# Comments on United States Environmental Protection Agency Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards

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## I. Summary of Comments

The stated purpose of the proposed Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (the "Rule") is to address the urgent and closely intertwined challenges of energy independence and security and global warming by increasing the fuel economy of the nation's light duty vehicle fleet. Vehicle electrification technology, including plug-in hybrid electric vehicles (PHEVs), extended range electric vehicles (EREVs), and full battery electric vehicles (BEVs) (hereinafter "plug-in electric vehicles" or "PEVs"), is widely regarded as a viable, near-term technology to substantially reduce petroleum consumption and associated carbon emissions from light-duty cars and trucks. However, whether the full potential of PEVs to dramatically reduce petroleum consumption and carbon emissions is achieved will depend on the availability of public charging infrastructure (PCI) (i.e. charging equipment located in the public domain, including at places-of-work, shopping centers, parking garages, and roadside locations). In the absence of PCI, data shows that PHEVs perform only marginally better than conventional hybrid electric vehicles (HEVs) even though they are capable of a dramatic improvement if charged at some point during the work day using PCI. PCI substantially increases the real-world fuel economy of PHEVs and EREVs by enabling consumers to rely to a greater extent on battery power throughout the day. PCI also will enhance the market penetration of PEVs and EREVs, particularly in urban areas where fewer drivers have the space for home-based charging and yet where commuting distances are more suitable to electric technology and where the associated health benefits of criteria pollutant reduction will be greatest. Finally, PCI will speed the market penetration of BEVs—vehicles powered exclusively by electricity—because it is an essential tool for overcoming "range anxiety"—driver fear of running out of electricity without an opportunity to recharge quickly and conveniently.[1]

### A. Why Lack of Public Charging Infrastructure Is a Barrier to PEV Market Penetration

Meaningful penetration of PEVs in the nation's light duty vehicle fleet may never occur unless PCI is widely available. Market expansion of PEVs is likely to occur in heterogeneous and

[1] *See* Securing America's Future Energy and The Electrification Coalition, *Electrification Roadmap: Revolutionizing Transportation and Achieving Energy Security* (November 2009), pp. 14, 124, 94, 98, 127, available at http://electrificationcoalition.org/535928473533888957466293/EC-Roadmap-screen.zip.

pocketed fashion in urban areas.[2] This is because the best markets for PEVs are urban areas where population density, shorter daily commutes and high air pollution levels favor electric technology but at the same time where drivers lack the space to install home charging infrastructure.[3] With less ability to install home charging infrastructure urban drivers must have access to PCI if they are to choose to purchase PEVs.

Despite clear benefits to fuel economy, carbon reduction, and market development, the business case for installing PCI remains uncertain. The cost advantage of electric fuel happens also to be its barrier. Simply stated, electricity is cheap and one needs to sell lots of it to make a profit. Unfortunately, few PEV drivers are on the road today to buy electricity. At the same time the very act of selling electricity in most states may subject the PCI provider to rate regulation as a "public utility."[4] Also, electricity as a transportation fuel receives no production subsidy, unlike liquid renewable fuels receiving production tax credits projected to reach $5 billion in 2010 (by far the largest energy-related tax credit in the Internal Revenue Code), and a variety of other subsidies,[5] including a 1.2 mpg "flexible fuel vehicle" (FFV) credit under the CAFE program that will be continued by the Rule until MY2015.[6] Finally, the parties in the electric transportation value chain with the most to gain from PCI—consumers and OEMs—are the parties least able to pay for its deployment. OEMs view refueling infrastructure as a fuel supplier responsibility. Traditional fuel suppliers, namely petroleum refiners and marketers, view electricity as a competing fuel that threatens their monopoly in transportation fuels. Most electric utilities view PCI as an OEM or a consumer responsibility. Thus, the benefits of PCI are not well-aligned with the parties in the value chain best able to deploy it.

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[2] Markel T., Bennion K., and Kramer, W., U.S.DOE National Renewable Energy Laboratory, and Bryan, J. and Giedd, J., Xcel Energy Technical Report, *Field Testing Plug-in Hybrid Electric Vehicles with Charge Control Technology in the Xcel Energy Territory* NREL/TP-550-46345 (August 2009) available at http://www.nrel.gov/docs/fy09osti/46345.pdf; Melaina M., Bremson J., *Refueling availability for alternative fuel vehicle markets: Sufficient urban station coverage* Energy Policy 36 (2008) 3223–3231 available at http://pubs.its.ucdavis.edu/download_pdf.php?id=1184.

[3] U.S. Environmental Protection Agency, EPA Staff Technical Report: Cost and Effectiveness Estimates of Technologies Used to Reduce Light-duty Vehicle Carbon Dioxide Emissions EPA420-R-08-008 March 2008, p. 27.

[4] *See* e.g. California Pub. Util. Code §218.

[5] Support for alcohol fuels originated in the Energy Tax Act of 1978. Subsequently, at least seventeen pieces of legislation have been directed at this fuel. Currently, there are three ethanol-related tax expenditures. The Federal government also promotes ethanol production through mandatory blending of ethanol with gasoline. The Energy Policy Act of 2005 included a Renewable Fuels Standard that required that 4 billion gallons of renewable fuel be blended with gasoline in 2006, increasing to 7.5 billion gallons in 2012. The Energy Independence and Security Act of 2007 (EISA) increased the volumes of renewable fuels to be blended with gasoline to 9 billion gallons in 2008, increasing to 36 billion gallons in 2022. Ethanol production is also supported by a 54-cent-per-gallon tariff on imported ethanol, exclusive of ethanol produced by countries participating in the Caribbean Basin Initiative. *See* Energy Information Administration, *Federal Financial Interventions and Subsidies in Energy Markets 2007* (April 2008) available at http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/pdf/subsidy08.pdf; LA Times, *Brazil raises cane over U.S. ethanol tariff* (November 4, 2009) available at http://www.latimes.com/business/la-fi-biofuels4-2009nov04,0,2655002.print.story.

[6] *See* Energy Policy and Conservation Act of 1975; 74 Fed. Reg. 49532. According to the Union of Concerned Scientists, the FFV credit was worth $1.6 billion to domestic automakers over the period 1998 to 2004. *See* Union of Concerned Scientists, *Dual-Fuel Vehicle Incentive Program*, available at http://www.ucsusa.org/clean_vehicles/technologies_and_fuels/biofuels/the-dual-fuel-vehicle.html.

With low margins, regulatory hurdles, few customers, and misaligned benefits, it is difficult to envision a profitable PCI business model in the next ten years. Most experts find that PCI can not be deployed without sustained government intervention.[7] Like all alternative transportation fuels preceding it, electricity as a transportation fuel is bedeviled by a classic "chicken or egg" dilemma.[8]

### B. How the Rule Could Encourage Public Charging Infrastructure

The EPA and NHTSA have a unique opportunity finally to help solve this dilemma by making PCI eligible for CO2 credits under the Rule, like advanced air conditioners credits and other technologies. The importance of deploying vehicles and refueling infrastructure in a single coherent system is a consistent theme in prior analyses of transition barriers to alternative fuels.[9] By classifying PCI as a technology eligible for CO2 credits EPA could help support a business case for the deployment of PCI in advance of PEVs, thus helping to create the necessary market conditions for electric technology to take root. Absent such support it seems unlikely that the Rule will induce a significant level of vehicle electrification. The Agency readily admits that the proposed standards can be met with existing enhancements to internal combustion engine technology and with little to no penetration of diesel engines, hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), or pure-battery electric vehicles (BEV). In other words, by themselves, the CO2 standards will not necessarily induce investment in electric technology.[10] More will be needed.

By allocating CO2 credits to PCI under the Rule, EPA would align the benefits of PCI with primary beneficiaries in the value chain, the vehicle OEMs, by monetizing the fuel economy benefits of charging infrastructure. In turn, the Agency could help to solve the longstanding "chicken or egg" problem of how to pay for alternative fuel infrastructure before significant numbers of alternative fuel vehicles are on the road. At the same time EPA and NHTSA would reduce the costs of compliance with the Rule by expanding the supply of credits available to OEMs.

To create market conditions that will spur investment in public charging infrastructure, the Agency should provide CO2 credits to public charging stations at a level approximating their impact on fuel economy and market development. This approach is similar to the Agency's proposal to provide air conditioning leakage credits of between 12.6 and 15.7 g/mi CO2e for investments in improvements to A/C systems.

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[7] *See* Electrification Roadmap, n. 1, infra p. 95-96; Washington State Department of Transportation, Office of Public/Private Partnerships, *Alternative Fuels Corridor Economic Feasibility Study Final Report* (January 23, 2009), p. 81 available at http://www.wsdot.wa.gov/NR/rdonlyres/65838A53-92B4-4A97-8F9B-531C770B0451/0/AltFuelsReportExecSum.pdf; May, J. and Mattila, M., Rocky Mountain Institute, *Plugging In: A Stakeholder Investment Guide for Public Electric-Vehicle Charging Infrastructure* (July 2009), available at http://projectgetready.com/docs/Plugging%20In%20-%20A%20Stakeholder%20Investment%20Guide.pdf.

