



Viewpoint

Targeting plug-in hybrid electric vehicle policies to increase social benefits

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ABSTRACT

In 2009 the U.S. federal government enacted tax credits aimed at encouraging consumers to purchase plug-in hybrid electric vehicles (PHEVs). These tax credits are available to all consumers equally and therefore do not account for the variability in social benefits associated with PHEV operation in different parts of the country. The tax credits also do not consider variability in consumer income. This paper discusses why the PHEV subsidy policy would have higher social benefits at equal or less cost if the tax credits were offered at different levels depending on consumer income and the location of purchase. Quantification of these higher social benefits and related policy proposals are left for future work.

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1. Introduction

Three factors have recently coalesced to advance alternative fuels in the U.S. transportation sector. First, concern over the transportation sector's contributions to climate change is growing; second, memories of the 2008 oil price shocks are still fresh in the minds of consumers; and, third, an economic recession has created a fresh wave of federal dollars ("stimulus funding") of a magnitude not seen in generations. As a result, a crop of programs and policies aimed at incentivizing alternative fuel vehicle adoption has sprouted across the nation.

In particular, the federal government is encouraging purchases of plug-in hybrid electric vehicles (PHEVs) through the Energy Independence and Security Act (EISA), the American Reinvestment and Recovery Act (ARRA), and other bills aimed at stimulating the U.S. economy. Congress has approved tax credits amounting to \$758 million to subsidize the purchase of up to 250,000 PHEVs over the next few years. This amounts to about \$3000 per vehicle, although the precise amount may range from \$2500 to \$7500 depending on vehicle attributes (Associated Press, 2008).

As shown in a growing literature, the social benefits of PHEVs and other modes of electric transportation are significant (Bandivadekar et al., 2008; Bradley and Frank, 2009; EPRI and NRDC, 2007a; Granovskii et al., 2006; Hackney and de Neufville, 2001; Kromer and Heywood, 2008; Lindly and Haskew, 2002; Parks et al., 2007; Romm, 2006; Samaras and Meisterling, 2008;

Silva et al., 2009; Stephan and Sullivan, 2008; Tate et al., 2008). For this reason, the Obama Administration has established a goal of one million PHEVs on U.S. roads by 2015 (Lee, 2009). Achieving this goal would require average annual sales volumes of 200,000 vehicles or greater starting in 2010. Federal tax credits to help meet this goal will be uniformly available throughout the nation, without regard to the variability in social benefits that exists depending on the location of PHEV operation. In this paper we discuss the regional variability of PHEV social benefits and conclude that a uniform national policy for subsidizing PHEVs is at best sub-optimal, meaning that greater PHEV benefits could be achieved for the same government investment if subsidies were targeted to where the social benefits are largest. Available metrics are discussed that can be used to identify areas of the country where PHEV incentives would yield greater environmental, health, and energy security benefits. We also discuss the relationship of consumer income to vehicle choice and suggest that subsidy dollars would more effectively encourage new entrants to the PHEV market if they were offered to lower income individuals in a higher amount relative to individuals with affluent incomes.

2. Background: social benefits via PHEVs

The U.S. light-duty transportation sector is responsible for about 20% of U.S. greenhouse gas (GHG) emissions (Energy Information Administration, 2009). The sector is also 97% dependent on petroleum, over half of which is imported. Petroleum-based transportation, primarily in the form of gasoline in the U.S., is also a major cause of local air pollution and other externalities associated with petroleum production and distribution. Hybrid electric vehicles (HEVs) create social benefits by

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reducing gasoline combustion. New sales of HEV light-duty vehicles (LDV) were over 300,000 in 2008 (EDTA, 2009), and although only a small portion of the 12.6 million LDVs sold in the U.S. that year, HEV sales volumes were still more than three times their 2004 levels (Energy Information Administration, 2009). On the horizon are PHEVs, which not only are capable of operating in a highly efficient all-electric mode using batteries recharged by the electric grid, but also can operate on gasoline or other fuels when stored electricity is not sufficient to power the vehicle. Though more expensive than HEVs, PHEVs offer greater social benefits than HEVs (EPRI and NRDC, 2007a; Morrow et al., 2008; Samaras and Meisterling, 2008; Silva et al., 2009; Stephan and Sullivan, 2008) and are expected to be part of auto manufacturers' product lines in the coming years (Tate et al., 2008; Toyota, 2009). The social benefits of PHEVs include increased energy security and reduced emissions of GHGs and other air pollutants. While the social benefits of increased energy security are shared nationally, the benefits of improved air quality are more localized. Moreover, some social benefits of GHG emissions reductions are shared nationally while others are regionally concentrated.

