

STATE CLEAN ENERGY - ENVIRONMENT TECHNICAL FORUM

Call #21: Plug-in Hybrid Electric Vehicles

March 15, 2007, 2:00 p.m. - 3:30 p.m. EST

BACKGROUND

I. Introduction

As concerns over greenhouse gas (GHG) emissions and energy security continue to grow, reducing the transportation sector's environmental impacts and petroleum demand remain a critical element for state and national level discussions. Of the approximately 21 million barrels of petroleum per day consumed in the U.S., over 14 million barrels (two thirds) are consumed by the transportation sector.¹ The transportation sector's large reliance on petroleum also translates to significant GHG emissions. In 2003, 27% of the total U.S. GHG emissions came from the transportation sector.² By 2030, U.S. transportation sector's GHG emissions are forecasted to grow by 35% beyond today's level.³

Over the past several years, plug-in hybrid electric vehicles (PHEVs) have generated high levels of interest due to their potential environmental and energy security benefits. PHEVs are potentially a "game changing" or "disruptive innovation" because of their potential to shift transportation energy use from conventional fuels to electricity.⁴ Thus, PHEVs also allow potential greenhouse gas abatement options in the electricity sector to play a potentially major role in reducing transportation sector greenhouse gas emissions. Lastly, PHEVs can also provide a technological bridge to commercially viable electric vehicles (EV), by stimulating the high-volume production of components such as batteries, motors, and power electronics that are similar between PHEVs and EVs. While most do not envision any single technology being the "silver bullet" for the transportation sector, many do view PHEVs as a promising near-term option.

Technology, Costs, and Potential Issues

Current hybrid electric vehicles (HEVs), which draw propulsion energy from both the internal combustion engine and a rechargeable energy storage system such as a battery, can yield fuel economy improvements up to 30 to 60 percent compared to conventional gasoline-only models.⁵ By comparison, PHEVs would have a larger battery/energy storage system than current HEVs in addition to a plug, which would enable the vehicle to have greater "all electric range" capability. The additional charger and plug would also allow the battery to be charged from a conventional outlet, an option not available in current HEVs. This added electric capability allows for reduced dependence on gasoline and even further improvements to fuel economy. Currently, several vendors offer after-market battery conversion kits that allow some HEVs to be

¹ *Annual Energy Outlook (AEO) 2007*, Energy Information Administration, U.S. DOE.

² *Greenhouse Gas Emissions from the U.S. Transportation Sector (1990-2003)*, U.S. EPA, Office of Transportation and Air Quality, March 2006. (<http://www.epa.gov/otaq/greenhousegases.htm>). Note that these represent only the "tailpipe" GHG emissions resulting from the use of energy to power vehicles and do not include the upstream emissions during fuel production, vehicle production, and scrappage.

³ *AEO 2007*.

⁴ Christensen, Clayton M. (1997) *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Boston, Mass.: Harvard Business School Press.

⁵ Note that fuel economy improvements do not directly translate to GHG reductions. Rather, GHG emissions are proportional to fuel consumption (gallon per mile), as opposed to fuel economy (miles per gallon). For example, a 40% fuel economy improvement for a HEV would actually translate to 71% of the baseline fuel consumption ($1/(1+0.4) = 0.71$), or a fuel consumption reduction of $(1-0.71) = 29\%$. GHG emissions would also be reduced by 29%.

converted to PHEVs.⁶ Most recently, General Motors announced plans to produce the Saturn Vue and Chevy Volt, which, if they continue as planned, would be the first commercially available PHEVs.

One key issue for both manufacturers and consumers is the larger up-front costs of PHEVs compared to HEVs, primarily due to the larger battery, motors, and power electronics. Most believe that costs will need to be reduced significantly for PHEVs to have significant market penetration. For comparison, U.S. sales of HEVs in 2006 rose 28 percent for a total of 250,000 vehicles sold, representing 1.5% of total personal vehicle sales.

On the other hand, fuel costs for PHEVs will be lower since electricity costs, on a per-mile basis, are lower compared to gasoline. Mass production and further improvements to batteries could improve the range, efficiency, and cost-effectiveness of PHEVs over time. Additionally, since PHEVs can be charged overnight, owners can take advantage of lower, off-peak electric rates (in areas where such rates are available).