[8] Melaina, et al., n. 2, infra.

[9] Electric Transportation Association, Electric Vehicle Association of the Americas, U.S. Department of Energy, and U.S. Department of Transportation, *Vehicle Community Market Launch Manual: A Guide to Preparing Your Community for Electric Vehicles* (December 1995) available at http://ntl.bts.gov/lib/2000/2000/2088/vol1.pdf ; Electrification Roadmap, n. 2, infra; Melaina, et al., n. 2, infra.

[10] *See* U.S. Evironmental Protection Agency, *Draft Regulatory Impact Analysis, Proposed Rulemaking to Establish Light- Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards* EPA-420-D-09-003 (September 2009) Chapter 1 Technology Packages Cost Effectiveness.

The credit system for PCI could be structured in a simple fashion as follows:

1. EPA would a new subsection (e) "Credits for CO2 reductions from public charging infrastructure (PCI) supporting PHEVs and battery electric vehicles" to 40 CFR §86.1867-11 CO2 fleet average credit programs.

2. Any party installing PCI would be eligible to generate CO2 credits.

3. Each standard Level 2 PCI (30 amp 6.6 kw) would be eligible for a base credit calculated based on its CO2 reduction benefit. This would assume that opportunistic day time charging produces on average a 25% improvement in fuel economy of PHEVs (75 g/mi CO2) versus PHEVs charged at night time only, as EPA assumes (100 g/mi CO2).

4. In MY 2010 to MY 2016, before significant penetration of PEVs, the base credit would be equal to:

[25 g/mi (CO2 improvement with PCI) x 190,971 (vehicle life) x 1000] ÷ 1,000,000 = 4774 Mg

5. After MY2016, the number of credits per PCI connector would be calculated based on the number of PEVs sold and registered within a 30 mile radius of the PCI.

6. The number of credits per PCI connector would be increased in proportion to the increase in charger power from the base 30 amp Level 2 charger, to account for reduced charge times, consumer convenience and therefore market development potential. For example, a 60 kW Level 3 PCI is roughly 10 times faster than a standard Level 2 charger and therefore would be allocated 10 times the CO2 credits.

7. The number of credits per PCI connector would be increased for grid-enabled units with bi-directional communication, to account for grid benefits, such as demand management.

8. The number of credits would be increased by 100 for mobile chargers which directly respond to range anxiety and therefore directly promote the market for BEVs.

## II. Background on PEV Charging

To understand the importance of public charging infrastructure to the market adoption and performance of PEVs, it is helpful to review the forms, functions and methods of PEV chargers. The below summary is adapted from the California Air Resources Board Staff Report: *Initial Statements of Reasons Proposed Amendments to the California Zero Emission Vehicle Regulations: Treatment of Majority Owned Small or Intermediate Volume Manufacturers and Standardization of Battery Electric Vehicle Charging Systems for the Zero Emission Vehicle Program* (June 2001).

### A. Components of PEV Charging Systems

There are three basic components to a charging system: (1) the battery charger, (2) the connector or "plug," and (3) the wiring at the premises.

#### 1. PEV Battery Chargers

A battery charger is a device that transfers energy from the electricity grid to the vehicle battery for the purpose of charging the PEV traction battery.  PEV battery chargers have several specific functions.  They convert the alternating current (AC) distributed by electric utility providers (that is delivered from a 220 or 110 outlet) to the direct current (DC) needed to recharge the battery (known as rectification).  They also regulate voltage in a manner consistent with the ability of the battery to accept current.

While at one time there were two types of charging systems in use, conductive, and inductive, the conductive system has become the standard.  It uses a metal-to-metal contact to transfer electricity from the charger to the car, similar to the traditional plug.  A charger can be located on the vehicle itself, in which case the electronic components comprising the charger are incorporated into and are part of the vehicle design.  Or, as is typical with most non-vehicle battery chargers, the charger is a separate piece of equipment, and is not part of the vehicle.  In this case, the vehicle needs to go to where the charger is located in order to recharge the battery.

An alternate method of charging, described below, uses an off-board charger that can accommodate higher power levels (up to 440 volts).  In this case, the vehicle is basically equipped with a charger port, and the charger is a separate piece of equipment that is installed at the facility where the vehicle is garaged.  The vehicle is charged with direct current provided by an off-board charger.  The off-board charger uses a control pilot conductor which extends to equipment permanently connected to the AC electrical supply.

### 2. Connectors

The mechanical means by which the PEV is connected to the power source is very important. This is accomplished through the insertion of the "connector" or “plug.” The connector is analogous to a plug for household appliances--the part that connects the "charging station" to the vehicle.  The connector is the device that the consumers will use on a daily basis to connect their vehicles to the electricity grid.  The connector is attached by cable to the PEV charging equipment permanently affixed to the electrical outlet.  The connector is inserted into the charge port (or inlet) located on the vehicle.  This establishes the electrical connection (the technical term for this is coupling) for the purposes of charging the vehicle and for information exchange. A number of years ago the industry moved to a butt and pin connector as the standard conductive connector.  The Society of Automotive Engineers (SAE) is now completing revisions to conductive charging recommended practices (J1772) which should be adopted by the end of 2009.  All light and medium duty PEVs will be equipped with a single, uniform SAE J1772 connection standard that is actually three inter-connectable power types, including 15, 32, & 80 amp for varying degrees of charger power.[11]

### 3. Electric Vehicle Supply Equipment  (EVSE)

There is some confusion over the term "charger," because a typical "charging station" does not include the charger itself, but only the premises wiring, safety, communication, and other equipment needed to interface with the electrical outlet.  The term "charging station" is often incorrectly referred to by users as a charger, even though the actual charger is located on the vehicle.  Electric Vehicle Supply Equipment (EVSE) is the common term used to describe the equipment, power outlets, or apparatuses installed specifically for the purposes of delivering

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[11] See Childers C., *Electric Vehicle Charging Infrastructure*, California Air Resources Board,  Presentation to the California Air Resources Board Public Meeting on Electric Vehicle Charging Infrastructure Needs (September 23, 2009) available at http://www.arb.ca.gov/msprog/zevprog/infrastructure/0909meeting/childers.pdf.

energy from the premises to the PEV. The EVSE generally refers to the wiring and other equipment that provides an interface between the electrical outlet and the coupler. The system extends AC (alternating current) power to the charger, which is located on the vehicle. Conductive charging equipment (EVSE) can be described as a power outlet; connecting to the electricity grid that does not require proprietary or exclusive hardware. In essence, it is simply analogous to an upscale version of a GFCI. Since the charger is located on the vehicle, it allows each car manufacturer to optimize the charger to the vehicle battery requirements.

### B. Charging Methods

There are three different types of charging, based on the power levels utilized: (1) Level 1; (2) Level 2; and (3) Level 3.

#### 1. Level 1 Charging

Level 1 is a charging method that allows an electric vehicle to be connected to most grounded receptacles (NEMA 5-15R), typically found in residential garages, and to a more limited extent in outdoor receptacles. The power levels specified by industry standards are 120 volt, single phase. (This is also referred to as a 110 volt receptacle). The maximum current specified is 12 amps (continuous) with a branch circuit breaker rated at 15 amps. Continuous input power is specified as 1.44 kW. For a vehicle equipped with an on-board conductive charger, the equipment for Level 1 charging consists of an extension cord with a built in Ground Fault Control Interrupter (GFCI), a plug which fits into the electrical outlet, and connector which is compatible with the vehicle inlet.

Power limitations tend to limit the practical use of Level 1 charging for PEVs with large battery packs. The usefulness of Level 1 charging is inversely proportional to the size of the battery pack. While Level 1 can provide an important safety net for consumers if sufficient time is allowed it is likely to have much more practical applications with smaller EVs, such as Neighborhood Electric vehicles, or City vehicles, which have smaller battery packs.

#### 2. Level 2 Charging

Level 2 charging is the most common method to charge EVs. It uses a dedicated charging station which connects the PEV to the electrical AC supply. The EVSE can be located at private, public, or workplace locations. The EVSE includes equipment permanently interfaced and connected to the electrical outlet. The power levels specified by industry standards are 208-240 volt, single phase. The maximum current specified is 32 amps (continuous) with a branch circuit breaker rated at 40 amps. Maximum continuous input power is specified as 7.68 kW. The Level 2 EVSE consists of a wall box permanently interfaced to the AC electrical outlet, and a cable which connects from the wall box to the connector.

