

## WELL-TO-WHEELS EMISSIONS DATA FOR PLUG-IN HYBRIDS AND ELECTRIC VEHICLES

EV = electric vehicle; PHEV = plug-in hybrid; HEV = hybrid; ICE = gas car  
CO<sub>2</sub> = carbon dioxide; HC = hydrocarbons; CO = carbon monoxide; VOC = volatile organic compounds; ROG = reactive organic compounds; CH<sub>4</sub> = methane; N<sub>2</sub>O = nitrous oxide; GHG = greenhouse gases; SO<sub>x</sub> = sulfur oxides; NO<sub>x</sub> = nitrogen oxides; PM = particulate matter.

### SUMMARY:

In well-to-wheels analyses (and ignoring some outliers in the data), PHEVs reduce CO<sub>2</sub> emissions by 37%-67% compared with ICEs and by 19%-54% compared with HEVs.

EVs reduce CO<sub>2</sub> by 11%-99% compared with ICEs and by 24%-54% compared with HEVs if electricity comes from a mix of power sources. That means if all U.S. cars were EVs, we'd reduce greenhouse gases. If electricity comes strictly from coal, EVs may produce 30%-49% more CO<sub>2</sub> than HEVs (based on only two analyses) and may reduce CO<sub>2</sub> 0%-59% compared with ICEs (though only one study found 0%; six others found reductions of 17%-59%). If electricity comes from wind or solar power, EVs eliminate all emissions.

Both PHEVs and EVs greatly reduce hydrocarbons, CO, VOCs, ROG, CH<sub>4</sub>, N<sub>2</sub>O, and GHGs compared with ICEs or HEVs.

SO<sub>x</sub> -- PHEVs and EVs increase by 17%-296% compared with ICEs. Compared with HEVs, NO<sub>x</sub> -- EVs decrease by 32%-9% and PHEVs may decrease by 67% or increase up to 83% compared with ICEs. Compared with HEVs, PHEVs may decrease by 110% or increase up to 108%.

PM -- EVs and PHEVs may decrease 97% or increase up to 122% compared with ICEs. Compared with HEVs, PHEVs may increase 133% and EVs may increase up to 600%.

Except for CO<sub>2</sub>, regulations are in place and technology exists to contain any "extra" emissions that PHEVs or EVs might create. Only when electricity comes 100% from coal might PHEVs and EVs produce more CO<sub>2</sub>; in general, they reduce CO<sub>2</sub> and most other emissions. Moving away from coal and toward renewables should be a priority for many reasons. Scrubbers on power plants can handle SO<sub>x</sub>, and baghouses and electrostatic precipitators can contain PM. The 1990 acid rain amendments to the Clean Air Act cap total acid rain emissions, so no matter how much electricity we generate, total SO<sub>x</sub> emissions will be declining if the Act is enforced. While there is no absolute cap on PM, federal rules are in place to ensure that these emissions – especially the smallest particulates – will decrease as well, regardless of the amount of electricity produced. (Source: Charles Garlow, U.S. Environmental Protection Agency Air Enforcement Division)

### NATIONAL MIX, PHEVS and/or EVs vs. ICEs and/or HEVs:

1) M.Q. Wang, Argonne National Laboratory: Development and Use of GREET 1.6 Fuel-Cycle Model for Transportation Fuels and Vehicle Technologies. June, 2001. Assumes PHEVs drive electric 30% of time and on liquid fuel 70% of time.

Table 2: Well-to-Wheel Energy and Emission Changes for Fuel/Vehicle Technologies Relative to Gasoline Vehicles Fueled with Reformulated Gasoline, pages 22-25. Includes the following figures:

A) HEV (on RFG) / -29% total energy / -29% CO<sub>2</sub> / -26% CH<sub>4</sub> / -1% N<sub>2</sub>O / -28% GHG / -20% VOC / -1% CO / -25% NO<sub>x</sub> / -6% PM / -29% SO<sub>x</sub>

