Publication Review: What are the environmental benefits of plug-ins?

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Citation of Publication	Main Findings	Interesting Notes
Thompson T, Webber M and Allen D T 2009 *Air quality impacts of using overnight electricity generation to charge plug-in hybrid electric vehicles for daytime use* Environ. Res. Lett. **4** 014002	• Air quality modeling of the states served by the Pennsylvania, New Jersey, Maryland (PMJ) classic grid show that the substitution of 20% of the mobile vehicle fleet VMT would reduce ozone by up to 8 ppb in the most densely populated areas in the PJM.	• Assuming PHEVs in the northeastern United States charge at night with unused base-load electricity generating capacity during the summer ozone season. PHEVs are assumed to be operated in urban areas within the PMJ region. • With the full utilization of PHEVs, CO emissions are reduced by 2420 tons and VOC emissions are reduced by 180 tons. • There is also the potential for localized worsening of ozone concentrations as the spatial and temporal patterns of emissions change. • If coal-fired power plants are used to generated electricity to power PHEVs, local SO2 emissions are projected to increase (surrounding power plants), and more particulate sulfate would be formed. • Reduced emissions from vehicle exhaust would lower particulate matter concentration in most areas (aside from power plant localities).

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Kintner-Meyer M, Schneider K and Pratt R 2007 *Impact Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional US Power Grids. Part I: Technical Analysis* Pacific Northwest National Laboratory. Retrieved April 1, 2009 from: http://www.ornl.gov/info/ornlreview/v41_1_08/regional_phev_analysis.pdf	• With the proper changes in the operational paradigm, current US electric power infrastructure could generate and deliver the necessary energy to fuel the majority of the U.S. light duty vehicle fleet.	• The U.S. electric infrastructure is designed to meet the highest expected demand for power and, as a result, is underutilized the majority of the time. The system operates at its full capacity only a few hundred hours a year, at most (about 5% of the time). For the remainder of the time, the power system could generate and deliver a substantial amount of energy needed to fuel the nation's light duty vehicle fleet (LDV): cars, pickup trucks, sport utility vehicles (SUVs), and vans. This would require no additional investments in generation, transmission, and distribution capacities. • Report assumes PHEVs with 33 mile pure electric range (average daily driving requirements) charge off peak. • Existing electrical infrastructure and capacity could supply energy to 73% of U.S. light duty vehicle fleet including cars, pickup trucks, SUVs, and vans. • This has a gasoline displacement potential of 6.5 million barrels of oil equivalent per day, or 52% of the nation's oil imports. • Overall, PHEVs reduce greenhouse gas emissions with regional variations dependent on the local generation mix. Total NOX emissions may or may not increase, dependent on the utilization of coal generation in the region. Total SOX emissions increase in all but 3 regions. Particulate emissions increase in 8 of the 12 regions. The emissions in urban areas are found to improve across all pollutants and regions as the emission sources shift from million of tailpipes to a small number of large power plants in less-populated areas. • There are favorable economic impacts associated with a high fuel-displacement scenario. PHEVs provide power sales revenues without requiring additional new infrastructure. This translates into additional profits and, from a regulated electricity industry point of view, downward pressure on rates.

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Lemoine D M, Kammen D M and Farrell A E 2008 *An innovation and policy agenda for commercially competitive plug-in hybrid electric vehicles* Environ. Res. Lett. **3** 014003	• Study was conducted in California, and concluded that under recent conditions, well over 1 million PHEVs could economically charge even during peak hours with real-time electricity pricing. • The way PHEVs are charged strongly influences the number of PHEVs that can be charged without expanding the electric power system.	• To ensure “desirable outcomes” (avoid raising peak charging), “appropriate incentives are needed” (time-of-use charging rates, for instance).

Citation of Publication	Main Findings	Interesting Notes
Knipping E and Duvall M 2007 *Environmental Assessment of Plug-In Electric Hybrid Vehicles* vol 1 *Nation wide Greenhouse Gas Emissions* Electric Power Research Institute http://my.epri.com/portal/server.pt?open=512&objID=243&PageID=223132&cached=true&mode=2	• Scenario based modeling analysis to determine GHG impacts of PHEVs over a 2010 to 2050 timeframe (looking at well-to-wheel impacts) • Cumulative GHG emissions reductions from 2010 to 2050 can range from 3.4 to 10.3 billion metric tons. PHEVs result in small but significant improvements in ambient air quality. • In 2010, PHEVs using current coal technologies result in 28% to 34% lower GHG emissions to conventional vehicles and 1% to 11% higher GHG emissions compared to the hybrid electric vehicle. • In 2050, PHEVs have lower GHG emissions than conventional and hybrid vehicles in all cases	• Calculations took into account well-to-wheel emissions, including generation of electricity used to charge batteries and the emissions related to production, distribution and consumption of gasoline and diesel motor fuels. • Three scenarios were modeled representing high, medium and low levels of emissions (CO_2 and total GHG) intensity for the electric sector depending on the generating mix of technologies etc. • Three scenarios representing high, medium and low penetration of PHEVs in 2010-2050 were also modeled. • All nine scenarios significantly reduced GHG emissions in 2050 (annual reduction of GHGs in 2050 varied between 163 to 612 million metric tons depending on the scenario modeled). • Each region of the U.S. will yield reductions in GHG emissions in 2050 according to the modeled scenarios in this report.