Level 1 and Level 2 charging are sometimes referred to as “slow” charging because they typically are associated with overnight charging and translate into a six to twelve-hour period. Slow charging makes use of the PEV’s on-board charger, which is sized based on input voltage from the grid. For example, a 120V, 15A (80%) service would supply a 1.4kW charger, while a 240V, 32A service would supply a 6.6kW charger. A PEV with a 5kWh battery pack, for example, would have a 1.4kW on-board charger that allows complete recharge on the order of five hours. A PEV with a 40kWh battery pack might have a 6.6kW charger, which allows complete recharging on the order of six to eight hours, depending on thermal considerations and charge algorithms for the battery chemistry. While demonstration level PCI is being implemented today with Level 1 chargers these chargers typically require many hours to replenish an EV battery and therefore are impractical. They typically are viewed merely as “placeholders” to be replaced and/or upgraded in the future with Level 2 chargers once they become available. However, while Level 2 chargers are two to five times faster than Level 1 chargers, their charge times still are measured in hours not minutes. Accordingly, there is continuing pressure for faster fast charging performance as consumers strive for the convenience of the gasoline refueling experience.

### 3. Level 3 Charging

Level 3 is a charging method that utilizes dedicated EVSE in either private or public locations. It uses an off-board charger. The maximum power supplied for Level 3 charging typically is capable of replenishing more than half of the capacity of an PEV battery in as few as 10 minutes. Level 3 is defined by industry standards as a charging method that provides DC energy from an off-board charger. While there is no minimum energy requirement but the maximum current specified is 400 amps and 240 kW continuous power supplied. The Level 3 charging specifications for inductive are 208-400 volt, three phase, maximum amp of 400, with continuous power supplied of greater than 7.68 kW.

To achieve a level of convenience similar to the gasoline refueling experience, Level 3 fast charging for public infrastructure will gain importance particularly with the emergence of the smart grid and its capability to manage the higher power demands of Level 3. High rate Level 3 charging enables minute charging for PEVs and also supports charging of heavy duty BEVs such as buses.

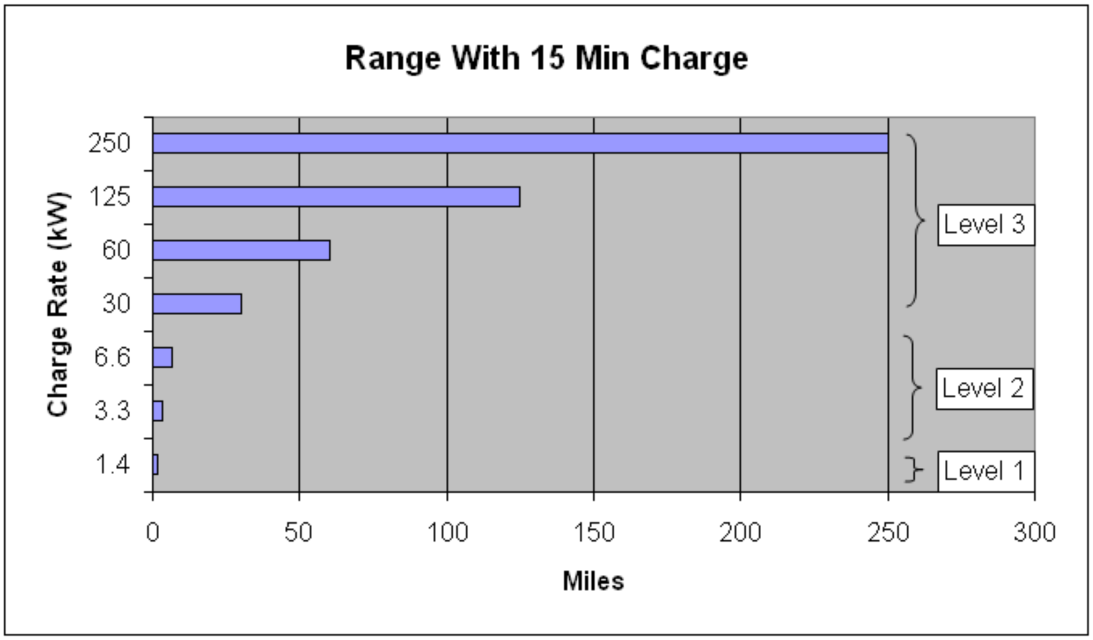
Level 3 "fast" charging can be defined as any scheme other than "slow" charging but the real definition, or set of definitions, is more complicated. Table 1 lists a few of the more commonly used terms, which include fast charge, rapid charge, and quick charge. The California Air Resources Board (ARB), in their Zero Emissions Vehicle (ZEV) mandate program, lists a certification requirement for fast charging as a ten-minute charge that enables the vehicle to travel 100 miles.

Table 1: Power Levels for DC Charging

| Type of Charge | Charger Power Level, kW | | |
|---|---|---|---|
| | Heavy Duty | SUV/Sedan | Small Sedan |
| Fast Charge, 10 minutes, 100% SOC | 500 | 250 | 125 |
| Rapid Charge, 15 minutes, 60% SOC | 250 | 125 | 60 |
| Quick Charge, 60 minutes, 70% SOC | 75 | 35 | 20 |
| Plug-In Hybrid, 30 Minutes | 40 | 20 | 10 |

Source: AeroVironment, Inc.

The following graph illustrates the theoretical difference in range a typical PEV could achieve with a 15 minute charge at a average efficiency of 4 miles per kWh.




Source: AeroVironment, Inc.

## II. Why EPA Should Provide Credits for Public Charging Infrastructure

Sustained government policies will be crucial to the deployment of PCI, a key enabler of vehicle electrification and enhanced petroleum and carbon reduction. Much like how fiber optic infrastructure investment in the late 1990's fostered an explosion of information technology, abundant PCI will be a critical factor in the electrification of vehicles. By crediting PCI under the Rule, EPA could encourage deployment of PCI and thereby achieve greater petroleum and carbon reduction.

### A. EPA Has Ample Authority to Credit Public Charging Infrastructure

EPA has ample authority under Section 202(a) of the Clean Air Act to include PCI as a creditable technology under the Rule. The purpose of the Rule is to prescribe standards applicable to the emission of greenhouse gases (GHGs) from new light duty motor vehicles, which in EPA's judgment cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare. Section 202(a) of the Clean Air Act authorizes EPA to issue technology-based standards that are based on levels deemed to be technologically feasible taking into account a reasonable period of time EPA determines is necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period.[12] Accordingly, EPA possesses considerable discretion under section 202(a) when assessing issues of technical feasibility and availability of lead time to implement new technology. For example, EPA is exercising this discretion under the Rule by creating a new credit trading program enabling OEMs over-complying with their overall fleet CO2 performance standard to generate credits that can be sold to OEMs struggling to achieve the standards. The Agency also is exercising its discretion under the Rule by proposing to give CO2 credits for better air conditioners and for other "off-cycle" devices that reduce GHG emissions. Based on the broad discretion afforded

[12] See Clean Air Act Section 202(a)(2); see also NRDC v. EPA, 655 F.2d 318, 322 (D.C. Cir. 1981)).

the Agency under Section 202(a) of the Clean Air Act, and the ample evidence demonstrating that PCI significantly improves the fuel economy and carbon emissions of PEVs, EPA is well within its bounds of discretion to provide credits for PCI investments as well.

### B. Maximum Fuel Economy and GHG Reduction Potential for All Types of PEVs Depends on Availability of Public Charging Infrastructure

Because PHEV and EREVs can be driven exclusively on gasoline in hybrid electric vehicle (HEV) or "charge-depleting" (CD) mode their potential to substantially improve fuel economy and GHG emissions over and above HEVs depends on the ability to recharge on-board batteries from an off-board source of electricity. According to EPA, the CO2 reduction potential of PHEVs depends on many factors, the most important being the electrical capacity designed into the battery pack.[13] To estimate the tailpipe CO2 reduction potential of PHEVs, EPA ran its in-house vehicle energy model (PEREGRIN) to estimate the CO2 emissions reductions of PHEVs, assuming that PHEVs have an all-electric range (AER) of 20 miles. This yielded a fuel economy of 70.1 mpg compared to 49.1 mpg for HEVs.

Importantly, based on several recent studies of the real-world fuel economy of existing PHEVs, EPA's modeling appears to over-estimate the fuel economy of PHEVs by not accounting for how the unavailability of PCI can impact PHEV fuel economy, regardless of all-electric range. The potential reduction in petroleum usage and in associated GHG emissions from PHEVs depends on more than simply the size of the battery pack, as EPA's model assumes. Rather, it is a function of the amount of electric drive the vehicle is capable of under its duty cycle, which in addition to battery capacity is a function of driving conditions *and* recharging opportunity and behavior. A number of recent studies show that substantial improvements in AER and fuel economy can be achieved within a rich charging infrastructure environment that provides drivers with greater opportunities to recharge during their work day.

#### 1. Improving Petroleum Displacement Potential of PHEVs Using Enhanced Charging Scenarios (NREL 2009)

In 2009, DOE's National Renewable Energy Laboratory (NREL) studied the impacts of charge management scenario options and the potential to reduce battery size while providing equivalent or greater fuel savings.[14] Using a developed battery life assessment method and sets of PHEV simulations, NREL modeled 227 unique driving profiles collected from vehicles with GPS data loggers in a 2002 St. Louis, MO metropolitan travel survey. The analysis showed that opportunity charging a PHEV-20 during the day will displace 23% more fuel than a PHEV-20 charged only once each night and 5% more than a PHEV-40 charged only once each night. While a PHEV- 20 may seem to have less potential for petroleum displacement as a result of its smaller electric range, NREL found that recharging between trips enables greater utilization of its smaller battery. The following charts from the NREL study show the improved fuel efficiency of opportunity charging.

