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Executive Summary

Environmental Assessment of Plug-In Hybrid Electric Vehicles

Volume 2: United States Air Quality Analysis Based on AEO-2006 Assumptions for 2030

Environmental Assessment of Plug-In Hybrid Electric Vehicles

In the most comprehensive environmental assessment of electric transportation to date, the Electric Power Research Institute (EPRI) and the Natural Resources Defense Council (NRDC) are examining the greenhouse gas emissions and air quality impacts of plug-in hybrid electric vehicles. The purpose of the program is to quantify the nationwide environmental impacts of potentially large numbers of PHEVs over a time period of 2010 to 2050. 2010 is assumed to be the first year PHEVs would be available, while 2050 would allow the technology sufficient time to fully penetrate the U.S. fleet.

Two Study Components, Two Reports

Phase 1 of the study, completed in June 2007, has two major components. The first is a scenario-based modeling analysis to determine the greenhouse gas impacts of PHEVs over a timeframe of 2010 to 2050. The second component is a nationwide air quality analysis for the year 2030 that assumes an aggressive market penetration of PHEVs.

The methodology and findings of these two analyses are presented separately in two technical reports:

- *Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions* (1015325)
- *Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 2: United States Air Quality Analysis Based on AEO-2006 Assumptions for 2030* (1015326)

Summary of Air Quality Methodology

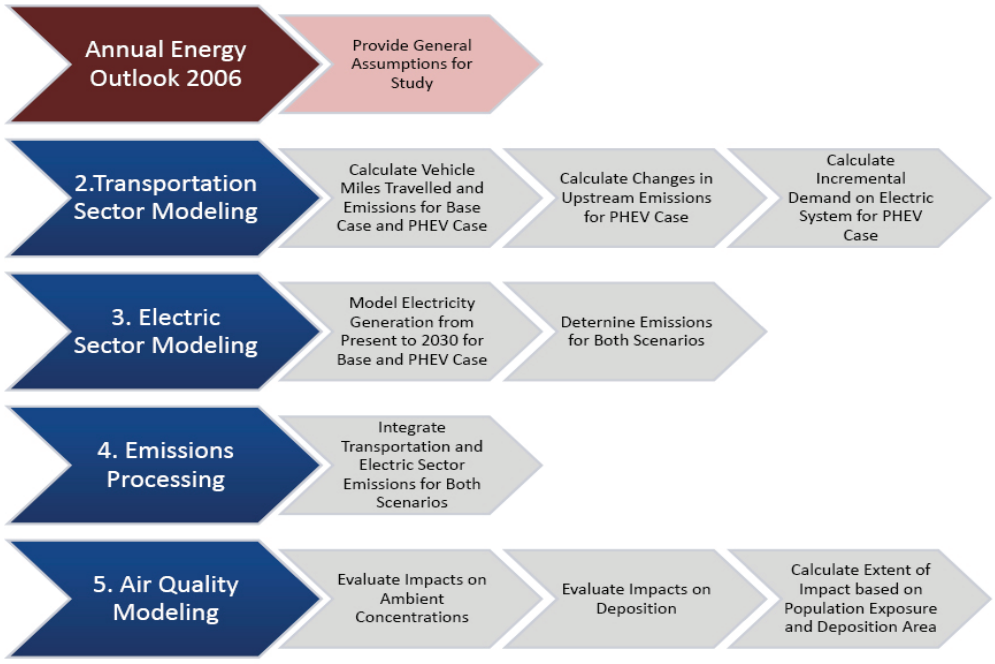
The air quality study evaluated two scenarios for the year 2030: (1) a base case without any penetration of PHEVs in the U.S. vehicle fleet and (2) a PHEV case with PHEVs having reached 50% of new vehicle sales and constituting 40% of on-road vehicles by 2030. In the PHEV case, the overall fraction of vehicle miles traveled by the U.S. vehicle fleet using electricity stored in PHEV batteries is 20%.