B) PHEVs (on RFG + U.S. mix elec) / -41% total energy / -40% CO<sub>2</sub> / -39% CH<sub>4</sub> / -31% N<sub>2</sub>O / -40% GHGs / -46% VOC / -34% CO / +2% NO<sub>x</sub> / +2% PM / +53% SO<sub>x</sub>

C) EVs (U.S. mix) / -44% total energy / -42% CO<sub>2</sub> / -48% CH<sub>4</sub> / -88% N<sub>2</sub>O / -43% GHGs / -89% total VOC / -98% CO / +83% NO<sub>x</sub> / +30% PM / +296% SO<sub>x</sub>

PHEV vs. HEV: 38% less CO<sub>2</sub> / 50% less CH<sub>4</sub> / 300% less N<sub>2</sub>O / 43% less GHGs / 450% less VOC / 330% less CO / 108% less NO<sub>x</sub> / 130% more PM / 283% more SO<sub>x</sub>

EV vs. HEV: 45% less CO<sub>2</sub> / 85% less CH<sub>4</sub> / 870% less N<sub>2</sub>O / 54% less GHGs / 69% less VOC / 970% less CO / 432% more NO<sub>x</sub> / 600% more PM / 1120% more SO<sub>x</sub>

**2)** CalCars.org: Says an Argonne researcher reached consensus with researchers from other national labs, universities, CARB, automakers, utilities and AD Little to estimate in July, 2002 that PHEVs using nighttime power reduce GHGs by 46%-61%. (Summarized in Nov. 2003 presentation by EPRI.)

**3)** Gilbert Masters, Ph.D., professor of civil and environmental engineering, Stanford University, Calif.; 2006

Grid Assumptions for carbon emissions: Average grid (52% coal, 3% oil, 16% natural gas) = 700 g CO<sub>2</sub>/kWh; Natural gas, combined cycle, 50% efficiency = 425 g CO<sub>2</sub>/kWh; Gasoline, 80% WTP = 11.2 kg/CO<sub>2</sub>/gallon; Hydrogen, 60% WTP (well to pump), 57 mi/gallon = 200 g CO<sub>2</sub>/mile; Fuel cell/electrolysis = 663 g CO<sub>2</sub>/mile (average grid) or 402 g CO<sub>2</sub>/mile (natural gas combined cycle)

Vehicle Assumptions: Drive cycle = 15,600 miles/year. Weekdays = 50 mi/day, 13,000 mi/year, \_ city, \_ highway. Weekends – 25 mi/day, local streets, 2,600 mi/year. Fuel prices: Gas \$2.50/gallon. Electricity 12.5 cents/kW or 6 cents/kW off peak. Hydrogen \$3/kg. Fuel efficiency: Ford Focus 24 mpg. Toyota Prius 49 mpg. Prius+ 45 mpg highway plus 200 Wh/mile. Electric vehicle (generic) 250 Wh/mile. Honda FCX (fuel cell) 57 mi/kg H<sub>2</sub>.

Results: Well-to-wheels CO<sub>2</sub> emissions: Focus 467 g/mile. Prius 229 g/mile. Prius+ on average grid 185 g/mile. Prius+ on natural gas combined cycle 153 g/mile. EV on average grid 175 g/mile. EV on natural gas combined cycle 106 g/mile. Honda FCX on natural gas reformer 200 g/mile. Honda FCX on average grid 663 g/mile. Honda FCX with from electrolysis by natural gas combined cycle 402 g/mile.

CO<sub>2</sub> reductions vs. ICE: Prius+ average grid 60% reduction. Prius+ natural gas 67%. EV 77%. FCX natural gas 56%. FCX average grid increases CO<sub>2</sub> 42%. FCX electrolysis 14% reduction.

CO<sub>2</sub> reductions vs. HEV: Prius + average grid 19%. Prius+ natural gas 33%. EV 54%. FCX natural gas 13%. FCX average grid increases CO<sub>2</sub> by 190%. FCX electrolysis 24% decrease in CO<sub>2</sub>.