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[13] EPA-NHTSA Draft Joint Technical Support Document Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (September 2009) p. 3-67.

[14] Markel, T., Smith, K., and Pesaran, A., *Improving Petroleum Displacement Potential of PHEVs Using Enhanced Charging Scenarios,* Conference Paper NREL/CP-540-45730 (May 2009), available at http://www.nrel.gov/vehiclesandfuels/energystorage/pdfs/45730.pdf.

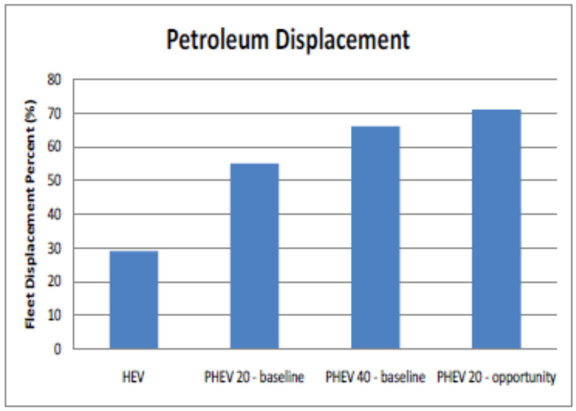
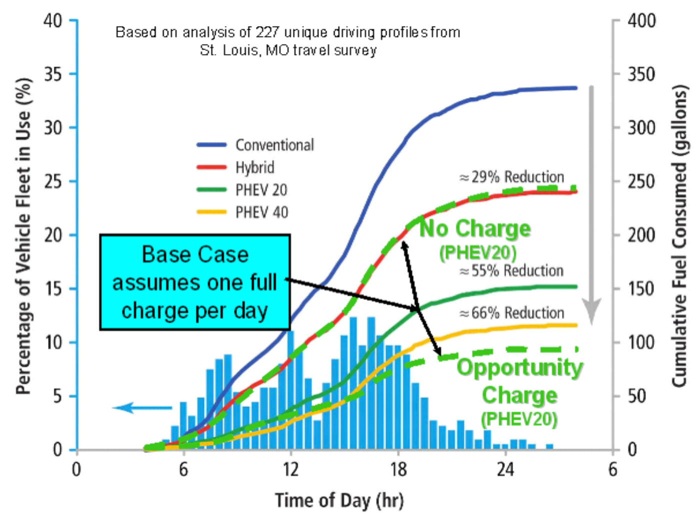



Figure 3: Fuel displacement potential of various hybrid scenarios over the fuel use of the conventional vehicle

Source: Markel, et al., *Field Testing Plug-in Hybrid Electric Vehicles with Charge Control Technology in the Xcel Energy Territory*.




Source: Markel, et al., *Field Testing Plug-in Hybrid Electric Vehicles with Charge Control Technology in the Xcel Energy Territory*.

### 2. Plug-in Hybrid Electric Vehicle Charging Infrastructure Review (INL 2008)

In 2008, DOE's Idaho National Laboratory (INL) Advanced Vehicle Testing Activity Program completed a study of the real-world fuel economy of PHEVs in a "lean" charging infrastructure environment.[15] INL studied nine Toyota Prius PHEV conversions operating during the months of January and February 2008 in a variety of applications in five different states. Laboratory testing showed that the vehicles had a 30-mile all-electric range and should achieve a fuel economy of 140 mpg. However, no PCI was available as all of the charging took place at home. Data collected by INL showed that the absence of PCI negatively impacted the gasoline fuel economy of the PHEVs. Little benefit was achieved from the plug-in capability of these

[15] U.S. Department of Energy Vehicle Technologies Program – *Advanced Vehicle Testing Activity, Plug-in Hybrid Electric Vehicle Charging Infrastructure Review* (Nov. 2008) available at http://avt.inel.gov/pdf/phev/phevInfrastructureReport08.pdf.

vehicles, which achieved only 50 mpg, a slight improvement over their fuel efficiency prior to their conversion to plug-ins. The INL study concluded that in the absence of PCI 40 miles of charge depleting range is necessary for an average PHEV. In contrast, with PCI, INL concluded that charge depleting range could be lowered to 13 miles.

### 3. Costs and Emissions Associated with Plug-In Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory (NREL 2009)

In 2009, NREL completed another study to simulate the impacts on the Colorado utility system of Xcel Energy under four different operating scenarios: 1) No utility control, 2) delayed charging, 3) valley fill charge, and 4) opportunity charging. The study assumed 500,000 vehicles or approximately 30% of the fleet were PHEVs. NREL found that PHEVs can reduce petroleum consumption between 35-70% depending on the consumer charging and driving pattern with up to a 70% reduction possible if consumers are given the opportunity to charge during the day.[16] In the study, the first three cases included a single recharge after driving was complete for the day and the fourth scenario allowed recharging between trips throughout the day. The four scenarios reduce petroleum consumption relative to a comparable hybrid electric vehicle (HEV) between 25% for single daily charge and 43% for multiple daily or "opportunity" charge scenarios. The superior fuel economy of the opportunity charging scenario confirmed earlier 2007 findings which found that compared to a PHEV with only home-based charging, a PHEV opportunity charged throughout the day using PCI reduces gasoline consumption by about 40%.[17]

Importantly, the 2009 NREL study also found the negative impacts of coincident loading to the utility peak were encountered only during 17 hours under the opportunity charge scenario and 6 hours under the no utility control scenario, suggesting that only a small amount of utility involvement would be necessary to avoid capacity expansion while offering consumers great flexibility throughout the year.

Finally, an important purpose of NREL's study was to understand the consumer ability and willingness to plug-in the vehicle because the more often a vehicle is plugged in, the greater the opportunity for fuel displacement. The data suggest that the behavior of the consumer changed over the duration of the project. At the beginning of the study the percentage of time plugged in was as low as 20% and a trend of increasing time plugged in is observed. The time plugged-in stabilized around 60% near the middle of the study.

### 4. Impact of Battery Weight and Charging Patterns on the Economic and Environmental Benefits of Plug-in Hybrid Vehicles (Carnegie-Mellon University 2009)

The findings of the NREL and INL studies were reinforced by a 2009 Carnegie-Mellon University study which found that the best choice of PHEV battery capacity depends critically on the

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[16] Markel, T., Bennion K., and Kramer W., National Renewable Energy Laboratory, Bryan J. and Giedd J., Xcel Energy, *Field Testing Plug-in Hybrid Electric Vehicles with Charge Control Technology in the Xcel Energy Territory* Technical Report NREL/TP-550-46345 (August 2009) available at http://www.nrel.gov/docs/fy09osti/46345.pdf.

[17] See Parks K., Denholm P., Markel T., *Costs and Emissions Associated with Plug-In Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory* Technical Report NREL/TP-640-41410 (May 2007) Table 3: Vehicle Performance Under Various Charging Scenarios.

distance that the vehicle will be driven between charges.[18] CMU found that for urban driving conditions and frequent charges every 10 miles or less, a low-capacity PHEV sized with an AER of about 7 miles would be a robust choice for minimizing gasoline consumption, cost, and greenhouse gas emissions. CMU found that PHEVs perform best when the batteries are sized according to the charging patterns of the driver. However, three potential complications arise when sizing PHEVs based on the number of miles that drivers travel: 1) if the variance in miles traveled per day is large, then a capacity designed for the average distance may be suboptimal; 2) it is unclear whether it is safe to assume that drivers will consistently charge their vehicles once per day as irregular charging behavior could lead to significantly longer distances between charges than the average daily distances would suggest; and conversely, 3) widespread installation of charging infrastructure in public parking places would enable charging more than once per day, enabling shorter distances between charges.

The CMU study points to the fact that abundant PCI benefits all types of PEVs because it gives drivers maximum flexibility and therefore overcomes range anxiety.

### 5. Determining PHEV Performance Potential – User and Environmental Influences on A123 Systems' Hymotion™ Plug-In Conversion Module for the Toyota Prius (INL and A123Systems 2009)

In yet another study of real-world PHEV performance, INL in conjunction with A123Systems studied the fuel economy performance of 50 identical prototype PHEV conversions deployed in fleets in California, Seattle, North and South Carolina, and Toronto from August 2007 to March 2009.[19] What is remarkable about the data is that the top performing PHEVs achieved about 20% better fuel economy than the bottom performing, identical PHEVs with most of the difference attributable to charging frequency.[20]

> The frequency with which the vehicle were charged, relative to the distance driven between charging events, determined the proportion of distance driven in charge depleting versus charge sustaining mode…. In order to achieve charge depleting operation, there must be charge in the PCM battery. Although this statement seems obvious, many fleet vehicles drive for days without being recharged, essentially driving as a stock Prius.