A question currently subject to debate is: what are the greenhouse gas emissions impacts of PHEVs?⁷ The amount of greenhouse gas (GHG) emission benefits associated with PHEVs depends upon the sources of electricity generation. If coal (without carbon capture and storage) is the primary energy source for electricity, greenhouse gas emissions benefits from PHEVs will be lower than if no/low greenhouse gas electricity sources supply the power.⁸ Current studies have found that a PHEV will have significant GHG benefits compared to current conventional gasoline vehicles even if coal is used. When compared to current hybrid electric vehicles, PHEVs also appear to have additional GHG benefits, with the degree depending on the source of electricity and specific scenario modeled.

In addition to new R&D efforts in the auto industry, PHEV related analysis, research and development is on-going at a number of universities, federal agencies, research/consulting organizations and utility companies. Most of these efforts focus on technology assessment, lifecycle analysis, macroeconomic modeling, battery R&D, vehicle modeling, and laboratory testing. For example, researchers at the National Renewable Energy Laboratory (NREL) and several other organizations are seeking lighter weight, less expensive energy storage for PHEVs. NREL is also conducting longer-term research on the potential for the PHEV owners to use surplus extra electrical storage capacity in vehicle batteries to contribute electricity back to the electricity grid to help meet peak demand. Studies of how “smart-grid” technologies and related incentive programs can help manage power availability and emissions are part of this research.

⁶ The PHEV conversion kits adds a larger battery pack, charger, and battery management system to the current HEV. The conversion kits do void the vehicle manufacturer’s warranty, since it constitutes a modification. Initial indications suggest substantial fuel economy improvements – however, these are largely dependent on driver behavior, charging frequency, and the battery management/control strategy.

⁷ This backgrounder only covers emissions of GHGs due to the the limited information regarding criteria pollutant emissions (and their precursors) from PHEVs, which are still under development.

⁸ As an estimate, the total greenhouse gas reductions of a PHEV40 (40 miles of all electric range) could range from 30 to 65% versus a conventional gasoline vehicle, when both tailpipe and upstream emissions are included. The lower end might represent, for instance, a PHEV charged from electricity generated at an ultra supercritical pulverized coal plant. The higher end might represent, for instance, a PHEV charged from electricity generated at an IGCC plant with carbon capture and sequestration. Given there are no optimized, production vehicles at this time, estimates will need to be refined over time as additional technical information, laboratory and real-world test data becomes available.

II. State and Local Efforts

Several states, cities, and counties, as well as universities and other public and private organizations are working to bring PHEVs into the market. A few of the programs involving states and localities are briefly described below.

Austin, Texas

Austin Energy, the municipal electric utility for Austin, Texas, has initiated a national "Plug-in Partners" campaign, seeking commitments from US cities and utilities to demonstrate to automakers that a market for flexible-fuel Plug-in Hybrid Electric Vehicles (PHEVs) exists today. Dozens of cities, utilities, and other organizations have shown their support for the program. A cornerstone of the program is "soft orders," or commitments to purchase plug-in hybrids as fleet vehicles if/when they become available.

<http://www.austinenergy.com/About%20Us/Environmental%20Initiatives/Plug-in%20Hybrid%20Vehicles/index.htm>

Minnesota

As of May 31, 2006, Minnesota law (House File 3718) requires the state to buy plug-in hybrids on a preferred basis when they become available. The law also encourages research into developing flexible-fuel plug-in hybrid vehicles and strategies for PHEV use and production in Minnesota.

<http://www.revisor.leg.state.mn.us/bin/bldbill.php?bill=S3440.2.html&session=ls84>

New York

New York State is buying six PHEVs, including three Ford Escapes, two Toyota Prius and a Honda Civic, for evaluation by the New York State Energy Research and Development Authority (NYSERDA). The vehicles are 2007 model-year hybrids converted to plug-in configuration by four teams representing a variety of technical approaches. The U.S. Department of Energy will assist in performing the evaluations, which will be carried out at test facilities around the country. This work is the initial step in a \$10 million program to add plug-in capability to the 400-plus hybrids operated by New York State agencies.

