Debunking the Myth of EVs and Smokestacks

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Introduction

As ozone levels in the U.S. remain at unhealthy levels, researchers and government officials continue to study alternatives to reduce air pollution from gasoline-powered cars.

Among the alternatives are ultra-low emission vehicles (ULEVs) and zero-emission vehicles (ZEVs). ULEVs are equipped with emission controls that release only 45 pounds of carbon monoxide per 12,000 miles.[1] ZEVs produce no tailpipe emissions at all. ZEVs include vehicles powered by electricity, flywheels, hydrogen fuel cells, and other zero-emission energy sources. Although some ZEVs are still in the experimental stage, electric vehicles (EVs) are available today. In fact, more EVs roamed the nation's roads in the early 1900's than gas-powered cars did.

Unlike a gasoline car that is powered by an internal combustion engine (ICE), an EV uses electricity stored in batteries to power one or more electric motors. When the batteries need recharging you simply "plug-in" from the convenience of your home. EVs have no tailpipe or evaporative emissions[2] because they have no fuel, combustion, or exhaust systems. In fact, EVs are virtually maintenance free because they never need oil changes, air filters, tune-ups, mufflers, timing belts, or emission tests.

One of the most common issues surrounding EVs today is their status as ZEVs. Critics proclaim that EVs are simply "elsewhere emission vehicles" because they transfer emissions from the tailpipe to the smokestack. Although there are emissions associated with coal and oil-fired power plants, smokestack emissions associated with charging EVs are extremely low.[3] In fact, EVs can charge from zero-emission sources such as nuclear, hydroelectric, solar, and wind power.

The purpose of this paper is to prove that EVs recharging from today's power plants are substantially cleaner than even the most efficient ICE vehicles. The myth that EVs are "elsewhere emission vehicles" will be put to the test with facts that clearly show EVs and power plants are cleaner, more efficient and more reliable then the infrastructure that supports ICE vehicles.

The Effects of the ICE Age

The golden age of the automobile has lasted more than 50 years, however, the golden haze caused by our love affair with the ICE car will have long lasting effects. Despite stringent standards to improve tailpipe emissions, the number of vehicles and miles traveled are increasing every year. Scientists predict that our increased reliance on the automobile could increase pollution levels 40 percent by the year 2010.[4] In California, where the automobile is considered a necessity, ICE vehicles account for 90 percent of the carbon monoxide, 77 percent of nitrous oxides, and 55 percent of reactive organic gases.[5] In addition, greenhouse gases such as carbon dioxide, are expected to increase approximately 33 percent by the year 2010.[6]

Continual exposure to these pollutants can cause a variety of symptoms and aggravate existing medical conditions. The elderly and the young are more susceptible to the risks imposed by air pollution. Children in the Los Angeles area have 10 to 15 percent less lung capacity than children in cleaner cities such as Houston, Texas.

The following list describes the potential health risks associated with these emissions.

Carbon Monoxide (CO): an odorless and colorless gas which is highly poisonous. CO can reduce the blood's ability to carry oxygen and can aggravate lung and heart disease. Exposure to high concentrations can cause headaches, fatigue and dizziness.

Sulfur Oxides (SOx) and Sulfur Dioxide (SO2): When combined with water vapor in the air, SO2 is the main contributor of acid rain. Gasoline typically contains .03 percent sulfur.[7]

Nitrogen Oxides (NOx) and Nitrogen Dioxide (NO2): These chemicals are the yellowish-brown haze seen over dirty cities. When combined with oxygen from the atmosphere, NO becomes NO2, a poisonous gas that can damage lung tissue.

Hydrocarbons (HC): This is a group of pollutants containing Hydrogen and Carbon. Hydrocarbons can react to form Ozone. Some (HCs) are carcinogenic and others can irritate mucous membranes. Hydrocarbons include:

- Volatile organic compounds (VOC)
- Volatile organic gases (VOG)
- Reactive organic gases (ROG)
- Reactive organic compounds (ROC)
- Non-methane hydrocarbons (NMHC)
- Non-methane organic gases (NMOG)

Ozone (O3): This is the white haze or smog seen over many cities. Ozone is formed in the lower atmosphere when NMOG and NOx react with heat and sunlight. Ozone can irritate the respiratory system, decrease lung function and aggravate chronic lung disease such as asthma.