The study concluded that:

> to achieve a PHEV's potential for gasoline fuel displacement, it must operate in charge depleting mode. It is important to look beyond individual driving trips and consider the overall distance driven between charging events. Increasing charging frequency relative to driving distance will result in a greater proportion of charge depleting operation, thereby reducing overall vehicle fuel consumption.

Although not discussed in the study, the top performing PHEVs were located in California, where PCI already exists in some areas and routinely is used by owners of BEVs sold under the California ZEV program. In fact, a 2007 survey of 132 owners of nickel metal-hydride Toyota

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[18] Ching-Shin N., Samaras C., Hauffe R., Michalek J., Impact of battery weight and charging patterns on the economic and environmental benefits of plug-in hybrid vehicles, Energy Policy 37 (April 1, 2009).

[19] See Huang-Yee L. and Smart, J. *Determining PHEV Performance Potential – User and Environmental Influences on A123 Systems' Hymotion™ Plug-In Conversion Module for the Toyota Prius,* Proceedings of EVS24 Stavanger, Norway, (May 13-16, 2009).

[20] Id., Table 5 Trip Distance and Fuel Consumption.

RAV4-EVs found that over 90% use PCI established under the ZEV program. On average, the drivers use the PCI 34.6 times per year (with some using it daily) to extend the possible driving horizon beyond the charge depleting range provided by their home chargers.[21] This data from actual BEV owners shows the value of PCI in supporting drivers' ability to extend driving range by using PCI.

### 6. UC Davis Study

In 2009, the University of California, Davis studied the charging behavior of 2,373 plug-in Prius consumers to assess whether PHEV owners will recharge their PHEVs even if they do not have to recharge and, if yes, when, where and how much.[22] The study found that PEV drivers will plug in their vehicles during the day and that many will do so more than once a day. Furthermore, it concluded that PCI and social norms likely will result in more plugging in and more variability of demand throughout the day. Across the group of households, the mean CS fuel economy was 44.7 mpg, while the mean CD fuel economy was 67.1mpg, a 49% improvement. The range of percent total energy savings achieved by plugging in the PHEV-conversions in comparison to not plugging them in was from -1 to 19 percent. Higher percent savings were achieved by households who drove higher percentages of their miles in CD operation—either because they tended to drive fewer miles per day than their achieved CD range (and generally recharge everyday) or they tended to recharge multiple times per day. Accordingly, recharging during the day was a critical factor in increased fuel economy.

### C. Market Development of PEVs Will Depend on Availability of Public Charging Infrastructure

Nearly all alternative fuel experts agree that a lack of refueling infrastructure is and has been the top transitional barrier to the market's transition to alternative transportation fuels.[23] This is because consumer choices among vehicle technologies are made based on vehicle characteristics, which include among other characteristics refueling options.[24] Often, market conditions do not permit a promising new technology to ever enter the market and ultimately to gain the share projected by long-run comparative statics. For example, long-run static-equilibrium modeling in 1996 predicted that the Energy Policy Act of 1992 (EPACT), which required that the nation displace 30% of its motor gasoline with alternative fuels by the year

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[21] Freund R., *Toyota RAV4-EV Driver Experience A Survey of Capability, Reliability, and Failures*, Presentation to CARB ZEV Technical Review (September 27, 2006) available at http://www.energy.ca.gov/ab1007/documents/2006-10-16_joint_meeting/presentations/RON_FREUND.PDF; Freund R., *Living with a BEV: A Survey of User Experiences* available at http://www.eaaev.org/Info/RAV4-EV_User_Experiences.pdf

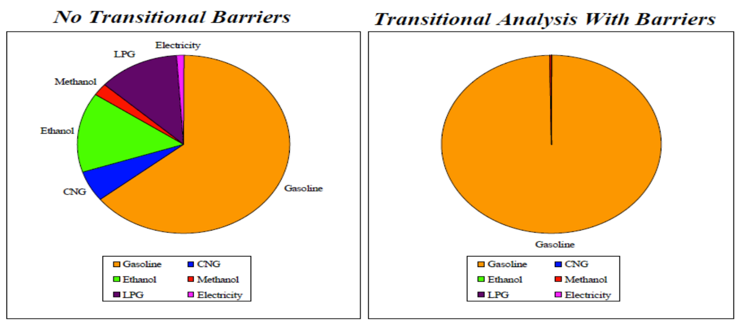
[22] Kurani, K., Plug-In Hybrid Electric Vehicle (PHEV) Demonstration and Consumer Education, Outread, and Market Research Program, conducted under a grant by the California Air Resources Board (June 30, 2009) available at
http://pubs.its.ucdavis.edu/download_pdf.php?id=1310.

[23]Melendez, M. and Milbrandt, A., U.S.DOE National Renewable Energy Laboratory, *Regional Consumer Hydrogen Demand and Optimal Hydrogen Refueling Station Siting*, Technical Report NREL/TP-540-42224 (April 2008) available at http://www.nrel.gov/docs/fy08osti/42224.pdf; Melendez, M. and Milbrandt, A., *Lessons Learned from the Alternative Fuels Experience and How They Apply to the Development of a Hydrogen-Fueled Transportation System* Technical Report NREL/TP-560-40753 (August 2007) available at http://www.afdc.energy.gov/afdc/pdfs/40753.pdf; Green, D., Oak Ridge National Laboratory, Transitional Alternative Fuels and Vehicles (TAFV) Model Alternative Fuels and Vehicles Choice Model Documentation (July 2001), Docket No. EPA-HQ-OAR-2009-0472-0038, p. 30.

[24]Green, n. infra, p. 3.

2010, would enable a significant market penetration of four or five alternative fuels. Of course, the prediction was completely inaccurate because it failed to account for transitional barriers and the time path of market evolution, as shown in the chart below.

**Figure 1: Static V. Transitional Analyses Yield Differing Conclusions: 2010 Alternative Fuel Demand Shares, Base Case, No New Policies**




Source: Leidy, et al., *Transitions in Light-Duty Vehicle Transportation: Alternative Fuel and Hybrid Vehicles and Learning*.

More recent Transitional Alternative Fuel Vehicle (TAFV) modeling by the Oak Ridge National Laboratory finds that absent a major and permanent shift in oil prices, adequate and sustained tax credits for alternative fuels is essential.[25] As previously discussed, however, electricity receives no alternative fuel production tax credit nor any of the other subsidies accorded biofuels.[26] Accordingly, without a sustained government policy to encourage electricity as a transportation fuel and installation of PCI that provides consumers the same level of convenience currently afforded by gasoline refueling stations, wide deployment of PEVs is unlikely to occur. This is the finding of several very recent regulatory proceedings and reports.

First, on August 20, 2009, the California Public Utility Commission initiated rule making to consider alternative-fueled vehicle tariffs and infrastructure and policies to support California's Greenhouse Gas Emission Reduction Goals,[27] which concluded that:

> A mix of charging level options at standardized charging facilities (standard 120V (Level 1), 240V (Level 2) and DC charging options) will likely be required to support a mass electric vehicle market. Many electric vehicle drivers may prefer Level 2 off-peak charging in order to charge larger BEV batteries within a reasonable time and expedite smaller PHEV battery charging. However, Level 1 charging is as ubiquitous as a standard 120V outlet. Level 1 and Level 2 charging at residential EVSE facilitates off-peak charging when electricity demand, driving demand, and electricity cost of service are low. Night time

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[25] Leiby, P., Rubin, J., *Transitions in Light-Duty Vehicle Transportation: Alternative Fuel and Hybrid Vehicles and Learning* (2004) available at http://cta.ornl.gov/trbenergy/trb_documents/leiby_rubin_transions%20in%20light_duty.pdf .

[26] See n. , infra.

[27] See California Public Utility Commission, ORDER INSTITUTING RULEMAKING TO CONSIDER ALTERNATIVE-FUELED VEHICLE TARIFFS, INFRASTRUCTURE AND POLICIES TO SUPPORT CALIFORNIA'S GREENHOUSE GAS EMISSIONS REDUCTIONS GOALS, Docket No. 09-08-009 available at http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/106042.pdf.

vehicle charging is convenient for a homeowner and has the potential to integrate increased levels of intermittent off-peak wind energy, flatten the electricity system load curve, and realize generation, transmission, and distribution system efficiencies. However, some drivers may prefer daytime opportunistic charging at a residential, commercial, or public charging facility. Daytime charging may be necessary to make electricity refueling as convenient as gasoline refueling, and may be a requirement for a mass electric vehicle market. The potential adverse impact of daytime charging, however, is that if it occurs during peak load time (approximately noon to 7:00 p.m.), this could have a negative impact on the grid, causing more expensive and polluting peak generation units to operate. This rulemaking will also explore centralized charging as a potential charging option to complement decentralized residential charging. DC charging may offer a charge rate adequate to enable a geographically centralized electricity refueling model similar to the gasoline filling station model for conventional vehicles. Replaceable battery swapping stations located in urban areas, exurban areas, and along highways are another means of making electricity refueling time and location similar to the gasoline filling station model.