**4)** Joseph Romm, Ph.D., energy consultant, Capital E Group, Washington, D.C.

A) Interviewed Feb. 2, 2006: Back-of-the-envelope calculation. Assumptions: 10,000 miles traveled, U.S. grid mix:

Prius real-world 50 mpg (generous: Consumer Reports says 44 mpg) = 200 gallons X 25 total pounds CO<sub>2</sub>/gallon lifecycle = 5,000 pounds CO<sub>2</sub>.

Prius+ = 250 Wh/mile = 2,500 kWh X 1.2 pounds CO<sub>2</sub>/kWh = 3,000 pounds CO<sub>2</sub>. If Prius+ = 300 Wh/mile = 3,600 pounds CO<sub>2</sub>. So 28%-40% less than Prius HEV, and even greater reduction than other hybrids, and far greater reduction than the “average” car out there.

B) Romm’s post to calcars.org: For 12,000 miles traveled (typical vehicle/year):

Prius HEV = 240 gallons = 6,000 lbs. CO<sub>2</sub> (based on lifecycle GHG emissions of burning 1 gallon of gas = 25 lbs, 20 from car and 5 from petroleum production chain; these numbers would be slightly higher for reformulated gasoline and considerably higher for oil from tar sands).

ICE = 11,000-12,000 lbs. CO<sub>2</sub>

PHEV on U.S. grid = 3,000 kWh = 3,900 lbs. CO<sub>2</sub> (based on 1.3 lbs/kWh average emissions) = 35% better than Prius, 65% better than ICE

EV on 100% coal = about double the CO<sub>2</sub> = 7,800 lbs. CO<sub>2</sub>, 29% better than ICE but 30% worse than the Prius.

#### **NATIONAL MIX, EV ONLY:**

**5)** Therese Langer and Daniel Williams. Greener Fleets: Fuel Economy Progress and Prospects, December, 2002 (Report Number T024). American Council for an Energy-Efficient Economy, Washington, D.C. Table 1 on page 4: Characteristics of Selected Alternative Fuels, includes data

on EV: Full-fuel-cycle GHG (on a per-mile basis) as % of conventional gasoline: 69% (so 31% improvement).

**7) Climate Change.** (Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing To Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles), California Environmental Protection Agency Air Resources Board: August 6, 2004. Cited by Lucy Sanna, Driving the Solution: The Plug-in Hybrid Vehicle, EPRI Journal, Fall 2005: CEC study, page 95: Using U.S. grid, an EV generates one third of the GHGs as an ICE.

**8) Daryl Slusher of Austin Energy at EDTA, Dec. 8, 2005 compared emissions from a gallon of gasoline and an equivalent "gallon" of electricity obtained from the utility's coal power plant or from the utility's wind energy. Combined with tailpipe emissions, if the car drove 12,500 miles/year:**

Carbon dioxide: 10,000 pounds from gas; 7,000 pounds from coal (30% less); 0 wind (100% less).

NOx: 41 pounds gas; 7.5 pounds electric (82% less); 0 wind.

Carbon monoxide: 606 pounds gas; 1.1 pounds electric (99% less); 0 wind.

Hydrocarbons: 80 pounds gas; 0.13 pounds electric (99% less); 0 wind.

SOx: trace amounts from gas; 25 pounds from electric (250% increase); 0 wind.

**9) "Debunking the Myth of EVs and Smokestacks," Chip Gribben, EVA of Greater Washington, D.C., circa 1997. Referenced the following studies:**

A) EVs on coal would reduce CO<sub>2</sub> by 17-22% (Cites *The Keys to the Car*, James J. MacKenzie, World Resources Institute, Baltimore, Md., May, 1994, p. 92).

B) EVs on U.S. grid would decrease HCs 96%, CO 99%, and NO<sub>x</sub> 67%, but increase SO<sub>2</sub> (from SO<sub>x</sub>) by 203% and Particulates 122% (Cites "The Case for Electric Vehicles," Daniel Sperling, *Scientific American*, November, 1996.)