Ozone gases have contributed to smog levels as high as 80 parts per billion an average of 84.3 days per year since 1982 in Baltimore, Maryland. Federal safety standards state the risk level is 120 parts per billion when exposed to smog for an hour. However, recent studies suggest that exposure to 80 parts per billion is enough to cause lung inflammation which can lead to permanent scarring.[8]

Carbon Dioxide (CO2): CO2 is a naturally occurring gas in the atmosphere and is a necessary ingredient of the ecosystem. However, in large quantities it can allow more light to enter the atmosphere than can escape. The excess heat from the trapped light can lead to the "greenhouse effect" and global warming.

Clearing the Air About Power Plant Emissions

EVs have the unique advantage of using electricity generated from a variety of fuels and renewable resources. The overall mix of power plants in the U.S. is 55 percent coal, 9 percent natural gas, and 4 percent oil.[9] The other 32 percent include nuclear power and renewable energy sources such as hydroelectric, solar, wind, and geothermal.

Many EV critics point out that charging thousands of EVs from aging coal plants will increase greenhouse gases such as CO2 significantly. Although half the country uses coal-fired plants, EVs recharging from these facilities are predicted to produce less CO2 than ICE vehicles. According to the World Resources Institute, EVs recharging from coal-fired plants will reduce CO2 emissions in this country from 17 to 22 percent.[10]

Reductions in pollutants such as HCs, CO, NOx, SO2, and particulates vary according to a region's power plant mix. If EVs were introduced on a global scale urban pollution would improve significantly. See Table 1. In France, where most of the power comes from nuclear energy, emissions produced to charge EVs would be cut across the board. Countries such as the U.S. and the U.K. use a mix of coal and oil-fired facilities that produce an elevated level of SO2 and particulates. However, levels of HC, CO and NOx would decrease significantly.

Table 1. Electric Vehicles Reduce Pollution[11]
(percentage change in emissions)

	HCs	CO	NOx	SO2	Particulates
France	-99	-99	-91	-58	-59
Germany	-98	-99	-66	+96	-96
Japan	-99	-99	-66	-40	+10
United Kingdom	-98	-99	-34	+407	+165
United States	-96	-99	-67	+203	+122
California	-96	-97	-75	-24	+15

Although half the electricity generated in the U.S. comes from coal-fired plants, larger regions of the country such as California and the Northeast are turning toward cleaner fuels such as natural gas.

In California, where over half of the state's pollution comes from ICE vehicles, the overall mix of power plants is one of the cleanest in the country. See Table 2. Power plants burning cleaner fuels, such as natural gas, account for a major share of the state's electricity. In fact, natural gas facilities in California emit 40 times less NOx than existing coal plants in the Northeast.[12] Renewable sources such as hydro, solar, wind, and geothermal produce a respectable share of the electricity generated in California.

Table 2. Power Plant Mix in California[13]

Power Plant	Percent
Natural Gas	33
Hydroelectric	20
Coal	16
Nuclear	15
Solar and Wind	6
Geothermal	6

Taking advantage of California's abundance of sunlight, several utilities are using Solar Charge Ports to charge EVs. Charge Ports are facilities that have an array of solar panels placed strategically on the roof of the structure. The solar panels convert sunlight into electricity where it is distributed to the vehicles or the adjacent building's power supply. On cloudy days the building supplies the electricity to charge the EVs. Charge Ports are in operation in several cities in California including Diamond Bar, Azusa, and Santa Monica.

Because California has a mix of cleaner fuels and renewable sources, several studies have concluded that improvements in air quality can be achieved easily by "plugging-in" to EVs.

The California Air Resources Board (CARB) estimates that EV's operating in the Los Angeles Basin would produce 98 percent fewer hydrocarbons, 89 percent fewer oxides of nitrogen, and 99 percent less carbon monoxide than ICE vehicles.

In a study conducted by the Los Angeles Department of Water and Power, EVs are significantly cleaner over the course of 100,000 miles than ICE cars. The electricity generation process produces less then 100 pounds of pollutants for EVs compared to 3000 pounds for ICE vehicles. See Table 3.