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We note that early PHEV consumer behavioral research indicates after-market converted-PHEV drivers prefer charging at multiple times and locations, including daytime charging. Again, this rulemaking is an opportunity to invite charging behavior research findings to analyze infrastructure performance requirements.

*See* CPUC, *Rulemaking to Consider Alternative-fueled Vehicle Tariffs and Infrastructure and Policies to Support California's Greenhouse Gas Emission Reduction Goals* at pp. 10-11.

Second, on November 16, 2009, the group Securing America's Future Energy (S.A.F.E.) and its Electrification Coalition, released their report *Electrification Roadmap: Revolutionizing Transportation and Achieving Energy Security* (the "Roadmap").[28] The report finds that reliable access to a network of PCI is essential for consumer confidence and flexibility, as drivers likely will demand the ability to recharge frequently particularly during the early years of deployment. The Roadmap finds that, as important as access to home charging will be for achieving high rates of PEV deployment, "public charging is arguably even more important for moving past the very early stages of PEV adoption." The Roadmap cites at least two reasons for this:

First, drivers are accustomed to being able to fill up using the ubiquitous gasoline infrastructure developed over the last 100 years. Inability to do so will generate significant hesitancy for most consumers and will hinder adoption of electric vehicles. This hesitancy is most often termed "range anxiety," and obviously applies to pure EVs more than to PHEVs. It will be in the interest of all market participants to ensure that consumer range anxiety is mitigated. One way to do this could be to roll out an expansive and pervasive public infrastructure, though important questions about utilization rates and power prices will determine the profitability of such an infrastructure for private owners. A second factor that highlights the importance of public recharging infrastructure relates to anticipated patterns of GEV refueling. In essence, without access to Level II EVSEs or Level III chargers away from the home, most drivers will be inclined to plug in each time they return home. For a large percentage of drivers, this will be at the end of the work day. Pilot testing carried out by the Idaho National Laboratory largely

[28] See Roadmap, n. 1, supra.

> confirms the notion that, in the absence of accessible public recharging equipment, consumer charging tends to the hours between 6:00 pm and 10:00 pm. Despite the extremely small scale of testing, the exercise confirms that while driving is spread throughout the day, charging is concentrated in the evening. Two distinct issues arise in such a 'home only' charging pattern. First, concentrating charging to a few hours has the potential to place heavy strain on the electric power sector, particularly at the local distribution (transformer) level. A number of emerging smart grid applications could mitigate this risk, but it would be preferable to spread charging somewhat more evenly. Second, because PHEVs will generally have smaller batteries than pure EVs, it is conceivable that they will need to be charged somewhat frequently in order to obtain the fuel-economy benefits of all- electric driving. In both cases, access to a reliable network of public charging equipment will enhance the operability of grid-enabled vehicles.

*See* Roadmap, n. 2, supra, p. 95.

Third, on November 25, 2009, the California Air Resources Board published a white paper analyzing the need for revisions to the state's zero emission vehicle program.[29] CARB concluded that:

> In addition, fuel infrastructure needs and market pull policies will likely be needed to support the initial entry of these technologies into the market. This suggests to staff the necessity of a regulatory requirement to identify the need for ZEVs and provide some degree of certainty to investors in these technologies, combined with industry/government efforts to establish fueling infrastructure and provide consumer incentives to purchase these vehicles in their initial years of sales. In order for ZEV sales to successfully expand as mandated under the ZEV Regulation, fueling infrastructure will need to be in place, publicly accessible, and reliable to give future ZEV consumers and manufacturers confidence that their ZEV investment will be worthwhile.
>
> *******************
>
> The challenge is that private investment and a viable business opportunity for commercial ZEV infrastructure is lacking for the short term, and varies widely depending on the fuel.....Infrastructure for electric vehicle charging also faces many challenges. Although early vehicle charging for PHEVs can take advantage of existing residential infrastructure, distribution upgrades and installations of home and workplace charging stations will be needed as vehicle volumes increase. As the numbers of BEVs increase, the demand for home, workplace and eventually public charging infrastructure will also increase.

*See* California Air Resources Board, *White Paper: Summary of Staff's Preliminary Assessment of the Need for Revisions to the Zero Emission Vehicle Regulation* (November 25, 2009), p. 15 and Attachment C *Complimentary Policies*

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[29] *See* California Air Resources Board, White Paper: *Summary of Staff's Preliminary Assessment of the Need for Revisions to the Zero Emission Vehicle Regulation* (November 25, 2009), p. 15 and Attachment C *Complimentary Policies* available at http://www.arb.ca.gov/msprog/zevprog/2009zevreview/zevwhitepaper.pdf and http://www.arb.ca.gov/msprog/zevprog/2009zevreview/attachment_c_comppolicies.pdf.

### 1. PCI Needed to Overcome "Range Anxiety"

A recent study by the Tokyo Electric Power Company demonstrates the value of PCI and fast-charging infrastructure, in particular, to overcome range anxiety.[30] TEPCO substituted its conventional internal combustion engine (ICE) service vehicles with Mitsubishi iMiev BEVs. The BEVs operated with essentially unlimited access over TEPCO's entire 8 x 15 km service area. However, within a few months of deployment, TEPCO discovered that drivers only accessed a small portion of the service area and typically returned the vehicles to the facility with greater than a 50% state-of-charge (SOC). When the BEVs were first introduced they were charged overnight using slow chargers. It was clear that drivers feared running out of electric fuel and were thus operating the BEVs conservatively. TEPCO then added a single fast-charger in the middle of the service territory to provide drivers access to charging during the day. Immediately following TEPCO's installation of the fast charger drivers began accessing the entire service area and vehicles returned at the end of the day averaged a SOC well below 50%. The following figure depicts vehicle travel patterns before and after installation of the fast-charger.

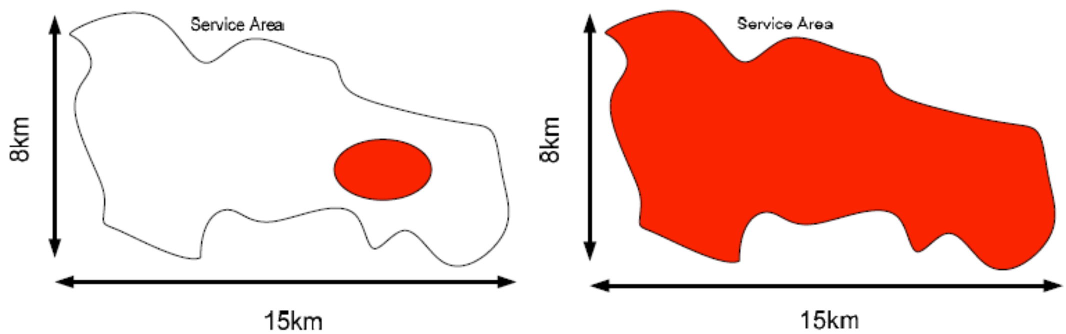


Figure 7: Service Area accessed by EV w/Slow Charger

Figure 8: Service Area accessed after Fast Charger added

Source: Botsford, C. and Szczepanek, A., *Fast Charging vs. Slow Charging: Pros and cons for the New Age of Electric Vehicles*, Proceedings EVS24 Stavanger, Norway (May 13-16, 2009) available at http://www.cars21.com/files/news/EVS-24-3960315%20Botsford.pdf

A vital insight from the TEPCO study is that the second charger was used only infrequently by the BEV drivers, indicating that mere awareness of the second charger was sufficient to reassure the drivers that they would not run out of fuel. This phenomenon, described in the literature as "range anxiety," has been documented throughout the effort to promote alternative transportation fuels. For example, the general consensus from diesel fuel vehicle studies is that consumer anxiety about a lack of fuel availability becomes a minor consideration when the percent of stations offering diesel moves above 10 percent. In the case of PEVs, the saturation of PCI needed to overcome range anxiety will be much less due to the ability to refuel at home and the availability of the internal combustion engine.

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[30] See Santini, A., Argonne National Laboratory, *Highway Vehicle Electric Drive in the United States: Current Status and Issues: A Discussion Paper for Clean Cities Coalitions and Stakeholders to Develop Strategies for the Future* (September 2009) at pp. 32-33 available at http://www1.eere.energy.gov/cleancities/pdfs/santini_electric_drive_briefing.pdf; Anegawa, T., Tokyo Electric Power Company, *Desirable characteristics of public quick charger* available at http://www.emc-mec.ca/phev/Presentations_en/S12/PHEV09-S12-3_TakafumiAnegawa.pdf .