C) EVs in Los Angeles would produce 10 tons of CO<sub>2</sub> (72% less) vs. 35 tons for ICEs for each 100,000 miles (Cites 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)

D) EVs in Arizona (67% coal-fired grid) would reduce GHGs by 71% (cites "Emissions, Quantifying the Air Quality Impact of EV Recharging," *Green Car Journal*, October, 1993, p. 116)

E) EVs in the northeast would reduce CO<sub>2</sub> by as much as 60% (cites Center for Technology Assessment Transportation Technology Review, "CTA Findings Reveal Carnegie-Mellon Study Misrepresents Environmental Impacts of Electric Vehicles," 1996, p.5).

## **CALIFORNIA MIX:**

**10) Climate Change.** (Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing To Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles), California Environmental Protection Agency Air Resources Board: August 6, 2004.

Table 5.3-7, p. 95, Incremental Costs of Alternative Fuel Vehicles includes these figures: Compared with ICE, if electricity came mostly from natural gas plants:

HEV20 would reduce CO<sub>2</sub> emissions by 62%. EV would reduce CO<sub>2</sub> emissions by 67%.

(An advanced HEV would reduce CO<sub>2</sub> by 54% compared with ICE. So compared with an HEV, an HEV20 would decrease CO<sub>2</sub> by 15% and an EV would decrease CO<sub>2</sub> by 24%.)

Table 5.2-13, page 78 and Table 5.2-3, page 59 were mined for a chart created in 2005 by David Modisette, executive director of the California Electric Transportation Coalition and reprinted in EV World Dec. 30, 2005, in Bill Moore's column, "Why Well-to-Wheel Matters." It shows same percentages as above. Total CO<sub>2</sub> equivalent emissions (well to wheels): Conventional ICE 449 g/mi. Advanced HEV 210 g/mi (53% reduction). PHEV20 (primarily natural gas electricity) 171 g/mi (62% less vs. ICE, 19% less vs. HEV). EV (nat gas) 150 g/mi (67% less vs. ICE, 29% less vs. HEV).

**11)** “Draft Technology and Cost Assessment for Proposed Regulations to Reduce Vehicle Climate Change Emissions Pursuant to Assembly Bill 1493,” California Air Resources Board Mobile Source Control Division, El Monte, Calif., April 1, 2004, Table II-13, p. II-31: Plug-in hybrid would reduce lifetime CO<sub>2</sub> equivalent emissions by 50% vs. ICEs.

**12)** “Choose a car to stabilize the climate and your wallet,” Stephen Heckerth, Energy Conversion Devices, Inc., Rochester hills, Mich. Presented at California Public Utilities Commission “Climate Change Policy En Banc,” Feb. 23, 2005, San Francisco. Assumptions: upstream emissions for both electricity and gasoline; gas costs \$2.50/gallon; time-of-use off-peak electricity is 5 cents/kWh; there are 40 kWh of energy in a gallon of gasoline; burning 1 gallon produces 23 pounds of CO<sub>2</sub>; all gas or hybrid vehicles hold 5 passengers and have a 350-mile gas range; and EV1 has 120-mile range. Results: Total CO<sub>2</sub> emissions (tailpipe and upstream) per year of driving 50 miles/day = 24 tons for 20-mpg gas car, 12 tons for 40 mpg hybrid, 5.5 tons for plug-in hybrid with 25-mile EV range and 40 mpg (77% less vs. ICE, 54% less vs. HEV), and 0.2 tons for EV1 (99% less vs. ICE, 98% less vs. HEV).

**13)** Mark Duvall, EPRI, presentation Nov. 15, 2003 at American Public Power Association conference: Fuel cycle CO<sub>2</sub> emissions estimated:

A) Compact sedan: 300 g/mi ICE; 240 g/mi HEV (70% less); 190 PHEV20 (37%); 140 PHEV60 (53%). PHEV20 is 21% less than HEV. PHEV60 is 42% less than HEV.

B) Midsize sedan: 400 / 290 (27% less) / 220 (45%) / 170 (57%). PHEV20 is 24% less vs. HEV; PHEV60 is 41% less.

