare to 41-50 mpg gasoline vehicles; and less than a fifth live in regions where EVs compare to 31-40 mpg gasoline vehicles. Assuming the same well-to-wheels emissions from a gasoline vehicle in the United States and China as in the U.S.[6], the UCS study can be applied to China and checked against the "Electric Vehicles in China" study. While China's electric grid is more coal dependent and less efficient in comparison to the U.S. grid, a common metric that can be used to determine the Chinese and U.S. grids' environmental effect is their global warming emissions intensity[7]. The U.S. has 26 regional grids with intensities ranging from 293 to 991 gCO_2e/kWh[8]. The following table shows the carbon intensities for China's seven regional grids, ranging from 613 to 1,026 gCO_2/kWh[9].

Grid	Share of Chinese electricity production	Emissions intensity
Northeast China	25.4%	1,026
North China	7%	984
East China	23.2%	743
Central China	19.4%	634
Northwest China	8%	765
South China	16.6%	613
Hainan	0.3%	705

All but one of China's grids – Northeast China – fall within the range of U.S. grids, of which the dirtiest would still allow EVs to produce lower emissions than a 31-mpg gasoline vehicle. The Northeast China grid's emissions are just slightly higher that the highest-polluting U.S. regional grid (the Rockies grid): a Northeast China grid-powered EV would be equivalent to a 30-mpg vehicle. Given that the average fuel economy of China's light-duty vehicle fleet is 29 mpg[10], EVs run cleaner than the average gasoline-powered light-duty vehicle across China. Of course, this does not mean that any EV will produce fewer emissions than any gasoline vehicle. In the U.S., hybrids and the most fuel-efficient subcompacts can outperform EVs in areas with the dirtiest grids[11]. In China, EVs might even be outperformed by their gasoline equivalent in the Northeast. Compared to fleet averages, however, EVs would be considered part of the solution in reducing pollution.

Because the margins are so small, using a different methodology to calculate the emissions intensity of electric grids can easily tip the scale for EVs in China and make them appear to be part of the pollution problem instead. For example, in the same vein as the "Electric vehicles in China" study, the United Nations report on "Electric vehicles in the context of sustainable development in China" concluded that vehicle electrification should not be pursued in areas covered by the North and Northeast China grids, which include major Chinese cities Beijing, Changchun, Dalian, Shenyang, Tangshan, and Tianjin[12]. When calculating the "well-to-tank" GHG intensity of China's power grids, the UN study assumed more efficiency losses than the UCS study. In addition to transmission and distribution losses, it included a charger efficiency loss of 12% and 4% heat loss from the battery, bringing the total emissions intensity for the Northeastern grid to 1,288 gCO2e/kWh. Under this scenario EVs become more polluting than the average gasoline-powered light-duty vehicle in China.

It is important to note that regardless of the methodology, study, and conclusion one accepts, the facts remain that the environmental health impact of EVs can only improve over time as that of ICEs deteriorates. At current production rates, China has 38 years of coal reserves left, but since most of it is inconveniently located and difficult to extract the country is increasingly importing coal[13]. China is also a major oil importer. China therefore has a growing incentive to shift its electricity generation away from coal, and its vehicle fleet away from gasoline. While the U.S. has much larger coal reserves – 245 years' worth – old and inefficient plants are being retired and new ones will have to comply with the EPA's new higher standards[14]. Furthermore, the mix of energy sources is changing in both countries, with a slew of nuclear plants coming on line in China, a glut of natural gas in the U.S., and slow but steady rise in renewable energy sources in China and the U.S. In both countries power plants and EVs will therefore become cleaner over time. The ability to reuse EV batteries beyond the lifespan of the vehicle further enhances the environmental value proposition of EVs. Even in situations where a power grid is so dirty that an EV would be more polluting to run than its gasoline equivalent, electrification would still make sense because of the vehicles' zero tailpipe emissions, probability of lower emissions over time, and potential for zero well-to-wheels emissions.

Notes & Sources:

1 Christopher R. Cherry, Shuguang Ji, Matthew J. Bechle, Ye Wu, and Julian D. Marshall, "Electric Vehicles in China: Emissions and Health Impacts," Environmental Science and Technology, 2012, 46 (4), pp. 2018–2024.

2 See the U.S. Environmental Protection Agency's basic information on fine particle designations at: http://www.epa.gov/pmdesignations/basicinfo.htm.

3 The intake fraction can be defined as "the integrated incremental intake of a pollutant released from a source or source category (such as mobile sources, power plants, and refineries) and summed over all exposed individuals during a given exposure time, per unit of emitted pollutant." See Deborah H. Bennett, Thomas E. McKone, John S. Evans, William W. Nazaroff, Manuele D. Margni, Olivier Jolliet, and Kirk R. Smith, "Defining Intake Fraction," Environmental Science and Technology, 2002, 36, p. 208.

4 The average compact gasoline car in the U.S. has a fuel economy of 27mpg.

5 Union of Concerned Scientists, "State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-cost Savings Across the United States", 04/12/12 revision, p. 9. Available at: http://www.ucsusa.org/clean_vehicles/smart-transportation-solutions/advanced-vehicle-technologies/electric-cars/emissions-and-charging-costs-electric-cars.html

6 Union of Concerned Scientists, "State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-cost Savings Across the United States", 04/12/12 revision, p. 9. Available at: http://www.ucsusa.org/clean_vehicles/smart-transportation-solutions/advanced-vehicle-technologies/electric-cars/emissions-and-charging-costs-electric-cars.html

7 Measured in grams of CO2 emitted per kWh (gCO2e/kWh).

8 Union of Concerned Scientists, "State of Charge: Technical Appendix", p. 8.

9 The emissions intensities for China were calculated based on data from the 2011 UN study "Electric Vehicles in the Context of Sustainable Development in China". The figures were recalculated to be compatible with the methodology used in the UCS study.

10 Calculated from International Energy Agency, Working Paper Series, "International comparison of light-duty vehicle fuel characteristics", 10 May 2011.

11 Paul Stenquist, "How green are electric cars? Depends on where you plug in," New York Times, April 13, 2012.

12 United Nations Department of Economic and Social Affairs, Commission on Sustainable Development, 19th Session, New York, 2-13 May 2011, "Electric Vehicles in the Context of Sustainable Development in China."

13 "Burning ambitions: What is good news for miners in bad news for the environment", The Economist, January 27th 2011.

14 The U.S. Environmental Protection Agency (EPA) has issued greenhouse gas New Source Performance Standards (NSPS) for electric generation units that run on coal or natural gas. Any new plant with more than 25 MW in output will be held to a 1,000 pounds/MWh standard. Standards for existing coal plants are forthcoming.