Table 3. Pounds of Emissions Produced per 100,000 Miles[14]

Engine Type	CO	ROG	NOx	Total
Gasoline	2574	262	172	3008 lbs
Diesel	216	73	246	835 lbs
Electric	9	5	61	75 lbs

CO_2 emissions are also significantly lower. Over the course of 100,000 miles, CO_2 emissions from EVs are projected to be 10 tons versus 35 tons for ICE vehicles.[15]

Many EV critics remain skeptical of such findings because California's mix of power plants is relatively clean compared to that in the rest of the country. However, in Arizona where 67 percent of power plants are coal-fired, a study concluded that EVs would reduce greenhouse gases such as CO_2 by 71 percent.[16]

Similar comparisons to those in California and Arizona can be found in the Northeastern part of the country where the majority of power plants are coal-fired.

A study conducted by the Union of Concerned Scientists found that EVs in the Northeast would reduce CO emissions by 99.8 percent, volatile organic compounds (VOC) by 90 percent, NOx by 80 percent, and CO_2 by as much as 60 percent.[17]

According to a Northeast States for Coordinated Air Use Management (NESCAUM) study, EVs result in significant reductions of carbon monoxide, greenhouse gases, and ground level ozone in the region with magnitudes cleaner than even the cleanest ULEV.

In the future, EVs in the Northeast will reap the benefits of switching to cleaner fuels such as natural gas. In the next 15 years, aging coal plants will be replaced by modern natural-gas fired plants. This improvement alone will reduce power plant emissions significantly.

Several northeastern states are also exploring renewable sources such as solar energy to generate electricity for EVs. The EVermont Project is using a successful solar-powered system to charge a mail delivery truck used at the General Services Center in Middlesex, Vermont. A solar array was installed and wired into the system's power grid. The solar array generates electricity during the day and the truck charges at night. Overall, the solar panels put out more power than the truck uses on its daily rounds.[18]

The Efficiency Advantage of EVs and Power Plants

EVs recharging from fossil-fueled power plants such as coal and oil have unique efficiency advantages over ICE vehicles. As a system, EVs and power plants are twice as efficient as ICE vehicles and the system that refines gasoline. See Table 4. Although there are losses associated with generating electricity from fossil-based fuels, EVs are significantly more efficient in converting their energy into mechanical power.

Table 4. Operating Efficiency Comparison Between EVs and ICE Vehicles[19]

	EVs and Power Plants	**ICE and Fuel Refining**
Processing	39% (Electricity Generation)	92% (Fuel Refining)
Transmission Lines	95%	–
Charging	88%	–
Vehicle Efficiency	88%	15%
Overall Efficiency	**28%**	**14%**

Since EVs operate more efficiently then their ICE-powered counterparts, overall fuel economy is higher. However, making a direct comparison between the fuel efficiencies of both vehicles is difficult. By applying a common unit of energy, such as British Thermal Units (Btus) we can get a fair comparison between the two.

For the following example we will compare the fuel efficiencies of a 1995 Acura 3.2 TL and GM's new electric vehicle— the EV1. See Table 5. Both vehicles cost about $34,000 and can accelerate from 0 to 60 mph in 8.5 seconds.

Table 5. Fuel Efficiency Comparison Between EVs and ICE Vehicles[20]

Electric-Powered GM EV1		**Gasoline-Powered Acura**	
Start with	1 million Btus	Start with	1 million Btus
Energy left after generation (39% efficiency)	390,000 Btus	Energy left after refining (92% efficiency)	920,000 Btus
Energy left after charging losses (88% efficiency)	343,200 Btus	Energy left after transportation (95% efficiency)	874,000 Btus
Btus per Kilowatt-hour	3412 Btus[21]	Btus per gallon of gasoline	115,400 Btus[22]
Electricity Available	100.6 kWhr	Gallons available	7.6 gallons
Energy Efficiency	.19 kWhr/mile	Fuel economy	24 mpg
Miles per million Btus	**529.5 miles**	**Miles per million Btus**	**182.5 miles**
Equivalent mpg	**59 mpg[23]**	**Equivalent mpg**	**24 mpg**

Even though the GM EV1 has 43 percent fewer Btus after electricity generation, it can be driven almost 350 miles farther because the vehicle is more efficient than the Acura. In fact, the GM EV1 has the gasoline equivalency of 59 mpg[23] even after factoring in losses from electricity generation and charging!