C) Midsize SUV: 500 / 360 (28% less) / 280 (44%) / 200 (60%). PHEV20 is 23% less vs. HEV; PHEV60 is 45% less.

D) Fullsize SUV: 650 / 440 (32% less) / 320 (51%) / 250 (61%). PHEV20 is 27% less vs. HEV; PHEV60 is 43% less.

**14)** Jon Leonard, TIAX LLC (R&D consultants), presented at EDTA Dec. 7, 2005, Vancouver a 2005 update of 2002 study for California Electric Transportation Coalition: TIAX Update to 2002 ADL LEV EV Market Assessment, October 25, 2005.

Assumptions: Calculated emissions improvements from new (not existing) plug-in vehicles, assuming each replaced a gas car, and including upstream emissions from production of gasoline or electricity.

For PHEVs, “expected” numbers assume introduction in 2009 and sales following pattern of Toyota Prius growth. Range of benefit based on PHEV20 on low end and PHEV60 on high end. For EVs (full-size, city, and neighborhood EVs), “expected” numbers assume that automakers choose to meet the ZEV program’s gold category with half fuel-cell vehicles and half EVs, and that the EVs will be divided between full-size and city cars. NEVs assumed to grow by 1,000-2,000/year. After 2010, 5% market growth assumed. “Achievable” numbers assume very aggressive incentive programs and regulations.

Bottom line: CO<sub>2</sub>, NO<sub>x</sub>, ROG, and PM reduced in all PHEV and EV scenarios compared with gas cars.

Results for emissions reduction with “expected” scenario by 2020:

PHEVs: CO<sub>2</sub> 1.12-1.63 million tons/year; NO<sub>x</sub> 0.21-0.44 tons/day; ROG 0.34-0.73 tons/day; PM 0.03-0.07 tons/day.

EVs: CO<sub>2</sub> 0.03-0.05 million tons/year; NO<sub>x</sub> 0.01-0.02 tons/day; ROG 0.02-0.03 tons/day; PM 0.

Results for emissions reduction with “achievable” scenario by 2020:

PHEVs: CO<sub>2</sub> 10-12.99 million tons/year; NO<sub>x</sub> 1.8-3.5 tons/day; ROG 0.37-0.7 tons/day; PM 0.8-0.88 tons/day

EVs: CO<sub>2</sub> 1.24 million tons/year; NO<sub>x</sub> 0.43 tons/day; ROG 0.73 tons/day; PM 0.07 tons/day

Combined with expected increases in truck stop electrification, alternative electric marine power, electrified transportation refrigeration units, off-road electric industrial vehicles (like forklifts), and hydrogen fuel cell vehicles by 2020, the total could reduce greenhouse gases by 4 million tons/year, and criteria pollutants by 72 tons/day. (Note: 72 tons/day is equivalent to taking off the road 1.7 million cars made in 2000.)

Under the “achievable” scenario, expansion of all these electric-drive technologies could reduce greenhouse gases by 20.5 million tons/year and criteria pollutants by 194.5 tons/day.

**15)** Calcars.org chart derived from EPRI Technical Report 1006892, July 2002, “Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options for Compact Sedan and Sports Utility Vehicles.” Mark Duvall, project manager, Palo Alto.

Compared to Saturn compact sedan ICE:

HEV: 21% less CO<sub>2</sub>; 10% less nitric oxide;

PHEV: 40% less CO<sub>2</sub>; 32% less nitric oxide;

PHEV VS. HEV: 90% greater CO<sub>2</sub> reduction, 220% greater NO<sub>x</sub> reduction

Compared with Explorer mid-size SUV:

HEV: 31% less CO<sub>2</sub>; 19% less nitric oxide;

PHEV: 46% less CO<sub>2</sub>; 37% less nitric oxide;

PHEV vs. HEV: 48% greater CO<sub>2</sub> reduction; 10% greater NO<sub>x</sub> reduction.