PCI's value in overcoming consumer range anxiety was recently highlighted by the Sacramento Municipal Utility District (SMUD) in its comments submitted to the California Public Utility Commission in response to its pending rulemaking concerning Alternative-Fueled Vehicle Tarrifs, Infrastructure and Policies to Support California's Greenhouse Gase Emissions Reductions Goals.[31] In response to the CPUC's request for comment on whether the Commission should adopt policies to favor certain charging options taking into consideration cost-effectiveness, grid benefits, ability to meet PHEV and BEV driver charging demand, and ability to reduce BEV driver "range anxiety," SMUD summed-up the value of PCI:

> Currently, commercial charging, excluding fleet applications, is usually deployed as a service to employees who commute to work. Since current technology requires approximately four hours to recharge most BEVs, workplace charging should focus on Level 2 charging infrastructure. The Commission should consider time-of-use rates that promote morning recharging at Level 2 charging facilities because when the four hour recharge time is combined with normal daytime commute hours, workplace recharging can be accomplished by mid-day, or at least prior to peak power usage. In addition, workplace charging could also have benefits in future vehicle-to-grid or vehicle-to-home energy use scenarios by potentially having more stored energy on-board the vehicle when it got home each night for power transfer to the grid during critical summer peak hours. Generally, "public" charging takes many shapes and is hard to categorize. The range of public charging can vary from street-side charging for dense urban areas, to "public" parking garages that really serve as workplace parking facilities, all the way to businesses that provide free charging to employees in publicly accessible retail parking lots. It is important to note that for normal work schedules, street-side parking for dense urban areas can serve as both "residential" type home charging locations during the night-time as well as workplace charging during the daytime. The Commission should consider the wide variability of "public" charging options when developing policies with regard to charging levels.
>
> Another issue for "public" charging is technology maturity for DC fast charging and battery technology. Depending on the pace of technology, DC fast charging with larger battery packs may be viable approach for all public applications. Urban dwellers could fill up their vehicles at DC fast charging service centers similarly to how gasoline is distributed now. The fast charging service centers could also support workplace charging needs in the vicinity of any given workplace and would significantly reduce the phenomena of "range anxiety." Thus, the Commission should consider policies that enable this service niche. Given the issues of "public" charging and the technology maturity of DC fast charging, a phased approach would probably provide the best benefits. In the near term, the Commission should deal with Level 2 charging to meet both residential and workplace applications, particularly in urban area setting. However, as the practicality of DC fast charging and battery energy storage performance improve, DC fast charging may be a more effective solution in the future. A mixture of all types will be required to meet the range anxiety of the general public.

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[31]See RESPONSE AND OPENING COMMENTS OF THE SACRAMENTO MUNICIPAL UTILITY DISTRICT TO THE ORDER INSTITUTING RULEMAKING ON THE COMMISSION'S OWN MOTION TO CONSIDER ALTERNATIVE-FUELED VEHICLE TARIFFS, INFRASTRUCTURE AND POLICIES TO SUPPORT CALIFORNIA'S GREENHOUSE GAS EMISSIONS REDUCTION GOALS, available at http://docs.cpuc.ca.gov/efile/CM/108010.pdf

SMUD's views on PCI are particularly valuable on this issue given its long-standing work deploying PCI throughout California and Arizona.[32]

### 2. A Modest PCI Saturation May Be Sufficient to Catalyze PEVs

Because PEVs also can be refueled overnight at home, the amount of PCI needed to catalyze a market for PEVs actually may be much less than for alternative liquid fuels that rely exclusively on public refueling infrastructure. In fact, data shows that at least with respect to BEVs comparatively fewer PCI locations in a given area may be needed to overcome range anxiety, suggesting that a concentrated governmental policy to improve the economics of PCI deployment will be effective.

NREL's analysis of regional consumer hydrogen demand and optimal hydrogen refueling station siting suggests that a modest investment in PCI in key sub-regional metropolitan areas would give PEVs a foothold from which to grow.[33] NREL's analysis of hydrogen refueling infrastructure suggests that only about 700 Level 3 stations would be necessary to seed the market in fourteen metropolitan sub-regions of the country distinguished by their high levels of HEVs, ZEV requirements, household income and household vehicle ownership.

**Table 11. Proposed Subregional Hydrogen Station Coverage**

| Subregion | Population | Number of Stations | Stations per Million People | Population within Distance of a Station | | |
|---|---|---|---|---|---|---|
| | | | | 3 mi | 5 mi | 10 mi |
| Denver | 3,463,445 | 33 | 9.5 | 49% | 84% | 96% |
| East Texas | 15,512,273 | 143 | 9.2 | 36% | 65% | 90% |
| Salt Lake City | 1,903,127 | 23 | 12.1 | 57% | 87% | 97% |
| Chicago | 11,714,972 | 62 | 5.3 | 26% | 56% | 96% |
| Detroit | 5,919,388 | 33 | 5.6 | 23% | 53% | 91% |
| Minneapolis - St. Paul | 2,547,509 | 14 | 5.5 | 23% | 54% | 92% |
| St. Louis | 2,288,078 | 19 | 8.3 | 21% | 46% | 94% |
| Phil - New York - Boston | 37,451,570 | 141 | 3.8 | 25% | 56% | 93% |
| Washington-Baltimore | 6,389,207 | 34 | 5.3 | 38% | 70% | 96% |
| Southern California | 20,730,299 | 76 | 3.7 | 36% | 72% | 98% |
| Phoenix | 3,915,528 | 35 | 8.9 | 53% | 87% | 99% |
| Seattle - Portland | 5,457,743 | 33 | 6.0 | 31% | 66% | 97% |
| Northern California | 11,131,278 | 51 | 4.6 | 36% | 67% | 93% |
| Atlanta | 4,095,659 | 41 | 10.0 | 37% | 74% | 97% |

To derive this prediction NREL used a GIS approach to spatially analyze key attributes affecting hydrogen market transformation and identified refueling station locations in target sub-regions that would provide 90% of the potential population with access to refueling infrastructure within

[32]Boyce B., Sacramento Municipal Utility District, *Electric Vehicle Infrastructure Market History and Observations*, Presentation to the California Air Resources Board Public Meeting on Electric Vehicle Charging Infrastructure Needs (September 23, 2009) available at http://www.arb.ca.gov/msprog/zevprog/infrastructure/0909meeting/boyce.pdf.

[33]Melendez, M. and Milbrandt, A., U.S.DOE National Renewable Energy Laboratory, *Geographically Based Hydrogen Consumer Demand and Infrastructure Analysis* Technical Report NREL/TP-540-40373 (October 2006) available at http://www.nrel.gov/hydrogen/pdfs/40373.pdf.

10 miles. NREL's mapping of estimated hydrogen demand and proposed hydrogen station locations can be applied reliably to PEV demand because the mapping was based on areas of high HEV registrations, household income, multiple household vehicles, and Zero Emission Vehicle mandates—the very same attributes likely to drive consumer demand for PEVs. The data shows that each area's unique demand characteristics should be considered to maximize the effectiveness of a limited initial PSI deployment.

#### 3. PCI Will Reduce the Costs of PHEVs Because it a Less-costly Option to Extend Charge Depleting Range, Thereby Speeding Market Transition to PEVs

The NREL and INL studies discussed above have profound implications for potential cost-reduction opportunities for PEVs and the development of the market for PEVs. Both studies found that battery size and charge times can be reduced by providing a rich charging infrastructure that enables drivers to charge away from their residence or apartment where the vehicle is housed overnight. What this means is that with PCI PHEVs with smaller, less costly batteries can achieve the same or better fuel economy as more costly vehicles with larger batteries. INL found that the additional battery cost need to achieve 40 miles of all electric range cost $8,268 more per vehicle even using the most favorable battery cost of $300/kWh. Deployment of a robust network of PCI ultimately saves consumers $6,416 per vehicle according to the INL study.[34]

### D. Benefits of PEVs to the Electric Grid Depend on Public Charging Infrastructure

The average U.S. vehicle is driven only one hour per day. The remaining 23 hours presents an opportunity either to draw recharge electricity or to provide electricity back to the grid. Several studies demonstrate that PEVs are capable of providing grid regulation service, which could provide owners with significant revenue from grid operators.[35] Grid regulation service essentially is standby electric generation that is called-upon by the grid operator to feed electricity into or withdraw electricity from the grid in a matter of seconds so that the balance between the electricity being supplied to the grid (generation) and the electricity being consumed (load) supports stability at the specified frequency range of 60 Hz. This balance or "frequency range" is maintained by frequent, small adjustments in the output of some of the generators operating on the grid, typically representing between 1%-2% of the total power being generated. To maintain this balance the grid operator typically reserves up to 400 MW of generation capacity for frequency regulation in the form of highly inefficient peaking combustion turbines. Not all generators can be effectively operated with constantly varying output. This results in increased fuel consumption, emissions and maintenance.

#### 1. Opportunity Charging with PCI Throughout the Day Is Essential for Demand-Side Management and Vehicle-to-Grid

A central finding of the 2009 NREL—Xcel Energy study discussed above, *Field Testing Plug-in Hybrid Electric Vehicles with Charge Control Technology in the Xcel Energy Territory,* is that the

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[34] See INL, *Plug-in Hybrid Electric Vehicle Charging Infrastructure Review, supra,* n. 14.