Scrubbing Out Power Plant Emissions

We've discussed how the system of power plants and EVs can improve air quality, improve operating efficiencies, and save fuel, but just how efficient are power plant emissions controls?

Controlling emissions from several hundred power plants is much easier then controlling the emissions from 187 million ICE vehicles. In fact, electric utilities go through considerable efforts to monitor and remove emissions from their facilities. Teams of engineers carefully maintain the plants at peak operating efficiency. State of the art equipment such as scrubbers are installed to remove emissions. Electrostatic precipitators (ESPs) between the boilers and smokestacks remove up to 99.75 percent of the ash emitted by power plants. Coal-fired plants in Texas using ESPs remove up to 13.4 million tons of ash each year, releasing only 3000 tons into the atmosphere.[24] The amount released falls below U.S. EPA regulations for ash emissions.

Over the next seven years, electric utilities in the Northeast are committed to reducing NOx emissions by 55 to 70 percent.[25] When one power plant upgrades its emission controls, thousands of EVs immediatly reap the benefits from this improvement.

Catalytic Clunkers

Upgrading and maintaining emissions for ICE vehicles is a different story. According to Drew Kodjak, a lawyer from NESCAUM, ICE vehicles pollute more over time while power plants tend to pollute less over time. Over the course of its lifetime, a gasoline car will spew out 60 times more CO, 30 times more VOC, and twice as much CO2 as electric power plants.

The U.S. Environmental Protection Agency estimates that tailpipe emissions increase 25 percent for every 10,000 miles traveled.[26] As gasoline cars age, their engines, catalytic converters, and other emission control devices become less efficient. The cleanest a gasoline car ever will be is the day it rolls off the assembly line.

The deterioration of emission control systems on ICE vehicles can increase emissions up to 90 percent. To deal with increased emissions, state governments have adopted emission inspection programs with varied degrees of success. Many of these programs have been delayed due to public concern for the cost of repairing emission components. In Maryland, drivers can receive a waiver if they document attempts to repair their ICE cars even though the cars continue to fail emission tests.

Newer cars entering the market are not necessarily the cleanest either. The hottest vehicles on the market today are sport utility vehicles (SUV) which now account for 40 percent of all new car sales. These gas guzzlers are driving up this country's demand for imported oil, decreasing overall fuel efficiency, and increasing emissions.

Today's Power Plants Meeting Tomorrow's Recharging Needs

Many critics ask how this country could possibly support millions of EVs on today's existing power grid. The Electric Power Resource Institute (EPRI) estimates that this country has the ability to support 50 million EVs without building any more power plants. Another study puts this number closer to 20 million.[27] Even so, 20 million EVs is only 10 percent of today's fleet of 187 million cars. Thousands more could be added if they are charged at night during off-peak hours. Twenty million EVs, each with 100,000 miles on the odometer, would reduce CO2 emissions in this country by 500 million tons without building more power plants.

Southern California Edison (SCE) estimates that it has enough off-peak capacity to refuel up to 2 million cars, 25 percent of the area's automobiles. SCE estimates it will only need to add 200 megawatts of capacity by 2008 to accommodate EVs.

Summary

In conclusion, EVs will have a considerable impact on reducing air pollution, improving fuel efficiency, and reducing our overall dependency on foreign oil. As power plants improve efficiency and turn to cleaner fuels such as natural gas and zero-emission sources, EVs will continue to be the best solution towards attaining clean air.

Notes

1. Bob Brandt, *Build Your Own Electric Car*, (Tab Books, Blue Ridge Summit, PA, 1994), Table 2-2, p. 35.

2. Evaporative emissions include fumes and gases that evaporate during refueling, and fumes and gases from components of the engine, such as the carburetor.

3. Bob Brandt goes one step further stating, "*There is no emission from an electric vehicle* and, until there exists an appreciable number of them they do not impact in any way the emissions from the power plant used to generate the electricity." Bob Brandt, *Build Your Own Electric Car,* (Tab Books, Blue Ridge Summit, PA, 1994), p. 32.

4. Electric Power Research Institute, "Electric Vehicle Infrastructure," *Will Electric Vehicles Contribute to a Cleaner Environment* , (1992).