**16)** *Plug-in Hybrid Electric Vehicles*, presentation by Mark Duvall of EPRI at American Public Power Association Plug-in PHEV Symposium, Nov. 17, 2005. A PHEV20 compared with HEV0 in lifetime of car would: Produce 20%-30% less CO<sub>2</sub>; produce 30%-40% less NO<sub>x</sub> and ROG; use 42% less petroleum (and fewer trips to gas station).

**17)** “A Vision of the Future: A Global Perspective of PHEVs and the Impact on Electric Utilities and Generation,” PowerPoint presentation by William Glauz, Los Angeles Department of Water and Power, at APPA PHEV Symposium, Nov. 17, 2005. Annual emissions:

CO<sub>2</sub>: ICE 11,000 lbs; HEV 7,300 lbs (34% less); PHEV 3,700 lbs.(66% less). PHEV vs. HEV: 49% less.

NO<sub>x</sub>: ICE 45 lbs.; HEV 30 lbs. (33% less); PHEV 15 lbs. (67% less). PHEV vs. HEV: 50% less.

EV (coal): CO<sub>2</sub> 11,000 lbs. (0 reduction vs. ICE, 49% increase vs. HEV); NO<sub>x</sub> 20 lbs. (56% less vs. ICE, 33% less vs. HEV)); (no figures for CO or HC)

EV (natural gas): CO<sub>2</sub> 5,500 lbs. (50% less vs. ICE, 25% less vs. HEV); NO<sub>x</sub> <1 lb. (98% less vs. ICE, 97% less vs. HEV); (no figures for CO or HC)

EV (renewable): 0 / 0 / 0 / 0 = 100% reduction in all emissions

**18)** Phil Karn, EV1 driver, compared on-road emissions from gasoline cars with upstream emissions from electricity production for an electric vehicle getting 4 miles/kWh. EV emissions in g/mile compared with gas car: CO and VOCs reduced more than 99%, NO<sub>x</sub> reduced 99%, SO<sub>x</sub> reduced 95%, and PM and PM<sub>10</sub> reduced 97%. [http://www.ka9q.net/ev/ev\\_emissions.html](http://www.ka9q.net/ev/ev_emissions.html)

#### **CANADA:**

**19)** *Full Fuel Cycle Emissions Reductions through the replacement of ICEVs with BEVs*, Electric Vehicle Association of Canada, July 10, 2000. Prepared for Health Canada, Air and Waste Section.

EVs using 1999 technology reduce GHG 55%-99.9% depending on the electricity source, compared with “average” of conventional ICEs on road in 2005 (new & used). If used new 2005 ICEs, GHG emissions would not change but non-CO<sub>2</sub> would be less.

If from coal, EVs reduce GHG 55%-59% and non-GHG by 80%-92%.

If from conventional natural gas, reduce GHG by 74% and non-GHG by 99.5%.

If from combined cycle nat gas, reduce GHG by 85% and non-GHG by >99.5%.

#### **OTHERS:**

**20)** MarkKapner, Austin Energy, presented to Electric Auto Association chapters meeting, April, 2005. Assumptions: Driving 12,500 mile/year, and EV charges using \_ kW per hour:

A) If charge solely on electricity from coal-fired plant, EV vs. average gasoline car:  
CO<sub>2</sub>: EV = 7,000 pounds/MWh (39% less), Gas car = 11,450 pounds/MWh

NOx: EV = 8 pounds/MWh (79% less), Gas car = 38 pounds/MWh  
Hydrocarbons; EV = 0.13 pounds/MWh (99% less), Gas car = 77 pounds/MWh  
CO: EV = 1 pounds/MWh (99% less), Gas car = 575 pounds/MWh  
SOx: EV = 25 pounds/MWh, Gas car = (EPA report didn't list SOx)

B) If charge on mix from Calif. South Coast Air Basin (mostly natural gas) vs. new gasoline car:

CO2: EV = 3,965 pounds/MWh (65% less), Gas car = 11,450 pounds/MWh  
NOx: EV = 4 pounds/MWh (33% less), Gas car = 6 pounds/MWh  
Hydrocarbons: EV = 0.08 pounds/MWh (97% less), Gas car = 3 pounds/MWh  
CO: EV = 0.4 pounds/MWh (99% less), Gas car = 192 pounds/MWh  
Sox: EV = 2.5 pounds/MWh (108% increase), Gas car = 1.2 pounds/MWh