[35] Brooks A., *Final Report, Vehicle-to-Grid Demonstration Project: Grid Regulation Ancillary Service with a Battery Electric Vehicle*, Prepared for the California Air Resources Board and the California Environmental Protection Agency (December 10, 2002) available at http://www.udel.edu/V2G/docs/V2G-Demo-Brooks-02-R5.pdf; Tomic J., Kempton, W., *Using fleets of electric-drive vehicles for grid support*, Journal of Power Sources (March 2007) available at http://www.udel.edu/V2G/docs/TomicKemp-Fleets-proof-07.pdf

more often PEVs are plugged into the grid, the greater the opportunity for grid operators to use the energy storage as a controllable demand-side load or even as a generation source in the future. In fact, the study found that increasing the total connected time of PEVs during the day could justify their use as a demand side controllable load or even as a reserve capacity if they are equipped with vehicle-to-grid power flow potential.[36] Furthermore, the study found that limited available infrastructure on the weekends meant no opportunity for bi-directional communication with the grid thus highlighting the value of PCI.[37] The study concluded that for utilities to use PEVs for demand-side load management programs or for ancillary services PCI is essential so that vehicle connectivity can be ensured during all time slots and locations.

Grid regulation service payments to PEV owners, enabled by PCI, could offset the higher incremental cost of PEVs, substantially increasing the potential to accelerate the market penetration. Such payments also could be incorporated into vehicle financing, effectively eliminating all incremental first costs to the consumer and bringing parity to the initial cost of PEVs and conventional gas-powered vehicles. According to Kempton, the key to realizing economic value from V2G is the ability to aggregate a fleet of PEVs of sufficient number to meet the time-critical "dispatch" needed by the grid operator without compromising driving requirements of any one vehicle owner. IP or broadcast protocols from the utility grid operators to third party demand management aggregators are currently under development within most regions of the U.S. These aggregators manage the integration and coordination of PEVs in a demand management program, offering vehicle owners simple but powerful transportation choices.

Because PEVs are capable of supplying spinning reserves and ancillary services to the grid substantial stationary source emission reductions are possible by enabling grid operators effectively to shift spinning reserves to more efficient intermediate units by storing the output from intermediate units in PEVs. Accordingly, abundant PCI actually can enable further net emission reductions of NOx and CO2.

However, in order for this to occur, vehicles must be plugged-in to the grid, requiring drivers to have access to charging not just in the home but out in the public domain during the day, such as at shopping malls, office buildings, and along highway corridors. The value of PEVs to the grid therefore depends on chargers being available during the working day when peak load conditions exist.

#### 2. Opportunity Charging with PCI Can Reduce Emissions from Stationary Source Intermediate Units

The flexibility in choosing when to recharge PHEV batteries can have a significant impact on marginal unit emissions. For example, the case below from NREL's study of the Xcel Energy system in Colorado shows the total NOx and CO2 emissions under various charging scenarios, ranging from uncontrolled charging at home to continuous charging throughout the day with PCI. Noteworthy is the fact that total NOx and CO2 emissions are lowest under the continuous charging scenario, despite the fact that generating loads are higher.

[36] Markel, et al., n. 13.

[37] Id.

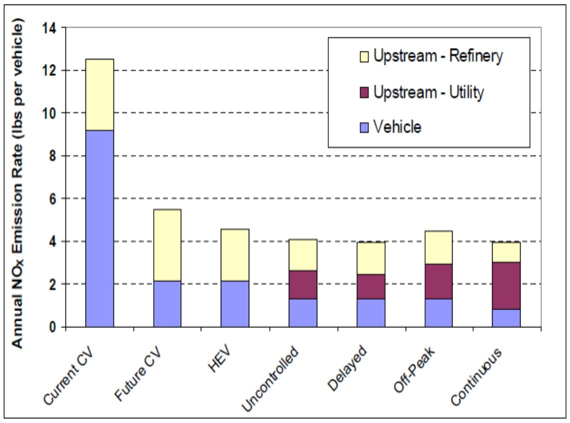


Figure 17: Net Vehicle $NO_X$ Emissions Rates

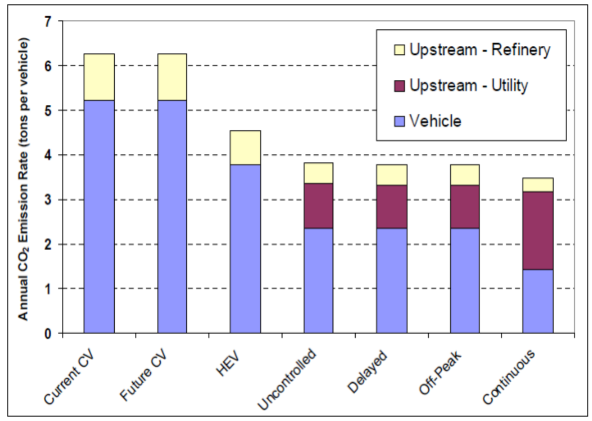


Figure 19: Net Vehicle $CO_2$ Emissions Rates

Source: NREL, Costs and Emissions Associated with Plug-In Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory, n. 15, supra. The benefit to urban air quality of PEVs are very substantial, according to NREL, because PHEVs are far more likely to be operated almost exclusively in zero-emissions EV-only mode in urban.

### 3. Grid Impacts of Opportunity Charging Using PCI Can Be Managed Through Advanced Metering Infrastructure and Time-of-Use Pricing

Some utilities have expressed concern that fast charging, or even Level 2 charging could negatively impact the grid. Clearly, it will be helpful to better understand PEV charging impacts on the distribution-level grid. EPA should initiate research of the impacts of all forms of charging on the distribution grid. However, recent modeling has shown minimal real impact to the grid, particularly with PCI chargers equipped with bi-directional communications with the grid which enable grid operators to moderate or even prevent charging during peak load conditions.[38] AMI will provide a powerful market tool for utilities to control the grid. For example, the results of NREL's 2009 analysis of the distribution level grid impacts of opportunity charging though out the day in Xcel's Colorado service territory shows that 500,000 PHEVs could be deployed and opportunity charged with only 17 hours of grid impact. The study suggests that utilities easily could manage the coincidence without capacity expansion while offering consumers great flexibility throughout the year.

Also, charging schemes that include battery storage between the grid and the charger bank, as detailed in a recently issued patent, could provide a buffer and further reduce the potential for adverse grid impacts.[39] Li-ion batteries have tremendous potential for redeployment in secondary high-value stationary storage applications. In fact, the Energy Policy Act of 2005 required DOE to establish a Secondary Electric Vehicle Battery Use Program to research, develop, demonstrate commercial applications of energy technology for the secondary use of batteries, but only if the Secretary finds that there are sufficient numbers of batteries to support the program. The program was intended to demonstrate the use of batteries in secondary applications, including utility and commercial power storage and power quality, and to evaluate the performance of such batteries in field operations, including the necessary supporting infrastructure, reuse and disposal. The program was to be coordinated with ongoing secondary

[38] *See* Botsford C. and Szczepanek A., *Fast Charging vs. Slow Charging: Pros and cons for the New Age of Electric Vehicles*, Proceedings EVS24 Stavanger, Norway (May 13-16, 2009) available at http://www.cars21.com/files/news/EVS-24-3960315%20Botsford.pdf

[39] Id.

battery use programs at DOE's National Laboratories and in industry. To date, DOE has not implemented the program, presumably because sufficient numbers of batteries are not available to sustain the program.

Even at the end of their useful lives in a BEV—defined as an 80% state-of-charge (SOC)—advanced Li-ion batteries still have significant residual value for less demanding applications. (Few applications rival the extreme duty cycle demanded by automobiles.) A Li-based battery with an 80% SOC still is capable of fulfilling many other applications, including distributed applications. Potentially viable battery "second-life" applications include transmission support, ancillary services such as frequency regulation and spinning reserves, load leveling, transmission deferral, firming of renewable energy generation, power reliability, peak shaving, commercial load-following, uninterruptible power supply, and residential load-following. The economic case for redeploying Li-ion batteries in secondary stationary applications was substantiated by a 2003 Sandia National Laboratory study, Technical and Economic Feasibility of Applying Used EV Batteries in Stationary Applications, which concluded that EV batteries have a variety of viable secondary stationary applications. The study found that there are no insurmountable technical barriers to the implementation of a second use scheme. Furthermore, the Sandia study corroborated an earlier Argonne study finding that Ni/MH EV battery modules tested to end-of-life on the USABC Dynamic Test profile could compete favorably with new lead-acid batteries in several stationary storage applications. The Federal Battery Guarantee program presents an opportunity for federal government to catalyze a secondary market for used Li-ion batteries by monetizing the value of electricity storage beyond vehicle applications and thereby further reducing the incremental cost of batteries.

EPA should consider sponsoring further work to update the results of the Sandia study, which was limited to nickel metal hydride battery technology.