Citation of Publication	Main Findings	Interesting Notes
Knipping E and Duvall M 2007 *Environmental Assessment of Plug-In Electric Hybrid Vehicles* vol 2 *United States Air Quality Analysis Based on AEO-2006 Assumptions for 2030* Electric Power Research Institute http://my.epri.com/portal/server.pt?open=512&objID=243&PageID=223132&cached=true&mode=2	• Many regions in the U.S. would see a reduction in exposures to ozone and particulate matter, and reduced deposition rates for acids, nutrients and mercury with the deployment of PHEVs.	• Two scenarios were designed to evaluate air quality in 2030: (1) a base case without any penetration of PHEVs in the U.S. vehicle fleet and (2) a PHEV case with PHEVs having reached 50% of new vehicles sales and constituting 40% of on-road vehicles by 2030 (overall fraction of vehicle miles traveled by the U.S. vehicle fleet using electric batteries is 20%). • Additional electricity demand due to PHEV market penetration was assumed to be met by coal fired generation technology with present day environmental controls. • In most U.S. regions, PHEVs result in small but significant ambient air quality improvements and reduction in deposition of various pollutants (acids, nutrients and mercury). • Ozone levels decreased for most regions, but increased in some local areas (61% of population would see decreased ozone levels and 1% of the population would see increased ozone levels). • Mercury emissions increase by 2.4% with increased generation needs to meet PHEV charging loads. • Primary emissions of particulate matter increase by 10% with the use of PHEVs due to the large growth in coal generation assumed in the study. That said, Particulate matter concentrations decreased in most regions due to reductions in VOC and NOx emissions.
Bradley T and Frank A 2009 *Design, demonstrations and sustainability impact assessments for plug-in hybrid electric vehicles* Renew. Sustain. Energy Rev. **13** 115–28	• The large impact of PHEVs on the petroleum consumption of the transportation energy sector is universally acknowledged according to this review of various PHEV studies.	• According to a diverse set of studies referred to in this paper, the reduction of carbon dioxide emissions affiliated with simulated and tested PHEVs to date vary between 27% and 67% depending on electricity source, EV range, and vehicle size compared to baseline emissions. Although there exists some variation among the studies cited in this paper, those studies that power PHEVs using future grid electricity find that PHEVs can achieve a significant reduction in the CO2 emissions of transportation.

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Stephan C H and Sullivan J 2008 *Environmental and energy implications of plug-in hybrid-electric vehicles* Environ. Sci. Technol. **42** 1185–90	• A switch to PHEVs from conventional vehicles will lead to reductions in GHG emissions of 25% in the short term, and up to 50% in the long term using existing spare nighttime capacity (compared to conventional hybrid counterparts).	• According to this paper, PHEVs emit fewer grams of CO2 per km than gas powered HEVs even when PHEVs are supplied with coal generated electricity.
Samaras C and Meisterling K 2008 *Life cycle assessment of greenhouse gas emissions from plug-in hybrid vehicles: implications for policy* Environ. Sci. Technol. **42** 3170–6	• Looked at the entire life cycle of PHEVs and found that the worst-case scenario would lead to CO_2 emissions that are no greater than conventional vehicles.	• Lithium-ion battery materials account for 2-5% of life cycle emissions from PHEVs. • Automobiles and light-duty trucks account for approximately 17% of total U.S. GHG emissions. Together, burning fossil fuels in the transport and power sectors account for about 59% of emissions. • PHEVs were found to reduce use phase GHG emissions by 38-41% compared to conventional vehicles (CV) and 7-12% compared to HEVs (assuming U.S. average GHG intensity of electricity). • When life cycle emissions are measured using an average U.S. electricity GHG intensity, PHEVs reduce emissions by 32% compared to CVs. • To encourage large GHG reduction with PHEVs, it is suggested that public policies encourage low-carbon electricity generation (adjusting renewable portfolio standards, for example). • Considerable reductions in GHG emissions in relation to PHEV adoption will require decisions within the next ten years to develop a low-carbon electricity supply.

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Romm J 2006 *The car and fuel of the future* Energy Policy 34 2609–14	• The most promising alternative fuel vehicle (AFV) is the plug-in hybrid electric vehicle. Of all AFVs, the PHEV has clear environmental benefits and substantially lower GHG emissions.	• PHEVs avoid several of the barriers associated with other AFVs: they do not have major safety/liability issues and they have low fueling costs compared to gasoline, for example.

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Kromer, Matt 2008 *Electricity as a Low Carbon Fuel: A Comparison of Future Vehicle Technologies*	• In 2030-2035, the PHEV is projected to offer a 67% reduction in GHG emissions and an 85% reduction in onboard fuel use compared to present-day technology.	• [T]he projected GHG benefits are modest compared to future HEVs without significant de-carbonization of the electric grid.

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Laboratory for Energy and the Environment, MIT July 2008 *On the Road in 2035*	• 7.5% hybrids needed in 2035 to offset GHG impact from 10% oil sands. • A 2–6% reduction in 2035 well-to-wheel CO_2 emissions is possible by changing fuel mix.	Increases in fuel tax induce two types of response: 1) a change in the amount of vehicle travel, and 2) a change in the rate of fuel consumption in vehicles.

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Webber; King 2008 *The Water Intensity of the Plugged-In Automotive Economy* University of Texas	• In displacing gasoline miles with electric miles, approximately 3 times more water is consumed (0.32 versus 0.07–0.14 gallons/mile) and over 17 times more water is withdrawn (10.6 versus 0.6 gallons/mile) primarily due to increased water cooling of thermoelectric power plants to accommodate increased electricity generation.	• If 25% of the US fleet were PHEVs with a 60 mile all electric range, our water usage would increase by 3.3%