**23)** "The Future of Electric Transportation in Broward County, Florida," Broward County Board of County Commissioners, Department of Planning and Environmental Protection, 1999, p. 6-7 and 13: Estimate that EVs would reduce vehicular air emissions by 95% and CO2 by 28% vs. gasoline vehicle. If EVs replaced 10% of the conventional fleet, an extra 20 million gallons of gasoline (out of 2 billion) per year would be saved because of less need to transport, store, and distribute gasoline, besides what's saved by the EVs themselves.

**24)** "A Critical Evaluation of Electric Vehicle Benefits," Todd Litman, Victoria (B.C.) Transport Policy Institute, Nov. 28, 1999. Referenced the following studies:

A) "Driving Out Pollution: The Benefits of Electric Vehicles," Roland Hwang et al, Union of Concerned Scientists, 1994. Compared lifetime emissions for ultra-low-emission gasoline vehicle and electric vehicle in the Los Angeles area (including electric power generation resources outside the South Coast Air Basin: ROG = 46-54 kg vs. 0.49 kg (99% less). CO = 198-478 kg vs. 2.76 kg (99% less). NOX = 60-66 kg vs. 24.28 kg (60% less). PM10 = 2.5 kg vs. 1.1 kg (56% less). SOX = 11.8 kg vs. 13.8 kg (60% increase). Carbon = 19,200 kg vs. 5,509 kg (71% less).

B) EVs would reduce CO2 by 50%, per "Magnitude and Value of Electric Vehicle Emissions Reductions for Six Driving Cycles in Four U.S. Cities," Quanlu Wang and Danilo Santini, Transportation Research, Argonne National Laboratory, Argonne, Ill. Record 1416, March 1993, p. 22-42. Compared with mid-1990s gasoline vehicle, electric vehicle would reduce hydrocarbons and CO by 98% or more and reduce NOX in all four cities. CO2 emissions reductions are uniformly large at low speed but variable at high speed.  
<http://pubsindex.trb.org/document/view/default.asp?Ibid=388959>.

C) "Texas Transportation Energy Savings: Assessment of Control Measures, Technologies and Policies," Texas Sustainable Energy Development Council, Austin, Tex., 1995, p. 99. Compared with average gasoline car, EV would produce 33% of air pollution if electricity came from natural gas and 80% if came from coal.

D) "Transport and Greenhouse Gas Costs and Options for Reducing Emissions," Bureau of Transport and Communications Economics, Australian Gov. Publishing Service (Canberra), July 1996, p. 296. Electric vehicle would reduce lifecycle CO2-equivalent gases 11% vs. petroleum car.

E) "The Role of Electric Cars in Amsterdam's Transport System in the year 2015," Sytze Rienstra and peter Nijkamp, Transportation Research D, Vol. 3, No. 1, January 1998, p. 31. Estimates that electric vehicles reduce CO2 emissions by 20%.

**25)** "Electric Vehicles: Technology, Performance and Potential, Organization for Economic Co-operation and Development (OECD), Paris, France, 1993, referenced in "A Critical Evaluation of Electric Vehicle Benefits," Todd Litman, Victoria (B.C.) Transport Policy Institute, Nov. 28, 1999, p. 12: Concluded that electric vehicles may increase CO2 emissions if the electricity is generated with fossil fuels. (assumptions and comparison vehicle unclear; no further information)

**26)** "Audi Duo Demonstration Project: Environmental Comparison and User Survey," Peter Hendriksen et al, Audi, presented at EVS-17, Montreal, Canada, October, 2000. Study compared diesel-electric plug-in hybrid with diesel cars, and found that under some (but not all) driving conditions, the PHEV may increase CO2 or other emissions.

*Source: Plug-in Hybrids: The Cars that Will Recharge America, by Sherry Boschert (New Society Publishers, 2006)*