5. California Air Resources Board, *Draft Technical Document for the Low-Emission Vehicle and Zero-Emission Vehicle Workshop on March 25, 1994, Zero-Emission Vehicle Update*, (1994), Table 1, p. 3.

6. Bob Brandt, *Build Your Own Electric Car*, (Tab Books, Blue Ridge Summit, PA, 1994), p. 33.

7. Ibid, p. 31.

8. Timothy B. Wheeler, "Smog risk greater than believed," *The Baltimore Sun*, (March 5, 1995), Section C 1.

9. James J. MacKenzie, *The Keys to the Car*, (World Resources Institute, Baltimore, Maryland, May 1994), p. 91.

10.James J. MacKenzie, *The Keys to the Car,* (World Resources Institute, Baltimore, Maryland, May 1994), p. 92.

11.Daniel Sperling, "The Case for Electric Vehicles," *Scientific American* , (November 1996), article available from the *Scientific American* website, http://www.sciam.com/1196issue/1196sperling.html

12.Drew Kodjak, "EVs: Clean Today, Cleaner Tomorrow," *Technology Review*, (August/September 1996), p. 66-67.

13. California Air Resources Board, *Draft Technical Document for the Low-Emission Vehicle and Zero-Emission Vehicle Workshop on March 25, 1994, Zero-Emission Vehicle Update*, (1994), Table C-6, p. 61.

14.Steve McCrea, *Why Wait for Detroit*, (South Florida Electric Vehicle Auto Association, 1992), p. 39.

15. California Air Resources Board, *Draft Technical Document for the Low-Emission Vehicle and Zero-Emission Vehicle Workshop on March 25, 1994, Zero-Emission Vehicle Update*, (1994), Table C-6, p. 68.

16."Emissions, Quantifying the Air Quality Impact of EV Recharging," *Green Car Journal*, (October 1993), p. 116.

17. Center for Technology Assessment Transportation Technology Review, "CTA Findings Reveal Carnegie-Mellon Study Misrepresents Environmental Impacts of Electric Vehicles," (1995), p. 5.

18.Hilton Dier III, *VT Electric Car Co.*

19.Ovonic fact sheet, "Fuel Efficiency Comparison."

20.Table derived from "Why Wait for Detroit," Steve McCrea, (1992), p. 42.

In the comparison, each vehicle is given 1 million Btus to start with. After losses are factored in, the results are divided by the Btu equivalents of kilowatt-hours (3,412 Btus/kWh) for the EV and gallons (114,500 Btus/gallon) for the ICE car. These results are divided by the given efficiency for each vehicle. The final results are miles each vehicle can travel.

21.Equivalent for 3,412 Btus per kilowatt hour obtained from CARB.
California Air Resources Board, *Draft Technical Document for the Low-Emission Vehicle and Zero-Emission Vehicle Workshop on March 25, 1994, Zero-Emission Vehicle Update*, (1994), p.72.

22.Equivalent for 114,500 Btus per gallon obtained from CARB.
California Air Resources Board, *Draft Technical Document for the Low-Emission Vehicle and Zero-Emission Vehicle Workshop on March 25, 1994, Zero-Emission Vehicle Update*, (1994), p.72.

23.The formula for figuring equivalent mpg for the electric car is:

1) Vehicle Efficiency x Btus per kWh ÷ power plant efficiency = Btus per mile
2) Btus per mile ÷ charging efficiency = Btus per mile
3) Btus per gallon ÷ Btus per mile = mpg

To obtain 59 mpg for EV substitute the numbers from Table 5.

1) 190 Wh/mi x 3.412 Btus /Wh ÷ 0.39 (power plant effic.) = 1662.25 Btus /mi
2) 1662.25 Btus /mi ÷ 0.88 (charging effic.) = 1955.58 Btus /mi
3) 114,500 Btus /gal ÷ 1955.58 Btus /mi = 58.55 mpg

24. Central Southwest System Homepage, "Air Quality," http://www.csw.com/er/airqual.html

25.Drew Kodjak, "EVs: Clean Today, Cleaner Tomorrow," *Technology Review*, (August/September 1996), p. 66-67.

26.Ibid, p. 66-67.

27. Fortune Magazine, "Electric Vehicles, Technology Recreates the Automobile." (Reprint from June 26, 1995)

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