<http://www.dec.state.ny.us/website/environmentdec/2007a/hybridvehicle122106.html>

South Carolina

South Carolina's budget includes a \$300 sales tax rebate for the purchase of plug-in hybrid vehicles when they become available. A \$500 sales tax rebate is also available for the purchase of equipment to convert a standard hybrid to a plug-in hybrid. See section 72.113 in the South Carolina general appropriations bill.

http://www.scstatehouse.net/sess116_2005-2006/appropriations2006/tap1b.htm#s72

Southern California

California's South Coast Air Quality Management District (AQMD) has supported PHEV development since 2000. Among their many PHEV research efforts, AQMD is demonstrating the use of DaimlerChrysler PHEV Sprinter delivery vans through EPRI and Prius PHEVs converted by EnergyCS. AQMD just awarded funding to Quantum Technologies for 20 Escape PHEVs and to Hymotion for 10 Prius PHEVs to be demonstrated at up to 15 sites in southern California <http://www.aqmd.gov/hb/2007/March/07034a.html>

AQMD also supports the Austin, Texas based national "Plug-in Partners" campaign to promote and create a market for plug-in hybrid vehicles described below.

http://www.aqmd.gov/tao/conferencesworkshops/plug-in_partners/plug-in_partners_agenda.htm

III. Resources

A New Type of HEV: The Plug-in Hybrid

General information on hybrid and plug-in hybrids from the DOE Office of Energy Efficiency and Renewable Energy (EERE).

http://www.eere.energy.gov/cleancities/hev/hev_history.html

An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles

A 2006 report on the potential effects of PHEVs on electricity supply and demand, sponsored by the DOE's National Renewable Energy Laboratory.

<http://www.nrel.gov/docs/fy07osti/40293.pdf>

H.R.6203, Alternative Energy Research and Development Act

Congress is considering legislation, introduced in 2006, that would direct the DOE to fund research, development, demonstration, and commercial application on technologies needed for the development of plug-in hybrid electric vehicles. See Section 8. Plug-in Hybrid Electric Vehicle Technology Program.

<http://thomas.loc.gov/cgi-bin/query/F?c109:1:./temp/~c109Niy1z9:e5934:>

Minnesota and South Carolina Promote Plug-in Hybrids...

EERE article on legislation in MN and SC to promote plug-in hybrids

http://www.eere.energy.gov/states/state_news_detail.cfm/news_id=10069/state=MN

New York State Plug-In Hybrid Program

Information about current New York plug-in hybrid activities and their program to convert hundreds of state fleet hybrids to plug-ins.

<http://www.dec.state.ny.us/website/environmentdec/2007a/hybridvehicle122106.html>

National Renewable Energy Laboratory's Plug-in Hybrid Web Page

Up-to-date information on about NREL research on PHEVs.

<http://www.nrel.gov/vehiclesandfuels/hev/plugins.html>

Plug-In Austin (Austin Energy)

Website for the City of Austin and Austin Energy national campaign to promote plug-in hybrid vehicles as an economically and environmentally preferable transportation option.

<http://www.austinenergy.com/About%20Us/Environmental%20Initiatives/Plug-in%20Hybrid%20Vehicles/index.htm>

South Coast AQMD Plug-In Hybrid Vehicle Program

Website related to a recent expansion of AQMD PHEV activities.

<http://www.aqmd.gov/hb/2006/April/06049a.html>

South Coast AQMD Plug-in Hybrid Utility Boom Truck

AQMD will collaborate with the Electric Power Research Institute (EPRI) to develop and demonstrate a plug-in hybrid utility boom truck.

<http://www.aqmd.gov/hb/2007/February/07024a.htm>

DOE Workshop on Plug-In Hybrid Vehicles - Discussion Issues and Questions

Overview of benefits, technological issues and cost issues associated with PHEVs, including their relationship to utility electricity grids and electricity generation sources.

<http://www.keystone.org/html/documents.html>

Preliminary Literature Search on Key PHEV Studies

Lists 16 PHEV papers, including market and utility effects as well as technological issues such as emissions assessment and advanced batteries.

<http://www.keystone.org/html/documents.html>