In this article we point out that regardless of where the social benefits occur, the magnitudes of all PHEV social benefits depend strongly on the region where the PHEVs are used. Important regional factors impacting the magnitude of PHEV benefits include (1) *the efficiency, emissions, and accessibility of the electric grid used for PHEV charging*, and (2) *the location and amount of vehicle miles travelled (VMT) displacing gasoline which would have been otherwise consumed*. The hypothesis we present is that these factors are heterogeneous enough across the country that targeting PHEV subsidies to consumers in locations where they are most favorable can significantly increase social benefits for the whole country.

3. Increasing PHEV social benefits through geographically focused incentives

For instance, it is interesting to consider an alternative to a uniform tax credit where significantly larger credits are offered in regions featuring high net benefits of PHEV use (what we call "high-leverage" regions) and reduced credits are offered in regions featuring low net benefits ("low-leverage" regions). A similar idea is to consider adjusting the tax credit by consumer income, since an affluent consumer might have purchased the PHEV anyway (meaning the tax credit is wasted) and a lower income consumer might not find the tax credit large enough to bring a PHEV purchase within reach (meaning a higher subsidy for these consumers might increase PHEV adoption among lower income individuals). A revised tax credit formulation considering such regional and income heterogeneity could increase the net social benefits of PHEVs, while also mitigating income-based PHEV accessibility disparities inherent to a uniform policy. In the following we elaborate on the possible benefits of identifying and targeting high-leverage PHEV subsidy regions and consumers. We begin by recognizing the regionally dependent social benefits of PHEV use and continue by recognizing that the effectiveness of a given subsidy to aid PHEV diffusion will vary due to heterogeneity in consumer preference, demographics, network effects, and complementary policies that exist at the state and local level.

4. PHEV use: regionally dependent air pollution and human health benefits

One of the main benefits of PHEVs is the opportunity to reduce human exposure to harmful criteria pollutants including carbon

monoxide, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide (EPRI and NRDC, 2007b). In most cases PHEVs have demonstrated emissions that are lower than conventional gasoline vehicles, even when considering emissions from the power plants used to charge these vehicles (Romm, 2006; Samaras and Meisterling, 2008; Silva et al., 2009; Stephan and Sullivan, 2008). PHEV emissions reductions lead to human health benefits that are related to pollutant fate and transport and population exposure. Therefore a unit of emissions reduction in a location with high pollution levels combined with large population exposure would provide greater benefits than the same emissions reduction in a location with lower pollution and less population density. Therefore there are decreasing marginal benefits achievable by introducing PHEVs in airsheds that are relatively clean with respect to background automotive emissions. Since on-road emissions tend to be closer to large population centers than off-road (power plant) emissions, there are significantly increased benefits of PHEV use in traffic-congested metropolitan nonattainment areas.

At first it might be assumed that increased PHEV use would lead to higher NO_x and SO_x exposures due to power plant emissions. However the existing cap-and-trade regulations in place for power plants mean that total NO_x and SO_x emissions will not increase nationally. These caps are not expected to increase while also remaining independent of a potential cap-and-trade mechanism that could be applied to CO₂ emissions. In fact power plants affecting nonattainment air quality zones already have strict limits beyond which emissions would not be allowed to increase. Therefore as a first estimate we would not expect PHEVs to cause a major shift of health burden away from exposed populations of tailpipe emissions towards exposed populations of power plant emissions.

5. PHEV use: regionally dependent greenhouse gas reduction benefits

The literature has shown that GHG emissions for PHEVs are typically less than gasoline vehicles on a total fuel cycle basis, but the magnitude of the difference depends strongly on whether the electricity generated to power the PHEVs is derived from coal, natural gas, renewable fuels, or other electricity feedstock (EPRI and NRDC, 2007a; Samaras and Meisterling, 2008; Silva et al., 2009; Stephan and Sullivan, 2008). For example, a region with a large proportion of low-carbon electricity generation (e.g., nuclear, wind, solar) would be favored for PHEV deployment relative to a region with a large proportion of high-carbon electricity generation (e.g., coal and oil). However, determining GHG emissions of PHEVs is complicated by the fact that different fuels are used for base-load, load-following, and peak-load electricity production. Considering the average GHG emissions from the electricity grid in a given region is a start but ultimately insufficient for understanding GHG social benefits, since PHEV emissions are unlikely to come from existing base-load sources. Understanding load-following and peak-load emissions expected from PHEV diffusion on a regional basis would be a daunting task but worthwhile since time-of-day and seasonal variations in GHG emissions can also be significant relative to the average. Additionally, as states move towards renewable portfolio standards, the emissions attributable to PHEVs can be expected to decrease significantly.

Appropriate local incentives to recharge PHEVs with low-carbon electricity could be implemented in cases where large variations exist between base-load, load-following, and peak-load power plants. Better still would be implementation of a "smart grid" to handle vehicle-to-grid (V2G) technology, whereby stored

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