The air quality study models both the transportation and electric power sectors in the year 2030 to explore the impact of PHEVs on criteria emissions and subsequent effects on air quality and deposition. The study examined a high electric-sector emission case where nearly all additional electricity demand needed to power an aggressive market penetration of PHEVs was assumed to be met by an increase in the use of present-day coal-fired generation technology with only currently required environmental controls. This is consistent with the U.S. Department of Energy's 2006 Annual Electric Outlook, which assumes no national greenhouse gas policies or constraints, and a sizable increase in coal-fired generation.

The study consisted of four key steps:

1. ***Transportation Sector Modeling*** – For both the base case and the PHEV case, the transportation sector and its emissions were modeled out to 2030. Emissions offset due to vehicle miles traveled using electricity (and reductions in upstream emissions) are calculated by the transportation models. In addition, the incremental electricity demand due to PHEVs was calculated for the PHEV case. The incremental load takes into account losses during transmission and battery charging. This incremental load is also attributed to different hours of the day assuming an overall charging profile for the fleet.
2. ***Electric Sector Modeling*** – For both the base case and PHEV case, the U.S. electric sector was modeled from 2006 to 2030. New generation capacity and electricity dispatch is simulated by the models to account for increased load due to population and economic growth. Emissions associated with electricity generation is also calculated and constrained by environmental regulations as explained earlier. In the PHEV case, the incremental electrical load due to PHEVs is added for all intermediate years in which PHEVs are present as well as 2030.
3. ***Emissions Processing*** – For each scenario, emissions from the transportation sector and electric sector are merged with emissions from all other sectors into an emissions inventory. Natural emissions from vegetation and soil are also added into the emissions inventory. The emissions inventory is then transformed into a format suitable for use in a three-dimensional model of air quality for the entire continental United States.
4. ***Air Quality Modeling*** – The U.S. Environmental Protection Agency's Community Multiscale Air Quality (CMAQ) model was used to simulate U.S. air quality in 2030 in each scenario. The key air quality indicators investigated in the air quality modeling were:
   - ozone mixing ratios;
   - daily and annual particulate matter concentrations (for both PM_{10} and $PM_{2.5}$);
   - deposition of sulfate, nitrate, total nitrogen (sum of oxidized and reduced nitrogen) and mercury; and
   - visibility at Class I areas (e.g. national parks).

In addition, population-weighted exposure indicators were also calculated for ozone and particulate matter.



Roadmap of Study Methodology

Summary of Results

Because of the significant reduction in emissions from gasoline and diesel fuel use and because caps are in place for some conventional pollutants for the electric power sector, the study finds that in many regions deployment of PHEVs would reduce exposures to ozone and particulate matter, and reduce deposition rates for acids, nutrients, and mercury.

On the other hand, because of assuming no further controls beyond existing regulations for the power sector, ozone levels would increase locally in some areas. Similarly, the direct emissions of particulate matter and mercury would increase somewhat and some regions and populations would experience marginal increases in exposures to those pollutants. However, as explained in the key findings, PHEVs do not increase the U.S. contribution to the global mercury budget over the long term.

The air quality study is not meant to project carbon dioxide (CO_2) emissions and does not include any climate-change policies or greenhouse gas emissions constraints. As explained earlier, it is based on the U.S. Department of Energy's 2006 Annual Electric Outlook. A separate report modeled both the transportation and electricity sectors out to 2050 in order to analyze greenhouse gas emissions.

Overall, the air quality benefits from PHEVs are due to a reduction of vehicle emissions below levels required by current regulation (due to their non-emitting operation in all-electric mode), and because most electricity generation emissions are constrained by existing regulatory caps. Any additional increase in the amount of all-electric vehicle miles traveled or further emissions constraints on the electric sector would tend to magnify these benefits.

The key results of the air quality study are summarized below:

- In most regions of the United States, PHEVs result in small but significant improvements in ambient air quality and reduction in deposition of various pollutants such as acids, nutrients and mercury.
- On a population weighted basis, the improvements in ambient air quality are small but numerically significant for most of the country.
- The emissions of gaseous criteria pollutants (NOx and SO_2) are constrained nationally by regulatory caps. As a result, changes in total emissions of these pollutants due to PHEVs reflect slight differences in allowance banking during the study's time horizon.
- Considering the electric and transportation sector together, total emissions of VOC, NOx and SO_2 from the electric sector and transportation sector decrease due to PHEVs. Ozone levels decreased for most regions, but increased in some local areas. When assuming a minimum detection limit of 0.25 parts per billion, modeling estimates that 61% of the 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. The study assumes that mercury is constrained by a cap-and-trade program, with the option for using banked allowances, proposed by EPA during the execution of the study. The electric sector modeling indicates that utilities take advantage of the banking provision to realize early reductions in mercury that result in greater mercury emissions at the end of the study timeframe (2030).
- Primary emissions of particulate matter (PM) increase by 10% with the use of PHEVs due primarily to the large growth in coal generation assumed in the study.
- In most regions, particulate matter concentrations decrease due to significant reductions in VOC and NOx emissions from the transportation sector leading to less secondary PM.

EPRI Perspective

This report describes a study to explore the air quality impacts of large numbers of plug-in hybrid electric vehicles (PHEVs) in year 2030 using a combination of transportation-sector, electric-sector and atmospheric (air quality) models.

PHEVs represent an important technical step toward increased fuel efficiency, decreased emissions, and greater energy independence. EPRI has supported the development of PHEV technology and continues to support its deployment with collaborative R&D and analyses.

Policymakers, technology developers, and utility and environmental planners need objective and accurate information to make sound decisions about developing and deploying PHEVs in support of national energy and environmental policy. PHEVs offer the potential for reducing both emissions and fuel consumption, simultaneously addressing the issues of global warming and the nation's dependence on imported oil. Quantifying these benefits has proved challenging, however, and misinformation has circulated about the environmental performance of PHEVs.

The objective of this study was to evaluate the impact of PHEVs on key air quality parameters for a future-year scenario with substantial penetration of PHEVs in the U.S. light-duty vehicle fleet (passenger cars and light-trucks).

This study is one component of a comprehensive environmental assessment of PHEVs conducted in collaboration with the Natural Resources Defense Council (NRDC). A second component is a nationwide analysis of the greenhouse gas (GHG) emissions from 2010-2050. Results of the GHG emissions analysis are presented in an EPRI technical report, Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions (1015325).

Study findings will help support informed decision-making regarding PHEV development and deployment in support of national energy and environmental policy. Study results will also dispel misunderstandings about PHEVs and emissions—such as the common misunderstanding that PHEVs would worsen air quality due to emissions from electricity generation for battery charging.

NRDC Perspective

The Natural Resources Defense Council's purpose is to safeguard the Earth: its people, its plants and animals and the natural systems on which all life depends. The organization uses law, science, and the support of its members to promote solutions to our environmental challenges.

- Participation in this study does not imply NRDC endorses the power plant emission control assumptions in the air quality report. The study's air quality modeling and analysis are based on an assumption that regulatory caps govern NOx, SO_2 and mercury emissions during the study period, and that EPA rules do not change during the study time horizon. However, the actual situation is more complex—for example, a number of states have declined to participate in EPA's model cap-and-trade rule for mercury in favor of more stringent approaches. In addition, EPA's Clean Air Mercury Rule and Clean Air Interstate Rule (resulting in tighter NOx and SO_2 caps in the eastern U.S.) are currently being challenged in court. NRDC firmly believes that stronger emissions controls are necessary to protect human health. This study does not attempt to determine the adequate level of power plant controls or adequate levels of ambient air pollution and strives only to determine the specific impacts of large-scale PHEV penetration given the assumptions of the study.
- NRDC does not support trading off pollution benefits in some regions for pollution increases in others regions. NRDC believes that no areas or populations should be allowed to experience increases in air pollution exposures and that further emission controls from all sources are needed in order to protect public health. Consequently, NRDC supports more stringent emissions control requirements for the electric and transportation sectors, as well as other economic sectors.
- NRDC does believe that with sufficient emissions controls in place PHEVs have the potential to improve air quality and to substantially contribute to meeting our long term GHG reduction goals of 80% below 1990 levels by 2050.

- NRDC supports the introduction of PHEVs accompanied by substantial additional improvements in power plant emission rates. In areas where there are potential adverse impacts from air pollution as a result of PHEV charging, NRDC believes it is not appropriate to promote introduction until the public can be assured that air pollution will not increase.

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